An Assessment Methodology for Enviro-Economic Justification of Low and Zero Carbon Building Technologies

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Abstract

The imperative to reduce the carbon footprint of buildings will inevitably require adopting higher levels of insulation and on-site low and zero carbon technologies. This will significantly increase the embodied carbon of materials and products that have been used in the building. With buildings requiring less operational energy, future low and zero carbon buildings could see equivalence between operational and embodied carbon. It is essential therefore that embodied carbon is factored into carbon reduction strategies. Hence, this research has established an assessment methodology based on a combined operational and embodied carbon analyses as means of providing more representative assessments of life cycle carbon burdens and cost appraisals for low and zero carbon building technologies.

The methodology has been applied to a series of case studies of low and zero carbon building technologies to provide exemplar quantified appraisals of selected products. The case studies include insulation materials (Polyurethane, mineral wool, VIP and hemp) and renewable technologies (Photovoltaics and Transpired Solar Collectors) applied with different operational scenarios to selected industrial (small and medium warehouses and retail sheds), residential (semidetached house) and office (typical 4 storey) buildings.

The application of the methodology identifies how the inclusion of embodied CO_2 in carbon reduction equations can suggest ‘death points’ (points beyond which associated embodied carbon outweighs the operational carbon savings) for conventional building technologies and ‘birth points’ (points beyond which novel technologies are required to offset the carbon disbenefit of conventional technologies) for novel products. This for the first time introduces sensible ‘maximum’ level of insulation that can be incorporated into buildings or required by standards, and sets limits to the amount by which current approaches to carbon thrift can be escalated.

The study demonstrates the absolute significance of combining operational and embodied carbon analyses in demonstrating the effectiveness of carbon reduction strategies and requirements to shift away from ‘operational carbon only’ methods. The approach must be an integral part of any holistic appraisal of low and zero carbon performance.

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CHAPTER 1: Introduction

UK, EU and international targets for the reduction of anthropogenic carbon and Greenhouse Gas emissions necessitate fundamental changes to the ways that buildings are designed and operated. As the international targets on reducing carbon emissions become stricter, so does the imperative for better performing carbon efficiency technologies in the most carbon intensive sectors such as buildings and industrial activities.

This chapter provides an overview of the environmental concerns that are driving the energy and carbon reduction targets and the associated legislative frameworks that have emerged with which buildings are required to comply. This is a vast and rapidly developing field and it is therefore neither possible nor desirable to be comprehensive. Therefore the intention is instead to highlight the significance of adopting whole life carbon approaches in building performance standards, and how it is anticipated that compliance with carbon targets will need to be demonstrated.

1.1 Greenhouse Gas (GHG) emissions and global warming

The term 'Greenhouse Gas' refers to various heat-trapping trace gases which are present in the Earth's atmosphere and have the potential to cause atmospheric warming. The contribution that individual GHGs make to the greenhouse effect depends on how much heat each absorbs and subsequently re-radiates.

Notable GHGs include:

- **Carbon Dioxide (CO_2)**: Carbon dioxide is generated by burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also chemical reactions such as those associated with production of cement.

- **Methane (CH_4)**: Methane is emitted during the production and transportation of fossil fuels. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in solid waste landfills.

- **Nitrous Oxide (N_2O)**: Nitrous oxide is emitted during agricultural and industrial activities, and also in the process of combustion of fossil fuels and solid waste.

- **Fluorinated Gases**: Hydro fluorocarbons, perfluorocarbons, and sulphur hexafluoride are powerful, artificial greenhouse gases emitted from a variety of industrial processes.

The presence of greenhouse gases in the atmosphere shifts the proportion of solar radiation that is reflected into space in comparison to the component that is transmitted, thus increasing the total amount of radiation entering the atmosphere. Once radiation has entered the atmosphere, greenhouse gases absorb the reflected long-wave radiation from the Earth's surface. In tandem these effects cause a trapping of heat in the atmosphere and net temperature increases (Figure 1.1).

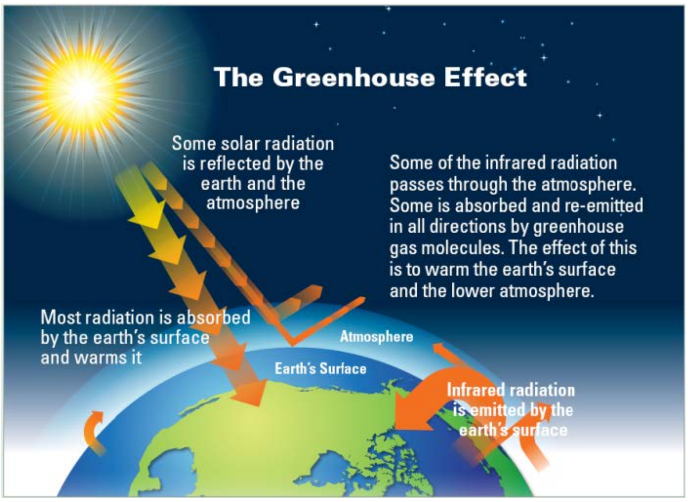


Figure 1.1 The greenhouse effect (source: www.epa.gov)

Levels of atmospheric greenhouse gases are essential to the way that the atmosphere functions. It is however increasingly accepted that elevated levels of anthropogenic gases produced as a result of human activities are problematic. These combine with the gases that are naturally present in the atmosphere with significant adverse effect.

Although carbon dioxide is not on a volume or weight basis, the most powerful of the gases in terms of GWP (Global Warming Potential), is believed to be responsible for 60% of the greenhouse effect (unfccc.int, 2012). Current levels of carbon dioxide exceed 380 parts per million, a figure which appears to be beyond long term norms generally ranging between approximately 180 and 300 parts per million (Figure 1.2).

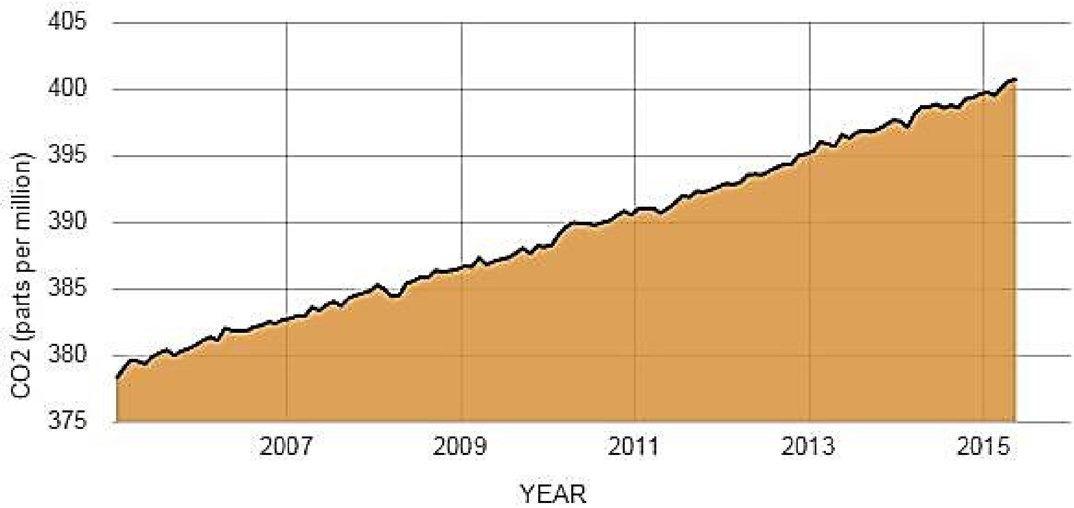


Figure 1.2 Global CO_2 levels (source: NASA GISS database)

The International Panel for Climate Change (IPCC) in their 2007 annual report influentially stated that if the greenhouse gases emission trend continues at or above the current pace, an average global temperature increase of 3 to 7°C is likely to happen by 2100.

The IPCC's Fifth Assessment Report, Working Group 1 (2013, p.5) further noted that:

> Even if emissions are stopped immediately, temperatures will remain elevated for centuries due to the effect of greenhouse gases from past human emissions already present in the atmosphere. Past, present and future emissions of carbon dioxide represent a substantial multi-century climate change commitment.

Also according to the IPCC report (2014, p.1):

Scenarios show that to have a likely chance of limiting the increase in global mean temperature to two degrees Celsius, means lowering global greenhouse gas emissions by 40 to 70 percent compared with 2010 by mid-century, and to near-zero by the end of this century.

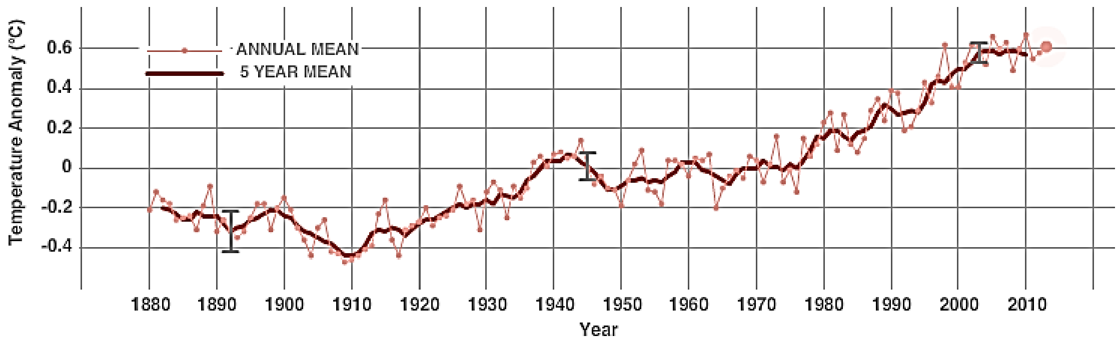


Figure 1.3 Temperature rise pattern since year 1880 (source: NASA GISS database)

According to NASA's GISS database, the global surface temperature of the earth has risen by 0.7 C since 1950s. The finding agrees with results from both the Japanese Meteorological Agency and the UK Climatic Research Unit (Figure 1.3). Based on these trends it is believed that even if greenhouse gas emissions were significantly reduced to year 2000 levels, the Earth is still likely to warm by approximately 1°C over the next 100 years (Figure 1.4) (IPCC, 2007).

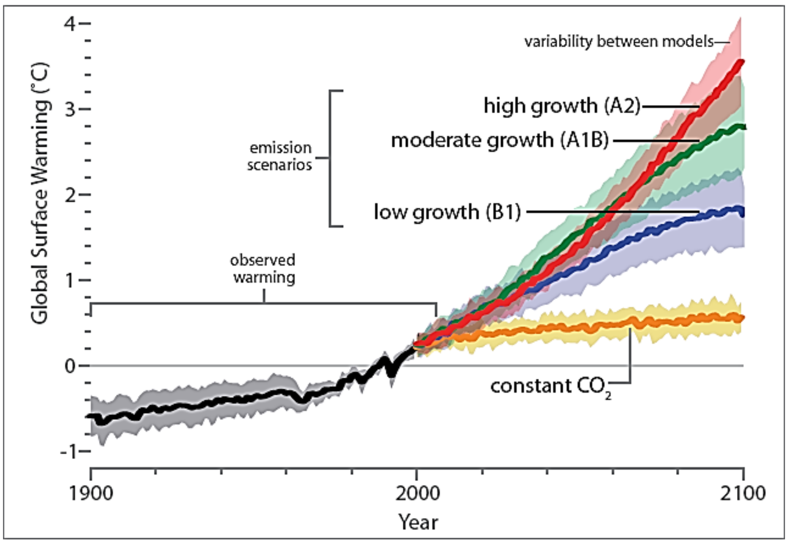


Figure 1.4 Temperature projections to the year 2100 based on a range of emission scenarios and global climate models. Source: NASA (adapted from IPCC, 2007)

Current upward trend in the global temperature can lead to serious climate disruptions such as rises in sea level (Figure 1.5) (global sea level rose about 17 centimetres in the last century), increasing volumes and intensity of rainfall, changes in weather, higher summer temperatures (ten of the warmest years occurred between 2002 and 2013), ocean acidification, declining Arctic sea ice and increased frequency of extreme weather events.

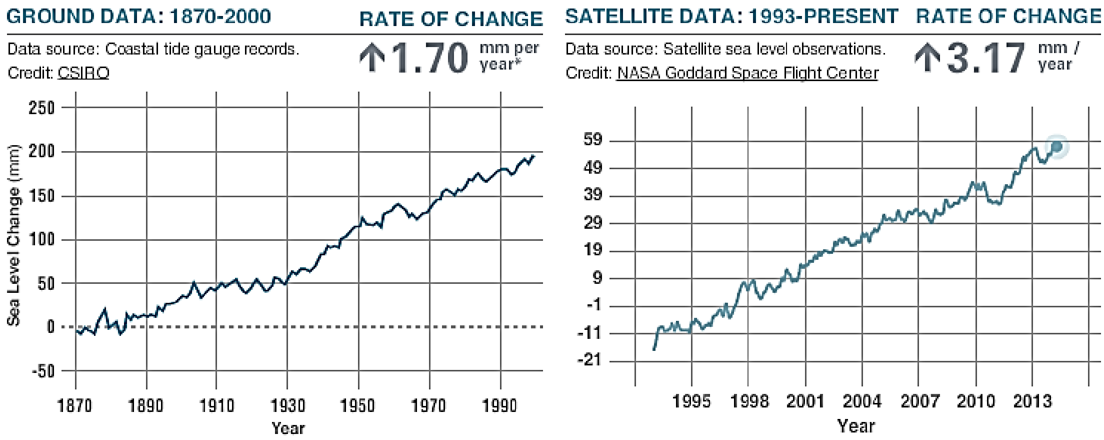


Figure 1.5 Global sea level rise pattern (NASA GISS database)

1.2 Reduction targets of GHG emissions

It is increasingly evident that one of the world's most serious long-term challenges is climate change. Evidence gathered by various climatic research institutions has demonstrated the seriousness and urgency of this issue. The debate has effectively moved from whether or not the climate change is happening to what we need to do to control it and how we adapt to live with it (Zero carbon building definition, 2008). As an international response to the problem, carbon reduction targets were agreed in place to put heavier burden on developed and industrialised countries for 150 years of their industrial activities.

The world's first climate conference took place in 1979 in Geneva sponsored by World Meteorological Organization (WMO). In 1988 the Intergovernmental Panel on Climate Change (IPCC) was set up focusing on the science of climate change. The IPCC's first assessment report was released in time for the second climate conference in 1990 which highlighted the risks. In 1994 the United Nations Framework Convention on Climate Change (UNFCCC) came into force and an 'overall framework for intergovernmental efforts to tackle the challenge posed by climate' was set up. This led to the Kyoto Protocol which was formally adopted in 1997 as the world's first international agreement on tackling climate change. Most recently however the Paris summit is to be held in December 2015, to ensure meaningful action on climate change.

According to the Green alliance 2014 report, getting a global agreement on climate change, the deal must contain the following elements:

- ambitious action before and after 2020
- a strong legal framework and clear rules
- a central role for equity
- a long term approach
- public finance for adaptation and the low carbon transition
- a framework for action on deforestation and land use
- clear links to the 2015 Sustainable Development Goals

1.2.1 The European 20-20-20 targets

In order to achieve the committed carbon reduction targets, the European countries set a series of demanding energy targets to be met by 2020, known as the '20-20-20' targets (http://unfccc.int, 2012). Targets include:

- Reduction in EU greenhouse gas emissions of at least 20% below 1990 levels.
- 20% of EU energy consumption to come from renewable resources.
- 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

1.2.2 The European Union Emissions Trading System (EU ETS)

The EU ETS, also known as the European Union Emissions Trading Scheme, was the first large emissions trading scheme in the world (EU-ETS fact sheet, 2013). The scheme was launched in 2005 to reduce industrial greenhouse gas emissions cost effectively (European Commission Climate Action, Emissions Trading System).

Under the EU-ETS, large European emitters of CO_2 must monitor their CO_2 emissions, and report them annually. They are obliged to pay an amount of emission allowance to the government equivalent to their CO_2 emissions in that year.

1.2.3 The Effort Sharing Decision

The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for the period 2013–2020. These targets concern emissions from sectors that are not included in the EU Emissions Trading System (EU ETS). This includes transport, buildings, agriculture and waste. The Effort Sharing Decision requires 10% reduction from all sectors not included in the EU-ETS.

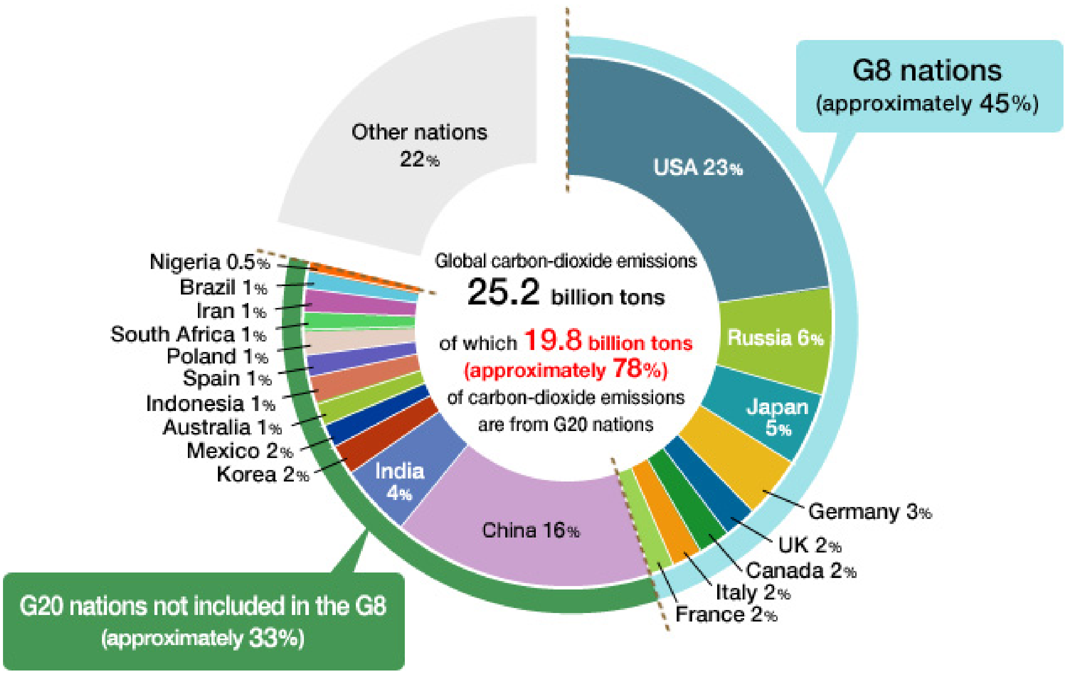


Figure 1.6 World CO_2 emissions by country (Source: the Ministry of the Environment, Japan (partially supplemented by UNFCCC data))

1.3 UK national carbon reduction strategies

Carbon dioxide accounts for 82% of greenhouse gas emissions in the UK (DECC, 2014). The UK Government has taken a number of steps to reduce the UK's emissions of greenhouse gases (as agreed in the Kyoto Protocol) through legally binding targets.

1.3.1 UK Climate Change Act

The UK Climate Change Act was introduced in 2008 and established a framework to develop an economically credible emissions reduction path in the UK as the world's first legally binding framework to tackle the climate change (Climate Change Act, 2008). The key aim of the Act is to improve carbon management strategies, helping the transition towards a low-carbon economy in the UK.

The act sets a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050 and a reduction in emissions of at least 34% by 2020 against 1990 levels. In respect of this, the Government has set specific principles to ensure that the policies contribute effectively to the greenhouse gas reduction targets. Features of these policies include:

- Setting 'carbon budgets'[1] to limit the amount of greenhouse gases the UK is allowed to emit over a specified time.
- Using statistics on greenhouse gas emissions and further evidence, analysis and research to inform energy and climate change policy.

[1] Carbon budgeting is designed by UK government to limit the total amount of greenhouse gases that can be emitted over a 5-year period. It considers the greenhouse gases emitted between now and 2050. Where emissions rise in one sector, corresponding falls need to be achieved in other sectors to recover the rise. 'Carbon budgets' is introduced as part of the Climate Change Act 2008 to help the UK reduce greenhouse gas emissions by at least 80% by 2050. A 35% greenhouse gas emission reduction is targeted in the 'carbon budgets' in the UK by 2027 relative to 2012 levels.

- Using the 'EU Emissions Trading System (EU ETS)' (introduced in section 2.1.3) to deliver a significant proportion of the UK's carbon emission reductions between 2013 and 2020.
- Using the '2050 Calculator' which is a tool to let policy makers and the public explore the different options for meeting the 2050 emissions reduction targets.

1.3.2 UK energy efficiency schemes

The energy efficiency schemes in order to contribute to UK global carbon reduction targets are introduced by UK Government. Schemes include:

1.3.2.1 UK Green Deal

The Green Deal was a government scheme to reduce the UK's carbon emissions by improving the energy efficiency of buildings (the Green Deal Home Improvement Fund (GDHIF) is closed to new applications). Many buildings in the UK are poorly insulated and have inefficient heating systems resulting in high energy bills. The associated energy use is responsible for millions of tonnes of unnecessary CO_2 being released to the atmosphere. Improving the thermal efficiency of buildings is progressing slowly due to the high capital cost. The Green Deal scheme supports the initiative by financing thermal efficiency improvements with no upfront cost to the house owner. The cost of the work is repaid over time from the energy cost savings due to the efficiency measures.

Despite the unsatisfactory statistics (only 1,612 homes had Green Deal plans in progress as of December 2013) recent Government reports suggest that more than 150,000 assessments have been carried out since January 2013. The main difficulty though seems to be quantifying projected energy use reduction and also the confusion caused by the planning of the scheme between both home owners and the supply chain.

1.3.2.2 The Energy Companies Obligation (ECO)

The Energy Companies Obligation (ECO) was a programme administered by Ofgem (Office of Gas and Electricity Markets) for the UK Government to place legal obligations on the larger energy suppliers to deliver energy efficiency measures to domestic energy users from 2013 until 31 March 2015. ECO was designed to work alongside the Green Deal with a particular focus on vulnerable consumers.

The scheme requires energy suppliers with more than 250,000 domestic customers to provide free or subsidised home energy efficiency measures in harder-to-treat homes and to support the installation of efficient boilers.

1.4 Investment on renewable energies

The growth of renewable energies such as solar and wind energy has increased significantly in the last few decades as renewables are now considered essential toward achieving the carbon reduction targets. According to the International Energy Agency (IEA), approximately 22% of world energy is generated using renewables. According to a report released by IEA in 2013, more than $250 billion has been invested in renewable energy generation. Investment is still less than UN targets. In April 2014 the United Nations warned that to mitigate climate change, investment in renewable energies should be at least three times greater than at present. Although the use of renewable energies is growing, investment has fallen compared to 2011 when the total investment reached a peak of $280 billion.

The cost effectiveness of renewable technologies is being questioned. IEA however argues that the cost of renewable energy generation reduces with scale and that economic incentives can be used effectively to stimulate growth. The UK renewable energy roadmap states that the costs of renewable energy technologies are uncertain but are expected to fall over time as supply chains develop and technical challenges are overcome (DECC, 2011). This has already happened to solar PVs and costs have fallen by factor of four over ten years.

The European Wind Energy Association believes that if there is any intention by European countries to achieve energy and carbon security, a minimum of 30% renewable energy target is required to be defined. The current trend determines a compelling case for uptake of novel energy thrift technologies and methodologies through a global determination to tackle climate change (Netherlands Environmental Assessment Agency, 2012).

1.5 Reducing energy use from the built environment

There are compelling rationales for reducing energy use in the built environment. These include:

- Buildings are major contributors to anthropogenic greenhouse gas emissions believed to be responsible for climate change
- Carbon based fuel reserves are depleting and alternative energy sources are proving difficult to develop safely and in sufficient volume to meet demand
- Many countries are faced with major issues of energy security
- Energy costs are increasing prejudicing economic development and raising concerns regarding fuel poverty
- Future global development and population growth appears likely to exasperate current issues.

As a consequence in the UK and in most developed countries building standards increasingly require improved standards of energy thrift. From the perspective of the construction sector supply chain this means that many existing building systems will become obsolete on the grounds that they are uncompetitive or unable to meet new standards, whilst new products with superior performance will become commercially viable in ways that they are not at present. This research addresses the need to identify when products will experience ‘death’ and ‘birth’ points in relation to progressively changing standards.

According to the IEA (International Energy Agency), the building sector represents around 30-40% of the world’s final energy consumption, and is a significant contributor to CO_2 emissions (CO_2 being a key metric and currently accepted proxy for greenhouse gas emissions in the built environment). The overall global position is echoed in the European Union where buildings account for 40% of energy consumption and 36% of CO_2 emissions (Buildings Energy Data book, 2006), (US Department of Energy and Annual Energy Review, 2007). In the UK the position is slightly worse than the European average with buildings accounting for approximately 45% of total CO_2 emissions (27% from the domestic sector and 18% from the non-domestic sector), with energy principally being used for space heating and cooling, water heating and lighting.

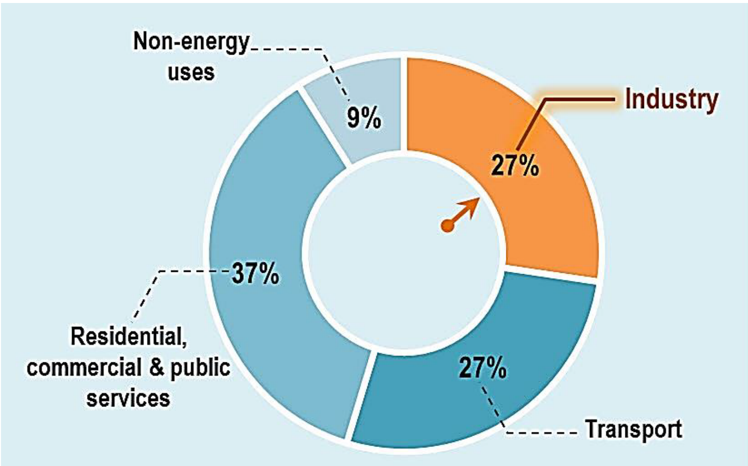


Figure 1. 7 Final energy consumption in the world (Source: IEA 2012)

1.5.1 Existing buildings

The majority of buildings that will be in use in 2050 have already been constructed (UNEP 2009, Carbon trust 2007) and will generally have lower standards of energy thrift than buildings constructed to current standards, and buildings that will be constructed to future standards. Whilst therefore the performance standards against which new buildings are designed are important, effective strategies need to be found for improving the existing stock, and it may reasonably be anticipated that future government policies will reflect this.

Whilst progress is being made in reducing carbon, it is not yet commensurate with the scale of the transformation required to ensure transition to a low carbon built environment (in line with international carbon reduction targets). Detailed issues associated with the necessary transition vary between sectors.

1.5.1.1 Residential sector

According to the Office for National Statistics, almost 40% of the housing stock in England and Wales was built before 1944 with 23% and 33% respectively built before 1919. Scotland's and Northern Ireland's housing stock are slightly newer on average, with only a third built before 1944, and nearly half of the stock (47%) built since 1965 (The UK State of Housing, 2000).

In England, only 50% of post-1990 dwellings have insulated cavities or over 150mm of loft insulation. The relative figures for pre 1944 dwellings are 28% and 40% respectively (UK national statistics, 2010). Whilst thermal retrofitting of existing buildings appears under-represented, in 2010 over 400,000 existing homes in the UK received cavity wall insulation (11 million since 1990) and over 1 million received loft insulation (9 million since 1990) (DECC 2011) and major Government sponsored schemes are beginning to appear aimed at promoting more general retrofitting (for example 'Green Deal' see Chapter 3).

1.5.1.2 Non–residential sector

17% of UK emissions come from non-domestic buildings. Of these only 2% are less than five years old and a large proportion of the remaining stock is characterised by poor standards of energy performance. Around 31% of existing non-domestic buildings were completed prior to 1939, 46% between 1940-1985 and 23% from 1985 onwards (Carbon trust, 2009). It has been estimated that 80% of all existing commercial buildings would be rated below C using the Energy Performance Certificate scale (Caleb Management Services, 2010).

In the case of industrial buildings, currently, only about 30% of the annual market for profiled roofing and cladding is used for refurbishment, representing just 1-2% of the existing 'cladding area' in the UK. At these rates, and recognising the inaccuracies and uncertainties of future trends, it may reasonably be expected that replacement of 50% of the existing building stock with upgraded systems compliant with current and future building standards is likely to take a period of the order of 100 years. Better and more effective thermal retrofit strategies may accelerate this transformation.

1.5.2 New buildings

1.5.2.1 Residential buildings

There were an estimated 23.2 million dwellings in England and Wales at the end of March 2013, an increase of 125000 dwellings (0.54% of the total existing homes) on the previous year (Office for National Statistics). In 2007 the UK Government set a target of increasing the supply of housing to 240,000 additional homes per year (1% of the total existing homes) by 2016 (Health, 2014). Whilst such targets are currently not being met carbon reduction in this sector is important given the large numbers of buildings in the category.

1.5.2.2 Non-residential buildings

According to the UK Green Building Council, there are 1.8 million non-domestic buildings in the UK. The energy used by non-domestic buildings accounts for approximately 18% of UK carbon emissions. Again, given the large size of the sector, energy saving potential is considerable. Estimations suggest that measures in non-domestic buildings could potentially save 18MtCO_2 by 2020 and 86 MtCO_2 by 2050, depending upon the level at which the carbon reduction measures are adopted (LCICG, 2012). Furthermore the sector is anticipated to grow substantially. By 2050 total UK non-domestic floor area is predicted to increase by 35% (DCLG, 2013).

1.6 Effective whole life carbon reduction

While the UK CO_2 emissions have dropped by 26% in the past 20 years, research carried out at the University of Leeds has demonstrated that underlying emissions are rising as the burdens associated with goods imported from countries such as China are omitted from current calculations. Research suggests that the 194 M tonnes CO_2 emission reduction claimed by the UK in 2012 (compared with 1990 levels) has been outweighed by a rise of 280M tonnes CO_2 associated with imported goods to the UK (Scott and Barrett, 2015).

UK Regulations have so far tended to focus on reducing the operational energy of buildings. As a consequence better and more effective technologies (including improved insulation levels, energy efficient lighting, heat recovery systems, and renewable technologies) have reduced operational energy but have tended to increase embodied energy as a result of increased material usage in areas such as insulation. Issues are therefore emerging as to the validity of the approach and methods to facilitate more comprehensive appraisal are likely to be required in the future, and are the broad concern of this thesis.

Carbon reduction strategies in the future will need to adopt 'whole life' perspectives taking full account of all aspects of energy including operational carbon and the energy associated with the extraction, processing, manufacture and transportation of the materials and products that constitute the building (known as embodied energy). This is evident in various research studying the significance of including embodied carbon into carbon reduction equations. The literature includes:

The Low Carbon Construction Innovation and Growth Team (IGT) final report in 2010 provides a series of recommendations aiming at supporting the UK government's transition to a low carbon economy. The report considers embodied CO_2 as a progressively more important aspect of effective carbon reduction strategies. The IGT (2010) states:

> Recommendation 2.1: That as soon as a sufficiently rigorous assessment system is in place, the Treasury should introduce into the Green Book a requirement to

conduct a whole-life (embodied + operational) carbon appraisal and that this is factored into feasibility studies on the basis of a realistic price for carbon.
Recommendation 2.2: That the industry should agree with Government a standard method of measuring embodied carbon for use as a design tool and for the purposes of scheme appraisal.

Also the ‘Embodied Carbon Industry Task Force Recommendations’ report by Guy Battle, 2014, recommends to the Government that:Embodied Carbon be included as an Allowable Solution within the Zero Carbon Building Regulations for both Homes and Commercial Development. It also suggests that Government should support and fund the development of a UK wide materials database (similar to those developed in Germany and the Netherlands), the development and upkeep of the WRAP Buildings Database, include whole life carbon emission in the Building Regulations and support further research on the benefits of managing and reducing embodied carbon.

Also internationally, there are several studies considering and suggesting a whole life carbon approach for reducing carbon emissions from the building sector. This includes:

The Athena Sustainable Materials Institute which is a non-profit research collaborative considers whole life carbon approaches as the effective approach. The Athena SMI offers green labelling programs to reduce the carbon footprints in the production and consumption of construction materials considering a whole life carbon approach.

The US Institute for Passive House (PHIUS) has also undertaken a comprehensive study considering whole life views (cost and carbon) of achieving ‘Passive house’ level efficiencies. The embodied CO_2 of buildings constructed under Passivehaus standards has also been studied in several studies including McHendry (2013) and the results suggest that embodied CO_2 accounts for approximately 25% of the estimated lifetime energy demand of a house.

The UK Government is acknowledging the significance of embodied carbon and this research is intended to support improved practice. It suggests that combined embodied and operational CO_2 approaches should logically be the basis of all strategic decision making.

This research has therefore addressed the use of combined operational and embodied carbon approaches as means of providing true life cycle carbon appraisals for low and zero carbon building technologies.

1.7 Aim and objectives of the research

The aim of this research is to establish an assessment methodology for appraising the commercial and carbon advantages of new low and zero carbon building technologies. This will enable manufacturers and producers to assess their potential and competitiveness with established products, on grounds of combined operational and embodied CO_2 and in terms of cost effectiveness.

The objectives in support of the aim are to:

1. Identify and review current new product development demands relating to low and zero carbon building technologies and the economic cases on which they are based.

2. Identify optimal approaches to:

    a. Assessing the relative financial competitiveness of comparator new and existing products based on 'first' and 'life cycle' cost (using appropriate future value discounting procedures).

    b. Quantifying relative carbon efficiencies of new products for low and zero carbon buildings based on computer modelling and best practice modelling assumptions. This identifies 'death points' beyond which existing products become obsolete as new products present definitive advantages on the basis of carbon.

    c. Determining the physical limitations of comparator products such that financial and carbon comparisons are considered only where there is genuine product competition, and the limits of technologies are fully recognised.

3. Apply the methodology to a series of selected case studies of novel low and zero carbon building technologies and identify the threshold where these technologies will present financial advantage (in relation to energy costs), or carbon advantage (in relation to meeting tightening regulations for energy thrift).

4. Develop an Excel-based assessment tool based on the proposed methodology (Chapter 8).

1.8 Structure of thesis

An overview of the Chapters is as follows in this section.

Chapter 1 provided an overview of the environmental concerns that are driving the energy and carbon reduction targets. Aim and objectives of the research were defined in Chapter 1.

Chapter 2 reviews the improvement of the thermal performance standards within Building Regulations since 1985 and determines the limits of existing regulatory approaches concerning the combined approach.

Chapter 3 reviews the available approaches concerning cost and carbon quantification methods.

Chapter 4, Informed by the available approaches reviewed in Chapter 3, describes the assessment methodology used in the course of this research. The buildings analysed in accordance with this methodology and the assumptions used to assess a series of case studies of low and zero carbon building technologies is also described.

Chapter 5 investigates the effect of adding embodied CO_2 to carbon reduction analyses associated with a highly insulated building envelope comparing mainstream conventional insulation materials with novel insulation materials for new and thermally retrofitted domestic and non-domestic buildings.

Chapter 6 presents the Life Cycle Costing analysis associated with the building fabric energy efficiency investigated in Chapter 5.

Chapter 7 determines the maximum level of carbon reductions achievable through a combination of fabric energy efficiency and onsite low and zero carbon solutions. The analyses will include industrial and office buildings as exemplar building types for application of the methodology.

Chapter 8 describes the development of an Excel-based assessment tool which has been developed to enable manufacturers to determine the most cost effective ways of achieving zero carbon non-domestic buildings using different design scenarios and service lives.

Chapter 9 presents the thesis conclusions and recommendations for further research.

CHAPTER 2: Regulatory Approaches to Anthropogenic Gas Emission Reduction

Chapter 1 reviewed the UK, EU and international targets for the reduction of anthropogenic carbon and Greenhouse Gas emissions necessitating fundamental changes to the ways that buildings are designed and operated. This chapter provides an overview of how the thermal performance standards within Building Regulations have been improved since 1985 and determines the limits of existing regulatory approaches concerning the combined operational and embodied CO_2.

2.1 Introduction

There is a strong argument being made by the Government for regulating at the point of design. The cost of upgrading buildings after construction, aggregated with their initial construction cost is much higher than designing to an appropriate initial standard. As the price of energy rises, the cost of running less efficient buildings increases significantly, but technologies are effectively locked in and difficult to replace at acceptable cost. Improving the thermal performance could prove difficult subsequently (DCLG, 2013).

Apart from very energy intensive industries, the overall consumption patterns of businesses are generally not hugely affected by energy bills, reducing the incentive to pay for a highly carbon efficient building. Application of energy reduction measures in existing commercial buildings is affected by the split incentive between landlords and tenants. Tenants are usually reluctant to invest on improving energy efficiency measures due to the short lease periods and owners are only obliged to improve the energy efficiency of buildings that are rated below E of Energy Performance Certificate (EPC) (Energy Act 2011).

The Government has gathered evidence (DCLG, 2013) showing that the market will not make the required changes voluntarily even with the influence of market-focused policies such as the EU Emissions Trading Scheme (EU ETS) and the CRC. The Government therefore, legislated the building related regulations to reduce the carbon emissions associated with new and retrofitted domestic and non-domestic buildings as an integrated part of the overall carbon reduction targets.

2.2 Building Regulations

The first mandatory Building Regulations, enforced by local authorities, were introduced in 1966. These were revised in 1972 and then again in 1976. The 1985 Building Regulations were the first to include the modern system of building control (Strickland, 2014). In 1984 the Building Act, changed the form of regulations introducing a system of Approved Documents (England & Wales) and Technical Standards (Scotland and Northern Ireland). This defined those subject to statutory control (McAdam, 2007).

Building Regulations through Approved Documents support fourteen technical ‘Parts’ including; structural safety, fire safety, resistance to contaminants and moisture, toxic substance, resistance to sound, ventilation, sanitation, drainage and waste disposal, heat producing appliances, protection from falling, conservation of fuel and power, access to use of buildings, glazing safety (only relevant to Wales) and electrical safety together with Regulation 7 (workmanship and materials) (available at: http://www.planningportal.gov.uk).

The energy and carbon reduction targets are set for each type of building individually in Part L (Conservation of Fuel and Power) of the Building Regulations through which planned reductions are expected to be achieved.

2.2.1 Building Regulations Part L

The Building Regulations Part L[2] introduces targets to reduce carbon emissions per square meter by a certain percentage with respect to those of a notional building defined in previous version of the Building Regulations (Building Regulations Part L, 2010). The calculation procedure includes space heating and cooling, hot water and fixed lighting and pertains to all types of buildings including new and substantially modified existing, domestic and non-domestic.

2.2.2 How Building Regulations evolved

The thermal performance standards set by Building Regulations have been progressively improved in each revision since 1985.

Historically, the Building Regulations simply prescribed minimum level of thermal performance for each building element individually. Factors such as the ratio of building volume to surface area were not acknowledged. Also good performance in one area could not be offset against weaker performance in another. Given that only relatively low standards of thermal engineering were required, such principles were generally adequate.

More recently however, codes and regulations have evolved to better address total carbon reductions. The new approach allows good performance in one area to offset

[2] Part L of the Building Regulations controls:
insulation requirements
limitation of openings of the building fabric (door and window apertures)
solar heating and heat gains to structures
heating
mechanical ventilation and air conditioning systems
lighting efficiency
space heating controls
air permeability
solar emission
the certification, testing and commissioning of heating and ventilation systems
requirements for energy meters

lesser performance in other areas. Whilst flexible methods have been introduced, minimum backstop U-Values[3] have also been applied to key building elements (Table 2.1).

Table 2.1 Changes in thermal performance standards of Building Regulations since 1985

Element	1985	1991	2002	2006		2010		2013	
				Notional Building	Backstop value	Notional Building	Backstop value	Notional Building	Backstop value
Wall ($W/m^2.K$)	0.45	0.45	0.35	0.35	0.7	0.2	0.3	0.18	0.3
Roof ($W/m^2.K$)	0.25	0.25	0.25	0.25	0.35	0.13	0.2	0.13	0.2
Floor ($W/m^2.K$)	0.45	0.35	0.25	0.25	0.7	0.2	0.25	0.13	0.25
Windows ($W/m^2.K$)	-	3	2.2	2.2	3.3	1.5	2	1.4	2

In 2010, differentiated performance standards were presented to the regulations, with targets differing according to building type (sizes of buildings and different occupancy patterns), on grounds of their respective carbon reduction potential. This allowed standards to be flexible without forcing reduction levels for which the cost-effective approaches were not available.

In the case of housing for example, apartments and mid-terrace houses have lower external floor/wall/roof area per dwelling (and thus lower conductive heat loss through the building fabric) than semi-detached and detached houses. This change maximises the level of carbon reduction that can be achieved cost effectively.

The change away from prescriptive standards (strictly defined building element thermal specifications) to total carbon reduction target based approaches, poses important issues for the effective engineering of building technologies. For example, building envelope systems that incorporate thermal insulation have historically been matched to the U-

[3] U-value, is the total amount of heat loss (in watts) per square metre of building element (for example wall, roof, floor etc.) when the temperature (k) outside is at least one degree lower.

values required by building regulations, and the specification of these components would be adjusted with consecutive iterations of building regulations. Currently however, only backstop values are standard and specifiers of building envelopes are able to design to any U-value equal to or exceeding these. Identification of optimised insulation values for standard building envelope products is therefore difficult. This allows design and construction flexibility to meet a host of economic, functional and architectural criteria but is a more complex paradigm for manufacturers to address.

2.2.3 Meeting the carbon reduction targets

Building Regulations have sought to reduce the energy needs of new buildings, and buildings subject to major alterations, by setting performance standards. Their approach has been to focus on 'operational energy' whilst ignoring 'embodied energy'.

2.2.3.1 Operational energy/carbon

Operational energy is the amount of energy consumed during the 'in-use' phase of building operation. Operational energy can be considered as comprising two parts, 'regulated' and 'unregulated'. Only regulated energy is considered by Building Regulations and refers principally to the energy used for heating, hot water, cooling, and fixed lighting. Unregulated energy includes that used by appliances such as televisions, cookers, computers and fridges and most 'small power' applications. Regulated operational energy consumption is influenced by factors such as: hours of operation, occupation levels, building use and occupant behaviour.

2.2.3.2 Embodied energy/carbon

'Embodied energy' can be defined as 'the sum of the energy requirements associated, directly or indirectly, with the delivery of a good or service' (Cleveland & Morris, 2009). In practice however, there are various methods of defining embodied energy contingent on the chosen boundaries of the study. The three most common options are:

cradle-to-gate, cradle-to-site, and cradle-to-grave (Tingley & Davison, 2011) (refer Chapter 3, Section 2.1 for definitions).

Embodied energy can be converted to embodied carbon using the same conversion factors as cited in relation to operational energy. For the purposes of this study 'embodied Carbon' is defined to include all CO_2 and CO_2-equivalent emissions associated with the above definitions (viz: cradle-to-gate, cradle-to-site, and cradle-to-grave) excluding those associated with operational carbon as defined above. Embodied/operational carbon and embodied/operational CO_2 have been used interchangeably in this research. Embodied carbon therefore includes burdens such as those associated with resource extraction, transportation, and processing, and potentially with delivery, installation, and end-of-life treatments, disposal, incineration and recycling. Embodied carbon can also refer to the indirect emission of carbon related to the chemical reactions in the manufacturing stages of materials such as cement (when calcium carbonate is thermally decomposed, lime and carbon dioxide is produced).

In the 1980s operational carbon of buildings was assumed to be around ten times greater than their embodied carbon burdens. However, as building energy efficiencies have improved this ratio has shifted very considerably. Regulatory requirements together with the increased use of renewables as energy sources have reduced operational carbon whilst embodied carbon has remained essentially unchanged (apart potentially from that associated with increased insulation). This trend appears likely to continue. If so, future low and zero carbon buildings will achieve relative parity between operational and embodied carbon (RICS, 2012).

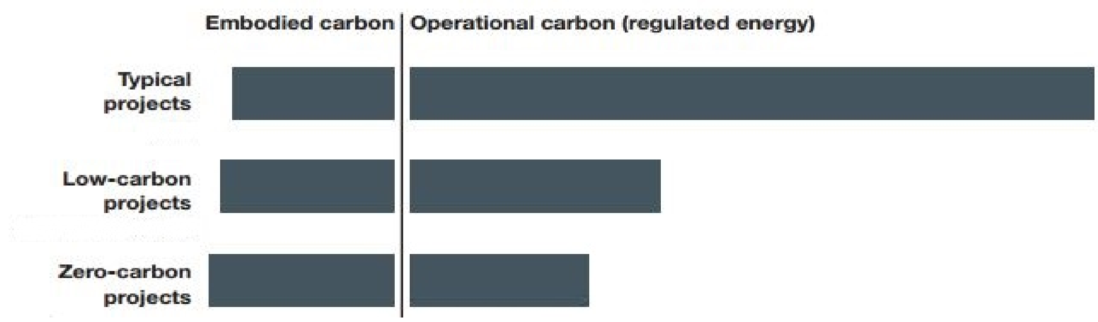


Figure 2. 1 Likely embodied to operational carbon proportion for future buildings

For example, according to the RICS Information Paper 'Methodology to Calculate the Embodied Carbon of Materials), the embodied carbon of materials and products accounted for more than a third of the total carbon emissions associated with housing (built to 2006 Building Regulations requirements) over a 30 year service life. This figure will have increased further under current design codes. Similarly, the ratio of embodied carbon to operational carbon for office buildings is around 1:3, and 1:5 for typical supermarkets where the operational carbon needs are particularly high.

Given the shift that has occurred, it is arguably no longer justifiable to consider energy efficiency in terms of 'Operational Carbon only'. In order to properly assess carbon burdens, it is the contention of this study that a whole-life carbon accounting method must be applied. It would appear entirely reasonable to suppose that such methods will be a feature of future carbon appraisals, and indeed that consideration of Embodied Carbon may appear, in some form, in regulations potentially including Building Regulations.

2.2.3.3 Carbon intensity and energy to carbon conversion factors

Energy can be converted to carbon but the conversion depends on the energy source since some sources of energy are more carbon intensive than others. Different conversion factors therefore apply to different energy sources, for example fossil fuels will have a far higher embodied carbon burdens than those of renewable energies such as wind or hydroelectric power. The associated carbon intensity of different sources of energy can affect the potential carbon savings when considering application of low and zero carbon solutions to buildings.

This research assumes Defra's 2015 energy to carbon conversion factors as follows:

- Natural gas: 0.184 $kgCO_2/kWh$
- Electricity: 0.462 $kgCO_2/kWh$

Conversion factors (expressed as kg carbon dioxide equivalents), are available at: www.ukconversionfactorscarbonsmart.co.uk.

The UK electricity conversion factor fluctuates from year to year as the fuel mix consumed in UK power stations (and auto-generators) and the proportion of net imported electricity changes. These annual changes can be large as the factor depends very heavily on the relative proportion of coal and natural gas as well as fluctuations in peak demand and renewables. For example, in the 2014 GHG conversion factors there was an 11% increase in the UK electricity factor from the previous year due to the significant increase in coal powered electricity generation share in 2012. In 2015 however, the factor has decreased (versus 2014) by 6.5% which is due to a decrease in coal powered electricity generation in 2013.

Note that Current conversion factors in the UK are in favour of technologies that save electricity comparing with gas saving technologies. Electric heating systems for instance could potentially result in different carbon savings. Also the analyses presented in chapter 7, can be different if the carbon intensity of the source of electricity generation is lower than fossil fuels i.e., from renewable energies such as wind or hydroelectric powers.

This study assumes natural gas for heating and hot water systems and electricity for lighting as the most common sources of heating and electricity consumption in the UK. Cooling is not included in the analysis.

2.3 Total carbon (combined operational and embodied carbon) approach; the likely future requirement

At present, UK building regulations, and comparable international regulations largely ignore embodied energy/carbon, but for the reasons already noted in the context of true low carbon design this lack of consideration appears irrational.

This can be due to the unreliability or/and inconsistency of existing databases. The UK Green Building Council 2015 report on 'tackling embodied carbon from buildings' suggests that the complexity of embodied carbon data arises from the fact that sources of accurate and exhaustive data are based on different parameters of assessment. Carbon factors for materials/products consider different end of life boundaries i.e., 'cradle to gate', 'cradle to grave' and 'cradle to cradle'. The report suggests ensuring consistency of data throughout the analysis before a comprehensive and consistent database is developed.

Proper consideration of embodied carbon will potentially have a significant effect upon building specifications. Many common conventional products with high embodied carbon may well become obsolete in the context of true low carbon design, being superseded by products with lower embodied carbon but with comparable performance characteristics. Insulation is perhaps the most obvious area in this regard (where low U-values are required, the embodied CO_2 of conventional insulation materials can significantly offset the operational CO_2 benefits, or cause a net CO_2 disbenefit), but the logic applies broadly across all areas of building specification.

Whilst there is an essentially linear relationship between U-values and heat losses through building fabric, embodied carbon tends to increase in an accelerating fashion as levels of insulation increase. Figure 2.2 describes a typical relationship between operational CO_2 emissions and U-value for a selected building example (a 3000m^2 industrial warehouse in southern England). The operational CO_2 is positively correlated only to thermal conductance (i.e. the graph is independent of the insulation material used).

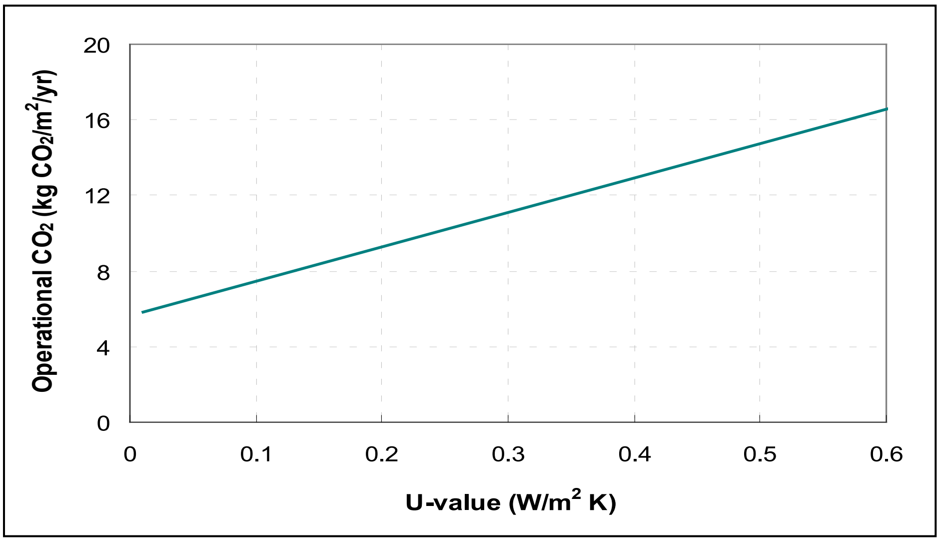


Figure 2.2 Example of typical linear relationship between CO_2 emissions associated with operational carbon, and envelope U-value.

In contrast, embodied carbon profiles are neither linear, nor independent of insulation material as:

a. required insulation thicknesses increase progressively more steeply as U-value is reduced, and

b. embodied carbon and thermal conductivity of individual insulation materials vary considerably. For example the embodied CO_2 of polyurethane (PUR) is 3.48 $kgCO_2/kg$ and k-value 0.025 W/mK whilst those of mineral wool are 1.2 $kgCO_2/kg$ and 0.04 W/mK.

Figure 2.3 illustrates a typical curve for embodied CO_2 (in this case associated with PUR insulation), and also the combined operational and embodied CO_2 arising for a notional building. The key feature is that the aggregate of a linear and non-linear relationship is by definition non-linear. Reductions in combined operational and embodied CO_2 become considerably more difficult to achieve as insulation thicknesses increase. This introduces 'death points' for conventional insulation materials and 'birth points' for novel products that offer significant advantages on grounds of carbon efficiency.

The concept of 'Death point' is for the first time developed in this study and is defined as the point beyond which carbon disbenefit occurs. In case of insulation material 'death point' can be defined as the thickness of insulation beyond which the amount of embodied carbon associated with thicker panel exceeds the related operational savings. This can vary for different building types and operational scenarios but is within a range of thicknesses that seem entirely possible to be the requirement of regulations in future. Death point for other low and zero carbon building technologies is defined as the point at which the carbon payback period is beyond the acceptable norms i.e., varying depending on the related service lives.

'Birth point' in context is referring to the same concept as 'death point' but is defined as the point at which the conventional solutions fail to comply with regulations and the development of new novel solutions is required. The development and availability of effective new low carbon building technologies is strategically important toward achieving carbon reduction targets. Delivering new products to market however requires significant investment and it is essential that the management and timing of research and development (informed by death/birth point analyses), and subsequent commercialisation is correct.

The graph for the notional building indicates an optimum thickness for PUR insulation of approximately 260mm based on certain assumptions (including a 25 year service life and typical building operation criteria). This equates to a U-value approximating 0.09 W/m^2K. Curves of this nature tend to flatten as service life increases or as a result of the use of lower embodied CO_2 insulation. Both of these factors increase the optimum insulation thicknesses. Conversely, if service life is decreased, or higher embodied CO_2 insulation materials are used, optimum insulation thickness decreases.

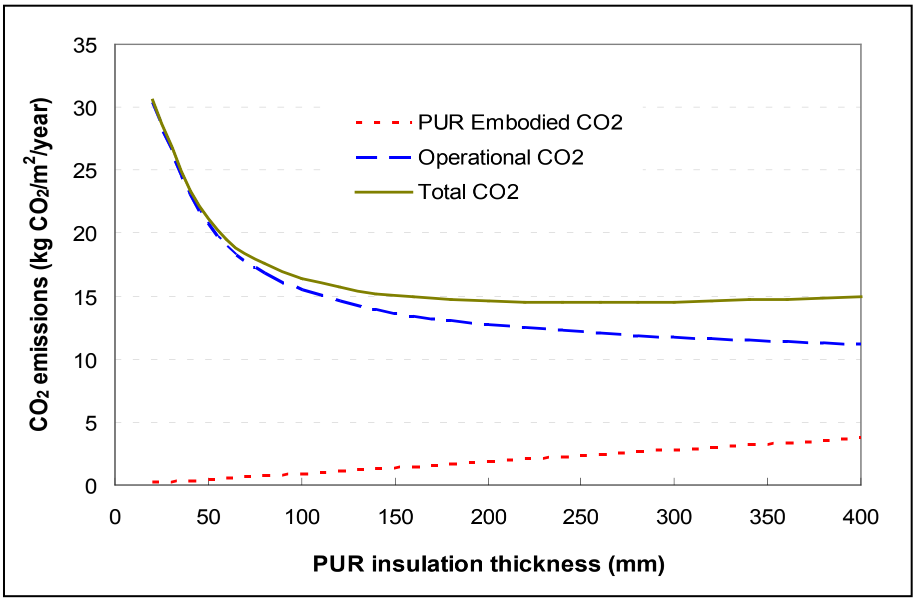


Figure 2.3 Example of typical non-linear relationship between embodied CO_2 (and combined embodied and operational CO_2) based on PUR insulation.

2.3.1 Previous work concerning total carbon approaches

Malmqvist et al, (2011), investigated the use of LCA (Life Cycle Assessment) methods in buildings. According to their research, LCA is currently used to a very limited extent in the building sector, mainly because making an LCA evaluation of buildings demands handling large datasets and this has to be adaptable to the different decisions taken throughout the life cycle of the building. They propose a simplified methodology that adopts a systematic approach guiding the user through the Life Cycle process and clarifying key issues such as choice of assessment tool, definition of system boundaries and options for simplifying the process. In a similar approach, Dixit et al, 2012, provided a literature review of the current embodied CO_2 standards and determined current interpretations of embodied CO_2 to be unclear and embodied CO_2 databases to suffer from problems of variation and incomparability. They contended that current LCA standards fail to provide complete guidance.

Yohanis and Norton (2002) discuss that improved energy efficiency measures make embodied carbon considerations increasingly important. It is discussed that reliable and accurate embodied carbon data is not easily accessible to do the wide variation in the data available. The variations of life-cycle operational and embodied carbon and capital cost as a function of building parameters (such as glazing ratio and insulation levels) are explored in their study.

Gustavsson and Joelsson, (2010) analysed primary energy use and CO_2 emissions associated with the production and operation of conventional and low-energy residential buildings. They demonstrated that for conventional and low-energy buildings, the primary energy use for production can be up to 45% and 60% respectively, of total whole life energy needs, depending on the energy supply system.

Rossi et al (2012) dealt with the development of a basic tool for life cycle assessment of residential buildings located in three different European towns. The tool focused on the structure and the materials of the buildings and permitted evaluation of the embodied carbon and yearly energy consumption. The tool took account of factors such as monthly temperatures, energy mix, heating and cooling systems.

Blengini and Di Carlo (2009) conducted a detailed life cycle assessment analysis comparing the energy consumption of a low energy house with that of a house built to comply with legal standard insulation in northern Italy. Whilst the operational carbon consumption of the low energy house was one tenth of that of the conventionally specified house (1:10), they demonstrated that factoring in the embodied CO_2 of materials and systems, shifted this ratio to 1:2.

Thormak (2002) studied the effect of material choice and recycling potential on the total energy needs of a building. It was demonstrated that embodied energy accounted for 45% of total energy demand of a very energy efficient apartment housing in Sweden (45 KWh/m^2) over a 50 year buiding life. The study demonstrated that through material substitution, embodied carbon could be decreased by approximately 17% or increased by about 6%.

Monahan and Powell (2010), Ramesh et al (2010), Yan and Zheng (2011) and Hacker et al (2008) also carried out life cycle energy studies combining operational and embodied carbon.

None of the existing approaches reviewed, investigated how the inclusion of embodied CO_2 into total carbon equations can push the use of mainstream conventional building technologies to their 'death points' where the development of new solutions are vital toward achieving the carbon reduction targets.

2.4 Financial justification of effective new low and zero carbon building technologies

Whilst it is very complicated to predict the future trend of the energy prices, it is highly likely that energy prices will continue their generally upward trend in the future (www.worldwatch.org, 2015), (www.carbonbrief.org, 2015), (www.ukpower.co.uk, 2015). Building owners therefore should logically plan 'future-proofing' the operational costs of their buildings by committing to required or better than required thermal standards in the regulations.

However, as many conventional insulation materials are proved to be unable to achieve the anticipated performance standards due to their high associated embodied CO_2, better performing low and zero carbon solutions are required to contribute to carbon reduction targets effectively.

There is a recognised concept, supported by suppliers and manufacturers of construction products, of ‘market pull’ supported by ‘technology push’. ‘Technology push’ is facilitated by products and systems that have potential to deliver better building technologies, but which require market acceptance and demand in order to become established. Technically the approach may be feasible but there isn’t enough market potential for it. On the other hand, ‘market pull’ represents the genuine need for products that satisfy demands but the available solutions fail to fully satisfy. The market pull will drive the translation of viable technology into commercialisable products.

Products, for which there is current limited economic or other demand, may well form the basis of future innovation as requirements create demand. Conventional 1960s products and techniques in much of Europe such as compressed strawboard roofing panels, steel framed single glazed windows and cementitious roof sheeting have given over to alternative products such as insulated roof decks, thermally broken double glazing systems and composite cladding panels. Revisions to regulations and subsequent demand for improved performance have driven this change.

2.5 Conclusion

New products that can potentially replace conventional solutions have to be developed and introduced in a way that is aligned to demand (market pull), and at a point where they become commercially viable (Kennedy, Whiteman and Van den Ende, 2013), (Davey, 2013). Accurately identifying this point is difficult as the demand is often a consequence of regulation, and the relative competitive advantages that exist between comparator products and solutions at any given time. Providers must therefore be equipped to analyse regulatory frameworks in relation to existing and proposed comparator offerings in order to inform their strategic planning processes.

Therefore in conclusion it seems to be essential that an assessment methodology is developed through which the ‘death points’ of existing technologies can be determined and the use of new technologies justified on grounds of both carbon efficiency and cost effectiveness. Within this, any methodology must take into account the technical feasibilities and manufacturing constraints that apply in order to ensure the practical feasibility of assessments. Technologies are generally limited by a range of performance or manufacturing constraints which establish ‘bounds of applicability’ for the technology. Broadly, these may be characterised as upper and lower thresholds beyond which the technology becomes insecure or unsuitable. For example, a basic timber beam can span distances up to 4.5m, beyond which deflection and strength criteria will become excessive. Limitations of this kind establish zones within which a product is potentially competitive and consideration of the product outside of these limits is inappropriate.

Simply stated, assessment methodologies should take account of:

- Carbon efficiency
- Economic and financial viability
- Technical constraints

CHAPTER 3: Available Cost and Carbon Quantification Approaches

As has been discussed in Chapter 2, cost and carbon quantifications need to be considered in the developing methodology. Available methods therefore need to be reviewed and the most appropriate approaches adopted.

The following chapter hence, provides an overview of the available approaches concerning cost and carbon quantification methods.

3.1 Available cost and carbon quantification methods

A comprehensive literature search has been conducted to investigate the current available 'whole life' cost and carbon quantification approaches.

Available approaches include:

3.2 Life cycle approaches

These include the tools, programs and procedures used to support decisions based on whole life analysis. They are principally categorised into two main groups: practical and analytical approaches.

Practical life cycle approaches are designed to translate theory from the use of analytical tools into practices such as policy programs, corporate programs and procedural tools. Analytical approaches are used to assess the effects of planned decisions or improvement scenarios made on a project. These approaches include analytical tools such as Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) which are of interest to this research (UNEP, 2005).

3.2.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a whole life approach aimed at investigating the variable range of environmental impacts associated with products and services in order to improve processes, support policies and provide an effective basis for informed decision making (Brander, 2013). LCA approaches can specify the environmental consequences of products or services from cradle (extraction of raw materials) to gate (relevant processes to the factory doors), or cradle to grave (the end of life stages).

The LCA approaches have in the last decade become standard procedures for exploring the environmental impacts of construction products and materials. Their origins however can be traced back to analyses carried out in the 1960s and 70s aimed at optimizing direct energy consumption. The technique was then developed to take account of raw material consumption and emissions along the full 'life cycle' of a product, from material extraction and processing, to manufacturing and installation and the end-of-life stages. LCA is now standardised by ISO norms 14040-14044, and, specifically for the construction sector, by the European standards EN 15804[4] and EN 15978[5].

Based on a survey of LCA practitioners carried out in 2006 (Cooper and Feva, 2006), LCA is mostly used to support business strategy (18%), R&D (18%), as input to product or process design (15%), in education (13%) and for labeling or product declarations (11%).

The use of LCA for ISO Type III labels called Environmental Product Declarations is also growing considerably (Singh and Bakshi, 2009). An environmental declaration is defined in ISO 14025 as 'quantified environmental data for a product with pre-set

[4] Published in 2012 by the European Committee for standardisation (CEN), EN 15804 is part of a suite of standards for the assessment of the sustainability of construction works at product and building levels.
[5] Sustainability of construction works - Assessment of environmental performance of buildings (calculation methods).

categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information' (Environdec.com, 2014).

Third-party certified LCA-based labels also are more recently providing an important basis for assessing the relative environmental merits of products and providing credibility in industry competitiveness. Independent certification can demonstrate companies' dedication to environmentally friendlier products (SGS, 2013).

The ISO 14040 describes the limitations of a LCA approach as:

- The nature of choices and assumptions made in LCA (e.g. system boundary setting, selection of data sources and impact categories) may be subjective.
- Models used for inventory analysis or to assess environmental impacts are limited by their assumptions, and may not be available for all potential impacts or applications.
- Results of LCA studies focused on global and regional issues may not be appropriate for local applications, i.e. local conditions might not be adequately represented by regional or global conditions.
- The accuracy of LCA studies may be limited by accessibility or availability of relevant data, or by data quality, e.g. gaps, types of data, aggregation, and average site-specific.
- The lack of spatial and temporal dimensions in the inventory data used for impact assessment introduces uncertainty in impact results. This uncertainty varies with the spatial and temporal characteristics of each impact category.

The limitations stated by the ISO 14040 implies that he accuracy of any LCA analysis including embodied carbon can only be as good as the data available for embodied carbon measures. Comparing results of different LCA studies therefore is only possible if the assumptions, context of study and embodied carbon sources are the consistent.

3.2.1.1 System boundaries

System boundaries define the processes which are included/excluded in a LCA or embodied carbon study. Different factors can be considered in a system boundary amongst which, determining the end of life stages within the system boundary are particularly important. Common examples of the end of life stage approaches include ‘cradle-to-gate’, ‘cradle-to-cradle’, ‘gate-to-gate’ and ‘cradle-to-grave’ (Figure 3.1). System boundaries and specifically end of life stages need to be defined clearly when undertaking comparative LCA or embodied carbon assessments.

Cradle-to-grave

Cradle-to-grave is the full Life Cycle Assessment from raw resource extraction (cradle) to use and disposal phases (grave). For instance paper (produced from trees) can be reused as low energy recycled insulation, thus operational carbon savings can be considered against embodied carbon associated with the production of the material. In this form of analysis all energy inputs and outputs are considered across all phases of the life cycle.

Cradle-to-cradle (closed loop production)

Cradle-to-cradle is a type of cradle-to-grave assessment, where the end-of-life disposal stage for the product is a recycling process.. Recycling helps effective reduction of the environmental impacts of products and materials.

Cradle-to-gate

Cradle-to-gate is a partial assessment of a product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is delivered to the consumer). The use phase and disposal phase of the product are omitted from cradle-to-gate assessment, hence it has limitations. However the technique is highly useful, for instance in situations where transportation from factory to point of use is impossible to predict or is highly variable. The majority of the available embodied carbon databases include cradle-to-gate values.

Gate-to-gate

Gate-to-gate is a partial LCA looking at only the 'manufacturing' stage of the whole life processes. Gate-to-gate analysis results may also be linked in their appropriate production chain to form a complete cradle-to-gate assessment (Jiménez-González et al, 2000).

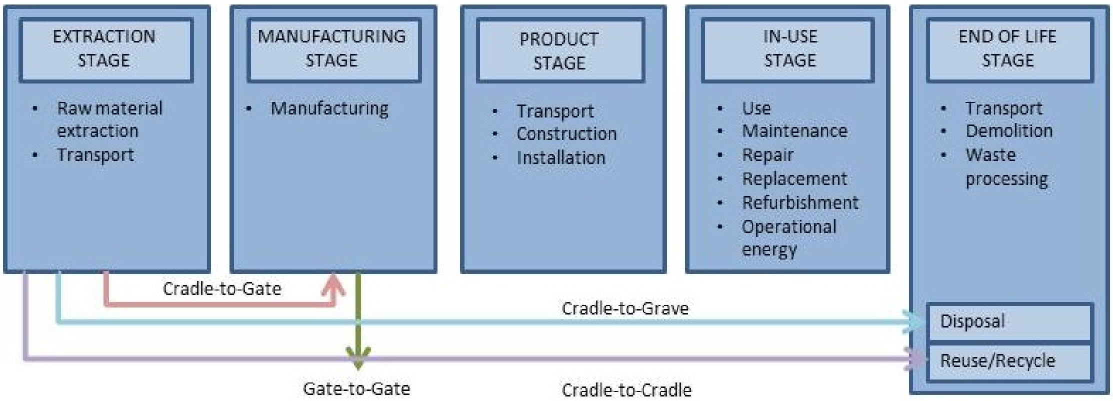


Figure 3.1 End of life scenarios

3.2.1.2 Quantifying embodied and operational carbon

As it has been discussed in Chapter 2, the UK Building Regulations and comparable international regulations pay little attention to embodied energy. As the required standards become more demanding this lack of consideration becomes increasingly concerning. The proposed methodology will include quantification of carbon emissions as an integral part of the combined operational and embodied analysis. An effective and accurate means of quantifying both the operational and embodied components is therefore required.

Available approaches for quantifying embodied carbon

There are a range of methods of calculating embodied CO_2.

Sophisticated commercially available software exists for life cycle analysis which is able to apportion a wide range of environmental impacts. Software includes: Envest 2, SimaPro, Impact and Gabi. Simpler software and approaches include embodied carbon calculators which simply assign embodied carbon on the basis of measured quantities of materials and databases. Examples of this latter class are the University of Bath's Inventory of Carbon and Energy (ICE) and WRAP databases.

Envest II

Envest II is a software tool intended to simplify the design of low environmental impact buildings and forecast whole life costs allowing clients and designers to optimise whole life cost value.

The users can either use the default environmental and financial data to provide an estimate of relative whole life costs for different designs through 'Envest Estimator' module or enter their own capital and lifetime financial cost information using 'Envest Calculator' module.

This provides a good basis for design teams who have their own specific data available.

IMPACT

IMPACT is a database for software developers to enable consistent LCA and LCC assessments. It was developed by BRE in collaboration with IES, Wilmott Dixon, AEC3 and Whole Life Ltd.

It multiplies quantity information from the BIM (Building Information Modelling) by environmental impact and cost data to produce an overall impact and cost evaluation for the design.

The generated results allow users to analyse their design to optimise cost and environmental impacts and compare whole-building results to a suitable benchmark to assess performance.

SimaPro

SimaPro is a LCA tool aimed at quantifying and analysing environmental impacts of processes and products.

SimaPro allows users to build complex models using different features introduced in the tool such as Parameters (to change values and assumptions in the model) and Monte Carlo analysis. The Ecoinvent database (the Swiss life cycle data inventory) is fully incorporated into SimaPro. It is used for a variety of applications, such as:

- Carbon footprint calculation
- Product design and eco-design
- Environmental Product Declarations (EPD)
- Environmental impact of products or services
- Environmental reporting (GRI)
- Determining of key performance indicator

GaBi

GaBi is a Life Cycle Assessment engine aimed at product sustainability solutions.

GaBi quantifies environmental impacts of every element of a product or system to facilitate the best informed decision making on grounds of manufacturing and life cycle evaluations.

It provides an easily accessible cost and environmental database. GaBi also presents alternative low impact options for manufacturing, distribution, recyclability, pollution and sustainability.

GaBi supports the following business applications:

- Developing products that meet environmental regulations with smaller environmental footprints such as fewer GHG emissions, reduced water consumption and waste.

- Eco-efficiency: reducing material, energy and resource use in the most cost-effective way.
- Efficient value chains: enhancing efficiency of value chains e.g. R&D, design, production, suppliers, distribution.
- Sustainable Product Marketing: product sustainability labels & claims, Environmental Product Declarations (EPDs).
- Sustainability Reporting: environmental communication & product sustainability reporting.
- LCA knowledge sharing: reporting and analysis for internal departments, management and supply chain.

Inventory of Carbon and Energy (ICE)

ICE is the University of Bath's embodied energy & embodied carbon database. It was designed to create an inventory of embodied energy and carbon coefficients for building materials. The data has been collected from secondary resources in the public domain, including journal articles, Life Cycle Assessments (LCA's), books, conference papers etc. to create a comprehensive embodied carbon database.

ICE provides a transparent data collection methodology and can be easily incorporated into complex weight-based carbon analyses.

WRAP database

WRAP and the UK Green Building Council have designed a database to capture embodied carbon data for whole buildings. Their aim was to create an open, web-based resource facilitating consistency of available data. The database focusses mainly on building applications.

Available approaches for calculating operational (in-use phase) carbon

Building simulation concept can be traced back to the 1960s when the US government evaluated the thermal environment in fallout shelters (Attia et al, 2012). Since then, the principles used for building simulation have evolved considerably, and due to the increasing significance of the decisions made early in the design process, dynamic simulation tools have been developed (Hensen, 2004). In the late 90s, the building simulation Virtual Environment (VE) tools were introduced to address measures such as thermal comfort and energy demand of buildings.

Whole building dynamic energy simulation packages focus on essential building performance parameters such as energy demand, temperature, humidity and cost (Crawley et al, 2008). Dynamic simulation methods are based on hourly (or even shorter) external data in order to solve the conduction, radiation and convective processes in relation to heat transfer and storage in a designed space. The fluctuations of internal and external variables are represented in the simulation methods, based on their accurate rates of alteration (Doyle, 2008). These can be used to compare different building specifications, service systems and control regimes.

There are several internationally accepted software packages available that calculate the operational energy/carbon requirements, environmental performance and thermal comfort of buildings. Leading software includes packages such as IES-VE, Tas, DesignBuilder, TRNSYS, EnergyPlus, DOE-2, eQUEST and Ecotect (based on full thermal dynamic simulation approaches), and simpler packages including SAP and SBEM (based on simplified, and therefore potentially less accurate approaches). There are also simple Excel-based calculating tools such as RETscreen for simulating the performance of specific renewable technologies such as Transpired Solar Collectors (TSCs).

The strengths, weaknesses and a comprehensive comparison of these software packages have been investigated in a joint report by US Department of Energy, University of Strathclyde, University of Wisconsin-Madison and the US National Renewable Energy Laboratory (Crawley et al, 2008). Also another comprehensive comparison has been provided by Stanford University considering the building energy performance simulation tools (Maile, Fischer and Bazjanac, 2007).

The referenced reports conclude that all of the investigated packages are capable of simulating the likely detailed analytical requirements in compliance with CIBSE[6] and NCM[7] guidance regardless of their advantages and disadvantages. The required criteria include the general modelling features such as;

Zone loads, building envelope and daylighting, infiltration, ventilation and multi-zone airflow, renewable energy systems, environmental emissions, climate data availability, results reporting, and Validation and User interface.

RETScreen

There are also simple Excel-based tools such as RETScreen that are available for modelling various renewable technologies including Transpired Solar Collectors.

RETScreen is an Excel-based renewable technology analysis tool enabling the users to conduct energy analysis, emission analysis, financial analysis, and sensitivity/risk analysis (www.retscreen.net, 2014). This is facilitated by incorporating a number of databases into the tool, including a comprehensive database of weather data obtained from 6,700 ground-based stations and NASA's satellite data and hydrology database.

3.2.2 Life Cycle Costing

Cost effectiveness models need to be undertaken in order to assess the financial competiveness of new and existing products. Comparative cost assessments that take account of all relevant economic factors (e.g. initial costs and future operational costs) are a useful method of ascertaining whether a solution is financially efficient (Gluch and Baumann, 2004).

LCC is a financial analysis technique that considers total aggregated costs (including the initial and on-going costs) associated with an activity during the estimated service time of it (Manuilova et al., 2005). In case of a building, LCC analysis can be used to

[6] The Chartered Institution of Building Service Engineers
[7] National Calculation Method

take full account of the initial cost of energy efficiency improvements and the on-going operational carbon savings associated with those improvements. When properly applied, LCC can be used to evaluate different investment scenarios.

LCC is especially useful in analysing a project when various scenarios that potentially meet the same performance requirements but differ in terms of initial and on-going costs have to be compared. This can be used to calculate the most cost effective scenario. For example, it will help determine whether the incorporation of a highly insulated building fabric or double glazing system, which may increase initial cost but result in potential reduced operational costs, is cost-effective or not.

Lowest life cycle cost is the simplest interpretable measure of financial evaluation when energy efficiency scenarios are being investigated. The literature provides an extensive variation of economic assessment methods for LCC analysis created for different purposes (Schade, 2010). All have advantages and disadvantages but are consistent with the lowest LCC measures if identical parameters are applied (NIBC, 2013).

There are five main economic evaluation methods for undertaking LCC analyses based on research carried out by Gorgolewski (1995). Methods include: Net Benefit (NB) or Net Savings (NS), Net Present Value (NPV), Internal Rate of Return (IRR), Saving-to-Investment Ratio (SIR) and Annual Equivalent Value (AEV).

3.2.2.1 Net benefit/Net saving

The Net Benefit (NB) approach calculates the difference between the present value of all on-going savings and costs incurred during a project. It identifies whether a project is cost effective or not i.e., the capital cost of the project will be recovered by on-going savings associated with the investment. This is particularly informing when sizing a project.

3.2.2.2 Internal Rate of Return

Internal Rate of Return (IRR) is the rate of growth a project is expected to achieve. The results in this method are presented as a percentage rate of return that is expected from an investment. The actual rate of return that is achieved often differ from its estimated IRR rate, but a project with a substantially higher IRR value would be the best available option. IRR is a more objective metric than NPV, as NPV depends on an arbitrarily chosen discount rate, while IRR is determined entirely by the cash flow figures and their timing. IRR is often used for evaluating investments and business case scenarios.

3.2.3 Saving-to-Investment Ratio

Saving to Investment Ratio (SIR) is recommended for establishing priorities among projects for producing the largest savings for a given budget considering the ratio of savings to investment cost. The Saving-to-Investment Ratio that provides cost effectiveness targets of greater than 1 shows that the project is profitable; the larger the SIR the greater its profitability.

3.2.3.1 Annual Equivalent Value

Annual Equivalent Value (AEV) is the cost per year of operating a project over its entire lifespan. It is calculated by dividing the Net Present Value of a project by the present value of annuity factor (cumulative discount factor when the capital cost is the same for each year through the project). This works well for assessing alternative projects with different expected service lives (where only the costs are relevant).

3.2.3.2 Net Present Value

Net Present Value (NPV) is a means of expressing the present value (PV) of initial and future cash flows. Future cash flows are discounted to better reflect their value at the point that the investment is made. When all future cash flows are incoming and the only outflow of cash is the initial cost of investment, the NPV is simply the present value of future cash flows (energy savings) minus the initial cost of insulation improvement.

3.3 Chapter summary

Several approaches for cost and carbon quantifications have been explored in this Chapter. Each of these approaches can be used for conducting research in support of building applications. Informed by the investigated approaches and the detailed requirements of the research, the most suitable approaches for undertaking the required analyses will be selected and explained within the context of the developing methodology in the next Chapter.

CHAPTER 4: Development and Application of Methodology

This chapter describes the assessment methodology used in the course of this research. It describes the buildings analysed in accordance with this methodology and the assumptions used to assess a series of case studies of low and zero carbon building technologies.

3.4 Main principles of the developing methodology

In Chapter 2, the significance of adopting an effective 'total carbon' approach in any holistic carbon reduction analysis (where all of the components of carbon footprints are appropriately represented) was addressed. In the following chapter, the proposed assessment methodology has been developed in relation to the aim and objectives of this project. Main principles of the developing methodology (summarising Chapter 2, Sections 4 and 5) is presented in Table 4.1.

- Relevant carbon efficiency of products and materials on grounds of combined operational and embodied carbon.

  Whilst current methods fail to address how the inclusion of embodied carbon may affect the decision making process, the proposed 'total carbon' analysis (associated with incremental increase in the thickness of insulation and also application of low and zero carbon technologies) identifies materials' 'death points' beyond which embodied CO_2 measures outweigh the operational CO_2 savings.

  The total carbon approach considers both embodied and operational carbon emissions associated with applied thermal improvement measures.

Table 4. 1 Main principles of the developing methodology in summary

Cost analysis	Approach type	Approach/Source	Details	
Life Cycle Costing	Future value discounting procedures	Net Present Value (NPV)	Formula	refer Section 4.2.2
			Discount rate-r	3.5
			Energy escalation rate-e	3
			Cost data	Table 6.1
			Service life	25, 40, 60
			gas price p/kWh	4.5
			Electricity price p/kWh	14.5
Carbon analysis				
Operational carbon quantification	Dynamic thermal simulation	IES-VE	Building types	Residential, commercial, industrial
			Modelling assumptions	Tables 4.7 and 4.8 and section 4.4.1.3
			Building fabric specifications	Tables 4.2, 4.4, 4.5, 4.6 and 4.9
			Insulation materials	PUR, Mineral wool, Hemp, VIP
			PV type	Monocrystalline
			location	London, UK
			Heating system efficiency	85%
Embodied carbon quantification	Embodied carbon databases	ICE V2	Embodied carbon measures	PUR: 3.48 kgCO2/kg, mineral wool: 1.2 kgCO2/kg, VIP: 1.001 kgCO2/kg, hemp:-0.56 kgCO2/kg PV:242kg/m2
			Material density	PUR: 40 kg/m3 Mineral wool: 50 kg/m3 VIP: 180 kg/m3 Hemp, 50 kg/m3
Manufacturing/ technical constraints				
practical feasibility	Bounds of applicability	Industry	Insulation materials-lowest U-value	PUR: 0.13 W/m2.K, mineral wool: 0.2 W/m2.K

- Economic and financial viability of existing and new low and zero carbon solutions.

Carbon efficiency graphs in combination with cost effectiveness results can provide optimum ranges in which applied products can save CO_2 in the most cost effective way.

- Relevant technical difficulties.

The bounds of applicability (which has been described in Chapter2 section 4) of materials and products need to be recognised and informed by practical limits to analyses. The methodology recognises bounds of applicability (the nature of which will be different for every technology) and within these limits establishes the ‘optimum net benefit’ ranges of each solution, in terms of both carbon and cost effectiveness.

3.5 The developed methodology

The developed methodology is simply applicable to a wide range of building types and applications that benefit from carbon or cost savings in different time periods comparable by either expressing their values in present terms (financially) or a carbon payback period (environmentally) i.e., thermal energy improvements such as windows upgrade or energy efficient lighting can be simply analysed using the developed methodology.

The methodology can be defined using three main stages: The total carbon stage (which is following a combined operational and embodied carbon approach), the financial assessment stage (which is adopting future discounting approaches) and the current technical restrictions stage.

Figure 4.1 clearly demonstrates how these three stages interact to inform the analysis. In this example, adding to the thickness of insulation beyond 100mm results in financial disbenefit (NPV purple line) whilst this improvement is beneficial in terms of CO_2 savings. The analysis then explores whether the additional 15% CO_2 savings associated with adding to the thickness of insulation (from 100 to 160mm insulation) can be achieved by taking a more cost effective approach (this is explained in more detail in Chapter 7).

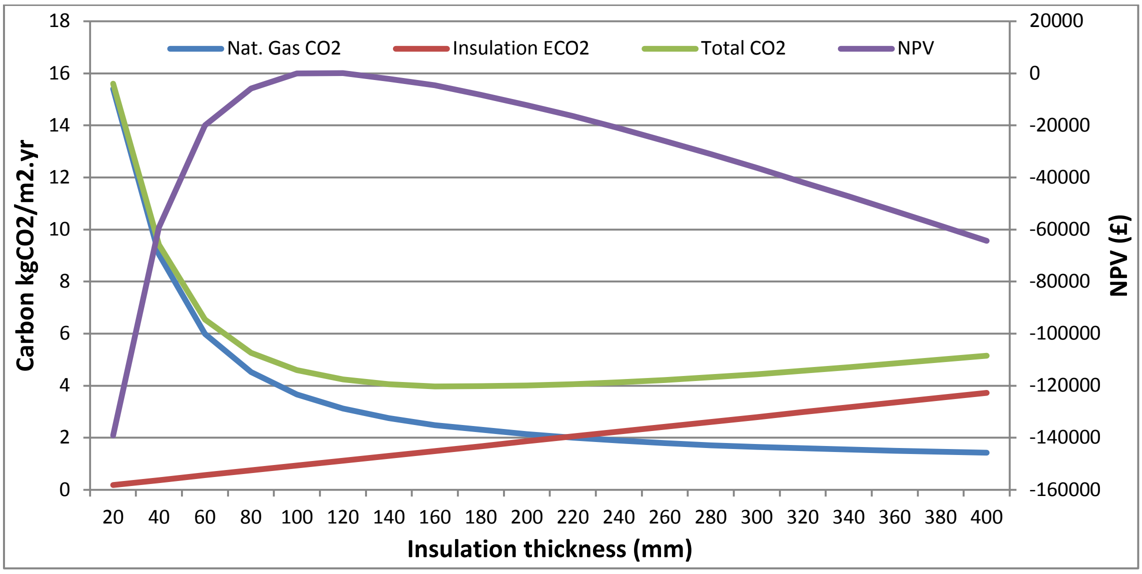


Figure 4. 1 Interaction between stages introduced in the methodology

The software packages and approaches adopted within the assessment methodology are as follows:

3.5.1 Carbon efficiency

An effective and accurate means of quantifying both the operational and embodied components has been developed based on the reliable information from the literature review. The existing best practice where this is available is presented under the following categories.

3.5.1.1 System boundaries

A cradle-to-gate approach has been selected. The benefit of this is that stages included in this approach are defined and do not change, whereas project specific stages (such as transportation and construction) once a product leaves the factory gate will differ considerably.

Furthermore, many manufacturers provide cradle-to-gate LCA information thus this approach is implementable with a relatively high level of data certainty. Databases such as Bath University's Inventory of Carbon and Energy (ICE) also presents the embodied energy/CO_2 data based on a 'cradle to gate' approach.

If end of life stages were included in analysis, numerous unresolved issues arise which in themselves are specialist research areas.

As has been discussed in Chapter 3, this is however acknowledged that a combined approach can use a cradle-to-gate measure for embodied carbon and model how a material or component has been processed during and after its life separately and then combining them to give a cradle-to-grave insight for further investigations. This might be necessary for insulation materials such as hemp that end of life stages effect the overall carbon burdens significantly.

3.5.1.2 Embodied carbon quantification

Taking into account the complex nature of the analyses and the complexity of using related software packages to calculate the embodied CO_2 of materials, the University of Bath's inventory of carbon and energy database has been adopted into the methodology. Process energy calculation techniques (where reliable data is not available) and LCA EPDs (Environmental Product Declaration) also have been used as complementary sources.

Calculating the embodied carbon of products for which reliable data is not available, requires compiling complete inventories of greenhouse gas (GHG) emissions arising from all the industrial processes that are directly and indirectly required for their production, delivery, installation, and end-of-life treatment (thus notably including the indirect emissions associated to thermal and electrical energy production and use). Non-CO_2 GHG emissions are then to be converted into CO_2-equivalents by means of appropriate equivalency factors provided by the Intergovernmental Panel on Climate Change (IPCC). Whilst some of the necessary emission data may be directly available, a very significant proportion of that will need to be estimated by combining first principle calculations based on 'process energy calculation techniques' and other criteria including typical fuel splits and local emission factors, with database information on representative background processes (e.g. nation-specific electricity generation mixtures, etc.).

As an example, this technique has been employed to determine the minimum combined operational and embodied carbon for VIPs (novel insulation systems), for which no data is available from standard sources due to the uncommon nature of materials (e.g., fumed silica and the uniqueness of the manufacturing process; refer to Appendix A).

The embodied CO_2 calculations for PVs are extracted from ICE database which complies with ISO 14040 and ISO 14044 standards. The embodied carbon data used for PUR, mineral wool and PV are collected from the same source (ICE database) to provide consistency in the calculations. In case of VIP also, apart from the energy consumption during relevant manufacturing stages, the embodied carbon of the materials are extracted from ICE database in compliance with ISO standards.

Different embodied carbon figures for the investigated materials could move the minimum carbon point on the graphs toward thicker or thinner panel (depending on the embodied carbon value) but do not compromise the existence of a minimum carbon point (death point) on the graph.

3.5.1.3 Operational carbon quantification

The most suitable packages for software analysis based on appraisal of likely detailed analytical requirements, complexity of the tool and software usage methods (compliant with CIBSE guidance) have been selected. Taking into account the low level of accuracy in SBEM and SAP, dynamic thermal simulation packages were employed. All of the investigated packages are capable of generating reliable demanded data despite the mentioned limitations. IES-VE however, as one of the most reliable existing packages and also Tas were the financially available packages during conducting the research and have been used for dynamic thermal analysis to calculate the operational CO_2 in investigated buildings. RETScreen (crosschecked with SWIFT and CRAFT) also has been used for simulations related to Transpired Solar Collectors.

3.5.2 Cost effectiveness

Amongst various cost analysis methods, an appropriate Net Present Value component as the most commonly used method in building related projects (Schade, 2007)(Rum and Akasah, 2011)(UNEP, 2003)(Target zero, 2011) has been incorporated into the developed methodology. The detail of which has been informed by review of best practice and use of the technique in relation to parallel modelling problems.

When the only outflow is the initial/capital cost of the project and all ongoing cash flows are incoming (savings) the NPV (Net Present Value) is simply the present value of all on-going savings minus the capital cost.

A recommended discount rate is given by the HM Treasury Green Book each year. Energy prices are more volatile than general inflation and tend to escalate at a higher rate (escalation rate). This will need to be acknowledged in any cost methodology in addition to any discounting procedures. For building services applications the CIBSE guide recommends energy price escalation rates.

The currently recommended discount rate given by the HM Treasury Green Book 2013 is 3.5%. The CIBSE guide also recommended an energy price escalation figure of 3% (over-and-above general inflation).

A suitable formula (Gorgolewski, 1995) to determine PV (that accounts for energy cost escalation and discount rates) is:

$$PV(A) = A \times [(1 + e) \div (r - e)] \times [1 - \{(1 + e) \div (1 + r)\}^{n}]$$

Where PV(A) is the present value of an annually occurring energy savings of A, appearing for n number of years, with a general discount rate of r, and a constant annual rate of change in the cost of energy compared to general inflation, of e.

Complicated spreadsheets have been designed based on initial and life cycle cost of applying low and zero carbon products. Extracted values from spreadsheets are used to generate graphs to demonstrate the optimum financial benefit of applying each technology to buildings (a range of results in relation to various design criteria, building type and service life scenarios is expected).

The cost analysis of low and zero carbon implementation has been carried out at the individual building level, but the energy saving measures for which engagements with regional scale is inevitable, such as exporting electricity from Photovoltaic cells to the grid, have been taken into account in the cost and carbon analyses. According to the 2010 Building Regulations, to deliver the targeted improvement in new build, individual buildings will be required to contribute to different levels of carbon efficiency based upon cost-effectiveness. Analyses at single buildings scale can examine the initial cost of low and zero carbon improvements, the cost of building energy price in operational stage, or include the energy embodied in materials used to construct the building (extraction and production stages), its services (maintenance stage) and any recycling options (end of life stage). These analyses can be based on new build or retrofitting existing buildings.

3.6 Application of methodology

The developed methodology has been applied to a series of case studies of low and zero carbon building technologies such as insulation materials (including Mineral wool, PUR, VIP and Hemp), Heat generating technologies (Transpired Solar Collectors) and Electricity generating technologies (Photovoltaic cells) to identify the levels where these technologies present financial and carbon advantage in a global system. The analysis is carried out for three building types of residential (a typical semi-detached house), industrial (standard single storey portal frame warehouse) and commercial (typical open plan four storey office).

Selected case studies are aimed at achieving zero carbon performance on grounds of combined operational and embodied carbon emissions. Achieving the zero carbon building was categorised into three parts of fabric energy efficiency (insulation materials), renewable technologies (on-site low carbon heat (TSC) and power (PV)) on single building scale and renewable technologies on regional scale (i.e. exporting energy from PVs to grid).

The results are extracted from more than 6000 computer simulations and analysed against a range of design scenarios (variables such as airtightness, rooflight area, liners reflectivity etc) and service life options.

Note that as thermal performance of building fabric improves the proportion of heat loss through windows increases. The U-value of windows therefore has been assumed as 1 $W/m^2.K$ for all cases.

3.7 General building description and performance specification

Principles of thermal dynamic simulation modelling are now embodied into regulation, whereby the energy needs and comfort standards of buildings, subject to local climates and set operating regimes, can be predicted. A performance specification for software analysis needs to be developed during the research based on appraisal of likely detailed requirements and appropriate software, and software usage methods (compliant with CIBSE[8] and NCM[9] guidance).

3.7.1 Domestic buildings

According to the UK Office for National statistics, 26% of the existing UK houses are semi-detached. Hence, a typical three bedroom semi-detached house built to the latest UK Part L Building Regulations with a total floor area of approximately $80m^2$ has been used for the analyses.

[8] The Chartered Institution of Building Service Engineers
[9] National Calculation Method

Figure 4.2 Ground and first floor plan

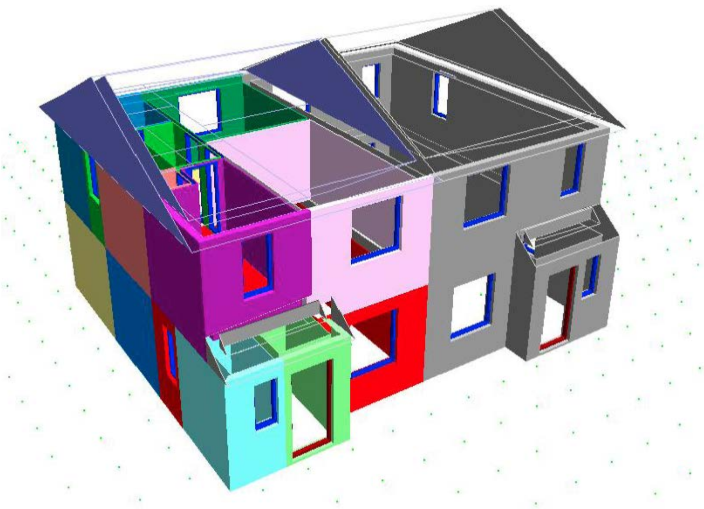


Figure 4.3 Simulated building

3.7.1.1 Orientation

Front door of the house is facing south.

3.7.1.2 Construction

External walls: Double (25mm) plasterboard/insulated frame/cavity/brick; (Table 4.1)
Party wall: Double plaster-board (25mm)/insulation in frame cavities/double plaster-board; Dry-lined stud partitions;
Floors: Solid ground floor; framed upper floor;
Roof: ventilated roof with tiles

Table 4.2 External wall material layout (inside to outside)

	mm	Thermal conductivity (W/mK)	Density (kg/m^3)	Specific heat capacity (J/kgK)
Plasterboard	2x12.5	0.21	960	837
Block	100	1.2	2000	960
PUR insulation	100	0.025	30	1260
Air cavity	50	-	-	-
Brick	102	0.77	2050	920

Table 4.3 Building specifications

	Semi-detached house
Ceiling area (m^2)	40
Rooflight area (m^2)	0
Ext. Wall area (m^2)	262.8
Total floor area (m^2)	80
Building height (m)	8
Building volume (m^3)	668.5

Windows: Double glazed low e with timber frames (U = $1W/m^2K$), approximately 25% opening area.

All U-values are based on 2010 Building Regulations Part L1a (Table 4.4).

Table 4. 4 Building element U-Values

Roof	0.20 $W/m^2.K$
Wall	0.30 $W/m^2.K$
Floor	0.25 $W/m^2.K$
Party wall	0.20 $W/m^2.K$

3.7.1.3 Modelling assumptions

Airtightness

A value for air infiltration of 0.25 air changes per hour was used, conforming in this case to an air permeability of $5m^3/h/m^2$.

Internal gains

The house is occupied by two adults and two children (out during weekdays) who are assumed to use lighting and appliances in the living room and kitchen during scheduled occupancy

Heating

Gas condensing boiler with radiator system (22°C for living areas, 18°C for bedrooms), scheduled (off at nights).

Occupation

Living room: 1700-2300h weekdays, 0700-2300h weekends
Bedrooms: 2300-0700h weekdays and weekends

Location

London ASHRAE weather database is used for thermal simulations

Ventilation

Weekdays: Living room windows start to open after 1700h when temperature exceeds 24°C, and are fully open (30% open area) when temp reaches 26°C. Closed at 2300h. Bedroom windows start to open after 1700 when temp exceeds 18°C and are fully open (30% open area) when temp reaches 20°C, remaining open all night until 0700h Weekends: Living room windows open 0700-2300h (temp control as above) Bedroom windows open 24 hours (temp control as above).

3.7.2 Non-domestic buildings

Industrial and office buildings have been analysed as non-domestic buildings. Standard single span portal frame warehouses of 1000 (25*40) and 3000 (40*75) square metre and a similar 3000m^2 retail outlet have been modelled as industrial buildings. A typical 2400 m^2 four story office building (13.5*48) has been modelled. Mineral wool, PUR, hemp and VIP as insulation materials have been used for the analysis. The office is assumed to be an open-plan office as presented in Figures 4.3 and 4.4.

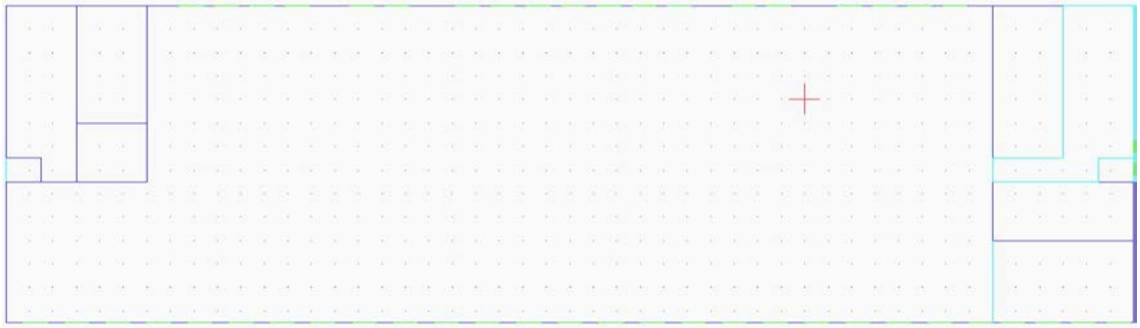


Figure 4. 4 Office plan

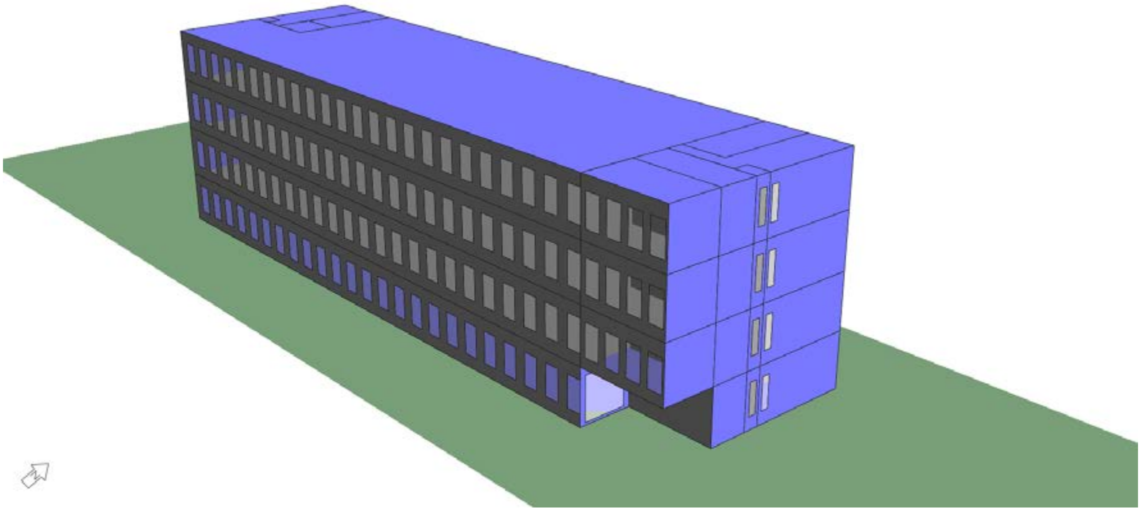


Figure 4. 5 Office building

The industrial warehouses are also as demonstrated in Figure 4.6.

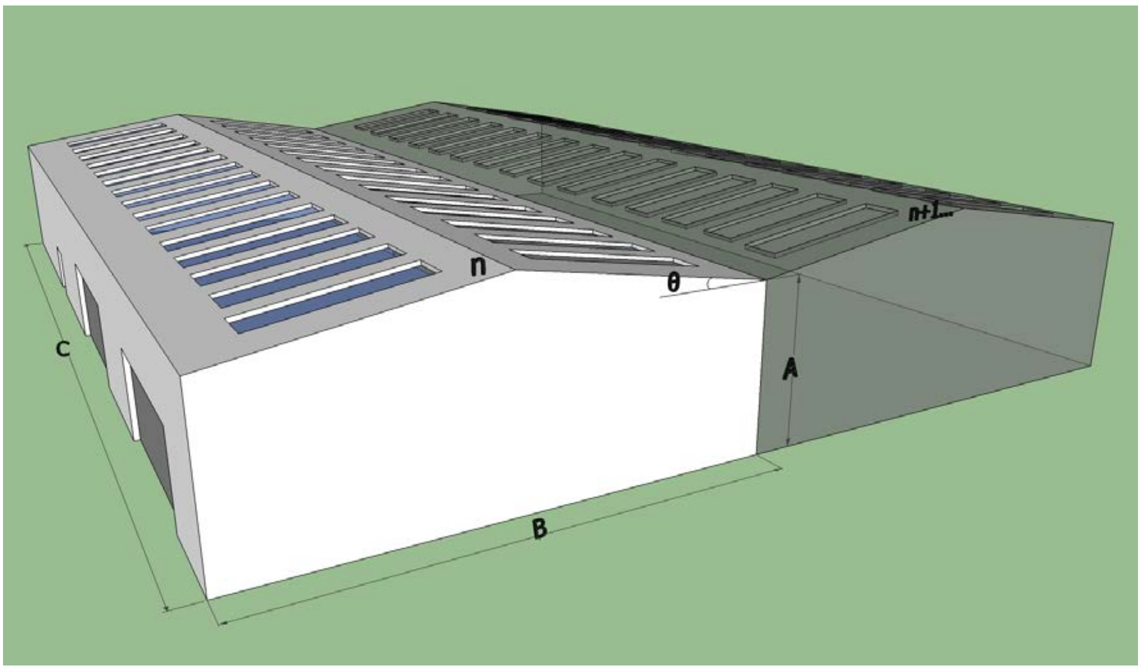


Figure 4. 6 Industrial warehouse

3.7.2.1 Construction and modelling assumptions for industrial buildings

Built up cladding systems with mineral wool and composite PUR cladding systems as conventional insulation materials have been used for industrial buildings. The analyses assume the general systems parameters described in Tables 4.4 & 4.5.

Built-up cladding systems for mineral wool and composite cladding systems for PUR insulation have been used. Built-up cladding systems comprise inner and outer profiled metal cladding sheets (steel or aluminium), separated by spacer systems, with insulation (normally mineral wool laid between them). Composite cladding systems also comprise two metal sheets but are bonded together with a foam material such that all parts of the panel are attached.

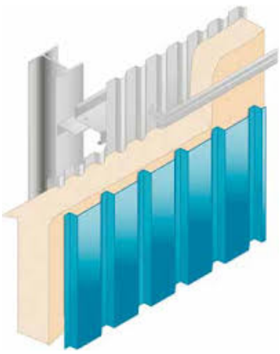


Figure 4.7 Built-up cladding system (source: Tata Steel)

Figure 4.8 PUR composite cladding

Buildings are assumed to be heated to 18°C during daytime occupation. 10-12% of the roof area is allocated to rooflights. Generated heat from lights, appliances and occupants (internal gains) has been taken into account when determining heating demands. The Building Regulations Part L 2010 backstop U-value was assumed as the base-case for calculations (Table 4.5).

Table 4.5 Building specifications

	1000 m² warehouse	**3000 m² warehouse & retail shed**
Roof area (m²)	1003.76	3010.5
Rooflight area (m²)	110	360
Ext. wall area (m²)	1327.34	2369.991
Floor area (m²)	1000	3000
Building height (m)	6	10.5
Building volume (m³)	6000	32624

Table 4.6 Base case U-values and thicknesses

	Mineral wool	PUR
Wall	Thickness : 100 mm	Thickness : 70 mm
	U-Value : 0.35 W/m²K	
Roof	Thickness : 140 mm	Thickness : 100 mm
	U-Value : 0.25 W/m²K	
Floor	U-Value fixed for all cases at 0.25 W/m²K	
Rooflight	U-Value fixed for all cases at 1W/m².K assumes triple glazed rooflight	

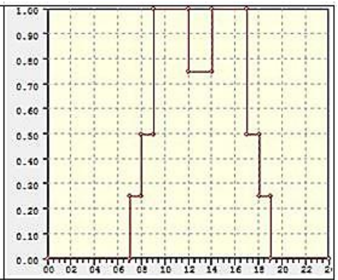
Table 4.7 Operational parameters for simulation modelling

	3000 m² Warehouse	1000 m² Warehouse	3000 m² Retail shed
Heating	Natural gas - Industrial heating system - heated to 18 °C from 8am-6pm		Natural gas - Industrial heating system - heated to 18 °C from 9am-9pm
Internal gain	LED lighting up to 12000W - people with 20 m²/person density	LED lighting up to 4000W -people with 20 m²/person density	LED lighting up to 12000W and displayed lighting up to 5W/m² -people with 5 m²/person density
Occupation	8am-6pm with 20 m²/person		9am-9pm with 5 m²/person
Ventilation	mechanical ventilation with maximum flow of 3ach over 25°C	mechanical ventilation with maximum flow of 1.5 ach over 25°C	mechanical ventilation with maximum flow of 3ach over 25°C
Lighting	controlled by sensors set at 300 lux		controlled by sensors set at 300 lux and displayed lighting up to 5w/m²
Airtightness	air infiltration value of 0.19 ach is used with 7.5 m³/h/m² air permeability rate	air infiltration value of 0.16 ach is used with 7.5 m³/h/m² air permeability rate	air infiltration value of 0.19 ach is used with 7.5 m³/h/m² air permeability rate

3.7.2.2 Construction and modelling assumptions for offices

Stick system curtain wall has been assumed to be the construction for the office buildings. NCM guidance has been used for simulation assumptions (Table 4.8).

Table 4. 8 Modelling assumption

occupancy pattern	
Internal gain	11.68 W/m2
People density	9 m2/person
Ventilation	Auxiliary ventilation with max flow of 1.11 (l/sm^2)
Lighting	3.75 W/m2/100 lux
Airtightness	air infiltration value of 0.25 ach is used with 5 m^3/h/m^2 air permeability rate

The overall thickness of wall technology has been used for the base case construction (Table 4.9):

Table 4.9 Typical external wall thickness

Aluminium sheet **Insulation (PUR)** **Aluminium sheet** **Cavity** **Aluminium Sheet (Black painted)**	1mm 55mm 0.5mm 50 mm 2.5mm
Total	109mm
U-value	0.35 W/m^{2}K (2010 backstop U-value)

Table 4. 10 U-value specifications

Wall	U-Value : 0.26 W/m²K
Roof	U-Value : 0.2 W/m²K
Floor	U-Value fixed for all cases at 0.22 W/m²K
Rooflight	U-Value fixed for all cases at 1 W/m².K assumes triple glazed rooflight

3.8 Design service life

The durability of building materials and products is a key component in the building design and lifetime performance taking effect from the selection and installation of materials and construction systems.

There are various environmental and chemical factors which can affect the durability of a material or component during its service life (such as being periodically exposed to moisture, humidity, temperature, wind and rain, chemical pollutants, solar radiation and site conditions). The durability of a material or component will be affected by some or a combination of these factors (www.sbsa.gov.uk, 2007).

Design service life according to the Scottish Building Standard Agency (SBSA) is defined as 'The assessment of a structure, both as a complete building and individual components, which predicts its potential lifetime based on levels of design, workmanship, maintenance and the environment' (2007, BRE design life of buildings: p1). Requirements for durability vary depending on building type (Figure 4.7) and component and concern the intended use, finance or periods for maintenance, repair and replacement.

DESCRIPTION	BUILDING LIFE FOR CATEGORY	EXAMPLES
Temporary	Agreed period up to 10 years	Non-permanent site huts and temporary exhibition buildings
Short life	Minimum period 10 years	Temporary classrooms; buildings for short life industrial processes; office internal refurbishment, retail and warehouse buildings; (see note 1.)
Medium life	Minimum period 30 years	Most industrial buildings; housing refurbishment
Normal life	Minimum period 60 years	New health and educational buildings; new housing and high quality refurbishment of public buildings
Long life	Minimum period 120 years	Civic and other high quality buildings

Figure 4.9 Categories of design life for buildings (BS 7543:2003)

Specific service lives can be determined for particular buildings, provided they do not exceed the period proposed for the next building type on the table; for instance most of the retail and warehouse buildings are expected to have a service life of 20-30 years.

An average of 25 year service life is often used for warehouse, industrial and retail premises but would be unusually short for housing and commercial buildings. Traditionally housing has been constructed to a notional 60 year service life, but in all application true service life can depart significantly and unpredictably from design life making calculations difficult. The notional 60 year service life (based around 2 mortgage periods and adopted by the council of mortgage lenders in the UK) is in many respects an arbitrary target but one that is nonetheless commonly adopted within the sector. Less clear still are the appropriate service life extensions that should be delivered by retrofit measures, whether these should essentially 'reset the clock', or whether they should extend service lives by a shorter period.

For the purposes of this research building envelope refurbishment assumes 25, 40 and 60 year service lives as different possible scenarios for industrial buildings and 30 and 60 year service lives for residential and office buildings. This is critical to 'net benefit' carbon calculations as the shorter the service life the greater is the impact of embodied carbon (i.e. annualising embodied carbon = total carbon / *n* years where n is the design life). Refurbishment applications where service lives are of the order of 25 years can therefore be significantly more susceptible to the effects of embodied carbon than new build applications where design lives are longer.

The maximum service life for VIPs is unknown at present but various studies are considering different methods of estimating the service life of VIPs. One of the most recent studies carried out by Yrieix et al (2014) suggests that four components should be considered with regard to lifetime of VIPs. They have demonstrated that the characteristics of the core material, the barrier envelope, service conditions and the thickness of the panels are considerably important when estimating the life expectancy. Consequently, any assessment method of lifetime which does not take into account these four components is likely to be partially wrong and thus not as reliable as expected. Therefore due to the uncertainties and complexities of estimating the service life of VIPs, in this study, it is assumed that insulation materials are not going to be replaced during the service life of the building.

Also in case of PV panels, UK Feed-in Tariffs for PV are calculated for an economic lifetime of 25 years, indicating that the Department of Energy and Climate Change believes that panels will produce for at least that long. However PVs are only used in the analyses with 25yeas design life and therefore are not required to be replaced.

3.9 Conclusion

The developing methodology has been discussed in detail and its main principles as well as the interaction between stages have been set out using an example. The developed methodology will be applied to a series of case studies of low and zero carbon building technologies the detail of which is described in the next Chapter.

CHAPTER 5: Total Carbon Quantification of Insulation Materials for New and Retrofitted Buildings

The following chapter investigates the effect of inclusion of embodied CO_2 in carbon analyses associated with a highly insulated building envelope, comparing mainstream conventional insulation materials with novel insulation materials for new and thermally retrofitted domestic and non-domestic buildings.

4.1 New build

4.1.1 Introduction

The UK Government is adopting regulations to reduce carbon emissions which will inevitably make low and zero carbon buildings a requirement (refer to Chapter 2). The imperative to reduce the carbon footprint of buildings will require higher levels of 'fabric energy efficiency' and 'application of low and zero carbon technologies' to minimise operational energy demand as an integrated part of any low and zero carbon performance.

The DCLG phase 3 final report (DCLG, 2011) in reference to 'zero carbon non-domestic buildings' supports a 'fabric first' approach through 4 main principles:

1. Building envelope energy efficiency measures principally involve lower whole life cycle costs than low and zero carbon (LZC) solutions due to maintenance and replacement costs (it is argued that the capital cost of low and zero carbon technologies are not fully reflected in the market price of buildings normally).

2. Building envelope energy efficiency measures are not as dependent as low and zero carbon technologies on the behaviour of occupants in achieving the targeted carbon thrifts. For example, occupants cannot change the settings of the insulation in an exterior wall in order to maintain its effectiveness. The

complexity of zero carbon technologies and need of maintenance can also contribute to larger gaps between predicted and actual energy consumption (real monitored data extracted from AIMC4 project (aimc4.com, 2014) is showing up to 3 times higher ‘as built’ energy consumption in comparison to ‘as designed’ figures in some cases).

3. Buildings are generally used for long terms, (although non-domestic buildings such as industrial buildings and supermarkets tend to be retrofitted or rebuilt more frequently than houses) and the cost of retrofitting is higher than building to higher standards at the time of build.

4. Reducing energy load demands by higher fabric standards at the time of build is more cost effective than supplying high energy demand with on-site low and zero carbon technologies.

The argument is that a minimum fabric energy efficiency standard works as a foundation for higher levels of carbon emission reductions using renewable technologies. A ‘fabric first’ approach should logically be the basis of any holistic energy efficiency strategy.

A ‘zero carbon buildings policy’ was introduced to form a part of Government’s wider strategy to achieving carbon reduction targets. It also supports the ‘fabric first’ approach. It comprises three main principles through which a building should have net carbon emission:

a. The fabric performance must, at a minimum, comply with the defined standard known as the Fabric Energy Efficiency Standard (FEES)

b. Any CO_2 emissions that remain after consideration of heating, cooling, fixed lighting and ventilation, must be less than or equal to the Carbon Compliance limit established for zero carbon homes

c. Any remaining CO_2 emissions, from regulated energy sources (after requirements a and b have been met), must be reduced to zero using on-site and/or off-site solutions (known as allowable solutions).

The zero carbon policy initially required all new homes from 2016, and all new non-domestic buildings from 2019, to be built to zero carbon standards (net carbon emission associated with only regulated energy use). The latest revision stated that small sites (developments with fewer than 50 homes), and also larger developers, are exempt from having to meet the highest energy efficiency standards. Larger developers, are able to offset carbon by paying into a Government fund for energy efficiency projects (The Telegraph, 2014). The UK's carbon reduction policy is in line with European policy (specifically the Energy Performance of Buildings Directive) which requires all new buildings to be nearly 'zero energy' buildings from 2020 (Zero Carbon Hub, 2014).

4.1.2 Insulation specifications for minimum carbon: mineral wool and PUR systems

Whilst cost criteria on life-cycle cost basis tend to dominate commercial specification decisions, carbon reduction is a primary driver of building codes and regulations and ultimately is probably the more important criterion. As already stated in Chapter 2, current legislation is founded on control of operational energy but as this is reduced the importance of embodied carbon becomes proportionately greater. The targets set by future regulations should logically be formed with reference to combined operational and embodied carbon analysis.

It is essential that the embodied carbon investments are entirely offset by operational carbon savings (arising as a result of improved standards of thermal insulation). If embodied carbon investments cannot be fully offset, moving to higher levels of thermal insulation represents an overall carbon disbenefit rather than the carbon benefit which is the over-riding aim of thermal standards. Given the relatively high embodied carbon investment in conjunction with high thermal conductivity of many conventional insulation materials, including mineral wool and PUR foam, overall carbon disbenefits can be achieved within the ranges of U-value that may increasingly be considered in relation to low and zero carbon performance relative to different service lives.

The point of minimum combined operational and embodied carbon, which will vary for individual buildings and building types, and will be influenced by factors including building operation regimes, represents the optimum building envelope specification. Critically it will also be influenced by insulation material types that offer high levels of thermal resistance relative to the embodied carbon investment. These are able to deliver better standards of energy thrift than materials that offer lower levels of thermal resistance relative to embodied carbon investments.

Applications for highly energy efficient building envelopes potentially include:

- Industrial buildings (where in terms of cost and performance any novel insulation systems must be competitive with conventional technologies),
- Residential and commercial buildings (where the combined performance and slimness of external walls can affect the net to gross area and consequently rental value of buildings).

4.1.2.1 Industrial buildings

A key and obvious market where highly insulated building envelope systems are required is industrial warehouses and retail sheds. Currently this sector produces and installs around 16 M m^2 of cladding, of which 13 M m^2 comprises insulated built-up or composite systems. These products service the industrial and retail sectors whose building related carbon emissions represent around 7.5% of total UK carbon emissions (Carbon Trust, 2009) i.e., a large proportion of total national energy related carbon emissions based almost entirely on standard product offerings, the engineering and specification of which is essential to achieving nationally agreed carbon reduction targets.

Minimum aggregated carbon analyses for industrial buildings

The following graphs (Figures 5.1 to 5.6) illustrate the range of insulation thicknesses and U-values around the point of minimum combined operational and embodied carbon for the standard single span portal frame warehouses of 1000 and 3000m^2 and similar 3000m^2 retail shed, based on explained modelling assumptions in Chapter 4. Embodied carbon measures for mineral wool and PUR insulation are extracted from the University of Bath's Inventory of Carbon and Energy (ICE) database. Only incremental increases in insulations embodied carbon has been taken into account in the analyses. Thicker insulation panels can require additional structural elements. This has been discounted in the analyses as the effect on the overall embodied carbon is negligible.

As previously stated, the proportion of embodied to operational carbon can shift considerably in buildings with lower operational carbon. As an example of this, Figures 5.1 and 5.2 demonstrate how lower operational carbon in 3000 m^2 retail shed in comparison to the same size warehouse, caused a life cycle carbon disbenefit beyond 260mm of mineral wool insulation panel (due to the high embodied carbon investment). In Figure 5.3 in contrast, the smaller warehouse is showing no difference in the optimum panel thickness comparing with the larger warehouse as the operational scenarios and the proportion of lighting and heating demands are the same.

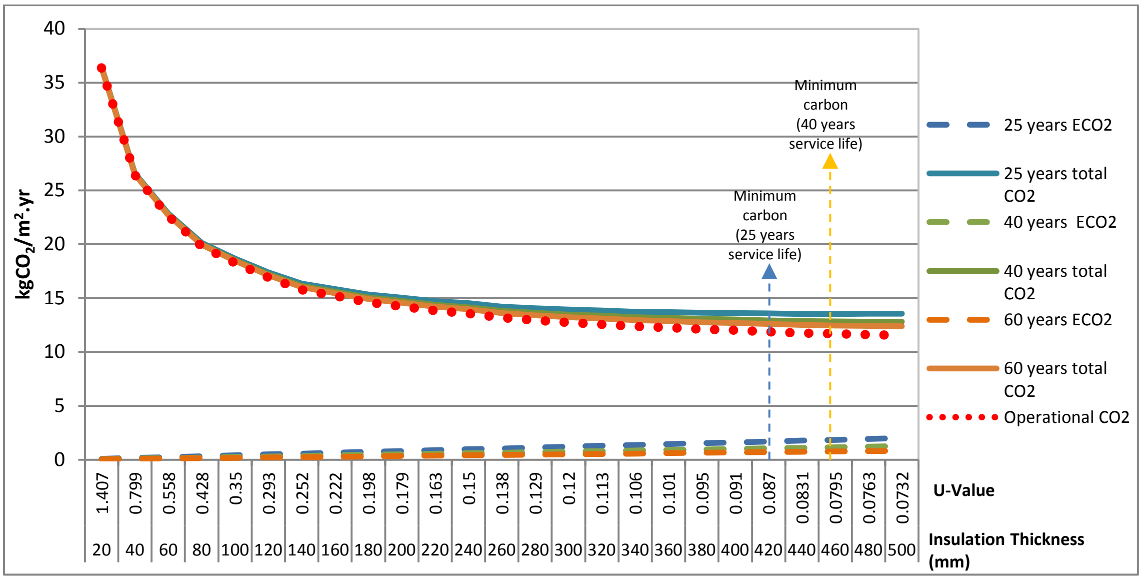


Figure 5.1 Carbon results of 3000m^2 warehouse insulated with mineral wool for 25, 40 and 60 years design life

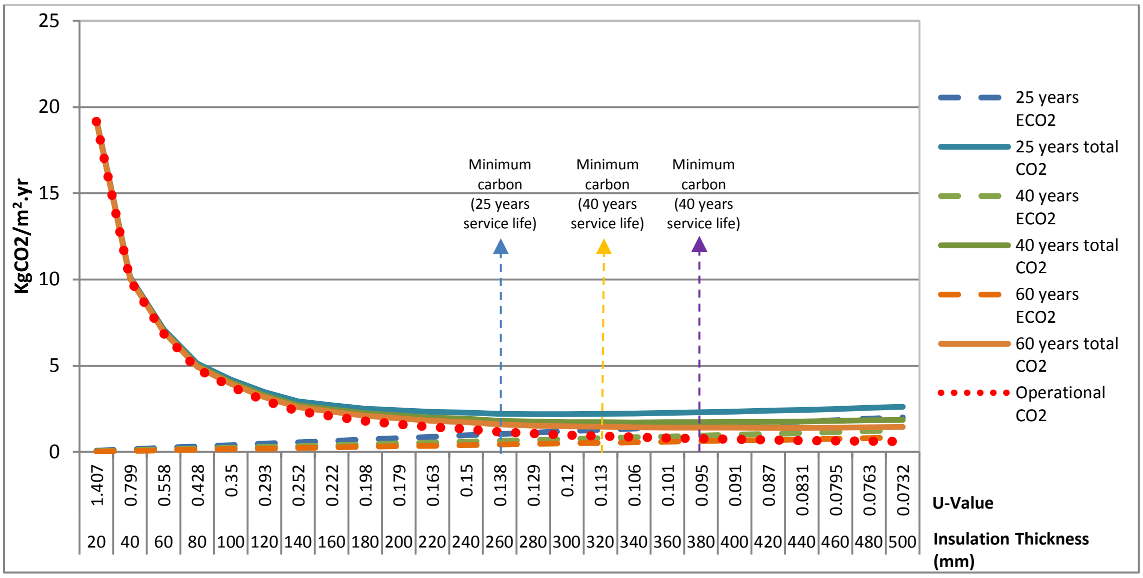


Figure 5.2 Carbon results of 3000m^2 retail shed insulated with mineral wool for 25, 40 and 60 years design life

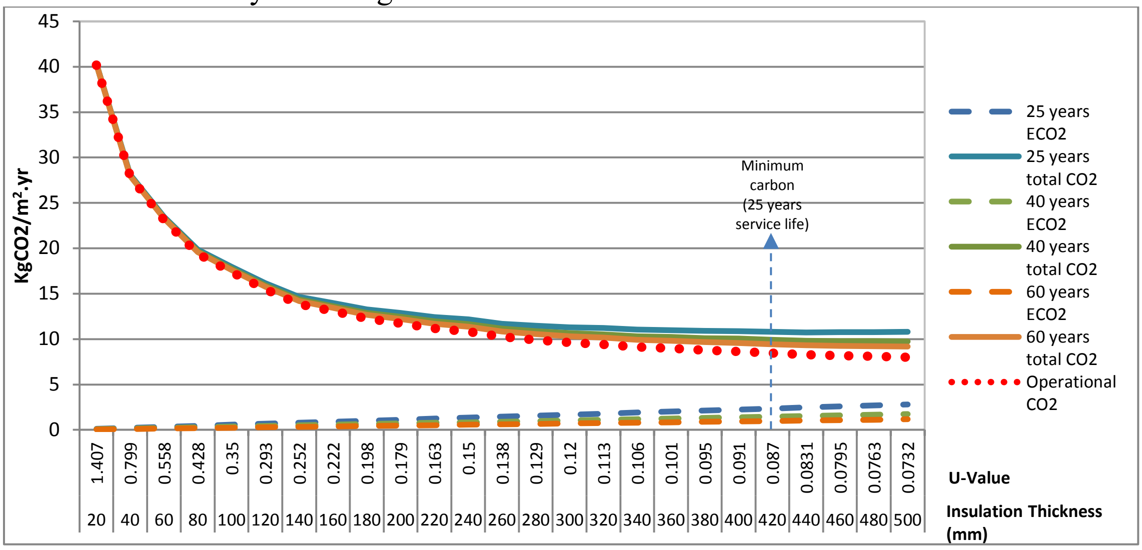


Figure 5.3 Carbon results of 1000m^2 warehouse insulated with mineral wool for 25, 40 and 60 years design life

The conventional insulation materials investigated are high in embodied carbon relative to their thermal resistance. For any insulation material to be justified to be used in a building, the amount of operational carbon saved as a result of thermal performance improvement of the cladding must be greater than its whole life carbon footprint. This is demonstrated in Figure 5.5, where the embodied carbon of PUR at 160mm in a retail shed outweighs the operational carbon savings and a total CO_2 disbenefit occurs.

Comparing Figures 5.4 and 5.5 shows that reduced operational CO_2 shifted the optimum thickness in terms of carbon benefit from 260mm in a warehouse to 160mm in retail shed for a 25 year design life of the building.

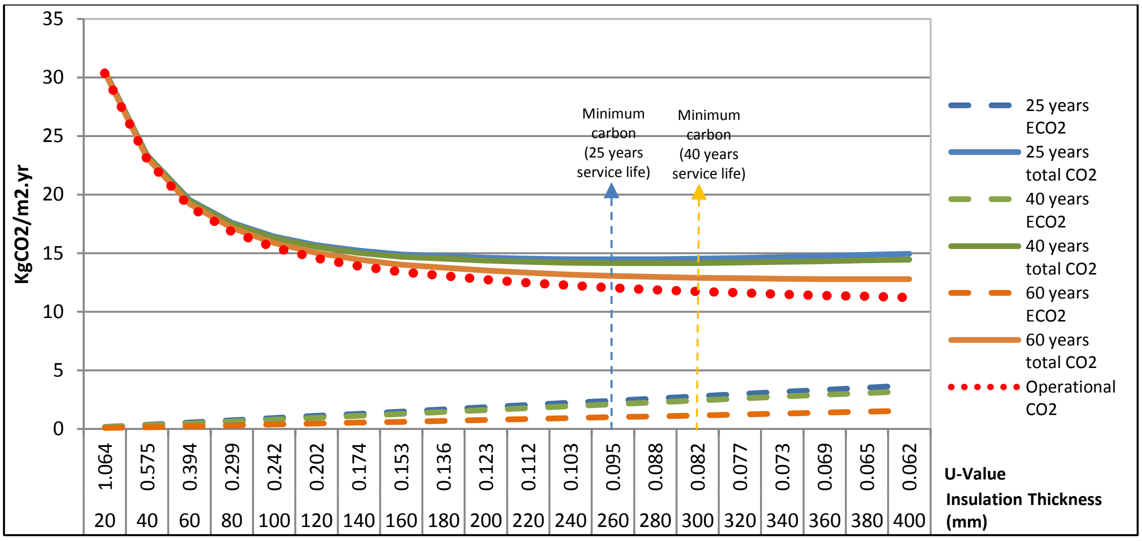


Figure 5.4 Carbon results of 3000m^2 warehouse insulated with PUR for 25, 40 and 60 years design life

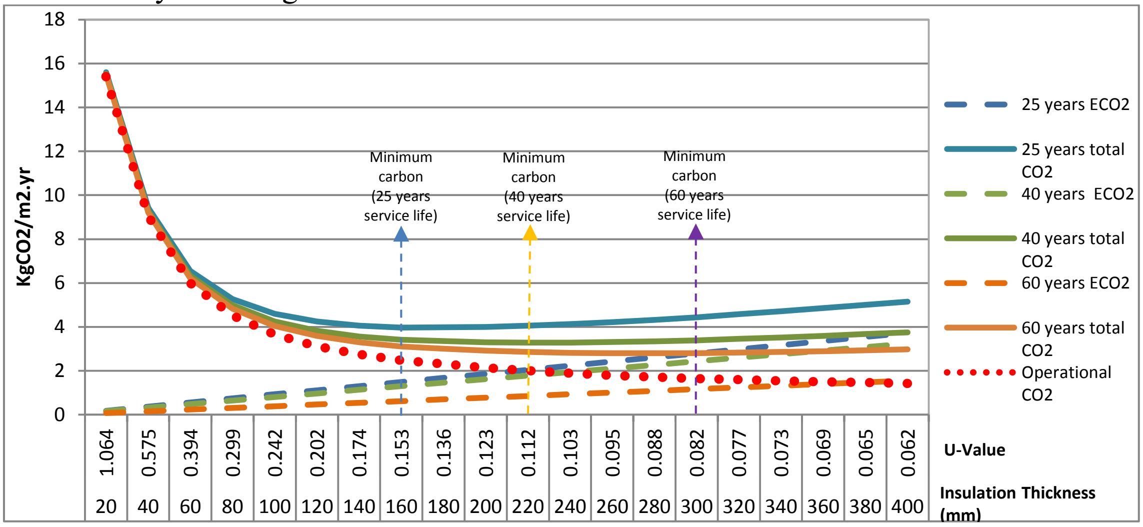


Figure 5.5 Carbon results of 3000m^2 retail shed insulated with PUR for 25, 40 and 60 years design life

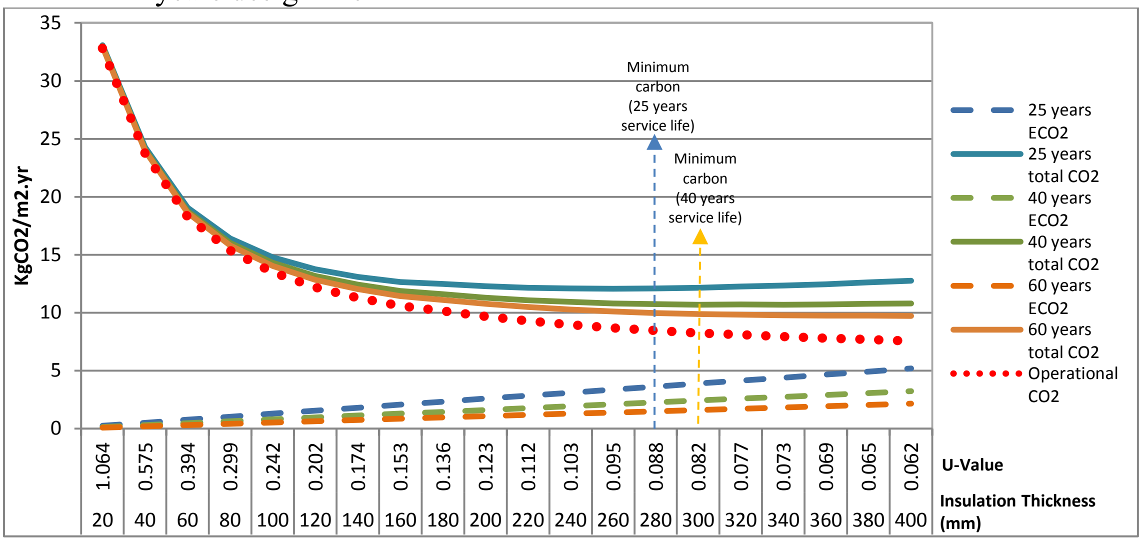


Figure 5.6 Carbon results of 1000m^2 warehouse insulated with PUR for 25, 40 and 60 years design life

For PUR insulation as well, as presented in Figure 5.6, the smaller warehouse is performing similarly to the larger warehouse in terms of the optimum insulation thickness associated with the minimum carbon.

Interpretation of Table 5.1 presents a number of key issues associated with conventional insulation technology:

1. A lower ratio of operational to embodied CO_2 restricts the maximum carbon benefit to thinner panels. Therefore, to reach the optimum carbon benefit, insulation materials with higher thermal resistance and lower associated embodied CO_2 are required to keep the operational to embodied CO_2 ratio high. As a result of that, the life cycle carbon disbenefit associated with combined operational and embodied CO_2 shifts towards thicker panels. Design life is also critical to optimum carbon benefit results as the shorter the design life the greater is the impact of embodied carbon (annualising embodied carbon being total embodied carbon divided by number of years life span).

2. Factoring embodied carbon into an aggregated analysis serves to limit the minimum CO_2 levels that can be justified. Higher embodied carbon insulation materials become more difficult to justify than lower embodied carbon materials as they more rapidly lead to a CO_2 disbenefit. Lower embodied carbon insulation materials allow for lower U-values (up to the point where the practical engineering difficulties prohibit effective adoption) whilst still presenting a CO_2 benefit, so more onerous insulation standards, giving improved energy thrift, can be achieved.

3. The R value (thermal resistance) of particular insulation materials is also a significant factor. It indicates how much insulation is required to deliver any prescribed U-value. The higher the R value, the lower the amount of insulation material needed, generating a corresponding reduction in embodied carbon. Critically therefore insulation with low embodied carbon coupled with high R value will achieve the lowest minimal CO_2. The relative carbon intensity of the investigated insulation materials as a measure of R-value to embodied CO_2 per metre square insulation material (associated with 0.1 $W/m^2.K$ U-value) has been

calculated. The level of carbon intensity is 26.1 $kgCO_2/m^2$ and 13.32 $kgCO_2/m^2$ for PUR and mineral wool respectively.

4. Greyed out cells on table 5.1 indicate where the values cannot be achieved using currently available systems, i.e. where the insulation and building envelope technology is unable to provide the required U-values due normally to the physical thickness of the required insulation (causing practical engineering difficulties). In these situations the optimal achievable values are reduced and the lowest CO_2 level is unachievable.

Table 5.1 Limits of conventional insulation materials in terms of minimum carbon emission for 25, 40 and 60 years design life

		Mineral Wool			PUR		
		3000 m² Retail shed	**3000 m² warehouse**	**1000 m² warehouse**	**3000 m² Retail shed**	**3000 m² warehouse**	**1000 m² warehouse**
25 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	2.19	13.5	10.74	3.97	14.48	12.08
	Roof Thickness (mm)	280	460	440	160	260	260
	Wall Thickness (mm)	200	330	320	115	185	185
	Roof U-value $W/m^2.K$	0.13	0.08	0.08	0.15	0.09	0.09
	Wall U-value $W/m^2.K$	0.18	0.111	0.116	0.21	0.14	0.14
40 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	1.71	NO MINIMUM UP TO 500 mm AND 0.07 $W/m^2.K$		3.28	13.5	10.69
	Roof Thickness (mm)	340			220	300	300
	Wall Thickness (mm)	245			155	215	215
	Roof U-value $W/m^2.K$	0.106			0.111	0.08	0.08
	Wall U-value $W/m^2.K$	0.15			0.15	0.115	0.11
60 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	1.41	NO MINIMUM UP TO 500 mm AND 0.07 $W/m^2.K$		2.8	NO MINIMUM UP TO 400 mm AND 0.06 $W/m^2.K$	
	Roof Thickness (mm)	380			280		
	Wall Thickness (mm)	270			200		
	Roof U-value $W/m^2.K$	0.09			0.08		
	Wall U-value $W/m^2.K$	0.13			0.12		
Current manufacturing limitations		Lowest possible U-Value: 0.2 $W/m^2.K$ for wall and 0.09 for Roof			Lowest possible U-Value: 0.13 $W/m^2.K$ for Wall and Roof		

Where very high levels of thermal insulation are able to deliver net carbon benefits on the basis of aggregated operational and embodied carbon analysis, practical technical constraints can become limiting. Two of the most common insulation materials, mineral wool and PUR foam, both have limitations that can constrain their usage.

PUR foam relies on a reaction between its constituent chemicals to cause the formation of cells and expansion (foaming) of the material (Jelle 2011, Al-Homoud 2005). Beyond around 170mm this reaction is slow and becomes difficult to control. 170mm of PUR foam equates to a U-value of 0.147 $W/m^2.K$. The maximum thickness of PUR that appears possible to obtain from standard sources at present appears to be around 200mm with U-value of 0.125 $W/m^2.K$ with 170mm being significantly more common.

Mineral wool can be produced to any thickness (if necessary in multiple layers) but where low U-values are required the necessary dimensions can become difficult to accommodate within construction systems (the support systems in built-up cladding becomes too large and problematic) (Papadopoulos 2005, Al-Homoud 2005). 280mm of mineral wool is required to achieve the same U-value as 170mm of PUR, whilst to achieve a U-value of 0.1 $W/m^2 \cdot K$ requires 360mm. This over-sizing has an adverse effect on net to gross internal area ratios, increases cost and presents significant engineering difficulties (including excessive eccentricities in spacer systems particularly on walls and inclined roofs). The transportation and handling of deep insulation systems can also be problematic. On these grounds very thick mineral wool assemblies are usually discounted although the maximum thickness that is acceptable is more difficult to identify precisely.

4.1.2.2 Residential buildings

Energy consumption in houses accounts for 27% of the total national energy consumption in the UK (DECC, 2010). Building codes and compliances therefore require performance standards to be met by residential building envelopes. This inevitably requires incremental increases in insulation thicknesses (to reduce the heat loss through building fabric) that consequently result in thick cladding systems using conventional insulation materials.

Traditionally, the external walls of residential buildings in the UK were constructed of solid brickwork. The cavity wall was designed to keep the majority of moisture at bay, whilst the ventilated cavity facilitates evaporation of any moisture that does penetrate to the cavity. The first experiments with insulated cavities however occurred in the 1950s in the UK when regulations dictated higher levels of insulation (Energy saving trust, 2009). Over the years, Building codes and Regulations have led to an incremental increase in the total cavity width from 35 to 100mm in accordance with insulation requirements.

More recently however as even higher insulated building fabric is required, the feasibility of wider cavities is being debated. The industry is keen on the 100 mm cavity width which provides approximately 0.25-0.2 $W.m^2k$ U-value (using mineral wool and PUR as insulation materials and when the cavity is fully filled). This makes it difficult to achieve lower U-values using conventional insulation materials. There are number of reasons why industry supports 100 mm cavity:

1. The first consideration is the cost effectiveness of 100mm cavities as they are widely accepted by the industry as being easily constructed.

2. A consequence of increased wall thickness could be the loss of the area of a house from the plot on a large building site in an extreme case. In cases where the land size is limited, increased wall thickness could lead to loss of livable area and to lower rental value per site. Flats and terraced houses (as most constructed types of housing since 2003 in the UK) are not extremely affected by this scenario.

3. In addition, thermal bridging needs to be investigated as higher number of steel ties are required to penetrate through the insulation to support wider cavities.

A 100mm insulated cavity supported by other carbon reduction technologies, can meet the requirements for compliance with Code for Sustainable Homes levels 3 and 4. However to achieve levels 5 and 6, it will be necessary to improve the U-value in a cost-effective way. The England and Wales Building Regulations Approved Document A presents guidelines for cavities up to 300mm width. Evidence from the Modern Masonry Alliance (MMA) suggests that cavities of 125-150mm are gaining acceptance (due to energy efficiency concerns) and being used more frequently by developers in the self-build market (energy saving trust, 2009). However, for the above reasons going beyond 100-150 mm cavity is not seen as a preferred route by much of the construction industry.

Calculations show limits for conventional insulation materials in achieving required low U-values at an industry level accepted cavity width (Table 5.2).

Table 5.2 Associated U-values with insulated cavity widths (fully filled)

	U-value W/m^{2}K	
Insulated cavity mm	**mineral wool**	**PUR**
50	0.389	0.31
100	0.255	0.19
150	0.189	0.138

Minimum aggregated carbon analysis

The following analyses illustrate the range of insulation thicknesses and U-values around the point of minimum combined operational and embodied carbon for a semi-detached residential building, based on NCM modelling assumptions. Embodied carbon figures for mineral wool and PUR insulation are extracted from the University of Bath's Inventory of Carbon and Energy (ICE) database.

Mineral wool is limited to 0.15 W/m^{2}K U-value for 30 years design life requiring a 200 mm cavity which is not seen as a preferred solution by industry (Figure 5.7). The U-value for 150mm of mineral wool is approximately 0.19 W/m^{2}K. For a 60 year design life however, no minimum carbon point is observed due to lower embodied CO_2 (Figure 5.8).

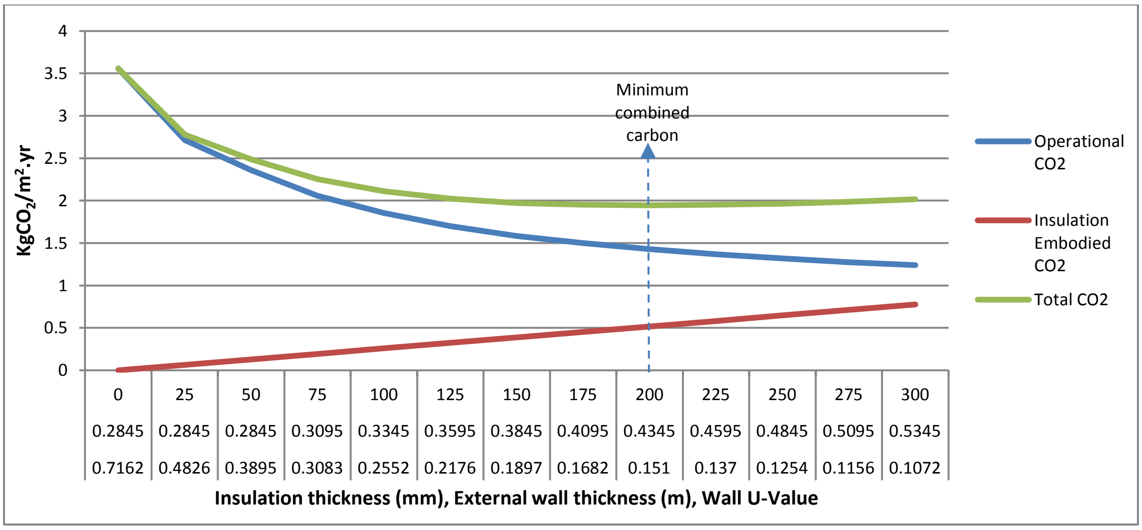


Figure 5.7 Carbon results of residential buildings insulated with mineral wool for 30 years design life

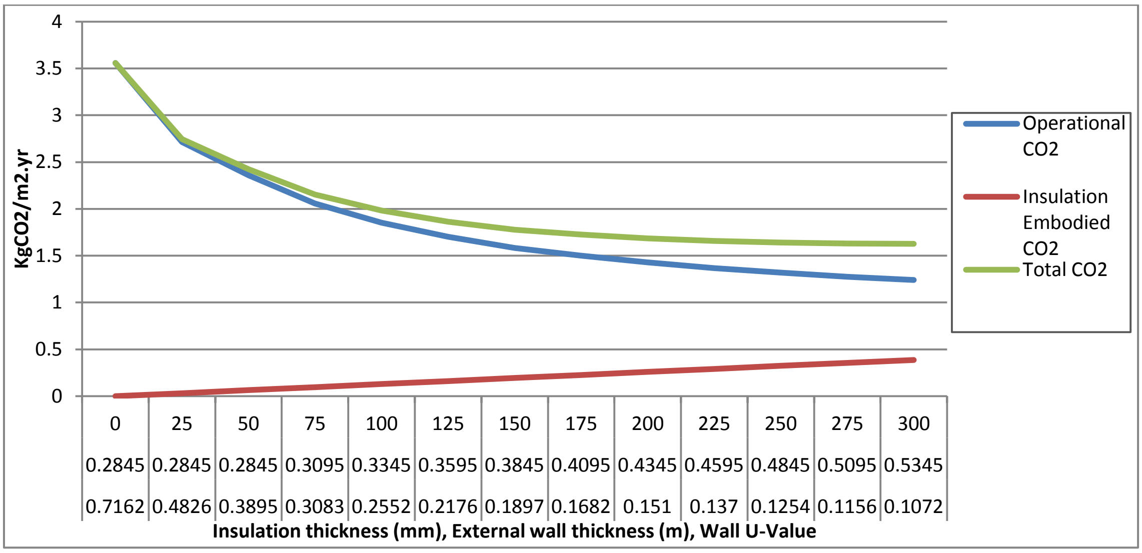


Figure 5.8 Carbon results of residential buildings insulated with mineral wool for 60 years design life

The graphs for the investigated residential buildings indicate an optimum thickness for PUR insulation of approximately 100mm and 150mm for 30 and 60 years design life assumptions respectively (Figures 5.9 and 5.10). This is based on typical building operational criteria described in Chapter 4. This equates to a U-value of approximately 0.19 W/m^{2}K for 30 years design life and 0.13 W/m^{2}K for 60 years design life. Both PUR and mineral wool are limited to 0.19 W/m^{2}K due to the structural issues and potential carbon disbenefit at 30 years design life. In case of 60 years design life, PUR is limited to 0.13 W/m^{2}K. Mineral wool is not showing any carbon disbenefit down to 0.1 W/m^{2}K U-value.

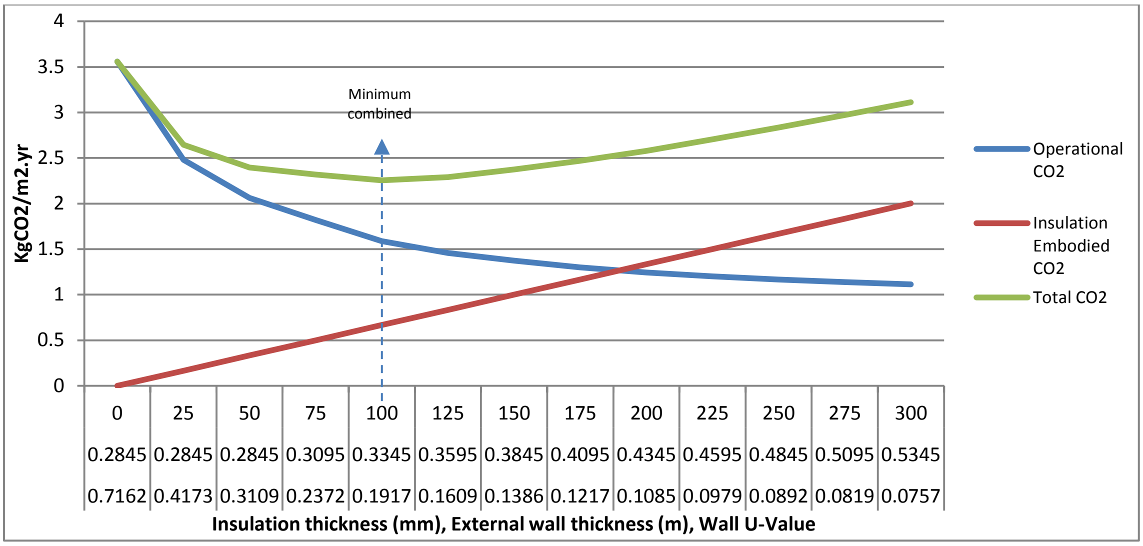


Figure 5.9 Carbon results of residential buildings insulated with PUR for 30 years design life

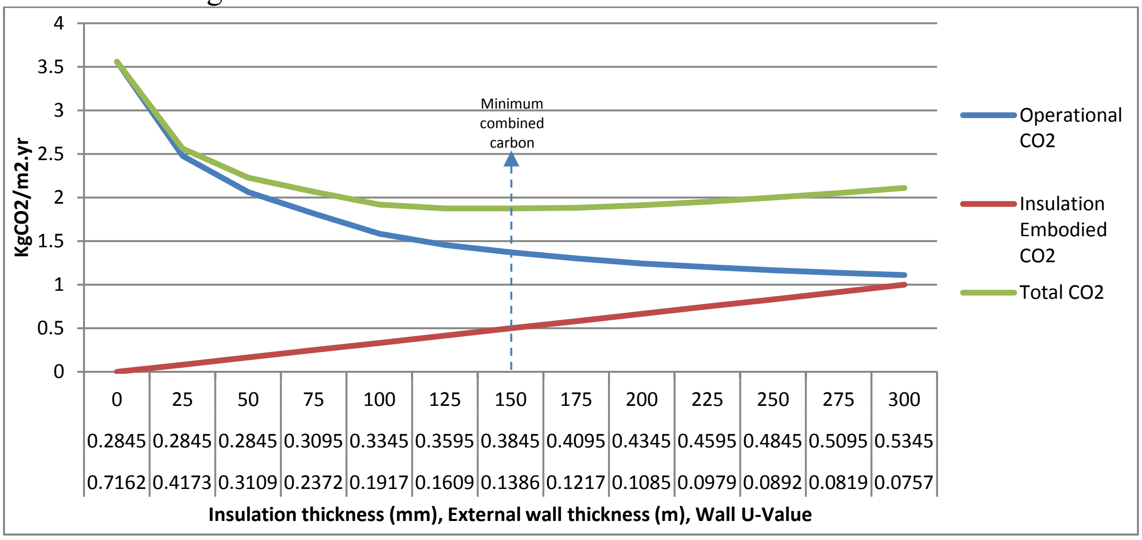


Figure 5.10 Carbon results of residential buildings insulated with PUR for 60 years design life

Note that curves of this nature tend to flatten as service life increases or as a result of the use of lower embodied carbon insulation. Both of these factors increase the optimum insulation thicknesses. Conversely, if service life is decreased, or higher embodied carbon insulation materials are used, optimum insulation thickness decreases.

Greyed out cells on Table 5.3 indicate where the values cannot be achieved using conventional insulation materials, i.e. where the insulation and building envelope technology is unable to provide the required U-values due normally to the physical thickness of the required insulation (causing the practical engineering difficulties previously described). In these situations the optimum achievable values are reduced and the lowest CO_2 level is unachievable.

Table 5.3 Limits of conventional insulation materials in terms of minimum carbon emission for 30 and 60 years design life

<table>
<tr><th colspan="2"></th><th>Mineral Wool</th><th>PUR</th></tr>
<tr><td rowspan="5">30 YEARS DESIGN LIFE</td><td>Minimum CO_2 ($kgCO_2/m^2.yr$)</td><td>1.944</td><td>2.25</td></tr>
<tr><td>Total wall Thickness (mm)</td><td>434</td><td>334</td></tr>
<tr><td>Roof U-value $W/m^2.K$</td><td>0.113</td><td>0.136</td></tr>
<tr><td>Total roof thickness</td><td>450</td><td>340</td></tr>
<tr><td>Wall U-value $W/m^2.K$</td><td>0.151</td><td>0.191</td></tr>
<tr><td rowspan="4">60 YEARS DESIGN LIFE</td><td>Minimum CO_2 ($kgCO_2/m^2.yr$)</td><td rowspan="4">NO MINIMUM CO_2 UP TO 300 mm INSULATION WITH 0.1 $W/m^2.K$ U-VALUE</td><td>1.89</td></tr>
<tr><td>Total wall Thickness (mm)</td><td>334</td></tr>
<tr><td>Roof U-value $W/m^2.K$</td><td>0.136</td></tr>
<tr><td>Wall U-value $W/m^2.K$</td><td>0.19</td></tr>
</table>

4.1.2.3 Office buildings

According to the DCLG report on 2014 build rate assumptions (DCLG, 2014), 44% of new non-domestic buildings are going to be Offices by 2050. Commercial office buildings therefore are a key sector in achieving the committed energy thrift targets. A survey commissioned by BCSA and Tata Steel (steelconstruction.info, 2015) shows that on average across the last 30 years steel frames have accounted for 70% of all non-domestic framed multi-storey UK commercial construction. Steel framed systems coupled with novel insulation solutions can lead to the expected slimness ideal for commercial buildings.

The slimness of cladding systems for commercial buildings and specifically offices are crucial as when the thickness of commercial building cladding systems increase, the ratio of net to gross floor area which is calculated on a building perimeter basis is adversely affected. The impacts of adjustments in net to gross floor areas that may be achieved by reducing the width of external walls are significant in rental value of buildings.

Therefore, in order to identify the optimum thickness on grounds of carbon efficiency and slimness of the cladding using mainstream conventional insulation materials (considering meeting the fabric energy efficiency standards), thermal performance of a typical four story office building has been modelled using dynamic thermal modelling software (IES-VE). Mineral wool and PUR as conventional insulation materials have been used for the analysis.

Minimum aggregated carbon analysis

The following analyses illustrate the range of insulation thicknesses and U-values around the point of minimum combined operational and embodied carbon for an office building, based on CIBSE modelling assumptions.

Mineral wool shows results limited to 0.13 $W/m^2.K$ U-value for 30 years design life requiring 240 mm insulation thickness (Figure 5.11). In case of a 60 year design life, no minimum carbon point occurs down to 0.09 $W/m^2.K$ U-value (Figure 5.12).

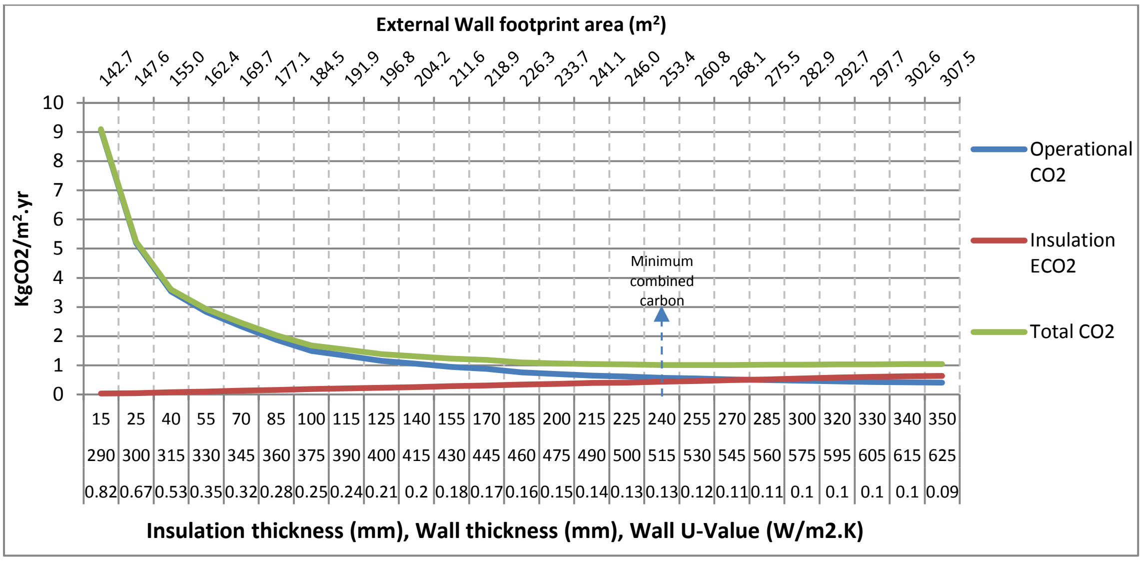


Figure 5.11 Carbon results of commercial buildings insulated with Mineral wool for 30 years design life

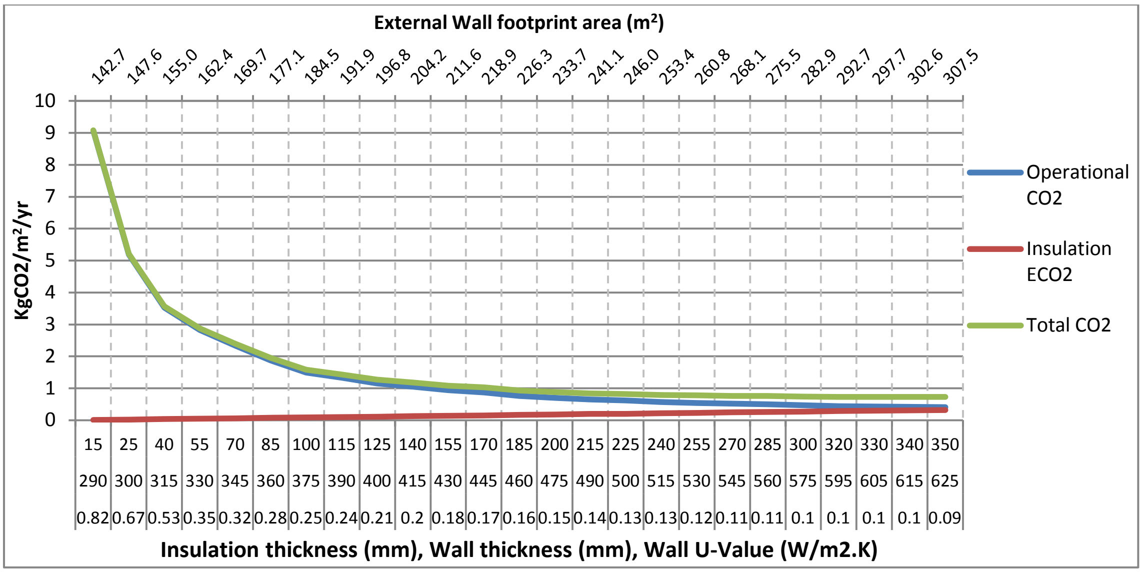


Figure 5.12 Carbon results of commercial buildings insulated with Mineral wool for 60 years design life

The PUR insulation results for the investigated office building demonstrate an optimum thickness of approximately 220mm and 280mm based on design life assumptions of 30 and 60 year respectively. This equates to a U-value of 0.1 and 0.08 W/m^2.K respectively (Figures 5.13 and 5.14).

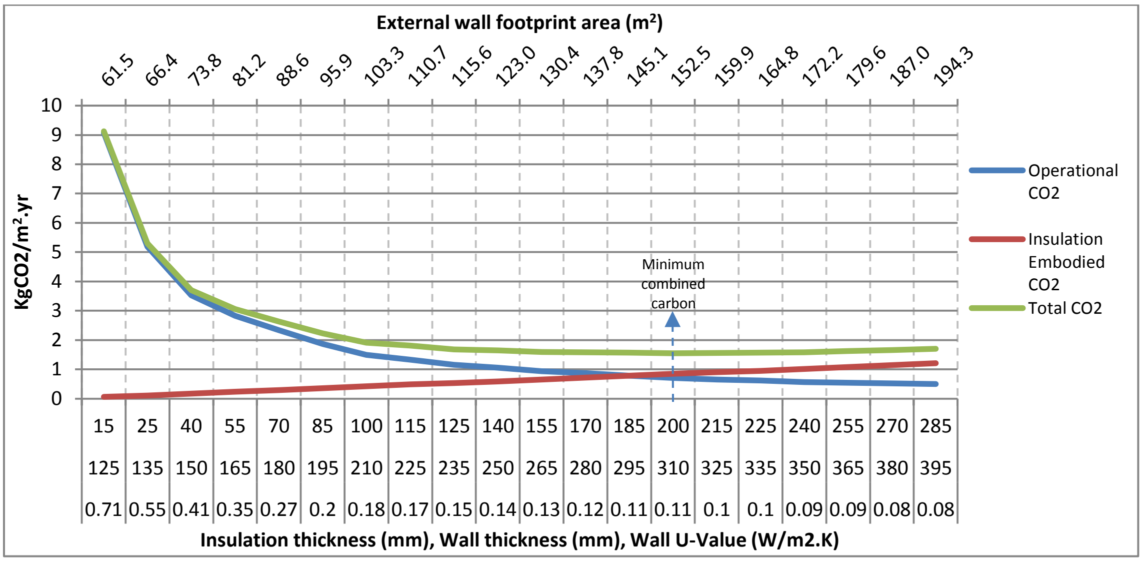


Figure 5.13 Carbon results of commercial buildings insulated with PUR for 30 years design life

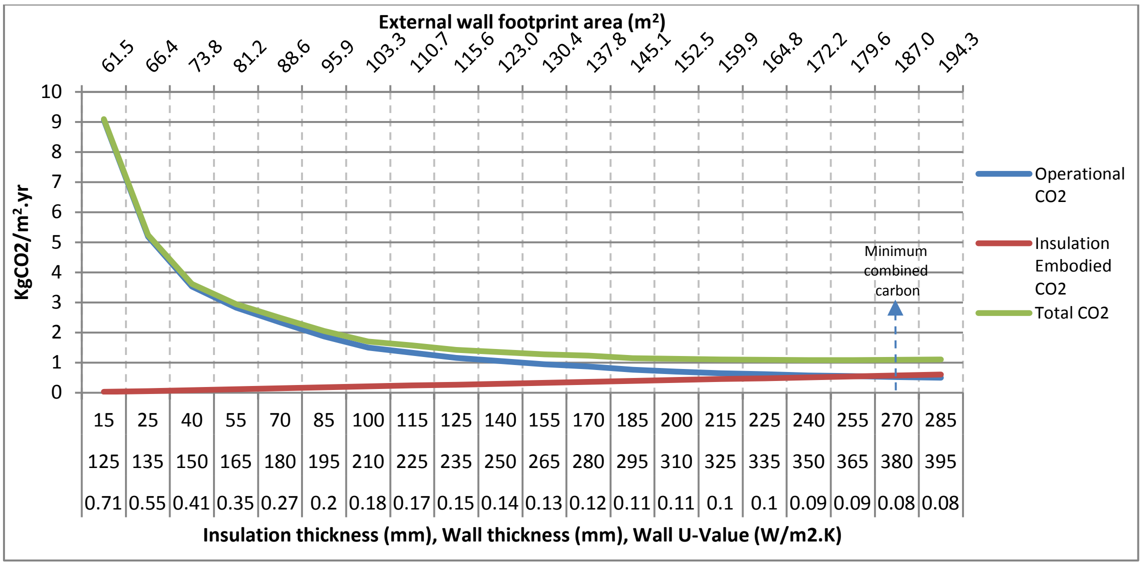


Figure 5.14 Carbon results of commercial buildings insulated with PUR for 60 years design life

Table 5.4 indicates where the values can theoretically be achieved using conventional insulation materials but are not normally used due to the unacceptable physical thickness of the required insulation and also the significant amount of lost rental values associated with thick insulation panels. In these situations the minimum achievable values are reduced and the lowest CO_2 level is unachievable.

Table 5.4 Limits of conventional insulation materials in terms of minimum carbon emission for 30 and 60 years design life

		Mineral Wool	PUR
30 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	1.007	1.87
	Wall Thickness (mm)	515	330
	Roof U-value $W/m^2.K$	0.106	0.08
	Wall U-value $W/m^2.K$	0.13	0.109
60 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	NO MINIMUM CO_2 UP TO 350 mm INSULATION WITH 0.09 $W/m^2.K$ U-VALUE	1.29
	Wall Thickness (mm)		390
	Roof U-value $W/m^2.K$		0.064
	Wall U-value $W/m^2.K$		0.086

4.1.3 Role of novel insulation materials: vacuum insulation panels and hemp

Certain modern insulation materials appear to have good potential to provide U-values better than those provided by conventional materials such as mineral wool and PUR, without there being a net carbon disbenefit arising from their embodied carbon. These materials essentially provide higher levels of thermal insulation relative to the embodied carbon investment. Some possible examples include Vacuum Insulation Panels and Hemp.

4.1.3.1 Vacuum Insulation Panels

Vacuum panels typically comprise 3 components (Figure 5.15):

- A core material which provides structural integrity and resistance to heat transfer.
- A thin film barrier or envelope to preserve the vacuum and reduce radiative heat losses.
- A 'getter' or desiccant material to absorb any residual water or gas inside the sealed envelope, as well as any water vapour or gases which may permeate the envelope.

Thermal conductivities of less than 0.004 W/m.K can be achieved. U-values associated with VIPs therefore, are typically 4-7 times better than conventional insulation materials.

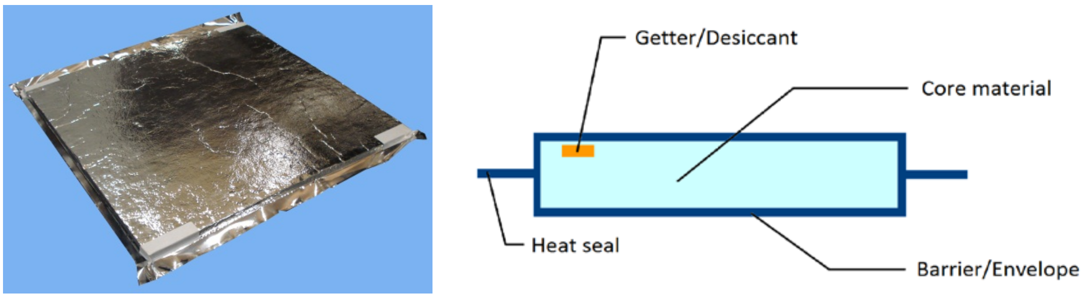


Figure 5.15 VIP panel components

Figures 5.16 and 5.17 present the differences in thickness of Vacuum Insulation Panels (VIPs) and PUR/mineral wool insulation for equivalent U-values. It schedules the specific dimensional reductions achieved for U-values in the range 1.1 to 0.1 W/m^2 K (the greatest differences occurring at the lowest U-values). Results are based on centre panel calculations, i.e. without edge effects.

VIP Thickness (mm)	PUR Thickness (mm)
3.4	19.7
3.8	21.8
4.2	24.4
4.7	27.6
5.4	31.7
6.3	37.3
7.6	45.2
9.6	57.1
12.8	77.2
19.3	118.1
38.8	244.5

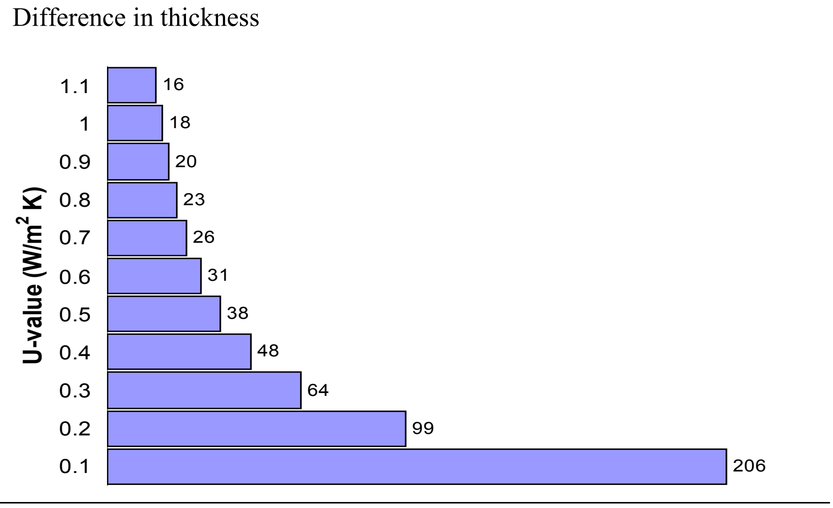


Figure 5.16 Comparison of thickness of VIP and PUR insulation of equivalent U-value

VIP Thickness (mm)	MW Thickness (mm)
3.4	28.3
3.8	31.3
4.2	35.1
4.7	39.8
5.4	45.9
6.3	54.1
7.6	65.8
9.6	83.6
12.8	113.8
19.3	175.7
38.8	369.1

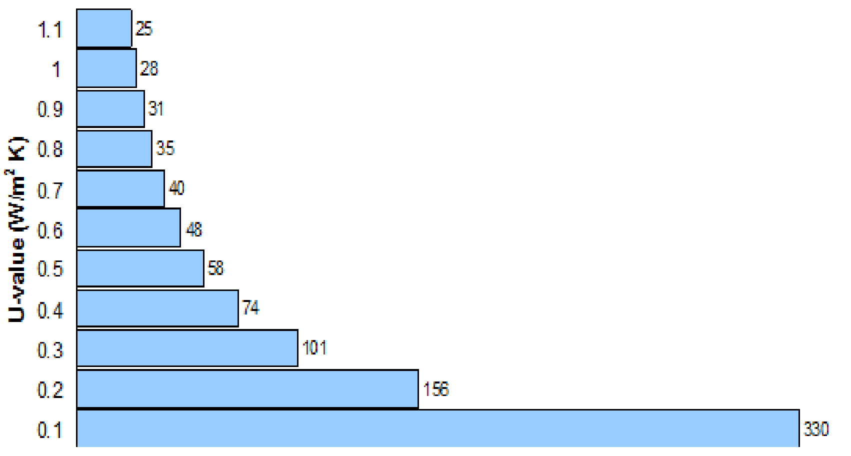


Figure 5.17 Comparison of thickness of VIP and mineral wool insulation of equivalent U-value

In conventional insulation materials, such as mineral wool and PUR, a large proportion of the total heat transfer is due to conduction across (non-convective) gas pockets within the material. Eliminating the conduction effects of such gas pockets improves resistance of the insulation to heat transfer (HiPTI IEA/ECBCS Annex 39, 2005). Vacuum Insulation Panels (VIPs) are a highly efficient form of thermal insulation comprising an open-celled core (fumed silica or mineral wool) and a sealed and evacuated air-tight membrane (normally multiple alternating layers of metallic and polymeric materials).

Conventional vacuum insulation panels (VIPs) based on evacuated fumed silica within metallised polymeric membranes have been considered for the analyses. This form of vacuum panel is now used in different industries including refrigerators, packaging, pipework wrapping and construction, to provide high levels of insulation at minimal thickness.

This should be noted that the edge effect in conventional vacuum insulations can affect the effective U-value of the panel significantly depending on the panel size and thickness. Due to the uncertainties associated with quantifying the edge effect the centre of the panel U-value has been used in the analyses.

Minimum aggregated carbon analyses of VIPs in industrial claddings

High thermal resistance of VIPs coupled with low embodied CO_2 implies a net benefit up to and beyond the levels of insulation that may be reasonably anticipated (i.e. extremely low U-values). Figures 5.18 to 5.20 demonstrate the optimum level of carbon efficiency which is achievable using VIP insulation.

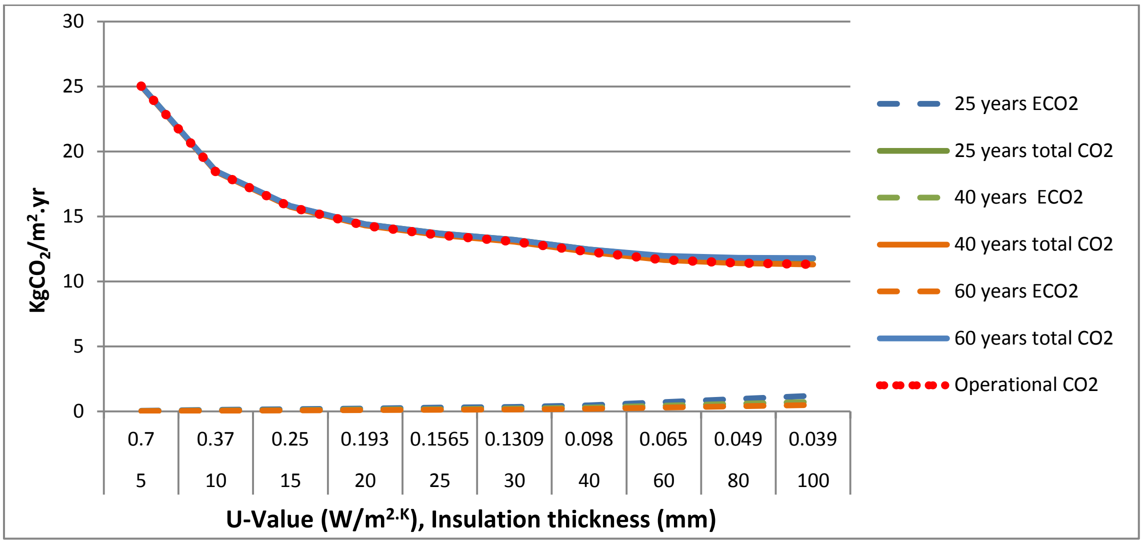


Figure 5.18 Carbon results of 3000m² warehouse insulated with VIP for 25, 40 and 60 years design life

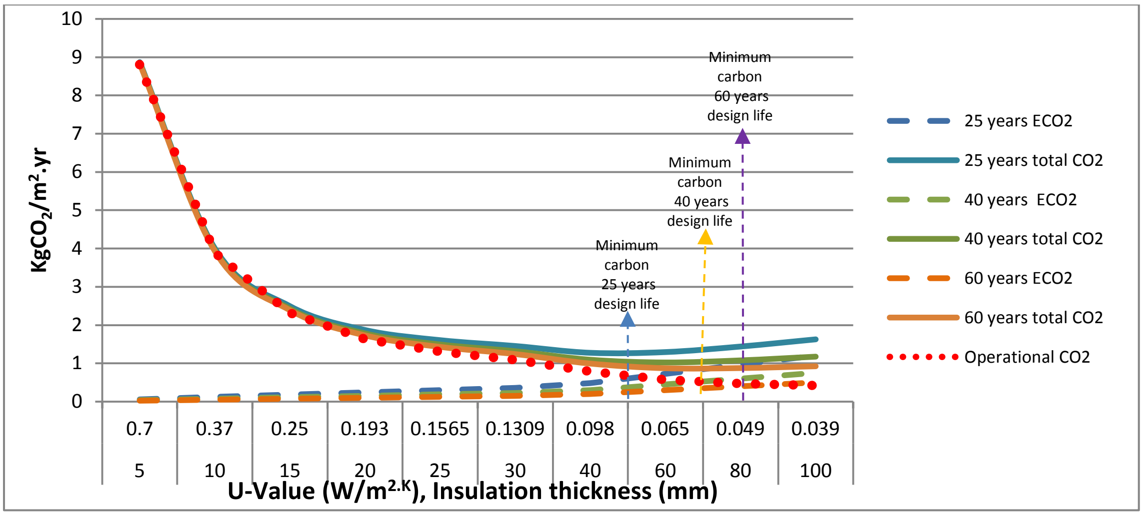


Figure 5.19 Carbon results of 3000m^2 retail shed insulated with VIP for 25, 40 and 60 years design life

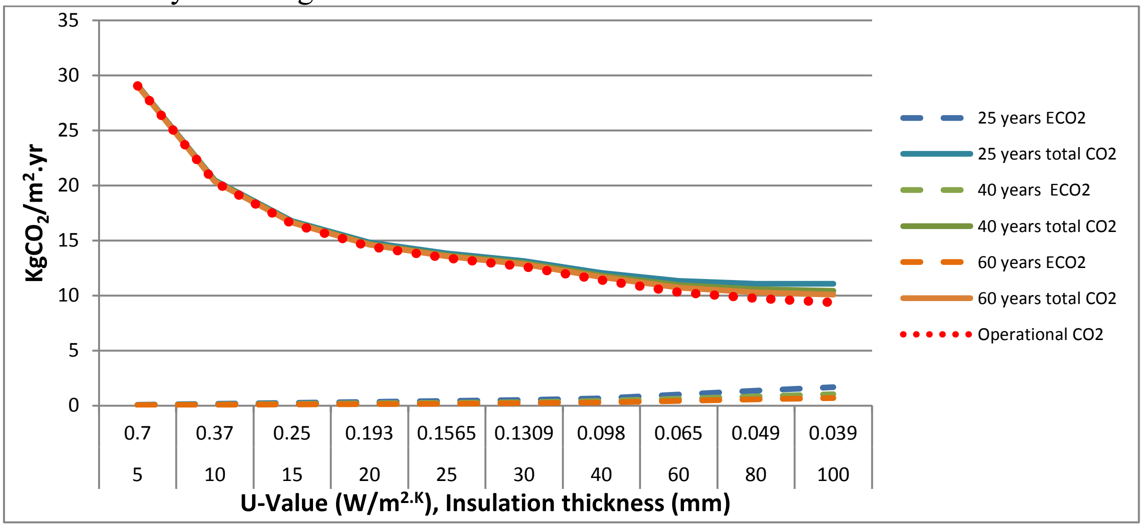


Figure 5.20 Carbon results of 1000m^2 warehouse insulated with VIP for 25, 40 and 60 years design life

Only in one of the cases analysed, that of a retail shed with a 25, 40 and 60 year design life, embodied CO_2 reaches a point where it offsets the savings associated with incremental increase of insulation material. In all other cases increasing the level of insulation provided by VIP continues to reduce the combined operational and embodied carbon requirements (Table 5.5).

According to the DCLG report on 2014 build rate assumptions (DCLG, 2014), 43% of new non-domestic buildings will be distribution and retail warehouses by 2050. This figure equates to 3.3 million square meters of warehouse buildings. The minimum achievable CO_2 associated with using VIPs in comparison to investigated conventional insulation materials saves about 3.8-9 thousand tonnes of CO_2 per annum (depending on building size and operation criteria) which is about 4-10% of total non-residential buildings in-use phase CO_2 emissions (Table 5.5) (BIS, 2010).

Table 5.5 Minimum achievable carbon emissions of conventional insulation materials in comparison to VIP for 25 years design life

	25 YEARS DESIGN LIFE (minimum achievable)								
	Mineral Wool			PUR			VIP		
	Retail shed	3000 m^2 warehouse	1000 m^2 warehouse	Retail shed	3000 m^2 warehouse	1000 m^2 warehouse	Retail shed	3000 m^2 warehouse	1000 m^2 warehouse
Minimum CO_2 ($kgCO_2/m^2.yr$)	2.25	14	11.5	3.97	14.5	12.2	1.27	11.76	11.05
Roof Thickness (mm)	280	400	400	160	170	170	80	110	110
Wall Thickness (mm)	170	170	170	115	170	170	60	100	100
Roof U-value $W/m^2.K$	0.13	0.09	0.09	0.15	0.13	0.13	0.049	0.03	0.03
Wall U-value $W/m^2.K$	0.2	0.2	0.2	0.21	0.13	0.13	0.068	0.039	0.039

Minimum aggregated carbon analyses of VIP in residential claddings

Vacuum Insulation Panels with 4 to 7 times better thermal resistance than conventional insulation materials enable building owners to gain higher rental value associated with thinner external walls. This also provides the industry with a solution to meet the thermal performance requirements with maximum 100 mm cavity width. The results from Figures 5.21 and 5.22 indicate a carbon disbenefit at 0.087 and 0.07 $W/m^2.K$ U-value for VIP for 30 and 60 years design life respectively. Such low U-values were achieved with only 40 and 60mm of insulation.

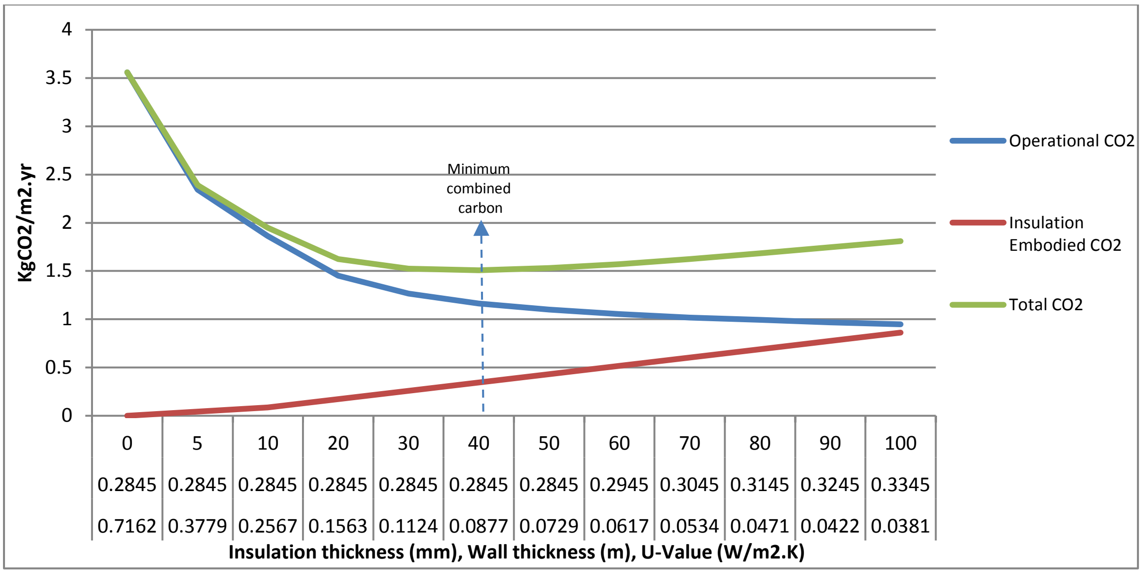


Figure 5.21 Carbon results of residential buildings insulated with VIP for 30 years design life

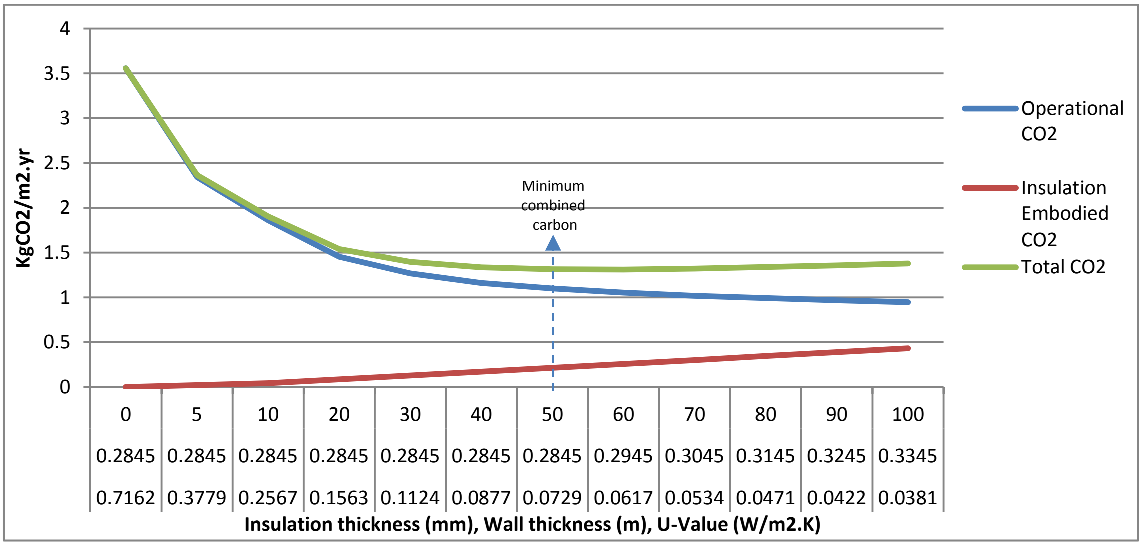


Figure 5.22 Carbon results of residential buildings insulated with VIP for 60 years design life

The average floor area of houses in the UK is about 80 m^2 (RIBA, 2008) which, multiplied by the average 100 thousand of new houses being built each year (DCLG, 2012), results in 8M m^2 of new domestic buildings. The minimum achievable combined operational and embodied CO_2 associated with VIPs in comparison to investigated conventional insulation materials shows between 4-6 thousand tonnes CO_2 savings per annum which is about 2.7- 4 % of total residential buildings in-use phase CO_2 emissions (BIS, 2010) (Table 5.6).

Table 5.6 Limits of VIP in terms of minimum carbon emission for 25, 40 and 60 years design life (residential)

		VIP
30 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	1.5
	Wall Thickness (mm)	284
	Roof U-value $W/m^2.K$	0.06
	Wall U-value $W/m^2.K$	0.08
60 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	1.3
	Wall Thickness (mm)	294
	Roof U-value $W/m^2.K$	0.045
	Wall U-value $W/m^2.K$	0.061
Current manufacturing constraints		No relevant technical limitations

Minimum aggregated carbon analyses of VIPs in office buildings

High thermal resistance of VIPs coupled with low embodied CO_2 investments results in very low achievable minimum carbon. Minimum achievable CO_2 for VIPs is 3 to 4 times lower than that associated with investigated conventional insulation materials (Figures 5.23 and 5.24). This equates to about 3000 tonnes CO_2/pa. Multiplying this figure by the 2 million m^2 floor area of office buildings results in about 3% reduction in total non-residential buildings in-use phase CO_2 emissions (BIS, 2010) (Table 5.7).

Table 5.7 Limits of VIPs in terms of minimum carbon emission for 25, 40 and 60 years design life (office buildings)

		VIP
30 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	0.6
	Wall Thickness (mm)	320
	Roof U-value $W/m^2.K$	0.065
	Wall U-value $W/m^2.K$	0.08
60 YEARS DESIGN LIFE	**Minimum CO_2 ($kgCO_2/m^2.yr$)**	0.45
	Wall Thickness (mm)	342
	Roof U-value $W/m^2.K$	0.05
	Wall U-value $W/m^2.K$	0.045
Current manufacturing constraints		No relevant technical limitations

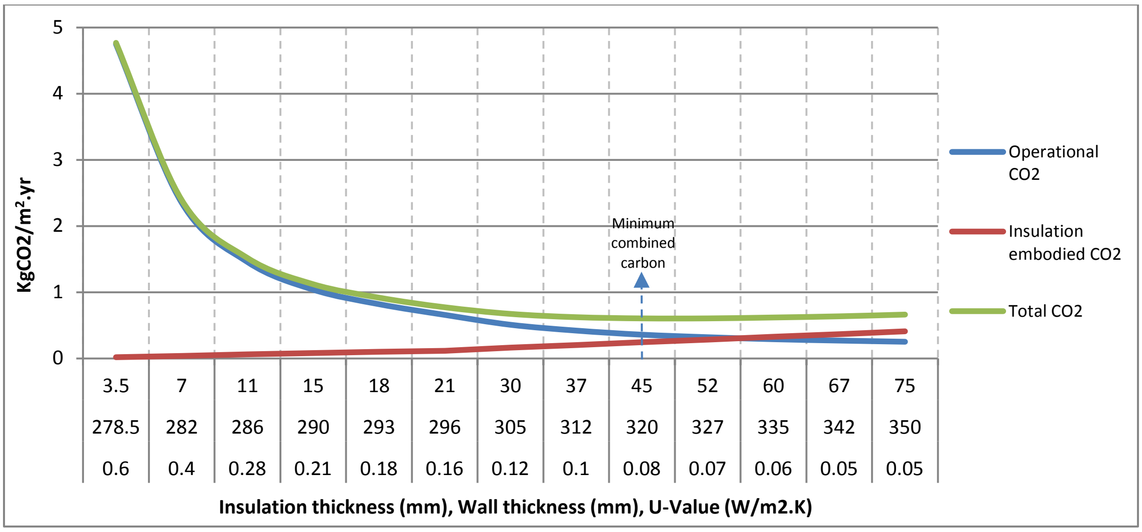


Figure 5.23 Carbon results of commercial buildings insulated with VIP for 30 years design life

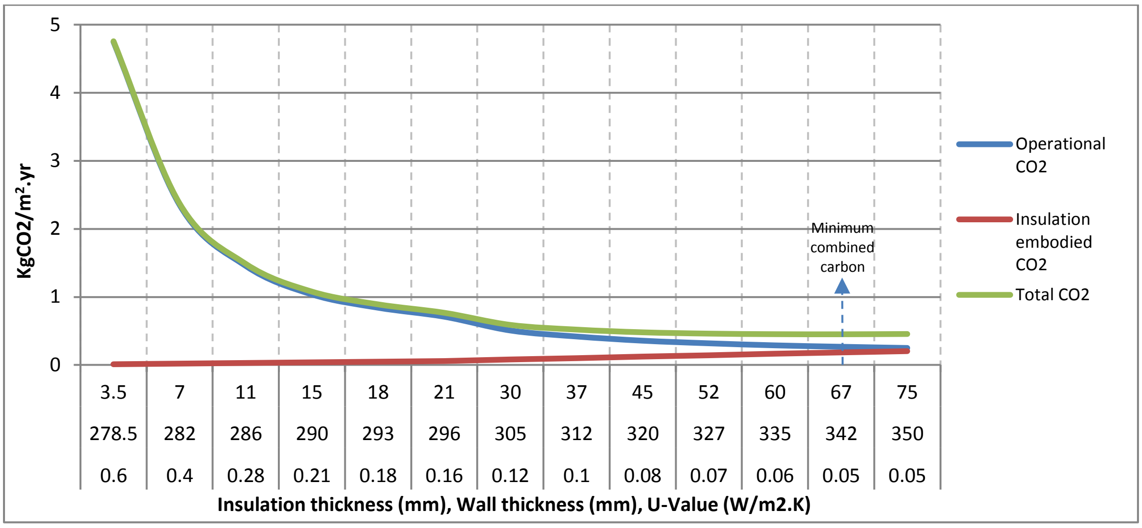


Figure 5.24 Carbon results of commercial buildings insulated with VIP for 60 years design life

4.1.3.2 Hemp insulation

What makes hemp a novel insulation material is its environmental performance. Like other Natural Fibre Insulation (NFI) materials, hemp during its growth stage locks away up to two tonnes of CO_2 per tonne of fibre harvested which has a significant positive impact on the environment. (www.hemptechnology.co.uk, 2013).

The CO_2 will remain stored in the hemp fibre throughout the life of the product. If the embodied CO_2 of the material is calculated on a cradle to gate basis (which is the case in this research) then the sequestered CO_2 in a hemp plant in its growth stage and low energy demand in farming and processing stages results in a negative embodied CO_2 value for hemp insulation (Table 5.8).

Table 5.8 Net Global Warming Potential associated with hemp farming and processing (hemptechnology.co.uk, 2012)

	Hemp farming	Hemp processing	Total
Energy (MJ/kg straw)	1.86	1.92	3.78
IPCC GWP 100 (kgCO_2/kg straw)	0.11	0.11	0.22
Net GWP inc. sequestered carbon (kgCO_2/kg straw)	-1.56	0.11	-1.46

Hemp insulation is produced from the long fibres obtained from hemp plants (Figure 5.25). After the hemp is harvested and dried, the dried hemp plant is separated into wood, fibres (used to create insulation), leaves, seeds and leftover dust. To hold the 'wool' together, strengthening polyester fibres are used that cannot be composted and should be treated as household waste (Duijve, 2012). Hemp has the ability to help manage condensation levels which not only decreases the risk of moisture damage but also improves indoor air quality by allowing the building to breathe. Hemp insulation is a hygroscopic material and is able to absorb, store and release over 20% of its weight in moisture without affecting product performance.

Figure 5.25 Hemp insulation (source: homesinharmony.co.uk)

The density of Hemp insulation is approximately 40 kg/m^3 and its thermal conductivity is 0.039 W/m.K (Hock, 2009) which in comparison to other novel insulation technologies is high.

Minimum aggregated carbon analyses of hemp in industrial claddings

Whilst the thermal conductivity of hemp insulation is similar to conventional insulation material such as mineral wool, negative embodied carbon implies a net carbon benefit down to the maximum levels of insulation that may be reasonably anticipated (i.e. extremely low U-values) (Figures 5.26 to 5.28).

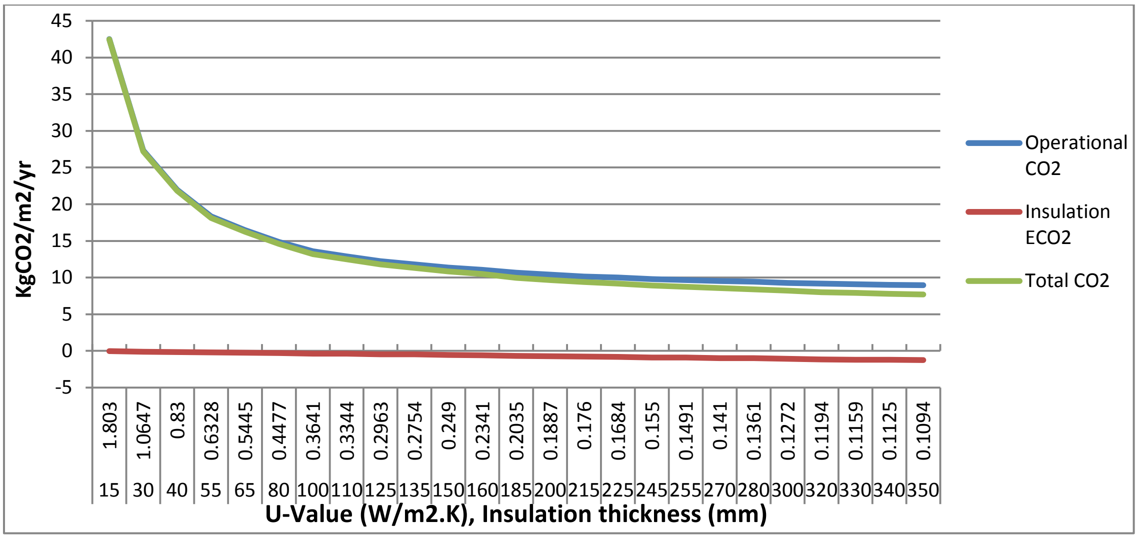


Figure 5.26 Carbon results of 3000m^2 warehouse building insulated with hemp for 25 years design life

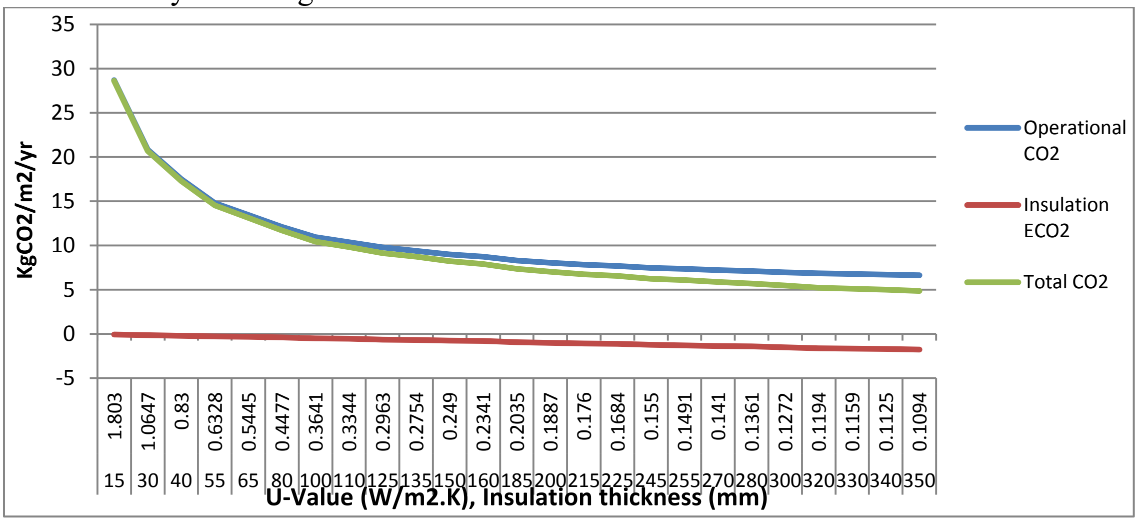


Figure 5.27 Carbon results of 1000m^2 warehouse building insulated with hemp for 25 years design life

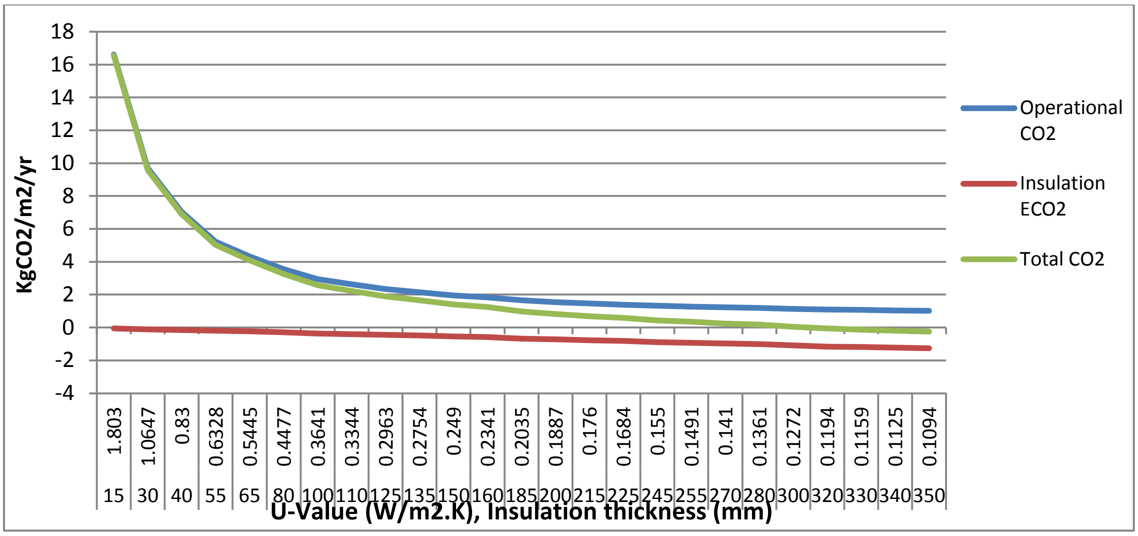


Figure 5.28 Carbon results of 3000m^2 retail shed insulated with hemp for 25 years design life

As previously stated, 3.3 M m^2 of new buildings will be distribution warehouses and retail sheds. Non-domestic buildings are responsible for 100.7 MtCO_2 per year (during their in-use phase) (BIS, 2010). The minimum achievable CO_2 associated with using hemp insulation (using the cradle to gate figure for embodied CO_2) in comparison to investigated conventional insulation materials saves about 5-7.7 kgCO_2 per square meter per annum depending on building size and operation criteria. This is about 17-25 million tonnes of CO_2 for 3.3 M m^2 of new non-residential buildings which is 16.8-24.8% of total non-residential buildings in-use phase CO_2 emissions (BIS, 2010).

Minimum aggregated carbon analyses of hemp in residential claddings

Approximately 8 M m^2 of new domestic buildings are going to be built each year (DCLG, 2012). The minimum achievable combined operational and embodied CO_2 analyses using hemp (assuming negative embodied carbon) in comparison to investigated conventional insulation materials shows between 1.55-1.85 kgCO_2/m^2 savings per annum. This multiplied by the floor area of new buildings equates to approximately 8.5-10% of total semidetached buildings CO_2 emissions associated with heating demand (BIS, 2010) (Figures 5.29 and 5.30).

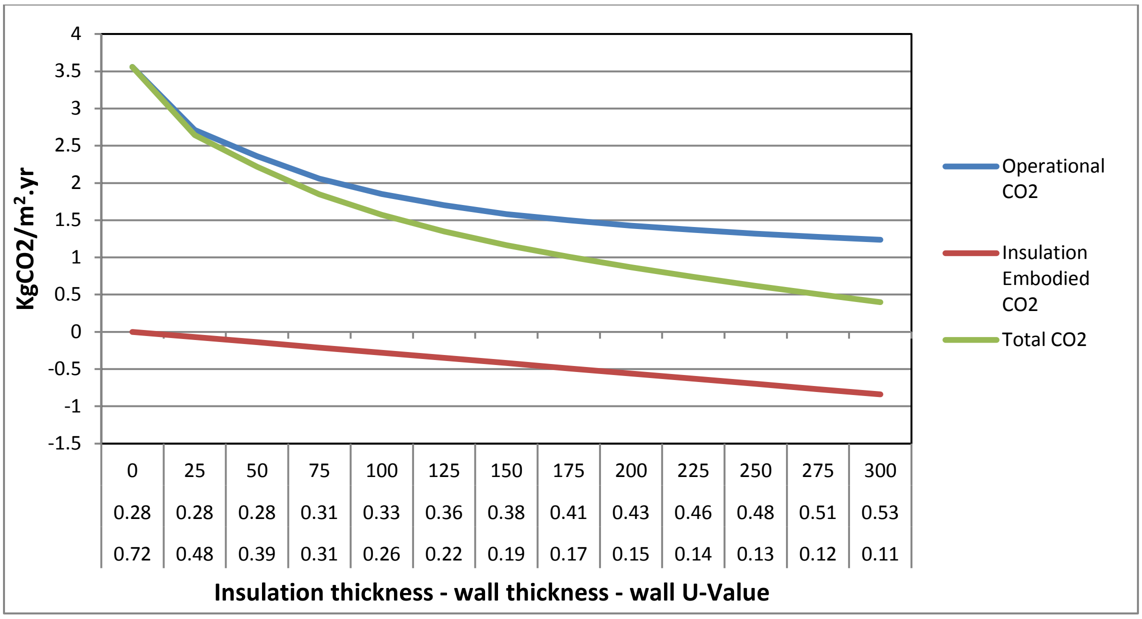


Figure 5.29 Carbon results of residential building insulated with hemp for 30 years design life

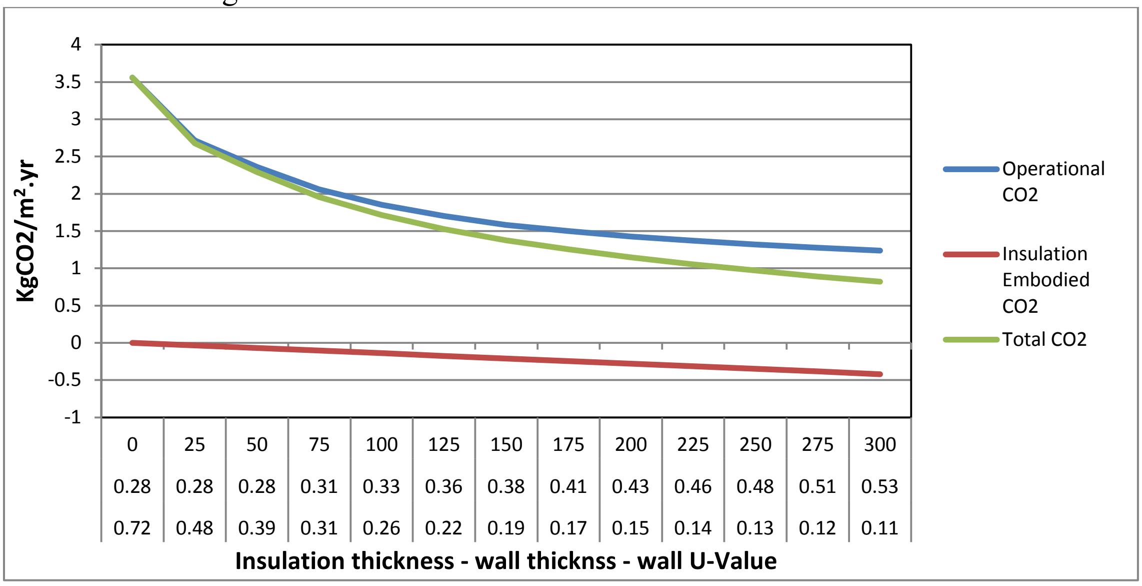


Figure 5. 30 Carbon results of residential building insulated with hemp for 60 years design life

Minimum aggregated carbon analyses of hemp in office buildings

Optimum CO_2 values for hemp insulation in comparison to investigated conventional insulation materials are about 1-1.15 $kgCO_2/m^2$ per annum. Multiplying this figure to 2 million m^2 floor area of office buildings (build rate assumptions for 2050) saves up to 3% of total non-residential buildings in-use phase CO_2 emissions (BIS, 2010) (Figures 5.31 and 5.32).

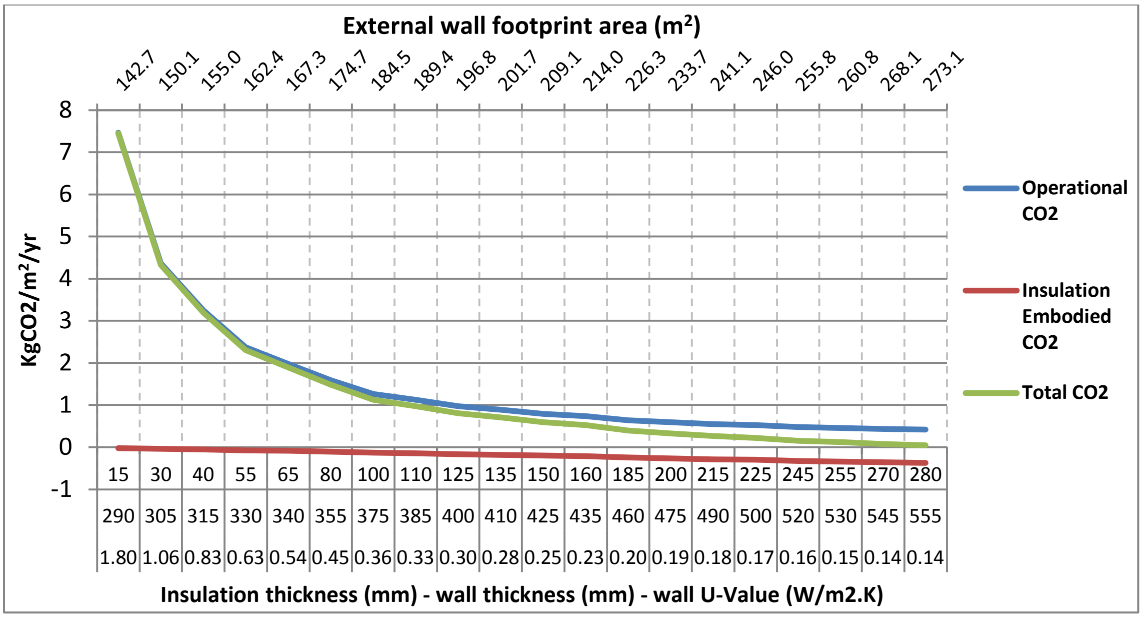


Figure 5.31 Carbon results of commercial building insulated with hemp for 30 years design life

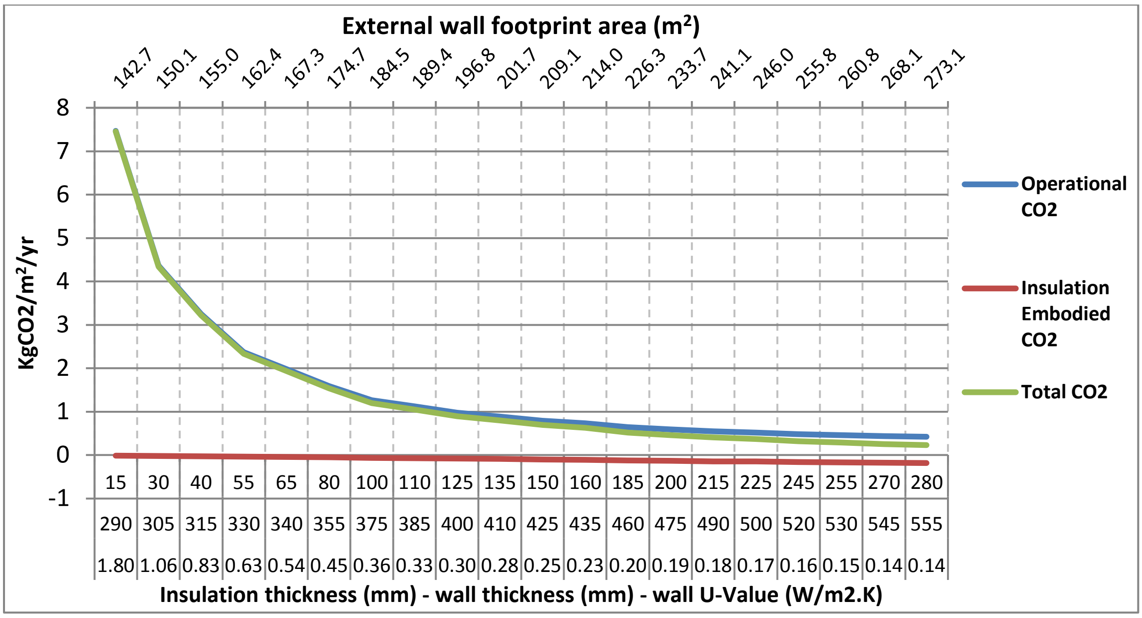


Figure5.32 Carbon results of commercial building insulated with hemp for 60 years design life

The benefit of hemp insulation when the embodied CO_2 calculation is based on the cradle to gate approach is the negative embodied CO_2 measure. At the end-of-life stage of hemp material however, it can be remixed with new material, used as biomass or otherwise sawn up to be returned to the soil. At this point as the hemp fibre is biodegradable it slowly releases the carbon through decomposition while also returning other nutrients to the soil. Because the material eventually releases the stored CO_2 back to the environment, the actual embodied CO_2 of the material taking into account the raw material processing energy and transportation to site is not negative as all other insulation materials. This should be taken into account in studies which are using hemp and are based on cradle to gate life cycle analysis as assuming negative carbon footprint for hemp insulation suggests very thick building fabric that can be misleading in a global building performance analysis.

4.2 Thermally retrofitted buildings

4.2.1 Introduction

It is estimated that 70% of the buildings that will be in use in 2050 have already been constructed (UNEP, 2009)(Carbon trust, 2007) and so, whilst the performance standards of new buildings are important, it is arguably more critical that effective strategies are found for improving the thermal performance of existing stock. However currently, thermal retrofitting of existing buildings appears under-represented in the effort to meet carbon reduction targets.

At present there are around 8000 dwelling demolitions per year accounting for only 0.03% of the total stock (Ravetz 2008). The equivalent rate for industrial and commercial premises is difficult to estimate. However based on there being 597 million m^2 of industrial and commercial premises in 2007 (CLG and ONS, 2008) and £6 billion of non-domestic construction in the same year (ONS, 2010) coupled with little net growth in the stock, and an assumed average construction cost of £1800 per m^2 the equivalent demolition figure can be estimated as being around 0.5%. At these rates, and recognising the inaccuracies and uncertainties of future trends, it may reasonably be expected that replacement of 50% of the existing building stock with new construction complying with improved current and future building standards is likely to take a period of the order of 100 years. In view of this slow rate of change it is essential that effective thermal retrofit strategies are developed but limitations in the existing technologies pose serious issues not least in terms of the embodied carbon associated with insulation materials and techniques.

As previously stated in Chapter 2, it is essential that embodied carbon is factored into carbon reduction equations especially for refurbishment scenarios with particularly shorter service lives. If so, a compelling case begins to emerge for the development of high performance insulation materials. Of the known possible alternatives vacuum insulation and hemp insulation are considered to be amongst the most promising as discussed previously (DTI project 2007, Caps 2001, Fine 1989, Materna 2001, Zwerger 2005).

Even disregarding considerations of embodied carbon, many existing insulation materials appear likely to struggle to meet future demands. Issues appear to be particularly acute in refurbishment markets where buildings may be dimensionally restricted or where structural issues may preclude certain solutions. Two of the most common insulation materials, mineral wool and PUR foam, both have significant performance limitations when used within composite or built-up systems as stated in Section 1.2.1.

The development of novel insulation materials that combine higher thermal performance with relatively low embodied carbon seems therefore to be essential. The case is particularly strong for retrofit applications where design lives tend to be less than those for new build, and where embodied carbon can offset a greater proportion of the total operational carbon savings.

4.2.2 Quantification of the carbon limits of conventional and alternative insulation technology for industrial buildings

Generally, there are two dominant categories of building envelope refurbishment for industrial buildings; re-sheeting and over cladding (Tata steel, 2013). In re-sheeting the existing building envelope is replaced completely with a new cladding system, but in over cladding, the existing envelope of the building is used as a base layer for installation of new cladding. The choice between the two options is dependent on individual project requirements and circumstances. One of the most commonly employed refurbishment solution is re-sheeting with profiled built-up and composite panel systems which are assumed to be the case for this study.

The following analyses are associated with re-sheeting of standard single span portal frame warehouses of 1000 and 3000m^2 and a similar 3000m^2 retail sheds similar to those analysed in Section 1 of this Chapter. As re-sheeting has been used as the retrofitting method in the present study, the CO_2 savings are assumed to be the same as new build analysis for industrial buildings. The service life associated with thermal retrofitting analysis is assumed to be 25 years.

According to the UK National Statistics Publication Hub, there are approximately 466 thousand warehouses and factories existing in the UK. This figure equates to 370 M m^2 of warehouse buildings. The minimum achievable CO_2 associated with using VIPs in comparison to investigated conventional insulation materials saves about 0.4-1 million tonnes of CO_2 per annum (depending on building size and operation criteria) which is about 5-12.6% of associated CO_2 with total space heating demand of industrial buildings (about 40 TWh/year) (DECC, 2013). The saving associated with improving the fabric U-value down to 0.25 W/m^{2}K (assuming 0.35 as the base-case) is approximately between 2.5-9.5% and to 0.15 W/m^{2}K is in range of 0.63-10.7%.

The minimum achievable CO_2 associated with using hemp insulation in comparison to the investigated conventional insulation materials saves about 1.9-2.5 million tonnes of CO_2 per annum (depending on building size and operation criteria) which is about 22-29% of associated CO_2 with total space heating demand of industrial buildings.

Currently about 30% of the annual market for profiled roofing and cladding is allocated to refurbishment which is only about 1-2% of existing cladding area. This slow paced process needs a significant change to contribute to achieving the carbon reduction targets.

4.2.3 Quantification of the Carbon Limits of Conventional and Alternative Insulation Technology for Residential Buildings

Residential buildings are responsible for 26% of UK emissions. It is estimated that 40% of available buildings in 2050 will be pre 1985. It is also estimated that about 30% of current housing stock do not have cavity walls and around 42% of houses with cavity walls are not insulated (Energy saving trust, 2011). The Environmental Change Institute reports that to achieve the carbon reduction targets, 100% of cavity walls are required to be insulated by 2050 (ECI, 2005). In 2009 30% of English homes failed the decent home standard and in approximately a quarter of cases this was due to poor fabric thermal performance. This highlights the importance of thermal retrofit solutions (DCLG, 2010).

The first step in retrofitting houses is to understand that there is no single solution applicable to all cases. Thermal retrofitting of the building fabric is fundamental in achieving carbon reduction targets in a cost and performance effective approach. Many basic retrofit solutions, such as loft insulation and cavity wall insulation are relatively cheap and effective and offer reasonable payback periods which make them suitable solutions economically. It is increasingly reported that a significant proportion of cavity walls are not suitable for cavity wall insulation (The centre for low carbon future, 2011). This is mainly due to potential problems such as areas of missing insulation, insulation material slippage and variations in density or incomplete filling of cavities. This is also believed that in the majority of existing cases, cavities are about 50mm wide which is not sufficient in achieving lower targeted U-values using conventional insulation materials (Table 5.9). These cases will normally require solid wall insulation as for non-cavity wall houses.

Table 5.9 U-values associated with insulated cavity widths

	U-value W/m^{2}K	
Insulated cavity mm	**Mineral wool**	**PUR**
50	0.389	0.31

Semidetached buildings account for about 26% of existing housing stock of which about 25.5% are built with non-cavity walls and 28.9% are un-insulated cavity walls. 43.9% of existing non-cavity walls was built between years 1919 to 1944 (ONS, 2008). A typical 1930' semi-detached house therefore (as the most common existing non-cavity wall building type) was selected to be simulated. It was assumed that all cases are externally insulated with mainstream conventional insulation materials such as mineral wool and PUR in comparison to hemp insulation and VIPs as novel solutions. The following analyses investigate the results associated with thermal retrofitting of typical

1930s semidetached houses assuming the general building specifications described in Tables 4.5.

According to the UK National Statistics Publication Hub, total household energy use for space heating is about 292.9 TWh/yr in the UK. This figure for space heating demand of semidetached buildings is 190.9kWh/m^2/yr which equates to 37.8 kgCO_2/m^2/yr. The minimum achievable CO_2 associated with using VIPs in comparison to investigated conventional insulation materials (depending on material used, service life and weather data employed) saves about 1.5-3.3% of associated CO_2 with total space heating demand of residential buildings. The saving associated with improving the building fabric U-value to 0.25 W/m^{2}K (assuming 0.35 as the base-case) is approximately between 0.8-1.7% and to 0.15 W/m^{2}K is in range of 1.2-2.2% (Table 5.10).

Table 5.10 Minimum aggregated CO_2 burden associated with embodied carbon of mineral wool, PUR and VIP and operational carbon required for heating (by building type and service life).

Service life	**Insulation type**	**Minimum CO_2** (kgCO_2/m^2/year)	**Thickness of roof insulation** (mm)	**Roof U-Value** (W/m^2.K)	**Thickness of wall insulation** (mm)	**Wall U-Value** (W/m^2.K)
25 years	**Mineral wool**	11.52	300	0.12	225	0.14
	PUR	11.95	300	0.12	142	0.16
	VIP	10.89	300	0.12	50	0.076
	Hemp	9.1 down to 0.08 W/m^2.K	300	0.12	no minimum down to 0.08 W/m^2.K	
40 years	**Mineral wool**	11.17	300	0.12	325	0.1
	PUR	11.45	300	0.12	195	0.12
	VIP	no minimum down to 0.039 W/m^2.K	300	0.12	no minimum down to 0.039 W/m^2.K	
	Hemp	9.1 down to 0.08 W/m^2.K	300	0.12	no minimum down to 0.08 W/m^2.K	
60 years	**Mineral wool**	10.97	300	0.12	350	0.09
	PUR	11.09	300	0.12	235	0.1
	VIP	no minimum down to 0.039 W/m^2.K	300	0.12	no minimum down to 0.039 W/m^2.K	
	Hemp	9.1 down to 0.08 W/m^2.K	300	0.12	no minimum down to 0.08 W/m^2.K	

Replacing the conventional insulation materials with hemp insulation results in 6.5-7.5% CO_2 saving associated with total heating demand of investigated semidetached buildings (assuming negative embodied CO_2 for hemp insulation).

4.2.4 Quantification of the Carbon Limits of Conventional and Alternative Insulation Technology for Office Buildings

Retrofitting solutions for commercial buildings have not been widely adopted. More than two-thirds of commercial properties are owned by short-term tenants who tend not to be willing to sustain the high upfront cost of improvements (Energy Saving Trust, 2011). This is becoming more acute due to reducing lease terms (currently on average in the UK, 4.8 years) which do not provide sufficient timescale for payback (Dixon, 2013). Energy costs also account for a relatively low proportion of the operational costs of most service sector companies (generally no greater than 6%). A further factor which has frustrated thermal retrofitting is belief that improvements can be more effectively achieved through replacement of existing lighting systems with low energy and efficient control systems. Minimum energy efficiency standard aiming at carbon emission reduction however is becoming a requirement by the Government.

There are approximately 350M m^2 of office buildings existing in the UK (ONS, 2008). Minimum achievable CO_2 for novel insulation materials (when the building fabric is upgraded from 0.35 to 0.15 $^{W/m2.K}$ U-Value) is approximately 0.23-1.68 $kgCO_2/m^2$ lower than that associated with investigated conventional insulation materials. This equates to about 1-6.5% reduction in total non-residential buildings in-use phase CO_2 emissions (BIS, 2010).

4.3 Technical Conclusions

The analyses demonstrate that there are limits for conventional insulation thicknesses (varies depending on building type and size) beyond which the increase in embodied carbon exceeds the decrease in operational carbon. These represent maximum insulation thicknesses or ‘death points’ associated with each insulation material. If lower U-values are required, the development (birth point) of alternative (low embodied carbon) insulation materials such as VIPs are essential.

Improving the fabric energy efficiency measures significantly reduces the space heating load demand of buildings. The maximum achievable CO_2 saving associated with fabric thermal efficiency when including the regulated energy consumption (lighting and hot water requirements) however, contributes to a maximum of 10% for non-domestic and 15-20% saving for residential buildings (refer to appendix B for detailed calculations).

CHAPTER 6: Insulation Specifications for Minimum Life-Cycle Costs

The following chapter presents the Life Cycle Costing analysis associated with building fabric energy efficiency for industrial, residential and office buildings. PUR and mineral wool as mainstream conventional insulation materials and VIPs as exemplar novel insulation material have been used for the analyses.

5.1 Introduction

Whilst all cladding systems must deliver acceptable levels of performance, ‘first cost’ criteria (procurement and construction costs) often have primacy in the selection of building envelope systems. This is particularly the case for industrial buildings where subsequent on-going costs are more associated with the lighting loads rather than heating requirements. The target therefore for the industrial building owners is to comply with the Building Regulation standards concerning the level of insulation.

The cost Analyses for residential and office buildings, however, are more complicated. As the thickness of building cladding systems increase as a consequence of higher levels of insulation (to reduce the conductive heat loss through building envelope), the ratio of net to gross floor area calculated on a building perimeter basis is adversely affected. Hence the rental value of buildings changes considerably. This will make the thickness of building cladding a determinant factor in achieving the optimum level of thermal performance for residential and office building envelopes.

The use of mainstream conventional insulation materials, such as mineral wool and PUR, would demand thicker insulation panels in the wall construction (around 200-300 mm external wall to meet the performance requirements) which will consequently affect the financial benefit of energy savings associated with the better thermal performance of the building envelope. A substantial improvement in energy performance and cladding slimness is however expected to be achieved by novel insulation materials such as VIPs where low embodied CO_2 is coupled with high thermal resistance and subsequently a thinner panel can be adopted.

Life Cycle Costing (LCC) analysis has been carried out therefore to investigate the cost effectiveness of conventional and novel insulation materials for industrial, residential and office buildings. The price/m^2 floor area was extracted from the property market report (Valuation Office Agency, 2011). Average insulation prices provided by different suppliers have been used for conventional insulation materials. For VIPs an estimated reduced price has been calculated based on the price of products involved in the similar manufacturing process (see Section 2.3 for more detail) (Table 6.1).

Table 6. 1 Average cost of renewable technologies and insulation materials supplied by various manufacturers in the UK

	Wall			Roof		
PUR	U value	Thickness mm	Price/m^2	U value	Thickness mm	Price/m^2
	0.25	100	67	0.2	125	47
	0.21	119	68.5	0.17	147	48
	0.19	132	70	0.15	167	49
	0.17	147	71.5	0.12	208	50
	0.15	167	73	0.11	227	51
	0.11	227	79	0.1	250	55
	0.1	250	82	0.08	312.5	57
Mineral wool	U value	Thickness mm	Price/m^2	U value	Thickness mm	Price/m^2
	0.25	160	43.7	0.2	200	35.7
	0.21	190	45	0.17	235	36.4
	0.19	211	48.6	0.15	267	37
	0.17	235	50.4	0.12	333	38.4
	0.15	267	52.2	0.11	364	39
	0.11	364	63	0.1	400	43
	0.1	400	66.6	0.08	500	44.7
VIP	U value	Thickness mm	Price/m^2	U value	Thickness mm	Price/m^2
	0.25	16	75	0.2	20	52.5
	0.21	19	80.4	0.17	24	56.28
	0.19	21	85.75	0.15	27	60.025
	0.17	24	98.5	0.12	33	68.95
	0.15	27	106	0.11	36	74.2
	0.11	36	123	0.1	40	86.1
	0.1	40	127.5	0.08	50	89.25
PV	-	-	183	-	-	-

5.2 Industrial buildings

5.2.1 Minimum Life Cycle Cost analyses

The following section presents the NPV results for standard single span portal frame warehouses of 1000 and 3000m^2 and similar 3000m^2 retail shed using built up cladding systems with mineral wool and composite PUR cladding systems. The analyses assume the general system parameters described in Tables 4.1 and 4.3 (refer to Chapter 4). The internal gains including generated heat from lighting, occupants and solar gain have been taken into account when determining heating demands. The 2010 Building Regulations backstop U-values for building fabric have been assumed as the basecase for LCC calculations.

5.2.1.1 NPV analyses for conventional insulation materials: mineral wool and PUR

The following graphs illustrate the cost analysis associated with the incremental increases in insulation levels and consequent decreases in U-values. Bars refer to the initial cost of thermal performance improvements (left axis) and lines refer to NPV results for 25, 40 and 60 years building service life (Right axis).

According to the results from Figures 6.1 to 6.6, improving the building fabric thermal performance beyond the required standards (in this case the backstop U-value for building envelope) results in small financial profit as for thicknesses where the NPV reaches its highest level, the future energy cost savings over buildings design life will only recover the capital cost of highly insulated envelope (except for 60 years design life).

The Building Regulations suggest lower U-Values for Roofs compared to walls. This is due to the higher conductive heat loss through roofs. There is a ratio of 0.7 between current roof and wall backstop U-values in the Regulations which has been assumed to be the case in this research.

In case of mineral wool over 25, 40 and 60 years design life:

- For wall U-value; Maximum NPV occurs in range of 0.18 - 0.27 W/m^{2}K in investigated buildings whilst the required backstop U-value is 0.35 W/m^{2}K.

- For the relative roof U-value (calculated by multiplying wall U-value by 0.7); Maximum NPV occurs in range of 0.13 - 0.20 W/m^{2}K in the buildings investigated whilst the required backstop U-value is 0.25 W/m^{2}K.

- 12 to15% more investment on initial cost of insulating the building beyond the required standards, results in up to £ 30k cost benefit (NPV) during 60 years of buildings design life.

- For retail sheds however, as the energy consumption is mainly associated with lighting, improving the building fabric (aiming at reducing the heating demand) is not financially justifiable.

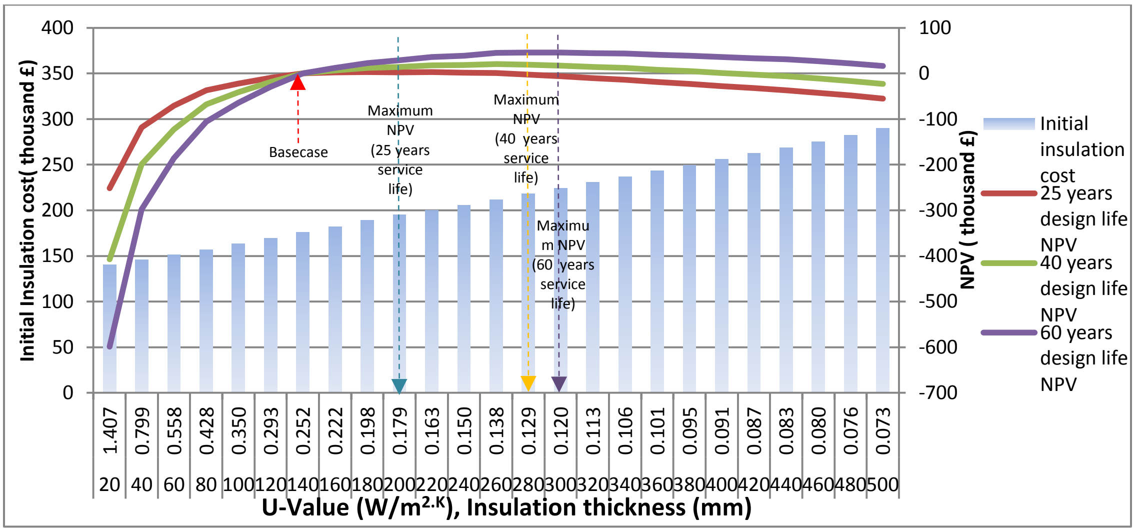


Figure 6.1NPV results of 3000m^2 warehouse insulated by mineral wool for 25, 40 and 60 years design life

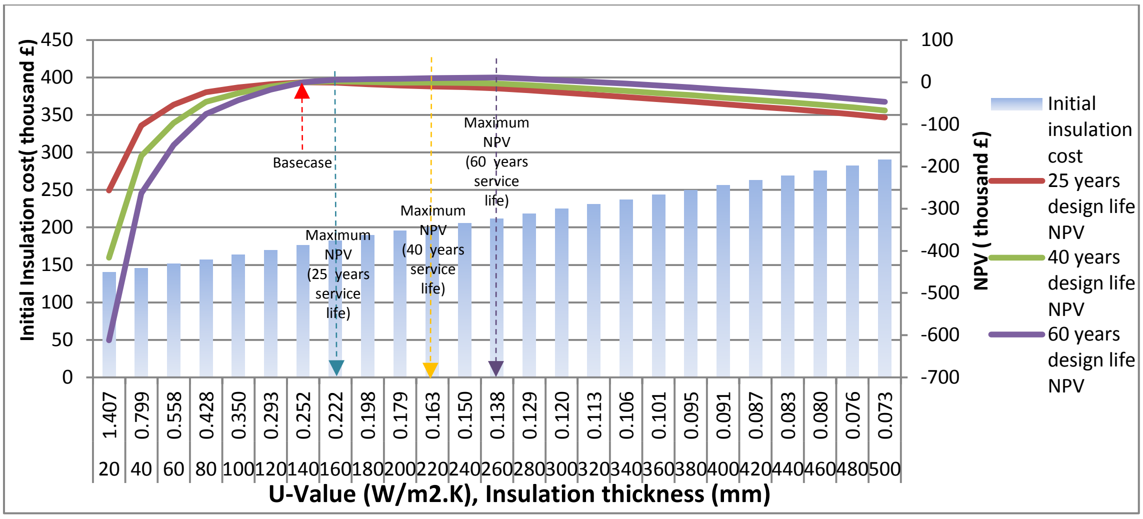


Figure 6.2NPV results of 3000m^2 retail shed insulated by mineral wool for 25, 40 and 60 years design life

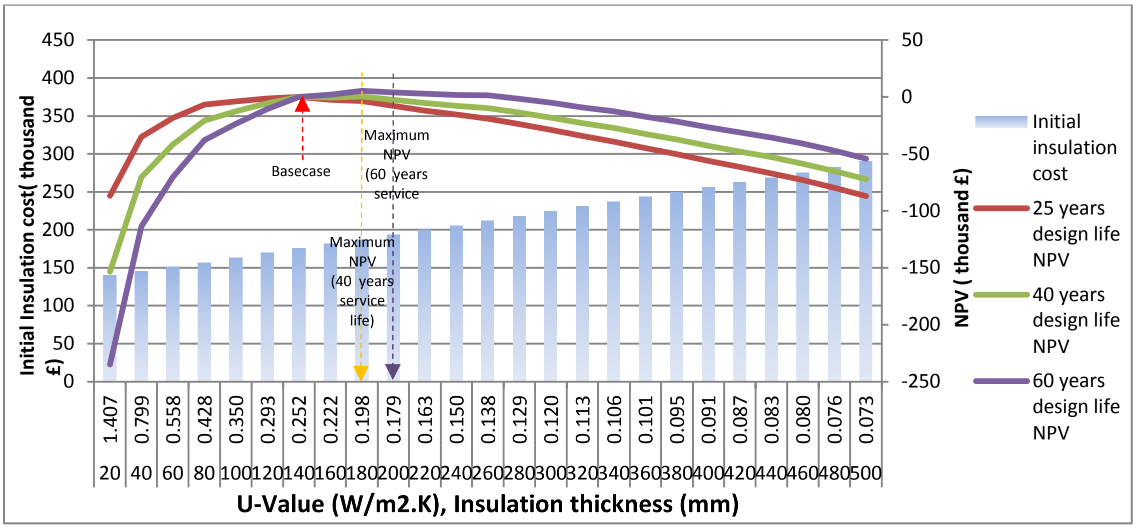


Figure 6.3 NPV results of 1000m^2 warehouse insulated by mineral wool for 25, 40 and 60 years design life

In the case of PUR over 25, 40 and 60 years design life:

- For wall U-value; Maximum NPV occurs in range of 0.14 - 0.24 W/m^{2}K in investigated buildings (the backstop U-value is 0.35 W/m^{2}K).

- For roof U-value; Maximum NPV occurs in range of 0.1 - 0.17 W/m^{2}K in the buildings investigated (the backstop U-value is 0.25 W/m^{2}K).

- 8 to15% more investment on initial cost of insulating the building beyond the required standards, results in £25k to £50k cost benefit for 60 years building design life.

Achieving the thicknesses in which the NPV reaches its highest level for PUR roof panels seems however to be difficult as the maximum available thickness currently produced in the market is restricted to 0.13 W/m^{2}K U-value due to manufacturing constraints.

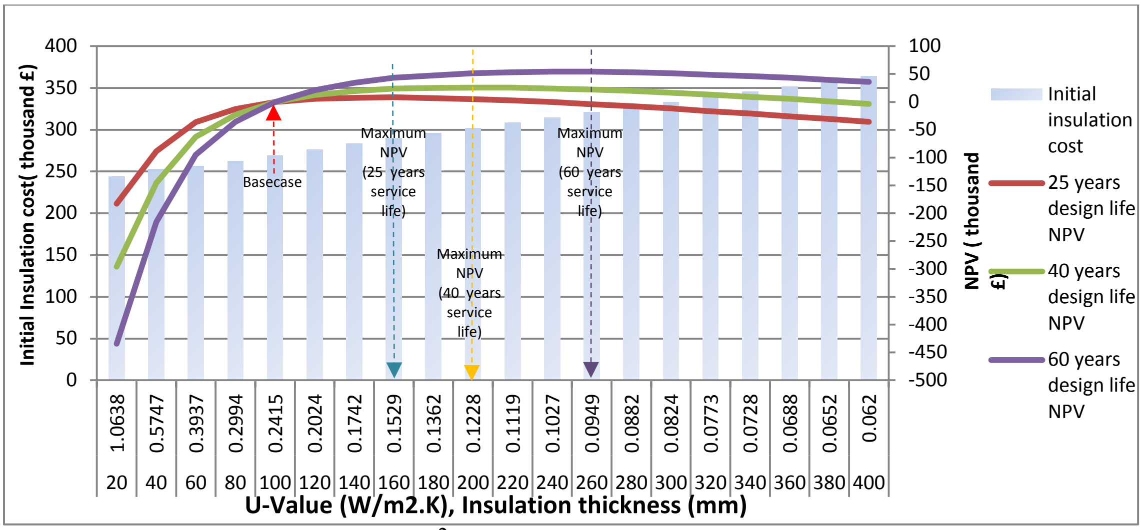


Figure 6.4 NPV results of 3000m^2 warehouse insulated by PUR for 25, 40 and 60 years design life

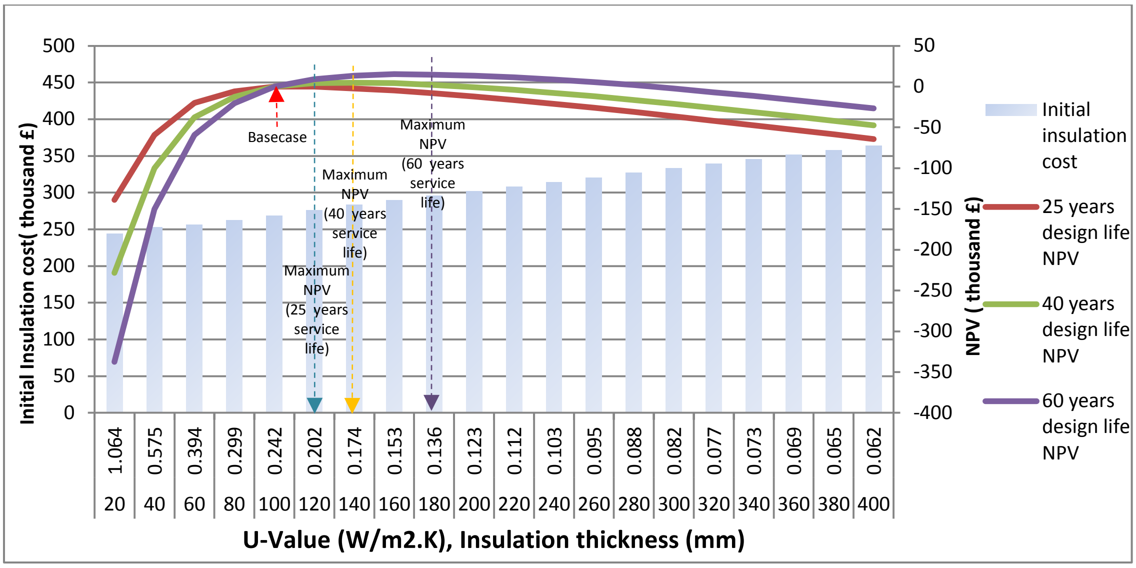


Figure 6.5 NPV results of 3000m^2 retail shed insulated by PUR for 25, 40 and 60 years design life

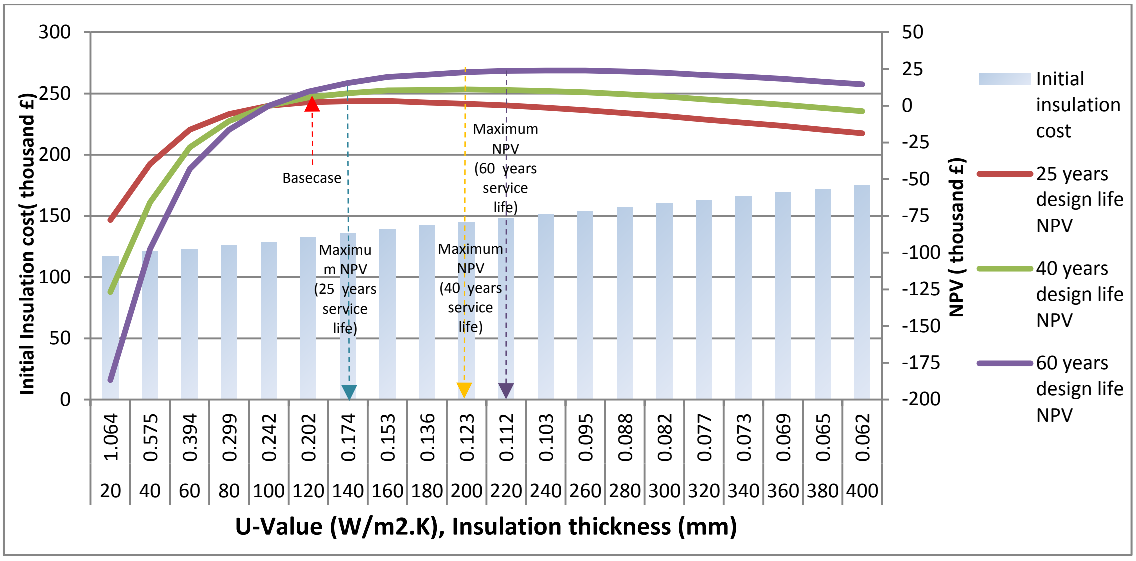


Figure 6.6 NPV results of 1000m^2 warehouse insulated by PUR for 25, 40 and 60 years design life

Interpretation of NPV analyses of novel insulation materials: VIPs

Parallel with the cost analysis of incremental increases in insulation thickness for conventional insulation materials, the cost analyses of VIPs are presented in the following graphs. Bars refer to the initial cost of thermal performance improvements (left axis) and lines refer to NPV results for 25, 40 and 60 years design life of insulation panels (Right axis).

At present, whilst there is good technical potential supporting the development of vacuum insulation, there is limited market demand and therefore limited opportunities for large scale economic commercialisation. Costs are therefore relatively high since high volume production and supply chains have not thus far been established (Tenpierik 2009, Erb 2010, Tenpierik 2006). Therefore in order to make the financial comparison of VIP with conventional mainstream insulations materials feasible, an estimated reduced price for VIPs has been calculated based on the price of products involved in the similar manufacturing process such as argon filled double glazed units, vacuum double glazed units and a similar insulation material such as PUR. The lower price limit has been assumed not to be lower than manufacturing and raw materials price taking into account a similar commercial profit as the products mentioned. The upper price limit is not to be higher than the price for which VIPs are competitive with PUR in relation to the NPV and payback period. The average of upper and lower price limit has been set as the justified price of VIP in this research.

Even with the justified prices, as presented in Figures 6.7 to 6.9, adding to the thickness of VIP insulation would not be financially beneficial. Conventional insulation materials still retain a cost advantage and are considered proven reliable solutions by specifiers for industrial buildings. Insulating beyond the regulated levels of fabric thermal performance does not demonstrate financial benefits in terms of energy saving payback for industrial buildings.

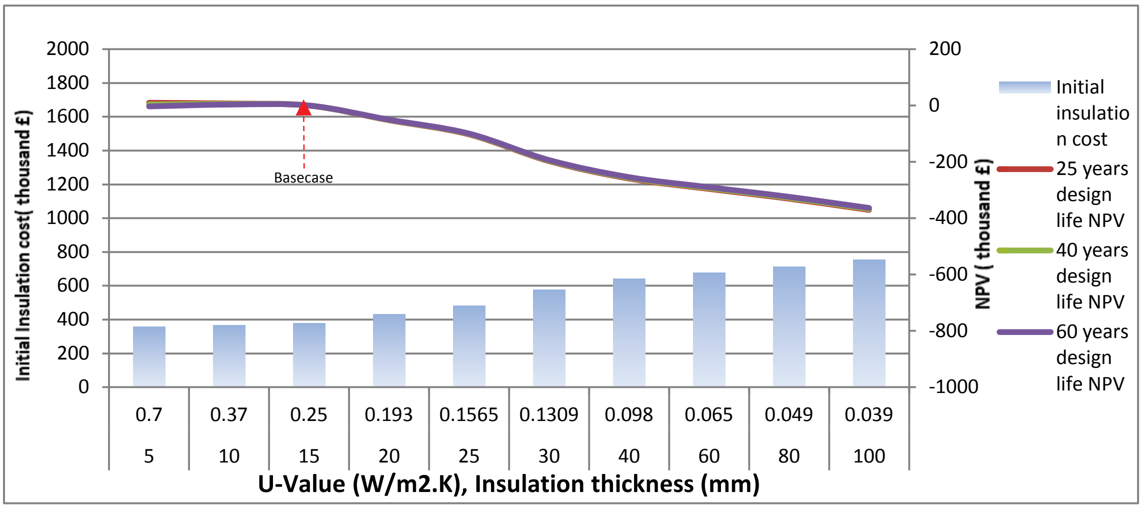


Figure 6.7 NPV results of 3000m^2 warehouse insulated with VIP for 25, 40 and 60 years design life

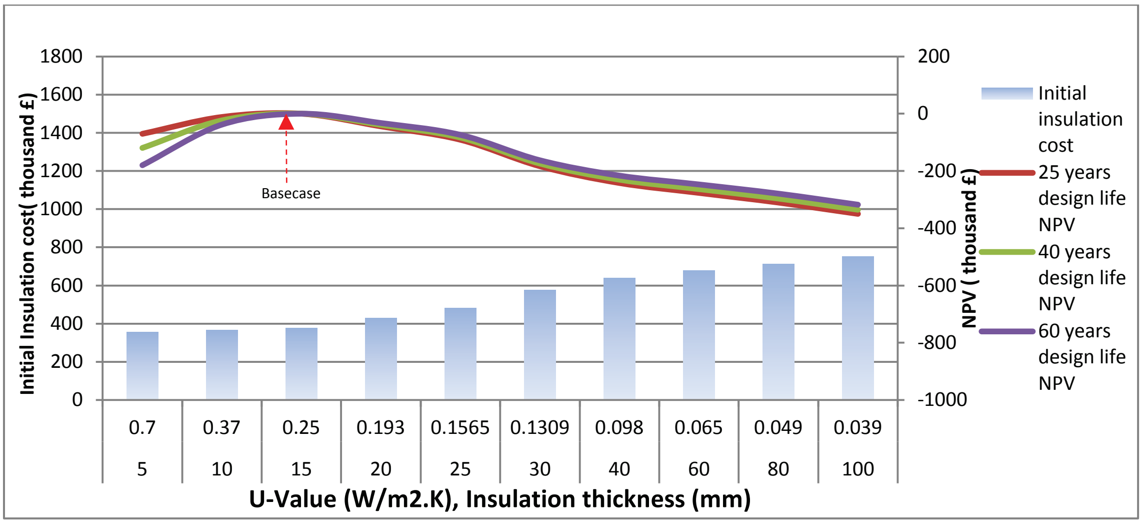


Figure 6.8 NPV results of 3000m^2 retail shed insulated with VIP for 25, 40 and 60 years design life

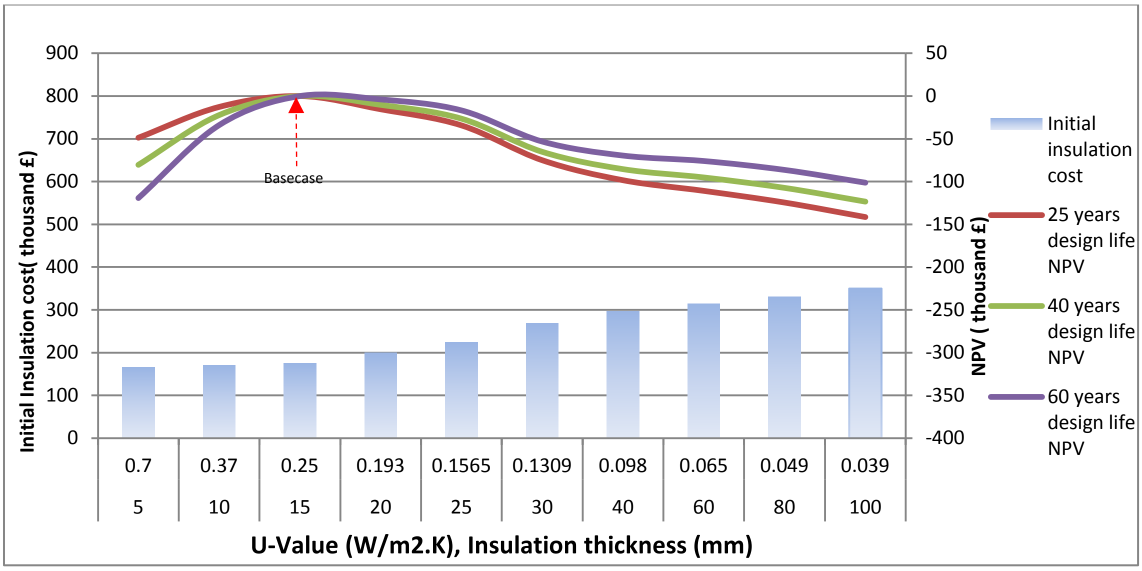


Figure 6.9 NPV results of 1000m^2 warehouse insulated with VIP for 25, 40 and 60 years design life

5.3 Office buildings

As has been discussed in section 1 of this Chapter, increases in the thickness of commercial building cladding systems, will adversely affect the ratio of net to gross floor area calculated on a building perimeter basis. The impacts of adjustments in net to gross floor areas that may be achieved by reducing the width of external walls are significant in maximising the rental value of buildings.

Thermal performance of three insulation materials (two mainstream conventional insulation materials and a novel solution) for a typical four-story office building in 'central London' has been modelled using dynamic thermal modelling software (IES-VE). Simulation settings were assumed to be based on CIBSE 2008 guidance for office buildings. Modelling assumptions are as presented in Chapter 4, Section 4.2.

It is believed that the rental income is becoming the key performance driver in the central London office market (www.building.co.uk, 2012). Current rental values for centrally located office accommodation in key areas of London (as an example location) are given in Table 6.1 according to the property market report 2011.

Table 6.2 Typical rental values for office accommodation (property market report 2011)

		Value of land for offices (£/m².yr)
London	City	565
	West end	860

Table 6.3 Office building specifications

Building specifications
Total floor area: 4 × 48 × 13.5 = 2592 m^2
Total Perimeter length: 4 × (48 + 13.5) × 2 = 492 m

The NPV analysis for office buildings in this study takes into account the capital cost of fabric energy efficiency improvements, the associated operational energy savings and the additional rental income associated with the thinner external walls for 30 and 60 years design life scenarios. The NPV of the additional rental income from the application of VIPs is compared with PUR and Mineral wool using the below expression (Gorgolewski, 1995).

$PV(C) = C. [1-(1+d)^{-n}]/d$

Where C is the rental gained as a result of the reduced external wall width.

The analysis also identifies the most cost effective insulation level assuming the required levels of insulation in the Regulations as the basecase.

5.3.1 NPV results

Table 6.3 presents the additional rental income associated with using thin VIP panels in comparison to investigated conventional insulation materials. Considerable economic benefit for using VIPs is demonstrable. The lost rental value is such that even the high price of VIPs will be fully recovered as a part of a greater saving.

Table 6.4 The NPV of the additional rental income of VIP in comparison to conventional insulations

City/area	U-Value $W/m^2.K$	30 Years Design life		60 Years Design life	
		Mineral Wool	PUR	Mineral Wool	PUR
London-City	0.25	503 K	425 K	1.08 M	831 K
	0.2	754 K	456 K	1.50 M	913 K
	0.15	1 M	630 K	2.20 M	1.30 M
	0.1	Not achievable	Not achievable	3.98 M	2.49 M
London-West end	0.25	865 K	677 K	1.76 M	1.30 M
	0.2	1.26 M	740 K	2.52 M	1.44 M
	0.15	1.8 M	1.04 M	3.59 M	2.08 M
	0.1	Not achievable	Not achievable	3.98 M	2.49 M

The greyed out cells are not achievable using conventional insulation materials as the embodied CO_2 associated with thicker panels exceeds the overall CO_2 savings and a net carbon disbenefit occurs (as presented in Chapter 5).

Improving the building fabric beyond the backstop U-values using conventional and novel insulation materials however is not showing any financial benefit as the operational energy savings cannot recover the increased rental loss (Figures 6.10 to 6.15).

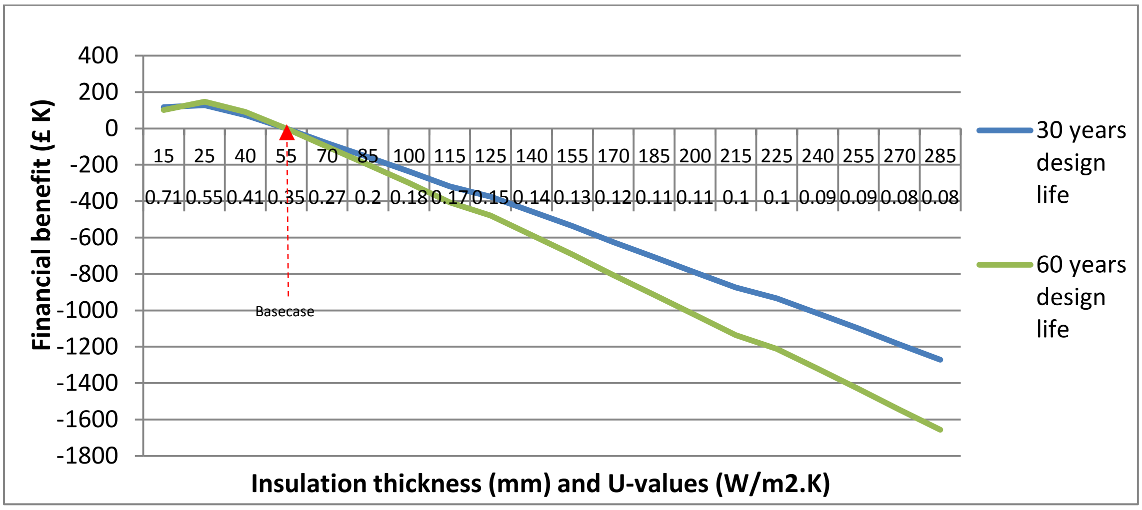


Figure 6.10 NPV results of the office building insulated with PUR for 30 and 60 years design life in London City

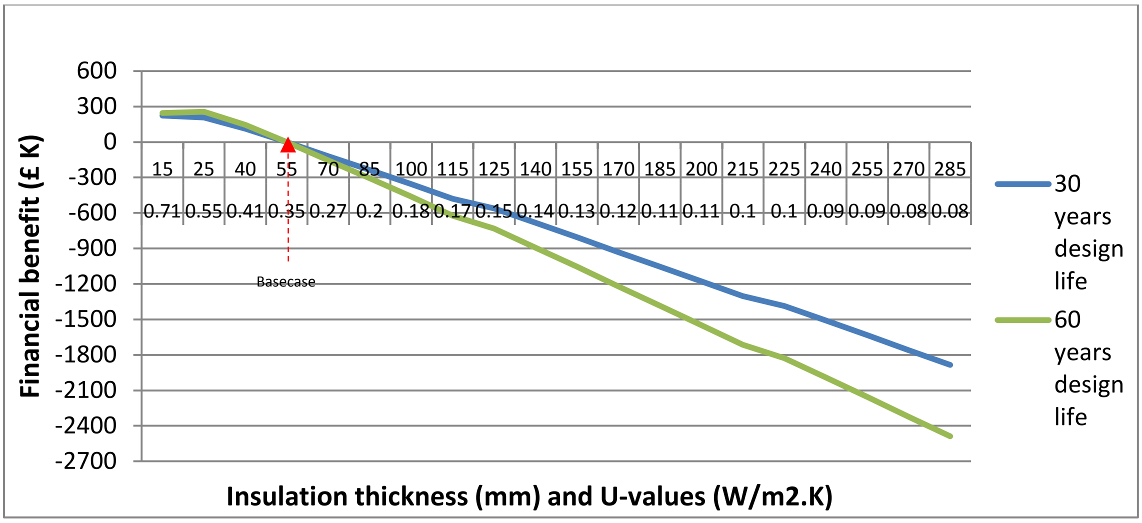


Figure 6.11 NPV results of the office building insulated with PUR for 30 and 60 years design life in London West-End

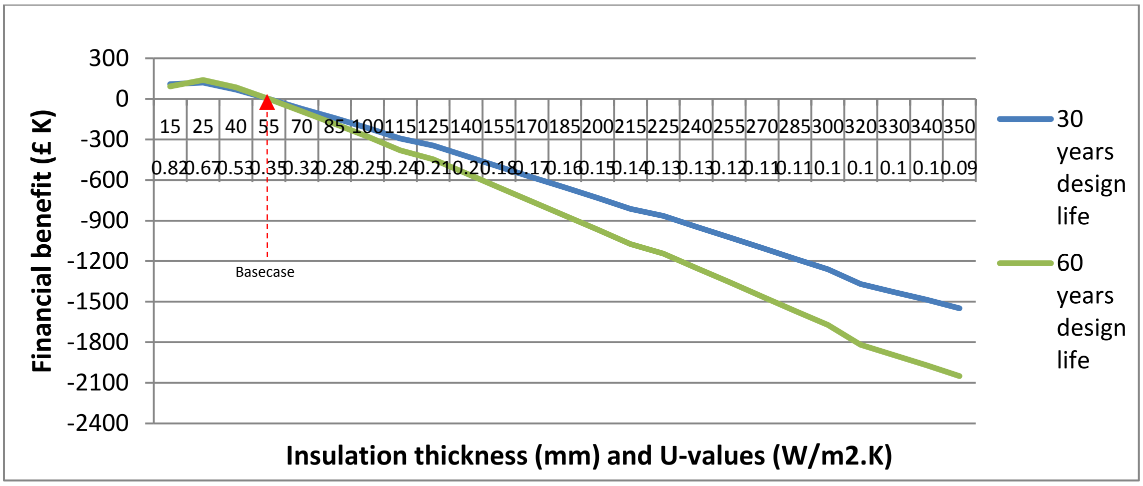


Figure 6.12 NPV results of the office building insulated with mineral wool for 30 and 60 years design life in London City

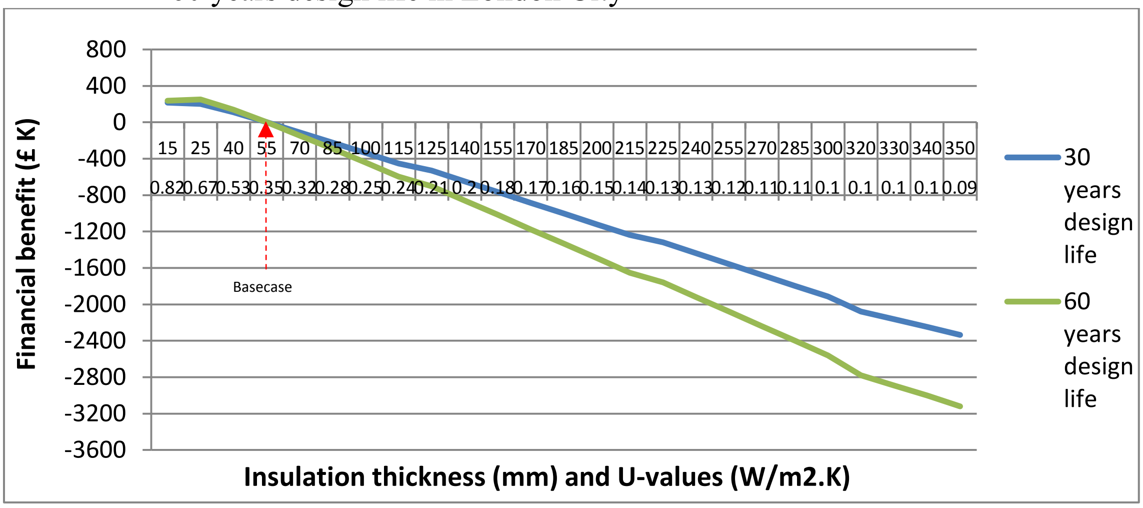


Figure 6.13 NPV results of the office building insulated with mineral wool for 30 and 60 years design life in London West End

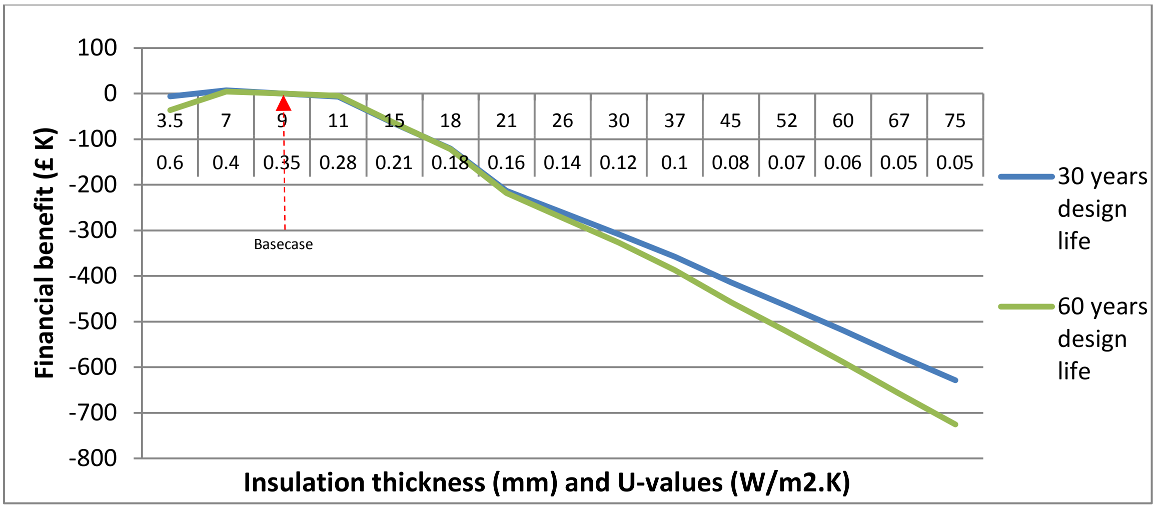


Figure 6.14 NPV results of the office building insulated with VIP for 30 and 60 years design life in London City

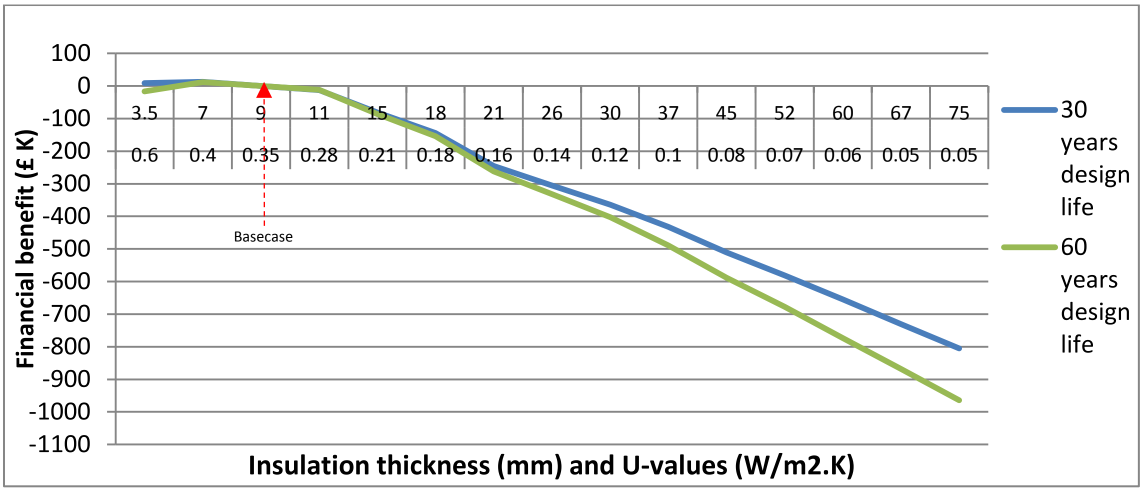


Figure 6.15 NPV results of the office building insulated with VIP for 30 and 60 years design life in London West End

5.4 Residential buildings

Space heating accounts for 65% of the energy consumption in residential buildings in the UK. Reducing heating load demands will inevitably require higher levels of fabric energy efficiency.

According to the definition of zero carbon buildings until 2008, house owners were required to reduce all CO_2 emissions to zero through on-site solutions. Both 'regulated' emissions (from heating, cooling, ventilation and lighting) and 'unregulated' emissions (other appliances) had to be taken into account. Various research have been undertaken and it was recognised that building to this level of efficiency was not the most cost effective approach for mainstream housing production in 2011. After a series of changes in the definition of zero carbon homes, unregulated emissions were removed from the definition. Recently however, in the latest definition of zero carbon new homes, the fabric energy efficiency is required to be at a level that keeps the total energy consumption associated with heating and cooling of buildings to maximum 46 $kWh/m^2/year$ (Zero carbon hub, 2013).

The following analysis aims to identify whether the most cost effective approach is to simply comply with fabric thermal standards, or if increasing the thickness of insulation beyond the backstop values would demonstrate financial benefit. The study is carried out with and without considering the rental value losses/gains.

The rental values used in the analyses is as stated in Table 6.5.

Table 6. 5 Rental value (residential buildings)

		Value of land for residential Buildings (£/m²/yr)
London	Ealing	1320
	Croydon	930

5.4.1 Interpretation of the NPV analyses

A similar rental value analysis as for commercial building cladding was carried out for residential buildings and the results are presented in table 6.4. The lost rental value associated with the thick external wall over the design life of a building is considerable and is not easily recovered by the amount of energy savings associated with improved thermal performance of the cladding.

Table 6.6 The NPV of the additional rental income of VIP in comparison to conventional insulations

City/area	U-Value W/m2.K	30 Years Design life		60 Years Design life	
		Mineral Wool	PUR	Mineral Wool	PUR
London-Croydon	**0.25**	34,000	35,500	52,000	52,600
	0.2	78,000	56,000	121,000	86,500
	0.15	145,000	Not achievable	226,000	167,000
	0.1	273,000	Not achievable	419,500	279,000
London-Ealing	**0.25**	48,000	47,000	74,000	74,500
	0.2	114,000	83,000	173,000	123,000
	0.15	211,000	Not achievable	325,000	241,000
	0.1	394,000	Not achievable	600,000	400,000

Note that the greyed out cells in Table 6.4 show that the stated U-values are not achievable using PUR as the embodied CO_2 associated with the insulation material outweighs the operational CO_2 savings associated with improved thermal performance of the material (thicker panel) (refer to Chapter 5).

The following analysis assumes that the rental value loss associated with the incremental increase of insulation thickness is negligible. This raises the question as to what level of thermal insulation, the overall energy saving over buildings' design life can recover and pay back the initial cost of fabric thermal improvements (Figures 6.16 to 6.18).

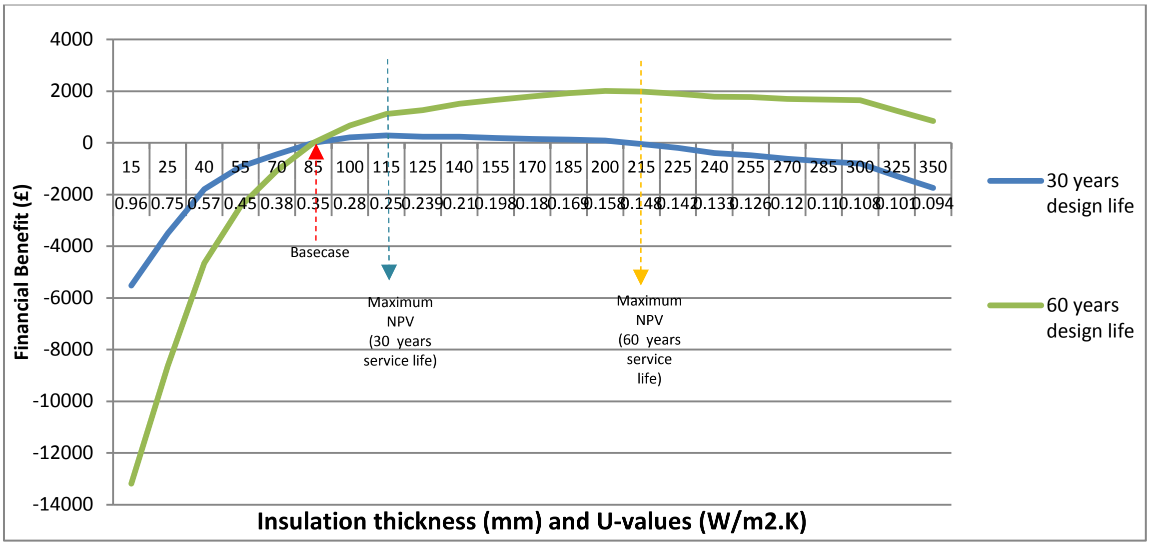


Figure 6.16 NPV results of the residential building insulated with mineral wool for 30 and 60 years design life in London- Croydon

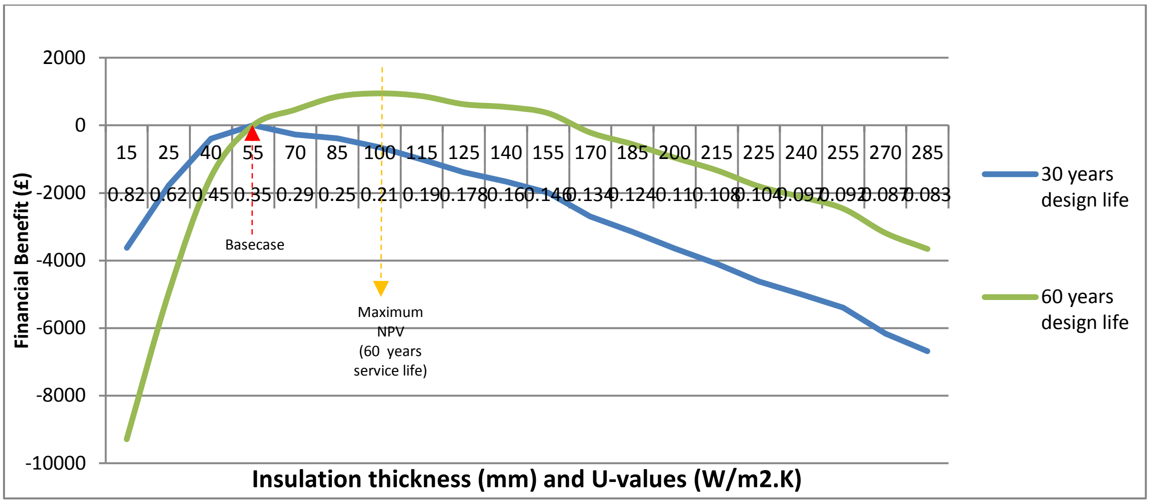


Figure 6.17 NPV results of the residential building insulated with PUR for 30 and 60 years design life in London- Croydon

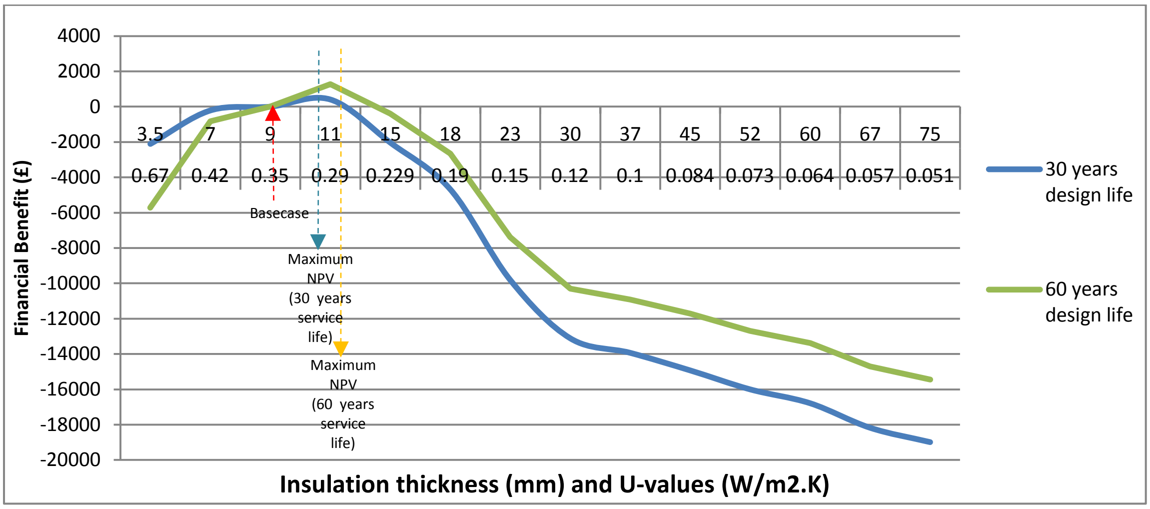


Figure 6.18 NPV results of the residential building insulated with VIP for 30 and 60 years design life in London- Croydon

The financial benefit associated with improving the fabric energy efficiency beyond the requirements of Building Regulations is reflected in Table 6.5 where the payback period for investigated insulation materials for different design life scenarios is presented.

Table 6.7 Payback periods associated with initial cost of thermal performance improvements and energy savings

	Fabric U-Value W/m^2.K	**Payback period (years)**		
		Mineral wool	**PUR**	**VIP**
London	**0.25**	15	33	Not within reasonable range of payback period
	0.2	20	Not within reasonable range of payback period	
	0.15	26		
	0.1	Not within reasonable range of payback period		

Not taking into account the rental value loss, mineral wool insulation is still the best material for insulating the residential building fabric as the lower cost of material can be recovered in a shorter period of time by operational carbon savings.

5.5 Conclusions

The LCC analyses are supporting the case for being restricted to the thermal performance requirements by building codes and regulations for all three types of buildings investigated. The analyses are demonstrating that the high initial cost of improvements cannot be recovered by associated operational energy savings. Buildings with lower carbon emissions associated with better thermal performance (thicker panels of conventional insulation materials) potentially do not result in a price premium to cover the cost of improvements made to the 'building fabric' only.

In buildings with high rental values, the slimness of the cladding is a determinant factor in applying construction solutions. On this basis energy savings associated with the increased levels of insulation cannot recover initial cost of improvement and/or lost rental value if thicker cladding had been used. Therefore, slim cladding systems using products such as VIPs can be justified financially and environmentally and be a replacement for conventional insulation materials such as PUR and mineral wool. This requires large scale economic commercialisation and subsequent price reduction for VIPs or other novel insulation materials.

The analyses are also providing compelling evidence supporting the view that although the ‘fabric first’ approach is essential towards achieving zero carbon performance, it is not necessarily the most cost effective approach. On-site low and zero carbon solutions (such as heat and electricity generating technologies) should be adopted to contribute to carbon savings in a more cost effective way.

It should also be stated that adding to the thickness of insulation and consequently decreased operational energy can affect the required capacity of the heating system i.e., lower heat demand requires smaller heating system. This can improve the NPV of the highly insulated cases but as it could cause further uncertainties in the analysis such as gathering cost data from different sources for the new heating system and different associated complexities, it has not been taken into account in this study.

CHAPTER 7: On-site low and zero carbon technologies

This chapter determines the maximum level of carbon (combined operational and embodied) reductions achievable through a combination of fabric energy efficiency and on-site low and zero carbon solutions. This will include the application of the developed methodology to on-site electricity and heat generating technologies (specifically Photovoltaics and Transpired Solar Collectors). The analyses will include industrial and office buildings as exemplar building types for application of the methodology. PUR and mineral wool as mainstream conventional insulation materials have been used for the analysis. A 25 and 30 year service life have been assumed for industrial and office buildings respectively.

6.1 Introduction

According to the analyses carried out in Chapter 5, the maximum CO_2 saving associated with improving the building fabric (only) is limited to a maximum of 10% for non-domestic buildings (Table 7.1).

Table 7.1 Maximum CO_2 savings associated with improving the building fabric U-value

	Building type	**Max CO_2 savings %**	**U-Value W/m^2K**	**Thickness (mm)**
PUR	**Retail shed**	6.3	0.21	115
	Warehouse	7.7	0.1	240
	Office	0.5	0.21	115
Mineral wool	**Retail shed**	9.4	0.2	180
	Warehouse	9.97	0.1	360
	Office	1	0.2	180
VIP	**Retail shed**	9.75	0.15	25
	Warehouse	10.05	0.1	40
	Office	1.15	0.15	25

Achieving low and zero carbon performance therefore requires on-site low and zero carbon technologies to contribute to CO_2 savings. To achieve an optimum level of carbon reduction cost effectively through a combination of fabric energy efficiency and onsite low and zero carbon energy, PVs and TSCs as on-site electricity and heat generating technologies have been selected to be analysed.

6.2 Photovoltaic cells

The government's support policies encourage development of renewable technologies at all scales – domestic, commercial and industrial. A Roadmap was set out with defined principles, which form the basis of the future strategy for solar PV. According to these principles, support for solar PV should ensure that it has a role alongside other energy generation technologies in delivering carbon reductions, energy security and affordability for consumers.

Between May 2006 and May 2010, £45 billion has been allocated to PVs in the UK which was about 51% of the total money allocated to all renewable technologies (EvoEnergy Ltd, 2012). Consequently, an exceptional growth in solar electricity has been achieved over recent years with installed capacity increasing from 94 MW at the end of 2010 to 2,413 MW at the end of June 2013 (DECC, 2013). Solar PV is now known as a mainstream renewable energy technology and is playing a vital role in the UK Government's policies to achieve the 2020 renewable energy targets.

Between 2011 and 2013 costs of solar PV have fallen by almost 50%. This price cut and the Feed in Tariffs[10] (see generation/export tariffs below) scheme are key factors initiating solar capacity to increase dramatically to 2.4GW capacity installed (DECC, 2013).

Monocrystalline PV modules are selected for this research. The embodied CO_2 of PV panels are available from ICE database and are assumed to be 242 $kgCO_2/m^2$.

[10] Feed-In Tariffs Scheme was introduced first in 2010 as UK government's main financial incentive to encourage uptake of renewable electricity-generating technologies such as PVs (http://www.energysavingtrust.org.uk).

6.2.1 Technology options (packages)

In order to determine the cost effectiveness of using PVs for delivering maximum CO_2 savings, a group of technology options (packages) are defined and discussed in the following Section.

Packages associated with PVs are based on 'current' and 'likely future' Feed in Tariff (FiT) scenarios.

The first scenario is the 'current FiT' scheme which consists two main principles:

- **Generation tariff**: the energy supplier pays a fixed rate for each kWh of electricity individual buildings generate (14 p/KWh at the time of the research).

- **Export tariff**: Buildings are also entitled to get a further payment with a fixed rate per kWh from the energy supplier for each unit of electricity they export back to the grid, so that the grid can benefit from the generated but not used electricity from the households (4.5 p/KWh at the time of the research). The exported electricity at the moment is assumed to be 50% of the total generated electricity.

The second scenario is the 'likely future scenario' which assumes that there will be no payment on the total generated electricity (generation tariff) and the payments on exported electricity will be limited to the actual exported amount. It is believed that at some stage, smart meters will be installed to measure what is actually exported to the grid. Two different payment rates have been selected as the most likely future FiT scenarios and are presented as options 1 and 2; 10 and 4.5 p/KWh export rate respectively.

The area of PV installed is assumed to provide the equivalent amount of electricity to 25 (I), 50 (II), 75(III) and 100(IV) % of the buildings electricity demand in all packages.

In the case of supplying 100% of building's total annual electricity demand by PVs, it should be noted that a significant amount of electricity is generated in the time of the year which is not required (normally in spring/summer). Conversely the amount of generated electricity in autumn/winter can be significantly below the required levels. Thus a net electricity generation of the annual required electricity load is taken as 100% supply case.

The selected technology packages (Table 7.2) are as follows:

- **Package A is defined as: PV (current FiT) plus the notional building fabric specification and taking full account of energy efficient services and lighting.**

- **Package B is defined as: PV (current FiT) plus the improved building fabric down to 0.1 W/m^2K U-value and taking full account of energy efficient services and lighting.**

- **Package C is defined as: PV (likely future FiT (option 1)) plus the notional building fabric specification and taking full account of energy efficient services and lighting.**

- **Package D is defined as: PV (likely future FiT (option 1)) plus the improved building fabric down to 0.1 W/m^2K U-value and taking full account of energy efficient services and lighting.**

- **Package E is defined as: PV (likely future FiT (option 2)) plus the notional building fabric specification and taking full account of energy efficient services and lighting.**

- **Package F is defined as: PV (likely future FiT (option 2)) plus the improved building fabric down to 0.1 W/m^2K U-value and taking full account of energy efficient services and lighting.**

Table 7.2 Investigated packages in summary

Package	Current FiT	Future FiT option 1	Future FiT option 2
Notional Building Fabric	A	C	E
Improved fabric down to 0.1 W/m^2.K	B	D	F

The above packages have been applied to three building types: distribution warehouses, retail sheds and offices. According to Table 7.3 the most cost effective and carbon efficient packages have been calculated through application of the methodology. 100% electricity demand supply demonstrates the maximum cost benefit amongst investigated packages. These packages are the basis of more sophisticated analyses in this chapter (Refer to Appendix B for detailed tables/calculations).

Table 7.3 NPV and CO_2 savings associated with selected technology packages

	PV+ Insulation assessed packages (25 years service life)					
	Warehouse		Retail shed		Office	
Packages	**NPV (£ K)**	**CO_2 savings (%)**	**NPV (£ K)**	**CO_2 savings (%)**	**NPV (£ K)**	**CO_2 savings (%)**
A(I)	63.50	8.70	146.10	17.61	132.60	19.75
A(II)	116.50	18.26	267.10	35.08	252.00	39.71
A(III)	163.10	27.43	372.10	52.30	352.40	59.57
A(IV)	207.10	36.61	471.70	69.85	443.00	79.38
B(I)	61.00	15.78	132.2	20.28	133.00	21.22
B(II)	114.00	25.33	253.30	37.74	253.00	41.18
B(III)	160.00	34.50	358.30	54.96	353.00	61.03
B(IV)	212.77	43.69	472.00	72.52	444.00	80.85
C(I)	21.20	8.70	50.30	17.61	47.20	19.75
C(II)	32.50	18.26	75.20	35.08	80.30	39.71
C(III)	36.80	27.43	84.50	52.30	94.80	59.57
C(IV)	38.50	36.61	88.40	69.85	100.40	79.38
E	70.40	36.61	161.00	69.85	150.2	79.38
D(I)	18.70	15.78	36.50	20.28	48.00	21.22
D(II)	30.00	25.33	61.40	37.74	81.30	41.18
D(III)	34.30	34.50	70.60	54.96	95.80	61.03
D(IV)	44.00	43.69	88.62	72.52	71.80	80.85
F	76.10	43.69	161.30	72.52	150.00	80.85
Opt U-Value	0.15-0.21		0.15-0.21		0.18-0.26	

6.2.1.1 Distribution warehouses

Previously in chapter 5, it was demonstrated that in a distribution warehouse, mineral wool insulation was limited to 330 mm thick panels as the amount of embodied CO_2 associated with the insulation material could exceed the operational CO_2 savings. The operational CO_2 demand from the grid was reduced by the electricity generated by PV panels. This consequently shifts the carbon disbenefit limits and continuous carbon benefit is demonstrated down to 0.1 W/m^2.K U-value.

Three financial scenarios have been investigated for a 3000m^2 distribution warehouse. According to Figure 7.1, increasing the thickness of insulation in order to decrease the amount of heat loss through the building fabric, leads to high capital cost which will not be recovered from savings in operational energy within 25 years of building service life. The most cost effective fabric specification U-value in this case for roof is 0.15 W/m^2.K and for wall is 0.21 W/m^2.K.

Within 5% of financial benefit, another 6% CO_2 can be saved by improving the building fabric from 0.15-0.21 W/m^2.K to 0.1-0.14 W/m^2.K. The analysis investigates whether improvements in building fabric thermal performance is the most cost effective approach towards achieving the further CO_2 saving.

Furthermore, mineral wool can be produced to any thickness (if necessary in multiple layers) but over-sizing in mineral wool panels causes significant engineering difficulties (including extreme eccentricities in spacer systems specifically on walls and inclined roofs). This will increase the capital cost of the construction even further.

Also, the payback period associated with improving the thermal performance of building fabric can be increased significantly due to very high capital cost of the improvement. In this case, the payback period increases from 12 to 17 years.

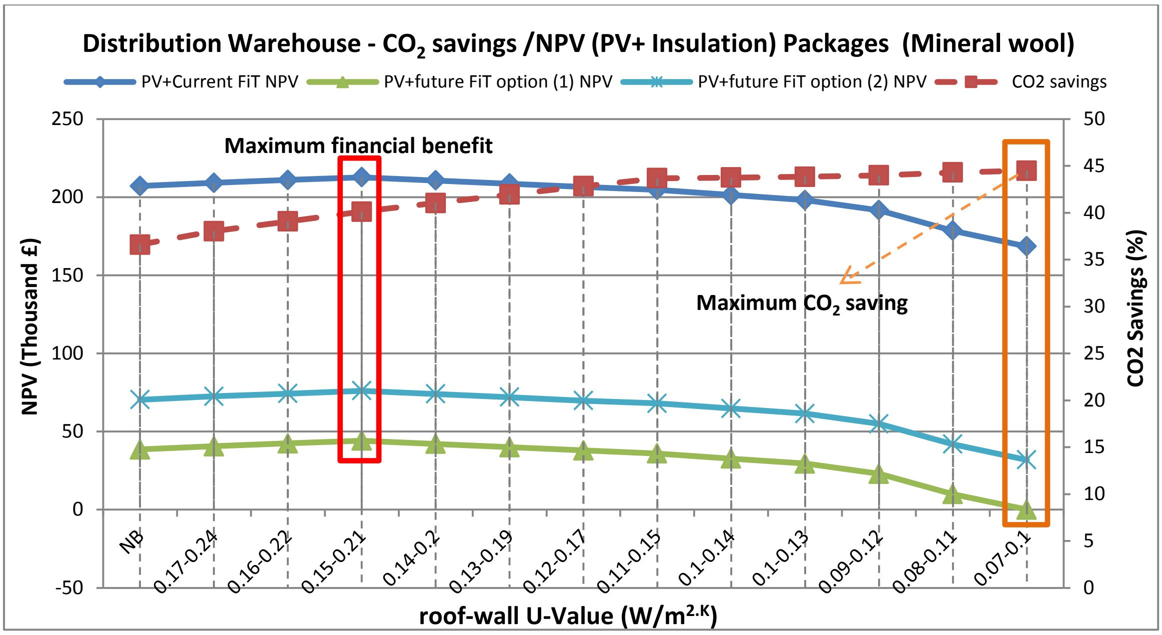


Figure7.1 NPV and CO_2 savings associated with 'PV+ mineral wool Insulation' package for distribution warehouse (NB: Notional Building)

According to the simulated distribution warehouse in chapter 5, PUR insulation is limited to 185 mm thick panels (due to embodied CO_2 issues). The reduction in the operational CO_2 demand from grid could not recover the high embodied CO_2 associated with PUR insulation and PV panels after 0.11 W/m^2.K roof U-Value and 0.15 W/m^2.K wall U-value. Consequently, there will be a reduction in the amount of CO_2 saving beyond this point.

In terms of financial scenarios that have been investigated for the 3000m^2 distribution warehouse, according to Figure 7.2, adding to the thickness of insulation leads to high capital cost of improvement. This increase will be recovered from savings in operational energy up to 0.15 W/m^2.K roof U-Value and 0.21 W/m^2.K wall U-value within 25 years of building service life. Beyond this point, there will be a reduction in financial benefits. The most cost effective fabric specification U-value in this case for roof is 0.15 W/m^2.K and for wall is 0.21 W/m^2.K.

Within 3% of financial benefit, another 2% CO_2 can be saved by improving the building fabric from 0.15-0.21 W/m^2.K to 0.11-0.154 W/m^2.K. Similar to the previous case, improvements in building fabric thermal performance is not proved to be the most cost effective approach towards achieving the further CO_2 savings.

Beyond approximately 170mm, the chemical reaction of foam expansion in PUR foam is slow and accordingly more difficult to control. At present, the maximum thickness of PUR that is possible to obtain appears to be around 200mm with U-value of 0.125 W/m^2.K (170mm being more common).

Furthermore, the payback period in this case increases from 13 years to 18 years.

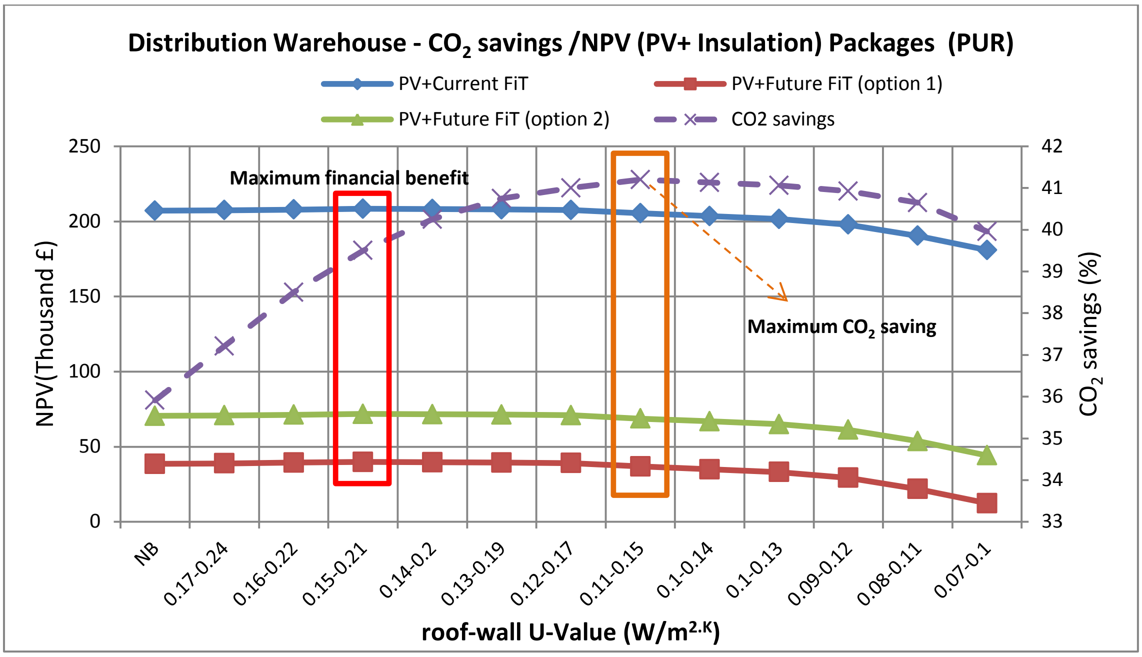


Figure 7.2 NPV and CO_2 savings associated with 'PV+ PUR Insulation' package for distribution warehouse (NB: Notional Building)

6.2.1.2 Retail sheds

According to the simulated Retail shed in Chapter 5, mineral wool insulation is limited to 200mm thick panels on grounds of total carbon efficiency. The reduction in the operational energy demand from the grid can recover the embodied CO_2 associated with mineral wool insulation and PV panels down to 0.1 W/m^2.K wall U-value. High embodied CO_2 of the building fabric outweighs CO_2 savings associated with lower operational energy demand down to the stated U-Value. Therefore, there is no point in going beyond the Notional Building fabric U-values as there will be a maximum of 1% carbon saving in fabric improvements.

In terms of financial scenarios that have been investigated for the 3000m^2 retail shed, according to Figure 7.3, adding to the thickness of insulation leads to a flat line in the graph meaning that no financial benefit in improving the building fabric is expected as the capital cost will not be recovered from savings in operational energy within 25 years of building service life.

Negligible financial benefit coupled with only 1% further CO_2 saving suggest that highly insulated building fabric for investigated type and size of building is neither cost effective nor carbon efficient.

Moreover, the payback period associated with improving the thermal performance of building fabric in this case increases from 15 years to 21 years.

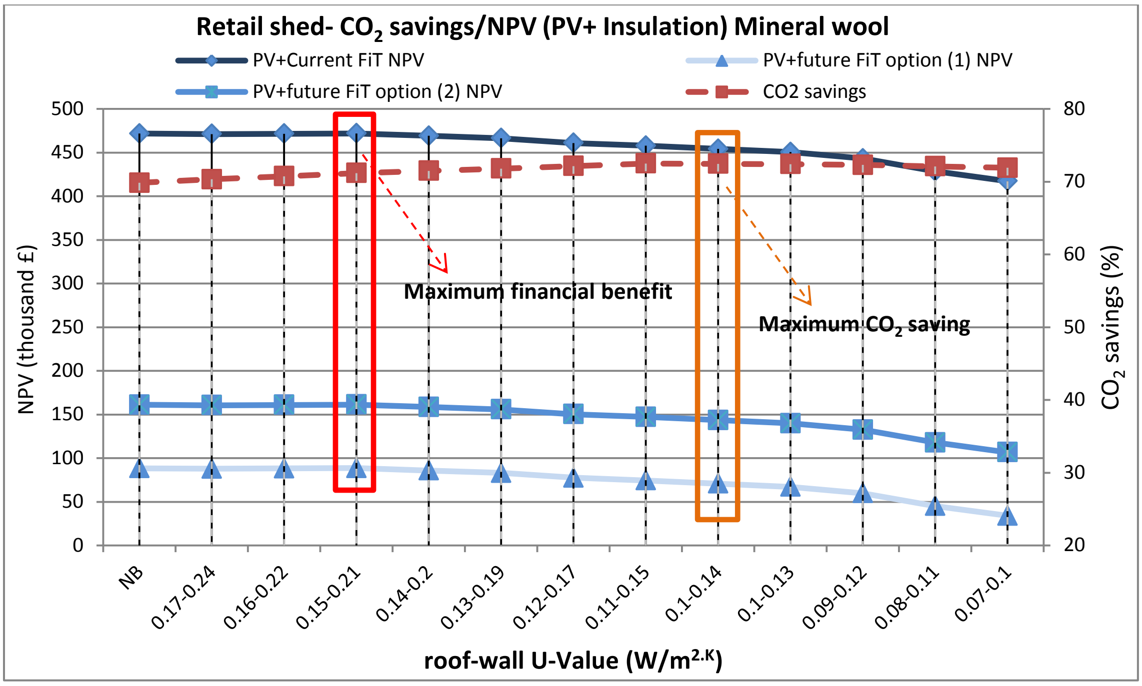


Figure 7.3 NPV and CO_2 savings associated with 'PV+ mineral wool Insulation' package for retail shed (NB: Notional Building)

Results from the simulated retail shed in Chapter 5 shows that PUR insulation is limited to 115 mm thick panel in terms of carbon efficiency. Even with the reduction in the operational CO_2 demand from grid, the high embodied CO_2 associated with PUR insulation and PV panels cannot be recovered for U-values lower than 0.19 W/m^2.K wall and 0.13 W/m^2.K roof U-values.

Regarding the cost effectiveness analyses that have been carried out for the 3000m^2 retail shed (Figure 7.4), adding to the thickness of insulation leads to a downward line in the graph meaning that the capital cost of improvements cannot be recovered by the operational carbon savings through the lifetime of the building. No financial benefit coupled with only 1.5% further CO_2 saving suggests no benefit for insulating the building beyond the Notional Building fabric specifications for the studied type and size of building.

In addition, the payback period associated with improving the thermal performance of building fabric in this case increases from 16 years to 22 years.

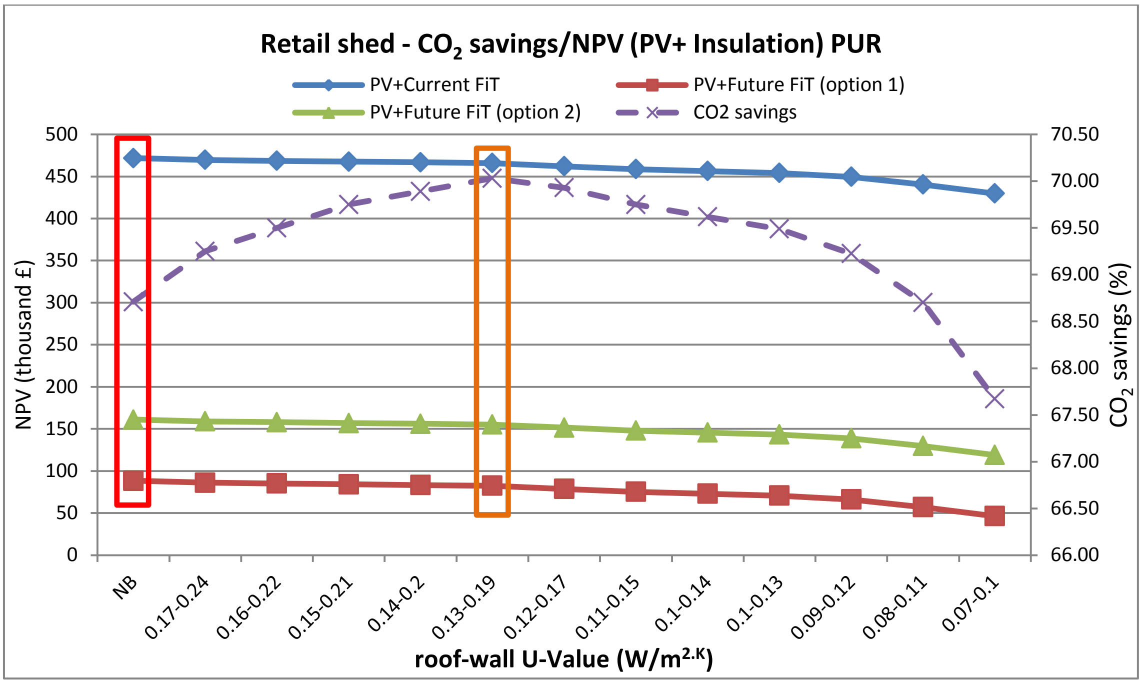


Figure 7.4 NPV and CO_2 savings associated with 'PV+ PUR Insulation' package for retail shed (NB: Notional Building)

6.2.1.3 Office buildings

According to the simulated Office building in Chapter 5, beyond 200 mm thick panels the amount of embodied CO_2 associated with the insulation material outweighs the operational CO_2 savings for mineral wool insulation. Savings associated with operational CO_2 reduction from the grid however, almost offsets the high embodied

CO_2 of the building fabric down to 0.11 W/m^2.K roof U-Value and 0.15 W/m^2.K wall U-value.

The embodied CO_2 associated with mineral wool insulation and PV panels cause carbon disbenefit below 0.15 W/m^2.K wall U-value. The maximum CO_2 saving associated with improving the building fabric is only 1%.

In terms of financial scenarios that have been investigated, according to figure 7.5, adding to the thickness of insulation leads to a flat line in the graph. This suggests that, beyond the Notional Building fabric, the high capital cost of improvement recovered through savings associated with operational carbon within 25 years of building service life. Negligible financial benefit coupled with only 1% further CO_2 saving suggests that a highly insulated building fabric for the investigated type and size of building is not recommended.

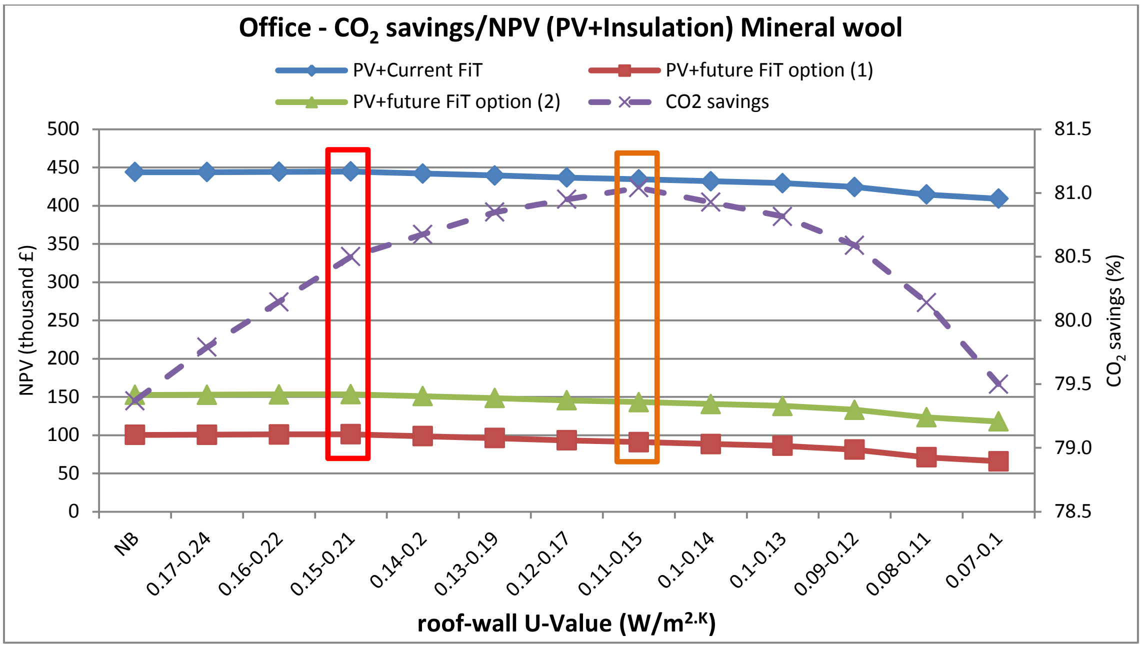


Figure 7.5 NPV and CO_2 savings associated with 'PV+ mineral wool Insulation' package for offices (NB: Notional Building)

The simulation results from Chapter 5 shows that beyond 140 mm thick panels, the amount of embodied CO_2 of the insulation material causes a carbon disbenefit for PUR insulation. The reduction in the operational energy demand from grid cannot recover the high embodied CO_2 associated with insulation materials and PV panels beyond Notional

Building U-value specifications. The maximum CO_2 saving associated with improving the building fabric is circa 0.8%.

Also according to Figure 7.6, adding to the thickness of insulation leads to a downward cost line in the graph. This suggests that no financial benefit is anticipated for improving the building fabric beyond Notional Building fabric specifications.

Financial disbenefit coupled with only 0.8% further CO_2 saving suggests no justification for insulating the building fabric beyond the Notional Building fabric for studied type and size of building.

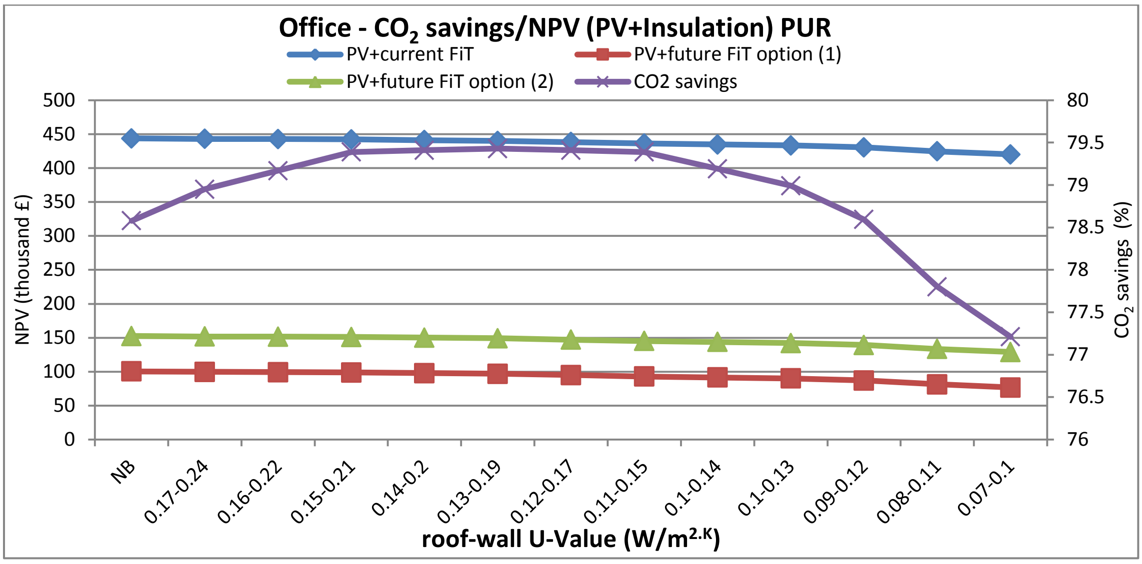


Figure 7.6 NPV and CO_2 savings associated with 'PV+ PUR Insulation' package for offices (NB: Notional Building)

Cost analysis of office buildings taking into account the rental value loss

As it has been previously discussed in Chapter 5, increasing the thickness of commercial building cladding systems adversely affects the ratio of net to gross floor area calculated on a building perimeter basis. The impacts of reductions in net to gross floor areas (caused by increased width of external walls) are significant on the rental value of buildings.

According to Figure 7.7, increased thickness of the external wall does not lead to considerable CO_2 savings, nor results in any financial benefits over 25 years design life of the building.

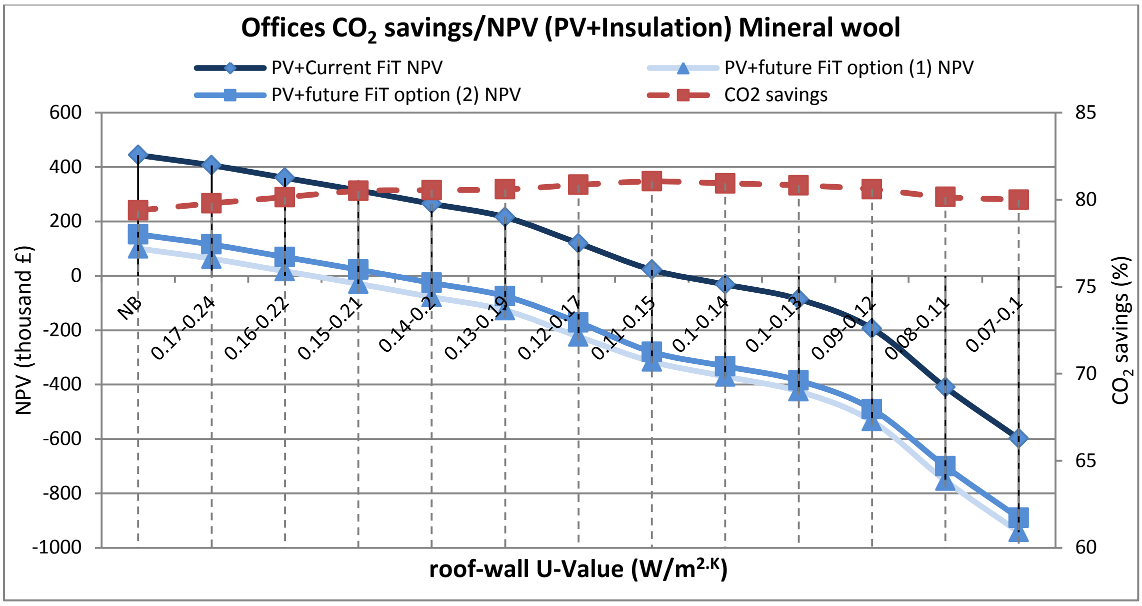


Figure 7.7 NPV and CO_2 savings associated with 'PV+ mineral wool Insulation' package for offices including rental value loss

According to Figure 7.8, improving the building fabric thermal performance consequently leads to thick cladding panels using conventional insulation materials. This results in a significant loss in the NPV over 25 years design life of the building.

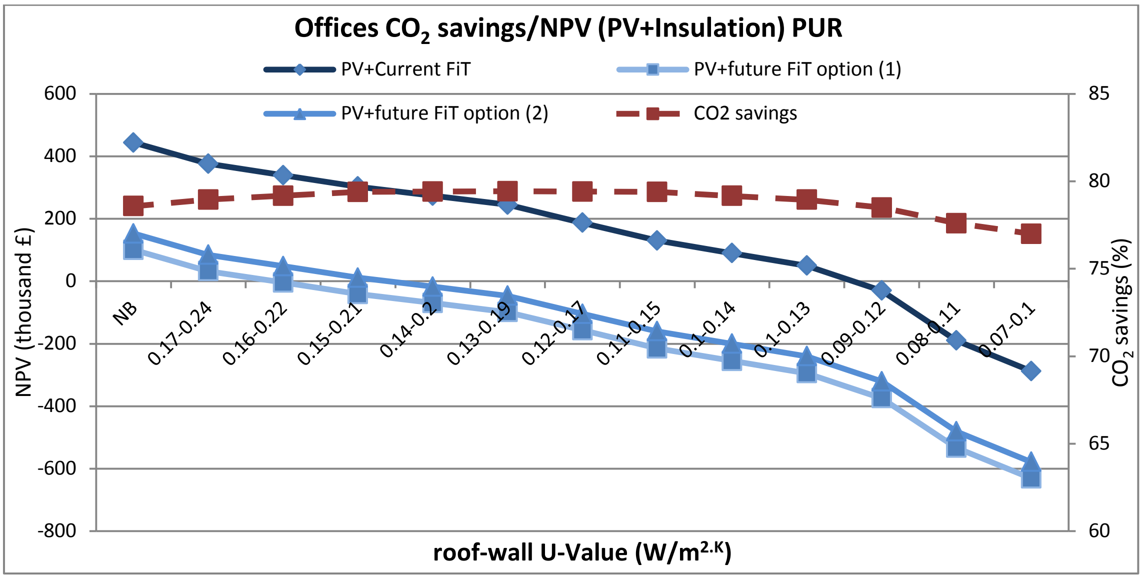


Figure 7.8 NPV and CO_2 savings associated with 'PV+ PUR Insulation' package for offices including rental value loss

6.3 Summarising 'PV + building fabric' packages

The previous analyses present the maximum CO_2 savings associated with improving the building fabric packages plus application of PV panels in the most cost effective way. All of the measures investigated fall short of zero carbon performance.

None of the cases investigated show significant financial benefit for improving the building fabric specifications beyond the Notional Building fabric specification. In terms of CO_2 savings, the total savings relative to application of PV panels is different for each building. The carbon savings for warehouses, retail sheds and offices are 35, 60.5 and 79 % respectively excluding the effect of improved fabric on CO_2 savings. The aggregate CO_2 saving is presented in Table 7.4.

Table 7.4 CO_2 savings associated with different packages and building types

Building type	Maximum CO_2 savings – 'Insulation' packages %	Maximum CO_2 savings – 'PV + Insulation' packages %
Warehouse	9.97	45
Retail shed	9.43	70
Office	1	80

Hence, in order to achieve the zero carbon performance, additional on-site zero carbon technologies are required to be coupled with the investigated packages. Transpired Solar Collectors (TSC) as a heat generating technology has been added to the 'technology packages'.

6.4 Transpired Solar Collectors

The TSC was originally developed in Canada for agricultural applications (specifically crop and process drying) and has been used successfully in the USA and Canada over the past 20 years (Heinrich, 2007). Agricultural operators consume significant quantities of energy which forms a substantial proportion of their total operational and capital costs. Rising energy prices and the considerable pressure on agricultural incomes emphasized the case for developing technologies to maximise the benefit from solar energy for the agricultural sector.

Convincing performance of TSCs in agricultural applications encouraged building manufacturers to apply the technology to other building types such as industrial warehouses and retail sheds. Monitored data from the US Department of Energy shows that a reduction of \$10–\$30 per m^2 of collector wall in annual heating costs can be achieved in the US, by preheating the incoming ventilation air using solar energy by as much as 30°C (DOE, 2000).

In the UK the first TSC installation goes back to year 2006 where it was installed on a single-storey industrial building and provided around 20% of the building's heating demand in the first year. Figures released from the Department of Energy and Climate Change (DECC) suggest that space heating accounts for approximately 40% of the UK's non-transport energy consumption. This raises a compelling case for development of renewable technologies generating heat from solar radiation. It is expected that the success of TSCs in the USA and Canada can potentially be replicated in the UK (Hall et al., 2011).

TSCs are specially perforated steel collector panels installed about 75mm from a south facing wall, creating an air cavity. The metal cladding (steel sheet) is heated by solar radiation. A ventilation fan creates negative pressure in the air cavity, drawing the solar heated air through the panel perforations. The heated air is then ducted into the building via a connection to the HVAC intake (Figure 7.9).

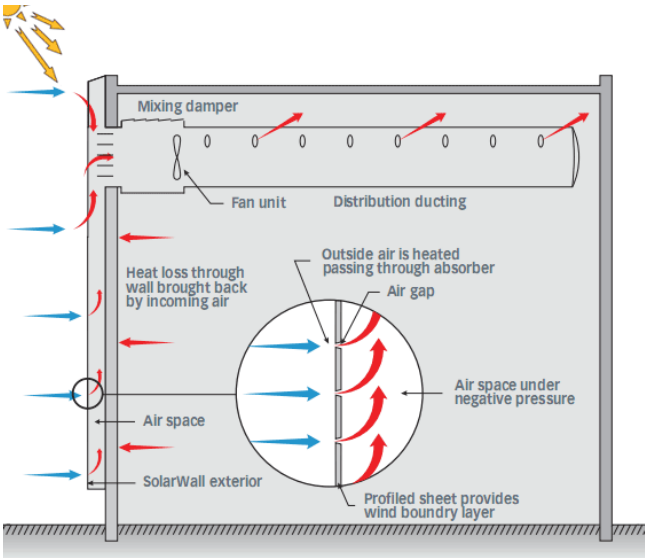


Figure 7.9 TSC performance diagram (source: Solarwall)

TSCs are mainly known as preheating air systems. By preheating the ventilating air with solar energy, a substantial load from buildings conventional heating system can be removed, saving energy and money. Research carried out at Oxford Brookes University for 95 days during the winter of 2010/2011 show that under typical operating conditions, TSCs heated the intake air by 10–15˚C on clear-skied days (Hall et al., 2014). TSCs may not be able to preheat the ventilation air up to the required indoor air temperature on cloudy days but it still can provide useful energy to reduce utility bills (DOE, 1998).

TSCs also save energy in other ways such as recapturing the heat loss through the building fabric and venting it back to the interior space. Also by introducing the air through ceiling mounted ducts, the system eliminates the wasteful air stratification. Stratified temperature can cause a high infiltration loss in addition to conduction loss through the roof construction. In a high ceiling building, additional fans are often required to de-stratify the air but using TSCs, the auxiliary energy associated with the fan power can be eliminated from total energy consumption of the building.

Figure 7.10 compares floor to ceiling temperature difference for a typical distribution warehouse with and without de-stratification fans. There is a 6 degree difference which can negatively contribute to the overall heat loss through infiltration and conduction loss through the roof construction.

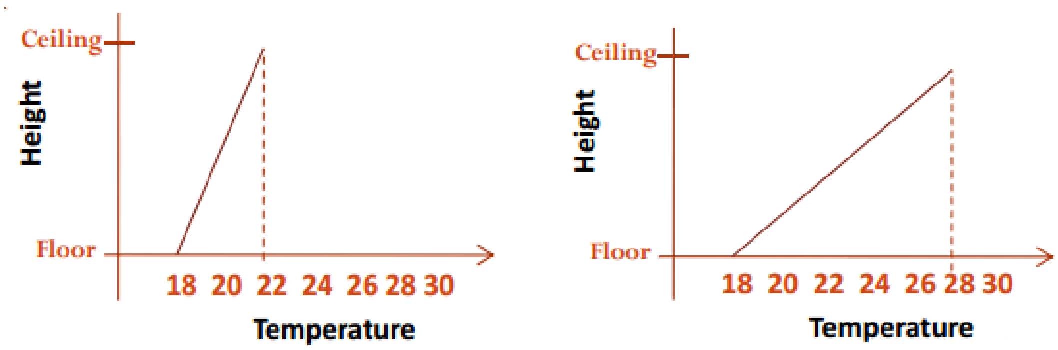


Figure 7.10 Buildings with (left) and without (right) de-stratification fans (or TSCs)

6.4.1 Technology options (packages) including TSCs

The area of TSC installed is assumed to provide the equivalent amount of heat to 25 (I), 50 (II) and 75(III) % of the buildings heat demand in all packages. Providing 100% of the heat demand by TSCs is practically unachievable as the majority of the heat generated by TSC is in the summer when heating demand is at its lowest. The generated heat in this period can be significantly above the required level, which is not taken into account as delivered heat.

Two mainstream conventional insulation materials, mineral wool and PUR, have been used for the analyses.

The selected technology packages (Table 7.5) are as follows:

- **Package G is defined as: TSC plus the notional building fabric specification and taking full account of energy efficient services and lighting.**

- **Package H is defined as: TSC plus the improved building fabric down to 0.1 W/m^{2}K U-value and taking full account of energy efficient services and lighting.**

Table 7.5 Investigated packages

Investigated packages			
Fabric	**percentage of the heat supplied by TSC %**		
	25	**50**	**75**
Notional Building fabric	G(I)	G(II)	G(III)
Improved insulation	H(I)	H(II)	H(III)

6.4.2 Application of TSCs to the investigated buildings

Package G: TSC + Notional Building fabric + energy efficient services and lighting

The results associated with applying TSC to industrial and office buildings are demonstrated in Figures 7.11 and 7.12. All the investigated packages are insulated to Notional Building fabric specifications. 25, 50 and 75% of the annual heat demand of the building is supplied with application of TSCs (respectively G(I), G(II) and G(III)).

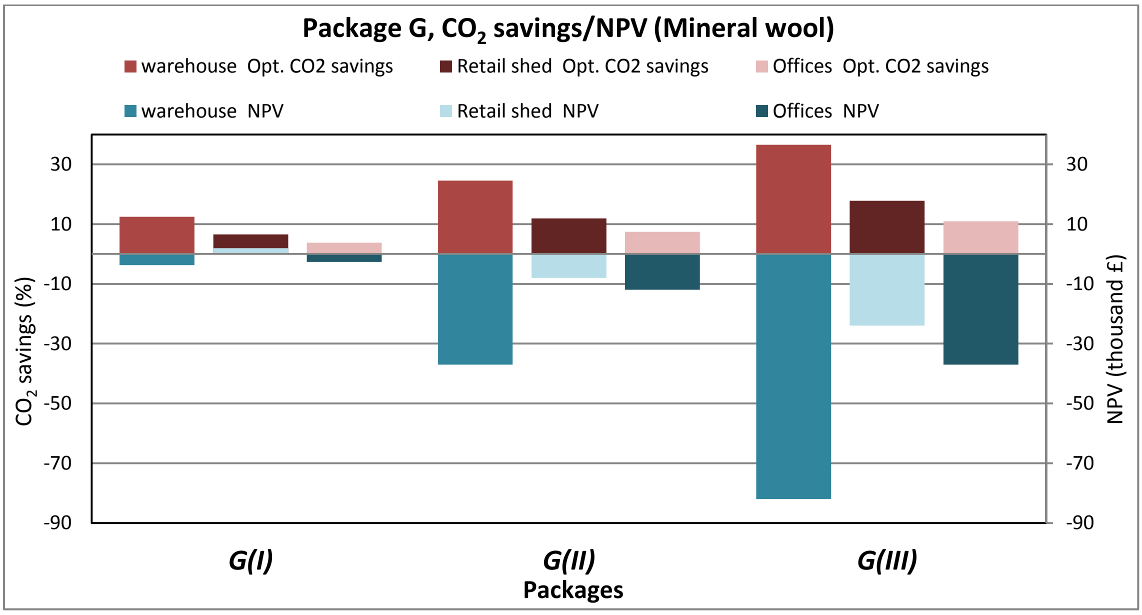


Figure 7.11 NPV and CO_2 savings associated with package G, mineral wool

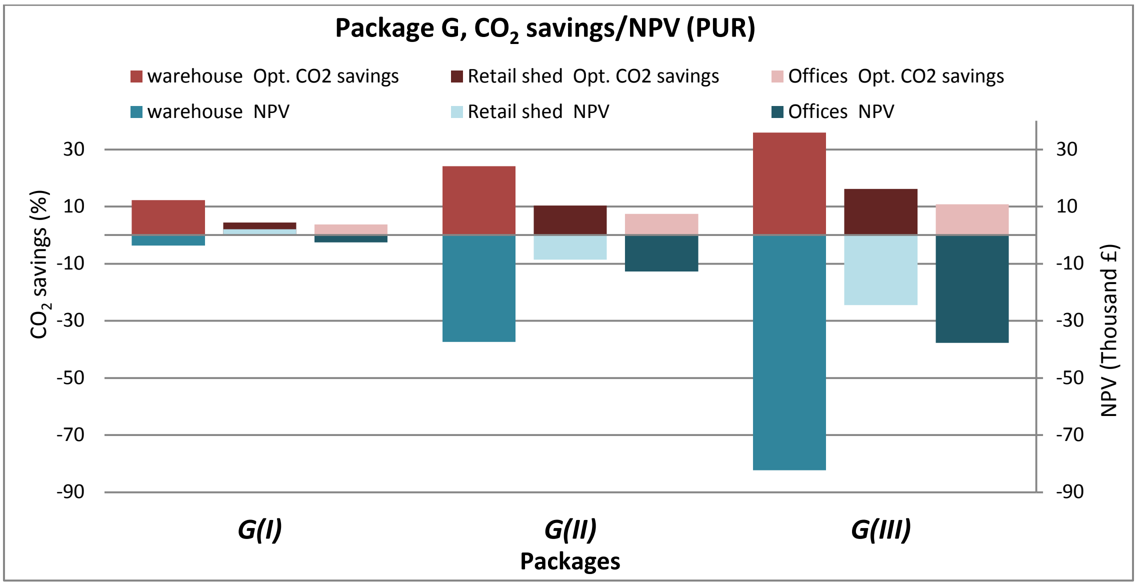


Figure 7.12 NPV and CO_2 savings associated with package G, PUR

The maximum CO_2 saving relative to application of TSCs is 36.5% which occurs in warehouse buildings. The relative figure for office buildings reduces to 10.92% saving due to the smaller annual heat demand (high internal gain from lighting, appliances and occupants in offices leads to lower annual heat demand) (Tables 7.6 and 7.7).

Table 7.6 NPV and CO_2 savings associated with package G and different building types, mineral wool

	warehouse		Retail shed		Offices	
	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)
G(I)	-3.7	12.51	2	6.6	-2.6	3.78
G(II)	-37	24.62	-8	11.97	-12	7.46
G(III)	-82	36.59	-24	17.82	-37	10.92

Table 7.7 NPV and CO_2 savings associated with package G and different building types, PUR

	warehouse		Retail shed		Offices	
	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)
G(I)	-3.7	12.27	2.06	4.45	-2.59	3.74
G(II)	-37.4	24.15	-8.62	10.36	-12.68	7.38
G(III)	-82.35	35.88	-24.5	16.21	-37.77	10.80

Package H: TSC + improved fabric + energy efficient services and lighting

The optimum CO_2 saving and cost effectiveness results associated with applying TSC plus improving the building fabric U-values are demonstrated in Figures 7.13 and 7.14. All the investigated packages are insulated down to 0.1 $W/m^2.K$ U-values. 25, 50 and 75% of the annual heat demand of the building is supplied with application of TSCs (respectively H(I), H(II) and H(III))

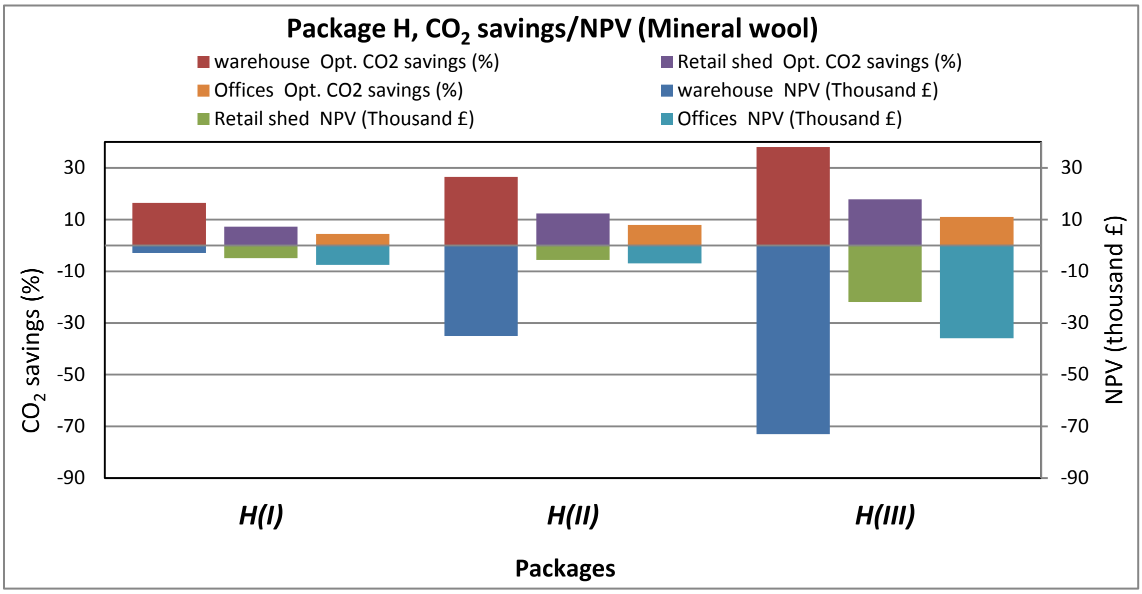


Figure 7.13 NPV and CO_2 savings associated with package H, mineral wool

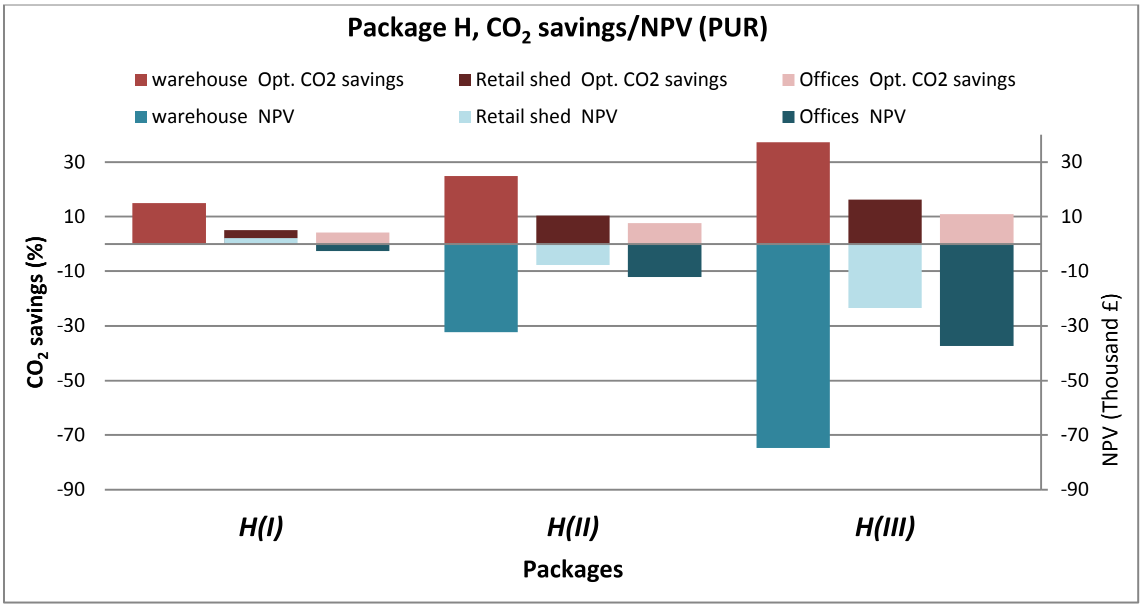


Figure 7.14 NPV and CO_2 savings associated with package H, PUR

The maximum CO_2 saving as a result of application of TSCs is 38% in warehouse buildings. This figure drops to 11% saving in offices, due to the lower annual heat demand (Tables 7.8 and 7.9).

Table 7.8 NPV and CO_2 savings associated with package H and different building types, mineral wool

	warehouse		Retail shed		Offices	
	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)
H(I)	-3	16.5	-5	7.25	-7.5	4.5
H(II)	-35	26.5	-5.6	12.43	-7	7.94
H(III)	-73	38	-22	17.86	-36	11

Table 7.9 NPV and CO_2 savings associated with package H and different building types, PUR

	warehouse		Retail shed		Offices	
	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)	NPV (£ K)	Opt. CO_2 savings (%)
H(I)	-0.18	14.98	2.06	4.98	-2.59	4.21
H(II)	-32.4	24.92	-7.6	10.43	-12.05	7.55
H(III)	-74.8	37.2	-23.4	16.21	-37.4	10.8

Financially, TSCs with current capital cost are not showing a reasonable payback period and in most cases the capital cost of installing TSCs cannot be recovered through 25 years of buildings service life.

There are debates on the method of calculating the cost of TSCs. The first view claims that as TSCs are preheating air systems and cannot provide the required heat demand in peak times of the year, a main heating system should be installed in addition to TSCs so the costs associated with the ducting etc should be taken into account in the price of TSCs. The second view argues that TSCs are additional renewable systems that add a certain amount towards the total cost of the heating system of buildings. Therefore only the cost of collectors should be taken into account as the price of TSCs.

In order to take both views into account, a range of prices have been defined and a payback period analysis has been carried out for TSCs. Results are associated with mineral wool insulation material. Mineral wool insulation applied to Package H(II) is used as an example in payback period study (Figure 7.15).

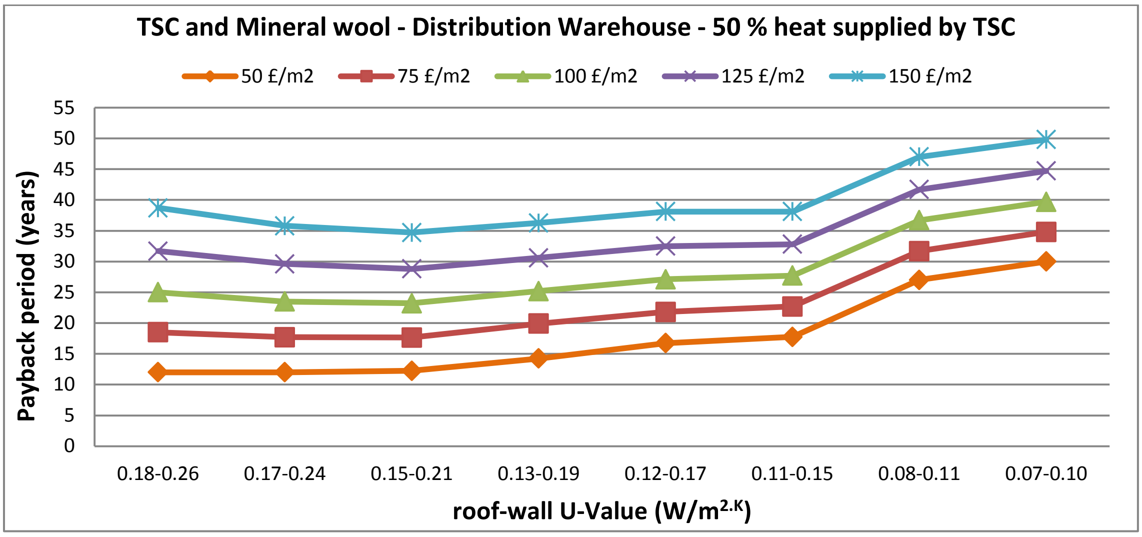


Figure 7.15 Payback period associated with TSC and mineral wool insulation for distribution warehouses

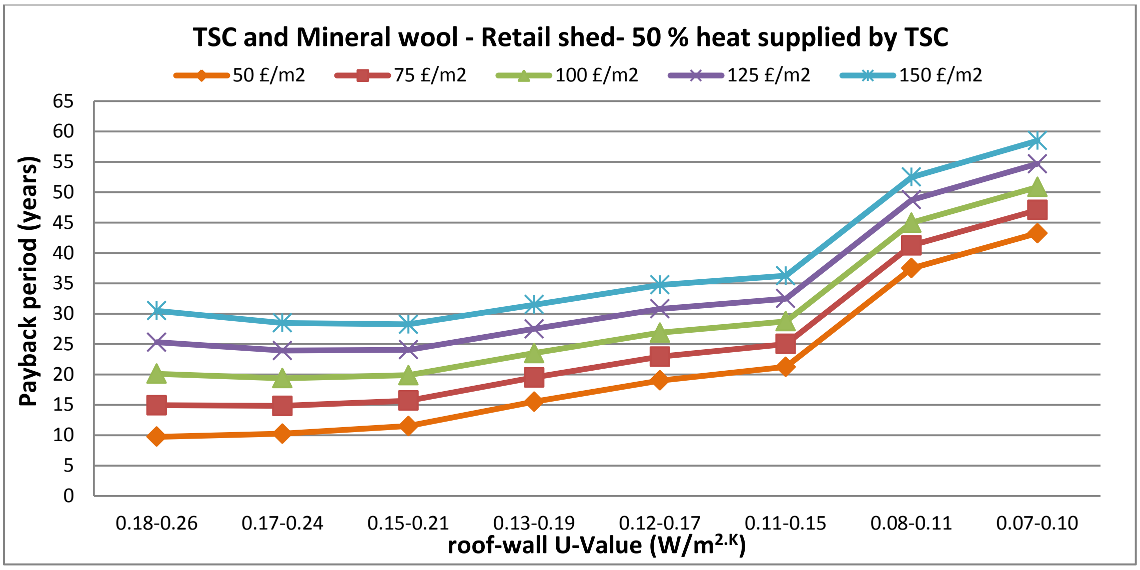


Figure 7.16 Payback period associated with TSC and mineral wool insulation for retail sheds

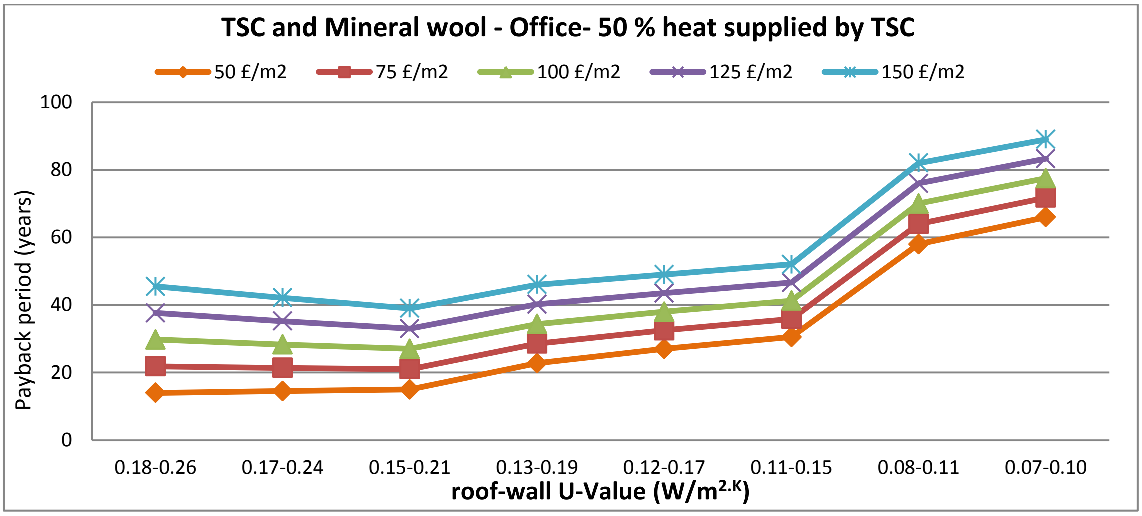


Figure 7.17 Payback period associated with TSC and mineral wool insulation for offices

In all studied cases, adding to the thickness of insulation irrespective to the price of TSC caused a slight upward line in the payback period graph beyond 0.15 W/m^2.K roof U-Value and 0.21 W/m^2.K wall U-Value. The steeply sloping line starting from 0.11 W/m^2.K roof U-Value and 0.15 W/m^2.K wall U-Value also demonstrates no financial benefit beyond this point.

6.5 'PV + TSC + Insulation' packages

6.5.1 Technology options (packages)

All of the measures discussed in the previous sections fall short of zero carbon performance as demonstrated in Table 7.10.

Table 7.10 Maximum CO_2 savings achievable with the investigated packages for analysed building types

Building type	Max CO_2 savings by 'PV+Insulation' Packages %	Max CO_2 savings by 'TSC+Insulation' Packages %	Max CO_2 savings by 'Insulation' Packages %
Warehouse	45	38	9.97
Retail shed	70	17.8	9.43
Office	80	11	1

In order to achieve the zero carbon performance, 'PV + TSC + Insulation' Packages have been combined (Table 7.11). The selected technology packages are as follows:

- **Package K is defined as; TSC + PV (current FiT) + the improved building fabric and taking full account of energy efficient services and lightings.**
- **Package M is defined as; TSC + PV (future FiT) + the improved building fabric and taking full account of energy efficient services and lightings.**

Table 7.11 Investigated packages including current and future FiT scenarios

Investigated packages (current FiT)				
Fabric	**percentage of heat and electricity supplied by renewables %**			
	25	50	75	100 % PV - 75% TSC
Insulation	K(I)	K(II)	K(III)	K(IV)
Investigated packages (future FiT)				
Fabric	**percentage of heat and electricity supplied by renewables %**			
	25	50	75	100 % PV - 75% TSC (Options 1&2)
Insulation	M(I)	M(II)	M(III)	M(IV)

6.5.1.1 Application of the introduced packages to the investigated building types

The above packages have been applied to distribution warehouses, retail sheds and office buildings. The results of analyses are presented in the following section:

- **Packages K&M: TSC + PV (current/future FiT) + the improved building fabric specification and energy efficient lighting and services**

NPV results associated with applying 'PV+TSC' packages are demonstrated in Figures 7.18 to 7.21.

Warehouse

All the investigated packages are insulated down to 0.1 W/m^2.K U-values. Comparing the results from Figure 7.18 with PV only packages demonstrates that application of TSCs is negatively affecting the NPV benefits of using renewable technologies. This is simply due to the high capital cost of applying TSCs which is not fully recovered by heating load savings during the service life of the building.

In terms of CO_2 savings in a medium sized distribution warehouse, the combination of studied renewables contributes to a further 38% to the overall CO_2 savings comparing with PV only packages (Table 7.12).

Table 7.12 NPV and CO_2 savings associated with different packages, medium sized warehouse

Investigated packages on a medium sized distribution warehouse		**Maximum saving**	**Optimum U-value (roof-wall U-values)**
PV (Current FiT)+TSC+ +Insulation	NPV (£ K)	130	0.15-0.21
	CO_2 savings (%)	73	0.07-0.1
PV (Future FiT (4.5p/KWh)) +TSC+Insulation	NPV (£ K)	-37	0.15-0.21
	CO_2 savings (%)	73	0.07-0.1
PV (Future FiT (10p/KWh))+TSC+ Insulation	NPV (£ K)	-6	0.15-0.21
	CO_2 savings (%)	73	0.07-0.1

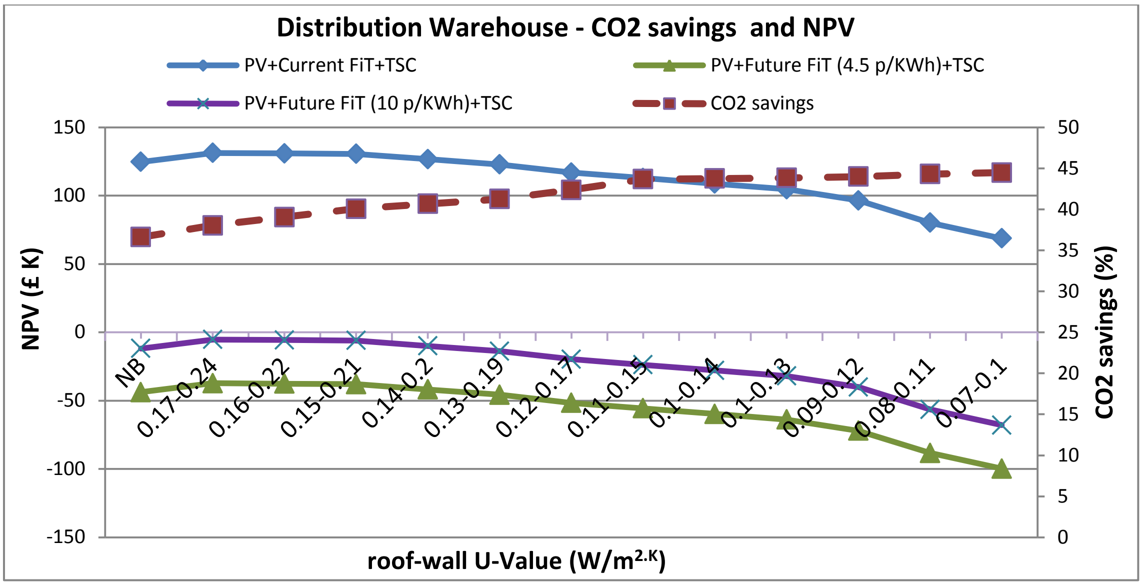


Figure 7.18 NPV analysis associated with different FiT scenarios in a distribution warehouse

Improving the building fabric specification beyond 0.15-0.21 W/m^2.K U-Value results in financial disbenefit whilst this improvement is beneficial in terms of CO_2 savings. The additional 5% CO_2 savings associated with adding to the thickness of insulation is likely to be achieved by taking a more cost effective approach which will be discussed in the following sections.

Retail shed

Figure 7.19 is demonstrating a downward line for NPV and CO_2 saving measures beyond 0.17-0.24 W/m^2.K U-Value. This is because lighting loads account for more than 50% of the annual energy consumption of retail sheds. Thus, generating electricity on-site can have much bigger effect on the overall CO_2 savings than controlling the heating loads using building fabric. Adding to the thickness of insulation in retail shed buildings therefore, due to high electricity demand (high lighting demand), is not the most effective solution. The CO_2 embodied in thicker insulation materials will not be recovered through energy savings associated with less heat loss through building fabric.

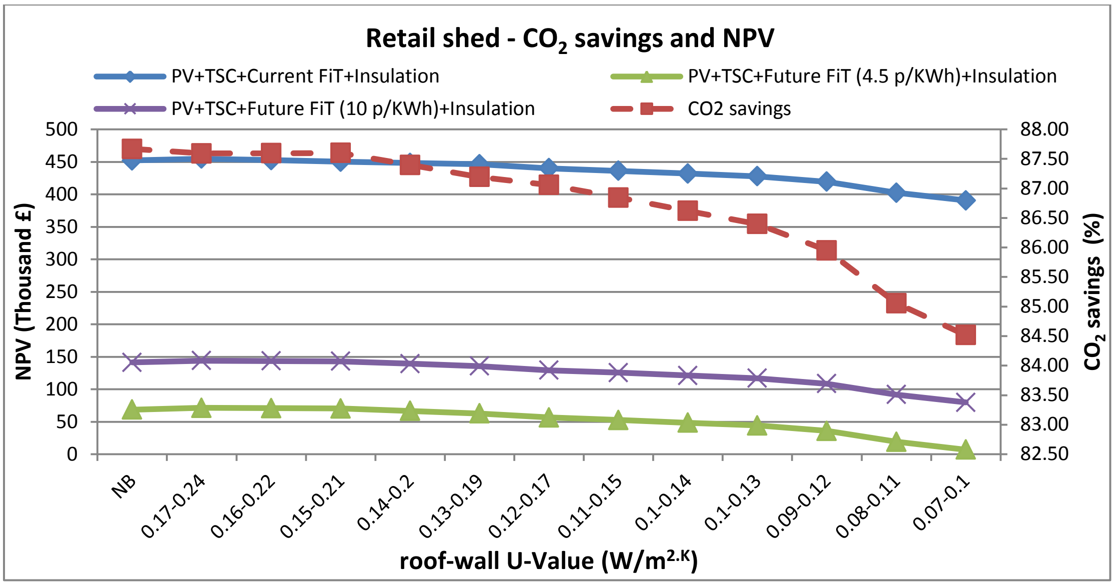


Figure 7.19 NPV and CO_2 saving analysis associated with different FiT scenarios in a retail shed

As presented in Table 7.13, the combination of studied renewables contributes a further 17% to the overall CO_2 savings beyond PV only packages (Table 7.4).

Table 7.13 NPV and CO_2 savings associated with different packages, retail shed

Investigated packages on a medium sized retail shed		**Maximum saving**	**Optimum U-value**
PV+TSC+Current FiT+Insulation	**NPV (£ K)**	452	0.17-0.24
	CO_2 savings (%)	87.6	0.15-0.21
PV+TSC+Future FiT (4.5 p/KWh)+Insulation	**NPV (£ K)**	71.4	0.17-0.24
	CO_2 savings (%)	87.6	0.15-0.21
PV+TSC+Future FiT (10 p/KWh)+Insulation	**NPV (£ K)**	144.1	0.17-0.24
	CO_2 savings (%)	87.6	0.15-0.21

Offices

In case of office buildings, due to the high internal gain generated by people, computers, lighting and other appliances, the heating load is only about 30% of the overall energy consumption. Lighting load on the other hand is responsible for over 60% of the annual energy consumption in an office (excluding cooling loads).

Supplying the electricity demand on-site seems to be the most cost effective way of saving CO_2. Application of TSCs has only contributed a further 13.5% CO_2 emission reduction towards achieving the zero carbon performance (Table 7.14).

Table 7.14 NPV and CO_2 savings associated with different packages, office

Investigated packages on an 2600m^2 Office		Maximum saving	Optimum U-value
PV+TSC+Current FiT+Insulation	NPV (£ K)	394.17	0.15-0.21
	CO_2 savings (%)	93.5	0.15-0.21
PV+TSC+Future FiT (4.5 p/KWh)+Insulation	NPV (£ K)	50.78	0.15-0.21
	CO_2 savings (%)	93.5	0.15-0.21
PV+TSC+Future FiT (10 p/KWh)+Insulation	NPV (£ K)	103.04	0.15-0.21
	CO_2 savings (%)	93.5	0.15-0.21

Adding to the thickness of insulation in order to reduce the heat loss through the building fabric is not showing any significant financial benefit in case of investigated office buildings (Figure 7.20).

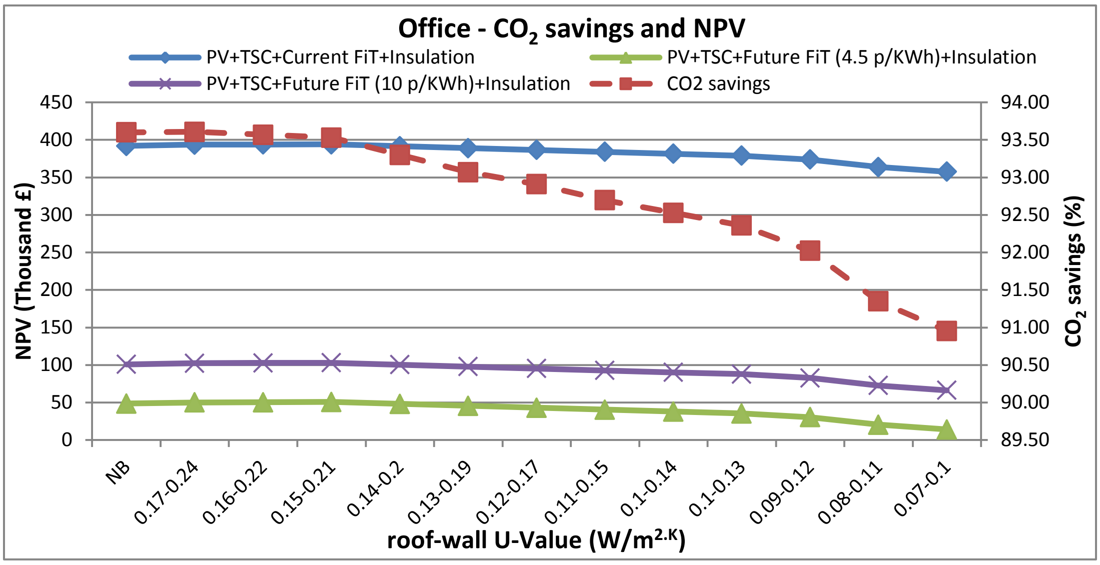


Figure 7.20 NPV and CO_2 savings associated with different packages, office

6.6 Summarising 'PV + TSC + building fabric' packages

None of the packages investigated thus far, could achieve zero carbon performance. In order to achieve absolute zero carbon performance in relation to the total carbon approach, not only annual operational carbon load, but also the carbon embodied in the materials and products need to be fully recovered.

Table 7.15 demonstrates the maximum CO_2 savings associated with the investigated packages. All packages fall short of the zero carbon performance. Therefore, the carbon emissions which cannot be cost-effectively offset on-site, after maximum carbon reduction has been achieved, will be tackled through remote measures (such as exporting electricity to the grid).

Table 7.15 Maximum achievable CO_2 saving associated with each package

Building type	Max CO_2 savings by 'Insulation' Packages %	Max CO_2 savings by 'TSC+Insulation ' Packages %	Max CO_2 savings by 'PV+Insulation' Packages %	Max CO_2 savings by 'PV+TSC+Insulation' Packages %
Warehouse	9.97	38	45	73
Retail shed	9.43	17.8	70	87.6
Office	1	11	80	93.5

Figure 7.21 demonstrates the additional CO_2 saving that is required to be made in a retail shed (as an example) in order to achieve the zero carbon performance. This additional CO_2 saving is different for each investigated package.

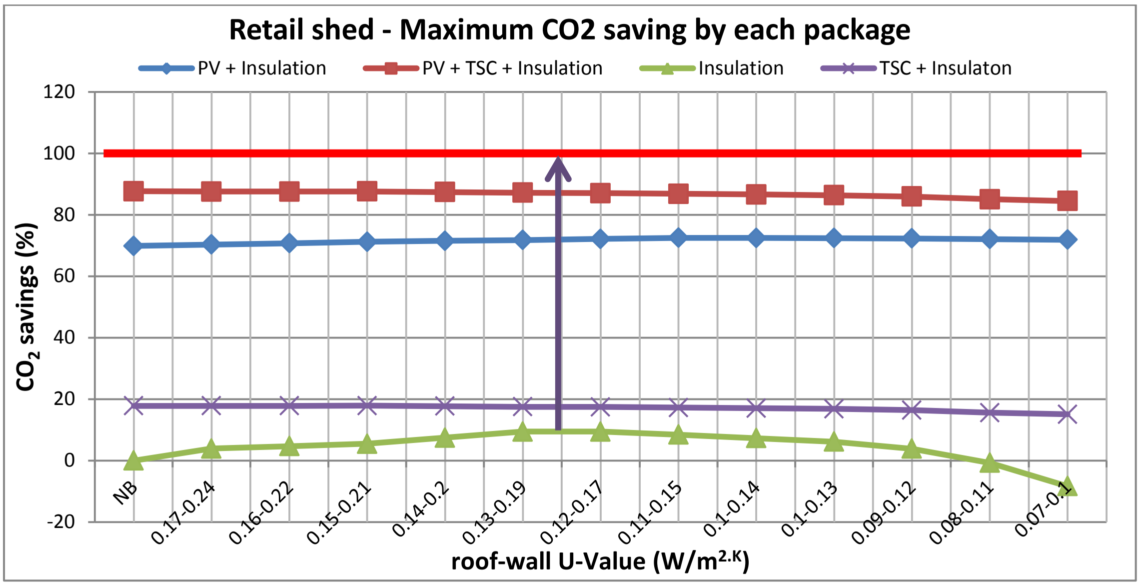


Figure 7.21 Maximum achievable CO_2 saving associated with each package

6.7 Carbon offsetting through exporting electricity to the gird and conclusions

Of all the technology packages investigated to achieve zero carbon performance, PV is the most cost effective solution (with current price range) in all three types of buildings (distribution warehouse, retail shed and office). The results are as presented in Figures 7.22 to 7.24. Therefore the surplus carbon has been tackled through exporting electricity, supplied by PVs, to the local energy grid above the electricity demand of the building.

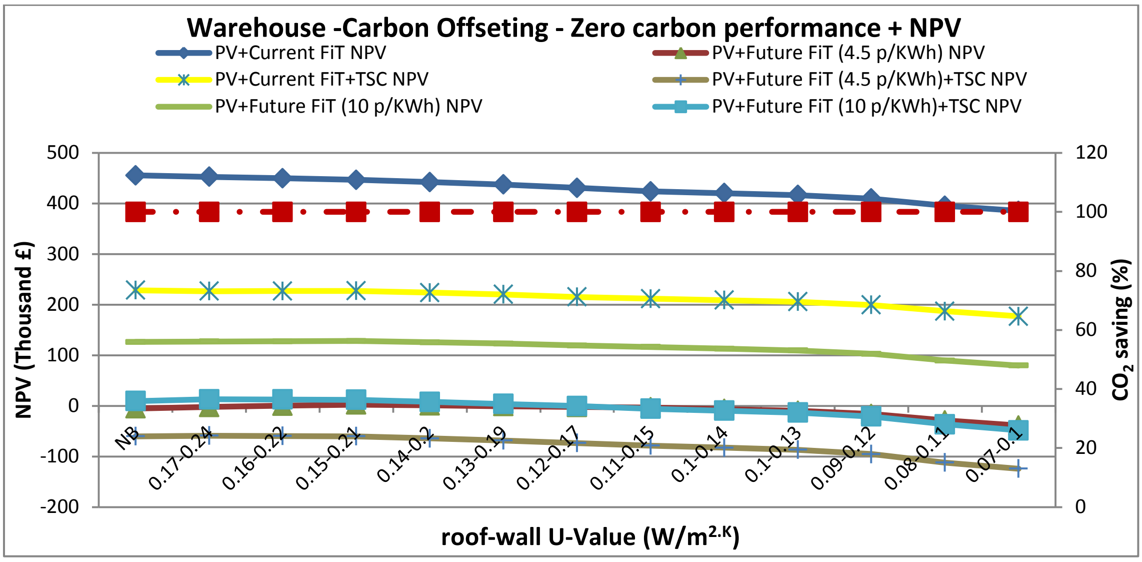


Figure 7.22 Carbon offsetting analysis, Distribution Warehouse

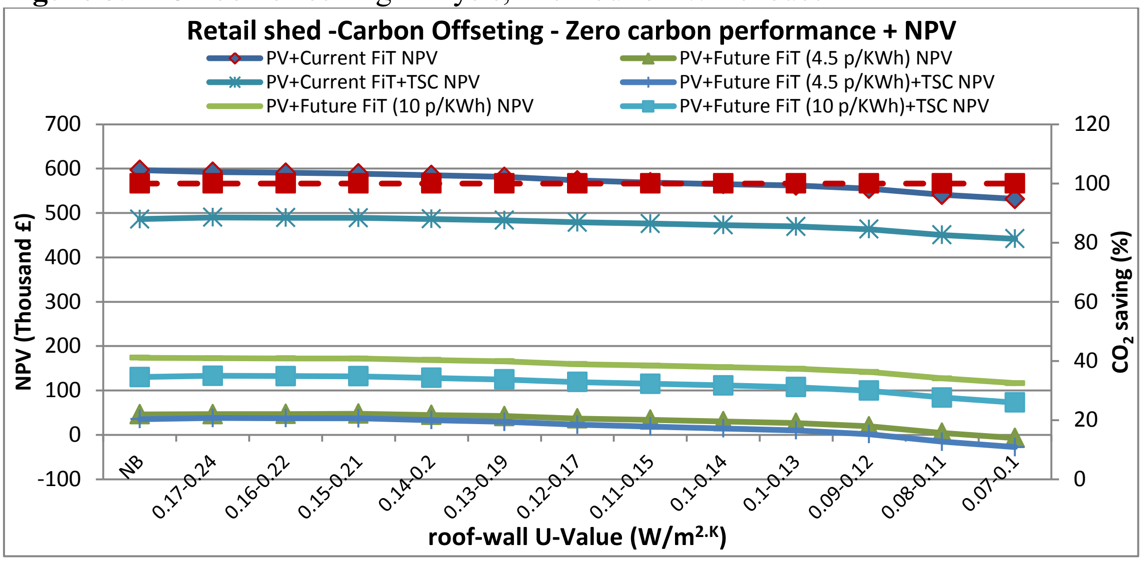


Figure 7.23 Carbon offsetting analysis, Retail shed

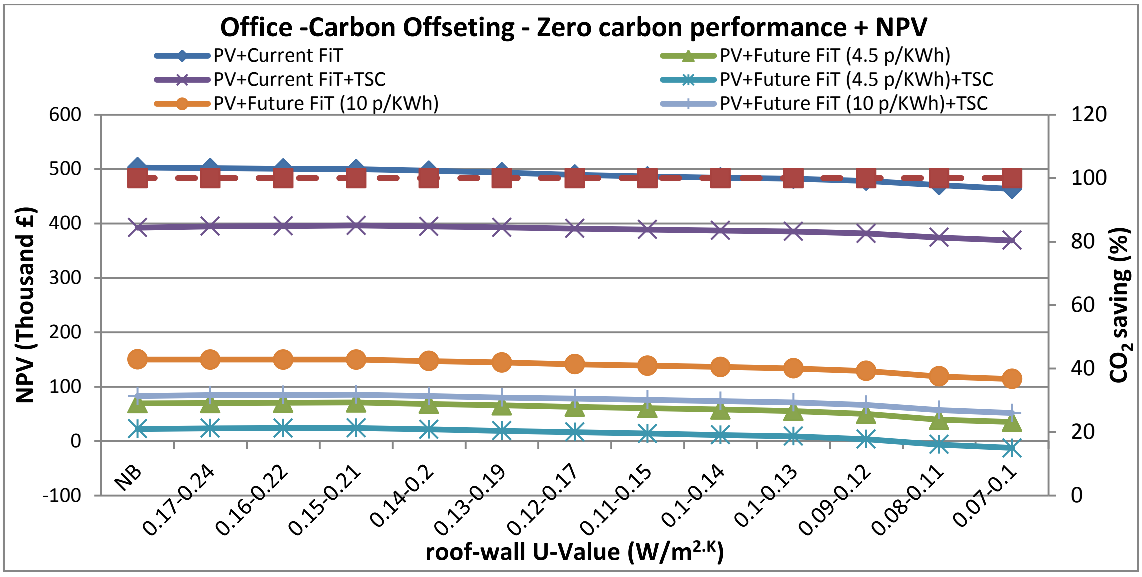


Figure 7.24 Carbon offsetting analysis, Office

The analysis is also demonstrating that adding to the thickness of insulation beyond 0.15-0.21 W/m^2.K roof and wall U-Values is not cost effective. This can be due to two main reasons:

- The capital cost of incremental increases in the level of insulation is not recovered by the associated operational energy savings
- Application of the low and zero carbon technologies can achieve the required carbon reduction targets in a more cost effective way.

The 'Total Energy Assessment Methodology' Tool in the next Chapter will be used to determine the embodied to operational carbon proportion when achieving zero carbon performance in non domestic buildings (Section 8.7).

CHAPTER 8: Total Energy Assessment Methodology (TEAM) Tool

To consolidate the results, an Excel-based assessment tool has been developed which enables designers and manufacturers to determine the most cost effective ways of achieving zero carbon non-domestic buildings using different design scenarios and service lives at the early design stages. A total carbon analysis has also been carried out to quantify the ratio of embodied to operational CO_2 for different scenarios and when achieving a zero carbon performance.

7.1 General description

The 'Total Energy Assessment Methodology' tool is an Excel-based calculator to determine the most cost effective way of achieving zero carbon buildings (using the total carbon approach). At present, it is designed for industrial warehouses and retail sheds but can be developed further to include other types of buildings.

The methodological framework for the tool consists 5 main modules including:

a) Operational carbon evaluation module (database for dynamic thermal simulation of building energy consumption)
b) Environmental evaluation module (embodied CO_2 database for materials and technologies)
c) Economic evaluation module (materials and technologies price database)
d) User Interface module (data input)
e) Results module (numerical and graphical output)

7.2 Operational carbon evaluation module

IES dynamic thermal simulation software has been used to create a heating and lighting demand database for the buildings investigated (Figure 8.1). These are used to compare different building specifications, service systems and control regimes. The lighting analysis associated with improving the liner reflectivity has been validated with Relux Pro software and real monitored data. The occupancy profiles, based on the National Calculation Methodology (NCM), the UK tool for assessment of carbon compliance in the Building Regulations, have been used for all simulations.

Building type	Building size m2	Lux	Reflectivity	Climate	Rooflight area %	Lighting load MWh	Lighting load KWh/m2
Warehouse	1000	300	standard	south	10	13.62	13.62
				North	10	15.15	15.15
			High ref	South	10	12.05	12.05
				North	10	13.32	13.32
Retail shed	1000	1000	standard	south	10	63.36	63.36
				North	10	66.39	66.39
			High ref	South	10	55.06	55.06
				North	10	57.35	57.35
Warehouse	4000	300	standard	south	10	58.05	14.5125
				North	10	63.56	15.89
			High ref	South	10	51.02	12.755
				North	10	55.86	13.965
Retail shed	4000	1000	standard	south	10	261.33	65.3325
				North	10	280.59	70.1475
			High ref	South	10	228.83	57.2075
				North	10	243.19	60.7975
Warehouse	10000	300	standard	south	10	91.55	9.155
				North	10	104.42	10.442
			High ref	South	10	80.52	8.052
				North	10	91.3	9.13
Retail shed	10000	1000	standard	south	10	466.51	46.651
				North	10	504.22	50.422
			High ref	South	10	398.94	39.894
				North	10	431.9	43.19

Figure 8.1 Screenshot of the lighting demand database for different operational scenarios

7.3 Environmental evaluation module

The environmental evaluation module consists of an embodied carbon database on the basis of measured quantities of materials and products EPDs (Figure 8.2). These measures are linked to different operational and envelope energy efficiency scenarios and will be automatically updated by selecting different options.

Embodied CO2

		U value	Density kg/m3	KgCO2/kg	Thickness mm	embodied CO2/m2 insulation		U value	Density kg/m3	KgCO2/kg	Thickness mm	embodied CO2/m2 insulation
PUR	Wall	0.35	30	3.48	65	6.786	Roof	0.25	30	3.48	95	9.918
		0.26	30	3.48	95	9.918		0.2	30	3.48	120	12.528
		0.2	30	3.48	120	12.528		0.18	30	3.48	135	14.094
		0.16	30	3.48	150	15.66		0.16	30	3.48	150	15.66
		0.13	30	3.48	190	19.836		0.13	30	3.48	190	19.836
		0.1	30	3.48	245	25.578		0.1	30	3.48	245	25.578

		U value	Density kg/m3	KgCO2/kg	Thickness mm	embodied CO2/m2 insulation		U value	Density kg/m3	KgCO2/kg	Thickness mm	embodied CO2/m2 insulation
Mineral wool	Wall	0.35	30	1.2	95	3.42	Roof	0.25	30	1.2	135	4.86
		0.26	30	1.2	135	4.86		0.2	30	1.2	165	5.94
		0.2	30	1.2	165	5.94		0.18	30	1.2	190	6.84
		0.16	30	1.2	215	7.74		0.16	30	1.2	215	7.74
		0.13	30	1.2	260	9.36		0.13	30	1.2	260	9.36
		0.1	30	1.2	340	12.24		0.1	30	1.2	340	12.24

	KgCO2/m2
TSC	30.75

	Cell type	KgCO2/m2	KgCO2
PV	Monocrystalline	242	60500
	Polycrystalline	208	52000
	Amorphous silicon	161.9	40475
	Thin film	67	16750

Figure 8.2 Screenshot of the embodied carbon database

7.4 Economic evaluation module

The price database includes the cost of the employed renewable technologies and fabric elements (depending on the required thicknesses associated with fabric U-value and insulation materials used) per square metre (Refer to Chapter 6 and Appendix B). The area of each building element is linked to the Geometry tab in the tool which takes into account the building size and rooflight area to calculate the area of building fabric.

7.5 User Interface (UI) module

The User Interface (UI) consists of menus through which users can select from various dropdown menus displayed on the screen (Figure 8.3). The variables introduced in the UI page of the tool include Building type, size, fabric U-value, rooflight percentage, liner type, air permeability level and insulation type. All scenarios can be assessed for UK south and north locations.

TATA STEEL

Building type	Warehouse
Size (m^2)	4000
Liner type	standard
Fabric	Spec c
Rooflight %	10
Air permeability $m^3/m^2/h$	3
Insulation type	PUR
Climate	south- London

TSC	
Panel type	Colorcoat Renew SC
Colour	Alaska Grey
Absorptivity (α)	0.70
Area m^2	350

PV	
Cell type	Monocrystalline
Efficiency %	16
Area m^2	250

Building element	Area m^2	U-value W/m^2K
Roof	3600	0.13
Wall	2190	0.13
Floor	4000	0.13
Rooflight	400	1
South wall	640	-

Figure 8.3 Screenshot of the User Interface (UI) module

7.5.1 Building type

Distribution warehouses and retail sheds have been selected to be investigated as example buildings in the tool. Industrial buildings are of interest to the sponsoring company and it was agreed that the analysis at this level be applied to these types of buildings in more detail.

7.5.2 Size

Three sizes of buildings, small, medium and large ($1000m^2$, $4000m^2$ and $10000m^2$ respectively) have been included in the tool.

7.5.3 Rooflight percentage

According to the Building Regulations Part L 2013, the recommended area for rooflights is 12% of the roof area. However, analysis carried out at Oxford Brookes University (Wang et al, 2013) is also demonstrating some benefits in lighting energy consumption savings beyond recommended figures up to 15% rooflight. According to the analysis, the percentage of rooflight affects both the amount of useful solar gains (winter solar gains) and the amount of heat loss through the window panes due to higher U-values of the rooflight panes compared to the solid roof panels. Whilst the heating demand is not increased significantly when enlarging the rooflight percentage (an increase of around 6% from the basecase), larger percentage of rooflights have proved to be more beneficial for saving artificial lighting energy (although the overheating risk is likely to rise for 15% rooflight area). The overall savings though, taking into account both lighting and heating load changes is quite close, therefore both options (12 and 15% rooflight areas) along with 10% rooflight are included in the tool.

7.5.4 Fabric U-value

Six fabric U-value scenarios have been introduced to the module including the Building Regulation 2013 Part L notional building specification as the base-case scenario. Backstop U-value specifications along with 4 incrementally improving U-value specifications down to 0.1 $W/m^2.K$ U-value are also available under the 'Fabric' heading (Table 8.1).

Table 8.1 Fabric U-value scenarios

Fabric U-values		
	Building element	**U-value W/m^{2}K**
Back-stop	**Roof**	0.25
	Wall	0.35
	Floor	0.25
	Rooflight	2.2
Notional Building	**Roof**	0.18
	Wall	0.26
	Floor	0.22
	Rooflight	1.6
Spec. a	**Roof**	0.2
	Wall	0.2
	Floor	0.2
	Rooflight	1.6
Spec. b	**Roof**	0.16
	Wall	0.16
	Floor	0.16
	Rooflight	1.2
Spec. c	**Roof**	0.13
	Wall	0.13
	Floor	0.13
	Rooflight	1
Spec. d	**Roof**	0.1
	Wall	0.1
	Floor	0.1
	Rooflight	1

7.5.5 Liner type

It has been shown that using high reflective liners can reduce the amount of energy required for lighting industrial sheds. The reflectivity these liners in comparison to standard ones is about 18% higher (assuming 70% for standard and 85% for reflective liners) and are expected to save between 6 to 12% of lighting energy (depending on the operational scenarios). Consequently, high reflective liners contribute a further 3% reduction in the overall CO_2 emissions (based on SBEM calculation under NCM conditions for Part L compliance)(TATA Steel, 2012).

7.5.6 Air permeability level

The air permeability figures are selected to comply with Building Regulations Part L 2013 standards relative to the selected building size (Table 8.2).

Table 8.2 Air permeability standards for industrial buildings

Air permeability $m^3/m^2/h$	Side lit or unlit (where HVAC specification is heating only)	Side lit or unlit (where HVAC specification include cooling)	Top lit
Gross internal area less than or equal to 250m^2	5	5	7
Gross internal area greater than 250m^2 and less than 3500m^2	3	3	7
Gross internal area greater than 3500m^2 and less than 10000m^2	3	3	5
Gross internal area greater than or equal to 10000m^2	3	3	3

7.5.7 Insulation type

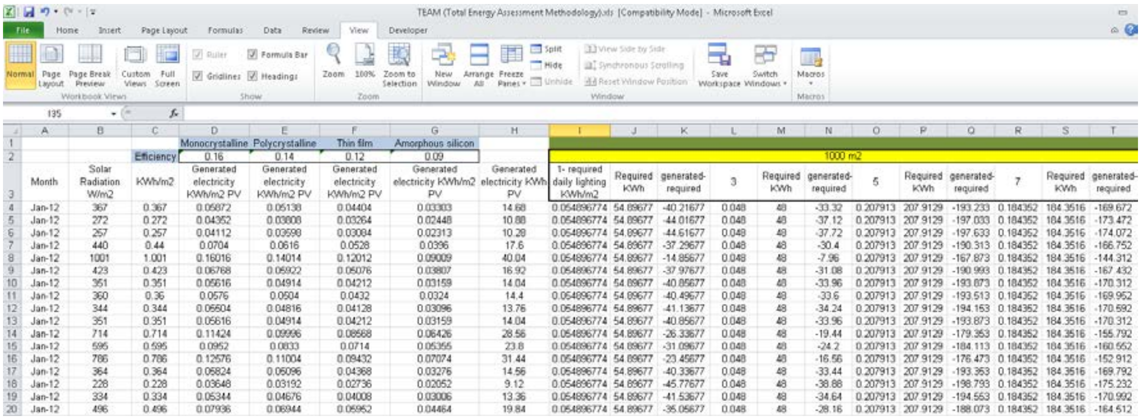
PUR and mineral wool, as two of the most commonly used insulation materials in composite and built-up systems, have been incorporated into the tool.

7.5.8 Renewable technologies

Transpired Solar Collectors (TSCs) and PV cells as dominant renewable technologies applicable to industrial buildings have been included in the tool. Users can change the colour of the steel sheets on TSCs which will affect the absorptivity of the material and consequently can either decrease or increase the amount of the heat generated by TSCs. The area of TSC on the wall is also adjustable but is limited to the area of the south wall and an error message box will pop up if the entered area is greater than the available area on the south wall.

Users can include both TSCs and PVs or include one or neither of them in the analysis. Under the PV section, the user can select the type of PV cells (monocrystalline, polycrystalline, thin films and amorphous silicon) and also the PV area on the roof. The efficiency of the PV panels will change with selecting different types of cells.

The majority of the energy generated by renewables is in the summer period when demand is at its lowest. Therefore an actual electricity demand analysis on a daily basis has been carried out to calculate the required generated electricity by PVs and consequently determine the accurate amount of electricity purchased from or exported to the grid (Figure 8.4).



	A	B	C	D	E	F	G	H
1				Monocrystalline	Polycrystalline	Thin film	Amorphous silicon	
2			Efficiency	0.16	0.14	0.12	0.09	
3	Month	Solar Radiation W/m2	KWh/m2	Generated electricity KWh/m2 PV	Generated electricity KWh/m2 PV	Generated electricity KWh/m2 PV	Generated electricity KWh/m2 PV	Generated electricity KWh PV
4	Jan-12	367	0.367	0.05872	0.05138	0.04404	0.03303	14.68
5	Jan-12	272	0.272	0.04352	0.03808	0.03264	0.02448	10.88
6	Jan-12	257	0.257	0.04112	0.03598	0.03084	0.02313	10.28
7	Jan-12	440	0.44	0.0704	0.0616	0.0528	0.0396	17.6
8	Jan-12	1001	1.001	0.16016	0.14014	0.12012	0.09009	40.04
9	Jan-12	423	0.423	0.06768	0.05922	0.05076	0.03807	16.92
10	Jan-12	351	0.351	0.05616	0.04914	0.04212	0.03159	14.04
11	Jan-12	360	0.36	0.0576	0.0504	0.0432	0.0324	14.4
12	Jan-12	344	0.344	0.05504	0.04816	0.04128	0.03096	13.76
13	Jan-12	351	0.351	0.05616	0.04914	0.04212	0.03159	14.04
14	Jan-12	714	0.714	0.11424	0.09996	0.08568	0.06426	28.56
15	Jan-12	595	0.595	0.0952	0.0833	0.0714	0.05355	23.8
16	Jan-12	786	0.786	0.12576	0.11004	0.09432	0.07074	31.44
17	Jan-12	364	0.364	0.05824	0.05096	0.04368	0.03276	14.56
18	Jan-12	228	0.228	0.03648	0.03192	0.02736	0.02052	9.12
19	Jan-12	334	0.334	0.05344	0.04676	0.04008	0.03006	13.36
20	Jan-12	496	0.496	0.07936	0.06944	0.05952	0.04464	19.84

	I	J	K	L	M	N	O	P	Q	R	S	T
2	1000 m2											
3	1- required daily lighting KWh/m2	Required KWh	generated-required	3	Required KWh	generated-required	5	Required KWh	generated-required	7	Required KWh	generated-required
4	0.054896774	54.89677	-40.21677	0.048	48	-33.32	0.207913	207.9129	-193.233	0.184352	184.3516	-169.672
5	0.054896774	54.89677	-44.01677	0.048	48	-37.12	0.207913	207.9129	-197.033	0.184352	184.3516	-173.472
6	0.054896774	54.89677	-44.61677	0.048	48	-37.72	0.207913	207.9129	-197.633	0.184352	184.3516	-174.072
7	0.054896774	54.89677	-37.29677	0.048	48	-30.4	0.207913	207.9129	-190.313	0.184352	184.3516	-166.752
8	0.054896774	54.89677	-14.85677	0.048	48	-7.96	0.207913	207.9129	-167.873	0.184352	184.3516	-144.312
9	0.054896774	54.89677	-37.97677	0.048	48	-31.08	0.207913	207.9129	-190.993	0.184352	184.3516	-167.432
10	0.054896774	54.89677	-40.85677	0.048	48	-33.96	0.207913	207.9129	-193.873	0.184352	184.3516	-170.312
11	0.054896774	54.89677	-40.49677	0.048	48	-33.6	0.207913	207.9129	-193.513	0.184352	184.3516	-169.952
12	0.054896774	54.89677	-41.13677	0.048	48	-34.24	0.207913	207.9129	-194.153	0.184352	184.3516	-170.592
13	0.054896774	54.89677	-40.85677	0.048	48	-33.96	0.207913	207.9129	-193.873	0.184352	184.3516	-170.312
14	0.054896774	54.89677	-26.33677	0.048	48	-19.44	0.207913	207.9129	-179.353	0.184352	184.3516	-155.792
15	0.054896774	54.89677	-31.09677	0.048	48	-24.2	0.207913	207.9129	-184.113	0.184352	184.3516	-160.552
16	0.054896774	54.89677	-23.45677	0.048	48	-16.56	0.207913	207.9129	-176.473	0.184352	184.3516	-152.912
17	0.054896774	54.89677	-40.33677	0.048	48	-33.44	0.207913	207.9129	-193.353	0.184352	184.3516	-169.792
18	0.054896774	54.89677	-45.77677	0.048	48	-38.88	0.207913	207.9129	-198.793	0.184352	184.3516	-175.232
19	0.054896774	54.89677	-41.53677	0.048	48	-34.64	0.207913	207.9129	-194.553	0.184352	184.3516	-170.992
20	0.054896774	54.89677	-35.05677	0.048	48	-28.16	0.207913	207.9129	-188.073	0.184352	184.3516	-164.512

Figure 8.4 Screenshot of the PV daily calculations

7.6 Results module

The Results module will give an indication of financial (NPV of energy savings) and environmental benefits of the products and technologies over their service life. This will determine the scenarios and energy saving packages in which a net carbon or cost benefit/disbenefit is achieved. The methodological approach takes into account the use of selected carbon reduction technologies that will satisfy a range of criteria such as environmental, cost, manufacturing limitations and resource constraints (Figure 8.5).

The base case building is introduced as the 2013 Building Regulations part L Notional Building (Table 8.3).

Table 8.3 Notional Building fabric U-value specifications

	U-Value (W/m^2.K)		
Element	**Side lit or unlit (where HVAC specification is heating only)**	**Side lit or unlit (where HVAC specification includes cooling)**	**Toplit**
Roof	0.18	0.18	0.18
Wall	0.26	0.26	0.26
Floor	0.22	0.22	0.22
Windows	1.6	1.6	1.6

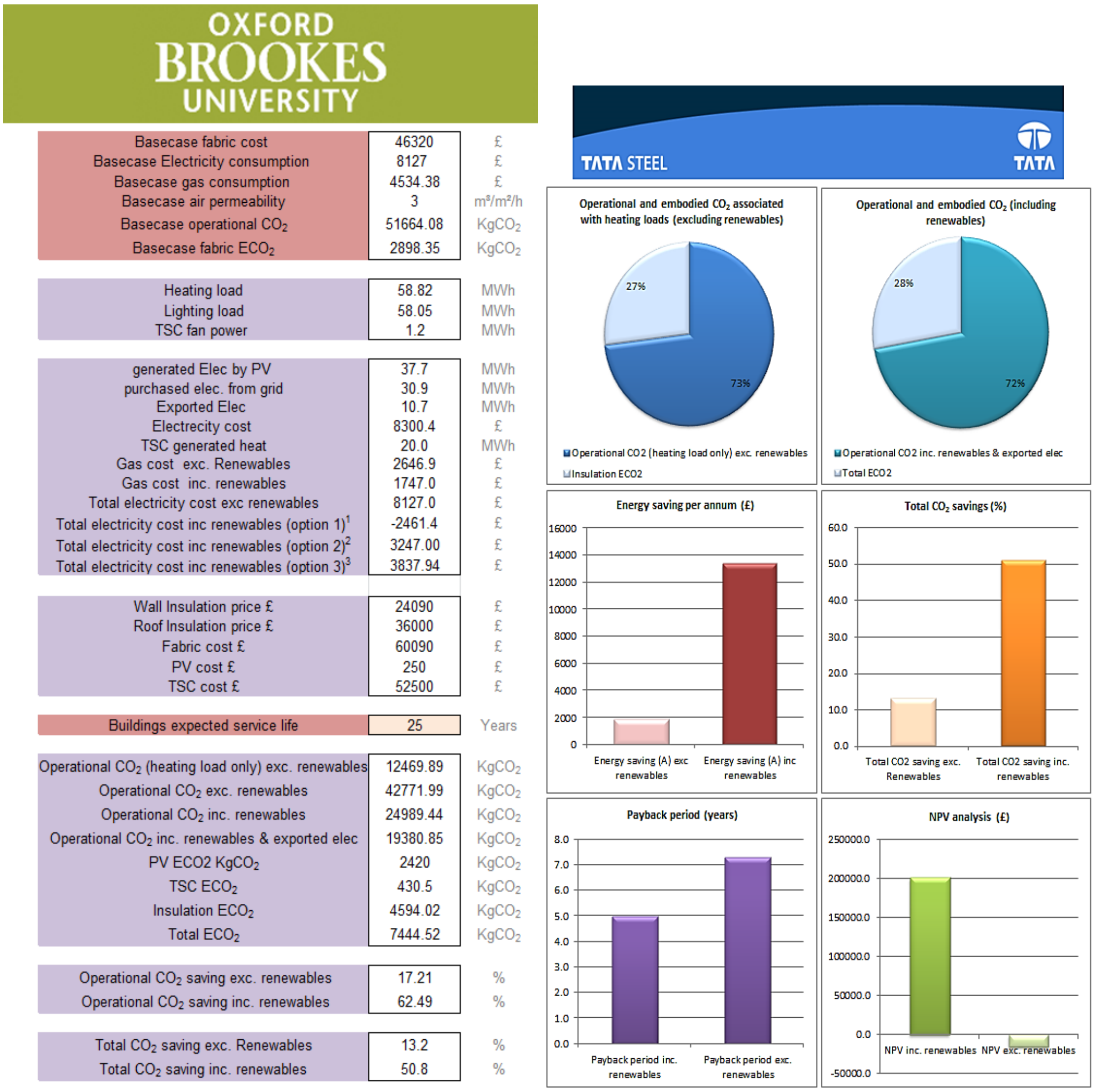


Figure 8.5 Screenshot of the Results module

7.7 Total carbon analyses in relation to zero carbon performance

Total carbon analyses in relation to different levels of 'fabric energy efficiency only' (Tabel 8.3), and a 'zero carbon building performance including renewable technologies'

(Table 8.4) have been carried out using the developed calculation tool. The shift in the ratio of embodied to operational CO_2 associated with each scenario is investigated.

Table 8.4 Embodied and operational carbon proportions in relation to different building fabric only scenarios

		%		%	
		heating only operational CO_2	**embodied CO_2**	**Total operational CO_2**	**embodied CO_2**
Building fabric only	**Backstop**	91	9	96	4
	Notional Building	84	16	93	7
	Spec. a	82	18	92	8
	Spec. b	73	27	90	10
	Spec. c	61	39	87	13
	Spec. d	48	52	83	17

According to Table 8.4, improving the building fabric from backstop to 'Specification d' U-values demonstrates an incremental shift in embodied to operational CO_2 proportion. Beyond 'Specification C' embodied CO_2 exceeds the operational CO_2 and a net carbon disbenefit occurs (more insulation increases embodied CO_2 with a decreasing effect on U-value).

Table 8.5 Embodied and operational carbon proportions in relation to different scenarios in order to achieve zero carbon performance

		%	
		Total operational CO_2	**Embodied CO_2**
Building fabric + renewables	**Backstop**	74	26
	Notional Building	68	32
	Spec. a	67	33
	Spec. b	62	38
	Spec. c	55	45
	Spec. d	50	50

Table 8.5, demonstrates that in order to achieve a zero carbon performance, using building fabric energy efficiency and on-site renewable technologies, embodied CO_2 investments can account for 25 to 50% of the total carbon emissions. 100m^2 TSC and a range of PV area between 135 to 170m^2 depending on building fabric specifications have been used for the analyses.

It also agrees with the result of analyses presented in the previous Chapters supporting the case for including embodied CO_2 in all carbon reduction strategies and potentially in the Building Regulations.

CHAPTER 9: Conclusions and Recommendations for further research

This Chapter presents the conclusions, contribution to knowledge and recommendations for further research with reference to the aim and objectives presented in Chapter 1.

8.1 Conclusions

As it has been discussed in Chapter 1, the aim of the research was to:

'Establish an assessment methodology for appraising the commercial and carbon advantages of new low and zero carbon building technologies'.

An assessment methodology therefore has been developed, the detail of which is presented in Chapter 4. It has addressed the use of combined operational and embodied carbon analyses as means of providing more representative assessments of life cycle carbon burdens and cost appraisals for low and zero carbon technologies. The analyses have demonstrated the importance of combining operational and embodied carbon in evaluating the effectiveness of carbon reduction strategies and requirements to shift away from 'operational carbon only' methods (refer to Chapter 2).

Whilst energy reduction strategies have so far focused only on operational energy (which historically has accounted for a far greater proportion of total building related CO_2 emissions than embodied carbon), the analyses demonstrated that such approaches may not be properly representative. As operational energy reduces, the ratio of it to embodied carbon becomes relatively evenly balanced so both must be considered (refer to Chapters 5 and 7). Discounting embodied carbon means that results may only partially reflect reality and optimisation processes are therefore at risk of being unrepresentative.

Already many building related organizations require embodied carbon data as part of tendering processes (often in the form of Environmental product declarations (EPDs)), and in the future it is anticipated that such requirements will become increasingly commonplace, and may potentially feature in legislation.

The objectives in support of the aim were to:

1. Identify and review new product development demands relating to low and zero carbon building technologies and the economic cases on which they are based.

The development and availability of effective new low carbon building technologies is strategically important toward achieving carbon reduction targets, but commercially is hindered by issues of predicting future market demands. Delivering new products to market however requires significant investment and it is essential that the management and timing of research and development, and subsequent commercialisation is correct.

The findings of the research support the case for development of novel insulation materials as conventional solutions such as PUR and mineral wool cannot be justified in relation to low U-values and/or relatively short service lives. This is due to the physical thicknesses that would be required and the associated engineering difficulties. Also, crucial to this research, increase in thickness results in high embodied CO_2. High performance insulation materials such as vacuum insulation, that provide low U-values relative to their embodied carbon, perform significantly better in reducing overall CO_2 emissions than conventional materials over a typical service life. At present however, whilst there is a good 'technology push', there is limited 'market pull'- commercialisation may only occur at large scale if regulatory requirements are in place that demand improved performance.

A prime example of novel insulation of the type that might reduce embodied carbon is Vacuum Insulation Panels (VIPs). VIPs can achieve low, or extremely low, U-values (to 0.03 $W/m^2.K$) coupled with low embodied CO_2. Emerging retrofit applications include thermal upgrading of facades and floors where the physical thinness of the panels is highly advantageous, limiting the amount by which the cross-sectional size of building elements is increased.

It is possible that other novel insulation materials may deliver similar levels of high performance, however few such materials have reached the same level of technical development as vacuum insulation. The results associated with hemp are based on cradle-to-gate life cycle analysis (refer to Chapter 5), but would be significantly different if appraised using results with cradle-to-grave approach.

2. Identify optimal approaches to:

a. Assessing the relative financial competitiveness of comparator new and existing products based on 'first' and 'life cycle' cost (using appropriate future value discounting procedures).

The financial competitiveness of conventional and novel low and zero carbon building technologies has been assessed and analysed using appropriate future value discounting procedures as presented in Chapter 4.

According to the analyses presented in Chapters 6 and 7, there are key points beyond which, and depending on factors such as products, building types and operational scenarios, additional cost of adding to the thickness of insulation materials or application of on-site energy generating technologies cannot be recovered by the associated operational energy savings. A net cost disbenefit occurs consequently.

Also if energy generating technologies such as TSCs are to be justified as a cost effective solution for low or zero carbon buildings, it appears essential that there should be a considerable price reduction from 150 to 50 £/m^2. A shift towards the next generation of TSCs is required to enable them to compete with rival technologies, particularly PV (refer to Chapter 6).

Of the technologies investigated PVs are the most cost effective way of achieving zero carbon buildings (refer to Chapter 7). The analyses demonstrate considerable financial benefit from 'Feed in Tariffs' recovering the capital cost of installing PVs easily.

b. Quantifying relative carbon efficiencies of new products for low and zero carbon buildings based on computer modelling and best practice modelling assumptions. This identifies 'death points' beyond which existing products become obsolete as new products present definitive advantages on the basis of carbon

Whilst there is a considerable body of work in the literature supporting the significance of adopting a combined embodied and operational carbon approach, none of the investigated studies identified how the inclusion of embodied CO_2 in carbon reduction equations can suggest 'death points' for conventional building technologies and relative 'birth points' for novel products.

The analyses presented however, demonstrate how such points can be determined (for various operational scenarios and building types) by quantified methodological approaches that aggregate operational and embodied carbon. This approach is useful for such things as determining the maximum levels of insulation that can be incorporated into buildings or required by standards, or for example, setting limits to the amount by which current approaches to energy thrift can be escalated using specific products.

c. *Determining the physical limitations of comparator products such that financial and carbon comparisons are considered only where there is genuine product competition, and the limits of technologies are fully recognised.*

As has been discussed in Chapter 5, PUR foam is limited to 170-200mm thickness as it relies on a reaction between its constituent chemicals to cause the formation of cells and expansion (foaming) of the material. Beyond around 200mm this reaction is slow and becomes difficult to control. It appears that 170-200mm with U-value of 0.147 to 0.125 $W/m^2.K$ are the most common thicknesses in use.

Mineral wool can be produced to any thickness (if necessary in multiple layers) but where low U-values are required the necessary dimensions can become difficult to accommodate within construction systems (the support systems in built-up cladding becomes too large and problematic). The transportation and handling of deep insulation systems can also be problematic. On these grounds very thick mineral wool assemblies are usually discounted although the maximum thickness that is acceptable is more difficult to identify precisely.

3. Apply the methodology to a series of selected case studies of novel low and zero carbon building technologies and identify the threshold where these technologies will present financial advantage (in relation to energy costs), or carbon advantage (in relation to meeting tightening regulations for energy thrift).

The findings arising from application of the methodology includes ‘methodological’ and ‘specific to case study’ findings.

The key ‘methodological’ findings arising from the analyses (as presented in Chapters 5 to 7) include:

- There is compelling evidence that a combined embodied and operational CO_2 approach should logically be the basis of all strategic decision making as the relative balance of these two components is sufficiently close that neither can be ignored. Designs made only on the basis of operational carbon have been quantified as unrepresentative on a life cycle basis. Given the compelling evidence, it is recommended that both operational and embodied carbon must be considered in the future assessment methods and potentially in regulations.

- Analyses demonstrate that there are key points beyond which, and depending on factors such as material and building types, additional embodied carbon investments in low and zero carbon technologies exceed operational carbon savings. This creates net carbon disbenefits.

Findings arising from the application of the methodology to ‘specific case studies’ include:

- Highly insulated envelopes, significantly exceeding current Building Regulation requirements, appear difficult to justify due to the carbon and cost disbenefits.

These disbenefits due to the additional insulation materials are difficult to be recovered from operational carbon savings (refer to Chapter 7).

- The optimum insulation level on grounds of carbon efficiency is contingent on the building type and size, operational patterns and insulation type. Financially however, focus on reducing all regulated energies rather than simple conservation of heat is required in order to identify the most cost effective approaches to carbon reduction (refer to Chapter 7).

- If novel insulation materials can be developed with lower embodied energies (for given thermal resistances) than those materials currently in common usage, the optimal insulation values will increase.

- Thin high performance insulation materials also offer advantages in terms of optimising rental values on the basis that the adjusted 'net to gross' floor areas are significantly altered such that a greater floor area is made available (refer to Chapter 6).

- For non-domestic buildings, a maximum of 10% CO_2 reduction can be achieved using 'fabric thermal efficiency' (only) when including the regulated energy consumption (lighting and hot water requirements) (refer to Chapter 5).

- As discussed in Chapter 7, the majority of the heat generated by TSCs occurs during warm periods (summer) when heating demand is low. The operational CO_2 savings associated with the 'actual' delivered heat therefore cannot recover the high capital costs of TSCs.

4. Develop an Excel-based assessment tool based on the proposed methodology.

The 'Total Energy Assessment Methodology' as an Excel-based tool has been developed to consolidate the results associated with the application of the methodology.

It was designed to determine the most cost effective way of achieving zero carbon buildings (on grounds of total carbon approach) using fabric energy efficiency and on-site low and zero carbon technologies.

Such a tool can be used to investigate other existing and/or novel low and zero carbon technologies on grounds of their carbon efficiency and cost effectiveness. As the background heating and lighting databases are based on dynamic thermal simulations, the tool offers a high level of accuracy and therefore can be used for real case assessments.

It allows cost and carbon analyses to be performed (similar to those of Chapters 5 to 7), for retrofitting and new build projects.

8.2 Contribution to knowledge

The main contribution to knowledge in this study is the developed assessment methodology based on a total carbon analysis taking account of all relevant carbon emissions from extraction of raw materials to the manufacturing energy consumption and in use phase carbon. The methodology provides a 'total carbon analyses graph' suggesting deathpoints, for conventional low and zero carbon building technologies, beyond which the associated embodied carbon burden outweighs the potential operational carbon savings. This for the first time introduces the concept of sensible maximum thickness for insulation materials suggesting the likely need for development of more carbon efficient novel products to replace conventional products available in the market.

The developed methodology enables manufacturers and suppliers to quantify the true carbon saving potentials of their products.

8.3 Limitations and recommendations for further research

8.3.1 Scale of the study

The analyses carried out in Chapter 7 were associated with non-domestic buildings due to the high number of simulations and the three year time limit of the study. Similar analyses can be applied to domestic buildings and also in relation to more operational scenarios.

8.3.2 System boundaries

Cradle to gate approaches have been adopted for this research due to the uncertainty of data associated with distances to the site and end of life scenarios. For further research, the results from this study can be incorporated into a cradle to grave analysis (assuming all variables are known) which would further improve accuracy of the assessments.

The inclusion of end of life stages, which may include the burdens of disposal and benefits of recycling or reuse, requires important methodological choices. It is vital that the pros and cons of each method for recycling are well understood so that an informed choice can be made.

8.3.3 Total Energy Assessment Methodology

The 'Total Energy Assessment Methodology' tool was developed in relation to industrial buildings and certain building specifications and operational scenarios. More options (such as different occupancy profiles, fabric specifications, temperature set-points etc) could appropriately be incorporated.

8.3.4 TSCs

These performance issues suggest a major agenda for future research as the systems in their current form whilst showing carbon benefits fail to demonstrate cost benefit using this form of analysis. Systems appear to need either long term heat storage capacity or performance enhancement such that they provide for a greater proportion of the annual heating demands.

Long term heat storage capacity would make it possible to reuse the generated heat in cooler seasons when the output of TSCs is limited. Currently however, there are no cost effective heat storage systems available. Coupling TSCs with technologies such as air source heat pumps is technically possible to provide hot water in the summer but capital costs are considerable.

Phase Change Materials (PCM) have been investigated in relation to TSC heat storage (because of their high thermal storage capacity coupled with moderate temperature variations) but reliable systems have not thus far been developed.

Ideas to enhance the performance of TSCs can also be investigated to provide limited amounts of high temperature air as opposed to the current systems that provide large volumes of low temperature air.

8.3.5 Consistent embodied CO_2 database

Finding accurate and reliable data for embodied carbon analyses, especially concerning unusual materials (such as fumed silica) or products such as PVs (due to the various manufacturers and cell types) and TSCs is difficult. Lack of consistent information through the supply chain is the main limitation.

Where accurate and reliable data is not available for calculating the embodied carbon of products, it has to be estimated based on ‘process energy calculation techniques’ through a step-by-step product manufacturing energy breakdown in addition to the embodied CO_2 of materials on a weight basis (again extracted from the ICE database). Further analyses and research would increase the range of products and materials that could be assessed.

8.3.6 Cost databases

The costs of building technologies and services are usually estimated by suppliers for each project taking into account the size and type of the building. The same or similar products will be available for different prices. The uncertainty of available cost data complicates analyses so assumed average figures have been used in this research, but analyses based on actual supply costs are also feasible.

8.4 Future significance

The application of the methodology identified how the inclusion of embodied CO_2 in carbon reduction equations and taking a total carbon approach can lead to points beyond which carbon disbenefit occurs for conventional building technologies. This can have the following implications for future research concerning policy making, and its global principles and practice:

- Discounting embodied carbon from carbon reduction equations in future is misleading and does not provide a true assessment of reductions. A shift away from 'operational carbon only' methods is therefore required.

- The inclusion of embodied carbon can set limits to the potential carbon saving through building fabric energy efficiency introduced in future Building Regulations

- If embodied carbon is included in the Building Regulation in future, building material manufacturers and suppliers should be able to supply materials that comply with true carbon burden requirements.

The study demonstrated the absolute significance of combining operational and embodied carbon analyses in demonstrating the effectiveness of carbon reduction strategies. The approach must be an integral part of any holistic appraisal of low and zero carbon performance. Recognition of this represents an important and necessary paradigm shift.

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Appendix A

Process energy calculation technique applied to VIPs

Process energy calculation technique applied to VIPs

- **Pump energy associated with evacuation (Pump EE)**

Assume vacuum pump energy is: w=p×V×k/(k-1) [(p2/p1)^((k-1)/k)-1]
= 1.0135 × 0.144 × (1.4 ÷ (1.4 - 1)) × ((1.0130.05 ((1.4 - 1) ÷ 1.4) - 1) = 317740 J
Where:
W = Energy,
p = pressure,
V = Volume of vacuum vessel,
k = Adiabatic constant of air,
p2/p1 = Pressure ratio (atmospheric to vacuum)

Assuming normal levels of mechanical inefficiency (67% volumetric inefficiency of pump chamber and 59% electric motor efficiency) the above figure changes to 803795J Commonly two VIP panels are evacuated at the same time and the total typical weight is 4.32kg (based on 2 × 1000 × 600 × 20mm panels). Evacuation energy is therefore: (803795 ÷ 4.32) / 106 = 0.186 MJ/kg

- **Drying energy**

Energy required to dry panels at 150 °C = mass × specific heat capacity × temperature difference for both air and panels = 0.108 MJ/kg + losses
Assume 20% losses total figure becomes 0.130 MJ/kg

- **Total evacuation plus drying energy**

Pump energy associated with evacuation plus drying energy = 0.316 MJ/kg
This equates to 0.0475 $kgCO_2/kg$ (based on 0.542 $kgCO_2/KWh$ conversion factor).
Embodied energy of fumed silica core = 0.9438 $kgCO_2/kg$

- **Embodied energy of barrier material (Barrier EE)**

Again assume 1000x600x20mm panels
Fumed silica volume = 1 × 0.6 × 0.02 = 0.012 m^3

Barrier's area = $2 \times 1 \times 0.6 + 0.02 \times 3.2 = 1.264\ m^2$

Assume barrier thickness of 60 micros, the volume of the barrier is $(1.264 \times 60) \div 106 = 0.00007584$ m3

Ratio of percentage of barrier volume to panel volume: $0.00007584 \div 0.012 = 0.63\%$

Notional embodied CO_2 of barrier material: 1.57 $kgCO_2/kg$

- **Total CO_2 for panel excluding barrier**

Evacuation plus drying energy + EE of core = 0.0475 + 0.9438 = 0.9913 $kgCO_2/kg$

- **Total embodied energy of panel including barrier**

Assume 1 kg of fumed silica requires 0.0063 kg barrier

Total embodied energy = $0.9913 + (0.0063 \times 1.57) = 1.001$ $kgCO_2/kg$

Appendix B

Appendix B includes full background calculation tables associated with each 'technology package' (A to M) investigated in Chapter 7. The 2010 Notional Building fabric has been assumed to be the basecase scenario.

The analyses have been carried out for office buildings with and without taking into account the rental loss/gain associated with the thickness of the cladding system. Two regions in London (City and West-End) have been used for rental value analyses comparisons.

Mineral wool and PUR as two mainstream conventional insulation materials have been used for the analyses in all cases.

Table B. 1 Distribution warehouse – PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool)

Storage and Distribution Warehouse-London

PV (current FiT)+Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25%	94	57.29	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9898.549	43.70	35.00	195010.00	17257.06	212267.06	17.46	0.30	0.80	18.56	8.70	3438.85	80775.10	63518.04	5
50%	187	57.29	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6905.8697	43.70	35.00	195010.00	34514.12	229524.12	15.21	0.60	0.80	16.62	18.26	6431.53	151070.08	116555.97	5.5
75%	281	57.29	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	4186.7281	43.70	35.00	195010.00	51771.18	246781.18	13.05	0.91	0.80	14.75	27.43	9150.67	214939.95	163168.77	5.75
100%	375	57.29	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1580.9652	43.70	35.00	195010.00	69028.24	264038.24	10.88	1.21	0.80	12.89	36.61	11756.43	276146.66	207118.42	6
Carbon Offset	1025	57.29	0	4.96	135265.253	8452.17178	101804.5	-23011.4	-15541.36	43.70	35.00	195010.00	222789.83	417799.83	-4.12	3.31	0.80	-0.02	100.08	28878.76	678332.63	455542.80	8

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	55.4	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9671.749	44.30	35.70	198280.00	17257.06	215537.06	17.09	0.30	0.88	18.27	10.13	3665.65	86102.40	65575.34	5.75
50	187	55.4	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6679.0697	44.30	35.70	198280.00	34514.12	232794.12	14.84	0.60	0.88	16.33	19.68	6658.33	156397.39	118613.27	5.75
75	281	55.4	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3959.9281	44.30	35.70	198280.00	51771.18	250051.18	12.68	0.91	0.88	14.46	28.86	9377.47	220267.25	165226.07	6
100	375	55.4	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1354.1652	44.30	35.70	198280.00	69028.24	267308.24	10.51	1.21	0.88	12.60	38.04	11983.23	281473.96	209175.72	6.15
Carbon Offset	1012	55.4	0	4.96	133549.693	8562.09068	100198.9	-22675	-15431.76	44.30	35.70	198280.00	219964.20	418244.20	-4.19	3.27	0.88	-0.05	100.24	28769.16	675758.27	452524.07	7.9

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	52.88	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9369.349	45.00	36.40	201780.00	17257.06	219037.06	16.59	0.30	0.95	17.85	12.22	3968.05	93205.47	69178.41	6.15
50	187	52.88	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6376.6697	45.00	36.40	201780.00	34514.12	236294.12	14.35	0.60	0.95	15.90	21.77	6960.73	163500.45	122216.33	6
75	281	52.88	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3657.5281	45.00	36.40	201780.00	51771.18	253551.18	12.18	0.91	0.95	14.04	30.95	9679.87	227370.31	168829.14	6.15
100	375	52.88	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1051.7652	45.00	36.40	201780.00	69028.24	270808.24	10.01	1.21	0.95	12.17	40.13	12285.63	288577.03	212778.79	6.3
Carbon Offset	988	52.88	0	4.96	130382.507	8767.56876	97237.17	-22053.7	-15112.88	45.00	36.40	201780.00	214747.66	416527.66	-4.13	3.19	0.95	0.00	99.98	28450.28	668267.97	446750.31	7.95

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	50.84	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9124.549	48.60	37.00	211680.00	17257.06	228937.06	16.19	0.30	1.12	17.62	13.35	4212.85	98955.57	65028.51	8.25
50	187	50.84	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6131.8697	48.60	37.00	211680.00	34514.12	246194.12	13.95	0.60	1.12	15.67	22.90	7205.53	169250.55	118066.44	7.2
75	281	50.84	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3412.7281	48.60	37.00	211680.00	51771.18	263451.18	11.78	0.91	1.12	13.81	32.08	9924.67	233120.42	164679.24	7.05
100	375	50.84	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	806.96519	48.60	37.00	211680.00	69028.24	280708.24	9.61	1.21	1.12	11.94	41.26	12530.43	294327.13	208628.89	7
Carbon Offset	975	50.84	0	4.96	128666.948	8880.38437	95700.43	-21720	-15023.97	48.60	37.00	211680.00	211922.03	423602.03	-4.25	3.15	1.12	0.02	99.90	28361.37	666179.71	437587.68	8.25

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	48.8	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8879.749	50.40	38.40	219600.00	17257.06	236857.06	15.79	0.30	1.2	17.30	14.92	4457.65	104705.67	62858.61	9.65
50	187	48.8	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5887.0697	50.40	38.40	219600.00	34514.12	254114.12	13.55	0.60	1.2	15.35	24.47	7450.33	175000.66	115896.54	8.15
75	281	48.8	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3167.9281	50.40	38.40	219600.00	51771.18	271371.18	11.38	0.91	1.2	13.49	33.65	10169.47	238870.52	162509.34	7.7
100	375	48.8	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	562.16519	50.40	38.40	219600.00	69028.24	288628.24	9.21	1.21	1.2	11.62	42.83	12775.23	300077.23	206458.99	7.5
Carbon Offset	963	48.8	0	4.96	127083.354	8985.40957	94155.86	-21406.1	-14954.94	50.40	38.40	219600.00	209313.76	428913.76	-4.36	3.11	1.2	-0.05	100.24	28292.34	664558.26	430654.50	8.45

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	47.4	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8711.749	52.20	39.00	225360.00	17257.06	242617.06	15.52	0.30	1.3	17.12	15.78	4625.65	108651.82	61044.76	10.55
50	187	47.4	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5719.0697	52.20	39.00	225360.00	34514.12	259874.12	13.28	0.60	1.3	15.18	25.33	7618.33	178946.81	114082.69	8.75
75	281	47.4	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2999.9281	52.20	39.00	225360.00	51771.18	277131.18	11.11	0.91	1.3	13.31	34.51	10337.47	242816.67	160695.49	8.15
100	375	47.4	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	394.16519	52.20	39.00	225360.00	69028.24	294388.24	8.94	1.21	1.3	11.45	43.69	12943.23	304023.38	204645.14	7.85
Carbon Offset	950	47.4	0	4.96	125367.795	9100.43548	92555.33	-21069.3	-14786.06	52.20	39.00	225360.00	206488.13	431848.13	-4.33	3.07	1.3	0.03	99.83	28123.46	660591.36	423753.22	8.6

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	44	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8303.749	63.00	43.00	261000.00	17257.06	278257.06	14.85	0.30	1.84	17.00	16.40	5033.65	118235.32	34988.27	17.3
50	187	44	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5311.0697	63.00	43.00	261000.00	34514.12	295514.12	12.61	0.60	1.84	15.05	25.95	8026.33	188530.31	88026.19	13
75	281	44	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2591.9281	63.00	43.00	261000.00	51771.18	312771.18	10.44	0.91	1.84	13.19	35.13	10745.47	252400.17	134639.00	11.25
100	375	44	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	-13.83481	63.00	43.00	261000.00	69028.24	330028.24	8.27	1.21	1.84	11.32	44.31	13351.23	313606.88	178588.65	10.4
Carbon Offset	944	44	0	4.96	124575.998	9153.99913	91817.09	-20913.7	-15038.53	63.00	43.00	261000.00	205184.00	466184.00	-4.86	3.05	1.84	0.03	99.87	28375.93	666521.62	395347.62	9.8

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	43	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8183.749	66.60	44.70	273870.00	17257.06	291127.06	14.66	0.30	2	16.96	16.58	5153.65	121054.00	24936.94	19.5
50	187	43	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5191.0697	66.60	44.70	273870.00	34514.12	308384.12	12.41	0.60	2	15.02	26.13	8146.33	191348.99	77974.87	14.5
75	281	43	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2471.9281	66.60	44.70	273870.00	51771.18	325641.18	10.24	0.91	2	13.15	35.31	10865.47	255218.85	124587.67	12.45
100	375	43	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	-133.8348	66.60	44.70	273870.00	69028.24	342898.24	8.08	1.21	2	11.29	44.49	13471.23	316425.56	168537.32	11.3
Carbon Offset	943	43	0	4.96	124575.998	9153.99913	91817.09	-20913.7	-15158.53	66.60	44.70	273870.00	205184.00	479054.00	-5.05	3.04	2	-0.01	100.06	28495.93	669340.30	385296.30	10.25

Table B. 2 Distribution warehouse – PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 $W/m^2.K$ (mineral wool)

Storage and Distribution Warehouse-London
PV (Future FiT)+Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0.00	57.29	13.97	4.96	0.00	0.00	0.00	5867.40	13337.40	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0.00
25%	94.00	57.29	10.48	4.96	12404.81	30259.93	203.18	4227.25	11697.25	43.70	35.00	195010.00	17257.06	212267.06	17.46	0.30	0.80	18.56	8.70	1640.15	38525.52	21268.46	11.00
50%	187.00	57.29	6.99	4.96	24677.66	23563.46	6327.85	3014.13	10484.13	43.70	35.00	195010.00	34514.12	229524.12	15.21	0.60	0.80	16.62	18.26	2853.27	67020.39	32506.27	12.50
75%	281.00	57.29	3.49	4.96	37082.47	19750.37	14919.21	2093.69	9563.69	43.70	35.00	195010.00	51771.18	246781.18	13.05	0.91	0.80	14.75	27.43	3773.71	88640.67	36869.50	14.25
100% (1)	375.00	57.29	0.00	4.96	49487.29	17131.25	24705.64	1286.62	8756.62	43.70	35.00	195010.00	69028.24	264038.24	10.88	1.21	0.80	12.89	36.61	4580.78	107597.80	38569.57	15.70
100% (2)	375.00	57.29	0.00	4.96	49487.29	17131.25	24705.64	-72.19	7397.81	43.70	35.00	195010.00	69028.24	264038.24	10.88	1.21	0.80	12.89	36.61	5939.59	139514.87	70486.63	12.00
Carbon Offset	1025.00	57.29	0.00	4.96	135265.25	8452.17	101804.52	-3397.90	4072.10	43.70	35.00	195010.00	222789.83	417799.83	-4.12	3.31	0.80	-0.02	100.08	9265.30	217632.43	-5157.40	25.65
Carbon Offset	1025.00	57.29	0.00	4.96	135265.25	8452.17	101804.52	-8997.15	-1527.15	43.70	35.00	195010.00	222789.83	417799.83	-4.12	3.31	0.80	-0.02	100.08	14864.55	349153.07	126363.24	15.60

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	55.4	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	11470.45	44.30	35.70	198280.00	17257.06	215537.06	17.09	0.30	0.88	18.27	10.13	1866.95	43852.82	23325.76	11.25
50	187	55.4	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	10257.33	44.30	35.70	198280.00	34514.12	232794.12	14.84	0.60	0.88	16.33	19.68	3080.07	72347.69	34563.57	12.75
75	281	55.4	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	9336.887	44.30	35.70	198280.00	51771.18	250051.18	12.68	0.91	0.88	14.46	28.86	4000.51	93967.97	38926.80	14.25
100 (1)	375	55.4	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	8529.822	44.30	35.70	198280.00	69028.24	267308.24	10.51	1.21	0.88	12.60	38.04	4807.58	112925.10	40626.87	15.7
100 (2)	375	55.4	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	7171.012	44.30	35.70	198280.00	69028.24	267308.24	10.51	1.21	0.88	12.60	38.04	6166.39	144842.17	72543.93	12.1
Carbon Offset	1012	55.4	0	4.96	133549.6932	8562.09068	100198.881	-3310.257	3932.943	44.30	35.70	198280.00	219964.20	418244.20	-4.19	3.27	0.88	-0.05	100.24	9404.46	220901.10	-2333.10	25.3
Carbon Offset	1012	55.4	0	4.96	133549.6932	8562.09068	100198.881	-8821.195	-1578	44.30	35.70	198280.00	219964.20	418244.20	-4.19	3.27	0.88	-0.05	100.24	14915.40	350347.42	127113.22	15.6

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	52.88	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	11168.05	45.00	36.40	201780.00	17257.06	219037.06	16.59	0.30	0.96	17.86	12.17	2169.35	50955.89	26928.83	11.5
50	187	52.88	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	9954.93	45.00	36.40	201780.00	34514.12	236294.12	14.35	0.60	0.96	15.91	21.72	3382.47	79450.76	38166.64	12.65
75	281	52.88	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	9034.487	45.00	36.40	201780.00	51771.18	253551.18	12.18	0.91	0.96	14.05	30.90	4302.91	101071.04	42529.86	14
100 (1)	375	52.88	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	8227.422	45.00	36.40	201780.00	69028.24	270808.24	10.01	1.21	0.96	12.18	40.08	5109.98	120028.17	44229.94	15.5
100 (2)	375	52.88	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	6868.612	45.00	36.40	201780.00	69028.24	270808.24	10.01	1.21	0.96	12.18	40.08	6468.79	151945.24	76147.00	12.1
Carbon Offset	988	52.88	0	4.96	130382.5068	8767.56876	97237.1723	-3148.213	3792.587	45.00	36.40	201780.00	214747.66	416527.66	-4.13	3.19	0.95	0.00	99.98	9544.81	224197.92	2680.26	24.7
Carbon Offset	988	52.88	0	4.96	130382.5068	8767.56876	97237.1723	-8496.258	-1555.46	45.00	36.40	201780.00	214747.66	416527.66	-4.13	3.19	0.95	0.00	99.98	14892.86	349818.03	128300.37	15.5

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	50.84	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	10923.25	48.60	37.00	211680.00	17257.06	228937.06	16.19	0.30	1.12	17.62	13.35	2414.15	56705.99	22778.93	14.5
50	187	50.84	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	9710.13	48.60	37.00	211680.00	34514.12	246194.12	13.95	0.60	1.12	15.67	22.90	3627.27	85200.86	34016.74	14.75
75	281	50.84	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	8789.687	48.60	37.00	211680.00	51771.18	263451.18	11.78	0.91	1.12	13.81	32.08	4547.71	106821.14	38379.97	15.6
100 (1)	375	50.84	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	7982.622	48.60	37.00	211680.00	69028.24	280708.24	9.61	1.21	1.12	11.94	41.26	5354.78	125778.27	40080.04	16.75
100 (2)	375	50.84	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	6623.812	48.60	37.00	211680.00	69028.24	280708.24	9.61	1.21	1.12	11.94	41.26	6713.59	157695.34	71997.10	13.2
Carbon Offset	975	50.84	0	4.96	128666.9475	8880.38437	95700.4286	-3063.265	3632.735	48.60	37.00	211680.00	211922.03	423602.03	-4.25	3.15	1.12	0.02	99.90	9704.67	227952.69	-639.34	25
Carbon Offset	975	50.84	0	4.96	128666.9475	8880.38437	95700.4286	-8326.789	-1630.79	48.60	37.00	211680.00	211922.03	423602.03	-4.25	3.15	1.12	0.02	99.90	14968.19	351587.49	122995.46	15.9

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	48.8	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	10678.45	50.40	38.40	219600.00	17257.06	236857.06	15.79	0.30	1.2	17.30	14.92	2658.95	62456.09	20609.03	16.25
50	187	48.8	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	9465.33	50.40	38.40	219600.00	34514.12	254114.12	13.55	0.60	1.2	15.35	24.47	3872.07	90950.96	31846.84	16
75	281	48.8	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	8544.887	50.40	38.40	219600.00	51771.18	271371.18	11.38	0.91	1.2	13.49	33.65	4792.51	112571.24	36210.07	16.7
100 (1)	375	48.8	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	7737.822	50.40	38.40	219600.00	69028.24	288628.24	9.21	1.21	1.2	11.62	42.83	5599.58	131528.38	37910.14	17.5
100 (2)	375	48.8	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	6379.012	50.40	38.40	219600.00	69028.24	288628.24	9.21	1.21	1.2	11.62	42.83	6958.39	163445.44	69827.20	13.95
Carbon Offset	963	48.8	0	4.96	127083.3543	8985.40957	94155.8606	-2979.056	3472.144	50.40	38.40	219600.00	209313.76	428913.76	-4.36	3.11	1.2	-0.05	100.24	9865.26	231724.81	-2178.95	25.25
Carbon Offset	963	48.8	0	4.96	127083.3543	8985.40957	94155.8606	-8157.629	-1706.43	50.40	38.40	219600.00	209313.76	428913.76	-4.36	3.11	1.2	-0.05	100.24	15043.83	353364.19	119460.43	16.2

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	47.4	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	10510.45	52.20	39.00	225360.00	17257.06	242617.06	15.52	0.30	1.3	17.12	15.78	2826.95	66402.24	18795.18	17.7
50	187	47.4	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	9297.33	52.20	39.00	225360.00	34514.12	259874.12	13.28	0.60	1.3	15.18	25.33	4040.07	94897.11	30032.99	16.75
75	281	47.4	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	8376.887	52.20	39.00	225360.00	51771.18	277131.18	11.11	0.91	1.3	13.31	34.51	4960.51	116517.39	34396.22	17.25
100 (1)	375	47.4	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	7569.822	52.20	39.00	225360.00	69028.24	294388.24	8.94	1.21	1.3	11.45	43.69	5767.58	135474.52	36096.29	18
100 (2)	375	47.4	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	6211.012	52.20	39.00	225360.00	69028.24	294388.24	8.94	1.21	1.3	11.45	43.69	7126.39	167391.59	68013.35	14.5
Carbon Offset	950	47.4	0	4.96	125367.795	9100.43548	92555.3273	-2890.929	3392.271	52.20	39.00	225360.00	206488.13	431848.13	-4.33	3.07	1.3	0.03	99.83	9945.13	233600.93	-3237.21	25.4
Carbon Offset	950	47.4	0	4.96	125367.795	9100.43548	92555.3273	-7981.472	-1698.27	52.20	39.00	225360.00	206488.13	431848.13	-4.33	3.07	1.3	0.03	99.83	15035.67	353172.59	116334.45	16.45

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	44	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	10102.45	63.00	43.00	261000.00	17257.06	278257.06	14.85	0.30	1.84	17.00	16.40	3234.95	75985.75	-7261.31	27.5
50	187	44	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	8889.33	63.00	43.00	261000.00	34514.12	295514.12	12.61	0.60	1.84	15.05	25.95	4448.07	104480.61	3976.50	24
75	281	44	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	7968.887	63.00	43.00	261000.00	51771.18	312771.18	10.44	0.91	1.84	13.19	35.13	5368.51	126100.90	8339.72	23.25
100 (1)	375	44	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	7161.822	63.00	43.00	261000.00	69028.24	330028.24	8.27	1.21	1.84	11.32	44.31	6175.58	145058.03	10039.79	23.2
100 (2)	375	44	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	5803.012	63.00	43.00	261000.00	69028.24	330028.24	8.27	1.21	1.84	11.32	44.31	7534.39	176975.09	41956.86	18.75
Carbon Offset	944	44	0	4.96	124575.9984	9153.99913	91817.0943	-2850.209	3024.991	63.00	43.00	261000.00	205184.00	466184.00	-4.86	3.05	1.84	0.03	99.87	10312.41	242227.97	-28946.02	28.2
Carbon Offset	944	44	0	4.96	124575.9984	9153.99913	91817.0943	-7900.15	-2024.95	63.00	43.00	261000.00	205184.00	466184.00	-4.86	3.05	1.84	0.03	99.87	15362.35	360845.92	89671.92	18.5

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	195010.00	19.53	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	94	43	10.4775	4.96	12404.8134	30259.929	203.179386	4227.247	9982.447	66.60	44.70	273870.00	17257.06	291127.06	14.66	0.30	2	16.96	16.58	3354.95	78804.42	-17312.64	31
50	187	43	6.985	4.96	24677.6607	23563.4558	6327.8518	3014.1305	8769.33	66.60	44.70	273870.00	34514.12	308384.12	12.41	0.60	2	15.02	26.13	4568.07	107299.29	-6074.83	26.5
75	281	43	3.4925	4.96	37082.4741	19750.3654	14919.208	2093.6868	7848.887	66.60	44.70	273870.00	51771.18	325641.18	10.24	0.91	2	13.15	35.31	5488.51	128919.57	-1711.60	25.4
100 (1)	375	43	0	4.96	49487.2875	17131.2544	24705.6387	1286.6219	7041.822	66.60	44.70	273870.00	69028.24	342898.24	8.08	1.21	2	11.29	44.49	6295.58	147876.71	-11.53	25
100 (2)	375	43	0	4.96	49487.2875	17131.2544	24705.6387	-72.18825	5683.012	66.60	44.70	273870.00	69028.24	342898.24	8.08	1.21	2	11.29	44.49	7654.39	179793.77	31905.53	20.35
Carbon Offset	943	43	0	4.96	124575.9984	9153.99913	91817.0943	-2850.209	2904.991	66.60	44.70	273870.00	205184.00	479054.00	-5.05	3.04	2	-0.01	100.06	10432.41	245046.65	-38997.35	29.25
Carbon Offset	943	43	0	4.96	124575.9984	9153.99913	91817.0943	-7900.15	-2144.95	66.60	44.70	273870.00	205184.00	479054.00	-5.05	3.04	2	-0.01	100.06	15482.35	363664.59	79620.60	19.25

Table B. 3 Distribution warehouse – PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC

Storage and Distribution Warehouse-London
PV (current FiT)+Insulation+TSC

TSC + PV + FIT + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25%	275	94	42.97	10.4775	4.96	0.2864	12404.8134	30259.929	203.1794	2428.549	8300.437046	43.70	35.00	195010.00	41250.00	17257.06	253517.06	14.80	0.30	0.11	0.80	16.02	21.22	5036.96	118313.12	59806.06	12
50%	750	187	28.65	6.985	4.96	0.5728	24677.6607	23563.4558	6327.852	-564.13	3709.645681	43.70	35.00	195010.00	112500.00	34514.12	342024.12	9.90	0.60	0.31	0.80	11.61	42.88	9627.75	226146.12	79132.01	15.9
75%	1300	281	14.32	3.4925	4.96	0.8594	37082.4741	19750.3654	14919.21	-3283.27	-608.7239498	43.70	35.00	195010.00	195000.00	51771.18	441781.18	5.07	0.91	0.53	0.80	7.31	64.02	13946.12	327580.22	80809.04	18.55
75-100	1300	375	14.32	0	4.96	0.8594	49487.2875	17131.2544	24705.64	-5889.03	-3214.486809	43.70	35.00	195010.00	195000.00	69028.24	459038.24	2.91	1.21	0.53	0.80	5.45	73.20	16551.89	388786.93	124758.70	16.65
Carbon Offsetting	1300	643	14.32	0	4.96	0	84722.2362	12542.2086	53801.54	-12949.9	-10636.28442	43.70	35.00	195010.00	195000.00	139542.51	529552.51	-3.44	2.07	0.53	0.80	-0.03	100.14	23973.68	563117.38	228574.88	14.5

TSC + PV + FIT + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	250	94	41.5	10.4775	4.96	0.3158	12404.8134	30259.929	203.1794	2428.549	8136.385046	44.30	35.70	198280.00	37500.00	17257.06	253037.06	14.53	0.30	0.10	0.88	15.81	22.21	5201.01	122166.53	64139.48	11.5
50	700	187	27.7	6.985	4.96	0.5918	24677.6607	23563.4558	6327.852	-564.13	3603.625681	44.30	35.70	198280.00	105000.00	34514.12	337794.12	9.73	0.60	0.29	0.88	11.50	43.45	9733.77	228636.43	85852.31	15.25
75	1250	281	13.42	3.4925	4.96	0.8774	37082.4741	19750.3654	14919.21	-3283.27	-709.1639498	44.30	35.70	198280.00	187500.00	51771.18	437551.18	4.91	0.91	0.51	0.88	7.21	64.55	14046.56	329939.45	87398.28	18.1
75-100	1250	375	13.42	0	4.96	0.8774	49487.2875	17131.2544	24705.64	-5889.03	-3314.926809	44.30	35.70	198280.00	187500.00	69028.24	454808.24	2.74	1.21	0.51	0.88	5.34	73.73	16652.33	391146.16	131347.93	16.25
Carbon Offsetting	1250	635	13.42	0	4.96	0.8774	83798.4735	12665.7142	55651.28	-12881.9	-10307.77847	44.30	35.70	198280.00	187500.00	138021.02	523801.02	-3.45	2.05	0.51	0.88	-0.01	100.06	23645.18	555401.11	226610.10	14.45

TSC + PV + FIT + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	235	94	39.66	10.4775	4.96	0.3526	12404.8134	30259.929	203.1794	2428.549	7931.041046	45.00	36.40	201780.00	35250.00	17257.06	254287.06	14.19	0.30	0.10	0.96	15.55	23.53	5406.36	126989.86	67712.80	11.25
50	685	187	26.44	6.985	4.96	0.617	24677.6607	23563.4558	6327.852	-564.13	3463.009681	45.00	36.40	201780.00	102750.00	34514.12	339044.12	9.49	0.60	0.28	0.96	11.34	44.24	9874.39	231939.35	87905.24	15.15
75	1235	281	13.22	3.4925	4.96	0.8814	37082.4741	19750.3654	14919.21	-3283.27	-731.4839498	45.00	36.40	201780.00	185250.00	51771.18	438801.18	4.87	0.91	0.51	0.96	7.24	64.37	14068.88	330463.73	86672.55	18.15
75-100	1235	375	13.22	0	4.96	0.8814	49487.2875	17131.2544	24705.64	-5889.03	-3337.246809	45.00	36.40	201780.00	185250.00	69028.24	456058.24	2.70	1.21	0.51	0.96	5.38	73.55	16674.65	391670.44	130622.20	16.3
Carbon Offsetting	1235	639	13.22	0	4.96	0.8814	84326.3379	12609.5221	55822.96	-12974	-10422.23095	45.00	36.40	201780.00	185250.00	138890.44	525920.44	-3.53	2.06	0.51	0.96	0.00	100.01	23759.63	558089.49	227179.05	14.45

TSC + PV + FIT + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	225	94	38.15	10.4775	4.96	0.3828	12404.8134	30259.929	203.1794	2428.549	7762.525046	48.60	37.00	211680.00	33750.00	17257.06	262687.06	13.91	0.30	0.09	1.12	15.42	24.14	5574.87	130948.12	63271.07	12.5
50	675	187	25.42	6.985	4.96	0.6374	24677.6607	23563.4558	6327.852	-564.13	3349.177681	48.60	37.00	211680.00	101250.00	34514.12	347444.12	9.30	0.60	0.28	1.12	11.30	44.40	9988.22	234613.15	82179.03	15.9
75	1230	281	12.7	3.4925	4.96	0.8918	37082.4741	19750.3654	14919.21	-3283.27	-789.5159498	48.60	37.00	211680.00	184500.00	51771.18	447951.18	4.77	0.91	0.50	1.12	7.31	64.07	14126.92	331826.84	78885.66	18.75
75-100	1230	375	12.7	0	4.96	0.8918	49487.2875	17131.2544	24705.64	-5889.03	-3395.278809	48.60	37.00	211680.00	184500.00	69028.24	465208.24	2.60	1.21	0.50	1.12	5.44	73.25	16732.68	393033.55	122835.32	16.9
Carbon Offsetting	1230	644	12.7	0	4.96	0.8918	84722.2362	12542.2086	55801.54	-13039.9	-10546.12842	48.60	37.00	211680.00	184500.00	139542.51	535722.51	-3.64	2.08	0.50	1.12	0.07	99.67	23883.53	560999.71	220287.21	14.8

TSC + PV + FIT + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	220	94	36.6	10.4775	4.96	0.4138	12404.8134	30259.929	203.1794	2428.549	7589.545046	50.40	38.40	219600.00	33000.00	17257.06	269857.06	13.62	0.30	0.09	1.2	15.21	25.17	5747.85	135011.25	60164.19	13.5
50	685	187	24.4	6.985	4.96	0.6578	24677.6607	23563.4558	6327.852	-564.13	3235.345681	50.40	38.40	219600.00	102750.00	34514.12	356864.12	9.11	0.60	0.28	1.2	11.20	44.92	10102.05	237286.95	75432.83	16.75
75	1225	281	12.21	3.4925	4.96	0.9016	37082.4741	19750.3654	14919.21	-3283.27	-844.1999498	50.40	38.40	219600.00	183750.00	51771.18	455121.18	4.68	0.91	0.50	1.2	7.29	64.13	14181.60	333111.31	73000.14	19.25
75-100	1225	375	12.21	0	4.96	0.9016	49487.2875	17131.2544	24705.64	-5889.03	-3449.962809	50.40	38.40	219600.00	183750.00	69028.24	472378.24	2.51	1.21	0.50	1.2	5.43	73.31	16787.36	394318.02	116949.79	17.25
Carbon Offsetting	1225	645	12.21	0	4.96	0.9016	84722.2362	12542.2086	56500.54	-13071.3	-10632.26742	50.40	38.40	219600.00	183750.00	139542.51	542892.51	-3.85	2.08	0.50	1.2	-0.07	100.32	23969.67	563023.03	215140.52	15.1

TSC + PV + FIT + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	215	94	35.55	10.4775	4.96	0.4348	12404.8134	30259.929	203.1794	2428.549	7472.365046	52.20	39.00	225360.00	32250.00	17257.06	274867.06	13.42	0.30	0.09	1.3	15.12	25.65	5865.03	137763.69	57906.63	14
50	665	187	23.7	6.985	4.96	0.6718	24677.6607	23563.4558	6327.852	-564.13	3157.225681	52.20	39.00	225360.00	99750.00	34514.12	359624.12	8.98	0.60	0.27	1.3	11.16	45.11	10180.17	239121.91	74507.79	16.9
75	1220	281	11.85	3.4925	4.96	0.9088	37082.4741	19750.3654	14919.21	-3283.27	-884.3759498	52.20	39.00	225360.00	183000.00	51771.18	460131.18	4.62	0.91	0.50	1.3	7.32	63.98	14221.78	334055.01	68933.83	19.6
75-100	1220	375	11.85	0	4.96	0.9088	49487.2875	17131.2544	24705.64	-5889.03	-3490.138809	52.20	39.00	225360.00	183000.00	69028.24	477388.24	2.45	1.21	0.50	1.3	5.46	73.16	16827.54	395261.72	112883.48	17.55
Carbon Offsetting	1220	646	11.85	0	4.96	0.9088	85250.1006	12510.9109	56300.11	-13143.2	-10744.34593	52.20	39.00	225360.00	183000.00	140411.93	548771.93	-3.89	2.08	0.50	1.3	0.00	100.01	24081.75	565655.64	211893.71	15.3

TSC + PV + FIT + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	200	94	33	10.4775	4.96	0.4858	12404.8134	30259.929	203.1794	2428.549	7187.785046	63.00	43.00	261000.00	30000.00	17257.06	308257.06	12.95	0.30	0.08	1.84	15.18	25.35	6149.61	144448.18	31201.12	19.35
50	660	187	22	6.985	4.96	0.7058	24677.6607	23563.4558	6327.852	-564.13	2967.505681	63.00	43.00	261000.00	99000.00	34514.12	394514.12	8.67	0.60	0.27	1.84	11.38	44.01	10369.89	243578.24	44074.12	20.25
75	1215	281	11	3.4925	4.96	0.9258	37082.4741	19750.3654	14919.21	-3283.27	-979.2359498	63.00	43.00	261000.00	182250.00	51771.18	495021.18	4.46	0.91	0.50	1.84	7.70	62.11	14316.64	336283.17	36271.99	22.15
75-100	1215	375	11	0	4.96	0.9258	49487.2875	17131.2544	24705.64	-5889.03	-3584.998809	63.00	43.00	261000.00	182250.00	69028.24	512278.24	2.29	1.21	0.50	1.84	5.84	71.29	16922.40	397489.88	80221.65	19.75
Carbon Offsetting	1215	665	11	0	4.96	0.9258	87757.4565	12252.2495	58596.8	-13646.4	-11342.33638	63.00	43.00	261000.00	182250.00	144541.69	587791.69	-4.49	2.15	0.50	1.84	-0.01	100.03	24679.74	579701.82	186920.13	16.6

TSC + PV + FIT + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	195	94	32.25	10.4775	4.96	0.5008	12404.8134	30259.929	203.1794	2428.549	7104.085046	66.60	44.70	273870.00	29250.00	17257.06	320377.06	12.81	0.30	0.08	2	15.20	25.26	6233.31	146414.21	21047.15	21.25
50	650	187	21.5	6.985	4.96	0.7158	24677.6607	23563.4558	6327.852	-564.13	2911.705681	66.60	44.70	273870.00	97500.00	34514.12	405884.12	8.58	0.60	0.27	2	11.45	43.70	10425.69	244888.92	34014.80	21.35
75	1210	281	10.75	3.4925	4.96	0.9308	37082.4741	19750.3654	14919.21	-3283.27	-1007.13595	66.60	44.70	273870.00	181500.00	51771.18	507141.18	4.41	0.91	0.50	2	7.82	61.56	14344.54	336938.51	24807.34	23.05
75-100	1210	375	10.75	0	4.96	0.9308	49487.2875	17131.2544	24705.64	-5889.03	-3612.898809	66.60	44.70	273870.00	181500.00	69028.24	524398.24	2.24	1.21	0.50	2	5.95	70.74	16950.30	398145.22	68756.99	20.5
Carbon Offsetting	1210	670	10.75	0	4.96	0.9308	88417.287	12184.9046	58689.29	-13755.6	-11479.50194	66.60	44.70	273870.00	181500.00	145628.47	600998.47	-4.56	2.16	0.50	2	0.09	99.54	24816.90	582923.70	176935.23	17.1

Table B. 4 Distribution warehouse – PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC

Storage and Distribution Warehouse-London
PV (future FiT)+Insulation+TSC

TSC + PV + Future FIT + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25%	275	94	42.97	10.4775	4.96	0.2864	12404.813	30259.929	203.1794	4227.247	10099.13	43.70	35.00	195010.00	41250.00	17257.06	253517.06	14.80	0.30	0.11	0.80	16.02	21.22	3238.27	76063.54	17556.48	19
50%	750	187	28.65	6.985	4.96	0.5728	24677.661	23563.4558	6327.852	3014.13	7287.906	43.70	35.00	195010.00	112500.00	34514.12	342024.12	9.90	0.60	0.31	0.80	11.61	42.88	6049.49	142096.43	-4917.69	26
75%	1300	281	14.32	3.4925	4.96	0.8594	37082.474	19750.3654	14919.21	2093.687	4768.235	43.70	35.00	195010.00	195000.00	51771.18	441781.18	5.07	0.91	0.53	0.80	7.31	64.02	8569.17	201280.95	-45490.23	31
75-100	1300	375	14.32	0	4.96	0.8594	49487.288	17131.2544	24705.64	1286.622	3961.17	43.70	35.00	195010.00	195000.00	69028.24	459038.24	2.91	1.21	0.53	0.80	5.45	73.20	9376.23	220238.08	-43790.16	30.35
75-100 (2)	1300	375	14.32	0	4.96	0.8594	49487.288	17131.2544	24705.64	-72.1883	2602.36	43.70	35.00	195010.00	195000.00	69028.24	459038.24	2.91	1.21	0.53	0.80	5.45	73.20	10735.04	252155.14	-11873.09	30.35
Carbon Offsetting	1300	643	14.32	0	4.96	0.8594	84722.236	12542.2086	53801.54	-665.16	2009.388	43.70	35.00	195010.00	195000.00	139542.51	529552.51	-2.99	2.07	0.53	0.80	0.42	97.92	11328.01	266083.45	-68459.06	30.9
Carbon Offsetting	1300	643	14.32	0	4.96	0.8594	84722.236	12542.2086	53801.54	-3624.24	-949.697	43.70	35.00	195010.00	195000.00	139542.51	529552.51	-2.99	2.07	0.53	0.80	0.42	97.92	14287.10	335589.33	1046.82	24.25

TSC + PV + FIT + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	250	94	41.5	10.4775	4.96	0.3158	12404.813	30259.929	203.1794	4227.247	9935.083	44.30	35.70	198280.00	37500.00	17257.06	253037.06	14.53	0.30	0.10	0.88	15.81	22.21	3402.32	79916.95	21889.90	18
50	700	187	27.7	6.985	4.96	0.5918	24677.661	23563.4558	6327.852	3014.13	7181.886	44.30	35.70	198280.00	105000.00	34514.12	337794.12	9.73	0.60	0.29	0.88	11.50	43.45	6155.51	144586.73	1802.61	24.7
75	1250	281	13.42	3.4925	4.96	0.8774	37082.474	19750.3654	14919.21	2093.687	4667.795	44.30	35.70	198280.00	187500.00	51771.18	437551.18	4.91	0.91	0.51	0.88	7.21	64.55	8669.61	203640.18	-38901.00	30.25
75-100	1250	375	13.42	0	4.96	0.8774	49487.288	17131.2544	24705.64	1286.622	3860.73	44.30	35.70	198280.00	187500.00	69028.24	454808.24	2.74	1.21	0.51	0.88	5.34	73.73	9476.67	222597.31	-37200.92	29.5
75-100 (2)	1250	375	13.42	0	4.96	0.8774	49487.288	17131.2544	24705.64	-72.1883	2501.92	44.30	35.70	198280.00	187500.00	69028.24	454808.24	2.74	1.21	0.51	0.88	5.34	73.73	10835.48	254514.37	-5283.86	29.5
Carbon Offsetting	1250	635	13.42	0	4.96	0.8774	83798.473	12665.7142	55651.28	-731.108	1843	44.30	35.70	198280.00	187500.00	138021.02	523801.02	-3.45	2.05	0.51	0.88	-0.01	100.06	11494.40	269991.72	-58799.29	30.9
Carbon Offsetting	1250	635	13.42	0	4.96	0.8774	83798.473	12665.7142	55651.28	-3791.93	-1217.82	44.30	35.70	198280.00	187500.00	138021.02	523801.02	-3.45	2.05	0.51	0.88	-0.01	100.06	14555.22	341887.28	13096.26	24

TSC + PV + FIT + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	235	94	39.66	10.4775	4.96	0.3526	12404.813	30259.929	203.1794	4227.247	9729.739	45.00	36.40	201780.00	35250.00	17257.06	254287.06	14.19	0.30	0.10	0.96	15.55	23.53	3607.66	84740.28	25463.22	17.25
50	685	187	26.44	6.985	4.96	0.617	24677.661	23563.4558	6327.852	3014.13	7041.27	45.00	36.40	201780.00	102750.00	34514.12	339044.12	9.49	0.60	0.28	0.96	11.34	44.24	6296.13	147889.66	3855.54	24.25
75	1235	281	13.22	3.4925	4.96	0.8814	37082.474	19750.3654	14919.21	2093.687	4645.475	45.00	36.40	201780.00	185250.00	51771.18	438801.18	4.87	0.91	0.51	0.96	7.24	64.37	8691.93	204164.45	-39626.72	30.2
75-100	1235	375	13.22	0	4.96	0.8814	49487.288	17131.2544	24705.64	1286.622	3838.41	45.00	36.40	201780.00	185250.00	69028.24	456058.24	2.70	1.21	0.51	0.96	5.38	73.55	9498.99	223121.59	-37926.65	29.6
75-100 (2)	1235	375	13.22	0	4.96	0.8814	49487.288	17131.2544	24705.64	-72.1883	2479.6	45.00	36.40	201780.00	185250.00	69028.24	456058.24	2.70	1.21	0.51	0.96	5.38	73.55	10857.80	255038.65	-6009.59	29.6
Carbon Offsetting	1235	639	13.22	0	4.96	0.8814	84326.338	12609.5221	55822.96	-746.7	1805.088	45.00	36.40	201780.00	185250.00	138890.44	525920.44	-3.53	2.06	0.51	0.96	0.00	100.01	11532.31	270882.24	-60028.20	31
Carbon Offsetting	1235	639	13.22	0	4.96	0.8814	84326.338	12609.5221	55822.96	-3816.96	-1265.17	45.00	36.40	201780.00	185250.00	138890.44	525920.44	-3.53	2.06	0.51	0.96	0.00	100.01	14602.57	342999.58	12089.14	24

TSC + PV + FIT + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	225	94	38.15	10.4775	4.96	0.3828	12404.813	30259.929	203.1794	4227.247	9561.223	48.60	37.00	211680.00	33750.00	17257.06	262687.06	13.91	0.30	0.09	1.12	15.42	24.14	3776.18	88698.54	21021.49	18.75
50	675	187	25.42	6.985	4.96	0.6374	24677.661	23563.4558	6327.852	3014.13	6927.438	48.60	37.00	211680.00	101250.00	34514.12	347444.12	9.30	0.60	0.28	1.12	11.30	44.40	6409.96	150563.46	-1870.66	25.25
75	1230	281	12.7	3.4925	4.96	0.8918	37082.474	19750.3654	14919.21	2093.687	4587.443	48.60	37.00	211680.00	184500.00	51771.18	447951.18	4.77	0.91	0.50	1.12	7.31	64.07	8749.96	205527.57	-47413.61	31.25
75-100	1230	375	12.7	0	4.96	0.8918	49487.288	17131.2544	24705.64	1286.622	3780.378	48.60	37.00	211680.00	184500.00	69028.24	465208.24	2.60	1.21	0.50	1.12	5.44	73.25	9557.02	224484.70	-45713.54	30.5
75-100 (2)	1230	375	12.7	0	4.96	0.8918	49487.288	17131.2544	24705.64	-72.1883	2421.568	48.60	37.00	211680.00	184500.00	69028.24	465208.24	2.60	1.21	0.50	1.12	5.44	73.25	10915.83	256401.76	-13796.47	30.5
Carbon Offsetting	1230	644	12.7	0	4.96	0.8918	84722.236	12542.2086	55801.54	-755.16	1738.596	48.60	37.00	211680.00	184500.00	139542.51	535722.51	-3.64	2.08	0.50	1.12	0.07	99.67	11598.80	272444.07	-68268.43	31.75
Carbon Offsetting	1230	644	12.7	0	4.96	0.8918	84722.236	12542.2086	55801.54	-3824.24	-1330.49	48.60	37.00	211680.00	184500.00	139542.51	535722.51	-3.64	2.08	0.50	1.12	0.07	99.67	14667.89	344533.74	3821.24	24.7

TSC + PV + FIT + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	220	94	36.6	10.4775	4.96	0.4138	12404.813	30259.929	203.1794	4227.247	9388.243	50.40	38.40	219600.00	33000.00	17257.06	269857.06	13.62	0.30	0.09	1.2	15.21	25.17	3949.16	92761.67	17914.61	19.85
50	685	187	24.4	6.985	4.96	0.6578	24677.661	23563.4558	6327.852	3014.13	6813.606	50.40	38.40	219600.00	102750.00	34514.12	356864.12	9.11	0.60	0.28	1.2	11.20	44.92	6523.79	153237.25	-8616.86	26.5
75	1225	281	12.21	3.4925	4.96	0.9016	37082.474	19750.3654	14919.21	2093.687	4532.759	50.40	38.40	219600.00	183750.00	51771.18	455121.18	4.68	0.91	0.50	1.2	7.29	64.13	8804.64	206812.04	-53299.14	32
75-100	1225	375	12.21	0	4.96	0.9016	49487.288	17131.2544	24705.64	1286.622	3725.694	50.40	38.40	219600.00	183750.00	69028.24	472378.24	2.51	1.21	0.50	1.2	5.43	73.31	9611.71	225769.17	-51599.07	31.2
75-100 (2)	1225	375	12.21	0	4.96	0.9016	49487.288	17131.2544	24705.64	-72.1883	2366.884	50.40	38.40	219600.00	183750.00	69028.24	472378.24	2.51	1.21	0.50	1.2	5.43	73.31	10970.52	257686.23	-19682.00	31.2
Carbon Offsetting	1225	645	12.21	0	4.96	0.9016	84722.236	12542.2086	56500.54	-786.615	1652.457	50.40	38.40	219600.00	183750.00	139542.51	542892.51	-3.85	2.08	0.50	1.2	-0.07	100.32	11684.94	274467.39	-73415.11	32.25
Carbon Offsetting	1225	645	12.21	0	4.96	0.9016	84722.236	12542.2086	56500.54	-3894.14	-1455.07	50.40	38.40	219600.00	183750.00	139542.51	542892.51	-3.85	2.08	0.50	1.2	-0.07	100.32	14792.47	347460.10	-422.41	25

TSC + PV + FIT + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	215	94	35.55	10.4775	4.96	0.4348	12404.813	30259.929	203.1794	4227.247	9271.063	52.20	39.00	225360.00	32250.00	17257.06	274867.06	13.42	0.30	0.09	1.3	15.12	25.65	4066.34	95514.11	15657.05	20.75
50	665	187	23.7	6.985	4.96	0.6718	24677.661	23563.4558	6327.852	3014.13	6735.486	52.20	39.00	225360.00	99750.00	34514.12	359624.12	8.98	0.60	0.27	1.3	11.16	45.11	6601.91	155072.21	-9541.91	26.7
75	1220	281	11.85	3.4925	4.96	0.9088	37082.474	19750.3654	14919.21	2093.687	4492.583	52.20	39.00	225360.00	183000.00	51771.18	460131.18	4.62	0.91	0.50	1.3	7.32	63.98	8844.82	207755.73	-57365.45	32.5
75-100	1220	375	11.85	0	4.96	0.9088	49487.288	17131.2544	24705.64	1286.622	3685.518	52.20	39.00	225360.00	183000.00	69028.24	477388.24	2.45	1.21	0.50	1.3	5.46	73.16	9651.88	226712.86	-55665.37	31.65
75-100 (2)	1220	375	11.85	0	4.96	0.9088	49487.288	17131.2544	24705.64	-72.1883	2326.708	52.20	39.00	225360.00	183000.00	69028.24	477388.24	2.45	1.21	0.50	1.3	5.46	73.16	11010.69	258629.93	-23748.31	31.65
Carbon Offsetting	1220	646	11.85	0	4.96	0.9088	85250.101	12510.9109	56300.11	-781.977	1616.919	52.20	39.00	225360.00	183000.00	140411.93	548771.93	-3.89	2.08	0.50	1.3	0.00	100.01	11720.48	275302.15	-78459.78	32.75
Carbon Offsetting	1220	646	11.85	0	4.96	0.9088	85250.101	12510.9109	56300.11	-3878.48	-1479.59	52.20	39.00	225360.00	183000.00	140411.93	548771.93	-3.89	2.08	0.50	1.3	0.00	100.01	14816.99	348035.91	-5726.02	25.5

TSC + PV + FIT + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	200	94	33	10.4775	4.96	0.4858	12404.813	30259.929	203.1794	4227.247	8986.483	63.00	43.00	261000.00	30000.00	17257.06	308257.06	12.95	0.30	0.08	1.84	15.18	25.35	4350.92	102198.60	-11048.46	28
50	660	187	22	6.985	4.96	0.7058	24677.661	23563.4558	6327.852	3014.13	6545.766	63.00	43.00	261000.00	99000.00	34514.12	394514.12	8.67	0.60	0.27	1.84	11.38	44.01	6791.63	159528.54	-39975.58	31.75
75	1215	281	11	3.4925	4.96	0.9258	37082.474	19750.3654	14919.21	2093.687	4397.723	63.00	43.00	261000.00	182250.00	51771.18	495021.18	4.46	0.91	0.50	1.84	7.70	62.11	8939.68	209983.90	-90027.28	36.75
75-100	1215	375	11	0	4.96	0.9258	49487.288	17131.2544	24705.64	1286.622	3590.658	63.00	43.00	261000.00	182250.00	69028.24	512278.24	2.29	1.21	0.50	1.84	5.84	71.29	9746.74	228941.03	-88327.21	35.5
75-100 (2)	1215	375	11	0	4.96	0.9258	49487.288	17131.2544	24705.64	-72.1883	2231.848	63.00	43.00	261000.00	182250.00	69028.24	512278.24	2.29	1.21	0.50	1.84	5.84	71.29	11105.55	260858.09	-56410.14	35.5
Carbon Offsetting	1215	665	11	0	4.96	0.9258	87757.457	12252.2495	58596.8	-921.541	1382.495	63.00	43.00	261000.00	182250.00	144541.69	587791.69	-4.49	2.15	0.50	1.84	-0.01	100.03	11954.91	280808.52	-111973.17	35.9
Carbon Offsetting	1215	665	11	0	4.96	0.9258	87757.457	12252.2495	58596.8	-4144.37	-1840.33	63.00	43.00	261000.00	182250.00	144541.69	587791.69	-4.49	2.15	0.50	1.84	-0.01	100.03	15177.73	356509.38	-36272.32	27.7

TSC + PV + FIT + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	43.70	35.00	195010.00	0.00	0.00	195010.00	19.53	0.00	0.00	0.80	20.33	0.00	0.00	0.00	0.00	0
25	195	94	32.25	10.4775	4.96	0.5008	12404.813	30259.929	203.1794	4227.247	8902.783	66.60	44.70	273870.00	29250.00	17257.06	320377.06	12.81	0.30	0.08	2	15.20	25.26	4434.62	104164.63	-21202.43	30.5
50	650	187	21.5	6.985	4.96	0.7158	24677.661	23563.4558	6327.852	3014.13	6489.966	66.60	44.70	273870.00	97500.00	34514.12	405884.12	8.58	0.60	0.27	2	11.45	43.70	6847.43	160839.23	-50034.89	33.5
75	1210	281	10.75	3.4925	4.96	0.9308	37082.474	19750.3654	14919.21	2093.687	4369.823	66.60	44.70	273870.00	181500.00	51771.18	507141.18	4.41	0.91	0.50	2	7.82	61.56	8967.58	210639.24	-101491.94	38.2
75-100	1210	375	10.75	0	4.96	0.9308	49487.288	17131.2544	24705.64	1286.622	3562.758	66.60	44.70	273870.00	181500.00	69028.24	524398.24	2.24	1.21	0.50	2	5.95	70.74	9774.64	229596.37	-99791.87	36.9
75-100 (2)	1210	375	10.75	0	4.96	0.9308	49487.288	17131.2544	24705.64	-72.1883	2203.948	66.60	44.70	273870.00	181500.00	69028.24	524398.24	2.24	1.21	0.50	2	5.95	70.74	11133.45	261513.43	-67874.80	36.9
Carbon Offsetting	1210	670	10.75	0	4.96	0.9308	88417.287	12184.9046	58689.29	-935.131	1341.005	66.60	44.70	273870.00	181500.00	145628.47	600998.47	-4.56	2.16	0.50	2	0.09	99.54	11996.40	281783.09	-124205.39	37
Carbon Offsetting	1210	670	10.75	0	4.96	0.9308	88417.287	12184.9046	58689.29	-4163.04	-1886.91	66.60	44.70	273870.00	181500.00	145628.47	600998.47	-4.56	2.16	0.50	2	0.09	99.54	15224.31	357603.42	-48385.05	28.65

Table B. 5 Retail shed – PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool)

Retail shed - London
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	32.9	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9648.058743	43.70	35.00	195010.00	39282.35	234292.35	18.55	0.69	0.80	20.04	17.61	7893.54	185411.23	146128.88	5
50%	427	32.9	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2823.151511	43.70	35.00	195010.00	78564.71	273574.71	13.61	1.38	0.80	15.79	35.08	14718.45	345721.34	267156.63	5.45
75%	640	32.9	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3320.33146	43.70	35.00	195010.00	117847.06	312857.06	8.74	2.07	0.80	11.60	52.30	20861.93	490025.48	372178.42	5.75
100%	853	32.9	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9233.42235	43.70	35.00	195010.00	157129.41	352139.41	3.78	2.75	0.80	7.33	69.85	26775.02	628917.95	471788.54	6
Carbon offsetting	1225	32.9	0	1.98	161658.4725	32022.1112	98592.39014	-23394	-19208.4405	43.70	35.00	195010.00	266261.01	461271.01	-4.80	3.95	0.80	-0.05	100.21	36750.04	863220.95	596959.94	7.4

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	31.9	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9528.058743	44.30	35.70	198280.00	39282.35	237562.35	18.35	0.69	0.88	19.92	18.09	8013.54	188229.91	145677.55	5.4
50%	427	31.9	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2703.151511	44.30	35.70	198280.00	78564.71	276844.71	13.41	1.38	0.88	15.67	35.55	14838.45	348540.01	266705.31	5.6
75%	640	31.9	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3440.33146	44.30	35.70	198280.00	117847.06	316127.06	8.54	2.07	0.88	11.48	52.77	20981.93	492844.16	371727.10	5.85
100%	853	31.9	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9353.42235	44.30	35.70	198280.00	157129.41	355409.41	3.58	2.75	0.88	7.22	70.33	26895.02	631736.63	471337.22	6
Carbon offsetting	1215	31.9	0	1.98	160338.8115	32185.1076	97635.72554	-23136.8	-19071.2203	44.30	35.70	198280.00	264087.45	462367.45	-4.80	3.92	0.88	0.00	100.02	36612.82	859997.79	592640.33	7.45

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	30.42	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9350.458743	45.00	36.40	201780.00	39282.35	241062.35	18.06	0.69	0.96	19.71	18.95	8191.14	192401.55	146349.20	5.75
50%	427	30.42	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2525.551511	45.00	36.40	201780.00	78564.71	280344.71	13.12	1.38	0.96	15.46	36.42	15016.05	352711.66	267376.95	5.75
75%	640	30.42	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3617.93146	45.00	36.40	201780.00	117847.06	319627.06	8.25	2.07	0.96	11.27	53.64	21159.53	497015.80	372398.74	6
100%	853	30.42	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9531.02235	45.00	36.40	201780.00	157129.41	358909.41	3.29	2.75	0.96	7.01	71.19	27072.62	635908.27	472008.86	6.15
Carbon offsetting	1205	30.42	0	1.98	159019.1505	32348.104	96379.06094	-22866.1	-18978.1	45.00	36.40	201780.00	261913.89	463693.89	-4.85	3.89	0.96	0.00	99.99	36519.70	857810.49	589126.59	7.5

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	28.84	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9160.858743	48.60	37.00	211680.00	39282.35	250962.35	17.75	0.69	1.12	19.56	19.57	8380.74	196855.06	140902.71	6.75
50%	427	28.84	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2335.951511	48.60	37.00	211680.00	78564.71	290244.71	12.81	1.38	1.12	15.31	37.03	15205.65	357165.17	261930.46	6.35
75%	640	28.84	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3807.53146	48.60	37.00	211680.00	117847.06	329527.06	7.94	2.07	1.12	11.13	54.25	21349.13	501469.31	366952.25	6.4
100%	853	28.84	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9720.62235	48.60	37.00	211680.00	157129.41	368809.41	2.98	2.75	1.12	6.86	71.81	27262.22	640361.78	466562.37	6.5
Carbon offsetting	1200	28.84	0	1.98	158359.32	32460.4765	95728.7049	-22725.4	-19027.0264	48.60	37.00	211680.00	260827.12	472507.12	-5.02	3.87	1.12	-0.03	100.13	36568.63	858959.72	581462.60	7.75

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	28	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9060.058743	50.40	38.40	219600.00	39282.35	258882.35	17.59	0.69	1.2	19.48	19.91	8481.54	199222.75	135350.40	7.75
50%	427	28	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2235.151511	50.40	38.40	219600.00	78564.71	298164.71	12.65	1.38	1.2	15.23	37.38	15306.45	359532.86	256378.15	6.85
75%	640	28	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3908.33146	50.40	38.40	219600.00	117847.06	337447.06	7.78	2.07	1.2	11.04	54.60	21449.93	503837.00	361399.94	6.75
100%	853	28	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9821.42235	50.40	38.40	219600.00	157129.41	376729.41	2.82	2.75	1.2	6.77	72.15	27363.02	642729.47	461010.06	6.75
Carbon offsetting	1194	28	0	1.98	157567.5234	32556.8816	95036.21142	-22566	-18968.357	50.40	38.40	219600.00	259522.98	479122.98	-5.05	3.85	1.2	0.00	99.99	36509.96	857581.64	573468.66	7.95

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	27.04	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8944.858743	52.20	39.00	225360.00	39282.35	264642.35	17.40	0.69	1.3	19.39	20.28	8596.74	201928.68	132296.33	8.25
50%	427	27.04	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2119.951511	52.20	39.00	225360.00	78564.71	303924.71	12.46	1.38	1.3	15.14	37.74	15421.65	362238.79	253324.08	7.2
75%	640	27.04	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4023.53146	52.20	39.00	225360.00	117847.06	343207.06	7.59	2.07	1.3	10.95	54.96	21565.13	506542.93	358345.87	7
100%	853	27.04	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9936.62235	52.20	39.00	225360.00	157129.41	382489.41	2.63	2.75	1.3	6.68	72.52	27478.22	645435.40	457955.99	7
Carbon offsetting	1190	27.04	0	1.98	157039.659	32623.0836	94574.5491	-22459.4	-18976.9736	52.20	39.00	225360.00	258653.56	484013.56	-5.15	3.84	1.3	-0.01	100.02	36518.57	857784.03	568780.47	8.1

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	24.8	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8676.058743	63.00	43.00	261000.00	39282.35	300282.35	16.96	0.69	1.84	19.49	19.86	8865.54	208242.52	102970.16	12.25
50%	427	24.8	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	1851.151511	63.00	43.00	261000.00	78564.71	339564.71	12.02	1.38	1.84	15.24	37.33	15690.45	368552.62	223997.92	9.5
75%	640	24.8	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4292.33146	63.00	43.00	261000.00	117847.06	378847.06	7.15	2.07	1.84	11.05	54.55	21833.93	512856.77	329019.71	8.6
100%	853	24.8	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-10205.4224	63.00	43.00	261000.00	157129.41	418129.41	2.19	2.75	1.84	6.78	72.10	27747.02	651749.24	428629.83	8.25
Carbon offsetting	1194	24.8	0	1.98	157567.5234	32556.8816	95136.21142	-22570.5	-19356.857	63.00	43.00	261000.00	259522.98	520522.98	-5.69	3.85	1.84	0.00	100.01	36898.46	866707.10	541194.12	9

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	24.22	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8606.458743	66.60	44.70	273870.00	39282.35	313152.35	16.85	0.69	2	19.53	19.67	8935.14	209877.35	91735.00	13.75
50%	427	24.22	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	1781.551511	66.60	44.70	273870.00	78564.71	352434.71	11.91	1.38	2	15.29	37.14	15760.05	370187.46	212762.75	10.25
75%	640	24.22	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4361.93146	66.60	44.70	273870.00	117847.06	391717.06	7.03	2.07	2	11.10	54.36	21903.53	514491.60	317784.54	9.2
100%	853	24.22	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-10275.0224	66.60	44.70	273870.00	157129.41	430999.41	2.08	2.75	2	6.83	71.91	27816.62	653384.08	417394.66	8.7
Carbon offsetting	1199	24.22	0	1.98	158227.3539	32476.8093	95613.28932	-22698.8	-19554.811	66.60	44.70	273870.00	260609.76	534479.76	-5.91	3.87	2	-0.04	100.15	37096.41	871356.84	531887.08	9.4

Table B. 6 Retail shed – PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool)

Retail shed - London
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	32.9	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13723.83	43.70	35.00	195010.00	39282.35	234292.35	18.55	0.69	0.80	20.04	17.61	3817.77	89675.48	50393.13	10.5
50%	427	32.9	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10993.83	43.70	35.00	195010.00	78564.71	273574.71	13.61	1.38	0.80	15.79	35.08	6547.77	153800.38	75235.67	12.25
75%	640	32.9	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8926.123	43.70	35.00	195010.00	117847.06	312857.06	8.74	2.07	0.80	11.60	52.30	8615.48	202368.77	84521.71	14.25
100% (1)	853	32.9	0	1.98	112567.08	38839.5238	56318.414	2903.20473	7088.805	43.70	35.00	195010.00	157129.41	352139.41	3.78	2.75	0.80	7.33	69.85	10452.80	245525.50	88396.08	15.65
100% (2)	853	32.9	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3991.292	43.70	35.00	195010.00	157129.41	352139.41	3.78	2.75	0.80	7.33	69.85	13550.31	318282.91	161153.50	15.65
Carbon offsetting	1225	32.9	0	1.98	161658.47	32022.1112	98592.39	46.4380101	4232.038	43.70	35.00	195010.00	266261.01	461271.01	-4.80	3.95	0.80	-0.05	100.21	13309.56	312628.03	46367.02	21.1
Carbon offsetting	1225	32.9	0	1.98	161658.47	32022.1112	98592.39	-5376.1434	-1190.54	43.70	35.00	195010.00	266261.01	461271.01	-4.80	3.95	0.80	-0.05	100.21	18732.14	439998.94	173737.92	14.75

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	31.9	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13603.83	44.30	35.70	198280.00	39282.35	237562.35	18.35	0.69	0.88	19.92	18.09	3937.77	92494.16	49941.81	11
50%	427	31.9	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10873.83	44.30	35.70	198280.00	78564.71	276844.71	13.41	1.38	0.88	15.67	35.55	6667.77	156619.05	74784.35	12.7
75%	640	31.9	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8806.123	44.30	35.70	198280.00	117847.06	316127.06	8.54	2.07	0.88	11.48	52.77	8735.48	205187.45	84070.39	14.4
100%	853	31.9	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6968.805	44.30	35.70	198280.00	157129.41	355409.41	3.58	2.75	0.88	7.22	70.33	10572.80	248344.17	87944.76	15.8
100% (2)	853	31.9	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3871.292	44.30	35.70	198280.00	157129.41	355409.41	3.58	2.75	0.88	7.22	70.33	13670.31	321101.59	160702.17	15.8
Carbon offsetting	1215	31.9	0	1.98	160338.81	32185.1076	97635.726	112.307413	4177.907	44.30	35.70	198280.00	264087.45	462367.45	-4.80	3.92	0.88	0.00	100.02	13363.69	313899.50	46542.05	21.1
Carbon offsetting	1215	31.9	0	1.98	160338.81	32185.1076	97635.726	-5257.6575	-1192.06	44.30	35.70	198280.00	264087.45	462367.45	-4.80	3.92	0.88	0.00	100.02	18733.66	440034.50	172677.04	14.85

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	30.42	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13426.23	45.00	36.40	201780.00	39282.35	241062.35	18.06	0.69	0.96	19.71	18.95	4115.37	96665.80	50613.45	11.5
50%	427	30.42	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10696.23	45.00	36.40	201780.00	78564.71	280344.71	13.12	1.38	0.96	15.46	36.42	6845.37	160790.70	75455.99	12.9
75%	640	30.42	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8628.523	45.00	36.40	201780.00	117847.06	319627.06	8.25	2.07	0.96	11.27	53.64	8913.08	209359.09	84742.03	14.5
100%	853	30.42	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6791.205	45.00	36.40	201780.00	157129.41	358909.41	3.29	2.75	0.96	7.01	71.19	10750.40	252515.82	88616.40	15.9
100% (2)	853	30.42	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3693.692	45.00	36.40	201780.00	157129.41	358909.41	3.29	2.75	0.96	7.01	71.19	13847.91	325273.23	161373.82	15.9
Carbon offsetting	1205	30.42	0	1.98	159019.15	32348.104	96379.061	191.676816	4079.677	45.00	36.40	201780.00	261913.89	463693.89	-4.85	3.89	0.96	0.00	99.99	13461.92	316206.84	47522.94	21.05
Carbon offsetting	1205	30.42	0	1.98	159019.15	32348.104	96379.061	-5109.1715	-1221.17	45.00	36.40	201780.00	261913.89	463693.89	-4.85	3.89	0.96	0.00	99.99	18762.77	440718.36	172034.46	14.9

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	28.84	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13236.63	48.60	37.00	211680.00	39282.35	250962.35	17.75	0.69	1.12	19.56	19.57	4304.97	101119.31	45166.96	13.5
50%	427	28.84	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10506.63	48.60	37.00	211680.00	78564.71	290244.71	12.81	1.38	1.12	15.31	37.03	7034.97	165244.21	70009.50	14
75%	640	28.84	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8438.923	48.60	37.00	211680.00	117847.06	329527.06	7.94	2.07	1.12	11.13	54.25	9102.68	213812.60	79295.54	15.35
100%	853	28.84	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6601.605	48.60	37.00	211680.00	157129.41	368809.41	2.98	2.75	1.12	6.86	71.81	10940.00	256969.33	83169.91	16.6
100% (2)	853	28.84	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3504.092	48.60	37.00	211680.00	157129.41	368809.41	2.98	2.75	1.12	6.86	71.81	14037.51	329726.74	155927.33	16.6
Carbon offsetting	1200	28.84	0	1.98	158359.32	32460.4765	95728.705	236.674991	3935.075	48.60	37.00	211680.00	260827.12	472507.12	-5.02	3.87	1.12	-0.03	100.13	13606.53	319603.39	42106.27	21.5
Carbon offsetting	1200	28.84	0	1.98	158359.32	32460.4765	95728.705	-5028.4038	-1330	48.60	37.00	211680.00	260827.12	472507.12	-5.02	3.87	1.12	-0.03	100.13	18871.60	443274.72	165777.60	15.3

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	28	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13135.83	50.40	38.40	219600.00	39282.35	258882.35	17.59	0.69	1.2	19.48	19.91	4405.77	103487.00	39614.65	15
50%	427	28	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10405.83	50.40	38.40	219600.00	78564.71	298164.71	12.65	1.38	1.2	15.23	37.38	7135.77	167611.90	64457.19	15
75%	640	28	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8338.123	50.40	38.40	219600.00	117847.06	337447.06	7.78	2.07	1.2	11.04	54.60	9203.48	216180.29	73743.23	16.15
100%	853	28	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6500.805	50.40	38.40	219600.00	157129.41	376729.41	2.82	2.75	1.2	6.77	72.15	11040.80	259337.02	77617.60	17.2
100% (2)	853	28	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3403.292	50.40	38.40	219600.00	157129.41	376729.41	2.82	2.75	1.2	6.77	72.15	14138.31	332094.43	150375.02	17.2
Carbon offsetting	1194	28	0	1.98	157567.52	32556.8816	95036.211	281.333906	3878.934	50.40	38.40	219600.00	259522.98	479122.98	-5.05	3.85	1.2	0.00	99.99	13662.67	320922.09	36809.11	22
Carbon offsetting	1194	28	0	1.98	157567.52	32556.8816	95036.211	-4945.6577	-1348.06	50.40	38.40	219600.00	259522.98	479122.98	-5.05	3.85	1.2	0.00	99.99	18889.66	443698.79	159585.81	15.65

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	27.04	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13020.63	52.20	39.00	225360.00	39282.35	264642.35	17.40	0.69	1.3	19.39	20.28	4520.97	106192.93	36560.58	16
50%	427	27.04	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10290.63	52.20	39.00	225360.00	78564.71	303924.71	12.46	1.38	1.3	15.14	37.74	7250.97	170317.83	61403.12	15.6
75%	640	27.04	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8222.923	52.20	39.00	225360.00	117847.06	343207.06	7.59	2.07	1.3	10.95	54.96	9318.68	218886.22	70689.16	16.6
100%	853	27.04	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6385.605	52.20	39.00	225360.00	157129.41	382489.41	2.63	2.75	1.3	6.68	72.52	11156.00	262042.95	74563.53	17.6
100% (2)	853	27.04	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3288.092	52.20	39.00	225360.00	157129.41	382489.41	2.63	2.75	1.3	6.68	72.52	14253.51	334800.36	147320.95	17.6
Carbon offsetting	1190	27.04	0	1.98	157039.66	32623.0836	94574.549	311.377001	3793.777	52.20	39.00	225360.00	258653.56	484013.56	-5.15	3.84	1.3	-0.01	100.02	13747.82	322922.33	33918.78	22.25
Carbon offsetting	1190	27.04	0	1.98	157039.66	32623.0836	94574.549	-4890.2232	-1407.82	52.20	39.00	225360.00	258653.56	484013.56	-5.15	3.84	1.3	-0.01	100.02	18949.42	445102.62	156099.06	15.9

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	24.8	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	12751.83	63.00	43.00	261000.00	39282.35	300282.35	16.96	0.69	1.84	19.49	19.86	4789.77	112506.77	7234.42	23.3
50%	427	24.8	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10021.83	63.00	43.00	261000.00	78564.71	339564.71	12.02	1.38	1.84	15.24	37.33	7519.77	176631.66	32076.96	20.25
75%	640	24.8	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	7954.123	63.00	43.00	261000.00	117847.06	378847.06	7.15	2.07	1.84	11.05	54.55	9587.48	225200.06	41363.00	20.2
100%	853	24.8	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6116.805	63.00	43.00	261000.00	157129.41	418129.41	2.19	2.75	1.84	6.78	72.10	11424.80	268356.78	45237.37	20.6
100% (2)	853	24.8	0	1.98	112567.08	38839.5238	56318.414	-194.30802	3019.292	63.00	43.00	261000.00	157129.41	418129.41	2.19	2.75	1.84	6.78	72.10	14522.31	341114.20	117994.79	20.6
Carbon offsetting	1194	24.8	0	1.98	157567.52	32556.8816	95136.211	276.833906	3490.434	63.00	43.00	261000.00	259522.98	520522.98	-5.69	3.85	1.84	0.00	100.01	14051.17	330047.55	4534.57	24.65
Carbon offsetting	1194	24.8	0	1.98	157567.52	32556.8816	95136.211	-4955.6577	-1742.06	63.00	43.00	261000.00	259522.98	520522.98	-5.69	3.85	1.84	0.00	100.01	19283.66	452953.44	127440.46	17.65

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	195010.00	23.52	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	213	24.22	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	12682.23	66.60	44.70	273870.00	39282.35	313152.35	16.85	0.69	2	19.53	19.67	4859.37	114141.60	-4000.75	26
50%	427	24.22	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	9952.233	66.60	44.70	273870.00	78564.71	352434.71	11.91	1.38	2	15.29	37.14	7589.37	178266.50	20841.79	21.9
75%	640	24.22	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	7884.523	66.60	44.70	273870.00	117847.06	391717.06	7.03	2.07	2	11.10	54.36	9657.08	226834.89	30127.83	21.5
100%	853	24.22	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6047.205	66.60	44.70	273870.00	157129.41	430999.41	2.08	2.75	2	6.83	71.91	11494.40	269991.62	34002.20	21.65
100% (2)	853	24.22	0	1.98	112567.08	38839.5238	56318.414	-194.30802	2949.692	66.60	44.70	273870.00	157129.41	430999.41	2.08	2.75	2	6.83	71.91	14591.91	342749.03	106759.62	21.65
Carbon offsetting	1199	24.22	0	1.98	158227.35	32476.8093	95613.289	244.155287	3388.155	66.60	44.70	273870.00	260609.76	534479.76	-5.91	3.87	2	-0.04	100.15	14153.44	332449.97	-7019.79	25.5
Carbon offsetting	1199	24.22	0	1.98	158227.35	32476.8093	95613.289	-5014.5756	-1870.58	66.60	44.70	273870.00	260609.76	534479.76	-5.91	3.87	2	-0.04	100.15	19412.18	455972.20	116502.44	18.3

Table B. 7 Retail shed – PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) +TSC

Retail shed- sales -London
PV (current FiT)+Insulation+TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	130	213	24.675	24.675	1.98	0.1645	28108.7793	68675.2667	1695.68	5462.45874	8661.0587	43.70	35.00	195010.00	19500.00	35205.88	249715.88	17.02	0.69	0.05	0.80	18.56	23.66	8880.54	208594.85	153888.97	6.25
50%	345	427	16.45	16.45	1.98	0.329	56349.5247	53315.7105	14577.0416	-1362.4485	849.15151	43.70	35.00	195010.00	51750.00	75847.06	322607.06	10.56	1.38	0.14	0.80	12.88	47.04	16692.45	392088.58	264491.52	7.8
75%	595	640	8.225	8.225	1.98	0.4935	84458.304	44755.5418	33894.5163	-7505.9315	-6281.331	43.70	35.00	195010.00	89250.00	116488.24	400748.24	4.16	2.07	0.24	0.80	7.27	70.12	23822.93	559576.35	353838.12	8.85
75-100	595	853	8.225	0	1.98	0.4935	112567.083	38839.5238	56318.4136	-13419.022	-12194.42	43.70	35.00	195010.00	89250.00	157129.41	441389.41	-0.80	2.75	0.24	0.80	3.00	87.67	29736.02	698468.82	452089.41	8.5
Carbon offsetting	595	1003	8.225	0	1.98	0.4935	132361.998	35860.2706	73242.651	-17467.971	-16243.37	43.70	35.00	195010.00	89250.00	218008.00	502268.00	-4.28	3.24	0.24	0.80	0.00	99.99	33784.97	793574.50	486316.50	9.35

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	115	213	23.92	24.675	1.98	0.1796	28108.7793	68675.2667	1695.68	5462.45874	8570.4587	44.30	35.70	198280.00	17250.00	35205.88	250735.88	16.88	0.69	0.05	0.88	18.50	23.94	8971.14	210722.95	154997.07	6.3
50	315	427	15.95	16.45	1.98	0.339	56349.5247	53315.7105	14577.0416	-1362.4485	789.15151	44.30	35.70	198280.00	47250.00	75847.06	321377.06	10.47	1.38	0.13	0.88	12.85	47.15	16752.45	393497.92	267130.86	7.7
75	560	640	7.97	8.225	1.98	0.4986	84458.304	44755.5418	33894.5163	-7505.9315	-6311.931	44.30	35.70	198280.00	84000.00	116488.24	398768.24	4.11	2.07	0.23	0.88	7.29	70.04	23853.53	560295.11	356536.88	8.75
75-100	560	853	7.97	0	1.98	0.4986	112567.083	38839.5238	56318.4136	-13419.022	-12225.02	44.30	35.70	198280.00	84000.00	157129.41	439409.41	-0.84	2.75	0.23	0.88	3.02	87.59	29766.62	699187.59	454788.17	8.4
Carbon offsetting	560	1006	7.97	0	1.98	0.4986	132757.897	35804.8269	73482.2773	-17543.922	-16349.92	44.30	35.70	198280.00	84000.00	218660.06	500940.06	-4.38	3.25	0.23	0.88	-0.02	100.09	33891.52	796077.26	490147.20	9.25

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	113	213	22.6	24.675	1.98	0.206	28108.7793	68675.2667	1695.68	5462.45874	8412.0587	45.00	36.40	201780.00	16950.00	35205.88	253935.88	16.64	0.69	0.05	0.96	18.33	24.62	9129.54	214443.61	155517.73	6.55
50	305	427	15.21	16.45	1.98	0.3538	56349.5247	53315.7105	14577.0416	-1362.4485	700.35151	45.00	36.40	201780.00	45750.00	75847.06	323377.06	10.33	1.38	0.13	0.96	12.79	47.40	16841.25	395583.74	267216.68	7.8
75	551	640	7.55	8.225	1.98	0.507	84458.304	44755.5418	33894.5163	-7505.9315	-6362.331	45.00	36.40	201780.00	82650.00	116488.24	400918.24	4.03	2.07	0.23	0.96	7.28	70.05	23903.93	561478.96	355570.72	8.85
75-100	551	853	7.55	0	1.98	0.507	112567.083	38839.5238	56318.4136	-13419.022	-12275.42	45.00	36.40	201780.00	82650.00	157129.41	441559.41	-0.92	2.75	0.23	0.96	3.02	87.60	29817.02	700371.43	453822.02	8.45
Carbon offsetting	551	1006	7.55	0	1.98	0.507	132757.897	35804.8269	73482.2773	-17543.922	-16400.32	45.00	36.40	201780.00	82650.00	218660.06	503090.06	-4.45	3.25	0.23	0.96	-0.02	100.09	33941.92	797261.11	489181.04	9.3

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	112	213	21.72	24.675	1.98	0.2236	28108.7793	68675.2667	1695.68	5462.45874	8306.4587	48.60	37.00	211680.00	16800.00	35205.88	263685.88	16.47	0.69	0.05	1.12	18.33	24.63	9235.14	216924.04	148248.16	7.65
50	295	427	14.18	16.45	1.98	0.3744	56349.5247	53315.7105	14577.0416	-1362.4485	576.75151	48.60	37.00	211680.00	44250.00	75847.06	331777.06	10.14	1.38	0.12	1.12	12.76	47.54	16964.85	398486.98	261719.92	8.25
75	542	640	7.24	8.225	1.98	0.5132	84458.304	44755.5418	33894.5163	-7505.9315	-6399.531	48.60	37.00	211680.00	81300.00	116488.24	409468.24	3.98	2.07	0.22	1.12	7.38	69.64	23941.13	562352.75	347894.51	9.2
75-100	542	853	7.24	0	1.98	0.5132	112567.083	38839.5238	56318.4136	-13419.022	-12312.62	48.60	37.00	211680.00	81300.00	157129.41	450109.41	-0.98	2.75	0.22	1.12	3.11	87.19	29854.22	701245.22	446145.81	8.75
Carbon offsetting	542	1012	7.24	0	1.98	0.5132	133549.693	35693.9393	74161.5299	-17704.823	-16598.42	48.60	37.00	211680.00	81300.00	219964.20	512944.20	-4.65	3.27	0.22	1.12	-0.04	100.18	34140.02	801914.30	483980.10	9.55

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	109	213	21	24.675	1.98	0.238	28108.7793	68675.2667	1695.68	5462.45874	8220.0587	50.40	38.40	219600.00	16350.00	35205.88	271155.88	16.34	0.69	0.04	1.2	18.27	24.86	9321.54	218953.49	142807.61	8.35
50	292	427	14	16.45	1.98	0.378	56349.5247	53315.7105	14577.0416	-1362.4485	555.15151	50.40	38.40	219600.00	43800.00	75847.06	339247.06	10.10	1.38	0.12	1.2	12.80	47.36	16986.45	398994.34	254757.28	8.7
75	535	640	7	8.225	1.98	0.518	84458.304	44755.5418	33894.5163	-7505.9315	-6428.331	50.40	38.40	219600.00	80250.00	116488.24	416338.24	3.93	2.07	0.22	1.2	7.42	69.51	23969.93	563029.23	341701.00	9.5
75-100	535	853	7	0	1.98	0.518	112567.083	38839.5238	56318.4136	-13419.022	-12341.42	50.40	38.40	219600.00	80250.00	157129.41	456979.41	-1.02	2.75	0.22	1.2	3.15	87.06	29883.02	701921.70	439952.29	9
Carbon offsetting	535	1015	7	0	1.98	0.518	133945.592	35638.4955	74501.1561	-17785.273	-16707.67	50.40	38.40	219600.00	80250.00	220616.27	520466.27	-4.76	3.28	0.22	1.2	-0.07	100.29	34249.27	804480.49	479024.22	9.75

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	107	213	20.2	24.675	1.98	0.254	28108.7793	68675.2667	1695.68	5462.45874	8124.0587	52.20	39.00	225360.00	16050.00	35205.88	276615.88	16.19	0.69	0.04	1.3	18.22	25.06	9417.54	221208.43	139602.55	8.85
50	288	427	13.52	16.45	1.98	0.3876	56349.5247	53315.7105	14577.0416	-1362.4485	497.55151	52.20	39.00	225360.00	43200.00	75847.06	344407.06	10.02	1.38	0.12	1.3	12.81	47.32	17044.05	400347.31	250950.25	9
75	527	640	6.76	8.225	1.98	0.5228	84458.304	44755.5418	33894.5163	-7505.9315	-6457.131	52.20	39.00	225360.00	79050.00	116488.24	420898.24	3.89	2.07	0.22	1.3	7.47	69.29	23998.73	563705.71	337817.48	9.65
75-100	527	853	6.76	0	1.98	0.5228	112567.083	38839.5238	56318.4136	-13419.022	-12370.22	52.20	39.00	225360.00	79050.00	157129.41	461539.41	-1.07	2.75	0.22	1.3	3.20	86.84	29911.82	702598.19	436068.77	9.15
Carbon offsetting	527	1017	6.76	0	1.98	0.5228	134341.49	35583.0517	74740.7824	-17861.224	-16812.42	52.20	39.00	225360.00	79050.00	221268.34	525678.34	-4.86	3.28	0.22	1.3	-0.06	100.26	34354.02	806940.97	476272.63	9.9

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	106	213	18.6	24.675	1.98	0.286	28108.7793	68675.2667	1695.68	5462.45874	7932.0587	63.00	43.00	261000.00	15900.00	35205.88	312105.88	15.90	0.69	0.04	1.84	18.47	24.06	9609.54	225718.32	108622.44	12.6
50	286	427	12.4	16.45	1.98	0.41	56349.5247	53315.7105	14577.0416	-1362.4485	363.15151	63.00	43.00	261000.00	42900.00	75847.06	379747.06	9.81	1.38	0.12	1.84	13.14	45.96	17178.45	403504.23	218767.17	11.1
75	524	640	6.2	8.225	1.98	0.534	84458.304	44755.5418	33894.5163	-7505.9315	-6524.331	63.00	43.00	261000.00	78600.00	116488.24	456088.24	3.78	2.07	0.21	1.84	7.90	67.50	24065.93	565284.17	304205.94	11.15
75-100	524	853	6.2	0	1.98	0.534	112567.083	38839.5238	56318.4136	-13419.022	-12437.42	63.00	43.00	261000.00	78600.00	157129.41	496729.41	-1.17	2.75	0.21	1.84	3.63	85.06	29979.02	704176.64	402457.23	10.35
Carbon offsetting	524	1037	6.2	0	1.98	0.534	136848.846	35231.9078	76991.7489	-18375.244	-17393.64	63.00	43.00	261000.00	78600.00	225398.10	564998.10	-5.42	3.35	0.21	1.84	-0.02	100.07	34935.24	820593.24	450605.14	10.9

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	105	213	18.17	24.675	1.98	0.2946	28108.7793	68675.2667	1695.68	5462.45874	7880.4587	66.60	44.70	273870.00	15750.00	35205.88	324825.88	15.82	0.69	0.04	2	18.55	23.73	9661.14	226930.35	97114.47	13.9
50	284	427	12.11	16.45	1.98	0.4158	56349.5247	53315.7105	14577.0416	-1362.4485	328.35151	66.60	44.70	273870.00	42600.00	75847.06	392317.06	9.75	1.38	0.12	2	13.25	45.52	17213.25	404321.64	207014.58	11.8
75	521	640	6.05	8.225	1.98	0.537	84458.304	44755.5418	33894.5163	-7505.9315	-6542.331	66.60	44.70	273870.00	78150.00	116488.24	468508.24	3.75	2.07	0.21	2	8.03	66.97	24083.93	565706.97	292208.74	11.7
75-100	521	853	6.05	0	1.98	0.537	112567.083	38839.5238	56318.4136	-13419.022	-12455.42	66.60	44.70	273870.00	78150.00	157129.41	509149.41	-1.20	2.75	0.21	2	3.77	84.52	29997.02	704599.45	390460.03	10.75
Carbon offsetting	521	1045	6.05	0	1.98	0.537	137904.575	35084.0577	77897.4189	-18589.779	-17626.18	66.60	44.70	273870.00	78150.00	227136.95	579156.95	-5.63	3.37	0.21	2	-0.05	100.19	35167.78	826055.25	441908.30	11.25

Table B. 8 Retail shed – PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) +TSC

Retail shed -London
PV (future FiT)+Insulation+TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25%	130	213	24.675	24.675	1.98	0.1645	28108.779	68675.2667	1695.68	9538.2317	12736.832	43.70	35.00	195010.00	19500.00	35205.88	249715.88	17.02	0.69	0.05	0.80	18.56	23.66	4804.77	112859.10	58153.22	11.75
50%	345	427	16.45	16.45	1.98	0.329	56349.525	53315.7105	14577.04	6808.2326	9019.8326	43.70	35.00	195010.00	51750.00	75847.06	322607.06	10.56	1.38	0.14	0.80	12.88	47.04	8521.77	200167.62	72570.56	15.6
75%	595	640	8.225	8.225	1.98	0.4935	84458.304	44755.5418	33894.52	4740.5226	5965.1226	43.70	35.00	195010.00	89250.00	116488.24	400748.24	4.16	2.07	0.24	0.80	7.27	70.12	11576.48	271919.64	66181.41	18.6
75-100	595	853	8.225	0	1.98	0.4935	112567.08	38839.5238	56318.41	2903.2047	4127.8047	43.70	35.00	195010.00	89250.00	157129.41	441389.41	-0.80	2.75	0.24	0.80	3.00	87.67	13413.80	315076.36	68696.95	19.25
75-100 (2)	595	853	8.225	0	1.98	0.4935	112567.08	38839.5238	56318.41	-194.308	1030.292	43.70	35.00	195010.00	89250.00	157129.41	441389.41	-0.80	2.75	0.24	0.80	3.00	87.67	16511.31	387833.78	141454.37	
Carbon offsetting	595	1003	8.225	0	1.98	0.4935	132362	35860.2706	73242.65	1724.5186	2949.1186	43.70	35.00	195010.00	89250.00	218008.00	502268.00	-4.28	3.24	0.24	0.80	0.00	99.99	14592.48	342762.50	35504.50	22.25
Carbon offsetting	595	1003	8.225	0	1.98	0.4935	132362	35860.2706	73242.65	-2303.827	-1079.227	43.70	35.00	195010.00	89250.00	218008.00	502268.00	-4.28	3.24	0.24	0.80	0.00	99.99	18620.83	437384.23	130126.23	17.25

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	115	213	23.92	24.675	1.98	0.1796	28108.779	68675.2667	1695.68	9538.2317	12646.232	44.30	35.70	198280.00	17250.00	35205.88	250735.88	16.88	0.69	0.05	0.88	18.50	23.94	4895.37	114987.21	59261.32	11.75
50	315	427	15.95	16.45	1.98	0.339	56349.525	53315.7105	14577.04	6808.2326	8959.8326	44.30	35.70	198280.00	47250.00	75847.06	321377.06	10.47	1.38	0.13	0.88	12.85	47.15	8581.77	201576.96	75209.90	15.3
75	560	640	7.97	8.225	1.98	0.4986	84458.304	44755.5418	33894.52	4740.5226	5934.5226	44.30	35.70	198280.00	84000.00	116488.24	398768.24	4.11	2.07	0.23	0.88	7.29	70.04	11607.08	272638.40	68880.17	18.4
75-100	560	853	7.97	0	1.98	0.4986	112567.08	38839.5238	56318.41	2903.2047	4097.2047	44.30	35.70	198280.00	84000.00	157129.41	439409.41	-0.84	2.75	0.23	0.88	3.02	87.59	13444.40	315795.13	71395.71	19.1
75-100 (2)	560	853	7.97	0	1.98	0.4986	112567.08	38839.5238	56318.41	-194.308	999.69198	44.30	35.70	198280.00	84000.00	157129.41	439409.41	-0.84	2.75	0.23	0.88	3.02	87.59	16541.91	388552.54	144153.13	
Carbon offsetting	560	1006	7.97	0	1.98	0.4986	132757.9	35804.8269	73482.28	1705.9733	2899.9733	44.30	35.70	198280.00	84000.00	218660.06	500940.06	-4.38	3.25	0.23	0.88	-0.02	100.09	14641.63	343916.87	37986.81	22.1
Carbon offsetting	560	1006	7.97	0	1.98	0.4986	132757.9	35804.8269	73482.28	-2335.552	-1141.552	44.30	35.70	198280.00	84000.00	218660.06	500940.06	-4.38	3.25	0.23	0.88	-0.02	100.09	18683.15	438848.18	132918.11	17.1

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	113	213	22.6	24.675	1.98	0.206	28108.779	68675.2667	1695.68	9538.2317	12487.832	45.00	36.40	201780.00	16950.00	35205.88	253935.88	16.64	0.69	0.05	0.96	18.33	24.62	5053.77	118707.86	59781.98	12
50	305	427	15.21	16.45	1.98	0.3538	56349.525	53315.7105	14577.04	6808.2326	8871.0326	45.00	36.40	201780.00	45750.00	75847.06	323377.06	10.33	1.38	0.13	0.96	12.79	47.40	8670.57	203662.78	75295.72	15.4
75	551	640	7.55	8.225	1.98	0.507	84458.304	44755.5418	33894.52	4740.5226	5884.1226	45.00	36.40	201780.00	82650.00	116488.24	400918.24	4.03	2.07	0.23	0.96	7.28	70.05	11657.48	273822.25	67914.01	18.5
75-100	551	853	7.55	0	1.98	0.507	112567.08	38839.5238	56318.41	2903.2047	4046.8047	45.00	36.40	201780.00	82650.00	157129.41	441559.41	-0.92	2.75	0.23	0.96	3.02	87.60	13494.80	316978.97	70429.56	19.2
75-100 (2)	551	853	7.55	0	1.98	0.507	112567.08	38839.5238	56318.41	-194.308	949.29198	45.00	36.40	201780.00	82650.00	157129.41	441559.41	-0.92	2.75	0.23	0.96	3.02	87.60	16592.31	389736.38	143186.97	
Carbon offsetting	551	1006	7.55	0	1.98	0.507	132757.9	35804.8269	73482.28	1705.9733	2849.5733	45.00	36.40	201780.00	82650.00	218660.06	503090.06	-4.45	3.25	0.23	0.96	-0.02	100.09	14692.03	345100.72	37020.65	22.15
Carbon offsetting	551	1006	7.55	0	1.98	0.507	132757.9	35804.8269	73482.28	-2335.552	-1191.952	45.00	36.40	201780.00	82650.00	218660.06	503090.06	-4.45	3.25	0.23	0.96	-0.02	100.09	18733.55	440032.02	131951.96	17.2

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	112	213	21.72	24.675	1.98	0.2236	28108.779	68675.2667	1695.68	9538.2317	12382.232	48.60	37.00	211680.00	16800.00	35205.88	263685.88	16.47	0.69	0.05	1.12	18.33	24.63	5159.37	121188.30	52512.41	13.75
50	295	427	14.18	16.45	1.98	0.3744	56349.525	53315.7105	14577.04	6808.2326	8747.4326	48.60	37.00	211680.00	44250.00	75847.06	331777.06	10.14	1.38	0.12	1.12	12.76	47.54	8794.17	206566.02	69798.96	16.25
75	542	640	7.24	8.225	1.98	0.5132	84458.304	44755.5418	33894.52	4740.5226	5846.9226	48.60	37.00	211680.00	81300.00	116488.24	409468.24	3.98	2.07	0.22	1.12	7.38	69.64	11694.68	274696.04	60237.80	19.25
75-100	542	853	7.24	0	1.98	0.5132	112567.08	38839.5238	56318.41	2903.2047	4009.6047	48.60	37.00	211680.00	81300.00	157129.41	450109.41	-0.98	2.75	0.22	1.12	3.11	87.19	13532.00	317852.76	62753.35	19.8
75-100 (2)	542	853	7.24	0	1.98	0.5132	112567.08	38839.5238	56318.41	-194.308	912.09198	48.60	37.00	211680.00	81300.00	157129.41	450109.41	-0.98	2.75	0.22	1.12	3.11	87.19	16629.51	390610.17	135510.76	
Carbon offsetting	542	1012	7.24	0	1.98	0.5132	133549.69	35693.9393	74161.53	1659.8827	2766.2827	48.60	37.00	211680.00	81300.00	219964.20	512944.20	-4.65	3.27	0.22	1.12	-0.04	100.18	14775.32	347057.13	29122.93	22.75
Carbon offsetting	542	1012	7.24	0	1.98	0.5132	133549.69	35693.9393	74161.53	-2419.001	-1312.601	48.60	37.00	211680.00	81300.00	219964.20	512944.20	-4.65	3.27	0.22	1.12	-0.04	100.18	18854.20	442865.95	124931.75	17.65

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	109	213	21	24.675	1.98	0.238	28108.779	68675.2667	1695.68	9538.2317	12295.832	50.40	38.40	219600.00	16350.00	35205.88	271155.88	16.34	0.69	0.04	1.2	18.27	24.86	5245.77	123217.74	47071.86	15.1
50	292	427	14	16.45	1.98	0.378	56349.525	53315.7105	14577.04	6808.2326	8725.8326	50.40	38.40	219600.00	43800.00	75847.06	339247.06	10.10	1.38	0.12	1.2	12.80	47.36	8815.77	207073.38	62836.32	17.1
75	535	640	7	8.225	1.98	0.518	84458.304	44755.5418	33894.52	4740.5226	5818.1226	50.40	38.40	219600.00	80250.00	116488.24	416338.24	3.93	2.07	0.22	1.2	7.42	69.51	11723.48	275372.52	54044.29	19.85
75-100	535	853	7	0	1.98	0.518	112567.08	38839.5238	56318.41	2903.2047	3980.8047	50.40	38.40	219600.00	80250.00	157129.41	456979.41	-1.02	2.75	0.22	1.2	3.15	87.06	13560.80	318529.24	56559.83	20.35
75-100 (2)	535	853	7	0	1.98	0.518	112567.08	38839.5238	56318.41	-194.308	883.29198	50.40	38.40	219600.00	80250.00	157129.41	456979.41	-1.02	2.75	0.22	1.2	3.15	87.06	16658.31	391286.66	129317.25	
Carbon offsetting	535	1015	7	0	1.98	0.518	133945.59	35638.4955	74501.16	1636.8373	2714.4373	50.40	38.40	219600.00	80250.00	220616.27	520466.27	-4.76	3.28	0.22	1.2	-0.07	100.29	14827.16	348274.92	22818.65	23.25
Carbon offsetting	535	1015	7	0	1.98	0.518	133945.59	35638.4955	74501.16	-2460.726	-1383.126	50.40	38.40	219600.00	80250.00	220616.27	520466.27	-4.76	3.28	0.22	1.2	-0.07	100.29	18924.73	444522.51	119066.24	18

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	107	213	20.2	24.675	1.98	0.254	28108.779	68675.2667	1695.68	9538.2317	12199.832	52.20	39.00	225360.00	16050.00	35205.88	276615.88	16.19	0.69	0.04	1.3	18.22	25.06	5341.77	125472.69	43866.80	16
50	288	427	13.52	16.45	1.98	0.3876	56349.525	53315.7105	14577.04	6808.2326	8668.2326	52.20	39.00	225360.00	43200.00	75847.06	344407.06	10.02	1.38	0.12	1.3	12.81	47.32	8873.37	208426.35	59029.29	17.65
75	527	640	6.76	8.225	1.98	0.5228	84458.304	44755.5418	33894.52	4740.5226	5789.3226	52.20	39.00	225360.00	79050.00	116488.24	420898.24	3.89	2.07	0.22	1.3	7.47	69.29	11752.28	276049.00	50160.77	20.25
75-100	527	853	6.76	0	1.98	0.5228	112567.08	38839.5238	56318.41	2903.2047	3952.0047	52.20	39.00	225360.00	79050.00	157129.41	461539.41	-1.07	2.75	0.22	1.3	3.20	86.84	13589.60	319205.73	52676.31	20.7
75-100 (2)	527	853	6.76	0	1.98	0.5228	112567.08	38839.5238	56318.41	-194.308	854.49198	52.20	39.00	225360.00	79050.00	157129.41	461539.41	-1.07	2.75	0.22	1.3	3.20	86.84	16687.11	391963.14	125433.73	
Carbon offsetting	527	1017	6.76	0	1.98	0.5228	134341.49	35583.0517	74740.78	1618.292	2667.092	52.20	39.00	225360.00	79050.00	221268.34	525678.34	-4.86	3.28	0.22	1.3	-0.06	100.26	14874.51	349387.01	18718.68	23.55
Carbon offsetting	527	1017	6.76	0	1.98	0.5228	134341.49	35583.0517	74740.78	-2492.451	-1443.651	52.20	39.00	225360.00	79050.00	221268.34	525678.34	-4.86	3.28	0.22	1.3	-0.06	100.26	18985.25	445944.17	115275.84	18.25

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	106	213	18.6	24.675	1.98	0.286	28108.779	68675.2667	1695.68	9538.2317	12007.832	63.00	43.00	261000.00	15900.00	35205.88	312105.88	15.90	0.69	0.04	1.84	18.47	24.06	5533.77	129982.57	12886.69	22.5
50	286	427	12.4	16.45	1.98	0.41	56349.525	53315.7105	14577.04	6808.2326	8533.8326	63.00	43.00	261000.00	42900.00	75847.06	379747.06	9.81	1.38	0.12	1.84	13.14	45.96	9007.77	211583.26	26846.21	21.65
75	524	640	6.2	8.225	1.98	0.534	84458.304	44755.5418	33894.52	4740.5226	5722.1226	63.00	43.00	261000.00	78600.00	116488.24	456088.24	3.78	2.07	0.21	1.84	7.90	67.50	11819.48	277627.46	16549.23	23.45
75-100	524	853	6.2	0	1.98	0.534	112567.08	38839.5238	56318.41	2903.2047	3884.8047	63.00	43.00	261000.00	78600.00	157129.41	496729.41	-1.17	2.75	0.21	1.84	3.63	85.06	13656.80	320784.19	19064.77	23.45
75-100 (2)	524	853	6.2	0	1.98	0.534	112567.08	38839.5238	56318.41	-194.308	787.29198	63.00	43.00	261000.00	78600.00	157129.41	496729.41	-1.17	2.75	0.21	1.84	3.63	85.06	16754.31	393541.60	91822.19	
Carbon offsetting	524	1037	6.2	0	1.98	0.534	136848.85	35231.9078	76991.75	1467.8384	2449.4384	63.00	43.00	261000.00	78600.00	225398.10	564998.10	-5.42	3.35	0.21	1.84	-0.02	100.07	15092.16	354499.48	-15488.62	26.15
Carbon offsetting	524	1037	6.2	0	1.98	0.534	136848.85	35231.9078	76991.75	-2766.708	-1785.108	63.00	43.00	261000.00	78600.00	225398.10	564998.10	-5.42	3.35	0.21	1.84	-0.02	100.07	19326.71	453964.65	83976.55	20.15

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	43.70	35.00	195010.00	0.00	0.00	195010.00	23.52	0.00	0.00	0.80	24.32	0.00	0.00	0.00	0.00	0
25	105	213	18.17	24.675	1.98	0.2946	28108.779	68675.2667	1695.68	9538.2317	11956.232	66.60	44.70	273870.00	15750.00	35205.88	324825.88	15.82	0.69	0.04	2	18.55	23.73	5585.37	131194.60	1378.72	24.7
50	284	427	12.11	16.45	1.98	0.4158	56349.525	53315.7105	14577.04	6808.2326	8499.0326	66.60	44.70	273870.00	42600.00	75847.06	392317.06	9.75	1.38	0.12	2	13.25	45.52	9042.57	212400.68	15093.62	23.15
75	521	640	6.05	8.225	1.98	0.537	84458.304	44755.5418	33894.52	4740.5226	5704.1226	66.60	44.70	273870.00	78150.00	116488.24	468508.24	3.75	2.07	0.21	2	8.03	66.97	11837.48	278050.26	4552.03	24.55
75-100	521	853	6.05	0	1.98	0.537	112567.08	38839.5238	56318.41	2903.2047	3866.8047	66.60	44.70	273870.00	78150.00	157129.41	509149.41	-1.20	2.75	0.21	2	3.77	84.52	13674.80	321206.99	7067.58	24.4
75-100 (2)	521	853	6.05	0	1.98	0.537	112567.08	38839.5238	56318.41	-194.308	769.29198	66.60	44.70	273870.00	78150.00	157129.41	509149.41	-1.20	2.75	0.21	2	3.77	84.52	16772.31	393964.40	79824.99	
Carbon offsetting	521	1045	6.05	0	1.98	0.537	137904.57	35084.0577	77897.42	1406.3842	2369.9842	66.60	44.70	273870.00	78150.00	227136.95	579156.95	-5.63	3.37	0.21	2	-0.05	100.19	15171.62	356365.77	-27781.17	27.1
Carbon offsetting	521	1045	6.05	0	1.98	0.537	137904.57	35084.0577	77897.42	-2877.974	-1914.374	66.60	44.70	273870.00	78150.00	227136.95	579156.95	-5.63	3.37	0.21	2	-0.05	100.19	19455.97	457000.97	72854.03	20.8

Table B. 9 Office - PV (curren FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – not taking into account the rental loss/gain

Office-London
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	7144.85	167825.31	132656.49	5
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	13726.02	322410.16	252072.52	5.2
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	19494.74	457911.44	352404.97	5.5
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	24883.30	584483.34	443808.05	5.75
Carbon offsetting	964	18.73	0	3.51	127215.3204	20513.36376	62294.1	-18377.6	-16064.625	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	30334.99	712537.85	503006.73	7

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	7215.57	169486.46	132830.83	5.15
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	13796.74	324071.30	252246.86	5.3
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	19565.46	459572.58	352579.31	5.55
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	24954.02	586144.48	443982.39	5.8
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-18270.1	-16027.867	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	30298.23	711674.45	501525.96	7.1

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	7319.57	171929.31	133614.69	5.3
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	13900.74	326514.16	253030.71	5.4
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	19669.46	462015.43	353363.16	5.6
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	25058.02	588587.34	444766.24	5.85
Carbon offsetting	954	17.05	0	3.51	125895.6594	20701.29836	61160.05	-18108.9	-15970.651	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	30241.01	710330.49	499827.14	7.1

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	7377.81	173297.31	128394.68	6.15
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	13958.98	327882.16	247810.71	5.85
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	19727.70	463383.43	348143.16	5.95
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	25116.26	589955.33	439546.24	6.1
Carbon offsetting	952	16.49	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-15975.152	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	30245.51	710436.22	493779.58	7.3

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	7428.77	174494.31	125584.88	6.75
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	14009.94	329079.15	245000.91	6.1
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	19778.66	464580.43	345333.36	6.15
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	25167.22	591152.33	436736.44	6.25
Carbon offsetting	949	16	0	3.51	125103.8628	20814.05912	60479.62	-17947.7	-15918.635	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	30188.99	709108.68	489314.66	7.45

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	7478.69	175666.88	123269.05	7.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	14059.86	330251.72	242685.08	6.35
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	19828.58	465753.00	343017.53	6.3
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	25217.14	592324.90	434420.61	6.4
Carbon offsetting	946	15.52	0	3.51	124839.9306	20851.64604	60252.81	-17893.9	-15914.816	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	30185.18	709018.98	486171.27	7.55

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	7532.77	176937.16	103349.74	10
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	14113.94	331522.01	222765.76	7.85
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	19882.66	467023.28	323098.21	7.4
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	25271.22	593595.19	414501.29	7.25
Carbon offsetting	959	15.52	0	3.51	126555.4899	20614.05106	61750.92	-18243.4	-16264.25	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	30534.61	717226.84	470363.90	8.25

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	7615.97	178891.44	98003.22	11
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	14197.14	333476.29	217419.24	8.35
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	19965.86	468977.57	317751.70	7.75
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	25354.42	595549.47	409154.78	7.5
Carbon offsetting	952	14.2	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-16213.312	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	30483.67	716030.36	463388.11	8.5

Table B. 10 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – not taking into account the rental loss/gain

Office-London
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	3509.19	82427.23	47258.41	10.25
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	6416.42	150715.06	80377.42	11.25
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	8530.33	200368.79	94862.32	12.75
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	10264.10	241093.14	100417.85	14.25
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1781.3295	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	1.44	5.54	74.84	12489.03	293354.58	152679.29	15.25
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	68.636402	2381.5964	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	11888.76	279254.93	69723.81	18.5
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	-3357.539	-1044.579	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	15314.94	359732.29	150201.18	14.15

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	3579.91	84088.37	47432.75	10.5
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	6487.14	152376.20	80551.76	11.5
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	8601.05	202029.93	95036.66	12.85
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	10334.82	242754.28	100592.19	14.3
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1710.6095	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	1.48	5.45	75.25	12559.75	295015.72	152853.63	15.3
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	99.573646	2341.8136	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	11928.55	280189.38	70040.89	18.5
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-3301.653	-1059.413	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	15329.77	360080.72	149932.23	14.25

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	3683.91	86531.22	48216.60	10.75
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	6591.14	154819.06	81335.61	11.5
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	8705.05	204472.79	95820.51	12.9
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	10438.82	245197.14	101376.04	14.3
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1606.6095	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	1.52	5.30	75.96	12663.75	297458.58	153637.48	15.3
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	145.97951	2284.2195	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	11986.14	281542.21	71038.85	18.4
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	-3217.823	-1079.583	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	15349.94	360554.50	150051.15	14.25

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	3742.15	87899.22	42996.60	12.5
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	6649.38	156187.06	76115.61	12.5
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	8763.29	205840.78	90600.51	13.65
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	10497.06	246565.14	96156.04	14.85
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1548.3695	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	1.61	5.28	76.05	12721.99	298826.57	148417.48	15.85
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	161.44814	2241.4481	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	12028.91	282546.87	65890.22	18.9
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1109.88	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	15380.24	361266.15	144609.50	14.65

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	3793.11	89096.22	40186.80	13.25
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	6700.34	157384.06	73305.81	13
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	8814.25	207037.78	87790.71	14
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	10548.02	247762.14	93346.24	15.2
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1497.4095	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	1.65	5.22	76.31	12772.95	300023.57	145607.68	16.2
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	192.38538	2221.4254	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	12048.93	283017.18	63223.16	19.15
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	-3133.994	-1104.954	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	15375.31	361150.43	141356.41	14.85

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	3843.03	90268.79	37870.97	14.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	6750.26	158556.63	70989.98	13.5
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	8864.17	208210.35	85474.88	14.35
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	10597.94	248934.71	91030.41	15.5
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1447.4895	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	1.7	5.18	76.51	12822.87	301196.14	143291.85	16.5
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	207.854	2186.974	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	12083.39	283826.41	60978.70	19.35
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	-3106.051	-1126.931	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	15397.29	361666.64	138818.93	15

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	3897.11	91539.07	17951.65	19.75
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	6804.34	159826.91	51070.66	16.75
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	8918.25	209480.64	65555.57	16.85
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	10652.02	250204.99	71111.09	17.6
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1393.4095	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	2	5.37	75.61	12876.95	302466.43	123372.53	18.6
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	107.17569	2086.2957	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	12184.06	286191.24	39328.30	21.4
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	-3289.125	-1310.005	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	15580.36	365966.88	119103.94	16.5

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	3980.31	93493.36	12605.13	21.5
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	6887.54	161781.19	45724.15	17.65
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	9001.45	211434.92	60209.05	17.55
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	10735.22	252159.27	65764.58	18.2
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1310.2095	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	2.09	5.31	75.91	12960.15	304420.71	118026.02	19.2
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	161.44814	2003.2881	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	12267.07	288141.00	35498.76	21.75
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1348.04	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	15618.40	366860.28	114218.04	16.9

Table B. 11 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC – not taking into account the rental loss/gain

Office-London

PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	7632.61	179282.30	132863.48	6.2
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	14699.98	345287.49	244949.84	6.95
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	20955.94	492233.54	322977.07	8.25
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	26831.22	630238.00	392062.70	9.1
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.1629	-14568.5	-14203.48	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	28473.84	668821.38	392437.45	10

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	7685.65	180528.16	133072.53	6.3
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	14735.34	346118.06	246543.61	6.9
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	20973.62	492648.82	324155.55	8.2
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	26831.22	630238.00	393575.90	9.05
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.1049	-14623.1	-14258.04	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	28528.40	670103.12	394797.68	9.9

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	7763.65	182360.30	133695.67	6.4
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	14787.86	347351.70	248068.25	6.85
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	20999.62	493259.53	324607.26	8.2
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	26831.22	630238.00	394166.90	9
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-14677.7	-14312.61	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	28582.97	671384.87	396235.71	9.9

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	7807.33	183386.29	128583.67	7.15
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	14816.98	348035.70	243214.25	7.2
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	21014.18	493601.53	319561.26	8.5
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	26831.22	630238.00	389078.90	9.2
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-14777.8	-14412.75	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	28683.11	673736.96	392630.38	10.05

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	7844.77	184265.72	125906.30	7.6
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	14841.94	348621.99	240543.74	7.45
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	21026.66	493894.68	317347.61	8.6
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	26831.22	630238.00	386572.10	9.3
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.4021	-14809.6	-14444.53	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	28714.89	674483.53	390652.80	10.15

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	7882.21	185145.15	123747.33	8
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	14866.90	349208.27	238241.62	7.65
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	21039.14	494187.82	314902.35	8.75
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	26831.22	630238.00	383983.70	9.4
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.3441	-14868.6	-14503.6	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	28773.96	675870.98	389017.13	10.25

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	7922.77	186097.86	103960.44	10.65
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	14893.94	349843.41	218137.17	9.05
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	21052.66	494505.39	294930.32	9.75
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	26831.22	630238.00	363844.10	10.2
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	29128.65	684202.32	374383.25	10.95

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	7985.17	187563.57	98425.35	11.55
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	14935.54	350820.55	212263.51	9.5
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	21073.46	494993.96	289018.09	10.05
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	26831.22	630238.00	357593.30	10.45
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.4094	-15282.4	-14917.36	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	29187.72	685589.77	369085.18	11.15

Table B. 12 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC – not taking into account the rental loss/gain

Office-London
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	3996.95	93884.21	47465.39	12
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	7390.38	173592.39	73254.74	14.1
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	9991.53	234690.89	65434.42	17.75
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	12212.02	286847.80	48672.50	20.55
200%	650	764	0	0	4.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	1.44	2.38	89.22	14436.95	339109.23	100933.94	
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	1179.658	1544.6976	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	12725.66	298912.83	22528.90	23
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	-1391.77	-1026.726	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	15297.09	359312.95	82929.02	18.95

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	4049.99	95130.07	47674.45	12.1
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	7425.74	174422.96	74848.51	13.9
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	10009.21	235106.17	66612.90	17.6
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	12212.02	286847.80	50185.70	20.4
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	14436.95	339109.23	102447.14	20.4
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	1163.36	1528.3998	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	12741.96	299295.64	23990.20	22.9
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	-1420	-1054.956	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	15325.32	359976.03	84670.59	18.85

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	4127.99	96962.21	48297.59	12.15
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	7478.26	175656.60	76373.16	13.75
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	10035.21	235716.89	67064.62	17.55
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	12212.02	286847.80	50776.70	20.35
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	14436.95	339109.23	103038.14	20.35
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	1147.062	1512.102	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	12758.26	299678.46	24529.31	22.85
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-1448.23	-1083.186	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	15353.55	360639.12	85489.96	18.8

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	4171.67	97988.21	43185.58	13.6
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	7507.38	176340.60	71519.15	14.5
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	10049.77	236058.89	62018.62	18.15
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	12212.02	286847.80	45688.70	20.8
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	14436.95	339109.23	97950.14	20.8
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	1123.466	1488.5065	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	12781.85	300232.70	19126.12	23.3
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-1484.68	-1119.645	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	15390.00	361495.51	80388.93	19.2

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	4209.11	98867.64	40508.21	14.4
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	7532.34	176926.89	68848.64	14.9
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	10062.25	236352.03	59804.96	18.4
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	12212.02	286847.80	43181.90	21.05
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	14436.95	339109.23	95443.34	21.05
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	1110.818	1475.8576	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	12794.50	300529.81	16699.07	23.55
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	-1508.8	-1143.76	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	15414.12	362061.94	78231.21	19.35

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	4246.55	99747.06	38349.24	15
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	7557.30	177513.17	66546.52	15.3
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	10074.73	236645.17	57359.70	18.65
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	12212.02	286847.80	40593.50	21.25
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	14436.95	339109.23	92854.94	21.25
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	1090.02	1455.0598	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	12815.30	301018.32	14164.48	23.75
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	-1547.03	-1181.989	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	15452.35	362959.91	76106.07	19.5

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	4287.11	100699.78	18562.35	20.15
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	7584.34	178148.31	46442.07	18.2
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	10088.25	236962.74	37387.67	20.85
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	12212.02	286847.80	20453.90	23.15
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	14436.95	339109.23	72715.34	23.15
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	12921.24	303506.64	-6312.43	25.55
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	15635.84	367269.96	57450.89	20.9

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	4349.51	102165.49	13027.26	21.6
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	7625.94	179125.45	40568.41	19.1
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	10109.05	237451.31	31475.44	21.5
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	12212.02	286847.80	14203.10	23.7
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	-531.63	-166.5905	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	14436.95	339109.23	66464.54	23.7
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	963.2865	1328.3265	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	12942.03	303995.16	-12509.42	26.1
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	-1768.75	-1403.711	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	15674.07	368167.93	51663.35	21.3

Table B. 13 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – taking into account the rental loss/gain- City

Office-London (City)
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	88119.66	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	7144.85	88119.66	167825.31	132656.49	5
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	13726.02	88119.66	322410.16	252072.52	5.2
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	19494.74	88119.66	457911.44	352404.97	5.5
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	24883.30	88119.66	584483.34	443808.05	5.75
Carbon offsetting	964	18.73	0	3.51	127215.3204	20513.36376	62294.1	-18377.6	-16064.625	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	30334.99	88119.66	712537.85	503006.73	7

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	7215.57	90400.00	131903.00	95247.38	5.15
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	13796.74	90400.00	286487.85	214663.40	5.3
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	19565.46	90400.00	421989.12	314995.85	5.55
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	24954.02	90400.00	548561.03	406398.93	5.8
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-18270.1	-16027.867	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	30298.23	90400.00	674090.99	463942.50	7.1

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	7319.57	96050.00	41225.29	2910.67	5.3
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	13900.74	96050.00	195810.14	122326.70	5.4
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	19669.46	96050.00	331311.42	222659.15	5.6
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	25058.02	96050.00	457883.32	314062.23	5.85
Carbon offsetting	954	17.05	0	3.51	125895.6594	20701.29836	61160.05	-18108.9	-15970.651	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	30241.01	96050.00	579626.48	369123.12	7.1

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	7377.81	101700.00	-50527.26	-95429.89	6.15
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	13958.98	101700.00	104057.58	23986.14	5.85
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	19727.70	101700.00	239558.86	124318.59	5.95
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	25116.26	101700.00	366130.76	215721.67	6.1
Carbon offsetting	952	16.49	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-15975.152	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	30245.51	101700.00	486611.65	269955.01	7.3

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	7428.77	107350.00	-142450.82	-191360.25	6.75
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	14009.94	107350.00	12134.02	-71944.22	6.1
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	19778.66	107350.00	147635.30	28388.23	6.15
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	25167.22	107350.00	274207.20	119791.31	6.25
Carbon offsetting	949	16	0	3.51	125103.8628	20814.05912	60479.62	-17947.7	-15918.635	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	30188.99	107350.00	392163.55	172369.53	7.45

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	7478.69	115825.00	-280959.09	-333356.91	7.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	14059.86	115825.00	-126374.24	-213940.89	6.35
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	19828.58	115825.00	9127.03	-113608.44	6.3
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	25217.14	115825.00	135698.94	-22205.36	6.4
Carbon offsetting	946	15.52	0	3.51	124839.9306	20851.64604	60252.81	-17893.9	-15914.816	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	30185.18	115825.00	252393.02	29545.31	7.55

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	7532.77	138142.50	-647515.01	-721102.43	10
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	14113.94	138142.50	-492930.16	-601686.41	7.85
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	19882.66	138142.50	-357428.88	-501353.95	7.4
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	25271.22	138142.50	-230856.98	-409950.87	7.25
Carbon offsetting	959	15.52	0	3.51	126555.4899	20614.05106	61750.92	-18243.4	-16264.25	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	30534.61	138142.50	-107225.33	-354088.26	8.25

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	7615.97	149273.00	-829008.22	-909896.45	11
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	14197.14	149273.00	-674423.37	-790480.42	8.35
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	19965.86	149273.00	-538922.10	-690147.97	7.75
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	25354.42	149273.00	-412350.20	-598744.89	7.5
Carbon offsetting	952	14.2	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-16213.312	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	30483.67	149273.00	-291869.31	-544511.55	8.5

Table B. 14 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – taking into account the rental loss/gain- City

Office-London (City)
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	88119.66	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	3509.19	88119.66	82427.23	47258.41	10.25
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	6416.42	88119.66	150715.06	80377.42	11.25
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	8530.33	88119.66	200368.79	94862.32	12.75
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	10264.10	88119.66	241093.14	100417.85	14.25
100% (2)	764	18.73	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1781.3295	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	12489.03	88119.66	293354.58	152679.29	14.25
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	68.636402	2381.5964	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	11888.76	88119.66	279254.93	69723.81	18.5
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	-3357.539	-1044.579	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	15314.94	88119.66	359732.29	150201.18	14.15

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	3579.91	90400.00	46504.91	9849.29	10.5
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	6487.14	90400.00	114792.75	42968.30	11.5
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	8601.05	90400.00	164446.47	57453.20	12.85
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	10334.82	90400.00	205170.83	63008.73	14.3
100% (2)	764	18.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1710.6095	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	12559.75	90400.00	257432.27	115270.17	14.3
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	99.573646	2341.8136	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	11928.55	90400.00	242605.93	32457.43	18.5
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-3301.653	-1059.413	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	15329.77	90400.00	322497.26	112348.77	14.25

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	3683.91	96050.00	-44172.79	-82487.41	10.75
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	6591.14	96050.00	24115.04	-49368.40	11.5
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	8705.05	96050.00	73768.77	-34883.50	12.9
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	10438.82	96050.00	114493.12	-29327.97	14.3
100% (2)	764	17.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1606.6095	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	12663.75	96050.00	166754.56	22933.47	14.3
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	145.97951	2284.2195	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	11986.14	96050.00	150838.20	-59665.16	18.4
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	-3217.823	-1079.583	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	15349.94	96050.00	229850.49	19347.13	14.25

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	3742.15	101700.00	-135925.35	-180827.97	12.5
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	6649.38	101700.00	-67637.51	-147708.96	12.5
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	8763.29	101700.00	-17983.79	-133224.06	13.65
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	10497.06	101700.00	22740.56	-127668.53	14.85
100% (2)	764	16.49	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1548.3695	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	12721.99	101700.00	75002.00	-75407.09	14.85
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	161.44814	2241.4481	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	12028.91	101700.00	58722.29	-157934.35	18.9
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1109.88	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	15380.24	101700.00	137441.57	-79215.07	14.65

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	3793.11	107350.00	-227848.91	-276758.33	13.25
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	6700.34	107350.00	-159561.07	-243639.32	13
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	8814.25	107350.00	-109907.35	-229154.42	14
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	10548.02	107350.00	-69182.99	-223598.89	15.2
100% (2)	764	16	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1497.4095	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	12772.95	107350.00	-16921.56	-171337.45	15.2
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	192.38538	2221.4254	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	12048.93	107350.00	-33927.95	-253721.97	19.15
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	-3133.994	-1104.954	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	15375.31	107350.00	44205.30	-175588.72	14.85

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	3843.03	115825.00	-366357.18	-418755.00	14.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	6750.26	115825.00	-298069.34	-385635.99	13.5
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	8864.17	115825.00	-248415.61	-371151.08	14.35
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	10597.94	115825.00	-207691.26	-365595.55	15.5
100% (2)	764	15.52	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1447.4895	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	12822.87	115825.00	-155429.82	-313334.12	15.5
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	207.854	2186.974	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	12083.39	115825.00	-172799.56	-395647.27	19.35
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	-3106.051	-1126.931	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	15397.29	115825.00	-94959.32	-317807.03	15

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	3897.11	138142.50	-732913.09	-806500.52	19.75
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	6804.34	138142.50	-664625.26	-773381.51	16.75
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	8918.25	138142.50	-614971.53	-758896.60	16.85
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	10652.02	138142.50	-574247.18	-753341.07	17.6
100% (2)	764	15	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1393.4095	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	12876.95	138142.50	-521985.74	-701079.63	17.6
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	107.17569	2086.2957	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	12184.06	138142.50	-538260.93	-785123.87	21.4
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	-3289.125	-1310.005	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	15580.36	138142.50	-458485.29	-705348.23	16.5

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	3980.31	149273.00	-914406.31	-995294.53	21.5
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	6887.54	149273.00	-846118.47	-962175.52	17.65
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	9001.45	149273.00	-796464.75	-947690.62	17.55
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	10735.22	149273.00	-755740.39	-942135.09	18.2
100% (2)	764	14.2	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1310.2095	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	12960.15	149273.00	-703478.96	-889873.65	18.2
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	161.44814	2003.2881	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	12267.07	149273.00	-719758.66	-972400.91	21.75
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1348.04	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	15618.40	149273.00	-641039.38	-893681.63	16.9

Table B. 15 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC – taking into account the rental loss/gain- City

Office-London (City)
PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	88119.66	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	7632.61	88119.66	179282.30	132863.48	6.2
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	14699.98	88119.66	345287.49	244949.84	6.95
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	20955.94	88119.66	492233.54	322977.07	8.25
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	26831.22	88119.66	630238.00	392062.70	9.1
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.1629	-14568.5	-14203.48	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	28473.84	88119.66	668821.38	392437.45	10

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	7685.65	90400.00	142944.70	95489.07	6.3
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	14735.34	90400.00	308534.60	208960.16	6.9
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	20973.62	90400.00	455065.36	286572.09	8.2
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	26831.22	90400.00	592654.54	355992.44	9.05
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.1049	-14623.1	-14258.04	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	28528.40	90400.00	632519.66	357214.22	9.9

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	7763.65	96050.00	51656.28	2991.66	6.4
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	14787.86	96050.00	216647.69	117364.24	6.85
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	20999.62	96050.00	362555.52	193903.25	8.2
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	26831.22	96050.00	499533.98	263462.89	9
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-14677.7	-14312.61	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	28582.97	96050.00	540680.85	265531.70	9.9

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	7807.33	101700.00	-40438.28	-95240.90	7.15
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	14816.98	101700.00	124211.13	19389.68	7.2
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	21014.18	101700.00	269776.96	95736.69	8.5
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	26831.22	101700.00	406413.42	165254.33	9.2
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-14777.8	-14412.75	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	28683.11	101700.00	449912.38	168805.81	10.05

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	7844.77	107350.00	-132679.41	-191038.83	7.6
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	14841.94	107350.00	31676.86	-76401.39	7.45
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	21026.66	107350.00	176949.55	402.48	8.6
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	26831.22	107350.00	313292.87	69626.97	9.3
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.4021	-14809.6	-14444.53	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	28714.89	107350.00	357538.40	73707.67	10.15

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	7882.21	115825.00	-271480.82	-332878.64	8
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	14866.90	115825.00	-107417.70	-218384.34	7.65
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	21039.14	115825.00	37561.85	-141723.62	8.75
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	26831.22	115825.00	173612.03	-72642.26	9.4
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.3441	-14868.6	-14503.6	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	28773.96	115825.00	219245.01	-67608.84	10.25

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	7922.77	138142.50	-638354.31	-720491.73	10.65
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	14893.94	138142.50	-474608.76	-606315.00	9.05
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	21052.66	138142.50	-329946.78	-529521.85	9.75
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	26831.22	138142.50	-194214.17	-460608.07	10.2
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	29128.65	138142.50	-140249.85	-450068.92	10.95

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	7985.17	149273.00	-820336.09	-909474.31	11.55
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	14935.54	149273.00	-657079.11	-795636.16	9.5
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	21073.46	149273.00	-512905.70	-718881.58	10.05
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	26831.22	149273.00	-377661.67	-650306.36	10.45
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.4094	-15282.4	-14917.36	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	29187.72	149273.00	-322309.90	-638814.48	11.15

Table B. 16 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 $W/m^2.K$ (mineral wool) + TSC – taking into account the rental loss/gain-City

Office-London (city)
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	88119.66	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	3996.95	88119.66	93884.21	47465.39	12
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	7390.38	88119.66	173592.39	73254.74	14.1
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	9991.53	88119.66	234690.89	65434.42	17.75
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	12212.02	88119.66	286847.80	48672.50	20.55
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	1179.658	1544.6976	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	12725.66	88119.66	298912.83	22528.90	23
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	-1391.77	-1026.726	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	15297.09	88119.66	359312.95	82929.02	18.95

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	4049.99	90400.00	57546.61	10090.99	21.1
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	7425.74	90400.00	136839.50	37265.06	18.35
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	10009.21	90400.00	197522.72	29029.45	21.3
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	12212.02	90400.00	249264.34	12602.25	23.75
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	1163.36	1528.3998	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	12741.96	90400.00	261712.19	-13593.26	26.25
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	-1420	-1054.956	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	15325.32	90400.00	275566.62	261.18	21.3

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	4127.99	96050.00	-33741.80	-82406.43	
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	7478.26	96050.00	44952.59	-54330.86	
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	10035.21	96050.00	105012.87	-63639.40	
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	12212.02	96050.00	156143.78	-79927.31	
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	1147.062	1512.102	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	12758.26	96050.00	168974.45	-106174.71	
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-1448.23	-1083.186	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	15353.55	96050.00	229935.10	-45214.05	

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	4171.67	101700.00	-125836.36	-180638.99	
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	7507.38	101700.00	-47483.97	-152305.42	
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	10049.77	101700.00	12234.31	-161805.96	
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	12212.02	101700.00	63023.23	-178135.87	
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	1123.466	1488.5065	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	12781.85	101700.00	76408.12	-204698.45	
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-1484.68	-1119.645	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	15390.00	101700.00	137670.94	-143435.64	

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	4209.11	107350.00	-218077.49	-276436.92	
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	7532.34	107350.00	-140018.24	-248096.49	
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	10062.25	107350.00	-80593.10	-257140.17	
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	12212.02	107350.00	-30097.33	-273763.23	
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	1110.818	1475.8576	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	12794.50	107350.00	-16415.32	-300246.06	
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	-1508.8	-1143.76	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	15414.12	107350.00	45116.81	-238713.92	

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	4246.55	115825.00	-356878.90	-418276.73	
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	7557.30	115825.00	-279112.79	-390079.44	
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	10074.73	115825.00	-219980.79	-399266.27	
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	12212.02	115825.00	-169778.17	-416032.46	
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	1090.02	1455.0598	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	12815.30	115825.00	-155607.64	-442461.49	
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	-1547.03	-1181.989	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	15452.35	115825.00	-93666.05	-380519.90	

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	4287.11	138142.50	-723752.39	-805889.81	
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	7584.34	138142.50	-646303.85	-778010.10	
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	10088.25	138142.50	-587489.43	-787064.50	
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	12212.02	138142.50	-537604.37	-803998.26	
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	12921.24	138142.50	-520945.52	-830764.60	
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	15635.84	138142.50	-457182.21	-767001.28	

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	4349.51	149273.00	-905734.18	-994872.40	
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	7625.94	149273.00	-828774.21	-967331.26	
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	10109.05	149273.00	-770448.35	-976424.22	
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	12212.02	149273.00	-721051.87	-993696.56	
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	963.2865	1328.3265	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	12942.03	149273.00	-703904.50	-1020409.09	
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	-1768.75	-1403.711	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	15674.07	149273.00	-639731.73	-956236.31	

Table B. 17 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – taking into account the rental loss/gain- West-End

Office-London (West End)
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	134129.04	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	7144.85	134129.04	167825.31	132656.49	5
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	13726.02	134129.04	322410.16	252072.52	5.2
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	19494.74	134129.04	457911.44	352404.97	5.5
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	24883.30	134129.04	584483.34	443808.05	5.75
Carbon offsetting	964	18.73	0	3.51	127215.3204	20513.36376	62294.1	-18377.6	-16064.625	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	30334.99	134129.04	712537.85	503006.73	7

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	7215.57	137600.00	112279.78	75624.15	5.15
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	13796.74	137600.00	266864.63	195040.18	5.3
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	19565.46	137600.00	402365.90	295372.63	5.55
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	24954.02	137600.00	528937.80	386775.71	5.8
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-18270.1	-16027.867	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	30298.23	137600.00	654467.77	444319.28	7.1

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	7319.57	146200.00	-27018.39	-65333.02	5.3
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	13900.74	146200.00	127566.45	54083.01	5.4
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	19669.46	146200.00	263067.73	154415.46	5.6
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	25058.02	146200.00	389639.63	245818.54	5.85
Carbon offsetting	954	17.05	0	3.51	125895.6594	20701.29836	61160.05	-18108.9	-15970.651	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	30241.01	146200.00	511382.79	300879.43	7.1

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	7377.81	154800.00	-167391.42	-212294.04	6.15
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	13958.98	154800.00	-12806.57	-92878.02	5.85
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	19727.70	154800.00	122694.70	7454.43	5.95
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	25116.26	154800.00	249266.61	98857.51	6.1
Carbon offsetting	952	16.49	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-15975.152	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	30245.51	154800.00	369747.49	153090.85	7.3

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	7428.77	163400.00	-307935.45	-356844.87	6.75
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	14009.94	163400.00	-153350.60	-237428.85	6.1
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	19778.66	163400.00	-17849.32	-137096.39	6.15
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	25167.22	163400.00	108722.58	-45693.32	6.25
Carbon offsetting	949	16	0	3.51	125103.8628	20814.05912	60479.62	-17947.7	-15918.635	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	30188.99	163400.00	226678.93	6884.91	7.45

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	7478.69	176300.00	-519374.42	-571772.24	7.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	14059.86	176300.00	-364789.57	-452356.22	6.35
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	19828.58	176300.00	-229288.29	-352023.76	6.3
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	25217.14	176300.00	-102716.39	-260620.68	6.4
Carbon offsetting	946	15.52	0	3.51	124839.9306	20851.64604	60252.81	-17893.9	-15914.816	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	30185.18	176300.00	13977.69	-208870.02	7.55

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	7532.77	210270.00	-1077981.18	-1151568.61	10
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	14113.94	210270.00	-923396.34	-1032152.58	7.85
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	19882.66	210270.00	-787895.06	-931820.13	7.4
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	25271.22	210270.00	-661323.16	-840417.05	7.25
Carbon offsetting	959	15.52	0	3.51	126555.4899	20614.05106	61750.92	-18243.4	-16264.25	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	30534.61	210270.00	-537691.50	-784554.44	8.25

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	7615.97	227212.00	-1355256.72	-1436144.94	11
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	14197.14	227212.00	-1200671.87	-1316728.92	8.35
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	19965.86	227212.00	-1065170.60	-1216396.47	7.75
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	25354.42	227212.00	-938598.69	-1124993.39	7.5
Carbon offsetting	952	14.2	0	3.51	125631.7272	20738.88528	60933.24	-18055.2	-16213.312	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	30483.67	227212.00	-818117.81	-1070760.05	8.5

Table B. 18 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) – taking into account the rental loss/gain- West-End

Office-London (West End)
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00	134129.04	0.00	0.00	0
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	43.70	35.00	97931.40	35168.82	133100.22	16.53	0.71	0.44	17.68	19.75	3509.19	134129.04	82427.23	47258.41	10.25
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	43.70	35.00	97931.40	70337.65	168269.05	11.42	1.42	0.44	13.28	39.71	6416.42	134129.04	150715.06	80377.42	11.25
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	43.70	35.00	97931.40	105506.47	203437.87	6.34	2.13	0.44	8.91	59.57	8530.33	134129.04	200368.79	94862.32	12.75
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	43.70	35.00	97931.40	140675.29	238606.69	1.26	2.84	0.44	4.54	79.38	10264.10	134129.04	241093.14	100417.85	14.25
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	68.636402	2381.5964	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	11888.76	134129.04	279254.93	69723.81	18.5
Carbon offsetting	964	18.73	0	3.51	127215.32	20513.36376	62294.101	-3357.539	-1044.579	43.70	35.00	97931.40	209531.12	307462.52	-4.07	3.59	0.44	-0.04	100.20	15314.94	134129.04	359732.29	150201.18	14.15

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	44.30	35.70	99418.20	35168.82	134587.02	16.40	0.71	0.48	17.59	20.17	3579.91	137600.00	26881.69	-9773.93	10.5
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	44.30	35.70	99418.20	70337.65	169755.85	11.29	1.42	0.48	13.19	40.13	6487.14	137600.00	95169.53	23345.08	11.5
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	44.30	35.70	99418.20	105506.47	204924.67	6.20	2.13	0.48	8.82	59.98	8601.05	137600.00	144823.25	37829.98	12.85
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	44.30	35.70	99418.20	140675.29	240093.49	1.13	2.84	0.48	4.45	79.79	10334.82	137600.00	185547.61	43385.51	14.3
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	99.573646	2341.8136	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	11928.55	137600.00	222982.70	12834.21	18.5
Carbon offsetting	960	18.05	0	3.51	126687.456	20588.5376	61840.48	-3301.653	-1059.413	44.30	35.70	99418.20	208661.69	308079.89	-4.10	3.57	0.48	-0.04	100.20	15329.77	137600.00	302874.04	92725.55	14.25

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	45.00	36.40	101077.20	35168.82	136246.02	16.21	0.71	0.52	17.43	20.88	3683.91	146200.00	-112416.48	-150731.10	10.75
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	45.00	36.40	101077.20	70337.65	171414.85	11.09	1.42	0.52	13.03	40.84	6591.14	146200.00	-44128.64	-117612.09	11.5
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	45.00	36.40	101077.20	105506.47	206583.67	6.01	2.13	0.52	8.66	60.69	8705.05	146200.00	5525.08	-103127.19	12.9
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	45.00	36.40	101077.20	140675.29	241752.49	0.93	2.84	0.52	4.30	80.50	10438.82	146200.00	46249.44	-97571.66	14.3
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	145.97951	2284.2195	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	11986.14	146200.00	82594.51	-127908.85	18.4
Carbon offsetting	954	17.05	0	3.51	125895.659	20701.29836	61160.05	-3217.823	-1079.583	45.00	36.40	101077.20	207357.56	308434.76	-4.13	3.55	0.52	-0.06	100.28	15349.94	146200.00	161606.80	-48896.56	14.25

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	48.60	37.00	107665.20	35168.82	142834.02	16.10	0.71	0.61	17.41	20.97	3742.15	154800.00	-252789.51	-297692.13	12.5
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	48.60	37.00	107665.20	70337.65	178002.85	10.98	1.42	0.61	13.02	40.93	6649.38	154800.00	-184501.67	-264573.12	12.5
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	48.60	37.00	107665.20	105506.47	213171.67	5.90	2.13	0.61	8.64	60.78	8763.29	154800.00	-134847.95	-250088.22	13.65
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	48.60	37.00	107665.20	140675.29	248340.49	0.82	2.84	0.61	4.28	80.59	10497.06	154800.00	-94123.59	-244532.69	14.85
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	161.44814	2241.4481	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	12028.91	154800.00	-58141.86	-274798.51	18.9
Carbon offsetting	952	16.49	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1109.88	48.60	37.00	107665.20	206922.84	314588.04	-4.19	3.54	0.61	-0.04	100.16	15380.24	154800.00	20577.42	-196079.23	14.65

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	50.40	38.40	111672.00	35168.82	146840.82	16.00	0.71	0.65	17.36	21.22	3793.11	163400.00	-393333.53	-442242.96	13.25
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	50.40	38.40	111672.00	70337.65	182009.65	10.89	1.42	0.65	12.96	41.18	6700.34	163400.00	-325045.70	-409123.95	13
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	50.40	38.40	111672.00	105506.47	217178.47	5.80	2.13	0.65	8.58	61.03	8814.25	163400.00	-275391.97	-394639.04	14
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	50.40	38.40	111672.00	140675.29	252347.29	0.73	2.84	0.65	4.22	80.85	10548.02	163400.00	-234667.62	-389083.51	15.2
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	192.38538	2221.4254	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	12048.93	163400.00	-199412.57	-419206.60	19.15
Carbon offsetting	949	16	0	3.51	125103.863	20814.05912	60479.62	-3133.994	-1104.954	50.40	38.40	111672.00	206053.42	317725.42	-4.18	3.53	0.65	0.00	99.98	15375.31	163400.00	-121279.32	-341073.35	14.85

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	52.20	39.00	115160.40	35168.82	150329.22	15.91	0.71	0.7	17.31	21.42	3843.03	176300.00	-604772.50	-657170.33	14.15
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	52.20	39.00	115160.40	70337.65	185498.05	10.79	1.42	0.7	12.91	41.38	6750.26	176300.00	-536484.67	-624051.31	13.5
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	52.20	39.00	115160.40	105506.47	220666.87	5.71	2.13	0.7	8.54	61.23	8864.17	176300.00	-486830.94	-609566.41	14.35
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	52.20	39.00	115160.40	140675.29	255835.69	0.63	2.84	0.7	4.18	81.05	10597.94	176300.00	-446106.59	-604010.88	15.5
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	207.854	2186.974	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	12083.39	176300.00	-411214.89	-634062.59	19.35
Carbon offsetting	946	15.52	0	3.51	124839.931	20851.64604	60252.81	-3106.051	-1126.931	52.20	39.00	115160.40	205618.71	320779.11	-4.22	3.52	0.7	0.00	99.99	15397.29	176300.00	-333374.65	-556222.36	15

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	63.00	43.00	136350.00	35168.82	171518.82	15.80	0.71	1	17.51	20.52	3897.11	210270.00	-1163379.27	-1236966.69	19.75
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	63.00	43.00	136350.00	70337.65	206687.65	10.69	1.42	1	13.11	40.48	6804.34	210270.00	-1095091.43	-1203847.68	16.75
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	63.00	43.00	136350.00	105506.47	241856.47	5.61	2.13	1	8.74	60.34	8918.25	210270.00	-1045437.71	-1189362.78	16.85
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	63.00	43.00	136350.00	140675.29	277025.29	0.53	2.84	1	4.37	80.15	10652.02	210270.00	-1004713.35	-1183807.25	17.6
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	107.17569	2086.2957	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	12184.06	210270.00	-968727.11	-1215590.04	21.4
Carbon offsetting	959	15.52	0	3.51	126555.49	20614.05106	61750.921	-3289.125	-1310.005	63.00	43.00	136350.00	208444.34	344794.34	-4.57	3.57	1	0.00	100.00	15580.36	210270.00	-888951.47	-1135814.40	16.5

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	97931.40	21.59	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	66.60	44.70	143650.80	35168.82	178819.62	15.65	0.71	1.09	17.44	20.82	3980.31	227212.00	-1440654.81	-1521543.03	21.5
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	66.60	44.70	143650.80	70337.65	213988.45	10.53	1.42	1.09	13.05	40.79	6887.54	227212.00	-1372366.97	-1488424.02	17.65
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	66.60	44.70	143650.80	105506.47	249157.27	5.45	2.13	1.09	8.67	60.64	9001.45	227212.00	-1322713.24	-1473939.12	17.55
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	66.60	44.70	143650.80	140675.29	284326.09	0.37	2.84	1.09	4.31	80.45	10735.22	227212.00	-1281988.89	-1468383.59	18.2
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	161.44814	2003.2881	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	12267.07	227212.00	-1246007.16	-1498649.41	21.75
Carbon offsetting	952	14.2	0	3.51	125631.727	20738.88528	60933.24	-3189.88	-1348.04	66.60	44.70	143650.80	206922.84	350573.64	-4.64	3.54	1.09	0.00	100.02	15618.40	227212.00	-1167287.88	-1419930.13	16.9

Table B. 19 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC – taking into account the rental loss/gain- West-End

Office-London (West End)
PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	134129.04	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	7632.61	134129.04	179282.30	132863.48	6.2
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	14699.98	134129.04	345287.49	244949.84	6.95
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	20955.94	134129.04	492233.54	322977.07	8.25
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	26831.22	134129.04	630238.00	392062.70	9.1
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.1629	-14568.5	-14203.48	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	28473.84	134129.04	668821.38	392437.45	10

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	7685.65	137600.00	123321.48	75865.85	6.3
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	14735.34	137600.00	288911.38	189336.94	6.9
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	20973.62	137600.00	435442.14	266948.87	8.2
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	26831.22	137600.00	573031.32	336369.22	9.05
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.1049	-14623.1	-14258.04	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	28528.40	137600.00	612896.44	337591.00	9.9

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	7763.65	146200.00	-16587.41	-65252.03	6.4
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	14787.86	146200.00	148404.00	49120.55	6.85
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	20999.62	146200.00	294311.83	125659.56	8.2
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	26831.22	146200.00	431290.29	195219.20	9
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-14677.7	-14312.61	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	28582.97	146200.00	472437.16	197288.01	9.9

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	7807.33	154800.00	-157302.43	-212105.06	7.15
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	14816.98	154800.00	7346.97	-97474.48	7.2
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	21014.18	154800.00	152912.81	-21127.47	8.5
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	26831.22	154800.00	289549.27	48390.17	9.2
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-14777.8	-14412.75	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	28683.11	154800.00	333048.23	51941.65	10.05

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	7844.77	163400.00	-298164.03	-356523.46	7.6
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	14841.94	163400.00	-133807.77	-241886.02	7.45
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	21026.66	163400.00	11464.92	-165082.15	8.6
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	26831.22	163400.00	147808.24	-95857.65	9.3
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.4021	-14809.6	-14444.53	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	28714.89	163400.00	192053.78	-91776.96	10.15

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	7882.21	176300.00	-509896.14	-571293.97	8
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	14866.90	176300.00	-345833.02	-456799.67	7.65
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	21039.14	176300.00	-200853.47	-380138.94	8.75
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	26831.22	176300.00	-64803.30	-311057.59	9.4
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.3441	-14868.6	-14503.6	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	28773.96	176300.00	-19170.32	-306024.16	10.25

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	7922.77	210270.00	-1068820.48	-1150957.90	10.65
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	14893.94	210270.00	-905074.93	-1036781.18	9.05
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	21052.66	210270.00	-760412.95	-959988.02	9.75
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	26831.22	210270.00	-624680.35	-891074.24	10.2
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	29128.65	210270.00	-570716.02	-880535.10	10.95

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	7985.17	227212.00	-1346584.59	-1435722.81	11.55
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	14935.54	227212.00	-1183327.61	-1321884.66	9.5
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	21073.46	227212.00	-1039154.20	-1245130.07	10.05
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	26831.22	227212.00	-903910.17	-1176554.86	10.45
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.4094	-15282.4	-14917.36	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	29187.72	227212.00	-848558.40	-1165062.98	11.15

Table B. 20 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (mineral wool) + TSC – taking into account the rental loss/gain- West-End

Office-London (West End)
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00	134129.04	0.00	0.00	0
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	43.70	35.00	97931.40	11250.00	35168.82	144350.22	15.66	0.71	0.04	0.44	16.85	23.53	3996.95	134129.04	93884.21	47465.39	12
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	43.70	35.00	97931.40	30000.00	70337.65	198269.05	9.68	1.42	0.09	0.44	11.64	47.17	7390.38	134129.04	173592.39	73254.74	14.1
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	43.70	35.00	97931.40	63750.00	105506.47	267187.87	3.73	2.13	0.20	0.44	6.50	70.48	9991.53	134129.04	234690.89	65434.42	17.75
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	43.70	35.00	97931.40	97500.00	140675.29	336106.69	-2.21	2.84	0.31	0.44	1.38	93.76	12212.02	134129.04	286847.80	48672.50	20.55
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	1179.658	1544.6976	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	12725.66	134129.04	298912.83	22528.90	23
Carbon offsetting	650	823	0	0	3.51	0.3746	108608.1	23453.9279	46753.163	-1391.77	-1026.726	43.70	35.00	97931.40	97500.00	178883.93	374315.33	-3.82	3.06	0.31	0.44	-0.01	100.03	15297.09	134129.04	359312.95	82929.02	18.95

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	44.30	35.70	99418.20	10800.00	35168.82	145387.02	15.57	0.71	0.03	0.48	16.79	23.79	4049.99	137600.00	37923.39	-9532.23	12.1
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	44.30	35.70	99418.20	27750.00	70337.65	197505.85	9.62	1.42	0.09	0.48	11.61	47.30	7425.74	137600.00	117216.28	17641.84	13.9
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	44.30	35.70	99418.20	61500.00	105506.47	266424.67	3.70	2.13	0.19	0.48	6.51	70.47	10009.21	137600.00	177899.50	9406.22	17.6
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	44.30	35.70	99418.20	94500.00	140675.29	334593.49	-2.21	2.84	0.30	0.48	1.41	93.61	12212.02	137600.00	229641.12	-7020.97	20.4
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	1163.36	1528.3998	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	12741.96	137600.00	242088.97	-33216.48	22.9
Carbon offsetting	630	825	0	0	3.51	0.3746	108872.033	23407.2466	46970.105	-1420	-1054.956	44.30	35.70	99418.20	94500.00	179318.64	373236.84	-3.87	3.07	0.30	0.48	-0.02	100.09	15325.32	137600.00	302769.36	27463.91	18.85

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	45.00	36.40	101077.20	10350.00	35168.82	146596.02	15.43	0.71	0.03	0.52	16.69	24.24	4127.99	146200.00	-101985.49	-150650.12	12.15
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	45.00	36.40	101077.20	25800.00	70337.65	197214.85	9.53	1.42	0.08	0.52	11.55	47.57	7478.26	146200.00	-23291.10	-122574.55	13.75
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	45.00	36.40	101077.20	60000.00	105506.47	266583.67	3.65	2.13	0.19	0.52	6.49	70.52	10035.21	146200.00	36769.18	-131883.09	17.55
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	45.00	36.40	101077.20	92250.00	140675.29	334002.49	-2.21	2.84	0.29	0.52	1.44	93.46	12212.02	146200.00	87900.09	-148171.00	20.35
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	1147.062	1512.102	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	12758.26	146200.00	100730.76	-174418.40	22.85
Carbon offsetting	615	827	0	0	3.51	0.3746	109135.965	23360.5653	47187.047	-1448.23	-1083.186	45.00	36.40	101077.20	92250.00	179753.35	373080.55	-3.92	3.08	0.29	0.52	-0.03	100.15	15353.55	146200.00	161691.42	-113457.74	18.8

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	48.60	37.00	107665.20	9900.00	35168.82	152734.02	15.35	0.71	0.03	0.61	16.70	24.19	4171.67	154800.00	-242700.52	-297503.14	13.6
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	48.60	37.00	107665.20	24750.00	70337.65	202752.85	9.48	1.42	0.08	0.61	11.59	47.41	7507.38	154800.00	-164348.13	-269169.57	14.5
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	48.60	37.00	107665.20	58800.00	105506.47	271971.67	3.63	2.13	0.19	0.61	6.56	70.25	10049.77	154800.00	-104629.84	-278670.11	18.15
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	48.60	37.00	107665.20	90750.00	140675.29	339090.49	-2.21	2.84	0.29	0.61	1.53	93.07	12212.02	154800.00	-53840.93	-295000.03	20.8
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	1123.466	1488.5065	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	12781.85	154800.00	-40456.03	-321562.61	23.3
Carbon offsetting	605	830	0	0	3.51	0.3746	109663.829	23267.2027	47420.931	-1484.68	-1119.645	48.60	37.00	107665.20	90750.00	180622.78	379037.98	-3.99	3.09	0.29	0.61	0.00	100.01	15390.00	154800.00	20806.78	-260299.80	19.2

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	50.40	38.40	111672.00	9450.00	35168.82	156290.82	15.29	0.71	0.03	0.65	16.67	24.32	4209.11	163400.00	-383562.12	-441921.54	14.4
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	50.40	38.40	111672.00	24000.00	70337.65	206009.65	9.43	1.42	0.08	0.65	11.58	47.44	7532.34	163400.00	-305502.87	-413581.12	14.9
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	50.40	38.40	111672.00	57300.00	105506.47	274478.47	3.60	2.13	0.18	0.65	6.57	70.19	10062.25	163400.00	-246077.73	-422624.80	18.4
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	50.40	38.40	111672.00	89250.00	140675.29	341597.29	-2.21	2.84	0.28	0.65	1.56	92.91	12212.02	163400.00	-195581.96	-439247.85	21.05
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	1110.818	1475.8576	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	12794.50	163400.00	-181899.95	-465730.68	23.55
Carbon offsetting	595	832	0	0	3.51	0.3746	109795.795	23243.862	47629.402	-1508.8	-1143.76	50.40	38.40	111672.00	89250.00	180840.13	381762.13	-4.04	3.10	0.28	0.65	-0.01	100.03	15414.12	163400.00	-120367.82	-404198.55	19.35

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	52.20	39.00	115160.40	9000.00	35168.82	159329.22	15.22	0.71	0.03	0.7	16.66	24.41	4246.55	176300.00	-595294.23	-656692.05	15
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	52.20	39.00	115160.40	23400.00	70337.65	208898.05	9.39	1.42	0.07	0.7	11.58	47.43	7557.30	176300.00	-517528.12	-628494.77	15.3
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	52.20	39.00	115160.40	56550.00	105506.47	277216.87	3.58	2.13	0.18	0.7	6.59	70.07	10074.73	176300.00	-458396.12	-637681.59	18.65
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	52.20	39.00	115160.40	88350.00	140675.29	344185.69	-2.21	2.84	0.28	0.7	1.61	92.70	12212.02	176300.00	-408193.50	-654447.79	21.25
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	1090.02	1455.0598	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	12815.30	176300.00	-394022.97	-680876.81	23.75
Carbon offsetting	589	834	0	0	3.51	0.3746	110059.727	23197.1807	47946.344	-1547.03	-1181.989	52.20	39.00	115160.40	88350.00	181274.85	384785.25	-4.11	3.11	0.28	0.7	-0.03	100.12	15452.35	176300.00	-332081.38	-618935.22	19.5

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	63.00	43.00	136350.00	8550.00	35168.82	180068.82	15.15	0.71	0.03	1	16.88	23.38	4287.11	210270.00	-1154218.57	-1236355.99	20.15
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	63.00	43.00	136350.00	22950.00	70337.65	229637.65	9.34	1.42	0.07	1	11.83	46.29	7584.34	210270.00	-1076770.03	-1208476.28	18.2
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	63.00	43.00	136350.00	55650.00	105506.47	297506.47	3.56	2.13	0.18	1	6.87	68.83	10088.25	210270.00	-1017955.60	-1217530.67	20.85
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	63.00	43.00	136350.00	87300.00	140675.29	364325.29	-2.21	2.84	0.28	1	1.91	91.35	12212.02	210270.00	-968070.55	-1234464.44	23.15
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	12921.24	210270.00	-951411.70	-1261230.77	25.55
Carbon offsetting	582	847	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	63.00	43.00	136350.00	87300.00	184100.47	407750.47	-4.45	3.15	0.28	1	-0.03	100.12	15635.84	210270.00	-887648.38	-1197467.45	20.9

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £	Payback period (years)
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	43.70	35.00	97931.40	0.00	0.00	97931.40	21.59	0.00	0.00	0.44	22.03	0.00	0.00		0.00	0.00	0
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	66.60	44.70	143650.80	8250.00	35168.82	187069.62	15.04	0.71	0.03	1.09	16.86	23.48	4349.51	227212.00	-1431982.68	-1521120.90	21.6
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	66.60	44.70	143650.80	22500.00	70337.65	236488.45	9.26	1.42	0.07	1.09	11.85	46.23	7625.94	227212.00	-1355022.71	-1493579.76	19.1
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	66.60	44.70	143650.80	54750.00	105506.47	303907.27	3.52	2.13	0.17	1.09	6.92	68.61	10109.05	227212.00	-1296696.85	-1502672.72	21.5
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.60	44.70	143650.80	86250.00	140675.29	370576.09	-2.21	2.84	0.27	1.09	1.99	90.96	12212.02	227212.00	-1247300.37	-1519945.06	23.7
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	963.2865	1328.3265	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	12942.03	227212.00	-1230153.00	-1546657.59	26.1
Carbon offsetting	575	850	0	0	3.51	0.3746	112039.219	22847.0708	49673.409	-1768.75	-1403.711	66.60	44.70	143650.80	86250.00	184535.18	414435.98	-4.53	3.16	0.27	1.09	0.00	100.01	15674.07	227212.00	-1165980.23	-1482484.81	21.3

Table B. 21 Distribution warehouse - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR)

Distribution Warehouse - London
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25%	94	57.29	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9898.549	66.00	46.00	276000.00	17257.06	293257.06	17.46	0.30	1.20	18.96	8.54	3438.85	80775.10	63518.04	5.15
50%	187	57.29	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6905.8697	66.00	46.00	276000.00	34514.12	310514.12	15.21	0.60	1.20	17.02	17.90	6431.53	151070.08	116555.97	5.45
75%	281	57.29	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	4186.7281	66.00	46.00	276000.00	51771.18	327771.18	13.05	0.91	1.20	15.15	26.90	9150.67	214939.95	163168.77	5.75
100%	375	57.29	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1580.9652	66.00	46.00	276000.00	69028.24	345028.24	10.88	1.21	1.20	13.29	35.91	11756.43	276146.66	207118.42	6
Carbon Offset	1045	57.29	0	4.96	137904.575	8287.42383	104279.1	-23528.5	-16058.48	66.00	46.00	276000.00	227136.95	503136.95	-4.58	3.37	1.20	-0.01	100.06	29395.88	690479.30	463342.36	7.9

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	55.4	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9671.749	67.00	47.00	281000.00	17257.06	298257.06	17.09	0.30	1.3	18.69	9.84	3665.65	86102.40	63845.34	6.2
50	187	55.4	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6679.0697	67.00	47.00	281000.00	34514.12	315514.12	14.84	0.60	1.3	16.75	19.21	6658.33	156397.39	116883.27	6
75	281	55.4	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3959.9281	67.00	47.00	281000.00	51771.18	332771.18	12.68	0.91	1.3	14.88	28.21	9377.47	220267.25	163496.07	6.15
100	375	55.4	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1354.1652	67.00	47.00	281000.00	69028.24	350028.24	10.51	1.21	1.3	13.02	37.21	11983.23	281473.96	207445.72	6.3
Carbon Offset	1032	55.4	0	4.96	136189.015	8392.98468	102669.1	-23192.5	-15949.3	67.00	47.00	281000.00	224311.32	505311.32	-4.66	3.33	1.3	-0.03	100.12	29286.70	687914.67	458603.35	8

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	52.88	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9369.349	68.50	48.00	287150.00	17257.06	304407.06	16.59	0.30	1.49	18.39	11.31	3968.05	93205.47	64798.41	7.25
50	187	52.88	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6376.6697	68.50	48.00	287150.00	34514.12	321664.12	14.35	0.60	1.49	16.44	20.67	6960.73	163500.45	117836.33	6.7
75	281	52.88	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3657.5281	68.50	48.00	287150.00	51771.18	338921.18	12.18	0.91	1.49	14.58	29.67	9679.87	227370.31	164449.14	6.65
100	375	52.88	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	1051.7652	68.50	48.00	287150.00	69028.24	356178.24	10.01	1.21	1.49	12.71	38.68	12285.63	288577.03	208398.79	6.65
Carbon Offset	1015	52.88	0	4.96	133945.592	8533.03983	100665.7	-22757.4	-15816.64	68.50	48.00	287150.00	220616.27	507766.27	-4.77	3.28	1.49	-0.01	100.04	29154.04	684798.72	453032.45	8.1

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	50.84	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	9124.549	70.00	49.00	293300.00	17257.06	310557.06	16.19	0.30	1.67	18.17	12.37	4212.85	98955.57	64398.51	8.45
50	187	50.84	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	6131.8697	70.00	49.00	293300.00	34514.12	327814.12	13.95	0.60	1.67	16.22	21.73	7205.53	169250.55	117436.44	7.35
75	281	50.84	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3412.7281	70.00	49.00	293300.00	51771.18	345071.18	11.78	0.91	1.67	14.36	30.74	9924.67	233120.42	164049.24	7.1
100	375	50.84	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	806.96519	70.00	49.00	293300.00	69028.24	362328.24	9.61	1.21	1.67	12.49	39.74	12530.43	294327.13	207998.89	7
Carbon Offset	1005	50.84	0	4.96	132625.931	8614.91183	99327.94	-22494.4	-15798.43	70.00	49.00	293300.00	218442.71	511742.71	-4.93	3.24	1.67	-0.01	100.06	29135.83	684370.91	448628.20	8.275

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	48.8	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8879.749	71.50	50.00	299450.00	17257.06	316707.06	15.79	0.30	1.86	17.96	13.38	4457.65	104705.67	63998.61	9.35
50	187	48.8	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5887.0697	71.50	50.00	299450.00	34514.12	333964.12	13.55	0.60	1.86	16.01	22.75	7450.33	175000.66	117036.54	8
75	281	48.8	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	3167.9281	71.50	50.00	299450.00	51771.18	351221.18	11.38	0.91	1.86	14.15	31.75	10169.47	238870.52	163649.34	7.55
100	375	48.8	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	562.16519	71.50	50.00	299450.00	69028.24	368478.24	9.21	1.21	1.86	12.28	40.75	12775.23	300077.23	207598.99	7.4
Carbon Offset	995	48.8	0	4.96	131306.27	8707.33698	98100.7	-22234.9	-15783.71	71.50	50.00	299450.00	216269.15	515719.15	-5.09	3.21	1.86	-0.02	100.12	29121.11	684025.24	444306.09	8.425

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	47.4	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8711.749	73.00	51.00	305600.00	17257.06	322857.06	15.52	0.30	2.04	17.86	13.83	4625.65	108651.82	61794.76	10.45
50	187	47.4	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5719.0697	73.00	51.00	305600.00	34514.12	340114.12	13.28	0.60	2.04	15.92	23.20	7618.33	178946.81	114832.69	8.65
75	281	47.4	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2999.9281	73.00	51.00	305600.00	51771.18	357371.18	11.11	0.91	2.04	14.05	32.20	10337.47	242816.67	161445.49	8
100	375	47.4	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	394.16519	73.00	51.00	305600.00	69028.24	374628.24	8.94	1.21	2.04	12.19	41.20	12943.23	304023.38	205395.14	7.8
Carbon Offset	990	47.4	0	4.96	130646.439	8750.35968	97483.9	-22105.5	-15822.26	73.00	51.00	305600.00	215182.37	520782.37	-5.25	3.19	2.04	-0.02	100.09	29159.66	684930.63	440148.26	8.6

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	44	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8303.749	79.00	55.00	330200.00	17257.06	347457.06	14.85	0.30	2.79	17.95	13.43	5033.65	118235.32	46778.27	14.75
50	187	44	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5311.0697	79.00	55.00	330200.00	34514.12	364714.12	12.61	0.60	2.79	16.00	22.80	8026.33	188530.31	99816.19	11.4
75	281	44	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2591.9281	79.00	55.00	330200.00	51771.18	381971.18	10.44	0.91	2.79	14.14	31.80	10745.47	252400.17	146429.00	10.15
100	375	44	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	-13.83481	79.00	55.00	330200.00	69028.24	399228.24	8.27	1.21	2.79	12.27	40.80	13351.23	313606.88	190378.65	9.5
Carbon Offset	993	44	0	4.96	131042.337	8724.54606	97853.98	-22183.1	-16307.93	79.00	55.00	330200.00	215834.44	546034.44	-5.99	3.20	2.79	0.00	99.98	29645.33	696338.59	426304.15	9.35

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	43	10.4775	4.96	12404.8134	30259.929	203.1794	2428.549	8183.749	82.00	57.00	342500.00	17257.06	359757.06	14.66	0.30	3.16	18.12	12.59	5153.65	121054.00	37296.94	17
50	187	43	6.985	4.96	24677.6607	23563.4558	6327.852	-564.13	5191.0697	82.00	57.00	342500.00	34514.12	377014.12	12.41	0.60	3.16	16.18	21.96	8146.33	191348.99	90334.87	12.85
75	281	43	3.4925	4.96	37082.4741	19750.3654	14919.21	-3283.27	2471.9281	82.00	57.00	342500.00	51771.18	394271.18	10.24	0.91	3.16	14.31	30.96	10865.47	255218.85	136947.67	11.2
100	375	43	0	4.96	49487.2875	17131.2544	24705.64	-5889.03	-133.8348	82.00	57.00	342500.00	69028.24	411528.24	8.08	1.21	3.16	12.45	39.96	13471.23	316425.56	180897.32	10.37
Carbon Offset	1002	43	0	4.96	132230.032	8647.1052	98964.23	-22416.2	-16660.95	82.00	57.00	342500.00	217790.64	560290.64	-6.39	3.23	3.16	0.00	100.00	29998.35	704630.64	420340.00	9.75

Table B. 22 Distribution warehouse - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR)

Distribution Warehouse - London
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25%	94	57.29	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	11697.25	66.00	46.00	276000.00	17257.06	293257.06	17.46	0.30	1.20	18.96	8.54	1640.15	38525.52	21268.46	10.8
50%	187	57.29	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	10484.13	66.00	46.00	276000.00	34514.12	310514.12	15.21	0.60	1.20	17.02	17.90	2853.27	67020.39	32506.27	12.5
75%	281	57.29	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	9563.687	66.00	46.00	276000.00	51771.18	327771.18	13.05	0.91	1.20	15.15	26.90	3773.71	88640.67	36869.50	14.25
100%	375	57.29	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	8756.622	66.00	46.00	276000.00	69028.24	345028.24	10.88	1.21	1.20	13.29	35.91	4580.78	107597.80	38569.57	15.75
Carbon Offset	1045	57.29	0	4.96	137904.57	8287.42383	104279.095	-3532.32	3937.68	66.00	46.00	276000.00	227136.95	503136.95	-4.58	3.37	1.20	-0.01	100.06	9399.72	220789.83	-6347.12	25.75
Carbon Offset	1045	57.29	0	4.96	137904.57	8287.42383	104279.095	-9267.67	-1797.67	66.00	46.00	276000.00	227136.95	503136.95	-4.58	3.37	1.20	-0.01	100.06	15135.07	355507.35	128370.41	15.625

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	55.4	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	11470.45	67.00	47.00	281000.00	17257.06	298257.06	17.09	0.30	1.3	18.69	9.84	1866.95	43852.82	21595.76	12.3
50	187	55.4	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	10257.33	67.00	47.00	281000.00	34514.12	315514.12	14.84	0.60	1.3	16.75	19.21	3080.07	72347.69	32833.57	13.25
75	281	55.4	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	9336.887	67.00	47.00	281000.00	51771.18	332771.18	12.68	0.91	1.3	14.88	28.21	4000.51	93967.97	37196.80	14.75
100	375	55.4	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	8529.822	67.00	47.00	281000.00	69028.24	350028.24	10.51	1.21	1.3	13.02	37.21	4807.58	112925.10	38896.87	16
Carbon Offset	1032	55.4	0	4.96	136189.02	8392.98468	102669.097	-3445.091	3798.109	67.00	47.00	281000.00	224311.32	505311.32	-4.66	3.33	1.3	-0.03	100.12	9539.29	224068.22	-5243.10	25.65
Carbon Offset	1032	55.4	0	4.96	136189.02	8392.98468	102669.097	-9091.892	-1848.69	67.00	47.00	281000.00	224311.32	505311.32	-4.66	3.33	1.3	-0.03	100.12	15186.09	356705.80	127394.48	15.75

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	52.88	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	11168.05	68.50	48.00	287150.00	17257.06	304407.06	16.59	0.30	1.49	18.39	11.31	2169.35	50955.89	22548.83	13.5
50	187	52.88	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	9954.93	68.50	48.00	287150.00	34514.12	321664.12	14.35	0.60	1.49	16.44	20.67	3382.47	79450.76	33786.64	14
75	281	52.88	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	9034.487	68.50	48.00	287150.00	51771.18	338921.18	12.18	0.91	1.49	14.58	29.67	4302.91	101071.04	38149.86	15.25
100	375	52.88	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	8227.422	68.50	48.00	287150.00	69028.24	356178.24	10.01	1.21	1.49	12.71	38.68	5109.98	120028.17	39849.94	16.4
Carbon Offset	1015	52.88	0	4.96	133945.59	8533.03983	100665.728	-3335.332	3605.468	68.50	48.00	287150.00	220616.27	507766.27	-4.77	3.28	1.49	-0.01	100.04	9731.93	228593.16	-3173.11	25.4
Carbon Offset	1015	52.88	0	4.96	133945.59	8533.03983	100665.728	-8871.947	-1931.15	68.50	48.00	287150.00	220616.27	507766.27	-4.77	3.28	1.49	-0.01	100.04	15268.55	358642.59	126876.33	15.8

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	50.84	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	10923.25	70.00	49.00	293300.00	17257.06	310557.06	16.19	0.30	1.67	18.17	12.37	2414.15	56705.99	22148.93	14.85
50	187	50.84	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	9710.13	70.00	49.00	293300.00	34514.12	327814.12	13.95	0.60	1.67	16.22	21.73	3627.27	85200.86	33386.74	14.9
75	281	50.84	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	8789.687	70.00	49.00	293300.00	51771.18	345071.18	11.78	0.91	1.67	14.36	30.74	4547.71	106821.14	37749.97	15.8
100	375	50.84	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	7982.622	70.00	49.00	293300.00	69028.24	362328.24	9.61	1.21	1.67	12.49	39.74	5354.78	125778.27	39450.04	16.8
Carbon Offset	1005	50.84	0	4.96	132625.93	8614.91183	99327.9391	-3263.67	3432.33	70.00	49.00	293300.00	218442.71	511742.71	-4.93	3.24	1.67	-0.01	100.06	9905.07	232659.98	-3082.73	25.35
Carbon Offset	1005	50.84	0	4.96	132625.93	8614.91183	99327.9391	-8726.706	-2030.71	70.00	49.00	293300.00	218442.71	511742.71	-4.93	3.24	1.67	-0.01	100.06	15368.11	360981.13	125238.43	16

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	48.8	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	10678.45	71.50	50.00	299450.00	17257.06	316707.06	15.79	0.30	1.86	17.96	13.38	2658.95	62456.09	21749.03	16
50	187	48.8	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	9465.33	71.50	50.00	299450.00	34514.12	333964.12	13.55	0.60	1.86	16.01	22.75	3872.07	90950.96	32986.84	15.6
75	281	48.8	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	8544.887	71.50	50.00	299450.00	51771.18	351221.18	11.38	0.91	1.86	14.15	31.75	4792.51	112571.24	37350.07	16.4
100	375	48.8	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	7737.822	71.50	50.00	299450.00	69028.24	368478.24	9.21	1.21	1.86	12.28	40.75	5599.58	131528.38	39050.14	17.25
Carbon Offset	995	48.8	0	4.96	131306.27	8707.33698	98100.7033	-3195.504	3255.696	71.50	50.00	299450.00	216269.15	515719.15	-5.09	3.21	1.86	-0.02	100.12	10081.70	236808.95	-2910.20	25.35
Carbon Offset	995	48.8	0	4.96	131306.27	8707.33698	98100.7033	-8591.043	-2139.84	71.50	50.00	299450.00	216269.15	515719.15	-5.09	3.21	1.86	-0.02	100.12	15477.24	363544.65	123825.50	16.15

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	47.4	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	10510.45	73.00	51.00	305600.00	17257.06	322857.06	15.52	0.30	2.04	17.86	13.83	2826.95	66402.24	19545.18	17.25
50	187	47.4	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	9297.33	73.00	51.00	305600.00	34514.12	340114.12	13.28	0.60	2.04	15.92	23.20	4040.07	94897.11	30782.99	16.5
75	281	47.4	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	8376.887	73.00	51.00	305600.00	51771.18	357371.18	11.11	0.91	2.04	14.05	32.20	4960.51	116517.39	35146.22	17.15
100	375	47.4	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	7569.822	73.00	51.00	305600.00	69028.24	374628.24	8.94	1.21	2.04	12.19	41.20	5767.58	135474.52	36846.29	17.9
Carbon Offset	990	47.4	0	4.96	130646.44	8750.35968	97483.8955	-3161.725	3121.475	73.00	51.00	305600.00	215182.37	520782.37	-5.25	3.19	2.04	-0.02	100.09	10215.92	239961.65	-4820.72	25.5
Carbon Offset	990	47.4	0	4.96	130646.44	8750.35968	97483.8955	-8523.339	-2240.14	73.00	51.00	305600.00	215182.37	520782.37	-5.25	3.19	2.04	-0.02	100.09	15577.54	365900.50	121118.13	16.4

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	44	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	10102.45	79.00	55.00	330200.00	17257.06	347457.06	14.85	0.30	2.79	17.95	13.43	3234.95	75985.75	4528.69	23.5
50	187	44	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	8889.33	79.00	55.00	330200.00	34514.12	364714.12	12.61	0.60	2.79	16.00	22.80	4448.07	104480.61	15766.50	21
75	281	44	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	7968.887	79.00	55.00	330200.00	51771.18	381971.18	10.44	0.91	2.79	14.14	31.80	5368.51	126100.90	20129.72	20.8
100	375	44	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	7161.822	79.00	55.00	330200.00	69028.24	399228.24	8.27	1.21	2.79	12.27	40.80	6175.58	145058.03	21829.79	21
Carbon Offset	993	44	0	4.96	131042.34	8724.54606	97853.9801	-3181.993	2693.207	79.00	55.00	330200.00	215834.44	546034.44	-5.99	3.20	2.79	0.00	99.98	10644.19	250021.22	-20013.21	27.15
Carbon Offset	993	44	0	4.96	131042.34	8724.54606	97853.9801	-8563.962	-2688.76	79.00	55.00	330200.00	215834.44	546034.44	-5.99	3.20	2.79	0.00	99.98	16026.16	376438.18	106403.74	17.65

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	57.29	13.97	4.96	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	276000.00	19.53	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	94	43	10.4775	4.96	12404.813	30259.929	203.179386	4227.247	9982.447	82.00	57.00	342500.00	17257.06	359757.06	14.66	0.30	3.16	18.12	12.59	3354.95	78804.42	-4952.64	26.75
50	187	43	6.985	4.96	24677.661	23563.4558	6327.8518	3014.1305	8769.33	82.00	57.00	342500.00	34514.12	377014.12	12.41	0.60	3.16	16.18	21.96	4568.07	107299.29	6285.17	23.5
75	281	43	3.4925	4.96	37082.474	19750.3654	14919.208	2093.6868	7848.887	82.00	57.00	342500.00	51771.18	394271.18	10.24	0.91	3.16	14.31	30.96	5488.51	128919.57	10648.40	22.85
100	375	43	0	4.96	49487.288	17131.2544	24705.6387	1286.6219	7041.822	82.00	57.00	342500.00	69028.24	411528.24	8.08	1.21	3.16	12.45	39.96	6295.58	147876.71	12348.47	22.75
Carbon Offset	1002	43	0	4.96	132230.03	8647.1052	98964.2342	-3242.796	2512.404	82.00	57.00	342500.00	217790.64	560290.64	-6.39	3.23	3.16	0.00	100.00	10825.00	254268.11	-30022.54	28.15
Carbon Offset	1002	43	0	4.96	132230.03	8647.1052	98964.2342	-8685.829	-2930.63	82.00	57.00	342500.00	217790.64	560290.64	-6.39	3.23	3.16	0.00	100.00	16268.03	382119.39	97828.75	18.3

Table B. 23 Distribution warehouse - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC

Distribution Warehouse-London
PV (current FiT) + Insulation + TSC

TSC + PV + FIT + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25%	275	94	42.97	10.4775	4.96	0.2864	12404.8134	30259.929	203.1794	2428.549	8300.437	66.00	46.00	276000.00	41250.00	17257.06	334507.06	14.80	0.30	0.11	1.20	16.42	20.81	5036.96	118313.12	59806.06	12
50%	750	187	28.65	6.985	4.96	0.5728	24677.6607	23563.4558	6327.852	-564.13	3709.646	66.00	46.00	276000.00	112500.00	34514.12	423014.12	9.90	0.60	0.31	1.20	12.01	42.05	9627.75	226146.12	79132.01	15.9
75%	1300	281	14.32	3.4925	4.96	0.8594	37082.4741	19750.3654	14919.21	-3283.27	-608.724	66.00	46.00	276000.00	195000.00	51771.18	522771.18	5.07	0.91	0.53	1.20	7.71	62.79	13946.12	327580.22	80809.04	18.55
75-100	1300	375	14.32	0	4.96	0.8594	49487.2875	17131.2544	24705.64	-5889.03	-3214.49	66.00	46.00	276000.00	195000.00	69028.24	540028.24	2.91	1.21	0.53	1.20	5.85	71.79	16551.89	388786.93	124758.70	16.65
Carbon Offsetting	1300	650	14.32	0	4.96	0	85777.965	12455.3763	56320.44	-13228.5	-10914.9	66.00	46.00	276000.00	195000.00	141281.35	612281.35	-3.89	2.10	0.53	1.20	-0.06	100.30	24252.27	569661.12	233379.77	14.4

TSC + PV + FIT + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	250	94	41.5	10.4775	4.96	0.3158	12404.8134	30259.929	203.1794	2428.549	8136.385	67.00	47.00	281000.00	37500.00	17257.06	335757.06	14.53	0.30	0.10	1.3	16.23	21.69	5201.01	122166.53	62409.48	11.85
50	700	187	27.7	6.985	4.96	0.5918	24677.6607	23563.4558	6327.852	-564.13	3603.626	67.00	47.00	281000.00	105000.00	34514.12	420514.12	9.73	0.60	0.29	1.3	11.92	42.52	9733.77	228636.43	84122.31	15.45
75	1250	281	13.42	3.4925	4.96	0.8774	37082.4741	19750.3654	14919.21	-3283.27	-709.164	67.00	47.00	281000.00	187500.00	51771.18	520271.18	4.91	0.91	0.51	1.3	7.63	63.21	14046.56	329939.45	85668.28	18.2
75-100	1250	375	13.42	0	4.96	0.8774	49487.2875	17131.2544	24705.64	-5889.03	-3314.93	67.00	47.00	281000.00	187500.00	69028.24	537528.24	2.74	1.21	0.51	1.3	5.76	72.21	16652.33	391146.16	129617.93	16.4
Carbon Offsetting	1250	665	13.42	0	4.96	0.8774	87757.4565	12247.1214	58091.67	-13624.4	-11050.3	67.00	47.00	281000.00	187500.00	144541.69	613041.69	-3.95	2.15	0.51	1.3	0.00	99.98	24387.65	572841.05	235799.36	14.35

TSC + PV + FIT + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	235	94	39.66	10.4775	4.96	0.3526	12404.8134	30259.929	203.1794	2428.549	7931.041	68.50	48.00	287150.00	35250.00	17257.06	339657.06	14.19	0.30	0.10	1.49	16.08	22.45	5406.36	126989.86	63332.80	12.15
50	685	187	26.44	6.985	4.96	0.617	24677.6607	23563.4558	6327.852	-564.13	3463.01	68.50	48.00	287150.00	102750.00	34514.12	424414.12	9.49	0.60	0.28	1.49	11.87	42.76	9874.39	231939.35	83525.24	15.65
75	1235	281	13.22	3.4925	4.96	0.8814	37082.4741	19750.3654	14919.21	-3283.27	-731.484	68.50	48.00	287150.00	185250.00	51771.18	524171.18	4.87	0.91	0.51	1.49	7.77	62.50	14068.88	330463.73	82292.55	18.5
75-100	1235	375	13.22	0	4.96	0.8814	49487.2875	17131.2544	24705.64	-5889.03	-3337.25	68.50	48.00	287150.00	185250.00	69028.24	541428.24	2.70	1.21	0.51	1.49	5.91	71.50	16674.65	391670.44	126242.20	16.6
Carbon Offsetting	1235	673	13.22	0	4.96	0.8814	88813.1853	12136.0521	59036.33	-13835.5	-11283.7	68.50	48.00	287150.00	185250.00	146280.54	618680.54	-4.18	2.17	0.51	1.49	-0.01	100.04	24621.11	578324.79	235644.25	14.45

TSC + PV + FIT + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	225	94	38.15	10.4775	4.96	0.3828	12404.8134	30259.929	203.1794	2428.549	7762.525	70.00	49.00	293300.00	33750.00	17257.06	344307.06	13.91	0.30	0.09	1.67	15.97	22.95	5574.87	130948.12	62641.07	12.65
50	675	187	25.42	6.985	4.96	0.6374	24677.6607	23563.4558	6327.852	-564.13	3349.178	70.00	49.00	293300.00	101250.00	34514.12	429064.12	9.30	0.60	0.28	1.67	11.85	42.82	9988.22	234613.15	81549.03	15.95
75	1230	281	12.7	3.4925	4.96	0.8918	37082.4741	19750.3654	14919.21	-3283.27	-789.516	70.00	49.00	293300.00	184500.00	51771.18	529571.18	4.77	0.91	0.50	1.67	7.86	62.11	14126.92	331826.84	78255.66	18.825
75-100	1230	375	12.7	0	4.96	0.8918	49487.2875	17131.2544	24705.64	-5889.03	-3395.28	70.00	49.00	293300.00	184500.00	69028.24	546828.24	2.60	1.21	0.50	1.67	5.99	71.11	16732.68	393033.55	122205.32	16.9
Carbon Offsetting	1230	677	12.7	0	4.96	0.8918	89341.0497	12080.5175	59508.66	-13941.1	-11447.3	70.00	49.00	293300.00	184500.00	147149.96	624949.96	-4.36	2.18	0.50	1.67	-0.01	100.03	24784.71	582167.63	233217.67	14.62

TSC + PV + FIT + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	220	94	36.6	10.4775	4.96	0.4138	12404.8134	30259.929	203.1794	2428.549	7589.545	71.50	50.00	299450.00	33000.00	17257.06	349707.06	13.62	0.30	0.09	1.86	15.87	23.43	5747.85	135011.25	61304.19	13.25
50	685	187	24.4	6.985	4.96	0.6578	24677.6607	23563.4558	6327.852	-564.13	3235.346	71.50	50.00	299450.00	102750.00	34514.12	436714.12	9.11	0.60	0.28	1.86	11.86	42.80	10102.05	237286.95	76572.83	16.6
75	1225	281	12.21	3.4925	4.96	0.9016	37082.4741	19750.3654	14919.21	-3283.27	-844.2	71.50	50.00	299450.00	183750.00	51771.18	534971.18	4.68	0.91	0.50	1.86	7.95	61.64	14181.60	333111.31	74140.14	19.15
75-100	1225	375	12.21	0	4.96	0.9016	49487.2875	17131.2544	24705.64	-5889.03	-3449.96	71.50	50.00	299450.00	183750.00	69028.24	552228.24	2.51	1.21	0.50	1.86	6.09	70.64	16787.36	394318.02	118089.79	17.2
Carbon Offsetting	1225	682	12.21	0	4.96	0.9016	90132.8463	12003.1919	60222.36	-14098.8	-11659.7	71.50	50.00	299450.00	183750.00	148454.10	631654.10	-4.59	2.20	0.50	1.86	-0.03	100.15	24997.15	587157.55	231503.45	14.8

TSC + PV + FIT + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	215	94	35.55	10.4775	4.96	0.4348	12404.8134	30259.929	203.1794	2428.549	7472.365	73.00	51.00	305600.00	32250.00	17257.06	355107.06	13.42	0.30	0.09	2.04	15.86	23.51	5865.03	137763.69	58656.63	14
50	665	187	23.7	6.985	4.96	0.6718	24677.6607	23563.4558	6327.852	-564.13	3157.226	73.00	51.00	305600.00	99750.00	34514.12	439864.12	8.98	0.60	0.27	2.04	11.90	42.60	10180.17	239121.91	75257.79	16.8
75	1220	281	11.85	3.4925	4.96	0.9088	37082.4741	19750.3654	14919.21	-3283.27	-884.376	73.00	51.00	305600.00	183000.00	51771.18	540371.18	4.62	0.91	0.50	2.04	8.06	61.10	14221.78	334055.01	69683.83	19.55
75-100	1220	375	11.85	0	4.96	0.9088	49487.2875	17131.2544	24705.64	-5889.03	-3490.14	73.00	51.00	305600.00	183000.00	69028.24	557628.24	2.45	1.21	0.50	2.04	6.20	70.10	16827.54	395261.72	113633.48	17.5
Carbon Offsetting	1220	687	11.85	0	4.96	0.9088	90660.7107	11949.0147	60694.69	-14204.2	-11805.3	73.00	51.00	305600.00	183000.00	149323.52	637923.52	-4.75	2.22	0.50	2.04	0.00	99.98	25142.71	590576.51	228652.98	14.95

TSC + PV + FIT + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	200	94	33	10.4775	4.96	0.4858	12404.8134	30259.929	203.1794	2428.549	7187.785	79.00	55.00	330200.00	30000.00	17257.06	377457.06	12.95	0.30	0.08	2.79	16.13	22.21	6149.61	144448.18	42991.12	17.25
50	660	187	22	6.985	4.96	0.7058	24677.6607	23563.4558	6327.852	-564.13	2967.506	79.00	55.00	330200.00	99000.00	34514.12	463714.12	8.67	0.60	0.27	2.79	12.33	40.51	10369.89	243578.24	55864.12	19
75	1215	281	11	3.4925	4.96	0.9258	37082.4741	19750.3654	14919.21	-3283.27	-979.236	79.00	55.00	330200.00	182250.00	51771.18	564221.18	4.46	0.91	0.50	2.79	8.65	58.26	14316.64	336283.17	48061.99	21.25
75-100	1215	375	11	0	4.96	0.9258	49487.2875	17131.2544	24705.64	-5889.03	-3585	79.00	55.00	330200.00	182250.00	69028.24	581478.24	2.29	1.21	0.50	2.79	6.79	67.26	16922.40	397489.88	92011.65	18.95
Carbon Offsetting	1215	717	11	0	4.96	0.9258	94619.6937	11567.1196	64253.54	-14991.9	-12687.8	79.00	55.00	330200.00	182250.00	155844.20	668294.20	-5.60	2.31	0.50	2.79	0.00	99.99	26025.23	611306.15	219011.95	15.7

TSC + PV + FIT + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO_2 (kgCO_2/m^2.yr)	TSC ECO_2 (kgCO_2/m^2.yr)	Insulation ECO_2 (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	195	94	32.25	10.4775	4.96	0.5008	12404.8134	30259.929	203.1794	2428.549	7104.085	82.00	57.00	342500.00	29250.00	17257.06	389007.06	12.81	0.30	0.08	3.16	16.36	21.10	6233.31	146414.21	33407.15	19
50	650	187	21.5	6.985	4.96	0.7158	24677.6607	23563.4558	6327.852	-564.13	2911.706	82.00	57.00	342500.00	97500.00	34514.12	474514.12	8.58	0.60	0.27	3.16	12.61	39.19	10425.69	244888.92	46374.80	20
75	1210	281	10.75	3.4925	4.96	0.9308	37082.4741	19750.3654	14919.21	-3283.27	-1007.14	82.00	57.00	342500.00	181500.00	51771.18	575771.18	4.41	0.91	0.50	3.16	8.98	56.70	14344.54	336938.51	37167.34	22.1
75-100	1210	375	10.75	0	4.96	0.9308	49487.2875	17131.2544	24705.64	-5889.03	-3612.9	82.00	57.00	342500.00	181500.00	69028.24	593028.24	2.24	1.21	0.50	3.16	7.11	65.71	16950.30	398145.22	81116.99	19.65
Carbon Offsetting	1210	735	10.75	0	4.96	0.9308	96995.0835	11331.2073	66379.03	-15465	-13188.8	82.00	57.00	342500.00	181500.00	159756.61	683756.61	-6.06	2.37	0.50	3.16	-0.03	100.15	26526.24	623074.27	215317.66	16

Table B. 24 Distribution warehouse - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC

Distribution Warehouse-London
PV (future FiT) + Insulation + TSC

TSC + PV + Future FIT + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25%	275	94	42.97	10.4775	4.96	0.2864	12404.813	30259.929	203.1794	4227.247	10099.13	66.00	46.00	276000.00	41250.00	17257.06	334507.06	14.80	0.30	0.11	1.20	16.42	20.81	3238.27	76063.54	17556.48	19
50%	750	187	28.65	6.985	4.96	0.5728	24677.661	23563.4558	6327.852	3014.13	7287.906	66.00	46.00	276000.00	112500.00	34514.12	423014.12	9.90	0.60	0.31	1.20	12.01	42.05	6049.49	142096.43	-4917.69	25.9
75%	1300	281	14.32	3.4925	4.96	0.8594	37082.474	19750.3654	14919.21	2093.687	4768.235	66.00	46.00	276000.00	195000.00	51771.18	522771.18	5.07	0.91	0.53	1.20	7.71	62.79	8569.17	201280.95	-45490.23	31.1
75-100	1300	375	14.32	0	4.96	0.8594	49487.288	17131.2544	24705.64	1286.622	3961.17	66.00	46.00	276000.00	195000.00	69028.24	540028.24	2.91	1.21	0.53	1.20	5.85	71.79	9376.23	220238.08	-43790.16	30.35
Carbon Offsetting	1300	650	14.32	0	4.96	0	85777.965	12455.3763	56320.44	-790.667	1522.933	66.00	46.00	276000.00	195000.00	141281.35	612281.35	-3.89	2.10	0.53	1.20	-0.06	100.30	11814.47	277509.78	-58771.58	30.75
Carbon Offsetting	1300	650	14.32	0	4.96	0	85777.965	12455.3763	56320.44	-3888.29	-1574.69	66.00	46.00	276000.00	195000.00	141281.35	612281.35	-3.89	2.10	0.53	1.20	-0.06	100.30	14912.09	350269.80	13988.45	23.95

TSC + PV + FIT + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	250	94	41.5	10.4775	4.96	0.3158	12404.813	30259.929	203.1794	4227.247	9935.083	67.00	47.00	281000.00	37500.00	17257.06	335757.06	14.53	0.30	0.10	1.3	16.23	21.69	3402.32	79916.95	20159.90	18.5
50	700	187	27.7	6.985	4.96	0.5918	24677.661	23563.4558	6327.852	3014.13	7181.886	67.00	47.00	281000.00	105000.00	34514.12	420514.12	9.73	0.60	0.29	1.3	11.92	42.52	6155.51	144586.73	72.61	25
75	1250	281	13.42	3.4925	4.96	0.8774	37082.474	19750.3654	14919.21	2093.687	4667.795	67.00	47.00	281000.00	187500.00	51771.18	520271.18	4.91	0.91	0.51	1.3	7.63	63.21	8669.61	203640.18	-40631.00	30.35
75-100	1250	375	13.42	0	4.96	0.8774	49487.288	17131.2544	24705.64	1286.622	3860.73	67.00	47.00	281000.00	187500.00	69028.24	537528.24	2.74	1.21	0.51	1.3	5.76	72.21	9476.67	222597.31	-38930.92	29.7
Carbon Offsetting	1250	665	13.42	0	4.96	0.8774	87757.457	12247.1214	58091.67	-899.528	1674.58	67.00	47.00	281000.00	187500.00	144541.69	613041.69	-3.95	2.15	0.51	1.3	0.00	99.98	11662.82	273947.75	-63093.94	31.25
Carbon Offsetting	1250	665	13.42	0	4.96	0.8774	87757.457	12247.1214	58091.67	-4094.57	-1520.46	67.00	47.00	281000.00	187500.00	144541.69	613041.69	-3.95	2.15	0.51	1.3	0.00	99.98	14857.86	348996.03	11954.34	24.1

TSC + PV + FIT + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	235	94	39.66	10.4775	4.96	0.3526	12404.813	30259.929	203.1794	4227.247	9729.739	68.50	48.00	287150.00	35250.00	17257.06	339657.06	14.19	0.30	0.10	1.49	16.08	22.45	3607.66	84740.28	21083.22	18.5
50	685	187	26.44	6.985	4.96	0.617	24677.661	23563.4558	6327.852	3014.13	7041.27	68.50	48.00	287150.00	102750.00	34514.12	424414.12	9.49	0.60	0.28	1.49	11.87	42.76	6296.13	147889.66	-524.46	25.1
75	1235	281	13.22	3.4925	4.96	0.8814	37082.474	19750.3654	14919.21	2093.687	4645.475	68.50	48.00	287150.00	185250.00	51771.18	524171.18	4.87	0.91	0.51	1.49	7.77	62.50	8691.93	204164.45	-44006.72	30.8
75-100	1235	375	13.22	0	4.96	0.8814	49487.288	17131.2544	24705.64	1286.622	3838.41	68.50	48.00	287150.00	185250.00	69028.24	541428.24	2.70	1.21	0.51	1.49	5.91	71.50	9498.99	223121.59	-42306.65	30.1
Carbon Offsetting	1235	673	13.22	0	4.96	0.8814	88813.185	12136.0521	59036.33	-957.588	1594.2	68.50	48.00	287150.00	185250.00	146280.54	618680.54	-4.18	2.17	0.51	1.49	-0.01	100.04	11743.20	275835.78	-66844.76	31.55
Carbon Offsetting	1235	673	13.22	0	4.96	0.8814	88813.185	12136.0521	59036.33	-4204.59	-1652.8	68.50	48.00	287150.00	185250.00	146280.54	618680.54	-4.18	2.17	0.51	1.49	-0.01	100.04	14990.20	352104.46	9423.92	24.3

TSC + PV + FIT + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	225	94	38.15	10.4775	4.96	0.3828	12404.813	30259.929	203.1794	4227.247	9561.223	70.00	49.00	293300.00	33750.00	17257.06	344307.06	13.91	0.30	0.09	1.67	15.97	22.95	3776.18	88698.54	20391.49	19
50	675	187	25.42	6.985	4.96	0.6374	24677.661	23563.4558	6327.852	3014.13	6927.438	70.00	49.00	293300.00	101250.00	34514.12	429064.12	9.30	0.60	0.28	1.67	11.85	42.82	6409.96	150563.46	-2500.66	25.45
75	1230	281	12.7	3.4925	4.96	0.8918	37082.474	19750.3654	14919.21	2093.687	4587.443	70.00	49.00	293300.00	184500.00	51771.18	529571.18	4.77	0.91	0.50	1.67	7.86	62.11	8749.96	205527.57	-48043.61	31.3
75-100	1230	375	12.7	0	4.96	0.8918	49487.288	17131.2544	24705.64	1286.622	3780.378	70.00	49.00	293300.00	184500.00	69028.24	546828.24	2.60	1.21	0.50	1.67	5.99	71.11	9557.02	224484.70	-46343.54	30.55
Carbon Offsetting	1230	677	12.7	0	4.96	0.8918	89341.05	12080.5175	59508.66	-986.617	1507.139	70.00	49.00	293300.00	184500.00	147149.96	624949.96	-4.36	2.18	0.50	1.67	-0.01	100.03	11830.26	277880.77	-71069.19	31.9
Carbon Offsetting	1230	677	12.7	0	4.96	0.8918	89341.05	12080.5175	59508.66	-4259.59	-1765.84	70.00	49.00	293300.00	184500.00	147149.96	624949.96	-4.36	2.18	0.50	1.67	-0.01	100.03	15103.24	354759.65	5809.68	24.55

TSC + PV + FIT + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	220	94	36.6	10.4775	4.96	0.4138	12404.813	30259.929	203.1794	4227.247	9388.243	71.50	50.00	299450.00	33000.00	17257.06	349707.06	13.62	0.30	0.09	1.86	15.87	23.43	3949.16	92761.67	19054.61	19.6
50	685	187	24.4	6.985	4.96	0.6578	24677.661	23563.4558	6327.852	3014.13	6813.606	71.50	50.00	299450.00	102750.00	34514.12	436714.12	9.11	0.60	0.28	1.86	11.86	42.80	6523.79	153237.25	-7476.86	26.25
75	1225	281	12.21	3.4925	4.96	0.9016	37082.474	19750.3654	14919.21	2093.687	4532.759	71.50	50.00	299450.00	183750.00	51771.18	534971.18	4.68	0.91	0.50	1.86	7.95	61.64	8804.64	206812.04	-52159.14	31.85
75-100	1225	375	12.21	0	4.96	0.9016	49487.288	17131.2544	24705.64	1286.622	3725.694	71.50	50.00	299450.00	183750.00	69028.24	552228.24	2.51	1.21	0.50	1.86	6.09	70.64	9611.71	225769.17	-50459.07	31
Carbon Offsetting	1225	682	12.21	0	4.96	0.9016	90132.846	12003.1919	60222.36	-1029.56	1409.513	71.50	50.00	299450.00	183750.00	148454.10	631654.10	-4.59	2.20	0.50	1.86	-0.03	100.15	11927.89	280173.90	-75480.20	32.3
Carbon Offsetting	1225	682	12.21	0	4.96	0.9016	90132.846	12003.1919	60222.36	-4341.79	-1902.72	71.50	50.00	299450.00	183750.00	148454.10	631654.10	-4.59	2.20	0.50	1.86	-0.03	100.15	15240.12	357974.80	2320.70	24.85

TSC + PV + FIT + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	215	94	35.55	10.4775	4.96	0.4348	12404.813	30259.929	203.1794	4227.247	9271.063	73.00	51.00	305600.00	32250.00	17257.06	355107.06	13.42	0.30	0.09	2.04	15.86	23.51	4066.34	95514.11	16407.05	20.5
50	665	187	23.7	6.985	4.96	0.6718	24677.661	23563.4558	6327.852	3014.13	6735.486	73.00	51.00	305600.00	99750.00	34514.12	439864.12	8.98	0.60	0.27	2.04	11.90	42.60	6601.91	155072.21	-8791.91	26.5
75	1220	281	11.85	3.4925	4.96	0.9088	37082.474	19750.3654	14919.21	2093.687	4492.583	73.00	51.00	305600.00	183000.00	51771.18	540371.18	4.62	0.91	0.50	2.04	8.06	61.10	8844.82	207755.73	-56615.45	32.35
75-100	1220	375	11.85	0	4.96	0.9088	49487.288	17131.2544	24705.64	1286.622	3685.518	73.00	51.00	305600.00	183000.00	69028.24	557628.24	2.45	1.21	0.50	2.04	6.20	70.10	9651.88	226712.86	-54915.37	31.55
Carbon Offsetting	1220	687	11.85	0	4.96	0.9088	90660.711	11949.0147	60694.69	-1058.4	1340.497	73.00	51.00	305600.00	183000.00	149323.52	637923.52	-4.75	2.22	0.50	2.04	0.00	99.98	11996.90	281795.01	-80128.52	32.7
Carbon Offsetting	1220	687	11.85	0	4.96	0.9088	90660.711	11949.0147	60694.69	-4396.61	-1997.71	73.00	51.00	305600.00	183000.00	149323.52	637923.52	-4.75	2.22	0.50	2.04	0.00	99.98	15335.11	360206.10	-1717.42	25.125

TSC + PV + FIT + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	200	94	33	10.4775	4.96	0.4858	12404.813	30259.929	203.1794	4227.247	8986.483	79.00	55.00	330200.00	30000.00	17257.06	377457.06	12.95	0.30	0.08	2.79	16.13	22.21	4350.92	102198.60	741.54	24.8
50	660	187	22	6.985	4.96	0.7058	24677.661	23563.4558	6327.852	3014.13	6545.766	79.00	55.00	330200.00	99000.00	34514.12	463714.12	8.67	0.60	0.27	2.79	12.33	40.51	6791.63	159528.54	-28185.58	29.75
75	1215	281	11	3.4925	4.96	0.9258	37082.474	19750.3654	14919.21	2093.687	4397.723	79.00	55.00	330200.00	182250.00	51771.18	564221.18	4.46	0.91	0.50	2.79	8.65	58.26	8939.68	209983.90	-78237.28	35.15
75-100	1215	375	11	0	4.96	0.9258	49487.288	17131.2544	24705.64	1286.622	3590.658	79.00	55.00	330200.00	182250.00	69028.24	581478.24	2.29	1.21	0.50	2.79	6.79	67.26	9746.74	228941.03	-76537.21	34.1
Carbon Offsetting	1215	717	11	0	4.96	0.9258	94619.694	11567.1196	64253.54	-1272.01	1032.023	79.00	55.00	330200.00	182250.00	155844.20	668294.20	-5.60	2.31	0.50	2.79	0.00	99.99	12305.38	289040.74	-103253.46	34.7
Carbon Offsetting	1215	717	11	0	4.96	0.9258	94619.694	11567.1196	64253.54	-4805.96	-2501.92	79.00	55.00	330200.00	182250.00	155844.20	668294.20	-5.60	2.31	0.50	2.79	0.00	99.99	15839.32	372049.50	-20244.70	26.45

TSC + PV + FIT + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	57.29	13.97	4.96	0	0	0	0	5867.4	13337.4	66.00	46.00	276000.00	0.00	0.00	276000.00	19.53	0.00	0.00	1.20	20.73	0.00	0.00	0.00	0.00	0
25	195	94	32.25	10.4775	4.96	0.5008	12404.813	30259.929	203.1794	4227.247	8902.783	82.00	57.00	342500.00	29250.00	17257.06	389007.06	12.81	0.30	0.08	3.16	16.36	21.10	4434.62	104164.63	-8842.43	27.25
50	650	187	21.5	6.985	4.96	0.7158	24677.661	23563.4558	6327.852	3014.13	6489.966	82.00	57.00	342500.00	97500.00	34514.12	474514.12	8.58	0.60	0.27	3.16	12.61	39.19	6847.43	160839.23	-37674.89	31.3
75	1210	281	10.75	3.4925	4.96	0.9308	37082.474	19750.3654	14919.21	2093.687	4369.823	82.00	57.00	342500.00	181500.00	51771.18	575771.18	4.41	0.91	0.50	3.16	8.98	56.70	8967.58	210639.24	-89131.94	36.55
75-100	1210	375	10.75	0	4.96	0.9308	49487.288	17131.2544	24705.64	1286.622	3562.758	82.00	57.00	342500.00	181500.00	69028.24	593028.24	2.24	1.21	0.50	3.16	7.11	65.71	9774.64	229596.37	-87431.87	35.35
Carbon Offsetting	1210	735	10.75	0	4.96	0.9308	96995.084	11331.2073	66379.03	-1400.69	875.4489	82.00	57.00	342500.00	181500.00	159756.61	683756.61	-6.06	2.37	0.50	3.16	-0.03	100.15	12461.95	292718.52	-115038.09	35.7
Carbon Offsetting	1210	735	10.75	0	4.96	0.9308	96995.084	11331.2073	66379.03	-5051.53	-2775.4	82.00	57.00	342500.00	181500.00	159756.61	683756.61	-6.06	2.37	0.50	3.16	-0.03	100.15	16112.80	378473.17	-29283.44	27.1

Table B. 25 Retail shed - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 $W/m^2.K$ (PUR)

Retail shed - London
PV (curent FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	32.9	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9648.058743	66.00	46.00	276000.00	39282.35	315282.35	18.55	0.69	1.20	20.44	17.32	7893.54	185411.23	146128.88	5.1
50%	427	32.9	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2823.151511	66.00	46.00	276000.00	78564.71	354564.71	13.61	1.38	1.20	16.19	34.51	14718.45	345721.34	267156.63	5.4
75%	640	32.9	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3320.33146	66.00	46.00	276000.00	117847.06	393847.06	8.74	2.07	1.20	12.00	51.45	20861.93	490025.48	372178.42	5.75
100%	853	32.9	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9233.42235	66.00	46.00	276000.00	157129.41	433129.41	3.78	2.75	1.20	7.73	68.72	26775.02	628917.95	471788.54	6
Carbon offsetting	1243	32.9	0	1.98	164033.8623	31728.7177	100674.3864	-23873.2	-19687.6369	66.00	46.00	276000.00	270173.42	546173.42	-5.22	4.01	1.20	-0.01	100.04	37229.24	874476.79	604303.37	7.4

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	31.9	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9528.058743	67.00	47.00	281000.00	39282.35	320282.35	18.35	0.69	1.3	20.34	17.71	8013.54	188229.91	143947.55	5.6
50%	427	31.9	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2703.151511	67.00	47.00	281000.00	78564.71	359564.71	13.41	1.38	1.3	16.09	34.90	14838.45	348540.01	264975.31	5.75
75%	640	31.9	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3440.33146	67.00	47.00	281000.00	117847.06	398847.06	8.54	2.07	1.3	11.90	51.84	20981.93	492844.16	369997.10	5.95
100%	853	31.9	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9353.42235	67.00	47.00	281000.00	157129.41	438129.41	3.58	2.75	1.3	7.64	69.11	26895.02	631736.63	469607.22	6.15
Carbon offsetting	1238	31.9	0	1.98	163505.9979	31793.9162	100211.7206	-23766.7	-19701.1488	67.00	47.00	281000.00	269304.00	550304.00	-5.32	3.99	1.3	-0.03	100.12	37242.75	874794.17	600490.17	7.5

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	30.42	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9350.458743	68.50	48.00	287150.00	39282.35	326432.35	18.06	0.69	1.49	20.24	18.12	8191.14	192401.55	141969.20	6.25
50%	427	30.42	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2525.551511	68.50	48.00	287150.00	78564.71	365714.71	13.12	1.38	1.49	15.99	35.30	15016.05	352711.66	262996.95	6.1
75%	640	30.42	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3617.93146	68.50	48.00	287150.00	117847.06	404997.06	8.25	2.07	1.49	11.80	52.24	21159.53	497015.80	368018.74	6.2
100%	853	30.42	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9531.02235	68.50	48.00	287150.00	157129.41	444279.41	3.29	2.75	1.49	7.54	69.51	27072.62	635908.27	467628.86	6.35
Carbon offsetting	1233	30.42	0	1.98	162714.2013	31891.7141	99517.72182	-23607	-19719.0167	68.50	48.00	287150.00	267999.86	555149.86	-5.48	3.98	1.49	-0.01	100.03	37260.62	875213.87	596064.00	7.65

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	28.84	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9160.858743	70.00	49.00	293300.00	39282.35	332582.35	17.75	0.69	1.67	20.11	18.64	8380.74	196855.06	140272.71	6.9
50%	427	28.84	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2335.951511	70.00	49.00	293300.00	78564.71	371864.71	12.81	1.38	1.67	15.86	35.83	15205.65	357165.17	261300.46	6.45
75%	640	28.84	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3807.53146	70.00	49.00	293300.00	117847.06	411147.06	7.94	2.07	1.67	11.68	52.77	21349.13	501469.31	366322.25	6.45
100%	853	28.84	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9720.62235	70.00	49.00	293300.00	157129.41	450429.41	2.98	2.75	1.67	7.41	70.04	27262.22	640361.78	465932.37	6.5
Carbon offsetting	1227	28.84	0	1.98	161922.4047	31989.5119	98823.72306	-23447.3	-19748.8846	70.00	49.00	293300.00	266695.73	559995.73	-5.65	3.96	1.67	-0.02	100.07	37290.48	875915.43	591919.71	7.8

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	28	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	9060.058743	71.50	50.00	299450.00	39282.35	338732.35	17.59	0.69	1.86	20.14	18.54	8481.54	199222.75	136490.40	7.55
50%	427	28	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2235.151511	71.50	50.00	299450.00	78564.71	378014.71	12.65	1.38	1.86	15.89	35.73	15306.45	359532.86	257518.15	6.8
75%	640	28	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-3908.33146	71.50	50.00	299450.00	117847.06	417297.06	7.78	2.07	1.86	11.70	52.67	21449.93	503837.00	362539.94	6.7
100%	853	28	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9821.42235	71.50	50.00	299450.00	157129.41	456579.41	2.82	2.75	1.86	7.43	69.93	27363.02	642729.47	462150.06	6.72
Carbon offsetting	1228	28	0	1.98	162054.3708	31973.2123	98939.38952	-23473.9	-19876.3066	71.50	50.00	299450.00	266913.08	566363.08	-5.83	3.96	1.86	-0.01	100.05	37417.91	878908.44	588545.36	7.93

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	27.04	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8944.858743	73.00	51.00	305600.00	39282.35	344882.35	17.40	0.69	2.04	20.13	18.57	8596.74	201928.68	133046.33	8.2
50%	427	27.04	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	2119.951511	73.00	51.00	305600.00	78564.71	384164.71	12.46	1.38	2.04	15.88	35.76	15421.65	362238.79	254074.08	7.15
75%	640	27.04	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4023.53146	73.00	51.00	305600.00	117847.06	423447.06	7.59	2.07	2.04	11.69	52.70	21565.13	506542.93	359095.87	7
100%	853	27.04	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-9936.62235	73.00	51.00	305600.00	157129.41	462729.41	2.63	2.75	2.04	7.42	69.97	27478.22	645435.40	458705.99	6.92
Carbon offsetting	1228	27.04	0	1.98	162054.3708	31973.2123	98939.38952	-23473.9	-19991.5066	73.00	51.00	305600.00	266913.08	572513.08	-6.02	3.96	2.04	-0.02	100.08	37533.11	881614.38	585101.29	8.1

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	24.8	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8676.058743	79.00	55.00	330200.00	39282.35	369482.35	16.96	0.69	2.79	20.44	17.32	8865.54	208242.52	114760.16	10.85
50%	427	24.8	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	1851.151511	79.00	55.00	330200.00	78564.71	408764.71	12.02	1.38	2.79	16.19	34.50	15690.45	368552.62	235787.92	8.65
75%	640	24.8	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4292.33146	79.00	55.00	330200.00	117847.06	448047.06	7.15	2.07	2.79	12.00	51.44	21833.93	512856.77	340809.71	8.05
100%	853	24.8	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-10205.4224	79.00	55.00	330200.00	157129.41	487329.41	2.19	2.75	2.79	7.73	68.71	27747.02	651749.24	440419.83	7.8
Carbon offsetting	1243	24.8	0	1.98	164033.8623	31728.7177	100674.3864	-23873.2	-20659.6369	79.00	55.00	330200.00	270173.42	600373.42	-6.81	4.01	2.79	-0.01	100.03	38201.24	897308.08	572934.66	8.7

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	24.22	23.85	1.98	28108.7793	68675.2667	1695.68	5462.459	8606.458743	82.00	57.00	342500.00	39282.35	381782.35	16.85	0.69	3.16	20.69	16.28	8935.14	209877.35	104095.00	12.2
50%	427	24.22	15.9	1.98	56349.5247	53315.7105	14577.04162	-1362.45	1781.551511	82.00	57.00	342500.00	78564.71	421064.71	11.91	1.38	3.16	16.45	33.46	15760.05	370187.46	225122.75	9.45
75%	640	24.22	7.95	1.98	84458.304	44755.5418	33894.51628	-7505.93	-4361.93146	82.00	57.00	342500.00	117847.06	460347.06	7.03	2.07	3.16	12.26	50.40	21903.53	514491.60	330144.54	8.6
100%	853	24.22	0	1.98	112567.0833	38839.5238	56318.41358	-13419	-10275.0224	82.00	57.00	342500.00	157129.41	499629.41	2.08	2.75	3.16	7.99	67.67	27816.62	653384.08	429754.66	8.25
Carbon offsetting	1257	24.22	0	1.98	165881.3877	31500.5227	102293.7169	-24245.9	-21101.9453	82.00	57.00	342500.00	273216.40	615716.40	-7.24	4.06	3.16	-0.03	100.11	38643.55	907697.45	567981.04	9

Table B. 26 Retail shed - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR)

Retail shed - London
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	32.9	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13723.83	66.00	46.00	276000.00	39282.35	315282.35	18.55	0.69	1.20	20.44	17.32	3817.77	89675.48	50393.13	10.5
50%	427	32.9	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10993.83	66.00	46.00	276000.00	78564.71	354564.71	13.61	1.38	1.20	16.19	34.51	6547.77	153800.38	75235.67	12.4
75%	640	32.9	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8926.123	66.00	46.00	276000.00	117847.06	393847.06	8.74	2.07	1.20	12.00	51.45	8615.48	202368.77	84521.71	14.2
100%	853	32.9	0	1.98	112567.08	38839.5238	56318.414	2903.20473	7088.805	66.00	46.00	276000.00	157129.41	433129.41	3.78	2.75	1.20	7.73	68.72	10452.80	245525.50	88396.08	15.65
Carbon offsetting	1243	32.9	0	1.98	164033.86	31728.7177	100674.39	-88.326915	4097.273	66.00	46.00	276000.00	270173.42	546173.42	-5.22	4.01	1.20	-0.01	100.04	13444.33	315793.52	45620.10	21.2
Carbon offsetting	1243	32.9	0	1.98	164033.86	31728.7177	100674.39	-5625.4182	-1439.82	66.00	46.00	276000.00	270173.42	546173.42	-5.22	4.01	1.20	-0.01	100.04	18981.42	445854.14	175680.72	14.8

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	31.9	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13603.83	67.00	47.00	281000.00	39282.35	320282.35	18.35	0.69	1.3	20.34	17.71	3937.77	92494.16	48211.81	11.55
50%	427	31.9	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10873.83	67.00	47.00	281000.00	78564.71	359564.71	13.41	1.38	1.3	16.09	34.90	6667.77	156619.05	73054.35	12.95
75%	640	31.9	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8806.123	67.00	47.00	281000.00	117847.06	398847.06	8.54	2.07	1.3	11.90	51.84	8735.48	205187.45	82340.39	14.6
100%	853	31.9	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6968.805	67.00	47.00	281000.00	157129.41	438129.41	3.58	2.75	1.3	7.64	69.11	10572.80	248344.17	86214.76	16
Carbon offsetting	1238	31.9	0	1.98	163506	31793.9162	100211.72	-58.379154	4007.221	67.00	47.00	281000.00	269304.00	550304.00	-5.32	3.99	1.3	-0.03	100.12	13534.38	317908.76	43604.76	21.4
Carbon offsetting	1238	31.9	0	1.98	163506	31793.9162	100211.72	-5570.0238	-1504.42	67.00	47.00	281000.00	269304.00	550304.00	-5.32	3.99	1.3	-0.03	100.12	19046.02	447371.66	173067.67	14.95

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	30.42	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13426.23	68.50	48.00	287150.00	39282.35	326432.35	18.06	0.69	1.49	20.24	18.12	4115.37	96665.80	46233.45	12.7
50%	427	30.42	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10696.23	68.50	48.00	287150.00	78564.71	365714.71	13.12	1.38	1.49	15.99	35.30	6845.37	160790.70	71075.99	13.6
75%	640	30.42	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8628.523	68.50	48.00	287150.00	117847.06	404997.06	8.25	2.07	1.49	11.80	52.24	8913.08	209359.09	80362.03	15.05
100%	853	30.42	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6791.205	68.50	48.00	287150.00	157129.41	444279.41	3.29	2.75	1.49	7.54	69.51	10750.40	252515.82	84236.40	16.35
Carbon offsetting	1233	30.42	0	1.98	162714.2	31891.7141	99517.722	-13.457512	3874.542	68.50	48.00	287150.00	267999.86	555149.86	-5.48	3.98	1.49	-0.01	100.03	13667.06	321025.24	41875.37	21.55
Carbon offsetting	1233	30.42	0	1.98	162714.2	31891.7141	99517.722	-5486.9322	-1598.93	68.50	48.00	287150.00	267999.86	555149.86	-5.48	3.98	1.49	-0.01	100.03	19140.53	449591.57	170441.71	15.2

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	28.84	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13236.63	70.00	49.00	293300.00	39282.35	332582.35	17.75	0.69	1.67	20.11	18.64	4304.97	101119.31	44536.96	13.65
50%	427	28.84	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10506.63	70.00	49.00	293300.00	78564.71	371864.71	12.81	1.38	1.67	15.86	35.83	7034.97	165244.21	69379.50	14.1
75%	640	28.84	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8438.923	70.00	49.00	293300.00	117847.06	411147.06	7.94	2.07	1.67	11.68	52.77	9102.68	213812.60	78665.54	15.45
100%	853	28.84	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6601.605	70.00	49.00	293300.00	157129.41	450429.41	2.98	2.75	1.67	7.41	70.04	10940.00	256969.33	82539.91	16.65
Carbon offsetting	1227	28.84	0	1.98	161922.4	31989.5119	98823.723	31.4641295	3729.864	70.00	49.00	293300.00	266695.73	559995.73	-5.65	3.96	1.67	-0.02	100.07	13811.74	324423.58	40427.86	21.7
Carbon offsetting	1227	28.84	0	1.98	161922.4	31989.5119	98823.723	-5403.8406	-1705.44	70.00	49.00	293300.00	266695.73	559995.73	-5.65	3.96	1.67	-0.02	100.07	19247.04	452093.35	168097.62	15.35

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	28	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13135.83	71.50	50.00	299450.00	39282.35	338732.35	17.59	0.69	1.86	20.14	18.54	4405.77	103487.00	40754.65	14.75
50%	427	28	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10405.83	71.50	50.00	299450.00	78564.71	378014.71	12.65	1.38	1.86	15.89	35.73	7135.77	167611.90	65597.19	14.85
75%	640	28	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8338.123	71.50	50.00	299450.00	117847.06	417297.06	7.78	2.07	1.86	11.70	52.67	9203.48	216180.29	74883.23	16
100%	853	28	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6500.805	71.50	50.00	299450.00	157129.41	456579.41	2.82	2.75	1.86	7.43	69.93	11040.80	259337.02	78757.60	17.1
Carbon offsetting	1228	28	0	1.98	162054.37	31973.2123	98939.39	23.9771892	3621.577	71.50	50.00	299450.00	266913.08	566363.08	-5.83	3.96	1.86	-0.01	100.05	13920.02	326967.13	36604.05	22.05
Carbon offsetting	1228	28	0	1.98	162054.37	31973.2123	98939.39	-5417.6892	-1820.09	71.50	50.00	299450.00	266913.08	566363.08	-5.83	3.96	1.86	-0.01	100.05	19361.69	454786.32	164423.24	15.6

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	27.04	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	13020.63	73.00	51.00	305600.00	39282.35	344882.35	17.40	0.69	2.04	20.13	18.57	4520.97	106192.93	37310.58	15.85
50%	427	27.04	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10290.63	73.00	51.00	305600.00	78564.71	384164.71	12.46	1.38	2.04	15.88	35.76	7250.97	170317.83	62153.12	15.5
75%	640	27.04	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	8222.923	73.00	51.00	305600.00	117847.06	423447.06	7.59	2.07	2.04	11.69	52.70	9318.68	218886.22	71439.16	16.5
100%	853	27.04	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6385.605	73.00	51.00	305600.00	157129.41	462729.41	2.63	2.75	2.04	7.42	69.97	11156.00	262042.95	75313.53	17.5
Carbon offsetting	1228	27.04	0	1.98	162054.37	31973.2123	98939.39	23.9771892	3506.377	73.00	51.00	305600.00	266913.08	572513.08	-6.02	3.96	2.04	-0.02	100.08	14035.22	329673.06	33159.98	22.35
Carbon offsetting	1228	27.04	0	1.98	162054.37	31973.2123	98939.39	-5417.6892	-1935.29	73.00	51.00	305600.00	266913.08	572513.08	-6.02	3.96	2.04	-0.02	100.08	19476.89	457492.25	160979.17	15.85

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	24.8	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	12751.83	79.00	55.00	330200.00	39282.35	369482.35	16.96	0.69	2.79	20.44	17.32	4789.77	93247.60	-234.75	20.55
50%	427	24.8	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	10021.83	79.00	55.00	330200.00	78564.71	408764.71	12.02	1.38	2.79	16.19	34.50	7519.77	132744.17	-20.53	18.5
75%	640	24.8	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	7954.123	79.00	55.00	330200.00	117847.06	448047.06	7.15	2.07	2.79	12.00	51.44	9587.48	172302.88	255.82	18.85
100%	853	24.8	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6116.805	79.00	55.00	330200.00	157129.41	487329.41	2.19	2.75	2.79	7.73	68.71	11424.80	211555.19	225.78	19.45
Carbon offsetting	1243	24.8	0	1.98	164033.86	31728.7177	100674.39	-88.326915	3125.273	79.00	55.00	330200.00	270173.42	600373.42	-6.81	4.01	2.79	-0.01	100.03	14416.33	324571.63	198.21	23.9
Carbon offsetting	1243	24.8	0	1.98	164033.86	31728.7177	100674.39	-5625.4182	-2411.82	79.00	55.00	330200.00	270173.42	600373.42	-6.81	4.01	2.79	-0.01	100.03	19953.42	322999.47	-1373.95	17

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	32.9	31.8	1.98	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	276000.00	23.52	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	213	24.22	23.85	1.98	28108.779	68675.2667	1695.68	9538.23174	12682.23	82.00	57.00	342500.00	39282.35	381782.35	16.85	0.69	3.16	20.69	16.28	4859.37	114141.60	8359.25	23
50%	427	24.22	15.9	1.98	56349.525	53315.7105	14577.042	6808.23259	9952.233	82.00	57.00	342500.00	78564.71	421064.71	11.91	1.38	3.16	16.45	33.46	7589.37	178266.50	33201.79	20.12
75%	640	24.22	7.95	1.98	84458.304	44755.5418	33894.516	4740.52262	7884.523	82.00	57.00	342500.00	117847.06	460347.06	7.03	2.07	3.16	12.26	50.40	9657.08	226834.89	42487.83	20.1
100%	853	24.22	0	1.98	112567.08	38839.5238	56318.414	2903.20473	6047.205	82.00	57.00	342500.00	157129.41	499629.41	2.08	2.75	3.16	7.99	67.67	11494.40	269991.62	46362.20	20.5
Carbon offsetting	1257	24.22	0	1.98	165881.39	31500.5227	102293.72	-193.14408	2950.856	82.00	57.00	342500.00	273216.40	615716.40	-7.24	4.06	3.16	-0.03	100.11	14590.74	342721.69	3005.29	24.75
Carbon offsetting	1257	24.22	0	1.98	165881.39	31500.5227	102293.72	-5819.2985	-2675.3	82.00	57.00	342500.00	273216.40	615716.40	-7.24	4.06	3.16	-0.03	100.11	20216.90	474874.32	135157.91	17.55

Table B. 27 Retail shed - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC

Retail shed- London
PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	130	213	24.675	24.675	1.98	0.1645	28108.7793	68675.2667	1695.68	5462.45874	8661.0587	66.00	46.00	276000.00	19500.00	35205.88	330705.88	17.02	0.69	0.05	1.20	18.96	23.28	8880.54	208594.85	153888.97	6.25
50%	345	427	16.45	16.45	1.98	0.329	56349.5247	53315.7105	14577.0416	-1362.4485	849.15151	66.00	46.00	276000.00	51750.00	75847.06	403597.06	10.56	1.38	0.14	1.20	13.28	46.28	16692.45	392088.58	264491.52	7.8
75%	595	640	8.225	8.225	1.98	0.4935	84458.304	44755.5418	33894.5163	-7505.9315	-6281.331	66.00	46.00	276000.00	89250.00	116488.24	481738.24	4.16	2.07	0.24	1.20	7.67	68.98	23822.93	559576.35	353838.12	8.85
75-100	595	853	8.225	0	1.98	0.4935	112567.083	38839.5238	56318.4136	-13419.022	-12194.42	66.00	46.00	276000.00	89250.00	157129.41	522379.41	-0.80	2.75	0.24	1.20	3.40	86.25	29736.02	698468.82	452089.41	8.5
Carbon offsetting	595	1025	8.225	0	1.98	0.4935	135265.253	35453.6829	75633.2437	-18053.442	-16828.84	66.00	46.00	276000.00	89250.00	222789.83	588039.83	-4.77	3.31	0.24	1.20	-0.02	100.06	34370.44	807326.61	495286.78	9.3

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	115	213	23.92	24.675	1.98	0.1796	28108.7793	68675.2667	1695.68	5462.45874	8570.4587	67.00	47.00	281000.00	17250.00	35205.88	333455.88	16.88	0.69	0.05	1.3	18.92	23.47	8971.14	210722.95	153267.07	6.5
50	315	427	15.95	16.45	1.98	0.339	56349.5247	53315.7105	14577.0416	-1362.4485	789.15151	67.00	47.00	281000.00	47250.00	75847.06	404097.06	10.47	1.38	0.13	1.3	13.27	46.30	16752.45	393497.92	265400.86	7.8
75	560	640	7.97	8.225	1.98	0.4986	84458.304	44755.5418	33894.5163	-7505.9315	-6311.931	67.00	47.00	281000.00	84000.00	116488.24	481488.24	4.11	2.07	0.23	1.3	7.71	68.83	23853.53	560295.11	354806.88	8.825
75-100	560	853	7.97	0	1.98	0.4986	112567.083	38839.5238	56318.4136	-13419.022	-12225.02	67.00	47.00	281000.00	84000.00	157129.41	522129.41	-0.84	2.75	0.23	1.3	3.44	86.09	29766.62	699187.59	453058.17	8.45
Carbon offsetting	560	1027	7.97	0	1.98	0.4986	135529.185	35416.7204	75859.6613	-18107.076	-16913.08	67.00	47.00	281000.00	84000.00	223224.54	588224.54	-4.86	3.31	0.23	1.3	-0.02	100.07	34454.68	809305.17	497080.64	9.3

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	113	213	22.6	24.675	1.98	0.206	28108.7793	68675.2667	1695.68	5462.45874	8412.0587	68.50	48.00	287150.00	16950.00	35205.88	339305.88	16.64	0.69	0.05	1.49	18.86	23.69	9129.54	214443.61	151137.73	7.1
50	305	427	15.21	16.45	1.98	0.3538	56349.5247	53315.7105	14577.0416	-1362.4485	700.35151	68.50	48.00	287150.00	45750.00	75847.06	408747.06	10.33	1.38	0.13	1.49	13.32	46.11	16841.25	395583.74	262836.68	8.05
75	551	640	7.55	8.225	1.98	0.507	84458.304	44755.5418	33894.5163	-7505.9315	-6362.331	68.50	48.00	287150.00	82650.00	116488.24	486288.24	4.03	2.07	0.23	1.49	7.81	68.39	23903.93	561478.96	351190.72	9
75-100	551	853	7.55	0	1.98	0.507	112567.083	38839.5238	56318.4136	-13419.022	-12275.42	68.50	48.00	287150.00	82650.00	157129.41	526929.41	-0.92	2.75	0.23	1.49	3.55	85.66	29817.02	700371.43	449442.02	8.6
Carbon offsetting	551	1032	7.55	0	1.98	0.507	136189.015	35324.3141	76425.7051	-18241.16	-17097.56	68.50	48.00	287150.00	82650.00	224311.32	594111.32	-5.05	3.33	0.23	1.49	-0.01	100.03	34639.16	813638.52	495527.20	9.4

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	112	213	21.72	24.675	1.98	0.2236	28108.7793	68675.2667	1695.68	5462.45874	8306.4587	70.00	49.00	293300.00	16800.00	35205.88	345305.88	16.47	0.69	0.05	1.67	18.88	23.63	9235.14	216924.04	147618.16	7.7
50	295	427	14.18	16.45	1.98	0.3744	56349.5247	53315.7105	14577.0416	-1362.4485	576.75151	70.00	49.00	293300.00	44250.00	75847.06	413397.06	10.14	1.38	0.12	1.67	13.31	46.17	16964.85	398486.98	261089.92	8.3
75	542	640	7.24	8.225	1.98	0.5132	84458.304	44755.5418	33894.5163	-7505.9315	-6399.531	70.00	49.00	293300.00	81300.00	116488.24	491088.24	3.98	2.07	0.22	1.67	7.93	67.91	23941.13	562352.75	347264.51	9.2
75-100	542	853	7.24	0	1.98	0.5132	112567.083	38839.5238	56318.4136	-13419.022	-12312.62	70.00	49.00	293300.00	81300.00	157129.41	531729.41	-0.98	2.75	0.22	1.67	3.66	85.18	29854.22	701245.22	445515.81	8.8
Carbon offsetting	542	1038	7.24	0	1.98	0.5132	136980.812	35213.4265	77104.9576	-18402.061	-17295.66	70.00	49.00	293300.00	81300.00	225615.45	600215.45	-5.25	3.35	0.22	1.67	-0.01	100.03	34837.26	818291.72	494076.26	9.55

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	109	213	21	24.675	1.98	0.238	28108.7793	68675.2667	1695.68	5462.45874	8220.0587	71.50	50.00	299450.00	16350.00	35205.88	351005.88	16.34	0.69	0.04	1.86	18.93	23.40	9321.54	218953.49	143947.61	8.2
50	292	427	14	16.45	1.98	0.378	56349.5247	53315.7105	14577.0416	-1362.4485	555.15151	71.50	50.00	299450.00	43800.00	75847.06	419097.06	10.10	1.38	0.12	1.86	13.46	45.54	16986.45	398994.34	255897.28	8.6
75	535	640	7	8.225	1.98	0.518	84458.304	44755.5418	33894.5163	-7505.9315	-6428.331	71.50	50.00	299450.00	80250.00	116488.24	496188.24	3.93	2.07	0.22	1.86	8.08	67.33	23969.93	563029.23	342841.00	9.45
75-100	535	853	7	0	1.98	0.518	112567.083	38839.5238	56318.4136	-13419.022	-12341.42	71.50	50.00	299450.00	80250.00	157129.41	536829.41	-1.02	2.75	0.22	1.86	3.81	84.60	29883.02	701921.70	441092.29	8.95
Carbon offsetting	535	1046	7	0	1.98	0.518	138036.541	35065.5765	78010.6277	-18616.596	-17539	71.50	50.00	299450.00	80250.00	227354.30	607054.30	-5.48	3.38	0.22	1.86	-0.02	100.09	35080.60	824007.40	492953.10	9.7

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	107	213	20.2	24.675	1.98	0.254	28108.7793	68675.2667	1695.68	5462.45874	8124.0587	73.00	51.00	305600.00	16050.00	35205.88	356855.88	16.19	0.69	0.04	2.04	18.96	23.28	9417.54	221208.43	140352.55	8.75
50	288	427	13.52	16.45	1.98	0.3876	56349.5247	53315.7105	14577.0416	-1362.4485	497.55151	73.00	51.00	305600.00	43200.00	75847.06	424647.06	10.02	1.38	0.12	2.04	13.55	45.18	17044.05	400347.31	251700.25	8.95
75	527	640	6.76	8.225	1.98	0.5228	84458.304	44755.5418	33894.5163	-7505.9315	-6457.131	73.00	51.00	305600.00	79050.00	116488.24	501138.24	3.89	2.07	0.22	2.04	8.21	66.80	23998.73	563705.71	338567.48	9.65
75-100	527	853	6.76	0	1.98	0.5228	112567.083	38839.5238	56318.4136	-13419.022	-12370.22	73.00	51.00	305600.00	79050.00	157129.41	541779.41	-1.07	2.75	0.22	2.04	3.94	84.06	29911.82	702598.19	436818.77	9.1
Carbon offsetting	527	1052	6.76	0	1.98	0.5228	138828.337	34954.6889	78689.8803	-18777.497	-17728.7	73.00	51.00	305600.00	79050.00	228658.44	613308.44	-5.66	3.39	0.22	2.04	-0.01	100.04	35270.30	828463.29	491154.85	9.8

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	
25	106	213	18.6	24.675	1.98	0.286	28108.7793	68675.2667	1695.68	5462.45874	7932.0587	79.00	55.00	330200.00	15900.00	35205.88	381305.88	15.90	0.69	0.04	2.79	19.42	21.45	9609.54	225718.32	120412.44	11.3
50	286	427	12.4	16.45	1.98	0.41	56349.5247	53315.7105	14577.0416	-1362.4485	363.15151	79.00	55.00	330200.00	42900.00	75847.06	448947.06	9.81	1.38	0.12	2.79	14.09	42.99	17178.45	403504.23	230557.17	10.35
75	524	640	6.2	8.225	1.98	0.534	84458.304	44755.5418	33894.5163	-7505.9315	-6524.331	79.00	55.00	330200.00	78600.00	116488.24	525288.24	3.78	2.07	0.21	2.79	8.85	64.19	24065.93	565284.17	315995.94	10.65
75-100	524	853	6.2	0	1.98	0.534	112567.083	38839.5238	56318.4136	-13419.022	-12437.42	79.00	55.00	330200.00	78600.00	157129.41	565929.41	-1.17	2.75	0.21	2.79	4.58	81.45	29979.02	704176.64	414247.23	9.95
Carbon offsetting	524	1085	6.2	0	1.98	0.534	143183.219	34409.6016	82490.5393	-19656.297	-18674.7	79.00	55.00	330200.00	78600.00	235831.18	644631.18	-6.52	3.50	0.21	2.79	-0.02	100.08	36216.30	850683.86	482052.67	10.45

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	105	213	18.17	24.675	1.98	0.2946	28108.7793	68675.2667	1695.68	5462.45874	7880.4587	82.00	57.00	342500.00	15750.00	35205.88	393455.88	15.82	0.69	0.04	3.16	19.71	20.28	9661.14	226930.35	109474.47	12.6
50	284	427	12.11	16.45	1.98	0.4158	56349.5247	53315.7105	14577.0416	-1362.4485	328.35151	82.00	57.00	342500.00	42600.00	75847.06	460947.06	9.75	1.38	0.12	3.16	14.41	41.71	17213.25	404321.64	219374.58	11.05
75	521	640	6.05	8.225	1.98	0.537	84458.304	44755.5418	33894.5163	-7505.9315	-6542.331	82.00	57.00	342500.00	78150.00	116488.24	537138.24	3.75	2.07	0.21	3.16	9.19	62.81	24083.93	565706.97	304568.74	11.15
75-100	521	853	6.05	0	1.98	0.537	112567.083	38839.5238	56318.4136	-13419.022	-12455.42	82.00	57.00	342500.00	78150.00	157129.41	577779.41	-1.20	2.75	0.21	3.16	4.93	80.08	29997.02	704599.45	402820.03	10.35
Carbon offsetting	521	1103	6.05	0	1.98	0.537	145558.608	34094.8964	84534.737	-20136.776	-19173.18	82.00	57.00	342500.00	78150.00	239743.59	660393.59	-6.96	3.56	0.21	3.16	-0.03	100.13	36714.78	862392.62	477999.03	10.77

Table B. 28 Retail shed - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC

Retail shed - London
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25%	130	213	24.675	24.675	1.98	0.1645	28108.779	68675.2667	1695.68	9538.2317	12736.832	66.00	46.00	276000.00	19500.00	35205.88	330705.88	17.02	0.69	0.05	1.20	18.96	23.28	4804.77	54747.09	41.21	11.75
50%	345	427	16.45	16.45	1.98	0.329	56349.525	53315.7105	14577.04	6808.2326	9019.8326	66.00	46.00	276000.00	51750.00	75847.06	403597.06	10.56	1.38	0.14	1.20	13.28	46.28	8521.77	127732.43	135.37	15.6
75%	595	640	8.225	8.225	1.98	0.4935	84458.304	44755.5418	33894.52	4740.5226	5965.1226	66.00	46.00	276000.00	89250.00	116488.24	481738.24	4.16	2.07	0.24	1.20	7.67	68.98	11576.48	205939.30	201.06	18.65
75-100	595	853	8.225	0	1.98	0.4935	112567.08	38839.5238	56318.41	2903.2047	4127.8047	66.00	46.00	276000.00	89250.00	157129.41	522379.41	-0.80	2.75	0.24	1.20	3.40	86.25	13413.80	246558.45	179.04	19.3
Carbon offsetting	595	1025	8.225	0	1.98	0.4935	135265.25	35453.6829	75633.24	1560.0196	2784.6196	66.00	46.00	276000.00	89250.00	222789.83	588039.83	-4.77	3.31	0.24	1.20	-0.02	100.06	14756.98	311840.54	-199.29	22.35
Carbon offsetting	595	1025	8.225	0	1.98	0.4935	135265.25	35453.6829	75633.24	-2599.809	-1375.209	66.00	46.00	276000.00	89250.00	222789.83	588039.83	-4.77	3.31	0.24	1.20	-0.02	100.06	18916.81	312299.87	260.04	17.25

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	115	213	23.92	24.675	1.98	0.1796	28108.779	68675.2667	1695.68	9538.2317	12646.232	67.00	47.00	281000.00	17250.00	35205.88	333455.88	16.88	0.69	0.05	1.3	18.92	23.47	4895.37	57392.74	-63.14	12.1
50	315	427	15.95	16.45	1.98	0.339	56349.525	53315.7105	14577.04	6808.2326	8959.8326	67.00	47.00	281000.00	47250.00	75847.06	404097.06	10.47	1.38	0.13	1.3	13.27	46.30	8581.77	128234.82	137.76	15.55
75	560	640	7.97	8.225	1.98	0.4986	84458.304	44755.5418	33894.52	4740.5226	5934.5226	67.00	47.00	281000.00	84000.00	116488.24	481488.24	4.11	2.07	0.23	1.3	7.71	68.83	11607.08	205425.49	-62.74	18.55
75-100	560	853	7.97	0	1.98	0.4986	112567.08	38839.5238	56318.41	2903.2047	4097.2047	67.00	47.00	281000.00	84000.00	157129.41	522129.41	-0.84	2.75	0.23	1.3	3.44	86.09	13444.40	246143.51	14.10	19.22
Carbon offsetting	560	1027	7.97	0	1.98	0.4986	135529.18	35416.7204	75859.66	1544.6561	2738.6561	67.00	47.00	281000.00	84000.00	223224.54	588224.54	-4.86	3.31	0.23	1.3	-0.02	100.07	14802.94	312149.13	-75.41	22.3
Carbon offsetting	560	1027	7.97	0	1.98	0.4986	135529.18	35416.7204	75859.66	-2627.625	-1433.625	67.00	47.00	281000.00	84000.00	223224.54	588224.54	-4.86	3.31	0.23	1.3	-0.02	100.07	18975.23	312393.55	169.01	17.2

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	113	213	22.6	24.675	1.98	0.206	28108.779	68675.2667	1695.68	9538.2317	12487.832	68.50	48.00	287150.00	16950.00	35205.88	339305.88	16.64	0.69	0.05	1.49	18.86	23.69	5053.77	63282.92	-22.96	12.95
50	305	427	15.21	16.45	1.98	0.3538	56349.525	53315.7105	14577.04	6808.2326	8871.0326	68.50	48.00	287150.00	45750.00	75847.06	408747.06	10.33	1.38	0.13	1.49	13.32	46.11	8670.57	132767.49	20.43	15.95
75	551	640	7.55	8.225	1.98	0.507	84458.304	44755.5418	33894.52	4740.5226	5884.1226	68.50	48.00	287150.00	82650.00	116488.24	486288.24	4.03	2.07	0.23	1.49	7.81	68.39	11657.48	210034.89	-253.35	18.9
75-100	551	853	7.55	0	1.98	0.507	112567.08	38839.5238	56318.41	2903.2047	4046.8047	68.50	48.00	287150.00	82650.00	157129.41	526929.41	-0.92	2.75	0.23	1.49	3.55	85.66	13494.80	251110.69	181.28	19.55
Carbon offsetting	551	1032	7.55	0	1.98	0.507	136189.02	35324.3141	76425.71	1506.2472	2649.8472	68.50	48.00	287150.00	82650.00	224311.32	594111.32	-5.05	3.33	0.23	1.49	-0.01	100.03	14891.75	318019.45	-91.87	22.6
Carbon offsetting	551	1032	7.55	0	1.98	0.507	136189.02	35324.3141	76425.71	-2697.167	-1553.567	68.50	48.00	287150.00	82650.00	224311.32	594111.32	-5.05	3.33	0.23	1.49	-0.01	100.03	19095.17	318221.97	110.65	17.42

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	112	213	21.72	24.675	1.98	0.2236	28108.779	68675.2667	1695.68	9538.2317	12382.232	70.00	49.00	293300.00	16800.00	35205.88	345305.88	16.47	0.69	0.05	1.67	18.88	23.63	5159.37	69668.08	362.20	14
50	295	427	14.18	16.45	1.98	0.3744	56349.525	53315.7105	14577.04	6808.2326	8747.4326	70.00	49.00	293300.00	44250.00	75847.06	413397.06	10.14	1.38	0.12	1.67	13.31	46.17	8794.17	137499.97	102.92	16.3
75	542	640	7.24	8.225	1.98	0.5132	84458.304	44755.5418	33894.52	4740.5226	5846.9226	70.00	49.00	293300.00	81300.00	116488.24	491088.24	3.98	2.07	0.22	1.67	7.93	67.91	11694.68	214959.41	-128.82	19.3
75-100	542	853	7.24	0	1.98	0.5132	112567.08	38839.5238	56318.41	2903.2047	4009.6047	70.00	49.00	293300.00	81300.00	157129.41	531729.41	-0.98	2.75	0.22	1.67	3.66	85.18	13532.00	255484.20	-245.22	19.85
Carbon offsetting	542	1038	7.24	0	1.98	0.5132	136980.81	35213.4265	77104.96	1460.1566	2566.5566	70.00	49.00	293300.00	81300.00	225615.45	600215.45	-5.25	3.35	0.22	1.67	-0.01	100.03	14975.04	324480.74	265.28	22.95
Carbon offsetting	542	1038	7.24	0	1.98	0.5132	136980.81	35213.4265	77104.96	-2780.616	-1674.216	70.00	49.00	293300.00	81300.00	225615.45	600215.45	-5.25	3.35	0.22	1.67	-0.01	100.03	19215.82	324282.61	67.16	17.65

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	109	213	21	24.675	1.98	0.238	28108.779	68675.2667	1695.68	9538.2317	12295.832	71.50	50.00	299450.00	16350.00	35205.88	351005.88	16.34	0.69	0.04	1.86	18.93	23.40	5245.77	74982.76	-23.12	14.85
50	292	427	14	16.45	1.98	0.378	56349.525	53315.7105	14577.04	6808.2326	8725.8326	71.50	50.00	299450.00	43800.00	75847.06	419097.06	10.10	1.38	0.12	1.86	13.46	45.54	8815.77	143516.93	419.87	17
75	535	640	7	8.225	1.98	0.518	84458.304	44755.5418	33894.52	4740.5226	5818.1226	71.50	50.00	299450.00	80250.00	116488.24	496188.24	3.93	2.07	0.22	1.86	8.08	67.33	11723.48	220276.78	88.54	19.75
75-100	535	853	7	0	1.98	0.518	112567.08	38839.5238	56318.41	2903.2047	3980.8047	71.50	50.00	299450.00	80250.00	157129.41	536829.41	-1.02	2.75	0.22	1.86	3.81	84.60	13560.80	260938.44	109.03	20.25
Carbon offsetting	535	1046	7	0	1.98	0.518	138036.54	35065.5765	78010.63	1398.7025	2476.3025	71.50	50.00	299450.00	80250.00	227354.30	607054.30	-5.48	3.38	0.22	1.86	-0.02	100.09	15065.30	331139.20	84.90	23.3
Carbon offsetting	535	1046	7	0	1.98	0.518	138036.54	35065.5765	78010.63	-2891.882	-1814.282	71.50	50.00	299450.00	80250.00	227354.30	607054.30	-5.48	3.38	0.22	1.86	-0.02	100.09	19355.88	331075.47	21.17	17.9

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	107	213	20.2	24.675	1.98	0.254	28108.779	68675.2667	1695.68	9538.2317	12199.832	73.00	51.00	305600.00	16050.00	35205.88	356855.88	16.19	0.69	0.04	2.04	18.96	23.28	5341.77	81055.29	199.41	15.8
50	288	427	13.52	16.45	1.98	0.3876	56349.525	53315.7105	14577.04	6808.2326	8668.2326	73.00	51.00	305600.00	43200.00	75847.06	424647.06	10.02	1.38	0.12	2.04	13.55	45.18	8873.37	148525.88	-121.18	17.5
75	527	640	6.76	8.225	1.98	0.5228	84458.304	44755.5418	33894.52	4740.5226	5789.3226	73.00	51.00	305600.00	79050.00	116488.24	501138.24	3.89	2.07	0.22	2.04	8.21	66.80	11752.28	225075.59	-62.65	20.15
75-100	527	853	6.76	0	1.98	0.5228	112567.08	38839.5238	56318.41	2903.2047	3952.0047	73.00	51.00	305600.00	79050.00	157129.41	541779.41	-1.07	2.75	0.22	2.04	3.94	84.06	13589.60	265790.61	11.20	20.6
Carbon offsetting	527	1052	6.76	0	1.98	0.5228	138828.34	34954.6889	78689.88	1352.6118	2401.4118	73.00	51.00	305600.00	79050.00	228658.44	613308.44	-5.66	3.39	0.22	2.04	-0.01	100.04	15140.19	337503.52	195.08	23.65
Carbon offsetting	527	1052	6.76	0	1.98	0.5228	138828.34	34954.6889	78689.88	-2975.332	-1926.532	73.00	51.00	305600.00	79050.00	228658.44	613308.44	-5.66	3.39	0.22	2.04	-0.01	100.04	19468.13	337444.88	136.44	18.15

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	106	213	18.6	24.675	1.98	0.286	28108.779	68675.2667	1695.68	9538.2317	12007.832	79.00	55.00	330200.00	15900.00	35205.88	381305.88	15.90	0.69	0.04	2.79	19.42	21.45	5533.77	105229.49	-76.39	20
50	286	427	12.4	16.45	1.98	0.41	56349.525	53315.7105	14577.04	6808.2326	8533.8326	79.00	55.00	330200.00	42900.00	75847.06	448947.06	9.81	1.38	0.12	2.79	14.09	42.99	9007.77	172921.15	-25.90	20.2
75	524	640	6.2	8.225	1.98	0.534	84458.304	44755.5418	33894.52	4740.5226	5722.1226	79.00	55.00	330200.00	78600.00	116488.24	525288.24	3.78	2.07	0.21	2.79	8.85	64.19	11819.48	249236.88	-51.35	22.3
75-100	524	853	6.2	0	1.98	0.534	112567.08	38839.5238	56318.41	2903.2047	3884.8047	79.00	55.00	330200.00	78600.00	157129.41	565929.41	-1.17	2.75	0.21	2.79	4.58	81.45	13656.80	289814.05	-115.36	22.45
Carbon offsetting	524	1085	6.2	0	1.98	0.534	143183.22	34409.6016	82490.54	1105.2699	2086.8699	79.00	55.00	330200.00	78600.00	235831.18	644631.18	-6.52	3.50	0.21	2.79	-0.02	100.08	15454.73	368474.31	-156.88	25.4
Carbon offsetting	524	1085	6.2	0	1.98	0.534	143183.22	34409.6016	82490.54	-3431.71	-2450.11	79.00	55.00	330200.00	78600.00	235831.18	644631.18	-6.52	3.50	0.21	2.79	-0.02	100.08	19991.71	368374.93	-256.26	19.35

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £	Payback period (years)
0	0	0	32.9	31.8	1.98	0	0	0	0	13356	17541.6	66.00	46.00	276000.00	0.00	0.00	276000.00	23.52	0.00	0.00	1.20	24.72	0.00	0.00	0.00	0.00	0
25	105	213	18.17	24.675	1.98	0.2946	28108.779	68675.2667	1695.68	9538.2317	11956.232	82.00	57.00	342500.00	15750.00	35205.88	393455.88	15.82	0.69	0.04	3.16	19.71	20.28	5585.37	117528.35	72.47	22.25
50	284	427	12.11	16.45	1.98	0.4158	56349.525	53315.7105	14577.04	6808.2326	8499.0326	82.00	57.00	342500.00	42600.00	75847.06	460947.06	9.75	1.38	0.12	3.16	14.41	41.71	9042.57	185002.56	55.50	21.6
75	521	640	6.05	8.225	1.98	0.537	84458.304	44755.5418	33894.52	4740.5226	5704.1226	82.00	57.00	342500.00	78150.00	116488.24	537138.24	3.75	2.07	0.21	3.16	9.19	62.81	11837.48	261245.49	107.26	23.4
75-100	521	853	6.05	0	1.98	0.537	112567.08	38839.5238	56318.41	2903.2047	3866.8047	82.00	57.00	342500.00	78150.00	157129.41	577779.41	-1.20	2.75	0.21	3.16	4.93	80.08	13674.80	301793.91	14.50	23.4
Carbon offsetting	521	1103	6.05	0	1.98	0.537	145558.61	34094.8964	84534.74	969.22233	1932.8223	82.00	57.00	342500.00	78150.00	239743.59	660393.59	-6.96	3.56	0.21	3.16	-0.03	100.13	15608.78	384512.13	118.54	26.3
Carbon offsetting	521	1103	6.05	0	1.98	0.537	145558.61	34094.8964	84534.74	-3680.188	-2716.588	82.00	57.00	342500.00	78150.00	239743.59	660393.59	-6.96	3.56	0.21	3.16	-0.03	100.13	20258.19	384310.04	-83.55	19.95

Table B. 29 Office - PV (curren FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) – not taking into account the rental loss/gain

Office-London
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	7144.85	167825.31	132656.49
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	13726.02	322410.16	252072.52
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	19494.74	457911.44	352404.97
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	24883.30	584483.34	443808.05
Carbon offsetting	972	18.73	0	3.51	128271.0492	20369.73608	63219.18	-18592.4	-16279.442	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	30549.80	717583.68	506313.72

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	7215.57	169486.46	131947.63
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	13796.74	324071.30	251363.66
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	19565.46	459572.58	351696.11
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	24954.02	586144.48	443099.19
Carbon offsetting	968	18.05	0	3.51	127743.1848	20444.90992	62767.41	-18485	-16242.768	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	30513.13	716722.24	503951.70

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	7319.57	171929.31	131159.49
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	13900.74	326514.16	250575.51
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	19669.46	462015.43	350907.96
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	25058.02	588587.34	442311.04
Carbon offsetting	964	17.05	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16239.373	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	30509.73	716642.50	501510.39

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	7377.81	173297.31	129296.48
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	13958.98	327882.16	248712.51
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	19727.70	463383.43	349044.96
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	25116.26	589955.33	440448.04
Carbon offsetting	964	16.49	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16297.613	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	30567.97	718010.50	499647.39

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	7428.77	174494.31	127262.48
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	14009.94	329079.15	246678.51
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	19778.66	464580.43	347010.96
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	25167.22	591152.33	438414.04
Carbon offsetting	964	16	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16348.573	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	30618.93	719207.50	497613.38

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	7478.69	175666.88	125204.05
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	14059.86	330251.72	244620.08
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	19828.58	465753.00	344952.53
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	25217.14	592324.90	436355.61
Carbon offsetting	964	15.52	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16398.493	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	30668.85	720380.07	495554.95

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	7532.77	176937.16	113550.34
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	14113.94	331522.01	232966.36
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	19882.66	467023.28	333298.81
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	25271.22	593595.19	424701.89
Carbon offsetting	987	15.52	0	3.51	130250.5407	20087.83418	64913.32	-18995.1	-17016.011	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	31286.37	734884.93	492136.63

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	7615.97	178891.44	109042.62
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	14197.14	333476.29	228458.64
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	19965.86	468977.57	328791.10
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	25354.42	595549.47	420194.18
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.72	-18807.2	-16965.351	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	31235.71	733694.98	486006.17

Table B. 30 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) – not taking into account the rental loss/gain

Office-London
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	3509.19	82427.23	47258.41
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	6416.42	150715.06	80377.42
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	8530.33	200368.79	94862.32
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	10264.10	241093.14	100417.85
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1781.3295	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	1.66	5.77	74.09	12489.03	293354.58	152679.29
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	6.8999979	2319.86	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	11950.50	280705.05	69435.09
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	-3470.155	-1157.195	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	15427.55	362377.52	151107.56

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	3579.91	84088.37	46549.55
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	6487.14	152376.20	79668.56
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	8601.05	202029.93	94153.46
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	10334.82	242754.28	99708.99
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1710.6095	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	1.71	5.68	74.47	12559.75	295015.72	151970.43
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	37.754058	2279.9941	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	11990.37	281641.46	68870.92
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	-3414.453	-1172.213	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	15442.57	362730.29	149959.75

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	3683.91	86531.22	45761.40
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	6591.14	154819.06	78880.41
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	8705.05	204472.79	93365.31
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	10438.82	245197.14	98920.84
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1606.6095	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	1.81	5.59	74.90	12663.75	297458.58	151182.28
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	68.608117	2206.8481	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	12063.51	283359.58	68227.47
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1220.512	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	15490.87	363864.77	148732.66

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	3742.15	87899.22	43898.40
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	6649.38	156187.06	77017.41
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	8763.29	205840.78	91502.31
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	10497.06	246565.14	97057.84
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1548.3695	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	1.91	5.58	74.94	12721.99	298826.57	149319.28
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	68.608117	2148.6081	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	12121.75	284727.58	66364.47
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1278.752	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	15549.11	365232.77	146869.66

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	3793.11	89096.22	41864.40
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	6700.34	157384.06	74983.41
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	8814.25	207037.78	89468.31
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	10548.02	247762.14	95023.84
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1497.4095	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	2.01	5.58	74.92	12772.95	300023.57	147285.28
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	68.608117	2097.6481	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	12172.71	285924.58	64330.47
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1329.712	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	15600.07	366429.77	144835.65

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	3843.03	90268.79	39805.97
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	6750.26	158556.63	72924.98
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	8864.17	208210.35	87409.88
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	10597.94	248934.71	92965.41
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1447.4895	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	2.11	5.59	74.90	12822.87	301196.14	145226.85
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	68.608117	2047.7281	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	12222.63	287097.15	62272.04
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1379.632	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	15649.99	367602.34	142777.22

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	3897.11	91539.07	28152.25
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	6804.34	159826.91	61271.26
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	8918.25	209480.64	75756.17
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	10652.02	250204.99	81311.69
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1393.4095	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	2.62	5.99	73.06	12876.95	302466.43	133573.13
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-108.8027	1870.3173	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	12400.04	291264.35	48516.05
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-3679.035	-1699.915	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	15970.28	375125.47	132377.17

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	3980.31	93493.36	23644.53
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	6887.54	161781.19	56763.55
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	9001.45	211434.92	71248.45
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	10735.22	252159.27	76803.98
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1310.2095	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	2.72	5.94	73.32	12960.15	304420.71	129065.42
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-54.80812	1787.0319	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	12483.33	293220.64	45531.83
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-3581.558	-1739.718	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	16010.08	376060.39	128371.58

Table B. 31 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC– not taking into account the rental loss/gain

Office-London
PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	7632.61	179282.30	132863.48
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	14699.98	345287.49	244949.84
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	20955.94	492233.54	322977.07
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	26831.22	630238.00	392062.70
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.4021	-14814.1	-14449.03	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	28719.39	674589.23	396249.10

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	7685.65	180528.16	132189.33
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	14735.34	346118.06	245660.41
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	20973.62	492648.82	323272.35
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	26831.22	630238.00	392692.70
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.8151	-14895.9	-14530.88	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	28801.24	676511.85	398149.65

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	7763.65	182360.30	131240.47
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	14787.86	347351.70	245613.05
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	20999.62	493259.53	322152.06
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	26831.22	630238.00	391711.70
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.2282	-14977.8	-14612.74	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	28883.10	678434.47	398439.20

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	7807.33	183386.29	129485.47
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	14816.98	348035.70	244116.05
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	21014.18	493601.53	320463.06
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	26831.22	630238.00	389980.70
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.5833	-15114.2	-14749.16	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	29019.52	681638.83	398825.78

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	7844.77	184265.72	127583.90
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	14841.94	348621.99	242221.34
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	21026.66	493894.68	319025.21
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	26831.22	630238.00	388249.70
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	29128.65	684202.32	398788.85

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	7882.21	185145.15	125682.33
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	14866.90	349208.27	240176.62
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	21039.14	494187.82	316837.35
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	26831.22	630238.00	385918.70
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.3514	-15332.5	-14967.43	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	29237.79	686765.81	398151.91

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	7922.77	186097.86	114161.04
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	14893.94	349843.41	228337.77
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	21052.66	494505.39	305130.92
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	26831.22	630238.00	374044.70
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.7139	-15932.7	-15567.68	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	29838.04	700865.01	395595.28

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	7985.17	187563.57	109464.75
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	14935.54	350820.55	223302.91
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	21073.46	494993.96	300057.49
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	26831.22	630238.00	368632.70
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-16069.1	-15704.1	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	29974.46	704069.37	392300.87

Table B. 32 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC– not taking into account the rental loss/gain

Office-London
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	3996.95	93884.21	47465.39
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	7390.38	173592.39	73254.74
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	9991.53	234690.89	65434.42
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	12212.02	286847.80	48672.50
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	1106.318	1471.3576	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	12799.00	300635.51	22295.37
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	-1518.8	-1153.76	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	15424.12	362296.83	83956.70

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	4049.99	95130.07	46791.25
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	7425.74	174422.96	73965.31
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	10009.21	235106.17	65729.70
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	12212.02	286847.80	49302.50
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	1081.871	1446.9109	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	12823.45	301209.73	22847.53
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	-1561.14	-1196.104	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	15466.46	363291.46	84929.25

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	4127.99	96962.21	45842.39
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	7478.26	175656.60	73917.96
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	10035.21	235716.89	64609.42
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	12212.02	286847.80	48321.50
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	1057.424	1422.4643	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	12847.90	301783.96	21788.69
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	-1603.49	-1238.448	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	15508.81	364286.08	84290.81

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	4171.67	97988.21	44087.38
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	7507.38	176340.60	72420.95
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	10049.77	236058.89	62920.42
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	12212.02	286847.80	46590.50
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	1016.68	1381.7198	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	12888.64	302741.01	19927.96
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	-1674.06	-1309.022	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	15579.38	365943.79	83130.74

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	4209.11	98867.64	42185.81
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	7532.34	176926.89	70526.24
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	10062.25	236352.03	61482.56
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	12212.02	286847.80	44859.50
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	12921.24	303506.64	18093.17
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	15635.84	367269.96	81856.49

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	4246.55	99747.06	40284.24
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	7557.30	177513.17	68481.52
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	10074.73	236645.17	59294.70
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	12212.02	286847.80	42528.50
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	951.4887	1316.5287	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	12953.83	304272.28	15658.38
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	-1786.98	-1421.941	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	15692.30	368596.13	79982.23

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	4287.11	100699.78	28762.95
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	7584.34	178148.31	56642.67
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	10088.25	236962.74	47588.27
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	12212.02	286847.80	30654.50
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	772.2132	1137.2532	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	13133.11	308483.28	3213.55
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	-2097.51	-1732.466	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	16002.83	375890.06	70620.33

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	4349.51	102165.49	24066.66
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	7625.94	179125.45	51607.81
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	10109.05	237451.31	42514.84
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	12212.02	286847.80	25242.50
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	731.4687	1096.5087	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	13173.85	309440.32	-2328.18
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-2168.08	-1803.04	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	16073.40	377547.77	65779.26

Table B. 33 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR)– taking into account the rental loss/gain- City

Office-London (City)
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	7144.85	72885.00	167825.31	132656.49
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	13726.02	72885.00	322410.16	252072.52
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	19494.74	72885.00	457911.44	352404.97
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	24883.30	72885.00	584483.34	443808.05
Carbon offsetting	972	18.73	0	3.51	128271.0492	20369.73608	63219.18	-18592.4	-16279.442	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	30549.80	72885.00	717583.68	506313.72

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	7215.57	76953.00	102439.65	64900.83
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	13796.74	76953.00	257024.50	184316.86
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	19565.46	76953.00	392525.78	284649.31
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	24954.02	76953.00	519097.68	376052.39
Carbon offsetting	968	18.05	0	3.51	127743.1848	20444.90992	62767.41	-18485	-16242.768	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	30513.13	76953.00	649675.43	436904.89

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	7319.57	81360.00	32248.47	-8521.35
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	13900.74	81360.00	186833.32	110894.67
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	19669.46	81360.00	322334.60	211227.13
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	25058.02	81360.00	448906.50	302630.21
Carbon offsetting	964	17.05	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16239.373	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	30509.73	81360.00	576961.67	361829.55

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	7377.81	84750.00	-22255.86	-66256.69
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	13958.98	84750.00	132328.99	53159.34
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	19727.70	84750.00	267830.26	153491.79
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	25116.26	84750.00	394402.16	244894.87
Carbon offsetting	964	16.49	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16297.613	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	30567.97	84750.00	522457.33	304094.22

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	7428.77	88140.00	-76931.20	-124163.02
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	14009.94	88140.00	77653.65	-4747.00
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	19778.66	88140.00	213154.93	95585.45
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	25167.22	88140.00	339726.83	186988.53
Carbon offsetting	964	16	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16348.573	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	30618.93	88140.00	467782.00	246187.88

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	7478.69	93225.00	-159567.13	-210029.95
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	14059.86	93225.00	-4982.28	-90613.93
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	19828.58	93225.00	130518.99	9718.52
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	25217.14	93225.00	257090.90	101121.60
Carbon offsetting	964	15.52	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16398.493	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	30668.85	93225.00	385146.06	160320.95

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	7532.77	110175.00	-437658.52	-501045.34
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	14113.94	110175.00	-283073.67	-381629.32
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	19882.66	110175.00	-147572.40	-281296.87
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	25271.22	110175.00	-21000.49	-189893.79
Carbon offsetting	987	15.52	0	3.51	130250.5407	20087.83418	64913.32	-18995.1	-17016.011	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	31286.37	110175.00	120289.25	-122459.05

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	7615.97	115825.00	-528824.79	-598673.62
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	14197.14	115825.00	-374239.95	-479257.59
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	19965.86	115825.00	-238738.67	-378925.14
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	25354.42	115825.00	-112166.77	-287522.06
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.72	-18807.2	-16965.351	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	31235.71	115825.00	25978.74	-221710.07

Table B. 34 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) – taking into account the rental loss/gain- City

Office-London (City)
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	3509.19	72885.00	82427.23	47258.41
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	6416.42	72885.00	150715.06	80377.42
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	8530.33	72885.00	200368.79	94862.32
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	10264.10	72885.00	241093.14	100417.85
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1781.3295	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	1.66	5.77	74.09	12489.03	72885.00	293354.58	152679.29
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	6.8999979	2319.86	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	11950.50	72885.00	280705.05	69435.09
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	-3470.155	-1157.195	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	15427.55	72885.00	362377.52	151107.56

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	3579.91	76953.00	17041.57	-20497.26
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	6487.14	76953.00	85329.40	12621.76
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	8601.05	76953.00	134983.13	27106.66
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	10334.82	76953.00	175707.48	32662.19
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1710.6095	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	1.71	5.68	74.47	12559.75	76953.00	227968.92	84923.63
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	37.754058	2279.9941	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	11990.37	76953.00	214594.66	1824.12
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	-3414.453	-1172.213	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	15442.57	76953.00	295683.49	82912.95

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	3683.91	81360.00	-53149.61	-93919.44
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	6591.14	81360.00	15138.22	-60800.42
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	8705.05	81360.00	64791.95	-46315.52
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	10438.82	81360.00	105516.30	-40759.99
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1606.6095	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	1.81	5.59	74.90	12663.75	81360.00	157777.74	11501.45
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	68.608117	2206.8481	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	12063.51	81360.00	143678.75	-71453.37
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1220.512	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	15490.87	81360.00	224183.94	9051.82

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	3742.15	84750.00	-107653.95	-151654.77
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	6649.38	84750.00	-39366.11	-118535.76
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	8763.29	84750.00	10287.61	-104050.86
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	10497.06	84750.00	51011.97	-98495.33
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1548.3695	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	1.91	5.58	74.94	12721.99	84750.00	103273.40	-46233.89
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	68.608117	2148.6081	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	12121.75	84750.00	89174.41	-129188.70
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1278.752	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	15549.11	84750.00	169679.60	-48683.52

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	3793.11	88140.00	-162329.28	-209561.11
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	6700.34	88140.00	-94041.45	-176442.10
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	8814.25	88140.00	-44387.72	-161957.19
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	10548.02	88140.00	-3663.37	-156401.66
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1497.4095	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	2.01	5.58	74.92	12772.95	88140.00	48598.07	-104140.23
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	68.608117	2097.6481	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	12172.71	88140.00	34499.08	-187095.04
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1329.712	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	15600.07	88140.00	115004.26	-106589.85

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	3843.03	93225.00	-244965.22	-295428.04
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	6750.26	93225.00	-176677.38	-262309.03
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	8864.17	93225.00	-127023.66	-247824.13
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	10597.94	93225.00	-86299.30	-242268.60
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1447.4895	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	2.11	5.59	74.90	12822.87	93225.00	-34037.86	-190007.16
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	68.608117	2047.7281	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	12222.63	93225.00	-48136.86	-272961.97
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1379.632	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	15649.99	93225.00	32368.33	-192456.78

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	3897.11	110175.00	-523056.61	-586443.43
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	6804.34	110175.00	-454768.77	-553324.42
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	8918.25	110175.00	-405115.04	-538839.51
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	10652.02	110175.00	-364390.69	-533283.98
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1393.4095	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	2.62	5.99	73.06	12876.95	110175.00	-312129.25	-481022.55
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-108.8027	1870.3173	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	12400.04	110175.00	-323331.33	-566079.63
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-3679.035	-1699.915	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	15970.28	110175.00	-239470.20	-482218.51

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 (kgCO_2/m^2.yr)	PV ECO$_2$ (kgCO_2/m^2.yr)	Insulation ECO$_2$ (kgCO_2/m^2.yr)	Total CO_2 (kgCO_2/m^2.yr)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	3980.31	115825.00	-614222.88	-684071.70
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	6887.54	115825.00	-545935.04	-650952.69
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	9001.45	115825.00	-496281.32	-636467.79
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	10735.22	115825.00	-455556.96	-630912.26
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	-531.6305	1310.2095	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	2.72	5.94	73.32	12960.15	115825.00	-403295.53	-578650.82
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-54.80812	1787.0319	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	12483.33	115825.00	-414495.60	-662184.41
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-3581.558	-1739.718	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	16010.08	115825.00	-331655.84	-579344.66

Table B. 35 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC– taking into account the rental loss/gain- City

Office-London (City)
PV (current FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	7632.61	72885.00	179282.30	132863.48
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	14699.98	72885.00	345287.49	244949.84
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	20955.94	72885.00	492233.54	322977.07
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	26831.22	72885.00	630238.00	392062.70
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.4021	-14814.1	-14449.03	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	28719.39	72885.00	674589.23	396249.10

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	7685.65	76953.00	113481.35	65142.53
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	14735.34	76953.00	279071.26	178613.61
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	20973.62	76953.00	425602.02	256225.55
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	26831.22	76953.00	563191.19	325645.90
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.8151	-14895.9	-14530.88	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	28801.24	76953.00	609465.05	331102.85

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	7763.65	81360.00	42679.46	-8440.36
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	14787.86	81360.00	207670.87	105932.22
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	20999.62	81360.00	353578.70	182471.23
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	26831.22	81360.00	490557.16	252030.86
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.2282	-14977.8	-14612.74	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	28883.10	81360.00	538753.63	258758.36

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	7807.33	84750.00	-12166.88	-66067.70
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	14816.98	84750.00	152482.53	48562.88
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	21014.18	84750.00	298048.36	124909.89
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	26831.22	84750.00	434684.82	194427.53
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.5833	-15114.2	-14749.16	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	29019.52	84750.00	486085.66	203272.61

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	7844.77	88140.00	-67159.78	-123841.61
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	14841.94	88140.00	97196.48	-9204.17
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	21026.66	88140.00	242469.17	67599.70
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	26831.22	88140.00	378812.49	136824.20
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	29128.65	88140.00	432776.82	147363.34

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	7882.21	93225.00	-150088.86	-209551.68
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	14866.90	93225.00	13974.26	-95057.38
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	21039.14	93225.00	158953.81	-18396.66
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	26831.22	93225.00	295003.99	50684.69
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.3514	-15332.5	-14967.43	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	29237.79	93225.00	351531.80	62917.91

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	7922.77	110175.00	-428497.82	-500434.64
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	14893.94	110175.00	-264752.27	-386257.91
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	21052.66	110175.00	-120090.29	-309464.76
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	26831.22	110175.00	15642.32	-240550.98
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.7139	-15932.7	-15567.68	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	29838.04	110175.00	86269.33	-219000.40

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	7985.17	115825.00	-520152.66	-598251.49
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	14935.54	115825.00	-356895.68	-484413.33
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	21073.46	115825.00	-212722.28	-407658.75
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	26831.22	115825.00	-77478.24	-339083.54
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-16069.1	-15704.1	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	29974.46	115825.00	-3646.86	-315415.37

Table B. 36 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC– taking into account the rental loss/gain- City

Office-London (City)
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	72885.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	3996.95	72885.00	93884.21	47465.39
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	7390.38	72885.00	173592.39	73254.74
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	9991.53	72885.00	234690.89	65434.42
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	12212.02	72885.00	286847.80	48672.50
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	1106.318	1471.3576	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	12799.00	72885.00	300635.51	22295.37
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	-1518.8	-1153.76	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	15424.12	72885.00	362296.83	83956.70

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	4049.99	76953.00	28083.27	-20255.56
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	7425.74	76953.00	107376.16	6918.51
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	10009.21	76953.00	168059.37	-1317.10
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	12212.02	76953.00	219801.00	-17744.30
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	1081.871	1446.9109	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	12823.45	76953.00	234162.93	-44199.27
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	-1561.14	-1196.104	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	15466.46	76953.00	296244.65	17882.45

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	4127.99	81360.00	-42718.63	-93838.45
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	7478.26	81360.00	35975.77	-65762.88
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	10035.21	81360.00	96036.05	-75071.42
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	12212.02	81360.00	147166.96	-91359.33
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	1057.424	1422.4643	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	12847.90	81360.00	162103.12	-117892.14
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	-1603.49	-1238.448	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	15508.81	81360.00	224605.25	-55390.02

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	4171.67	84750.00	-97564.96	-151465.79
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	7507.38	84750.00	-19212.57	-123132.22
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	10049.77	84750.00	40505.72	-132632.76
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	12212.02	84750.00	91294.63	-148962.67
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	1016.68	1381.7198	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	12888.64	84750.00	107187.84	-175625.21
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	-1674.06	-1309.022	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	15579.38	84750.00	170390.62	-112422.43

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	4209.11	88140.00	-152557.87	-209239.69
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	7532.34	88140.00	-74498.62	-180899.27
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	10062.25	88140.00	-15073.48	-189942.95
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	12212.02	88140.00	35422.29	-206566.00
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	12921.24	88140.00	52081.14	-233332.33
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	15635.84	88140.00	115844.46	-169569.02

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	4246.55	93225.00	-235486.94	-294949.77
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	7557.30	93225.00	-157720.84	-266752.48
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	10074.73	93225.00	-98588.84	-275939.31
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	12212.02	93225.00	-48386.21	-292705.50
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	951.4887	1316.5287	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	12953.83	93225.00	-30961.73	-319575.62
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	-1786.98	-1421.941	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	15692.30	93225.00	33362.12	-255251.77

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	4287.11	110175.00	-513895.90	-585832.73
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	7584.34	110175.00	-436447.37	-557953.01
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	10088.25	110175.00	-377632.94	-567007.41
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	12212.02	110175.00	-327747.88	-583941.18
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	772.2132	1137.2532	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	13133.11	110175.00	-306112.40	-611382.13
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	-2097.51	-1732.466	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	16002.83	110175.00	-238705.62	-543975.35

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	4349.51	115825.00	-605550.75	-683649.57
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	7625.94	115825.00	-528590.78	-656108.43
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	10109.05	115825.00	-470264.92	-665201.39
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	12212.02	115825.00	-420868.44	-682473.73
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	731.4687	1096.5087	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	13173.85	115825.00	-398275.91	-710044.42
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-2168.08	-1803.04	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	16073.40	115825.00	-330168.47	-641936.98

Table B. 37 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) – taking into account the rental loss/gain- West-End

Office - London (West End)
PV (current FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00	110940.00	0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	4812.547	7125.50664	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	7144.85	110940.00	167825.31	132656.49
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	544.341737	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	13726.02	110940.00	322410.16	252072.52
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5224.3753	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	19494.74	110940.00	457911.44	352404.97
100%	764	18.73	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10612.941	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	24883.30	110940.00	584483.34	443808.05
Carbon offsetting	972	18.73	0	3.51	128271.0492	20369.73608	63219.18	-18592.4	-16279.442	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	30549.80	110940.00	717583.68	506313.72

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	7054.78664	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	7215.57	117132.00	67432.92	29894.09
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	473.621737	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	13796.74	117132.00	222017.77	149310.12
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5295.0953	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	19565.46	117132.00	357519.04	249642.57
100%	764	18.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10683.661	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	24954.02	117132.00	484090.94	341045.65
Carbon offsetting	968	18.05	0	3.51	127743.1848	20444.90992	62767.41	-18485	-16242.768	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	30513.13	117132.00	614668.70	401898.16

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	4812.547	6950.78664	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	7319.57	123840.00	-40682.23	-81452.05
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	369.621737	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	13900.74	123840.00	113902.62	37963.97
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5399.0953	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	19669.46	123840.00	249403.90	138296.42
100%	764	17.05	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10787.661	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	25058.02	123840.00	375975.80	229699.50
Carbon offsetting	964	17.05	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16239.373	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	30509.73	123840.00	504030.97	288898.85

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	4812.547	6892.54664	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	7377.81	129000.00	-124358.85	-168359.67
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	311.381737	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	13958.98	129000.00	30226.00	-48943.64
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5457.3353	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	19727.70	129000.00	165727.28	51388.81
100%	764	16.49	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10845.901	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	25116.26	129000.00	292299.18	142791.89
Carbon offsetting	964	16.49	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16297.613	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	30567.97	129000.00	420354.35	201991.23

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	4812.547	6841.58664	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	7428.77	134160.00	-208206.46	-255438.29
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	260.421737	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	14009.94	134160.00	-53621.61	-136022.26
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5508.2953	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	19778.66	134160.00	81879.66	-35689.81
100%	764	16	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10896.861	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	25167.22	134160.00	208451.56	55713.27
Carbon offsetting	964	16	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16348.573	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	30618.93	134160.00	336506.73	114912.62

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	4812.547	6791.66664	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	7478.69	141900.00	-334600.82	-385063.64
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	210.501737	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	14059.86	141900.00	-180015.97	-265647.61
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5558.2153	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	19828.58	141900.00	-44514.69	-165315.16
100%	764	15.52	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-10946.781	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	25217.14	141900.00	82057.21	-73912.08
Carbon offsetting	964	15.52	0	3.51	127215.3204	20520.08376	62315.64	-18377.6	-16398.493	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	30668.85	141900.00	210112.38	-14712.74

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	4812.547	6737.58664	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	7532.77	167700.00	-758553.61	-821940.43
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	156.421737	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	14113.94	167700.00	-603968.76	-702524.41
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5612.2953	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	19882.66	167700.00	-468467.48	-602191.95
100%	764	15	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11000.861	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	25271.22	167700.00	-341895.58	-510788.88
Carbon offsetting	987	15.52	0	3.51	130250.5407	20087.83418	64913.32	-18995.1	-17016.011	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	31286.37	167700.00	-200605.83	-443354.14

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	4812.547	6654.38664	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	7615.97	176300.00	-898340.35	-968189.17
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.097	-1768.62	73.2217372	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	14197.14	176300.00	-743755.50	-848773.15
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.29	-7537.34	-5695.4953	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	19965.86	176300.00	-608254.23	-748440.70
100%	764	14.2	0	3.51	100822.1004	25097.89092	40453.35	-12925.9	-11084.061	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	25354.42	176300.00	-481682.32	-657037.62
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.72	-18807.2	-16965.351	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	31235.71	176300.00	-343536.82	-591225.63

Table B. 38 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) – taking into account the rental loss/gain- West-End

Office - London (West End)
PV (future FiT) + Insulation

PV + 2010 notional building fabric

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	18.73	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10761.173	66.00	46.00	143460.00	35168.82	178628.82	16.53	0.71	0.66	17.90	19.55	3509.19	110940.00	82427.23	47258.41
50%	382	18.73	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7853.944	66.00	46.00	143460.00	70337.65	213797.65	11.42	1.42	0.66	13.50	39.31	6416.42	110940.00	150715.06	80377.42
75%	573	18.73	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5740.0282	66.00	46.00	143460.00	105506.47	248966.47	6.34	2.13	0.66	9.13	58.97	8530.33	110940.00	200368.79	94862.32
100%	764	18.73	0	3.51	100822.1	25097.89092	40453.352	1693.3039	4006.2639	66.00	46.00	143460.00	140675.29	284135.29	1.26	2.84	0.66	4.77	78.59	10264.10	110940.00	241093.14	100417.85
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	6.8999979	2319.86	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	11950.50	110940.00	280705.05	69435.09
Carbon offsetting	972	18.73	0	3.51	128271.049	20369.73608	63219.179	-3470.155	-1157.195	66.00	46.00	143460.00	211269.96	354729.96	-4.29	3.62	0.66	-0.01	100.04	15427.55	110940.00	362377.52	151107.56

PV + 0.17 - 0.24

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	18.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10690.453	67.00	47.00	145830.00	35168.82	180998.82	16.40	0.71	0.71	17.82	19.92	3579.91	117132.00	-17965.17	-55503.99
50%	382	18.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7783.224	67.00	47.00	145830.00	70337.65	216167.65	11.29	1.42	0.71	13.42	39.69	6487.14	117132.00	50322.67	-22384.98
75%	573	18.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5669.3082	67.00	47.00	145830.00	105506.47	251336.47	6.20	2.13	0.71	9.05	59.34	8601.05	117132.00	99976.39	-7900.08
100%	764	18.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3935.5439	67.00	47.00	145830.00	140675.29	286505.29	1.13	2.84	0.71	4.68	78.96	10334.82	117132.00	140700.75	-2344.55
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	37.754058	2279.9941	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	11990.37	117132.00	179587.92	-33182.62
Carbon offsetting	968	18.05	0	3.51	127743.185	20444.90992	62767.407	-3414.453	-1172.213	67.00	47.00	145830.00	210400.54	356230.54	-4.31	3.60	0.71	0.00	100.00	15442.57	117132.00	260676.75	47906.21

PV + 0.15 - 0.21

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	17.05	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10586.453	68.50	48.00	149061.00	35168.82	184229.82	16.21	0.71	0.81	17.72	20.35	3683.91	123840.00	-126080.31	-166850.14
50%	382	17.05	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7679.224	68.50	48.00	149061.00	70337.65	219398.65	11.09	1.42	0.81	13.32	40.12	6591.14	123840.00	-57792.48	-133731.13
75%	573	17.05	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5565.3082	68.50	48.00	149061.00	105506.47	254567.47	6.01	2.13	0.81	8.95	59.78	8705.05	123840.00	-8138.75	-119246.22
100%	764	17.05	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3831.5439	68.50	48.00	149061.00	140675.29	289736.29	0.93	2.84	0.81	4.59	79.39	10438.82	123840.00	32585.60	-113690.69
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	68.608117	2206.8481	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	12063.51	123840.00	70748.05	-144384.07
Carbon offsetting	964	17.05	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1220.512	68.50	48.00	149061.00	209531.12	358592.12	-4.40	3.59	0.81	0.00	100.02	15490.87	123840.00	151253.23	-63878.88

PV + 0.13 - 0.19

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16.49	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10528.213	70.00	49.00	152292.00	35168.82	187460.82	16.10	0.71	0.91	17.71	20.40	3742.15	129000.00	-209756.93	-253757.76
50%	382	16.49	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7620.984	70.00	49.00	152292.00	70337.65	222629.65	10.98	1.42	0.91	13.32	40.16	6649.38	129000.00	-141469.10	-220638.74
75%	573	16.49	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5507.0682	70.00	49.00	152292.00	105506.47	257798.47	5.90	2.13	0.91	8.94	59.82	8763.29	129000.00	-91815.37	-206153.84
100%	764	16.49	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3773.3039	70.00	49.00	152292.00	140675.29	292967.29	0.82	2.84	0.91	4.58	79.43	10497.06	129000.00	-51091.02	-200598.31
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	68.608117	2148.6081	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	12121.75	129000.00	-12928.57	-231291.69
Carbon offsetting	964	16.49	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1278.752	70.00	49.00	152292.00	209531.12	361823.12	-4.51	3.59	0.91	-0.01	100.06	15549.11	129000.00	67576.62	-150786.50

PV + 0.12 - 0.17

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	16	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10477.253	71.50	50.00	155523.00	35168.82	190691.82	16.00	0.71	1.01	17.72	20.38	3793.11	134160.00	-293604.55	-340836.37
50%	382	16	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7570.024	71.50	50.00	155523.00	70337.65	225860.65	10.89	1.42	1.01	13.32	40.14	6700.34	134160.00	-225316.71	-307717.36
75%	573	16	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5456.1082	71.50	50.00	155523.00	105506.47	261029.47	5.80	2.13	1.01	8.94	59.80	8814.25	134160.00	-175662.99	-293232.46
100%	764	16	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3722.3439	71.50	50.00	155523.00	140675.29	296198.29	0.73	2.84	1.01	4.58	79.42	10548.02	134160.00	-134938.63	-287676.93
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	68.608117	2097.6481	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	12172.71	134160.00	-96776.19	-318370.30
Carbon offsetting	964	16	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1329.712	71.50	50.00	155523.00	209531.12	365054.12	-4.61	3.59	1.01	-0.01	100.05	15600.07	134160.00	-16271.00	-237865.12

PV + 0.11 - 0.15

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15.52	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10427.333	73.00	51.00	158754.00	35168.82	193922.82	15.91	0.71	1.11	17.72	20.35	3843.03	141900.00	-419998.90	-470461.73
50%	382	15.52	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7520.104	73.00	51.00	158754.00	70337.65	229091.65	10.79	1.42	1.11	13.32	40.12	6750.26	141900.00	-351711.07	-437342.71
75%	573	15.52	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5406.1882	73.00	51.00	158754.00	105506.47	264260.47	5.71	2.13	1.11	8.95	59.78	8864.17	141900.00	-302057.34	-422857.81
100%	764	15.52	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3672.4239	73.00	51.00	158754.00	140675.29	299429.29	0.63	2.84	1.11	4.59	79.39	10597.94	141900.00	-261332.99	-417302.28
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	68.608117	2047.7281	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	12222.63	141900.00	-223170.54	-447995.66
Carbon offsetting	964	15.52	0	3.51	127215.32	20520.08376	62315.636	-3358.752	-1379.632	73.00	51.00	158754.00	209531.12	368285.12	-4.70	3.59	1.11	0.00	100.02	15649.99	141900.00	-142665.35	-367490.47

PV + 0.08 - 0.11

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	15	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10373.253	79.00	55.00	171678.00	35168.82	206846.82	15.80	0.71	1.62	18.13	18.52	3897.11	167700.00	-843951.69	-907338.52
50%	382	15	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7466.024	79.00	55.00	171678.00	70337.65	242015.65	10.69	1.42	1.62	13.73	38.28	6804.34	167700.00	-775663.86	-874219.51
75%	573	15	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5352.1082	79.00	55.00	171678.00	105506.47	277184.47	5.61	2.13	1.62	9.36	57.94	8918.25	167700.00	-726010.13	-859734.60
100%	764	15	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3618.3439	79.00	55.00	171678.00	140675.29	312353.29	0.53	2.84	1.62	4.99	77.56	10652.02	167700.00	-685285.78	-854179.07
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-108.8027	1870.3173	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	12400.04	167700.00	-644226.42	-886974.72
Carbon offsetting	987	15.52	0	3.51	130250.541	20087.83418	64913.322	-3679.035	-1699.915	79.00	55.00	171678.00	214530.30	386208.30	-5.31	3.67	1.62	-0.02	100.09	15970.28	167700.00	-560365.29	-803113.60

PV + 0.07 - 0.10

provided Elec. by PV	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec Cost £	Energy cost Inc FIT	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	PV cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	18.73	32.85	3.51	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	143460.00	21.59	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	190	14.2	24.6375	3.51	25073.559	60344.37639	0	8448.2127	10290.053	82.00	57.00	178140.00	35168.82	213308.82	15.65	0.71	1.72	18.07	18.78	3980.31	176300.00	-983738.44	-1053587.26
50%	382	14.2	16.425	3.51	50411.0502	41744.91709	6740.0973	5540.984	7382.824	82.00	57.00	178140.00	70337.65	248477.65	10.53	1.42	1.72	13.68	38.54	6887.54	176300.00	-915450.60	-1020468.25
75%	573	14.2	8.2125	3.51	75616.5753	31431.65212	21630.292	3427.0682	5268.9082	82.00	57.00	178140.00	105506.47	283646.47	5.45	2.13	1.72	9.30	58.20	9001.45	176300.00	-865796.87	-1005983.35
100%	764	14.2	0	3.51	100822.1	25097.89092	40453.352	1693.3039	3535.1439	82.00	57.00	178140.00	140675.29	318815.29	0.37	2.84	1.72	4.94	77.81	10735.22	176300.00	-825072.52	-1000427.82
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-54.80812	1787.0319	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	12483.33	176300.00	-784011.15	-1031699.96
Carbon offsetting	980	14.2	0	3.51	129326.778	20219.3884	64122.722	-3581.558	-1739.718	82.00	57.00	178140.00	213008.81	391148.81	-5.39	3.65	1.72	-0.02	100.08	16010.08	176300.00	-701171.40	-948860.21

Table B. 39 Office - PV (current FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC – taking into account the rental loss/gain- West-End

Office - London (West End)
PV (current FIT) + Insulation + TSC

TSC + PV + 2010 notional building fabric																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	110940.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	4812.547	6637.7466	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	7632.61	110940.00	179282.30	132863.48
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.09727	-1768.62	-429.6183	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	14699.98	110940.00	345287.49	244949.84
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	-7537.34	-6685.575	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	20955.94	110940.00	492233.54	322977.07
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	26831.22	110940.00	630238.00	392062.70
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.4021	-14814.1	-14449.03	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	28719.39	110940.00	674589.23	396249.10

TSC + PV + 0.17 - 0.24																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	4812.547	6584.7066	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	7685.65	117132.00	78474.62	30135.79
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.09727	-1768.62	-464.9783	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	14735.34	117132.00	244064.52	143606.87
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	-7537.34	-6703.255	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	20973.62	117132.00	390595.28	221218.81
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	26831.22	117132.00	528184.46	290639.16
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.8151	-14895.9	-14530.88	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	28801.24	117132.00	574458.31	296096.11

TSC + PV + 0.15 - 0.21																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	4812.547	6506.7066	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	7763.65	123840.00	-30251.24	-81371.07
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.09727	-1768.62	-517.4983	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	14787.86	123840.00	134740.16	33001.52
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	-7537.34	-6729.255	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	20999.62	123840.00	280648.00	109540.53
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	26831.22	123840.00	417626.46	179100.16
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.2282	-14977.8	-14612.74	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	28883.10	123840.00	465822.93	185827.66

TSC + PV + 0.13 - 0.19																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	4812.547	6463.0266	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	7807.33	129000.00	-114269.86	-168170.68
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.09727	-1768.62	-546.6183	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	14816.98	129000.00	50379.55	-53540.10
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	-7537.34	-6743.815	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	21014.18	129000.00	195945.38	22806.91
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	26831.22	129000.00	332581.84	92324.55
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.5833	-15114.2	-14749.16	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	29019.52	129000.00	383982.68	101169.63

TSC + PV + 0.12 - 0.17																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	4812.547	6425.5866	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	7844.77	134160.00	-198435.05	-255116.87
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.09727	-1768.62	-571.5783	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	14841.94	134160.00	-34078.78	-140479.43
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	-7537.34	-6756.295	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	21026.66	134160.00	111193.91	-63675.56
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	26831.22	134160.00	247537.23	5548.93
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.4674	-15223.3	-14858.29	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	29128.65	134160.00	301501.55	16088.08

TSC + PV + 0.11 - 0.15																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	4812.547	6388.1466	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	7882.21	141900.00	-325122.54	-384585.37
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.09727	-1768.62	-596.5383	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	14866.90	141900.00	-161059.42	-270091.07
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	-7537.34	-6768.775	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	21039.14	141900.00	-16079.87	-193430.34
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	26831.22	141900.00	119970.30	-124348.99
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.3514	-15332.5	-14967.43	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	29237.79	141900.00	176498.12	-112115.78

TSC + PV + 0.08 - 0.11																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	4812.547	6347.5866	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	7922.77	167700.00	-749392.91	-821329.73
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.09727	-1768.62	-623.5783	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	14893.94	167700.00	-585647.36	-707153.00
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	-7537.34	-6782.295	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	21052.66	167700.00	-440985.38	-630359.85
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	26831.22	167700.00	-305252.77	-561446.07
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.7139	-15932.7	-15567.68	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	29838.04	167700.00	-234625.76	-539895.48

TSC + PV + 0.07 - 0.10																											
provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 $(kgCO_2/m^2.yr)$	PV ECO_2 $(kgCO_2/m^2.yr)$	TSC ECO_2 $(kgCO_2/m^2.yr)$	Insulation ECO_2 $(kgCO_2/m^2.yr)$	Total CO_2 $(kgCO_2/m^2.yr)$	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	4812.547	6285.1866	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	7985.17	176300.00	-889668.22	-967767.04
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.09727	-1768.62	-665.1783	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	14935.54	176300.00	-726411.24	-853928.89
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	-7537.34	-6803.095	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	21073.46	176300.00	-582237.83	-777174.30
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.3519	-12925.9	-12560.86	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	26831.22	176300.00	-446993.80	-708599.09
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-16069.1	-15704.1	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	29974.46	176300.00	-373162.42	-684930.93

Table B. 40 Office - PV (future FiT) + improving the building fabric U-value down to 0.07-0.1 W/m^2.K (PUR) + TSC – taking into account the rental loss/gain- West-End

Office-London (West End)
PV (future FiT) + Insulation + TSC

TSC + PV + 2010 notional building fabric

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00	110940.00	0.00	0.00
25%	75	190	14.04	24.6375	3.51	0.0938	25073.559	60344.3764	0	8448.213	10273.413	66.00	46.00	143460.00	11250.00	35168.82	189878.82	15.66	0.71	0.04	0.66	17.07	23.30	3996.95	110940.00	93884.21	47465.39
50%	200	382	9.365	16.425	3.51	0.1873	50411.0502	41744.9171	6740.0973	5540.984	6879.984	66.00	46.00	143460.00	30000.00	70337.65	243797.65	9.68	1.42	0.09	0.66	11.86	46.70	7390.38	110940.00	173592.39	73254.74
75%	425	573	4.68	8.2125	3.51	0.281	75616.5753	31431.6521	21630.292	3427.068	4278.8282	66.00	46.00	143460.00	63750.00	105506.47	312716.47	3.73	2.13	0.20	0.66	6.72	69.78	9991.53	110940.00	234690.89	65434.42
100%	650	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	66.00	46.00	143460.00	97500.00	140675.29	381635.29	-2.21	2.84	0.31	0.66	1.60	92.82	12212.02	110940.00	286847.80	48672.50
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	1106.318	1471.3576	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	12799.00	110940.00	300635.51	22295.37
Carbon offsetting	650	832	0	0	3.51	0.3746	109795.795	23243.862	47729.402	-1518.8	-1153.76	66.00	46.00	143460.00	97500.00	180840.13	421800.13	-4.06	3.10	0.31	0.66	0.01	99.96	15424.12	110940.00	362296.83	83956.70

TSC + PV + 0.17 - 0.24

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	72	190	13.53	24.6375	3.51	0.104	25073.559	60344.3764	0	8448.213	10220.373	67.00	47.00	145830.00	10800.00	35168.82	191798.82	15.57	0.71	0.03	0.71	17.02	23.51	4049.99	117132.00	-6923.47	-55262.29
50%	185	382	9.025	16.425	3.51	0.1941	50411.0502	41744.9171	6740.0973	5540.984	6844.624	67.00	47.00	145830.00	27750.00	70337.65	243917.65	9.62	1.42	0.09	0.71	11.84	46.79	7425.74	117132.00	72369.42	-28088.22
75%	410	573	4.51	8.2125	3.51	0.2844	75616.5753	31431.6521	21630.292	3427.068	4261.1482	67.00	47.00	145830.00	61500.00	105506.47	312836.47	3.70	2.13	0.19	0.71	6.74	69.73	10009.21	117132.00	133052.63	-36323.84
100%	630	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	67.00	47.00	145830.00	94500.00	140675.29	381005.29	-2.21	2.84	0.30	0.71	1.64	92.64	12212.02	117132.00	184794.26	-52751.04
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	1081.871	1446.9109	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	12823.45	117132.00	199156.20	-79206.01
Carbon offsetting	630	835	0	0	3.51	0.3746	110191.694	23173.84	48054.815	-1561.14	-1196.104	67.00	47.00	145830.00	94500.00	181492.20	421822.20	-4.14	3.11	0.30	0.71	-0.02	100.09	15466.46	117132.00	261237.92	-17124.28

TSC + PV + 0.15 - 0.21

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	69	190	12.78	24.6375	3.51	0.119	25073.559	60344.3764	0	8448.213	10142.373	68.50	48.00	149061.00	10350.00	35168.82	194579.82	15.43	0.71	0.03	0.81	16.98	23.69	4127.99	123840.00	-115649.33	-166769.15
50%	172	382	8.52	16.425	3.51	0.2042	50411.0502	41744.9171	6740.0973	5540.984	6792.104	68.50	48.00	149061.00	25800.00	70337.65	245198.65	9.53	1.42	0.08	0.81	11.84	46.78	7478.26	123840.00	-36954.94	-138693.58
75%	400	573	4.26	8.2125	3.51	0.2894	75616.5753	31431.6521	21630.292	3427.068	4235.1482	68.50	48.00	149061.00	60000.00	105506.47	314567.47	3.65	2.13	0.19	0.81	6.78	69.51	10035.21	123840.00	23105.35	-148002.12
100%	615	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	68.50	48.00	149061.00	92250.00	140675.29	381986.29	-2.21	2.84	0.29	0.81	1.73	92.22	12212.02	123840.00	74236.26	-164290.04
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	1057.424	1422.4643	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	12847.90	123840.00	89172.42	-190822.85
Carbon offsetting	615	838	0	0	3.51	0.3746	110587.592	23103.818	48380.228	-1603.49	-1238.448	68.50	48.00	149061.00	92250.00	182144.27	423455.27	-4.22	3.12	0.29	0.81	0.01	99.98	15508.81	123840.00	151674.54	-128320.73

TSC + PV + 0.13 - 0.19

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	66	190	12.36	24.6375	3.51	0.1274	25073.559	60344.3764	0	8448.213	10098.693	70.00	49.00	152292.00	9900.00	35168.82	197360.82	15.35	0.71	0.03	0.91	17.00	23.60	4171.67	129000.00	-199667.95	-253568.77
50%	165	382	8.24	16.425	3.51	0.2098	50411.0502	41744.9171	6740.0973	5540.984	6762.984	70.00	49.00	152292.00	24750.00	70337.65	247379.65	9.48	1.42	0.08	0.91	11.89	46.58	7507.38	129000.00	-121315.55	-225235.20
75%	392	573	4.12	8.2125	3.51	0.2922	75616.5753	31431.6521	21630.292	3427.068	4220.5882	70.00	49.00	152292.00	58800.00	105506.47	316598.47	3.63	2.13	0.19	0.91	6.86	69.19	10049.77	129000.00	-61597.27	-234735.74
100%	605	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	70.00	49.00	152292.00	90750.00	140675.29	383717.29	-2.21	2.84	0.29	0.91	1.83	91.79	12212.02	129000.00	-10808.36	-251065.65
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	1016.68	1381.7198	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	12888.64	129000.00	5084.85	-277728.20
Carbon offsetting	605	843	0	0	3.51	0.3746	111247.422	22987.1147	48922.583	-1674.06	-1309.022	70.00	49.00	152292.00	90750.00	183231.05	426273.05	-4.35	3.14	0.29	0.91	-0.01	100.06	15579.38	129000.00	68287.64	-214525.41

TSC + PV + 0.12 - 0.17

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	63	190	12	24.6375	3.51	0.1346	25073.559	60344.3764	0	8448.213	10061.253	71.50	50.00	155523.00	9450.00	35168.82	200141.82	15.29	0.71	0.03	1.01	17.03	23.45	4209.11	134160.00	-283833.13	-340514.96
50%	160	382	8	16.425	3.51	0.2146	50411.0502	41744.9171	6740.0973	5540.984	6738.024	71.50	50.00	155523.00	24000.00	70337.65	249860.65	9.43	1.42	0.08	1.01	11.94	46.35	7532.34	134160.00	-205773.88	-312174.53
75%	382	573	4	8.2125	3.51	0.2946	75616.5753	31431.6521	21630.292	3427.068	4208.1082	71.50	50.00	155523.00	57300.00	105506.47	318329.47	3.60	2.13	0.18	1.01	6.93	68.87	10062.25	134160.00	-146348.74	-321218.21
100%	595	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	71.50	50.00	155523.00	89250.00	140675.29	385448.29	-2.21	2.84	0.28	1.01	1.92	91.36	12212.02	134160.00	-95852.97	-337841.27
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	984.0843	1349.1243	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	12921.24	134160.00	-79194.13	-364607.60
Carbon offsetting	595	846	0	0	3.51	0.3746	111775.287	22893.7521	49356.467	-1730.52	-1365.481	71.50	50.00	155523.00	89250.00	184100.47	428873.47	-4.45	3.15	0.28	1.01	-0.01	100.06	15635.84	134160.00	-15430.81	-300844.28

TSC + PV + 0.11 - 0.15

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	60	190	11.64	24.6375	3.51	0.1418	25073.559	60344.3764	0	8448.213	10023.813	73.00	51.00	158754.00	9000.00	35168.82	202922.82	15.22	0.71	0.03	1.11	17.07	23.31	4246.55	141900.00	-410520.63	-469983.45
50%	156	382	7.76	16.425	3.51	0.2194	50411.0502	41744.9171	6740.0973	5540.984	6713.064	73.00	51.00	158754.00	23400.00	70337.65	252491.65	9.39	1.42	0.07	1.11	11.99	46.10	7557.30	141900.00	-332754.52	-441786.17
75%	377	573	3.88	8.2125	3.51	0.297	75616.5753	31431.6521	21630.292	3427.068	4195.6282	73.00	51.00	158754.00	56550.00	105506.47	320810.47	3.58	2.13	0.18	1.11	7.00	68.53	10074.73	141900.00	-273622.52	-450972.99
100%	589	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	73.00	51.00	158754.00	88350.00	140675.29	387779.29	-2.21	2.84	0.28	1.11	2.02	90.93	12212.02	141900.00	-223419.89	-467739.19
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	951.4887	1316.5287	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	12953.83	141900.00	-205995.41	-494609.31
Carbon offsetting	589	851	0	0	3.51	0.3746	112303.151	22800.3895	49790.351	-1786.98	-1421.941	73.00	51.00	158754.00	88350.00	184969.90	432073.90	-4.56	3.17	0.28	1.11	0.00	100.02	15692.30	141900.00	-141671.56	-430285.46

TSC + PV + 0.08 - 0.11

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	57	190	11.25	24.6375	3.51	0.1496	25073.559	60344.3764	0	8448.213	9983.2527	79.00	55.00	171678.00	8550.00	35168.82	215396.82	15.15	0.71	0.03	1.62	17.50	21.35	4287.11	167700.00	-834790.99	-906727.82
50%	153	382	7.5	16.425	3.51	0.2246	50411.0502	41744.9171	6740.0973	5540.984	6686.024	79.00	55.00	171678.00	22950.00	70337.65	264965.65	9.34	1.42	0.07	1.62	12.45	44.04	7584.34	167700.00	-757342.45	-878848.10
75%	371	573	3.75	8.2125	3.51	0.2996	75616.5753	31431.6521	21630.292	3427.068	4182.1082	79.00	55.00	171678.00	55650.00	105506.47	332834.47	3.56	2.13	0.18	1.62	7.49	66.36	10088.25	167700.00	-698528.03	-887902.50
100%	582	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	79.00	55.00	171678.00	87300.00	140675.29	399653.29	-2.21	2.84	0.28	1.62	2.53	88.65	12212.02	167700.00	-648642.97	-904836.27
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	772.2132	1137.2532	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	13133.11	167700.00	-627007.49	-932277.22
Carbon offsetting	582	873	0	0	3.51	0.3746	115206.405	22286.8949	52176.714	-2097.51	-1732.466	79.00	55.00	171678.00	87300.00	189751.73	448729.73	-5.15	3.25	0.28	1.62	0.00	100.00	16002.83	167700.00	-559600.71	-864870.44

TSC + PV + 0.07 - 0.10

provided Elec. & heating	TSC area m^2	PV area m^2	Heating (KWh/m^2)	Lighting (KWh/m^2)	Hot water (KWh/m^2)	TSC fan power (KWh/m^2)	generated Elec by PV (KWh)	purchased from grid elec (KWh)	Exported Elec (KWh)	Elec cost £	Energy cost Inc FIT £	Wall Insulation price £/m^2	Roof Insulation price £/m^2	Total Insulation price £	TSC cost £	PV Cost £	Fabric cost £	Operational CO_2 ($kgCO_2/m^2.yr$)	PV ECO_2 ($kgCO_2/m^2.yr$)	TSC ECO_2 ($kgCO_2/m^2.yr$)	Insulation ECO_2 ($kgCO_2/m^2.yr$)	Total CO_2 ($kgCO_2/m^2.yr$)	CO_2 saving %	Energy saving (A) £	Value of external footprint area £	PV(A) £	NPV £
0	0	0	18.73	32.85	3.51	0	0	0	0	11957.4	14270.36	66.00	46.00	143460.00	0.00	0.00	143460.00	21.59	0.00	0.00	0.66	22.25	0.00	0.00		0.00	0.00
25%	55	190	10.65	24.6375	3.51	0.1616	25073.559	60344.3764	0	8448.213	9920.8527	82.00	57.00	178140.00	8250.00	35168.82	221558.82	15.04	0.71	0.03	1.72	17.49	21.40	4349.51	176300.00	-975066.31	-1053165.13
50%	150	382	7.1	16.425	3.51	0.2326	50411.0502	41744.9171	6740.0973	5540.984	6644.424	82.00	57.00	178140.00	22500.00	70337.65	270977.65	9.26	1.42	0.07	1.72	12.48	43.93	7625.94	176300.00	-898106.34	-1025623.99
75%	365	573	3.55	8.2125	3.51	0.3036	75616.5753	31431.6521	21630.292	3427.068	4161.3082	82.00	57.00	178140.00	54750.00	105506.47	338396.47	3.52	2.13	0.17	1.72	7.55	66.09	10109.05	176300.00	-839780.48	-1034716.95
100%	575	764	0	0	3.51	0.3746	100822.1	25097.8909	40453.352	1693.304	2058.3439	82.00	57.00	178140.00	86250.00	140675.29	405065.29	-2.21	2.84	0.27	1.72	2.62	88.21	12212.02	176300.00	-790384.00	-1051989.29
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	731.4687	1096.5087	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	13173.85	176300.00	-767791.47	-1079559.98
Carbon offsetting	575	878	0	0	3.51	0.3746	115866.236	22170.1916	52719.069	-2168.08	-1803.04	82.00	57.00	178140.00	86250.00	190838.51	455228.51	-5.28	3.27	0.27	1.72	-0.02	100.08	16073.40	176300.00	-699684.03	-1011452.53