South Oxfordshire and Vale of White Horse Joint Local Plan: Net Zero Carbon Study

Task 4: Cost analysis

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Bioregional

Written by: Jess Daly, Richard Hill and Adam Mactavish
Checked by: Adam Mactavish

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Introduction to the cost findings

Introduction

The cost findings presented in this report, provide evidence to support a viability assessment of planning policies that include specific targets for reduction of operational and embodied carbon[1]. A representative selection of domestic and non-domestic archetypes are used to assess cost implications for different development types.

Using specifications developed to achieve energy and carbon targets (see Task 3), the capital costs of achieving each standard is estimated together with the uplift in cost from construction to either a Part L 2021 or Future Home Standard/Future Building Standard baseline.

Scope of work

This report presents the results of cost analysis of:

- the impact on capital costs of building to higher standards for new buildings
- retrofitting an existing building to this standard
- the relative utilities costs associated with each standard

Costing approach

The uplift costs associated with specifications to achieve each performance standard were estimated based on Currie & Brown's cost datasets for energy efficiency and low carbon technologies. These datasets incorporate information from competitive tenders and market testing. Where needed, first principles cost planning (i.e. creation of a bespoke cost based on a detailed breakdown of component and labour costs) was undertaken by specialist quantity surveyors.

The costs are based on Q3 2023 prices and an Oxfordshire cost base inclusive of overheads and profit.

Costs were developed for each change to the baseline Part L 2021 compliant building design and specification. Those building elements that are not materially affected by the energy efficiency / low carbon technology options were not costed in detail. For example, substructure, roof coverings, kitchen and bathrooms, etc. Instead, these costs were incorporated within a 'balance of construction' cost, estimated by reference to a typical whole building construction cost per m^2 for the building type in question. This whole building cost was then estimated for each option based on the variance in the building elements costed in detail to determine the overall percentage impact on construction costs.

The analysis considers costs for developers with reasonably efficient design development, construction processes and a supply chain. The costs that individual organisations incur will vary according to their procurement strategy and the detail of their product. These variations in design, location and delivery method could result in a cost range of +/-c.20%. Notwithstanding these variations, the proportional uplifts of moving from one specification to another are likely to be similar across market segments.

Costs associated with retrofit of existing buildings were developed on the same basis as those determined for new buildings. However, these cost estimates also include allowances for necessary costs to deliver these projects including, site setup and surface protection, strip out and disposal, preliminaries, design fees and VAT.

Utility costs for each specification are determined based on current energy costs (based on UK government retail prices) for both domestic and commercial/public customers. Costs include allowances for standing charges for electricity and (where present) gas supplies.

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[1] *This study and its findings were accurate prior to the release of the Written Ministerial Statement entitled 'Planning - Local Energy Efficiency Standards Update' dated 13 December 2023. The Councils will be reviewing their approach to Net Zero Carbon Buildings in light of the Written Ministerial Statement.*

Glossary of terms and acronyms

Base build cost	The cost of building to the minimum specification compliant with current building regulations.
Capital costs	The initial costs involved in the construction of a building or infrastructure prior to its completion.
Capital cost model	Analysis of the costs of completing a defined scope of construction work based on the materials, plant, and labour involved in delivery. A cost model predicts the likely cost of an activity based on analysis of previous costs incurred for similar work or based on a 'bottom up' calculation based on the quantity of materials at a given price and duration at a given cost of time for labour and plant. The capital cost model does not include financing costs, or site acquisition but may include site set up and management (preliminaries), contractor overheads and profit, contingency and where relevant design and other fees.
Compact heat pump	A low power air source heat pump that provides both space heating and (in the system used in this study) hot water supply utilising exhaust air from the home with supplementation from external air. In this study compact heat pumps are used to provide heating to the air supplied via the ventilation system thereby avoiding the need for water filled radiators. Some additional space heating is provided via electric panel heaters to enable localised control of temperature. Compact heat pumps cannot typically meet high heating loads and so are only suitable for homes that have achieved a high standard of energy efficiency.
Future Buildings Standard / Future Homes Standard	The version of national building regulations Part L (which regulates energy and carbon) that will be in place from 2025.
LETI retrofit best practice	A specification developed by LETI with the aim of achieving annual energy consumption of 50kWh per m2 in housing. Typically these sorts of retrofit works include insulation to walls, roof and potentially floors, improved airtightness, mechanical ventilation with heat recovery and the use of a heat pump for space heating and hot water supply.
Value engineering	A process of identifying and evaluating alternative solutions to deliver a given outcome (eg carbon emissions) to see if offers greater value for money.

Domestic

The scenarios

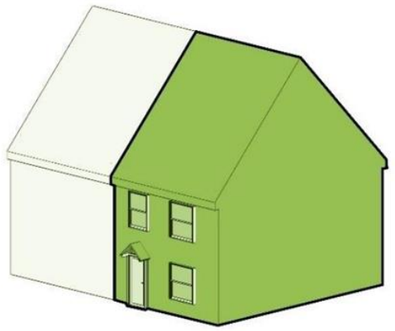
The terrace, semi-detached and detached archetypes have been assessed against the following four energy scenarios. Two additional Value Engineering options were explored for the domestic properties. As well as investigating a retrofit option, against an existing building baseline

Scenario	Details
Part L 2021	Compliant with a Part L 2021 notional building specification. A brick and block cavity wall with mineral wool insulation. Beam and block floor with EPS insulation. uPVC windows; timber truss roof with concrete tiles and mineral wool insulation at loft level. A PV array equivalent in size to 40% of the footprint is included.
Future Home Standard (FH(B)S)	This standard is based on the indicative Future Homes Standard and combines an improved performance fabric with a heat pump, natural ventilation and no PV and no wastewater heat recovery system. It uses the same building materials as stated in the Part L variant but with higher levels of insulation.
Zero operational carbon	This scenario includes triple glazed windows and doors, a good mechanical ventilation heat recovery (MVHR) system, air source heat pump (ASHP) and no wastewater heat recovery system. It uses the same building materials as stated in the Part L variant but with higher levels of insulation and triple glazed uPVC windows. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh/m^2_{fp}/yr.
Zero operational carbon with embodied carbon reduced - specification 1	This specification has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. This includes an a biobased (timber frame and timber fibre insulation) external wall construction, an insulated raft flooring and timber triple glazed windows. This scenario meets the embodied carbon LETI A target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	As per specification 1 but with the following cost savings to address achieve a lower embodied carbon target: standard polystyrene insulation and low carbon concrete for the floor insulation and the biobased external wall construction is replaced with a timber frame and mineral wool. The clay board was replaced with standard gypsum plaster. This scenario meets the embodied carbon LETI A target.
Value engineering – MVHR and ASHP	This value engineering option combines uses lower efficiency ASHP and MVHR installations. This reduces costs but increases the SHD and EUI.
Value engineering – no water-based heating system (e.g., water filled radiators) and a compact heat pump providing heating and hot water	This value engineering option combines fabric levels of the ‘zero operational carbon’ scenario but utilises a compact heat pump supplemented with minimal direct electric panel heaters in place of water filled radiators. This compact heat pump includes for MVHR ventilation, 180ltr domestic hot water storage and heating and cooling systems via air. No wastewater heat recovery system is included in this option. A PV array equivalent in size to 40% of the footprint is included.
Existing building	This scenario looks at existing housing stock from 1954 – 68 as a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, double glazed doors and windows, a gas boiler, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Triple glazed windows, an air source heat pump is also added alongside PVs on the roof and MVHR ventilation.

Semi-detached archetype

Introduction

A semi-detached house was modelled against the four different energy scenarios and two value engineering options by Transition by Design (TbD). These scenarios have then been incorporated into the capital cost model to determine fabric, services, Photovoltaics (PV) and overall cost for the specifications. For full technical details of these measures please refer to Task 3 of this study.



The semi-detached base build cost for a construction in line with current building regulations and used for uplift cost comparisons of the different scenarios, is £1,900/m^2.

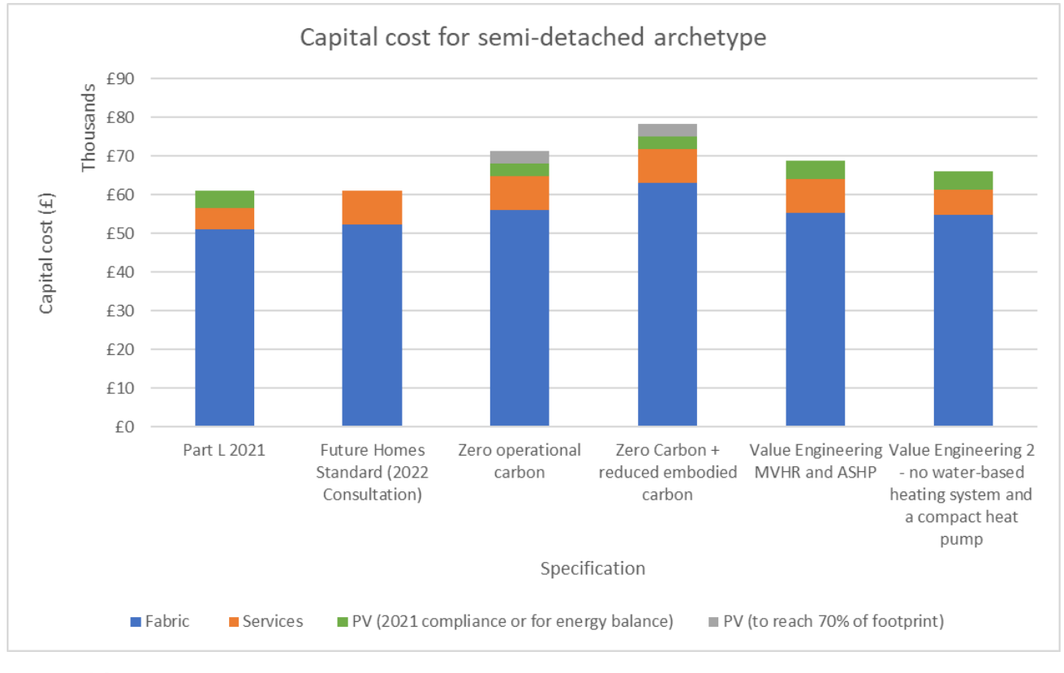
Capital costs

The following table and chart summarise capital costs for the semi-detached property. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L), and secondly to achieve an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. Where relevant, the additional costs of increasing the PV array to a target of 120 kWh/m2 footprint (approximately 70% of building footprint) are shown in the bracketed figures.

Capital cost for semi-detached archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£51,014	£52,326	£55,950	£63,067	£55,390	£54,718
Services	£5,645	£8,727	£8,727	£8,727	£8,727	£6,700
PV	£4,291 (+£0)	£0 (+£0)	£3,360 (+£3,192)	£3,360 (+£3,192)	£4,557 (+£-266)	£4,557 (+£-266)
Total	£60,949 (+£0)	£61,053 (+£0)	£68,037 (+£3,192)	£75,154 (+£3,192)	£68,674 (+£-266)	£65,975 (+£-266)
% uplift	0.0% (+0.0%)	0.1% (+0.0%)	4.6% (+2.1%)	9.2% (+2.1%)	5.0% (+-0.2%)	3.2% (+-0.2%)

Capital cost for semi-detached archetype



Cost uplift

The following tables present the cost uplift from Future Homes Standard and Part L 2021, with a PV allowance to meet regulation or achieve energy balance only. The additional cost uplift over a base build rate is presented for all energy scenarios.

Cost uplift from Future Homes Standard

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	-£1,312	£0	£3,624	£10,742	£3,064	£2,392
Services	-£3,082	£0	£0	£0	£0	-£2,027
PV	£4,291	£0	£3,360	£3,360	£4,557	£4,557
Total	-£103	£0	£6,984	£14,102	£7,621	£4,923

Cost uplift from Part L 2021

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£0	£1,312	£4,936	£12,054	£4,376	£3,704
Services	£0	£3,082	£3,082	£3,082	£3,082	£1,055
PV	£0	-£4,291	-£931	-£931	£266	£266
Total	£0	£103	£7,087	£14,205	£7,724	£5,026

Running costs of new homes built to different standards

The running costs of a new home built to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each home (see Task 3 report) with Ofgem data on energy prices and standing charges for October 2023.

Energy price assumptions

	Standing charge (£ per year)	Unit rate (£ per kWh)
Gas	109.5	£0.07
Electricity	193.45	£0.27

Where PV is included in the specification it is assumed that half of the power will be used in the home reducing demand for grid supplied electricity and half will be exported to the grid with revenue generated at £0.075 per kWh. Where 50% of the PV generation is greater than the annual energy demand, all of the energy demand is offset with the balance added to the amount exported. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for semi-detached archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£542	£0	£0	£0
Electricity (net of PV generation)	£0	£1,259	£383	£0
PV export revenue	£155	£0	£92	£257
Standing charge	£303	£193	£193	£193
Total	£689	£1,453	£484	-£63

Costs of retrofitting to zero operational carbon standard

A scenario for retrofitting an existing semi-detached home with an EPC rating of E to LETI retrofit best practice has also been modelled. For the house this included upgrades to the fabric including additional insulation including roof and floor insulation, triple glazed doors and windows, installation of MVHR and also the installation of a heat pump and allocation of a PV array sized to generate enough energy to balance annual energy demand. For full technical details of these measures please refer to Task 3 of this study.

The table below summarises the cost of these retrofit measures.

Semi-detached retrofit costs

	LETI Retrofit (best practice)
Fabric	£58,209
Services	£8,727
PV	£7,080
Total	£74,016
Total inc. ancillary project costs	£79,433

The retrofit ancillary project costs for the retrofit study, capture temporary protection of site, on site management costs allowing 1 day per week over 12 weeks and allowance for temporary welfare facilities.

Conclusions

The cost uplift for the zero operational carbon specification is around £7,000 or 4.6% above current building regulations or the proposed Future Homes Standard. The cost uplift differential between 'zero operational carbon' and 'zero carbon + reduced embodied carbon' is around £7,000 or 4.6% of build costs. Retrofitting an existing building to the LETI best practice standard would cost around £79,000 per home.

In terms of the value engineered compact heat pump scenario, the Nilan Compact P system has been used in the cost analysis. This system and cost are based on the inclusion of MVHR ventilation, 180lt domestic hot water and heating/cooling via air. There is a potential risk with this option as there are currently limited suppliers of this product in the UK market. Currently, most compact heat pumps are supplied by relatively small businesses with low turnover, therefore implementation at scale for a larger developer could be difficult in the short term albeit we would hope this market will develop over time.

The other value engineering option of MVHR and ASHP provides reduced capital costs in comparison to both the zero operational carbon and zero carbon + reduced embodied carbon options. This option includes for a basic MVHR, ASHP and reduced PV allocation compared to the zero carbon options.

The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

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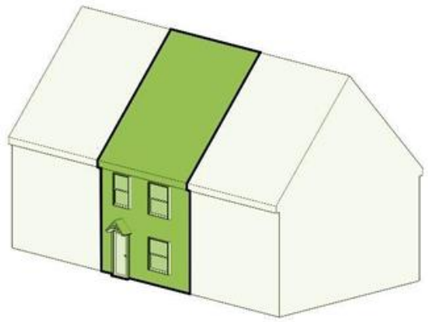
Terraced house archetype

Introduction

A terraced house was modelled against four different energy scenarios by Transition by Design (TbD). Two additional Value Engineered options were also explored. These scenarios have then been incorporated into the capital cost model to determine fabric, services, Photovoltaics (PV) and overall cost for the specifications. This specification follows the archetype of the semi-detached property but replaces the gable wall with a party wall.



The semi-detached base build cost for a construction in line with current building regulations and, used for uplift cost comparisons of the different scenarios, is £1,750/m^2.

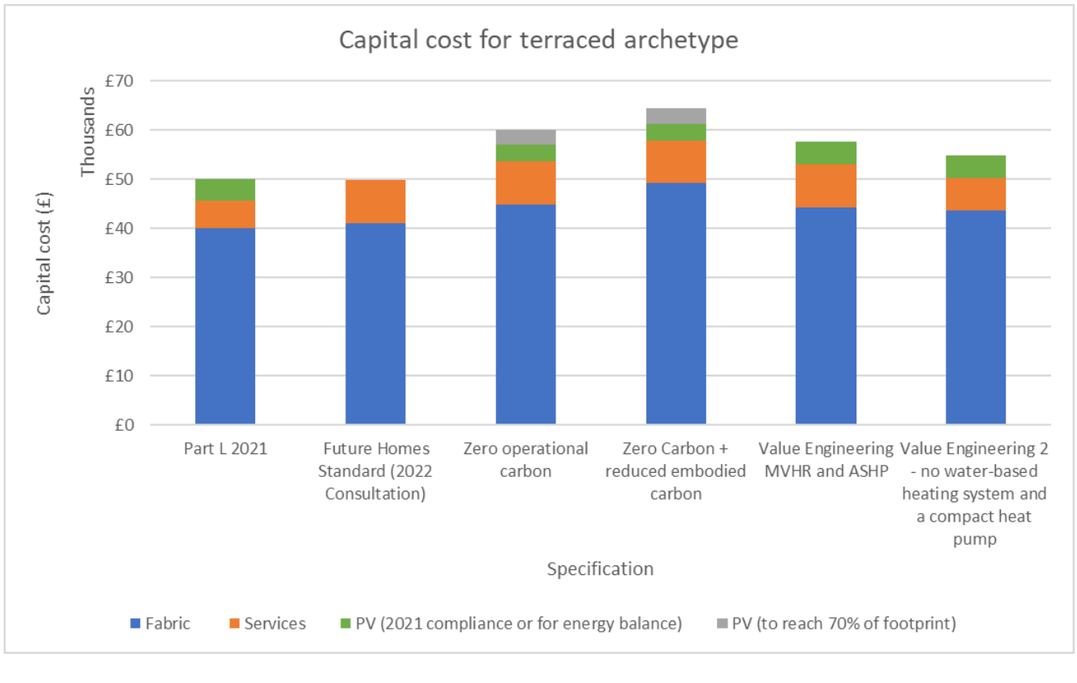
Capital costs

The following table and chart summarise capital costs for the terraced property. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for terraced archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£40,107	£41,114	£44,888	£49,216	£44,328	£43,656
Services	£5,645	£8,727	£8,727	£8,727	£8,727	£6,700
PV	£4,291 (+£0)	£0 (+£0)	£3,360 (+£3,192)	£3,360 (+£3,192)	£4,291 (+£0)	£4,291 (+£0)
Total	£50,043 (+£0)	£49,841 (+£0)	£56,974 (+£3,192)	£61,303 (+£3,192)	£57,345 (+£0)	£54,647 (+£0)
% uplift	0.0% (+0.0%)	-0.1% (+0.0%)	4.9% (+2.2%)	7.9% (+2.2%)	5.1% (+0.0%)	3.2% (+0.0%)

Capital cost for terraced archetype



Cost uplift

Cost uplift from Future Homes Standard

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	-£1,007	£0	£3,773	£8,102	£3,213	£2,541
Services	-£3,082	£0	£0	£0	£0	-£2,027
PV	£4,291	£0	£3,360	£3,360	£4,291	£4,291
Total	£202	£0	£7,133	£11,462	£7,504	£4,806

Cost uplift from Part L 2021

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£0	£1,007	£4,780	£9,109	£4,220	£3,548
Services	£0	£3,082	£3,082	£3,082	£3,082	£1,055
PV	£0	-£4,291	-£931	-£931	£0	£0
Total	£0	-£202	£6,931	£11,260	£7,302	£4,604

Running costs of new homes built to different standards

The running costs of a new home built to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each home (see Task 3 report) with Ofgem data on energy prices and standing charges for October 2023.

Energy price assumptions

	Standing charge (£ per year)	Unit rate (£ per kWh)
Gas	109.5	£0.07
Electricity	193.45	£0.27

Where PV is included in the specification it is assumed that half of the power will be used in the home offsetting demand for grid supplied electricity and half will be exported to the grid with revenue generated at £0.075 per kWh. Where 50% of the PV generation is greater than the annual energy demand, all of the energy demand is offset with the balance added to the amount exported. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for terraced house archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£406	£0	£0	£0
Electricity (net of PV generation)	£0	£1,117	£352	£0
PV export revenue	£155	£0	£90	£268
Standing charge	£303	£193	£193	£193
Total	£554	£1,310	£455	-£75

Costs of retrofitting to zero operational carbon standard

A scenario for retrofitting an existing terraced home with an EPC rating of E to LETI retrofit best practice has also been modelled. For the house this included upgrades to the fabric including additional insulation including roof and floor insulation, triple glazed doors and windows, installation of MVHR and also the installation of a heat pump and allocation of a PV array sized to generate enough energy to balance annual energy demand. For full technical details of these measures please refer to Task 3 of this study.

The table below summarises the cost of these retrofit measures.

Terraced retrofit costs

	LETI Retrofit (best practice)
Fabric	£56,509
Services	£8,727
PV	£7,080
Total	£72,316
Total inc. ancillary project costs	£77,733

The retrofit ancillary project costs for the retrofit study, capture temporary protection of site, on site management costs allowing 1 day per week over 12 weeks and allowance for temporary welfare facilities.

Conclusions

The cost uplift for the zero operational carbon specification is around £7,000 or 4.9% above current building regulations or the proposed Future Homes Standard. Retrofitting an existing building to the LETI best practice standard would cost around £78,000 per home.

The value engineered options of MVHR and ASHP provides reduced capital costs in comparison to both the zero operational carbon and zero carbon + reduced embodied carbon options. This option includes for a basic MVHR, ASHP and reduced PV allocation compared for the zero carbon options.

The cost uplift differential between ‘zero operational carbon’ and ‘zero carbon + reduced embodied carbon’ is under £4,700 or 3.0% of build costs.

The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

Detached house archetype

Introduction

A detached house was modelled against four different energy scenarios by Transition by Design (TbD) and two value engineering options. The detached property largely follows the specification of the semi-detached house but does not include a loft hatch and includes for insulation in the pitch of the roof rather than floor level. These scenarios have then been incorporated into the capital cost model to determine fabric, services, Photovoltaics (PV) and overall cost for the specifications.

The semi-detached base build cost for a construction in line with current building regulations and, used for uplift cost comparisons of the different scenarios, is £2,150/m^2.

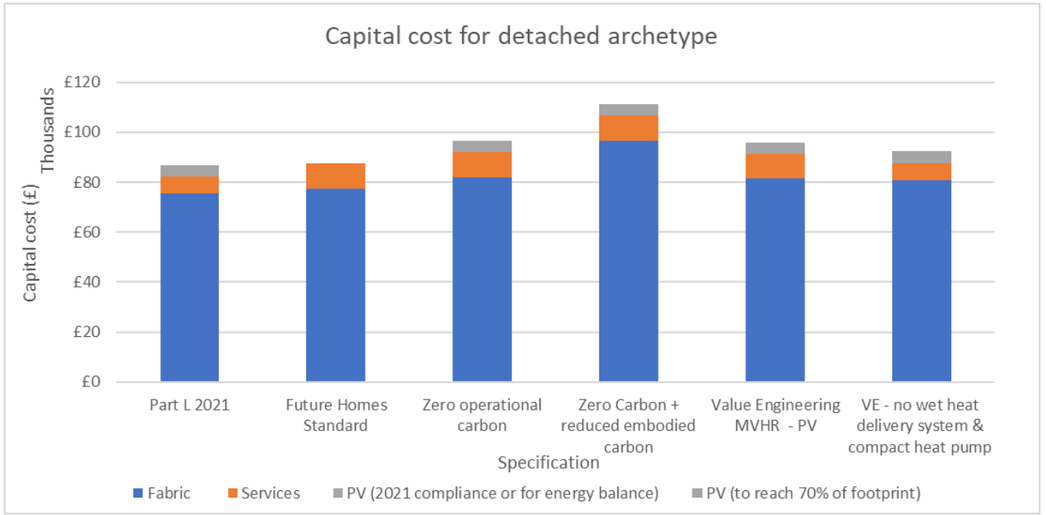
Capital costs

The following table and chart summarise capital costs for the detached property. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for detached archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£75,599	£77,414	£82,026	£96,599	£81,443	£80,744
Services	£6,790	£9,996	£9,996	£9,996	£9,996	£6,968
PV	£3,633 (+£0)	£0 (+£0)	£4,048 (+£1,383)	£4,048 (+£1,383)	£3,633 (+£0)	£3,633 (+£0)
Total	£86,022 (+£0)	£87,410 (+£0)	£96,069 (+£1,383)	£110,642 (+£1,383)	£95,071 (+£0)	£91,345 (+£0)
% uplift	0.0% (+0.0%)	0.6% (+0.0%)	4.1% (+0.6%)	10.1% (+0.6%)	3.7% (+0.0%)	2.2% (+0.0%)

Capital cost for detached archetype



Cost uplift

Cost uplift from FHS

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	-£1,815	£0	£4,611	£19,184	£4,029	£3,330
Services	-£3,205	£0	£0	£0	£0	-£3,028
PV	£3,633	£0	£4,048	£4,048	£3,633	£3,633
Total	-£1,388	£0	£8,659	£23,232	£7,662	£3,935

Cost uplift from Part L 2021

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon	Value Engineering MVHR and ASHP	Value Engineering 2 - no water-based heating system and a compact heat pump
Fabric	£0	£1,815	£6,427	£20,999	£5,844	£5,145
Services	£0	£3,205	£3,205	£3,205	£3,205	£178
PV	£0	-£3,633	£415	£415	£0	£0
Total	£0	£1,388	£10,047	£24,620	£9,049	£5,323

Running costs of new homes built to different standards

The running costs of a new home built to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each home (see Task 3 report) with Ofgem data on energy prices and standing charges for October 2023.

Energy price assumptions

	Standing charge (£ per year)	Unit rate (£ per kWh)
Gas	109.5	£0.07
Electricity	193.45	£0.27

Where PV[2] is included in the specification it is assumed that half of the power will be used in the home offsetting demand for grid supplied electricity and half will be exported to the grid with revenue generated at £0.075 per kWh. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for detached house archetype

	Part L 2021	Future Homes Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£827	£0	£0	£0
Electricity (net of PV generation)	£161	£1,058	£468	£468
PV export revenue	£121	£121	£121	£121
Standing charge	£303	£193	£193	£193
Total	£1,170	£1,130	£540	£540

Costs of retrofitting to zero operational carbon standard

A scenario for retrofitting an existing terraced home with an EPC rating of E to LETI retrofit best practice has also been modelled. For the house this included upgrades to the fabric including additional insulation to external walls, roof, floor, dormer cheeks, triple glazed doors and windows, installation of MVHR and heat pump and allocation of a PV array sized to generate enough energy to balance annual energy demand. For full technical details of these measures please refer to Task 3 of this study.

The table below summarises the cost of these retrofit measures.

Detached retrofit costs

	LETI Retrofit (best practice)
Fabric	£88,338
Services	£9,611
PV	£6,300
Total	£104,249
Total inc. ancillary project costs	£110,454

The retrofit ancillary project costs for the retrofit study, capture temporary protection of site, on site management costs allowing 1 day per week over 12 weeks and allowance for temporary welfare facilities.

[2] The quantity of PV installed on the detached archetype is constrained by the presence of a roof dormer.

Conclusions

The cost uplift for the zero operational carbon specification is around £10,000 or 4.1% above current building regulations or around 4% over the proposed Future Homes Standard. Retrofitting an existing building to the LETI best practice standard would cost around £110,000 per home.

The value engineering option of MVHR and ASHP provides reduced capital costs in comparison to both the zero operational carbon and zero carbon + reduced embodied carbon options. This option includes for a basic MVHR, ASHP and reduced PV allocation compared the zero carbon options.

The cost uplift differential between 'zero operational carbon' and 'zero carbon + reduced embodied carbon' is around £14,500 or 6.0% of build costs.

The adoption of zero operational carbon targets delivers reductions in running costs by around 50%.

Flats

Introduction

Two stories of flats above the retail archetype were modelled against four different energy scenarios by Transition by Design (TbD). The residential units have been modelled separately and do not include any for any costs of the retail development below. High level details of the four scenarios assessed can be found in the table below:

Scenario	Details
Part L 2021	Compliant with current Part L 2021 standard, this option specifies a gas boiler and no PV provision. Materials include concrete frame with a reinforced concrete slab and EPS insulation, uPVC double glazed windows, steel stud internal walls, gypsum plasterboard internally, concrete block external walls with PIR insulation, metal rainscreen cladding and a single ply roof with PIR insulation. A PV array equivalent in size to 40% of the footprint is included.
Future Building Standard (FBS)	This standard utilises an air source heat pump, improved fabric performance against Part L 2021 and no PV.
Zero operational carbon	This standard utilises an air source heat pump and improves on the fabric performance of the FBS option. The materials are the same as Part L but with higher levels of insulation and uPVC triple glazing. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh/m^2_{fp}/yr.
Zero operational carbon with embodied carbon reduced - specification 1	Specification 1 has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. Materials include: glulam and cross laminated timber (CLT) superstructure, timber frame external walls with cellulose insulation and timber cladding, timber stud internal walls, clayboard on all internal walls, timber triple glazed windows and reduced carbon concrete EPS insulated slab. This scenario meets the embodied carbon LETI A target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	Specification 2 focuses on reducing embodied carbon and is reflective of the specification 1 but with the following changes: the glulam and CLT superstructure is replaced with a concrete frame and composite steel and concrete deck. The insulation in the external walls are replaced for mineral wool and gypsum plasterboard is used instead of clayboard. This scenario meets the embodied carbon LETI B target.
Existing building	This scenario is a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, double glazed doors and windows, a gas boiler, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Triple glazed windows, an air source heat pump is also added alongside PVs on the roof and MVHR ventilation.

The flats base build cost used for uplift cost comparisons of the different scenarios is £2,000/m^2.

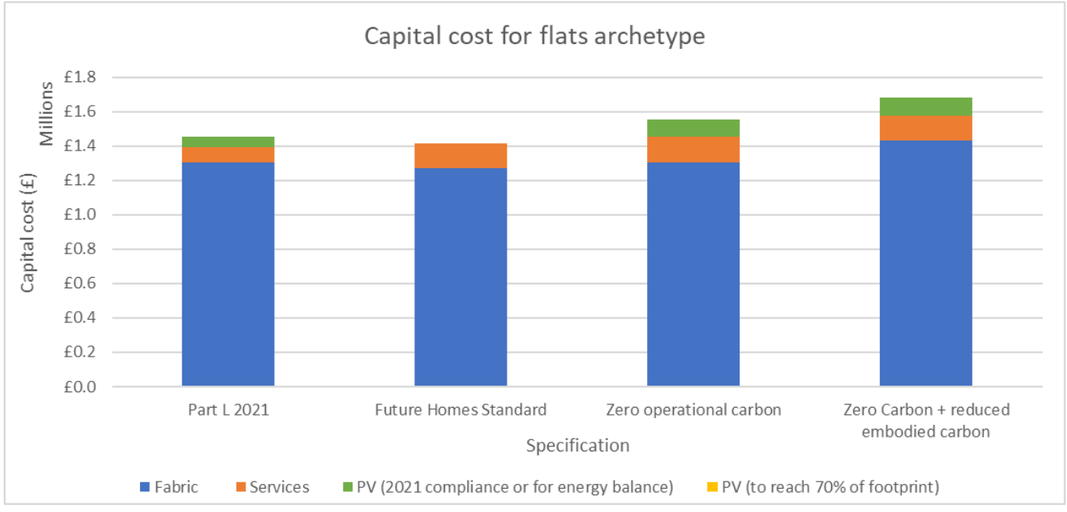
Capital costs

The following table and chart summarise capital costs for the flats archetype. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for flats archetype

	Part L 2021	Future Home Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£1,305,517	£1,267,818	£1,306,139	£1,429,477
Services	£87,485	£148,608	£147,700	£147,700
PV	£59,136 (+£0)	£0 (+£0)	£102,256 (+£0)	£102,256 (+£0)
Total	£1,452,138 (+£0)	£1,416,426 (+£0)	£1,556,095 (+£0)	£1,679,433 (+£0)
% uplift	0.0% (+0.0%)	-2.1% (+0.0%)	6.2% (+0.0%)	13.6% (+0.0%)

Capital cost for flats archetype



Cost uplift

Cost uplift from Future Homes Standard

	Part L 2021	Future Home Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£37,699	£0	£38,321	£161,659
Services	-£61,123	£0	-£908	-£908
PV	£59,136	£0	£102,256	£102,256
Total	£35,712	£0	£139,669	£263,006

Cost uplift from Part L 2021

	Part L 2021	Future Home Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£0	-£37,699	£622	£123,959
Services	£0	£61,123	£60,215	£60,215
PV	£0	-£59,136	£43,120	£43,120
Total	£0	-£35,712	£103,957	£227,294

Running costs of new homes built to different standards

The running costs of a new home built to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each home (see Task 3 report) with Ofgem data on energy prices and standing charges for October 2023.

Energy price assumptions

	Standing charge (£ per year)	Unit rate (£ per kWh)
Gas	109.5	£0.07
Electricity	193.45	£0.27

Where PV[3] is included in the specification it is assumed that half of the power will be used in the home offsetting demand for grid supplied electricity and half will be exported to the grid with revenue generated at £0.075 per kWh. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

[3] The quantity of PV installed reflects the ratio of roof to internal area in the illustrative three storey block. Taller blocks of flats would have less PV assigned to each flat, reducing the benefits from onsite generation.

Annual running costs for flat archetype (whole block)

	Part L 2021	Future Home Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)
Gas	£4,975	£0	£0
Electricity (net of PV generation)	£921	£10,238	£3,973
PV export revenue	£1,271	£0	£969
Standing charge	£303	£193	£193
Total	£4,928	£10,431	£3,197

Costs of retrofitting to zero operational carbon standard

A retrofit scenario showing upgrades required from existing EPC rating E to LETI retrofit best practice has also been modelled. This included upgrades to fabric, windows and doors, installation of MVHR and heat pump and allocation of PV to balance energy demand. For full technical details of these measures please refer to Task 3 of this study. The costs of this retrofit study are shown in the following findings section.

Flats retrofit costs

	LETI Retrofit best practice
Fabric	£391,908
Services	£8,727
PV	£25,800
Total	£426,435
Total inc. ancillary project costs	£455,719

The retrofit ancillary project costs for the retrofit study, capture temporary protection of site, on site management costs allowing 1 day per week over 12 weeks and allowance for temporary welfare facilities.

Conclusions

The results show there is a cost uplift of around £104,000 (£13,000 per flat) or 6.2% between the Part L 2021 compliant and the Zero operational carbon option for the flats. This premium increases by 7,4% to 13.6% over a design compliant with current building regulations by following the developed reduced embodied carbon specification. Much of this additional cost is linked to the use of timber framing systems. Retrofitting an existing building to the LETI best practice standard would cost around £456,000.

The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

Non-Domestic

The scenarios

Due to the large variation across the non-domestic archetypes, the details of the energy scenarios for each building are presented under the relevant headings.

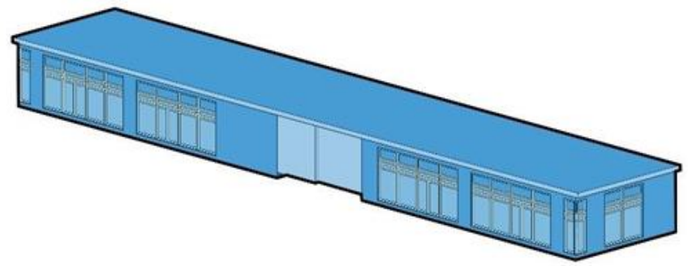
Retail archetype

Introduction

A retail building with four units was modelled against four different energy scenarios by TbD. These scenarios have then been incorporated into the capital cost model to determine fabric, services, PV and overall cost for the specifications.

High level details of the 4 scenarios assessed can be found in the table below:

Scenario	Details
Part L 2021	Compliant with current Part L 2021 standard, this option contains variable refrigerant flow (VRF) technology with standard fabric levels and no PV provision. It uses the freestanding form. Materials include concrete frame with a reinforced concrete slab and EPS insulation, uPVC double glazed windows, steel stud internal walls, gypsum plasterboard internally, concrete block external walls with PIR insulation, metal rainscreen cladding and a single ply roof with PIR insulation. A PV array equivalent in size to 40% of the footprint is included.
Future Building Standard (FBS)	This standard utilises an air source heat pump, improved fabric performance against Part L 2021 and no PV. It uses the freestanding form.
Zero operational carbon – Freestanding shoe shop	This standard utilises an air source heat pump. The materials are the same as Part L but with higher levels of insulation and uPVC triple glazing. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr. These two scenarios are explored for both if the retail space were to be used as a clothing store or as a grocery store.
Zero operational carbon – Freestanding grocery	This is the same as the retail scenario above, but the unregulated energy use has been changed to a convenience grocer with chilled storage and display.
Zero operational carbon – Inbuilt grocery use	This was modelled with the same fabric as the previous two zero operational carbon scenarios. It has convenience grocers use. The key difference is the form of the building which is inbuilt in this scenario.
Zero operational carbon with embodied carbon reduced - specification 1	Specification 1 has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. Materials include: glulam and cross laminated timber (CLT) superstructure, timber frame external walls with cellulose insulation and timber cladding, timber stud internal walls, clayboard on all internal walls, timber triple glazed windows and reduced carbon concrete EPS insulated slab. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr. These two scenarios are explored for both if the retail space were to be used as a clothing store or as a grocery store. It uses the freestanding form. This scenario meets the embodied carbon LETI A+ target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	Specification 2 focuses on reducing embodied carbon and is reflective of specification 1 but with the following changes: the glulam and CLT superstructure is replaced with a concrete frame and composite steel and concrete deck. The insulation in the external walls are replaced for mineral wool and gypsum plasterboard is used instead of clayboard. It uses the freestanding form. This scenario meets the embodied carbon LETI A target.
Existing building	This scenario is a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, single glazed doors and windows, a VRF, electric panel heaters, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Triple glazed windows, an air source heat pump is also added alongside PVs on the roof and MVHR ventilation.



The retail base build cost used for uplift cost comparisons of the different scenarios is based on the following elemental costs drawn from Currie & Brown's cost benchmarks. Rates include main contractor costs, and external services, but exclude site landscaping and drainage which are location dependent.

Element	£/m^2 GIA
Shell building	1,215
Fitout and services	1,350
Contractor on costs	695
Total (excl. VAT)	3,260

Capital costs

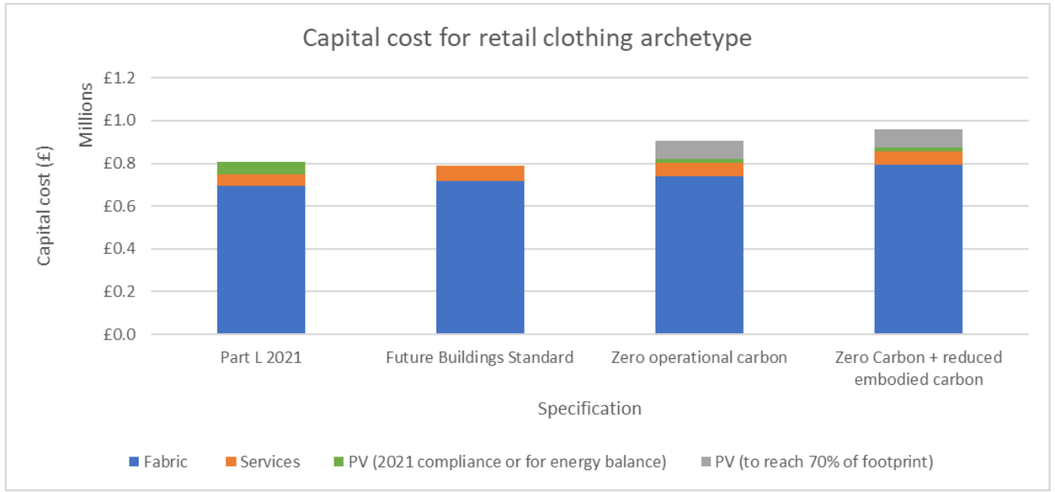
The following table and chart summarise capital costs for the retail property assuming a usage with relatively low energy consumption (eg a clothing store). Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options for a clothing store. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures. If the retail use had a higher energy load, e.g., a

grocery store with extensive chilling and freezer units, then the net zero operational target would require the larger PV array (70% of footprint) to be compliant.

Capital cost for retail archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£692,813	£719,403	£739,832	£795,244
Services	£53,712	£69,259	£62,751	£62,751
PV	£59,136 (+£0)	£0 (+£0)	£17,248 (+£85,008)	£17,248 (+£85,008)
Total	£805,661 (+£0)	£788,663 (+£0)	£819,831 (+£85,008)	£875,243 (+£85,008)
% uplift	0.0% (+0.0%)	-1.5% (+0.0%)	1.2% (+7.3%)	6.0% (+7.3%)

Capital cost for retail archetype



Cost uplift

Cost uplift from Future Building Standard

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	-£26,590	£0	£20,429	£75,841
Services	-£15,548	£0	-£6,508	-£6,508
PV	£59,136	£0	£17,248	£17,248
Total	£16,998	£0	£31,168	£86,580

Cost uplift from Part L 2021

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£0	£26,590	£47,019	£102,431
Services	£0	£15,548	£9,039	£9,039
PV	£0	-£59,136	-£41,888	-£41,888
Total	£0	-£16,998	£14,170	£69,582

Running costs of new buildings built to different standards

The running costs of a new building constructed to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each building (see Task 3 report) with UK Government retail energy prices data for 2023.

Energy price assumptions

	Unit rate (£ per kWh)
Gas	£0.09
Electricity	£0.29

Where PV is included in the specification it is assumed that half of the power will be used in the building, offsetting demand for grid supplied electricity, and half will be exported to the grid with revenue generated at £0.075 per kWh. Where 50% of the PV generation is greater than the annual energy demand, all of the energy demand is offset with the balance added to the amount exported. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for retail with clothing archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£2,599	£0	£0	£0
Electricity (net of PV generation)	£0	£3,986	£1,255	£0
PV export revenue	£2,067	£0	£357	£3,715
Total	£532	£3,986	£898	-£3,715

Costs of retrofitting to zero operational carbon standard

A retrofit scenario showing upgrades required from existing EPC rating E to LETI retrofit best practice has also been modelled. For the retail building this included upgrades to the fabric and windows, installation of MVHR and heat pump and allocation of PV to balance energy demand. For full technical details of these measures please refer to Task 3 of this study.

Retail retrofit costs with grocery store

	LETI Retrofit (best practice unconstrained)
Fabric	£339,008
Services	£69,259
PV	£11,500
Total	£419,767
Total inc. ancillary project costs	£449,632

The retrofit project ancillary costs account for temporary protection of the site, 15 days of work on general redecorations, 50 days of project management time over 25 weeks and the provision of temporary welfare facilities.

Conclusions

The results show there is a cost uplift of around £14,000 or 1.2% between the Part L 2021 compliant building regulations and the zero operational carbon option for the retail building. If the PV area on the roof were increased to 70% of the roof area, then this uplift would increase by a further 7.3% to 8.5%. Retrofitting an existing building to the LETI best practice standard would cost around £450,000.

This premium increases by 4.8% to 6% over a design compliant with current building regulations would be incurred by following the developed reduced embodied carbon specification.

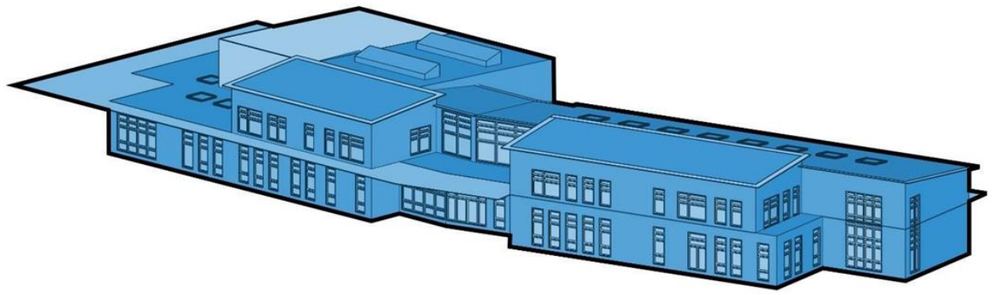
The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

School archetype

Introduction

A two-storey primary school building was modelled against four different energy scenarios by TbD. These scenarios have then been incorporated into the capital cost model to determine fabric, services, PV and overall cost for the specifications. High level details of the four scenarios assessed can be found in the table below:

Scenario	Details
Part L 2021	Compliant with current Part L 2021 standard, this option utilises a gas boiler, with radiators in classrooms and offices and fan convectors in the hall. No PV has been allocated. Materials include steel frame for large spans, structural blockwork with pre-cast concrete floors, a concrete slab with EPS insulation, uPVC double glazed windows, steel stud internal walls, gypsum plasterboard internally, external walls have PIR insulation and are clad in half brick and half timber and a single ply roof with PIR insulation. A PV array equivalent in size to 40% of the footprint is included.
Future Building Standard (FBS)	This scenario utilises a gas boiler and low temperature radiators, with an improved fabric performance against Part L 2021 and no PV has been allocated.
Zero operational carbon	This standard utilises an air source heat pump and the specification improves on the fabric performance of the FBS option. The materials are the same as Part L but with higher levels of insulation and uPVC triple glazing. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr.
Zero operational carbon with embodied carbon reduced - specification 1	Specification 1 has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. Materials include glulam and cross laminated timber (CLT) superstructure, timber frame external walls with cellulose insulation and timber cladding, timber stud internal walls, clayboard on all internal walls, timber triple glazed windows and reduced carbon concrete EPS insulated slab. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr. This scenario meets the embodied carbon LETI A target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	Specification 2 focuses on reducing embodied carbon and is reflective of specification 1 but with the following changes: the glulam and CLT superstructure is replaced with steel frame for large spans, structural blockwork with pre-cast concrete floors. The insulation in the external walls is replaced for mineral wool and gypsum plasterboard is used instead of clayboard. uPVC windows instead of timber. This scenario meets the embodied carbon LETI B target.
Existing building	This scenario is a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, double glazed doors and windows, a gas boiler, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Triple glazed windows, an air source heat pump is also added alongside PVs on the roof and natural ventilation.



The school base build cost used for uplift cost comparisons of the different scenarios is £3,620/m^2.

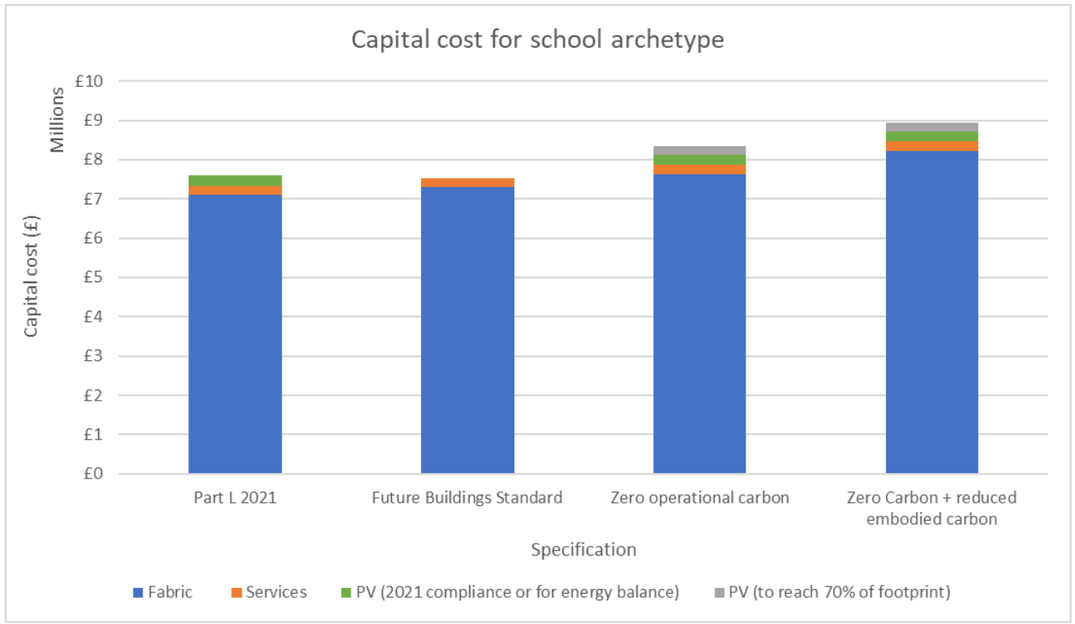
Capital cost

The following table and chart summarise capital costs for the school archetype. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for school archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£7,104,663	£7,297,808	£7,636,225	£8,231,305
Services	£221,039	£221,039	£229,872	£229,872
PV	£271,747 (+£0)	£0 (+£0)	£252,220 (+£221,303)	£252,220 (+£221,303)
Total	£7,597,449 (+£0)	£7,518,848 (+£0)	£8,118,316 (+£221,303)	£8,713,396 (+£221,303)
% uplift	0.0% (+0.0%)	-0.6% (+0.0%)	4.3% (+1.8%)	9.1% (+1.8%)

Capital cost for school archetype



Cost uplift

Cost uplift from Future Building Standard

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	-£193,145	£0	£338,416	£933,497
Services	£0	£0	£8,832	£8,832
PV	£271,747	£0	£252,220	£252,220
Total	£78,601	£0	£599,469	£1,194,549

Cost uplift from Part L 2021

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£0	£193,145	£531,562	£1,126,642
Services	£0	£0	£8,832	£8,832
PV	£0	-£271,747	-£19,527	-£19,527
Total	£0	-£78,601	£520,867	£1,115,948

Running costs of new buildings built to different standards

The running costs of a new building constructed to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each building (see Task 3 report) with UK Government retail energy prices data for 2023.

Energy price assumptions

	Unit rate (£ per kWh)
Gas	£0.09
Electricity	£0.29

Where PV is included in the specification it is assumed that half of the power will be used in the building, offsetting demand for grid supplied electricity, and half will be exported to the grid with revenue generated at £0.075 per kWh. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for school archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£28,697	£0	£0	£0
Electricity (net of PV generation)	£4,822	£46,874	£21,866	£8,230
PV export revenue	£3,799	£0	£3,993	£7,520
Total	£29,719	£46,874	£17,872	£710

Costs of retrofitting to zero operational carbon standard

A retrofit scenario showing upgrades required from existing EPC rating E to LETI retrofit best practice has also been modelled. For the school this included upgrades to the fabric, windows and doors, installation of MVHR and heat pump and allocation of PV to balance energy demand. For full technical details of these measures please refer to Task 3 of this study.

School retrofit costs

	LETI Retrofit (best practice unconstrained)
Fabric	£1,610,016
Services	£175,773
PV	£107,050
Total	£1,892,839
Total inc. ancillary project costs	£1,998,378

The retrofit project ancillary costs account for temporary protection of the site, 15 days of work on general redecorations, 50 days of project management time over 25 weeks and the provision of temporary welfare facilities.

Conclusions

The results show there is a cost uplift of around £521,000 or 4.3% between current building regulations and Zero operational carbon option for the school building, with a further uplift of 4.8% from zero carbon to the reduced embodied carbon option. Retrofitting an existing building to the LETI best practice standard would cost around £2million.

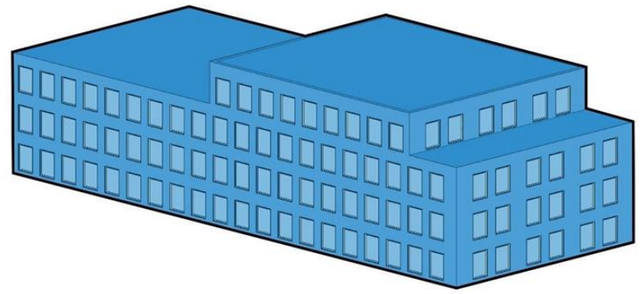
The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

Office archetype

Introduction

An office building was modelled against four different energy scenarios by TbD. These scenarios have then been incorporated into the capital cost model to determine fabric, services, PV and overall cost for the specifications. High level details of the four scenarios assessed can be found in the table below:

Scenario	Details
Part L 2021	Compliant with current Part L 2021 standard, this option utilises a gas boiler, with trench heaters at the perimeter and VRF units in the suspended ceiling. Materials include: steel frame with a reinforced concrete slab and EPS insulation, composite steel and concrete decks, uPVC double glazed windows, steel stud internal walls, gypsum plasterboard internally, concrete block external walls with PIR insulation, metal rainscreen cladding and a single ply roof with PIR insulation. A PV array equivalent in size to 40% of the footprint is included.
Future Building Standard (FBS)	This scenario utilises a gas boiler with trench heaters at the perimeter and VRF units in the suspended ceiling. The scenario has an improved fabric performance against Part L 2021 and no PV has been allocated.
Zero operational carbon	This standard utilises an air source heat pump. The materials are the same as Part L but with higher levels of insulation and uPVC triple glazing. Heating distribution is primarily via supply air heating and localised VRF to provide comfort/heating and cooling. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr.
Zero operational carbon with embodied carbon reduced - specification 1	Specification 1 has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. Materials include: glulam and cross laminated timber (CLT) superstructure, timber frame external walls with cellulose insulation and timber cladding, timber stud internal walls, clayboard on all internal walls, timber triple glazed windows and reduced carbon concrete EPS insulated slab. Heating distribution is primarily via supply air heating and localised VRF to provide comfort/heating and cooling. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr. This scenario meets the embodied carbon LETI A target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	Specification 2 focuses on reducing embodied carbon and is reflective of specification 1 but with the following changes: the glulam and CLT superstructure is replaced with a concrete frame and composite steel and concrete deck. The insulation in the external walls are replaced for mineral wool and gypsum plasterboard is used instead of clayboard. uPVC windows. This scenario meets the embodied carbon LETI B target.
Existing building	This scenario is a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, double glazed doors and windows, a gas boiler, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Triple glazed windows, an air source heat pump is also added alongside PVs on the roof and MVHR ventilation.



The office base build cost used for uplift cost comparisons of the different scenarios is £3,620/m^2.

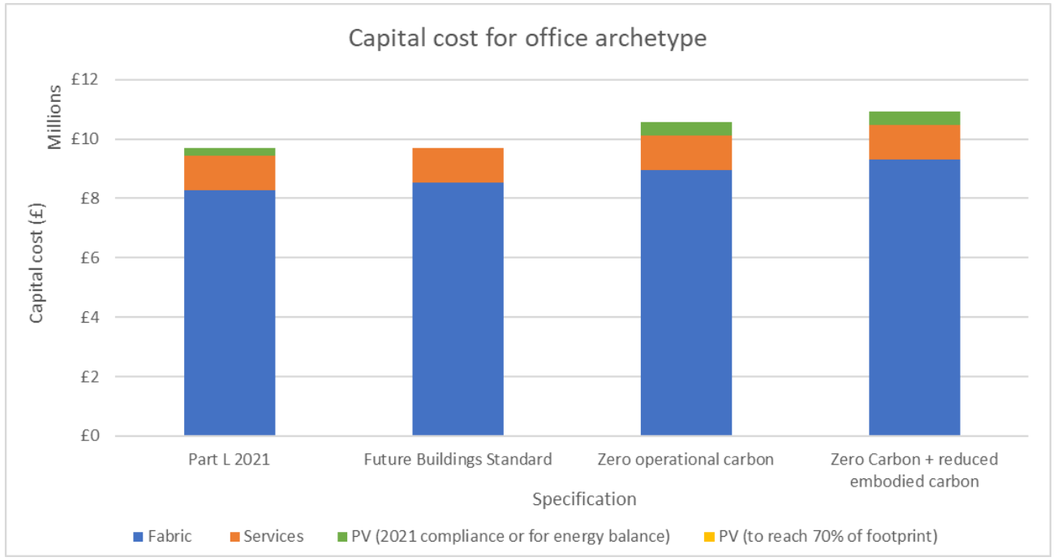
Capital cost

The following table and chart summarise capital costs for the office archetype. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current building regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for office archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£8,277,733	£8,518,102	£8,944,714	£9,313,453
Services	£1,161,549	£1,161,549	£1,160,093	£1,160,093
PV	£261,983 (+£0)	£0 (+£0)	£457,250 (+£0)	£457,250 (+£0)
Total	£9,701,265 (+£0)	£9,679,652 (+£0)	£10,562,058 (+£0)	£10,930,796 (+£0)
% uplift	0.0% (+0.0%)	-0.2% (+0.0%)	6.1% (+0.0%)	8.7% (+0.0%)

Capital cost for office archetype



Cost uplift

Cost uplift from Future Building Standard

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	-£240,370	£0	£426,612	£795,350
Services	£0	£0	-£1,456	-£1,456
PV	£261,983	£0	£457,250	£457,250
Total	£21,614	£0	£882,406	£1,251,145

Cost uplift from Part L 2021

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£0	£240,370	£666,982	£1,035,720
Services	£0	£0	-£1,456	-£1,456
PV	£0	-£261,983	£195,267	£195,267
Total	£0	-£21,614	£860,793	£1,229,531

Running costs of new buildings built to different standards

The running costs of a new building constructed to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each building (see Task 3 report) with UK Government retail energy prices data for 2023.

Energy price assumptions

	Unit rate (£ per kWh)
Gas	£0.09
Electricity	£0.29

Where PV is included in the specification it is assumed that half of the power will be used in the building, offsetting demand for grid supplied electricity, and half will be exported to the grid with revenue generated at £0.075 per kWh. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for office archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)
Gas	£15,477	£0	£0
Electricity (net of PV generation)	£34,331	£101,052	£54,629
PV export revenue	£4,308	£0	£6,884
Total	£45,500	£101,052	£47,745

Costs of retrofitting to zero operational carbon standard

A retrofit scenario showing upgrades required from existing EPC rating E to LETI retrofit best practice has also been modelled. For the office this included upgrades to the fabric, windows and doors, installation of MVHR and heat pump and allocation of PV to balance energy demand. For full technical details of these measures please refer to Task 3 of this study.

Office retrofit costs

	LETI Retrofit (best practice unconstrained)
Fabric	£1,861,849
Services	£881,162
PV	£262,400
Total	£3,005,411
Total inc. ancillary project costs	£3,135,126

The retrofit project ancillary costs account for temporary protection of the site, 15 days of work on general redecorations, 50 days of project management time over 25 weeks and the provision of temporary welfare facilities.

Conclusions

The results show there is a cost uplift of around £861,000 or 6.1% between current building regulations and zero operational carbon option for the office building, with an additional uplift of 2.6% from zero carbon to the reduced embodied carbon option. Retrofitting an existing building to the LETI best practice standard would cost around £3.1million.

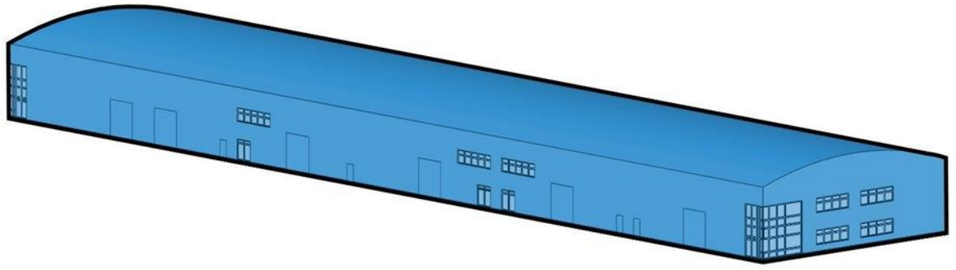
The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

Warehouse archetype

Introduction

A warehouse building with offices over two stories was modelled against four different energy scenarios by TbD. These scenarios have then been incorporated into the capital cost model to determine fabric, services, PV and overall cost for the specifications. High level details of the four scenarios assessed can be found in the table below:

Scenario	Details
Part L 2021	Compliant with current Part L 2021 standard, this option utilises suspended heaters and gas in the warehouse area with domestic gas boiler in the offices (5nr 12 kW) one per block). Materials include: steel frame with a reinforced concrete slab and EPS insulation, composite steel and concrete decks, uPVC double glazed windows, steel stud internal walls, gypsum plasterboard internally, external walls and roof are made from aluminium SIPs panels with metal cladding and roof finish. A PV array equivalent in size to 40% of the footprint is included.
Future Building Standard (FBS)	This standard this utilises suspended heaters and gas in the warehouse area with domestic gas boiler in the offices (5nr 12 kW) one per block), an improved fabric performance against Part L 2021 and no PV provision.
Zero operational carbon	This standard utilises a VRF system and distribution via supply air heating. The localised VRF provides comfort/heating and cooling. The materials are the same as Part L but with higher levels of insulation and uPVC triple glazing. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr.
Zero operational carbon with embodied carbon reduced - specification 1	This standard utilises a VRF system and distribution via supply air heating. The localised VRF provides comfort/heating and cooling. Specification 1 has the same fabric performance of the zero operational carbon but reduces the embodied carbon by replacing certain materials. Materials include: glulam and cross laminated timber (CLT) superstructure, timber frame external walls with hemp lime block insulation and timber cladding, timber stud internal walls, clayboard on all internal walls, timber triple glazed windows and reduced carbon concrete EPS insulated slab. Two scenarios have been explored for PV allocation, one for to achieve an energy generation level that balances demand and alternatively to maximise energy generation by installing a PV array of 120 kWh2/m^2_{fp}/yr. This scenario meets the embodied carbon LETI A target. *Costs for this specification are not included in this report.*
Zero operational carbon with embodied carbon reduced - specification 2	Specification 2 focuses on reducing embodied carbon and is reflective of specification 1 but with the following changes: the glulam and CLT superstructure is replaced with a steel frame and composite steel and concrete deck. The external walls and roof are made from aluminium SIPs panels, as outlined in the Part L spec and gypsum plasterboard is used instead of clayboard. uPVC windows. This scenario meets the embodied carbon LETI A target.
Existing building	This scenario is a baseline for the retrofit scenario. It involves no insulation in the floors, minimal insulation in the roof and walls, double glazed doors and windows, a gas boiler, natural ventilation, drafty and no PVs on the roof.
Retrofit	This retrofit option involves improving the insulation in the walls, floors, and roof, as well as installing membranes and repairs to reduce draft. Windows are triple glazed. An air source heat pump is also added alongside PVs on the roof and natural ventilation with MVHR.



The warehouse base build cost used for uplift cost comparisons of the different scenarios is £2,500/m^2.

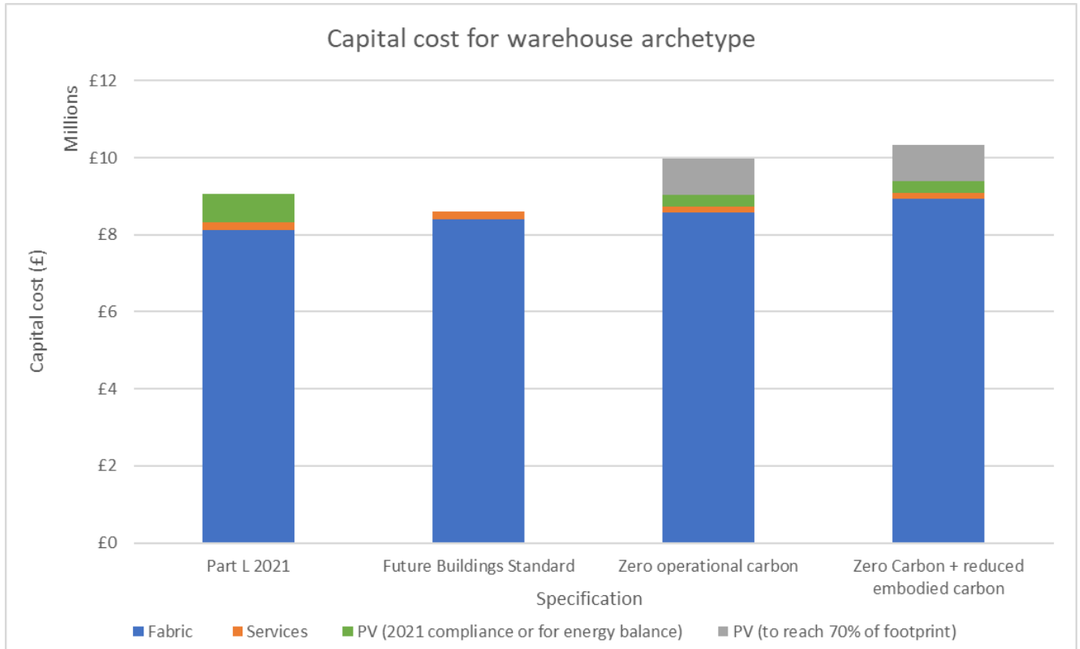
Capital cost

The following table and chart summarise capital costs for the warehouse archetype. Costs are shown for fabric, services and PV components of each standard. Costs for two levels of PV are shown, firstly sufficient to achieve compliance with current regulations (Part L) or an energy balance (i.e. annual energy generation from PV is equal to annual demand) in the case of the net zero carbon options. The additional costs of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Capital cost for warehouse archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£8,109,378	£8,390,736	£8,572,370	£8,929,615
Services	£221,229	£221,229	£157,710	£157,710
PV	£716,605 (+£0)	£0 (+£0)	£306,669 (+£946,607)	£306,669 (+£946,607)
Total	£9,047,212 (+£0)	£8,611,965 (+£0)	£9,036,750 (+£946,607)	£9,393,995 (+£946,607)
% uplift	0.0% (+0.0%)	-3.8% (+0.0%)	-0.1% (+8.2%)	3.0% (+8.2%)

Capital cost for warehouse archetype



Cost uplift

Cost uplift from Future Building Standard

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	-£281,359	£0	£181,634	£538,879
Services	£0	£0	-£63,519	-£63,519
PV	£716,605	£0	£306,669	£306,669
Total	£435,247	£0	£424,785	£782,030

Cost uplift from Part L 2021

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon	Zero Carbon + reduced embodied carbon
Fabric	£0	£281,359	£462,993	£820,238
Services	£0	£0	-£63,519	-£63,519
PV	£0	-£716,605	-£409,936	-£409,936
Total	£0	-£435,247	-£10,462	£346,783

Running costs of new buildings built to different standards

The running costs of a new building constructed to each of the tested energy standards are shown below. These costs are based on the modelled energy consumption of each building (see Task 3 report) with UK Government retail energy prices data for 2023.

Energy price assumptions

	Unit rate (£ per kWh)
Gas	£0.09
Electricity	£0.29

Where PV is included in the specification it is assumed that half of the power will be used in the building, offsetting demand for grid supplied electricity, and half will be exported to the grid with revenue generated at £0.075 per kWh. Where 50% of the PV generation is greater than the annual energy demand, all of the energy demand is offset with the balance added to the amount exported. Estimates of running costs are inherently uncertain and are influenced by energy prices, user behaviour, occupancy profiles and other factors. Nonetheless, these comparisons are deemed indicative of the scale and variation of energy costs that might be expected.

Annual running costs for warehouse archetype

	Part L 2021	Future Building Standard (2022 Consultation)	Zero operational carbon (incl low embodied carbon option)	Zero operational and PV array for 70% of footprint
Gas	£24,683	£0	£0	£0
Electricity (net of PV generation)	£0	£70,595	£14,684	£0
PV export revenue	£17,747	£0	£5,146	£36,717
Total	£6,936	£70,595	£9,537	-£36,717

Costs of retrofitting to zero operational carbon standard

A retrofit scenario showing upgrades required from existing EPC rating E to LETI retrofit best practice has also been modelled. For the warehouse, this included upgrades to the fabric, windows and doors, installation of MVHR and heat pump and allocation of PV to balance energy demand. For full technical details of these measures please refer to Task 3 of this study.

Warehouse retrofit costs

	LETI Retrofit (best practice unconstrained)
Fabric	£2,569,150
Services	£114,266
PV	£136,950
Total	£2,820,366
Total inc. ancillary project costs	£2,956,805

The retrofit project ancillary costs account for temporary protection of the site, 15 days of work on general redecorations, 50 days of project management time over 25 weeks and the provision of temporary welfare facilities.

Conclusions

The results show there is negligible impact between the zero operational carbon warehouse and specification compliant with current building regulations where the aim is to seek an energy balance. Where the aim is to increase the size of the PV array to 70% of building footprint the cost uplift increases to around £950,000 or 8.2%. The additional cost premium for moving to a low embodied carbon specification is a further cost increase of 3% on top of the cost of the zero carbon operational specification. Retrofitting an existing building to the LETI best practice standard would cost around £3.0million.

The adoption of zero operational carbon targets delivers reductions in running costs the scale of which is linked to the size of an associated PV array.

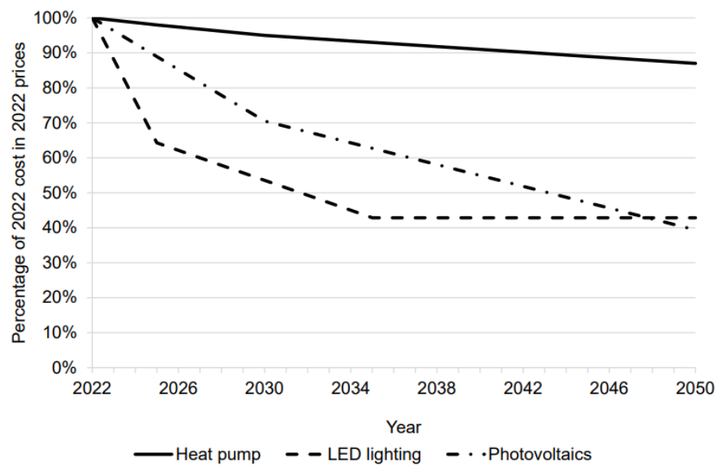
Cost trends

The future cost of achieving zero carbon standards will be influenced by several factors:

- **Design evolution** - whereby building form, orientation, detailing, glazing, etc is optimised to enable energy and carbon targets to be achieved more efficiently
- **Global technology costs** – for some technologies that have not yet reached full maturity it is anticipated that costs will reduce, and performance improve as their global market share increases. The figure below illustrates this for some key technologies
- **Local markets and supply chains** – as low carbon construction practices become more mainstream it is anticipated that local markets will gain experience and capacity to deliver these performance levels more easily and as the construction supply chain becomes more familiar with requirements, they are less likely to add additional risk premiums to their pricing.
- **Wider market and macro-economic factors** – these include commodity prices, trade policy, exchange rates, interest rates and other variables that could influence costs up or down in response to a wide range of national and international trends and events. Whilst wider market factors are likely to influence all elements of construction equally and therefore should not alter the relative cost of meeting carbon standards it is possible that some events could affect certain products or technologies disproportionately.

It is likely that the relative cost of meeting carbon standards will fall over time and in particular the costs of PV and to a less extent heat pumps are likely to fall. Nonetheless, market constraints or wider factors could result in costs increasing in the short term as local supply chains realign to be able to deliver new standards. Competitive pressures are likely to ensure that any cost increases are of short duration.

Projected cost trends for different technologies



Source – Future Buildings Standard, Consultation Stage Impact Assessment.

Costs of future retrofit for new homes

When considering the costs of building to higher performance standards, an important consideration is the relative costs of enhancing a building constructed to a lower standard to this level of performance at a later date. Previous work on this topic for the Climate Change Committee indicates that the costs of delivering the net zero operational standard by retrofitting a new building built to regulatory minimum standards (Part L 2013 in this case) would be around five times more expensive than constructing to this standard from the outset. It is expected that the uplift costs from a home built to current Part L standards would be slightly lower due to measures included in the 2021 revision to ensure that the heating system in new homes is designed to support lower temperature heating provided by heat pumps. Nonetheless it is expected that the additional costs would still be at least four to five times higher than those incurred during the new build stage.

In practice, there would be no practical scenario where this level of investment[4] in retrofit would be affordable by most owners before 2050. Therefore if these higher standards are desired, they would need to be incorporated into the new build specification.

[4] Other than installation of an ASHP and associated works when the gas boiler is due for replacement.

Summary of key findings

The percentage increase in capital costs of each archetype when constructed to each of the target performance standards are shown below. The additional percentage uplift of increasing the PV array to 70% of building footprint (generating approximately 120kWh/m2 footprint per year) are shown in the bracketed figures.

Percentage increase in capital costs for each archetype

	Part L 2021	Future Home / Building Standard	Zero operational carbon	Zero Carbon + reduced embodied carbon
Semi-detached house	0.0% (+0.0%)	0.1% (+0.0%)	4.6% (+2.1%)	9.2% (+2.1%)
Terraced house	0.0% (+0.0%)	1.5% (+0.0%)	4.1% (+0.6%)	7.9% (+2.2%)
Detached house	0.0% (+0.0%)	1.5% (+0.0%)	4.1% (+0.6%)	10.1% (+0.6%)
Flats	0.0% (+0.0%)	-2.1% (+0.0%)	6.2% (+0.0%)	13.6% (+0.0%)
Retail	0.0% (+0.0%)	-1.5% (+0.0%)	1.2% (+7.3%)	6.0% (+7.3%)
School	0.0% (+0.0%)	-0.6% (+0.0%)	4.3% (+1.8%)	9.1% (+1.8%)
Office	0.0% (+0.0%)	-0.2% (+0.0%)	6.1% (+0.0%)	8.7% (+0.0%)
Warehouse	0.0% (+0.0%)	-3.8% (+0.0%)	-0.1% (+8.2%)	3.0% (+8.2%)

Costs for the zero operational carbon standard range from under 1% for warehouses to over 6% for flats. For houses the cost premium relative to current building regulations (Part L 2021) for zero operational carbon is between 4-5%. An additional policy requirement of securing low embodied carbon (LETI A for houses and LETI B for non-domestic buildings) increases the cost premium beyond the regulatory minimum (Part L 2021) for each archetype. For housing the total cost premium is in the range of 8-10% whereas for flats the total cost premium increases to nearly 14%. For non-domestic buildings the inclusion of an embodied carbon target, achieved primarily through use of timber framing to external walls, increases the total cost premium by between 3-9%.

Investment in meeting a zero operational carbon emissions standard reduces the running costs of each building archetype. A saving in running costs is achieved when PV is installed to a level where the energy generated balances that used in the building over the course of a year. Installation of larger arrays (where possible) results in larger savings being achieved in each building.

Utility costs for each archetype when constructed to different standards

	Part L 2021	Future Home / Building Standard	Zero operational carbon	Zero Carbon with larger PV array equal to 70% of footprint
Semi-detached house	£689	£1,453	£484	-£63
Terraced house	£554	£1,310	£455	-£75
Detached house	£1,170	£1,130	£540	£540
Flats	£4,928	£10,431	£3,197	na
Retail	£532	£3,986	£898	-£3,715
School	£29,719	£46,874	£17,872	£710
Office	£45,500	£101,052	£47,745	na
Warehouse	£6,936	£70,595	£9,537	-£36,717

It is expected that the cost uplifts presented in this report will decline over the medium term as designs are refined and technology costs fall, and South Oxfordshire and Vale could work to aid the further development of local supply chains to accelerate this process.

Analysis of the costs and savings of retrofitting to higher standards at a future date suggests that it is highly unlikely that significant enhancements in fabric performance would be affordable as a retrofit measure before 2050 although it is expected that new homes built with gas would transition to electric heating when their boiler reaches its end of life. As well as being significantly more expensive, retrofitting new homes to improve their energy efficiency prior to 2050 would result in substantial and avoidable additional embodied carbon emissions associated with the works.