Greater Manchester Combined Authority

Carbon and Energy Policy Implementation Study

Part 1 – Technical Analysis

4101145

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Executive summary

Study aims

The report considers different options for achieving the Greater Manchester Spatial Framework (GMSF) target for all new developments to be net-zero carbon from 2028. This Part 1 report includes the technical analysis in terms of the on-site new buildings' energy and carbon performance levels sought and details the proposed policy pathway to meeting the 2028 target.

A Part 2 report, written in conjunction with this report, presents all the data and information for setting up and operating a carbon offset fund (carbon offsetting was within the scope of meeting the net-zero carbon ambition)[1].

GMSF Objective 7 includes, among other, the following two key elements:

- Promote carbon neutrality of new development by 2028
- Improve energy efficiency and the generation of renewable and low-carbon energy

Carbon neutrality within that context refers to net-zero carbon.

The analysis looks into:

- The target definition
- New domestic and non-domestic building upgrades required to achieve the target
- Influencing factors
- Potential associated implementation costs both in terms of capital and operational expenditure

The new domestic buildings' performance was evaluated using six main housing type models. These comprised a detached house, an end-terrace house, a mid-terrace house, an end-terrace townhouse and a small and large mid-floor flat.

The new non-domestic buildings' performance was evaluated through a literature review.

[1] Greater Manchester Combined Authority, Carbon and Policy Implementation Study – Part 2 - Carbon Offsetting

Policy context

The *Greater Manchester Plan for Homes, Jobs and the Environment, revised draft – January 2019* (GMSF 2019 Draft) Policy GM-S 2 sets the 2028 net zero carbon target for new developments.

The approach is supported by an energy hierarchy which includes the following instructions: minimise energy demand, maximise energy efficiency, utilise renewable energy, utilise low carbon energy, utilise other energy sources. It also provides the following supportive statements:

- Interim requirement, all new dwellings should seek a 19% carbon reduction against Part L of the 2013 Building Regulations
- Where practicable, connect to a renewable/low-carbon heat and energy network
- Achieve a minimum 20% reduction in carbon emissions (based on the dwelling emission or building emissions rates) through the use of on-site or nearby renewable and/or low-carbon technologies
- Include a carbon assessment to demonstrate how the design and layout of the development sought to maximise reductions in whole-life CO2 equivalent carbon emissions

GMSF also notes: *District Local Plans may set out specific carbon emission reduction targets or promote other measures through which energy efficiency of buildings can be achieved.*

In terms of district local plans, available information was reviewed for all ten districts. Energy and carbon targets presented in the policies appeared well-diverse and in misalignment with the current GMSF target. Furthermore, the technical support and planning guidance provided on how the different regional targets set should be met made some of the requirements hard to fully understand from an implementation perspective. This is flagged in order to ensure that the centralised GMSF target is properly transposed to the district level, and that regional guidance is updated and informed accordingly.

During the delivery of this research report (summer/autumn 2019), new consultation documents were released in terms of Building Regulations referring to the energy and carbon performance of new homes (Part L 2020)[2]. The proposed improvements within Part L 2020 exceeded the GMSF interim baseline improvement requirement (Part L 2020 proposed 20 or 31% improvement against Part L 2013). At the same time, changes were introduced to the Standard Assessment Procedure (SAP) which is used to assess and predict the energy and carbon performance of new homes (SAP10.1). The new assessment method was still on a trial mode during this research, with limitations existing as to the level of information provided. The report was subsequently updated to reflect new information available.

Net-zero carbon new developments from 2028

The World Green Building Council's (World GBC) definition of a net-zero carbon building is '*a building that is highly energy efficient and fully powered from on-site and/or off-site renewable energy sources.*'

The current version of the Building Regulations sets compliance requirements in terms of energy and carbon performance of new buildings based on **regulated energy use**. DER/TER[3]-based policy targets, therefore, are only relevant for addressing the predicted regulated energy use.

The UK Green Building Council's (UK GBC) definition of a **net-zero carbon building** sets out two approaches to achieving net-zero carbon.

- Net-zero carbon – construction: When the amount of carbon emissions associated with a building's production and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy.
- Net-zero carbon – operational energy: When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net-zero carbon building is highly energy efficient and powered

[2] The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings, 1st October 2019
[3] The target CO2 emission rate (TER) sets a minimum allowable standard for the carbon performance of new homes by using a 'notional' building to verify compliance with the Building Regulations. The dwelling emission rate (DER) is the predicted annual CO2 emissions of the proposed dwelling, which is then compared in SAP to the TER.

from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.

Current research quantified a policy pathway closely aligned with the UK GBC 'Net zero carbon – operational energy' definition, while setting the future principles of adding 'Net zero carbon – construction' gradually into the objective.

Regulated energy demand:

As calculated for compliance with the building regulations (SAP). Includes energy used for heating, hot water, installed services and lighting.

Operational unregulated energy demand:

In the case of residential buildings this includes the energy used by the occupant during the operation of the house for everyday needs such as computer/phone charging, refrigerators, washing machines etc.

In the case of non-domestic buildings this refers to small power consumption (includes computers, server, on-board specialist equipment and other).

Research main findings

The primary focus of the current research was to assess how technically robust and cost-viable solutions can address the GMSF energy hierarchy and deliver the 2028 net-zero carbon new developments target.

Main findings of the research include:

- A carbon metric is a 'green' metric, evaluating the impact of different construction decisions on the environment. In the case of a 'net-zero carbon-operational energy' building, carbon emissions are estimated using the type and amount of predicted energy use at the time of the assessment (impact of long-term future grid decarbonisation is not captured).

Consequently, a **policy referring only to carbon performance percentage improvements is not a reliable policy for addressing the energy hierarchy or delivering the full benefits of net-zero carbon from 2028 (which include high quality, introduction of resilient solutions and achieving low running costs)**.

- In addition, it was identified that any renewable/low-carbon energy use/generation policy requirement should be disassociated from a carbon performance-driven target and should be moved to minimum energy generation/use requirements through specification of minimum amounts of photovoltaic panels (PV) installation in its simplest form[4].

  If a Merton-type rule is introduced this needs to be based on either a minimum percentage of regulated energy demand covered through on-site renewable energy generation or a percentage of roof space covered with PV. A **percentage carbon performance contribution (DER/TER) based on the 'use of renewables', is not only confusing and open to misinterpretation but is also not a reliable policy for addressing the GMSF Objective 7 supporting increased renewable energy generation**.

- The **renewable heat generation** from heat pumps can be used within the DER/TER target calculations and for the renewable heat incentive calculations but it **needs to be separated from a PV or similar electricity generation target**.

  There are two main reasons for this. Firstly, the amount of renewable electricity generation (PV) can support lower running costs, while the benefits realised in terms of carbon reductions will appear reduced (decarbonising electricity grid).

[4] Alternative on-site energy generation measures can be considered. Due to the wide adoption of PV as the primary on-site renewable energy generation technology, a PV installation target was evaluated and suggested within the report.

Secondly, the renewable heat contributions of the heat pump, while leading to large carbon savings when compared to gas-based heating and hot water solutions, do not necessarily translate into low running costs.

This is because the technology operates using electricity (higher cost than gas). The concept of 'renewable heat' from heat pumps does not refer to an exclusively renewable source of energy, ie without some external source of electricity it could not operate.

- Affordability in the sense of low running costs, specifically in the case of domestic buildings, is key from a social value perspective.

  While SAP 10.1 will introduce an affordability calculator, it is not yet very clear how this will be progressed moving into the future. At the same time a potential performance gap could translate into increased running costs.

  It is advised that local policy reiterates that importance and potentially introduces a 'safety net' policy requirement in the format of 'no new home should be expected to have annual bills higher than a Part L 2013 gas-based boiler solution (using the 2020 gas and electricity price rates)'.

- An **interim performance improvement step is introduced in 2025**. The introduction of the interim step has two distinct benefits. First it follows the Future Home Standard (Part L 2025) introduction, allowing for a policy revision.

  Second, it produces a 'checkpoint' opportunity to evaluate policy success, gradually improve required energy and carbon standards and reassess the new construction landscape. **The carbon offset fund also becomes operational at the same year (2025)**.

- **Post-2028**, all new developments can align with the net-zero carbon-construction UK GBC requirements through simple adaptation of previously implemented policy requirements and the utilisation of the carbon offset funds.

  New policy provisions, addressing the different stages of a whole-life carbon assessment: **monitoring of performance and offsetting of construction related emissions, energy storage and embodied carbon** will need to be introduced.

  Further research will be required (2020-2025) on how to transition to that stage, and the calculation methods that will be required from a planning perspective.

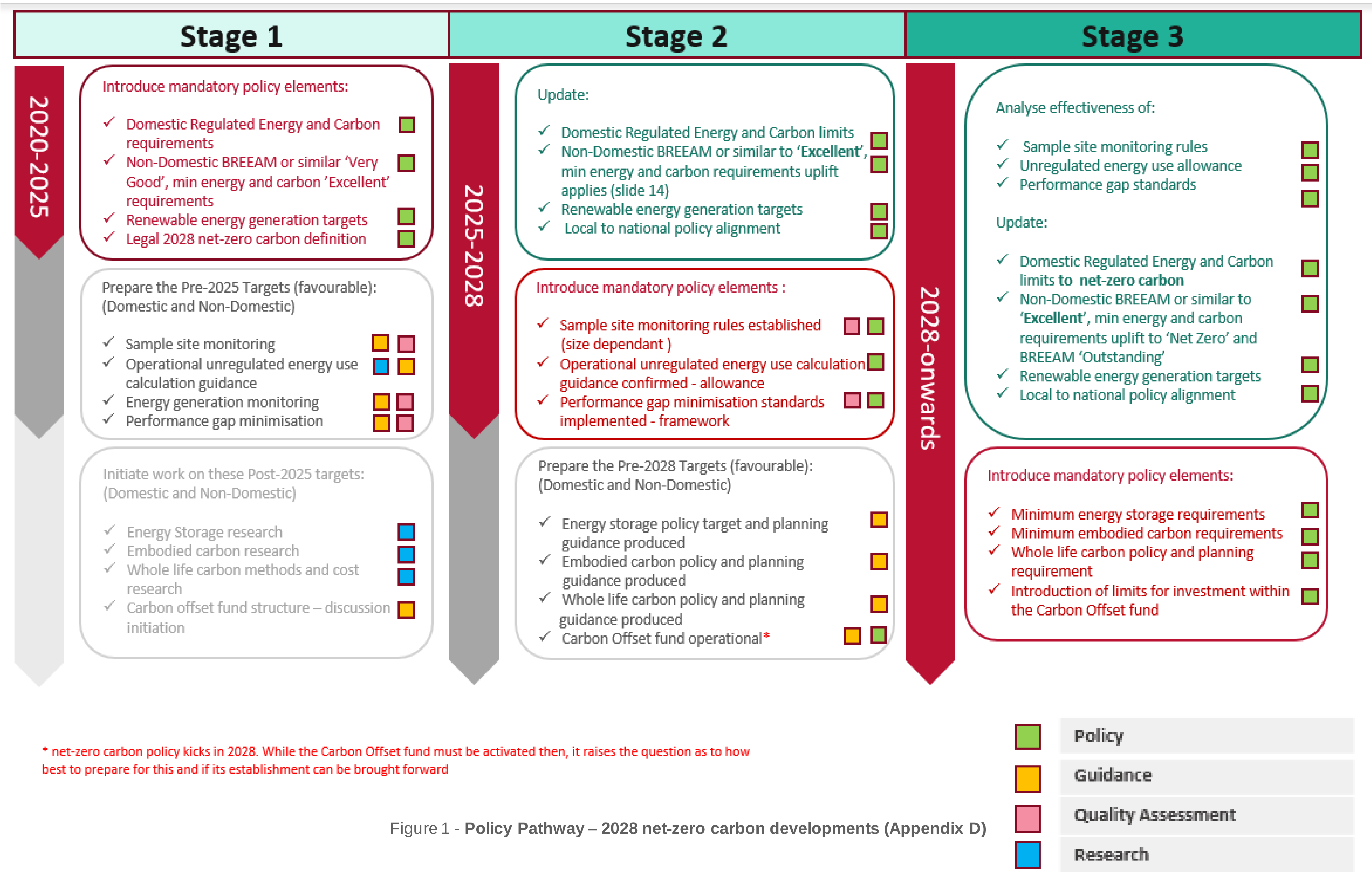


Figure 1 - **Policy Pathway – 2028 net-zero carbon developments (Appendix D)**

Policy Pathway 2028 net-zero carbon developments - recommendations

Please see Figure 1 for additional details.

Stage 1 (2020 – 2025)

It is recommended that the policy considers the introduction of the following:

- **Domestic buildings**

- ✓ New houses: energy required for heating as calculated within SAP 2012 Box98 or equivalent at later SAP versions should not exceed 30kWh/m^2 per year.
- ✓ New flats: energy required for heating as calculated within SAP 2012 Box98 or equivalent at later SAP versions should not exceed 25kWh/m^2 per year.
- ✓ Domestic hot water (DHW) energy-saving measures should be supported – with a guideline target of 20% reduction in expected DHW grid energy demand compared to the Part L 2013 concurrent notional building recommended (or mandated).
- ✓ Renewable energy generation (PV), if mandated, should be expressed in the sense of minimum installed capacity. For example, in the case of PV – minimum % of the roof space area targets can be introduced (20-40% of total roof area). An **initial PV installation requirement of up to 20% of total roof space** with a caveat around technical feasibility is considered a good starting point. **Please note that any benefits from the PV generation should be allocated to the occupant – direct energy use and store on site is also recommended**.
- ✓ It is recommended that in terms of carbon performance targets the policy aligns with the Part L trajectory (current Part L 2020 consultation likely to be a 20% or 31% reduction over the current Part L 2013).
- ✓ Reporting of quality assurance processes targeting a performance gap minimisation is strongly advised.

- **Non-domestic buildings**

✓ It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Very Good' is considered[5]. Carbon requirements-wise within the 'Very Good' target a **mandatory requirement for achieving the BREEAM 'Excellent' minimum standards, 4 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented**.

Stage 2 (2025 – 2028)

It is recommended that the policy considers the introduction of the following:

- **Domestic buildings**

✓ New houses: energy required for heating as calculated within SAP 2012 Box98 or equivalent at later SAP versions should not exceed 20kWh/m^2 per year.

✓ New flats: energy required for heating as calculated within SAP 2012 Box98 or equivalent at later SAP versions should not exceed 15kWh/m^2 per year.

✓ Domestic hot water (DHW) energy-saving measures should be introduced (or tightened if they have been introduced before) – a **minimum of 20% DHW grid energy demand reduction compared to the Part L 2020** should be considered. Additional research on technical solutions and cost implications is recommended in case the Future Homes Standard 2025-approved minimum requirements reflect a large improvement over the Part L 2020 DHW energy requirements.

✓ PV installation requirements to increase to up to 40% of total roof space as a minimum, with a caveat around technical feasibility. **Please note that any benefits from the PV generation should be allocated to the occupant – direct energy use and store on site is also recommended**.

✓ The Carbon Offset fund is introduced and should become operational (2025).

✓ It is recommended that in terms of carbon performance targets the policy aligns with the Part L trajectory and the Future Homes Standard targeting ~70-

[5] The overall BREEAM rating is not specific to the carbon and energy performance of buildings. The current research investigated the GMSF requirement for net-zero carbon buildings. Therefore, only the suggested BREEAM energy and carbon requirements are relevant to the policy recommendations.

80% improvement over Part L 2013. The policy should require for all remaining emissions (**regulated and operational unregulated**) to be offset off-site through the use of the Carbon Offset fund[6].

- ✓ It is recommended that the policy requires any specific performance gap minimisation provisions to be provided by the developer through a written statement during the planning application.
- ✓ It is recommended that the policy considers the introduction of mandatory monitoring and post-occupancy evaluation standards for major developments.
- ✓ Reporting of quality assurance processes targeting a performance gap minimisation is recommended.

- **Non-domestic buildings**

- ✓ It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Excellent' is considered.
- ✓ Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Excellent' with at least 6 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.
- ✓ It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'. Please note that Ene08 refers only to operational energy use and does not include embodied carbon or whole lifecycle carbon.

[6] The GMSF target for all new development to be net-zero carbon from 2028 introduces carbon offsetting within the scope of meeting the ambition. It is advised that the Carbon Offset Fund mechanism is introduced in 2025 to allow for compliance from 2028.

Stage 3 (2028 – onwards):

It is recommended that the policy considers the introduction of the following:

- **Domestic and non-domestic buildings**
- ✓ Full alignment with the net-zero carbon construction and operation UK GBC definitions is advised (upon confirmation of project viability and feasibility).

- **Non-domestic buildings:**
- ✓ It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Excellent' is considered.
- ✓ Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Outstanding' 9 credits for Energy Performance and 4 for energy modelling and reporting within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.
- ✓ It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'.

Additional requirements for consideration (see Policy Pathway, Figure 1):

- ✓ It is recommended that the policy considers the introduction of mandatory decentralised energy storage requirements.
- ✓ It is recommended that the policy considers the introduction of mandatory embodied carbon thresholds.
- ✓ It is recommended that the policy considers reduction of allowances in terms of carbon offsetting to support more on-site delivery.
- ✓ It is recommended that the policy considers the introduction of mandatory monitoring and post-occupancy evaluation standards for most developments.

Supportive evidence in terms of recommendations provided

The following table provides an easy-to-follow explanation of the different acronyms used to characterise the fabric upgrades reviewed for all new housing type models.

Archetype code	Description
N1	Naturally ventilated house/flat – small improvement of fabric performance compared to Part L 2013 minimum requirements
N2	Naturally ventilated house/flat – medium improvement of fabric performance compared to Part L 2013 minimum requirements
N3	Naturally ventilated house/flat – high improvement on fabric performance compared to Part L 2013 minimum requirements (close to a Passivhaus fabric performance)
M1	Mechanically ventilated house/flat – small improvement on fabric performance compared to Part L 2013 minimum requirements, high airtightness and installed mechanical ventilation heat recovery system (MVHR)
M2	Mechanically ventilated house/flat – medium improvement on fabric performance compared to Part L 2013 minimum requirements, high airtightness and MVHR
M3	Mechanically ventilated house/flat – high improvement on fabric performance compared to Part L 2013 minimum requirements (close to Passivhaus), Passivhaus airtightness levels and MVHR
Very High	Mechanically ventilated house/flat – extreme improvement on fabric performance compared to Part L 2013 minimum requirements, - Passivhaus airtightness and MVHR – potentially exceeding Passivhaus performance

General comments based on research outputs:

Meeting the highest modelled fabric standard (Very High), including 1.25kWp PV a heat pump and waste water heat recovery systems, did not increase the additional construction cost to more than 6% (materials and services) in any of the models.

As heating demand is reduced through fabric measures, main energy demand derives from a need for hot water generation and use of appliances.

The heating demand levels recommended within the report take into consideration the cost-effectiveness of the fabric solutions modelled and the small incremental changes occurring when very high standards are sought compared to the other energy needs. In that sense the fabric improvement recommendations derive from following a balanced heat reduction/cost approach.

In combination with the space heating target, the introduction of a requirement to avoid the use of fossil fuels and to ensure that modelled energy bills (via SAP) are no higher than that of the same home built to the Part L 2013 standard using gas would ensure that an efficient low-carbon heating system (eg a heat pump) is used rather than gas or a direct electric system.

Once there is experience in delivering more energy-efficient homes using low-carbon heating systems, a sensible further step would be to further tighten the energy performance standards.

This would have a relatively small impact on operational carbon emission but would reduce running costs for residents and help minimise any impacts on the wider energy system associated with the increased consumption of electricity.

For domestic buildings the main impact on the operational unregulated energy use is the occupants' lifestyle. In this case the developer would not be able to affect directly the levels of consumption through construction choices and only. Most of these emissions, if included within future policy, will require the use of additional energy generation on-site and the Carbon Offset fund.

Operational unregulated energy use, and deriving carbon emissions, in the case of domestic buildings, would require potentially unattainable amounts of PV installed to be completely offset (4-5kWp, 30-37 m^2). In the case of high-rise flats, allocating proportionate ‘roof space’ for PV installations for each flat could exceed the total roof space available. Therefore a % of roof space coverage (PV) is recommended as the preferred policy tool.

Embodied carbon and whole-life carbon emissions: embodied carbon emissions due to materials used are more relevant to construction choices and should be included in future policy.

Such an introduction would require additional research to be undertaken for the appropriate calculation methodologies and thresholds to be set for policy development. The earliest this is initiated, the more experience will be gained in developing the additional policy requirements.

Whole-life carbon assessments will become mandatory for new developments from 2028 to address the net-zero carbon – construction requirement. An early adoption for large developments is advised from 2025.

Current policy refers to a carbon assessment to demonstrate how the development sought to maximise reductions in whole-life CO2-equivalent carbon emissions.

This can be maintained for 2020-2025 while research is undertaken so the policy requirement becomes more specific at a later stage and introduces relevant thresholds.

New domestic buildings:

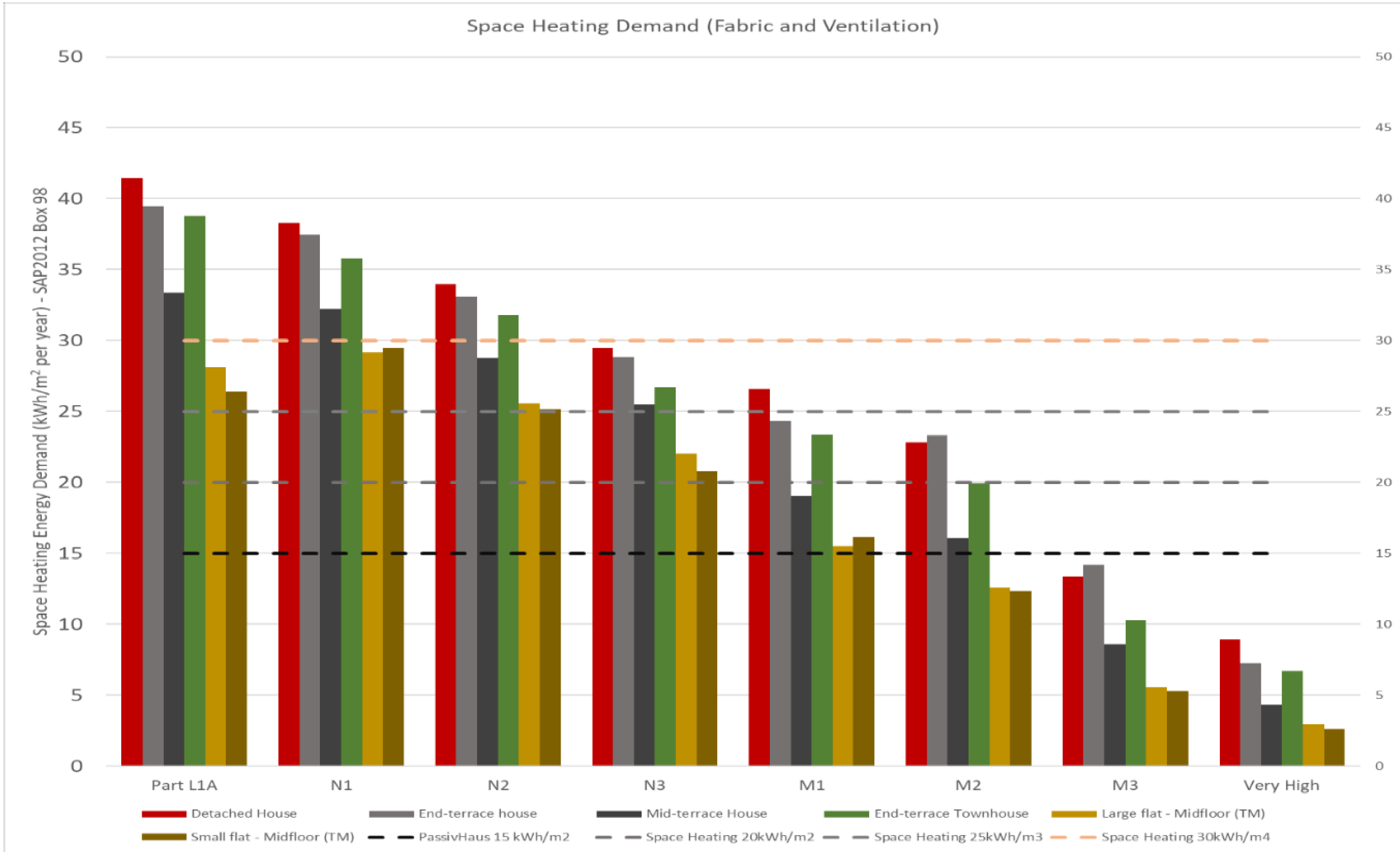
Properties should be designed to benefit from the carbon-saving opportunity presented by low-carbon heating systems while maintaining affordable running costs. They also need to be easy to operate and maintain with a reduced impact on the national grid.

This requires a combination of energy efficiency targets and the use of renewables. This should be achieved while minimising the potential for complication and performance issues in use and so **it is prudent to avoid introducing too many new systems and building methods at the same time**.

- ✓ Heating energy demand

Maximum space heating demand targets of 30kWh/m^2.year for houses and 25kWh/m^2.year for flats (prior to considering any system efficiencies, SAP Box 98) from 2020 were achievable in all naturally ventilated domestic models tested and are considered a proportionate initial step in reducing energy use, supporting the use of low-carbon heating while minimising the short-term impact of adopting and integrating too many new technologies.

Tightening up the maximum space heating demand targets from 2025 at 20kWh/m^2.year for houses and 15kWh/m^2.year for flats (prior to considering any system efficiencies, SAP Box 98) were achievable in all archetypes tested using mechanical ventilation systems (and associated high air-tightness levels) and are considered a proportionate next step in further reducing energy use, and are in line with the Committee on Climate Change recommendations. A summary of the different modelled archetypes space heating demand performances compared to the thresholds recommended above is shown in the graph below.



The graph above shows the Space Heating demand outputs of the various, models as explained later in the report.

In term of the additional construction cost expected to be incurred by meeting the suggested thresholds, this was calculated based on the cost of a Part L 2013 notional building (meeting minimum regulatory requirements). The average fabric upgrade cost for each housing model archetype is provided below (see Appendix C – Tabulated domestic models cost data).

Please note:

- Efficient forms such as the mid-terrace house and mid-floor flats can meet the Stage 1 standards using an N2 specification (naturally ventilated).
- The use of mechanically ventilated systems to meet Stage 1 thresholds led to substantial cost reductions in the case of the least efficient housing archetype forms (detached and end-terrace properties).
- On a number of occasions, a range of fabric improvements is noted as applicable (eg N2 to N3). This is because marginal improvements over the lower specification indicated can meet the standard. Therefore, the upgrade cost is expected to be somewhere between the range provided and closer to the lower end of the range.

The following table shows additional costs to deliver the housing models under review, as explained in more detail later in the report.

	Stage 1 <30kWh/m2 Houses <25kWh/m2 Flats				**Stage 2 <20kWh/m2 Houses <15kWh/m2 Flats**			
Archetype	**Naturally ventilated**		**Mechanically ventilated**		**Naturally ventilated**		**Mechanically ventilated**	
	Fabric Standard (FS)	Additional Cost (AC)	FS	AC	FS	AC	FS	AC
Detached	N3	~ £4,900	M1	~ £2,600	-	-	M2 to M3	~ £4,650 to £6,200
End-terrace	N3	~ £3,300	M1	~ £1,950	-	-	M2 to M3	~ £3,550 to £4,400
Mid-terrace	N2	~ £1,700	M1	~ £2,100	-	-	M1	~ £2,100
End-terrace Townhouse	N2 to N3	~ £1,700 to £3,000	M1	~ £1,500	-	-	M2	~ £2,900
1B Flat	N2	~ £800	M1	~ £950	-	-	M1 to M2	~ £950 to 1,300
2B Flat	N2	~ £1,250	M1	~ 1,150	-	-	M1 to M2	~ 1,150 to 1,800

- ✓ Renewable energy generation

An introduction of a Merton Rule for PV can be based on available roof space. An initial introduction of a 20% coverage can be introduced in 2020-2025 followed by an increase to 40% during 2025-2028.

It needs to be noted that the cost implication of such a requirement will vary based on the available roof space of the new houses or flats and the amount of PV that this translates into.

As an example, in the case of the detached house (based on ground floor area as a proxy to a flat roof area of 58.4m^2) 20% would translate into ~1.6kWp of PV installed and 40% into ~3.2 kWp of PV installed at an additional construction cost of ~£2,285 and £3,470 respectively.

- ✓ $CO2_e$ emissions (Table 12)

All new domestic models tested easily met a 20% regulated carbon emissions reduction utilising the N2 fabric standard and a gas boiler, while this reduction was increased to > 70% regulated carbon emissions reduction when a heat pump solution was used.

All new domestic models tested easily met a 31% carbon emissions reduction utilising the M2 fabric standard and a gas boiler, while this reduction was increased to > 75% regulated carbon emissions reduction when a heat pump solution was used.

Predicted carbon emissions heavily relied on the carbon intensity of the grid/fuel used during each review period.

It needs to be noted that for housing a **fabric first approach – securing heating energy demand targets is considered the most robust method moving forward** (energy demand reduction through passive measures should be as a priority, and then low and zero-carbon energy should be used to cover the remaining needs).

New non-domestic buildings:

Research project BREEAM performance recommendations as shown before, for up to 2028, could roughly cost up to 4% of the construction costs. Please note that this will heavily depend on the size, location and type of non-domestic buildings delivered.

Post 2028-recommendations cost impact will need to be reassessed as more information becomes available (including additional policy elements introduced).

In term of non-domestic new buildings, a literature review analysis indicated that an uplift associated with achieving a 15% energy efficiency target would cost between £37 and £59/m^2.

In many buildings this additional cost could be under 1% subject to its location, the base design and experience of the design and construction team. In general, lower uplift percentages will be seen in town centre buildings as these will have a higher base cost and levels of servicing.

As noted in 2017, the average energy efficiency saving in non-domestic buildings in London was 19.2% beyond the requirements of building regulations making such options technically feasible in GMSF[7]. Energy use in non-domestic buildings is highly variable depending on the building type and design aspiration.

The cost and potential for achieving savings beyond the requirements of Part L2013 will therefore depend on building type and design decisions. For example, the nature of energy demand (for heating, cooling, lighting and other) will be influenced by the intended building use, the extent and orientation of glazing and any associated shading, and plan depth.

[7] The direct applicability of savings seen in London within Tunbridge Wells may vary in some instances as the form of non-domestic developments may differ; however, analysis suggests that significant savings are possible through improved lighting and HVAC system and controls for a wide range of non-domestic buildings.

Substantial energy-efficiency savings are typically achievable in office and retail buildings, but other building types such as schools and particularly hotels may find it more difficult to achieve energy-efficiency savings because of the specific nature of their demand, eg the dominance of hot water supply as an energy source in hotels.

Quality assessment

As the electricity grid is expected to continue to decarbonise, it is also expected that a lot of new buildings will be occupying all electric solutions to achieve the different sustainability (energy and carbon) standards.

This could lead to a strong focus on energy efficient heating and hot water generation services. It is recommended that additional research is conducted on how best to accommodate for these new technological needs locally (skills, knowledge, grid capacity) as well as to ensure that the construction quality remains of a high standard.

A carbon-only metric can mask knock-on effects including increased operational costs, electricity grid upgrade requirements and evaluation of performance of fabric and services in-situ (performance gap).

Actual delivered quality of buildings should be of prime focus. New buildings within the area should be delivered following robust quality assurance (QA) frameworks. For public buildings, energy and carbon performance monitoring is advised.

Planning requirements for developers, including a request for description of methods and processes in place to reduce a potential performance gap, could be considered.

Soft landings and post-occupancy evaluations also need to be considered, initially brought in as good practice and a recommendation (2020-2025) in order to assess delivered standards, or in support of planning applications. Written statements on how a potential performance gap is avoided will need to accompany the planning application, with monitoring requirements imposed for large developments. As with any planning policy, the effectiveness of carbon and energy reduction standards is dependent on their effective delivery during design, construction and handover.

The increasing use of newer building solutions such as heat pumps (air source heat pumps – ASHP) and mechanical ventilation heat recovery (MVHR) systems together with any requirement for highly energy-efficient fabric standards will make it even more important that designs are robust and that technologies are integrated effectively. For example, ASHP systems should be designed to operate at lower temperatures, must be paired with sufficiently sized heat emitters (eg radiators or underfloor heating), and the external unit should also be located so as to avoid potential noise disturbance to neighbours.

Similarly, MVHR systems should be designed so that they remain within the insulated envelope (or have insulated ducting) so that filters can be readily accessed and changed.

Affordability (running costs)

In all housing models, the move to an ASHP with a coefficient of performance of 2.5 led to higher annual energy bills if no additional solutions were implemented. This was roughly £150-200 per year in houses for regulated energy use and £50-150 in the case of flats for regulated energy use.

It is worth noting that heat pump efficiencies are constantly improving and evidence from the Renewable Heat Incentive (RHI) premium payment scheme suggests that a heat pump COP of around 3 is possible. The use of heat pumps with a high COP would mean than even less energy would be required from the electricity grid directly translating to lower operational energy costs.

When all electric cooking was used in the properties instead of gas an additional £100-120 cost per year was estimated in most cases (compared to gas cooking options).

Removing the gas standing charge, no longer required for all electric solutions, would lead to annual household savings of around £88. PV electricity generation based on

2kWp for houses and 0.75kWp installed capacity in flats would lead to additional annual savings of £206 and £77 accordingly[8].

If waste water heat recovery systems were to be installed in the properties, additional annual savings of £15-25 could be achieved in the case of gas-supported properties, and £35-55 in the case of all electric properties.

With all of the above solutions considered, moving from N1 to 'Very High' fabric specification (better than Passivhaus) led to annual energy savings of around £90 for gas boiler-based houses and £55 for flats. The same upgrade in ASHP-supported models (N1 to Very High) led to annual savings of around £150 in both houses and flats.

It is recommended that when all electric solutions are considered, as in the case of heat pumps, special consideration is given to potential impact on running costs. This is why it was suggested that for regulated energy use, annual running costs estimated in SAP for the new designs are no higher than that of the same home built to the Part L 2013 standard using gas.

Changes in carbon intensity of electricity

The impact of the potential electricity grid decarbonisation was evaluated using current and future SAP carbon factors running to 2035 and Treasury Green Book carbon factors running from 2035 to 2050.

Currently, SAP does not recognise the dynamic profile of energy demand, daily variations in peak loads, and their impact onto the carbon intensity of the grid.

The current research assessed the carbon performance of new domestic building models using the government-approved methods – outputs of which are used within the planning applications.

As it was identified in the case of new domestic buildings, small fabric upgrades would be required to address the Part L 2020 20% or 31% carbon performance improvements (2013 baseline).

[8] Please note that based on a 7.3m2 per kWp PV that would equate to almost 5.5m^2 of flat roof area per flat. Depending on the total roof area and the number of flats it may not be feasible in the case of high-rise developments to allocate the required PV amount per flat.

This refers to regulated energy only as SAP does not produce operational unregulated energy thresholds. The current GMSF policy based on DER/TER targets refers to regulated energy use only too.

It needs to be noted that operational unregulated energy demand is not affected by the construction standards and choices but the occupants' lifestyle. Furthermore, the only way that operational unregulated energy use can be net-zero carbon is by offsetting the energy demand through the use of electricity generation on site (PV) or through the use of a Carbon Offset fund.

Meeting further regulated carbon performances improvements, more than 80% in 2025 (2013 baseline – Future Homes Standard), could be achieved using small fabric performance improvements (similar to standards used today) with the addition of a highly efficient heat pump (COP >3), (Table 12).

Also, while of benefit to the carbon performance predictions for new all-electric building services, the ever-reducing carbon factors of the electricity grid had a 'negative' effect on the ability of the PV to offset remaining carbon.

This was because current methodology (SAP) assumes carbon savings from PV based on the carbon intensity of energy saved from the grid. As the grid continues to decarbonise, the carbon savings attributed to PV reduce.

Key points:

A carbon-driven policy objective is expected to be initially delivered through the use of all electric solutions.

The focus is expected to be on extracting the carbon benefits of an ever-decarbonising electricity grid combined with the cost-effectiveness of heat pumps.

It is expected that such solutions will be commonly used by the developers to address the policy requirements. Nevertheless, it doesn't mean that energy required to operate the building and associated costs are reduced. Energy demand reduction targets should always be prioritised through cost-effective long-lasting solutions (fabric first).

The impact of a fabric first approach for housing, one of the most robust methods to secure energy and carbon savings through space heating demand reduction, as well as to secure a comfortable and affordable-to-run internal environment for the occupant, was obvious in the research results - especially in the case of the less-efficient forms (detached, end-terrace houses).

The impact of the increased efficiencies achieved by some services, as in the case of heat pumps, in combination with the potential decarbonisation of the grid, led to substantial carbon performance improvements even when energy demand requirements remained constant in time.

Without an energy demand metric in place, especially focusing on reducing the heating energy demand for homes, knock-on effects on running and operational costs are likely to occur.

In general, energy demand reduction and energy generation targets are key and should be clearly introduced along with any carbon emission reduction targets.

Upskilling and knowledge

Further training around installation and commissioning skills will be required to ensure products such as mechanical ventilation systems and heat pumps are installed correctly and are fully optimised.

A change in culture is required to ensure more ownership across the design and construction process, including accountability of the efficiency of the end-built product.

A stepped implementation of requirements, as identified within the report, along with the production of supplementary planning guidance will support the smooth transition to the 2028 target.

Performance monitoring and QA processes will enable the better evaluation of overall policy steps implementation success. They will also ensure that the right measures are put in place and will support the early identification of shortfalls.

1. Introduction

1.1 Research objectives

To consider how planning policy can help gradually reduce carbon emissions from new developments within Greater Manchester and meet the target for all new developments to be net-zero carbon by 2028. The research was undertaken by Currie & Brown on behalf of Greater Manchester Combined Authority (GMCA) and was conducted during July to October 2019.

1.2 Research methodology

The following research components supported the development of a detailed analysis framework and the production of all relevant outputs. These were:

- **Scoping activity**
  A review of relevant national and local policies and guidance documents.

- **Housing design archetypes (development)**
  Typical construction designs for Greater Manchester were selected based on Currie & Brown work undertaken for Part L 2013.

  Their form and size applicability for the Greater Manchester environment were reviewed through the assessment of information collected from recent Greater Manchester new housing development planning applications.

  Housing archetypes evaluated within the research include a typical detached house, end-terrace house, mid-terrace house, end-terrace townhouse, a small (1 bed, 43m^2) and a large flat (2 bed, 70m^2).

- **Housing models energy and carbon performance**
  Housing design archetypes were modified in terms of fabric and services specifications used to produce different energy and carbon performance models.

  The archetypes were modelled using the Standard Assessment Procedure (SAP) 2012, while compliance baselines were assessed against the current Part L 2013 minimum requirements. Future carbon performance was evaluated through the use of appropriate government predictions.

- **Non-domestic buildings energy and carbon performance**
  Energy and carbon levels, associated improvement costs and evaluation of relevant standards were identified and produced through a literature review.

- **Construction and running costs**
  Housing construction costs (fabric and services) followed an elemental costing approach, as detailed within the relevant section. This included using the in-house Currie & Brown construction cost database and expertise. Running costs were estimated using SAP energy demand predictions for both regulated and operational unregulated energy use.

Because the timing of the report writing coincided with the publication of proposed changes within Building Regulations, the impact of the ‘Future Homes’ Standard’ consultation options and changes within SAP carbon emissions factors were also assessed and discussed.

2. Scoping activity

2.1 Summary of findings

Key findings – sections:

2.2: Net-zero carbon new developments from 2028

- Greater Manchester energy demand could increase by 3% due to new development requirements if a business-as-usual activity was followed. Delivering the 'net zero carbon for new developments' 2028 target is critical in meeting Climate Change obligations.
- Achieving the net-zero target is supported by an energy hierarchy referenced in the Greater Manchester Spatial Framework (GMSF) (Revised Draft, January 2019).
- The energy hierarchy is in line with industry best practice and the London Plan guidelines. Areas open to interpretation were noted and discussed.
- Policy GM-S 2 Carbon and Energy within the GMSF introduces an interim new housing performance target of 19% - carbon performance improvement compared to Part L 2013. As noted, 20% of the 19% improvement should derive from on site or nearby renewable and/or low carbon technologies.
- Planning requirements in terms of energy and carbon performance of new developments, as identified within the ten Greater Manchester districts, included a number of inconsistencies both when compared against each other, as well as against the GMSF guidelines. Out-of-date policy references were identified in various instances, as well as loose terminology and complicated compliance criteria (including operational unregulated energy references or Merton-type rules).

Recommendations

- The unifying carbon and energy policy trajectory expected to be introduced with the GMCA should be clearly established and must be easy to follow/understand. Please refer to the policy pathway suggested within the report to address the requirement.
- Based on the energy hierarchy the policy trajectory should seek to deliver a ‘fabric first’ approach, supported by energy demand and carbon emissions reduction targets.
- Targets in terms of renewable energy generation on site should be separated from the concept of % carbon emission reductions and noted individually. This would improve simplicity and will ensure that renewable targets are not ‘gamed’.
- Carbon and energy performance requirements for new buildings needs to be clear. The two terms need to be separated and explained. This should include specific ‘fabric’-based predicted energy demand reduction targets as well as overall carbon emissions reduction targets.
- Delivering net-zero carbon from 2028 includes within its scope the introduction of carbon offsetting funds. Detailed relevant guidance based on the Part 2 outputs of this research needs to be produced.
- Using percentages to evaluate carbon performance improvements expected from new buildings against Part L 2013 requirements will be impacted by changes within the regulations and the grid decarbonisation. A mechanism to address this should be introduced.
- Consider producing appropriate detailed compliance guidance for planning officers and developers if more than one performance metric is introduced (energy demand, primary energy, affordability, carbon performance, minimum energy generation, etc).

2.2 Net-zero carbon new developments from 2028

2.2.1 Greater Manchester Spatial Energy Plan (2017)[9]

The Greater Manchester Spatial Energy Plan states that there is a high disparity in energy use between boroughs with Manchester using 2.5 times more energy than Oldham, the district with the lowest energy consumption. Greater Manchester uses 3% of the total UK energy use.

Greater Manchester housing stock is predominantly pre-1980s, with Manchester and Salford having the largest proportion of newer stock.

The largest proportion of older stock is within Trafford and Stockport. The vast majority of current homes in Greater Manchester are likely to exist in 2050; therefore, identifying the most cost-effective pathways for domestic retrofit is essential. A whole system approach is key to meeting the long-term decarbonisation targets.

Different fuels are used depending on the service they provide. Gas is primarily used for space and water heating and is the predominant fuel in Greater Manchester making up 42% of total energy consumption.

Electricity makes up 23% of Greater Manchester's total energy consumption. 28% of Greater Manchester's annual energy consumption is transport fuel. Other fuel makes up the remaining 7% of energy consumption in Greater Manchester.

While 95% of postcodes in Greater Manchester are connected to the gas grid, coal and oil heating are still a significant part of the energy mix in some districts. **These areas often have domestic buildings with poor thermal efficiency and high levels of fuel poverty**.

New development is estimated to increase energy demand by 2,400 GWh/yr which could increase carbon emissions by 0.4 MtCO2/yr under business-as-usual activity. This is equivalent to a 3% energy increase if no other factors are taken into account.

[9] https://es.catapult.org.uk/news/greater-manchester-spatial-energy-plan-full-report/

2.2.2 Tyndall research for Greater Manchester (2019)

The Tyndall Centre is a consortium of universities sharing research and developing sustainable responses to climate change.

Tyndall Manchester conducts research on topics such as carbon budgets and pathways, achieving rapid decarbonisation and negative emissions technologies[10].

The recent 'Quantifying the implications of the Paris Agreement for Greater Manchester report'[11] produced advice on taking prompt action to put Greater Manchester on a path to carbon neutrality by 2038.

2.2.3 5-Year Environment Plan for Greater Manchester, 2019-2024[12]

The *5-Year Environment Plan for Greater Manchester, 2019-2024* sets out the actions, steps and challenges present in meeting the 2038 carbon neutral regional target.

The target is based on evidence produced by the Tyndall Centre for Climate Change Research. Models of potential emission reductions pathways are presented as well as areas of priority for action[13].

2.2.4 Climate Emergency declaration by Greater Manchester Combined Authority (GMCA) – July 2019

The declaration of a climate emergency was made by the Greater Manchester Combined Authority (GMCA) on 26 July 2019. It follows the launch of the five-year environment plan '*5-Year Environment Plan for Greater Manchester, 2019-2024'*.

Urgent action is needed to put Greater Manchester on a path to carbon neutrality by 2038. The motion states that the GMCA will "take a mission-based approach to achieving this target date as part of the Local Industrial Strategy agreed with Government," and to ensure that GMCA "maximises the economic opportunities presented by the move to carbon neutrality."

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[10] Tyndall Manchester (2019) Carbon budgets and pathways https://www.tyndall.manchester.ac.uk/research/themes/carbon-budgets-pathways/
[11] Kuriakose, J., Anderson, K., Broderick, J. & McLachlan C. (2018) Quantifying the implications of the Paris Agreement for the city of Manchester http://www.manchesterclimate.com/sites/default/files/Manchester%20Carbon%20Budget.pdf
[12] 5-Year Environment Plan for Greater Manchester https://greatermanchester-ca.gov.uk/media/1986/5-year-plan-branded_3.pdf
[13] Anthesis Group, Scatter for GMCA, June 2019

2.2.5 Greater Manchester Spatial Framework (GMSF)[14] Revised Draft – January 2019

The plan sets out proposals to support the Greater Manchester ambition to be a carbon-neutral city-region by 2038. **A key element of this is to require all new developments to be net-zero carbon by 2028** and to **keep fossil fuels in the ground**.

Policy GM-S 2 Carbon and Energy

Policy GM-S 2 Carbon and Energy of the GMSF recommends an initial 19% carbon performance improvement compared to Part L 2013. 20% of the 19% improvement should derive from on-site or nearby renewable and/or low-carbon technologies.

Guidelines provided in terms of the energy hierarchy to be followed includes:

- Minimise energy demand
- Maximise energy efficiency
- Utilise renewable energy
- Utilise low-carbon energy
- Utilise other energy sources

In addition, it advises on the following:

- Incorporate adequate electric vehicle charging points to meet likely long-term demand
- Where practicable, connect to a renewable/low-carbon heat and energy network
- Achieve a minimum 20% reduction in carbon emissions (based on the dwelling emission or building emissions rates) through the use of on-site or nearby renewable and/or low-carbon technologies; and
- Include a carbon assessment to demonstrate how the design and layout of the development sought to maximise reductions in whole-life CO2-equivalent carbon emissions

[14] https://www.greatermanchester-ca.gov.uk/what-we-do/housing/greater-manchester-spatial-framework/gmsf-full-plan/

- District local plans may set out specific carbon emission reduction targets or promote other measures through which energy efficiency of buildings can be achieved.

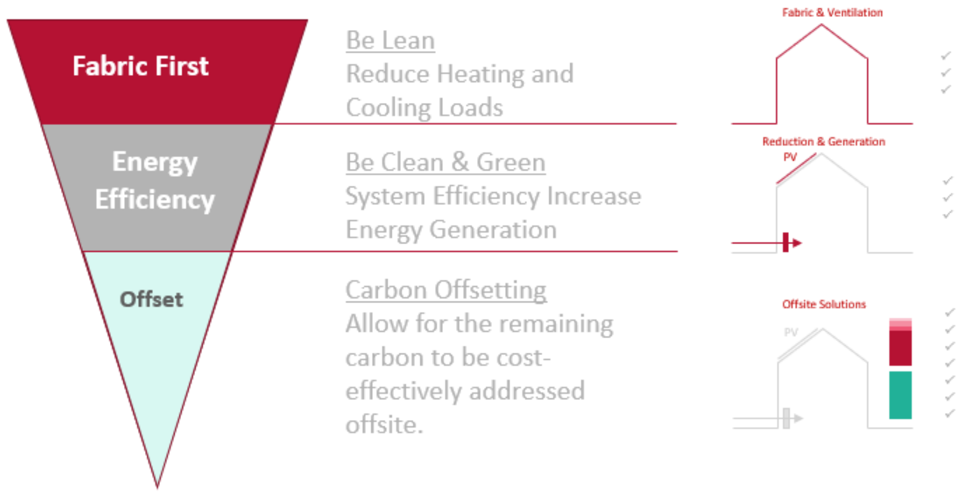


Figure 2 - Schematic interpretation of the GMSF energy hierarchy (Currie & Brown)

Figure 2 summarises the main points of the Policy GM-S 2 Carbon and Energy hierarchy, as interpreted by Currie & Brown researchers, in alignment with London Plan guidelines.

While in principle the hierarchy sets out an energy demand reduction-based pathway, the potential interpretation of the energy hierarchy was analysed and is presented in the following sections.

2.2.5.1 Minimise energy demand

A fabric first approach, as commonly referred to within literature, involves improving the thermal envelope of a building in order to reduce its energy demand for heating. It ensures that solutions are long-lived, and that little maintenance is required to retain these benefits.

Energy demand can also be minimised through the utilisation of low and zero-carbon technologies such as heat pumps. Because of their ability to perform with a higher than 100% efficiency they can reduce the amount of energy required from the grid to deliver the same amount of energy demand (covers heating and hot water generation).

In addition, energy recovery technologies such as mechanical ventilation heat recovery (MVHR) and waste water heat recovery systems (WWHR) can further reduce expected energy demand because of their ability to recover energy from different energy loss processes (hot air and water energy dissipation).

Finally, energy-efficient lighting and appliances also lead to energy demand reductions.

In that sense minimising energy demand and maximising energy efficiency become overlapping/complementary statements referring to the same or similar principles.

It is expected that minimising energy demand within the context of the policy statement refers mainly to a fabric first approach.

Additional wording will need to be developed to clarify the statement.

2.2.5.2 Maximise energy efficiency

Energy efficiency refers to the ability to optimise energy use. According to the EU Energy Efficiency Directive: ‘use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption.’[15]

[15] European Commission (2012) Energy efficiency directive https://ec.europa.eu/energy/en/topics/energy-efficiency/targets-directive-and-rules/energy-efficiency-directive

Complementary to the policy requirement for 'minimising energy demand', maximising energy efficiency in terms of new development could refer to supply/demand controls of installed systems, energy-efficient installed services and the use of renewable technologies.

Within the current context it would most likely support or should be interpreted as the installation of better performing and more efficient heat and hot water generation systems.

Additional wording will need to be developed to clarify the statement.

2.2.5.3 Utilise renewable energy

Renewable energy commonly refers to energy generation through renewable energy sources. These commonly include solar, wind, hydro, tidal and other.

In general, they consist of types of energy that can be extracted with no negative climatic impact ($CO2_e$) as opposed to the combustion of fossil fuels.

While renewable energy is produced through such means as the ones described above, some technologies can also be considered as 'renewables' from a renewable heat generation perspective.

As stated within the Domestic Renewable Heat Incentive[16] guidelines, heat pumps and biomass boilers would qualify as renewable heat generating technologies.

The interpretation of this step of the energy hierarchy would commonly include:

- The installation of energy generation technologies, with photovoltaics most commonly used
- Potential installation of heat pumps
- Use of existing or development of new heating networks supplying renewable heat

[16] Energy Saving Trust (2019) Renewable Heat Incentive https://www.energysavingtrust.org.uk/scotland/grants-loans/renewables/renewable-heat-incentive

It needs to be clarified that **current wording refers to utilisation of renewable energy, and not generation or implementation of technologies capable of generating part of the predicted energy demand** of the development from renewable energy resources.

2.2.5.4 Utilise low carbon energy and other energy sources

Low-carbon energy would refer to energy generated through such means that the generation, distribution and utilisation of the energy would have a reduced environmental, in terms of $CO2_e$, impact.

While it is not clear what this actually means in terms of technical solutions to be implemented (centralised CHP and heating networks may be some of the options) the continuous decarbonisation of the electricity grid could support a move towards all electric solutions.

Alternative energy sources are not covered within the modelling undertaken. These may include fuel cells and hydrogen boilers.

2.2.5.5 Carbon reduction 19% interim requirement

A 19% carbon reduction against Part L 2013 of the Building Regulations refers to a written ministerial statement on plan making, 25 March 2015, setting out central government's expectations on local policy requirements.

The statement specifies that local carbon and energy policies should not be used to set conditions on planning permissions with requirements above the equivalent of the carbon emissions requirement of Level 4 of the Code for Sustainable Homes[17] (this is approximately 19% above current Building Regulations across the build mix).

Nevertheless, provisions in the Planning and Energy Act 2008 still allow local plan policies to impose reasonable requirements for a proportion of energy used in development in their area to be energy from renewable sources and/or to be low-carbon energy from sources in the locality of the development.

[17] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/315504/250414__Code_Addedum_2014_Combined_Final_V10.pdf

At the time of the report writing, local authorities maintain the power to impose higher than the Building Regulations' performance requirements in terms of renewable energy generation and fabric energy performance.

Within the Future Homes Standard[18] consultation document, it is stated that such powers may cease to exist as the building regulations move forward to requesting higher energy and carbon performance standards from new buildings.

The Future Homes Standard consultation also discusses a $CO2_e$ uplift expected through the introduction of Part L 2020 of 20 to 31% compared to Part L 2013 (SAP10.1 carbon factors used).

In that sense, the interim GMCA requirement would fall short of the new minimum compliance requirements if Part L 2020 is implemented as described within the consultation and if the GM target was to remain the same (19% carbon emissions reduction compared to Part L 2013).

2.2.6 Existing policies within the ten Greater Manchester districts

Specific policy requirements were extracted from publicised data for all ten districts of Greater Manchester. These are listed in Table 1.

The main findings include:

- A number of policies included a requirement for carbon performance improvements for new developments of 10-15% over the now out-of-date Part L 2010.
- Special consideration was given on a number of cases on connectivity of new development to district heating networks[19]. In some instances, it was suggested that if a district heating system was not in place, the services strategy of the new development should allow for later connectivity once one in close proximity has been developed.
- In some cases, the differentiation between levels of carbon performance improvement required was based on the actual energy type; in others a more relaxed standard for predominantly electricity supplied developments was

[18] The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings
[19] Also supported by GMSF, Policy GM-S 3

used. This was due to the previously high-carbon intensity of the electricity grid.

- References to abandoned policies as in the case for Zero Carbon Homes from 2016 were noted.

Overall, the policies, while setting the foundations for energy and carbon performance improvement, were occasionally out of date.

The diversity of targets presented within the policies, and technical detailing on how targets set should be met, made some of the requirements hard to fully understand from an implementation perspective.

The variability of requirements and preferred approaches could lead to either confusion in terms of the different requirements within developers' operation within the region or could allow space for open interpretation of the requirements.

Table 1 - Energy and carbon Greater Manchester districts' requirements

Borough	Ref	Policy requirement
Stockport	Core Strategy	Minimum target 40% reduction in CO_2 emissions over and above the 2006 target emission rate. This is the minimum legal target that a development will be required to meet. The % target is calculated based on determining the carbon reduction of minimum cost 'on-site' technologies that meet current North West RSS target of 10% from renewable energy plus a notional 5% uplift (ie 15% overall). Small developments (less than 100 dwellings or less than 10,000m^2 non-residential) should connect to any available district heating networks. Where a district heating network does not yet exist, applicants should install heating and cooling equipment that is capable of connection at a later date and which could serve (or could be easily adapted to serve) that wider network if and when required. Large and mixed-use developments (over 100 dwellings or over 10,000m^2) should install a DHN to serve the site.
Trafford	Core Strategy	Low-carbon growth areas (Altrincham TC, Carrington, Trafford Park) - where there is potential to deliver a reduction target of up to 15% above current building regulations. Outside LCGAs - where there is potential to deliver a reduction target of up to 5% above current Building Regs. Major developments classified as more than ten dwellings or developments over 1,000m^2 area are required to demonstrate how they will seek to minimise their contribution to the effects of climate change.

Borough	Ref	Policy requirement
Salford	UDP	Major development proposals required to demonstrate how they will minimise their GHG emissions. Development proposals for more than 100 dwellings or 5,000m^2 will only be permitted where it can be demonstrated that: ▪ The impact on the conservation of non-renewable resource and on the local and global environments has been minimised as far as practicable ▪ Full consideration has been given to the use of realistic renewable energy options, and such measures have been incorporated into the development where practicable
Bury	Local plan 2018	It is proposed that the local plan should include a policy that seeks to ensure that residential development should be well designed, contributes to GM zero-carbon targets and makes a positive contribution to the surrounding area.
Wigan	Core Strategy	Encouraging residential developments of +10 units and developments of more than 700m^2 to produce and submit a carbon reduction strategy setting out how the development will incorporate or make provision for, subject to viability, decentralised, renewable or low carbon energy sources to reduce the CO2 emissions by 15%.

Borough	Ref	Policy requirement
Bolton	Core Strategy	Ensure that all proposals for five or more residential or 500m^2 non-residential achieve Level 3 Code for Sustainable Homes or BREEAM 'Very Good'; incorporate appropriate decentralised, renewable or low-carbon energy sources to reduce the CO2 emissions of predicted regulated and unregulated energy by at least 10%. Ensure all proposals for five or more residential or 500m^2 achieve the minimum targets outlined in the AGMA decentralised energy strategy; and connect to existing or planned/potential decentralised schemes where appropriate.
Tameside	Decentralised and Zero Carbon Energy Planning	The government has recently confirmed that the zero-carbon objective will be retained – although unregulated carbon emissions from buildings will no longer be the subject of regulation from 2016. A similar commitment is likely to be made for non-domestic buildings, following the broad approach set out in DCLG's consultation of November 2009. The mechanism for pooling investment in off-site infrastructure is still to be confirmed but may take a similar form to the Community Infrastructure Levy (CIL)

Borough	Ref	Policy requirement
Manchester	Manchester Core Strategy Development Plan Document	Applications for +10 residential units or over 1,000m^2 will be expected as a minimum to meet the target unless this can be shown not to be viable. Developments smaller than the threshold will also be expected to meet the minimum target where viable but will not be expected to submit an energy statement. Domestic ▪ Network development area target – CHP/district heating anchor or connection or where not feasible a 15% increase on Part L 2010 ▪ Electricity intense buildings target – 15% increase on Part L 2010 ▪ Microgeneration area target – 15% increase on Part L 2010 Non-domestic ▪ Network development area target – CHP/district heating anchor or connection or where not feasible a 15% increase on Part L 2010 ▪ Electricity intense buildings target – 10% increase on Part L 2010 ▪ Microgeneration area – 15% increase on Part L 2010
Rochdale	Adopted 2006 new local plan	Development proposals which include measures to conserve and assist the efficient use of energy will be supported where this can be successfully incorporated into the design and layout, and where there are no adverse impacts on the amenity of the surrounding area. Measures which will be especially encouraged include: ▪ Maximum use of local materials and recycled building materials ▪ Use of design, layout, landscaping and materials which help conserve energy ▪ Use of sustainable power generation systems such as solar PV, small scale CHP and other appropriate installations
Oldham	Oldham LDF: Joint DPD - Proposed Submission	The council will facilitate the achievement of national targets and where opportunities arise/circumstances warrant it, the council may also require developers to meet higher targets. All developments over 1,000m^2 or 10 homes will be required to reduce emissions in line with the targets identified. Developments below the threshold should aim to incorporate appropriate microgeneration technologies. Network expansion area – connect to a combined heat and power/district heating network. Up to 73% contributions to existing or future decentralised heat or power schemes. Electricity intense area – 17% increase on Part L for domestic and 10% increase on Part L for non-domestic buildings. Up to 56% for domestic and 28% for non-domestic contributions to existing or future decentralised heat or power schemes. Microgeneration areas – 15% increase on Part L for domestic and non-domestic buildings. Up to 49% for domestic and 42% for non-domestic contributions to existing or future decentralised heat or power schemes.

2.3 Carbon and energy policy development – national and international background

Relevant current policy requirements, national and international targets, policy statements and drivers were reviewed and are listed within this section of the report for reference purposes.

Key findings:

2.3: Carbon and energy policy development – national and international background

- Local authorities have an important role to play in terms of delivering carbon reduction targets, through the implementation of energy and carbon policies.
- Local planning authorities are bound by the legal duty set out in Section 19 of the 2004 Planning and Compulsory Purchase Act, as amended by the 2008 Planning Act, to ensure that, taken as whole, planning policy contributes to the mitigation of, and adaptation to, climate change.
- The National Planning Policy Framework supports and encourages local authorities developing viable and sustainable local plans in line with the objectives and provisions of the Climate Change Act 2008.
- It is not clear at this point if the local authorities' powers to impose higher than the minimum regulatory carbon energy performance in new buildings will be retained.
- The Future Homes Standard[20] consultation document includes a suggestion for local authorities to be stripped of the power of introducing higher than the minimum regulatory performance requirements for buildings.
- The public examination response of the London Plan Policy SI2[21] accepts the 35% reduction in emissions beyond the Building Regulations as realistic. Whole-life carbon and unregulated emissions requirements are also considered as good practice[22].

[20] The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings, 1 October 2019.
[21] New London Plan - Consultation draft, Chapter 9 Sustainable Infrastructure, Policy SI2 Minimising greenhouse gas emissions, accessed last in 2020.
[22] Current regulatory requirements under Building Regulations concern the use of regulated energy which exempts plug loads. It also excludes embodied carbon.

- Examples of requirements such as zero carbon in the London Plan for new domestic buildings include the ability of a developer to offset part of the expected remaining emissions from the building through a carbon credit mechanism.

Recommendations:

- Use guidance provided within the technical part of the report on energy efficiency, energy demand and association with carbon emissions to produce a robust, future-proofed local policy similar to the London Plan Policy SI2. This will provide a sound solution that GMCA can adopt[23] irrespective of the options taken forward for new national building standards.
- Achieving minimum energy and carbon performance requirements on site (along with the use of renewables) can be gradually tightened in light of the future 2025 Building Regulations. Whole-lifecycle carbon emissions requirements should be detailed as part of achieving the 2028 net-zero carbon developments target.

2.3.1 National context

The implementation of successful energy and sustainability policies through local plans is of high importance in meeting both local and national carbon emissions reductions targets, as well as providing sustainable environments for local communities. This is showcased through the introduction of appropriate regulations, policies and policy targets.

The Committee on Climate Change's *Reducing UK emissions – 2018 Progress Report to Parliament* reported that direct and indirect emissions from buildings accounted for almost 30% of the total UK GHG emissions in 2017. Furthermore, in the same year, buildings were responsible for 66% of the overall UK electricity consumption[24].

[23] Subject to any changes imposed by new regulations on the rights of local planning bodies to prescribe higher building standards.
[24] Committee on Climate Change (2018) Reducing UK emissions – 2018 Progress Report to Parliament https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/

Similar trends had been observed in previous years. Buildings have a huge impact on the country's total calculated carbon emissions, making building improvements a UK priority for addressing climate change (and overall sustainability targets).

Amended during 2019, the Climate Change Act 2008 (2050 Target Amendment) Order 2019, introduced a new net UK emissions target for 2050 as shown in

The target for 2050

1 The target for 2050

(1) It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least **[**F1 100%**]** lower than the 1990 baseline.

(2) "The 1990 baseline" means the aggregate amount of—

(a) net UK emissions of carbon dioxide for that year, and

(b) net UK emissions of each of the other targeted greenhouse gases for the year that is the base year for that gas.

Table *2*.

The target for 2050

1 The target for 2050

(1) It is the duty of the Secretary of State to ensure that the net UK carbon account for the year 2050 is at least **[**F1 100%**]** lower than the 1990 baseline.

(2) "The 1990 baseline" means the aggregate amount of—

(a) net UK emissions of carbon dioxide for that year, and

(b) net UK emissions of each of the other targeted greenhouse gases for the year that is the base year for that gas.

Table 2 - The Climate Change Act 2008 (2050 Target Amendment) Order 2019 (S.I. 2019/1056), Parts. 1, 2

Local planning authorities are bound by the legal duty set out in Section 19 of the 2004 Planning and Compulsory Purchase Act[25], as amended by the 2008 Planning Act, to ensure that, taken as whole, planning policy contributes to the mitigation of, and adaptation to, climate change.

This powerful outcome-focused duty on local planning clearly signals the priority to be given to climate change in plan-making. In discharging this duty, local authorities should consider guidance provided within the National Planning Policy Framework

[25] http://www.legislation.gov.uk/ukpga/2004/5/section/38

(NPPF) and understand the economic, social and environmental aspects of their current and future local plan targets.

National Planning Policy Framework (Feb 2019) - Paragraphs 7 and 8
The purpose of the planning system is to contribute to the achievement of sustainable development. At a very high level, the objective of sustainable development can be summarised as meeting the needs of the present without compromising the ability of future generations to meet their own needs. Achieving sustainable development means that the planning system has three overarching objectives, which are interdependent and need to be pursued in mutually supportive ways (so that opportunities can be taken to secure net gains across each of the different objectives): a) an economic objective – to help build a strong, responsive and competitive economy, by ensuring that sufficient land of the right types is available in the right places and at the right time to support growth, innovation and improved productivity; and by identifying and coordinating the provision of infrastructure; b) a social objective – to support strong, vibrant and healthy communities, by ensuring that a sufficient number and range of homes can be provided to meet the needs of present and future generations; and by fostering a well-designed and safe built environment, with accessible services and open spaces that reflect current and future needs and support communities' health, social and cultural well-being; and c) an environmental objective – to contribute to protecting and enhancing our natural, built and historic environment; including making effective use of land, helping to improve biodiversity, using natural resources prudently, minimising waste and pollution, and mitigating and adapting to climate change, including moving to a low carbon economy.

Furthermore, Paragraph 129 of the revised NPPF (2018)[26] encourages local authorities to use assessment frameworks as tools for improving design quality while paragraph 149 of the NPPF requests ensuring that policies and decisions are in line with the objectives and provisions of the Climate Change Act 2008.

The NPPF sets guidance that local authorities have to follow to demonstrate, through viability assessments, that higher sustainability standards will not affect housing delivery. Assessments need to be underpinned by a proportionate evidence base that reflects local circumstances.

The NPPF also says that plans should be prepared positively in a way that is aspirational but deliverable. This means that policies should be realistic, and the total cumulative cost of all relevant policies should not be of a scale that will make development unviable. Key points from the guidance are as follows.

'Policy requirements, particularly for affordable housing, should be set at a level that allows for sites allocated in the plan to be delivered without the use of further viability assessment at the decision-making stage.

Where proposals for development accord with all the relevant policies in an up-to-date development plan no viability assessment should be required to accompany the application. Plans should however set out circumstances in which viability assessment at the decision-making stage may be required.'

The Section 19 duty is much more powerful in decision-making than the status of the NPPF, which is guidance, not statute. Where local plan policy which complies with the duty is challenged by objectors or a planning inspector on the grounds, for

[26] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/779764/NPPF_Feb_2019_web.pdf

example, of viability, they must make clear how the plan would comply with the duty if the policy were to be removed.

Technically feasible and cost-effective 'tighter energy and carbon performance requirements for new buildings' within a local plan is further supported by the Planning and Energy Act 2008[27], section 1:

A local planning authority in England may in their development plan documents, a strategic planning panel may in their strategic development plan, and a local planning authority in Wales may in their local development plan, include policies imposing reasonable requirements for—

(a) a proportion of energy used in development in their area to be energy from renewable sources in the locality of the development;

(b) a proportion of energy used in development in their area to be low carbon energy from sources in the locality of the development;

(c) development in their area to comply with energy efficiency standards that exceed the energy requirements of building regulations.

The 2015 written ministerial statement includes[28]:

For the specific issue of energy performance, local planning authorities will continue to be able to set and apply policies in their Local Plans which require compliance with energy performance standards that exceed the energy requirements of Building Regulations until commencement of amendments to the Planning and Energy Act 2008 in the Deregulation Bill.

This is expected to happen alongside the introduction of zero carbon homes policy in late 2016. The Government has stated that, from then, the energy performance requirements in Building Regulations will be set at a level equivalent to the (outgoing) Code for Sustainable Homes Level 4.

Until the amendment is commenced, we would expect local planning authorities to take this statement of the Government's intention into account in applying existing

[27] https://www.legislation.gov.uk/ukpga/2008/21/section/1
[28] Planning update: Written statement - HCWS488, https://www.parliament.uk/business/publications/written-questions-answers-statements/written-statement/Commons/2015-03-25/HCWS488/

policies and not set conditions with requirements above a Code level 4 equivalent. This statement does not modify the National Planning Policy Framework policy allowing the connection of new housing development to low carbon infrastructure such as district heating networks.

2.3.2 The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings

It needs to be advised that the government is in the process of reviewing the national building regulations (Part L) against which the GMSF planning requirements will be set.

These changes will likely include revisions within the Approved Document L (Part L), Approved Document F of the Building Regulations and the introduction of a Future Homes Standard in 2025.

This review may result in changes to the national minimum standard, compliance metrics and assessment method (for example the adoption of SAP10.1 or a successor).

Changes to the regulatory baseline may impact in 2020 and therefore this must be considered in GMSF standards once the new regulations are known.

Part L could potentially change from carbon to primary energy as the main metric to assess building performance.

Primary energy is currently the required metric of the Energy Performance of Buildings Directive (EPBD) - kWh/(m2y) - for the purpose of both energy performance certification and compliance with minimum energy performance requirements.

The current research review was conducted based on the predicted energy demand and carbon performance requirements for new buildings.

While energy demand and type of energy use can be translated into primary energy requirements, based on primary energy factors, it is at this stage unknown what level of threshold or minimum compliance requirements will be imposed.

Therefore, such association has been omitted because of the inherited policy complexity it would introduce. Energy demand and carbon performance-based targets were considered as sufficient to address the GMSF 2028 net-zero carbon new developments requirement.

Furthermore, changes within the Part L 2020, and new minimum requirements imposed might deem current interim GMSF carbon improvement requirements redundant. This is further discussed in later sections within the report.

Latest guidance produced by the Ministry of Housing, Communities and Local Government also described the potential limitation in the authority of local authorities on imposing higher than the Building Regulations' minimum energy and carbon performance requirements.

While this is also discussed within the '*The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings'* consultation document, it is unclear at this stage whether or not the local authorities' powers on such manners will be revoked.

2.3.3 Committee on Climate Change and Spring Statement, March 2019

Renewable energy generation contributes positively to carbon emissions reductions through displacement of grid electricity, or by direct partial consumption at the point of generation.

Such contributions support the gradual decarbonisation of the electricity grid and, combined with smart local supply/demand solutions and/or energy storage technologies, provide a robust approach towards more resilient energy strategies.

In that respect it was important to consider PV generation within the research work. Renewable heat generation also has an important role to play in reducing energy required for hot water generation.

Energy used for hot water generation becomes increasingly important when space heating demand requirements of buildings are significantly decreased. In that sense, the use of low carbon heat and the use of technologies such as heat pumps will contribute to further carbon emission reductions from buildings and enable achieving the climate change targets.

The importance of combining high-fabric energy efficiency, low-carbon heat and hot water generation solutions and renewable energy/zero and low-carbon technologies in buildings has been recently restated by both the UK Government and the Committee on Climate Change (the independent, statutory body established under the Climate Change Act 2008).

Committee on Climate Change – UK Housing: Fit for the future? February 2019[29]
Immediate Government action is needed to ensure the new homes planned across the UK are fit for purpose, integrating the highest possible levels of emissions reduction with a package of design improvements to adapt to the changing climate. This will require an ambitious trajectory of standards, regulations and targets for new homes throughout the UK: ▪ By 2025 at the latest, no new homes should connect to the gas grid. Instead they should have low-carbon heating systems such as heat pumps and low-carbon heat networks. ▪ Make all new homes suitable for low-carbon heating at the earliest opportunity, through use of appropriately sized radiators and low-temperature compatible thermal stores. This can save £1,500 - £5,500 per home compared to later having to retrofit low-carbon heat from scratch. ▪ New homes should deliver ultra-high levels of energy efficiency as soon as possible and by 2025 at the latest, be consistent with a space heat demand of 15-20 kWh/m2/yr. Designing in these features from the start is around one-fifth of the cost of retrofitting to the same quality and standard. When installed alongside heat pumps in a typical home, ultra-high levels of fabric efficiency can deliver average bill savings of around £85 per household per year, contribute to reducing annual and peak electricity demand alongside other measures, provide comfort and health benefits for occupants, and create an industrial opportunity for the UK to export innovation and expertise. ▪ Statutory requirements should be in place to reduce overheating risk in new-build homes. Evidence suggests that all new-build homes are at risk of overheating. Passive cooling measures should be adopted to reduce overheating risks before considering active measures such as air conditioning. ▪

[29] https://www.theccc.org.uk/wp-content/uploads/2019/02/UK-housing-Fit-for-the-future-CCC-2019.pdf

- Improve focus on reducing the whole-life carbon impact of new homes, including embodied and sequestered carbon. Using wood in construction to displace high-carbon materials such as cement and steel is one of the most effective ways to use limited biomass resources to mitigate climate change.

UK Government - Spring Statement March 2019[30]

From HM Treasury and The Rt Hon Philip Hammond MP, the Spring Statement builds on the Industrial Strategy, Clean Growth Strategy, and 25 Year Environment Plan as set out in the Budget 2018. In terms of buildings, energy and carbon the following are noted:

- To help meet climate targets, the government will advance the decarbonisation of gas supplies by increasing the proportion of green gas in the grid, helping to reduce dependence on burning natural gas in homes and businesses
- To help ensure consumer energy bills are low and homes are better for the environment, the government will introduce a Future Homes Standard by 2025, so that new build homes are future-proofed with low carbon heating and world-leading levels of energy efficiency

[30] https://www.gov.uk/government/news/spring-statement-2019-what-you-need-to-know

2.3.4 London Plan

Since 2016 the London Plan has included policy which requires new major residential developments to be zero carbon. In 2017, a draft new London Plan was published by the Mayor for consultation, and the GLA commissioned an Aecom study of the carbon price at the same time – the London Carbon Offset Price. This iteration requires all new homes to be zero carbon and new non-domestic buildings to be zero carbon by 2019.

The GLA Supplementary Planning Document Sustainable Design and Construction (2014) encourages boroughs to set a price for carbon dioxide based on a nationally recognised carbon dioxide pricing mechanism, or the actual cost of off-setting carbon dioxide emissions.

London Plan, Public examination[31] (held between 15 January 2019 and 22 May 2019)

Minimising greenhouse gas emissions, energy infrastructure and managing heat risk

468. The Mayor's aspiration in the Environment Strategy is for London to become a zero-carbon city by 2050 and this is reflected in the Good Growth objectives. The sustainable infrastructure policies are geared towards achieving that end which is a justifiable approach. They would also contribute positively towards the objective of creating a healthy city as part of the Mayor's general duty to have regard to climate change and its consequences. As further suggested changes the Mayor has clarified that zero-carbon refers to net zero-carbon in all cases as defined in the Glossary.

469. This is an area where technology is evolving and so flexibility is required especially as changes to the Building Regulations are expected. When these are introduced this might, in turn, trigger the need for a partial review. In the meantime the policies build on existing established approaches in London. Whilst some argue that they do not go far enough we consider that they are ambitious and progressive and pursue carbon reductions as far as can be expected given the Mayor's limited

[31] Report of the Examination in Public of the London Plan 2019, File Ref: PINS/SDS0026, https://www.london.gov.uk/sites/default/files/inspectors_report_and_recommendations_2019_final.pdf

powers in this area and his resources. They also adequately emphasise the importance of the use of renewables.

470. The requirement to achieve a 35% reduction in emissions beyond the Building Regulations in policy SI2 is realistic but will become more challenging to meet through typical gas-based technologies as other energy sources become cleaner meaning that other ways are required to achieve it. The expectation that development will achieve a proportion of this through energy efficiency measures is based on firm evidence and is therefore justified. Where onsite measures to reduce carbon emissions have been fully explored but cannot be achieved, contributions to achieve net zero-carbon should be made to a carbon off-set fund. For example, this could provide valuable sums to improve the carbon performance of the existing stock. This is not the default position and the Mayor will continue to monitor its effectiveness as well as updating the existing guidance as necessary including the price for off-set carbon.

471. The NPPF refers to actively supporting energy efficiency improvements to existing buildings. The above measures would assist in this but retro-fitting may not require planning permission in many cases. There is nevertheless reference to major refurbishment in paragraph 9.2.1.

472. Policy SI2 includes criteria relating to unregulated emissions from plant and equipment outside the Building Regulations and the calculation of whole life cycle carbon emissions over the lifetime of a development including demolition. It is evident that in future these broader methods of measuring carbon impact will become increasingly important and there are existing tools to assess them. The provisions are intended as a starting point so that data and good practice is captured and understood as a pre-cursor to future policy development. As such, they do not introduce additional technical standards and their intent and application is justified. It also makes sense at this juncture to keep these parts of the policy separate from the well understood provisions relating to regulated emissions. Guidance is to be produced by the Mayor about such assessment including how information should be reported to enable verification and monitoring.

473. Policy SI3 contains provisions relating to energy masterplans for large scale development locations and given their scale this approach is justified and the list of matters to be covered is comprehensive. It also sets out a heating hierarchy for major development proposals within Heat Network Priority Areas. Based on the latest evidence it is reasonable to order the different types of communal low-temperature heating systems in this way rather than presenting them as a “menu” to select from. Equally it is wise not to expressly rule out options such as combined heat and power under certain circumstances given that technology may change over the period of the Plan. Therefore the sequence and content of the heating hierarchy is justified. The policy also sets a framework for boroughs to identify opportunities for expanding or establishing new networks.

474. As further suggested changes, the policy and supporting text would be strengthened to refer to good practice design and specification standards for new and existing networks. The Plan also makes specific reference to decarbonisation plans for existing networks and to ensure a reliable cost competitive service for customers.

475. The importance of managing heat risk through design is emphasised by policy SI4. This is warranted due to rising temperatures and the urban heat island effect. Major developments should seek to follow the cooling hierarchy as demonstrated through their energy strategies and these principles can also be applied to minor development.

476. Overall these policies concerned with greenhouse gas emissions, energy and infrastructure and managing heat risk would contribute effectively to achieving a healthy city as well as wider legal duties in respect of climate change.

2.3.5 United Nations Sustainable Development Goals

A report released in 2018 titled ‘Measuring up’ from the UK Stakeholders for Sustainable Development assesses the UK’s performance against the 17 sustainable development goals.

They report that 20% of homes in England fail to meet the government's Decent Homes Standard covering factors such as state of repair, basic facilities, warmth and health and safety.

A transformation of industry is required to increase the UK circular economy, with higher levels of reuse, repair, recycling, energy recovery and resource productivity[32].

[32] UKSSD (2018) Measuring up: How the UK is performing on the UN Sustainable Development Goals https://www.ukssd.co.uk/measuringup

2.4 Net-zero carbon – UK GBC Framework

Key findings:

2.4 Net-zero carbon – UK GBC Framework

- The definition framework supports the evaluation of a building's energy and carbon performance by considering a plethora of carbon producing construction elements.
- Unregulated energy use may include energy used during construction and demolition, as well as during operation.
- Embodied carbon of materials may need to be reviewed based on lifecycle carbon assessments.

Recommendations:

- Only the operational unregulated energy (plug loads) use for new domestic buildings is estimated within the report. For non-domestic building CIBSE guidance on small supply predictions can be used. This aligns with the UK GBC Operational Energy net-zero carbon definition.
- Other types of carbon (whole-life carbon) are harder to estimate. If such elements were to be included within the GMSF target, guidance on the calculation methodology for compliance needs to be specified/produced. The LETI Climate Emergency Design Guide can be used to inform the relevant GMSF policy development.

The world GBC's definition of a net-zero carbon building is a building that is highly energy efficient and fully powered from on-site and/or off-site renewable energy sources[33].

The current version of the Building Regulations sets compliance requirements in terms of energy and carbon based on regulated energy use, including heating, cooling, hot water, fans, pumps and lighting.

[33] World Green Building Council (2019) What is Net Zero? https://worldgbc.org/advancing-net-zero/what-net-zero

As highlighted on a number of publications before, including the most recent UK GBC Net Zero Carbon Buildings: A Framework Definition publication (Currie & Brown contributed to the technical authoring of the publication), there are elements of energy consumption and use that are currently not accounted for in terms of compliance purposes.

The UK GBC recent framework additionally discusses the concept of lifecycle carbon assessments, including construction and potential demolition and carbon sequestration.

The UK GBC's definition of a net-zero carbon building sets out two approaches to achieving net-zero carbon.

- **Net zero carbon – construction**:
  When the amount of carbon emissions associated with a building's production and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy.

- **Net zero carbon – operational energy**:
  When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net-zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.

Unregulated energy use may include energy required during construction, or additional operational energy use as in the case of energy used for appliances (eg plug loads).

CIBSE TM54: Evaluating Operational Energy Performance Buildings at the Design Stage highlights the significance of small supply (appliances) energy consumption which can include energy used by lifts and escalators, for catering facilities, or for server rooms in non-domestic buildings, for example.

The current technical report included the assessment of operational unregulated energy use in domestic models (plug loads).

For more information on future policy developments in terms of embodied carbon emissions and whole-life carbon assessments more research is required for establishing appropriate benchmarks.

A good starting point for developing the relevant guidance would be the London Energy Transformation Initiative (LETI) Climate Emergency Design guide[34].

[34] LETI, Climate Emergency Design Guide 2020, https://www.leti.london/cedg

2.5 Performance gap

Key findings: 2.5 Performance gap
▪ The performance gap refers to the difference between the energy and carbon performance of a building's design and the actual building delivered on site. ▪ Performance assessing tools, procurement, construction skills and knowledge as well as communications can all contribute to the presence of such a gap.
Recommendations:
▪ There needs to be a policy provision for development proposals to be accompanied by an energy assessment demonstrating how the targets for energy demand and CO2 emissions reduction will be met and how the likelihood of a potential performance gap is minimised. ▪ Specific guidelines/requirements in terms of QA processes for energy and carbon should be produced as supplementary planning guidance.

Both the design and fabric specifications of a building can affect its energy and carbon performance in terms of heating and ventilation requirements.

While highly energy-efficient buildings can deliver considerable reductions in energy demand requirements, the complexity of design can also allow for inaccurate delivery of intent on-site and the potential introduction of a performance gap[35].

This performance gap is the difference between the targeted level of performance and the actual performance of the building in-situ[36].

The performance gap in buildings can impact the national carbon reduction plan, in turn impacting on national and international policy goals.

There are also the resultant reputational impacts to the industry, reducing consumer confidence in energy efficient buildings if energy bills are substantially higher than anticipated[37].

A report by the Zero Carbon Hub in 2012, identified four key themes for the issues surrounding the performance gap: knowledge, communication, responsibility and skills[38].

In addition, target setting in terms of energy and carbon performance can be problematic when there is inconsistency in the definitions used and ambiguity over the information required to demonstrate compliance.

[35] BEIS (2016) Smart meter roll-out (GB): cost-benefit analysis 2016 https://www.gov.uk/government/publications/smart-meter-roll-out-gb-cost-benefit-analysis
[36] Natural Building Technologies (2015) What is "the Performance Gap"? https://www.natural-building.co.uk/news/what-performance-gap/
[37] Dollard, T. (2018) Designed to perform: an illustrated guide to delivering energy efficient homes. RIBA Publishing
[38] Zero Carbon Hub (2013) Closing the gap between design and as-built performance New Homes Interim Progress Report http://www.zerocarbonhub.org/sites/default/files/resources/reports/Closing_the_Gap_Bewteen_Design_and_As-Built_Performance_Interim_Report.pdf

Challenges include:

- A lack of suitable energy performance analysis tools prevents designers from routinely checking the robustness of their designs. Although the government's Standard Assessment Procedure (SAP) tool is important through the project design stage, it relies on a number of assumptions and inputs that require further clarity to accurately predict 'as-built performance'.

- Manufacturer verification and independent testing of structural materials' performance is often at a material/component level rather than whole-system outputs.

- One of the main concerns regarding procurement and the performance gap is product substitution, whereby products are replaced and do not meet the original design intent, which is then not fed back to the SAP assessor so implications can be checked and addressed.

- In terms of skills and knowledge, cultures and embedded behaviours can have a significant impact on the overall built product during the construction process. Misinterpretation of detailed design drawings or lack of information around how to install junctions can affect the thermal performance and air tightness of the build.

Further training around installation and commissioning skills is required to ensure products such as mechanical ventilation and heat pumps are installed correctly and their efficiencies fully optimised. A change in culture is required to ensure more ownership across the design and construction process, with accountability of the efficiency of the end-built product.

Platforms such as CarbonBuzz allow users to see how their buildings perform against others and track the design and actual CO2 emissions of a portfolio of buildings[39], creating a tool that enables the monitoring, tracking and evaluating of performance required.

[39] Carbon Buzz (2019) https://www.carbonbuzz.org/whatyoucando.jsp

As stated in the illustrative guide, 'Designed to Perform', greater emphasis on compliance and site checks within Part L is required[16]. Ensuring quality is delivered through design, construction and operation is pivotal to maintaining the integrity and energy efficiency of the build.

Greater assurance is required on site to monitor quality of construction, and the involvement of the design team through to construction would maintain the level of responsibility required.

This is also supported by the recent Passivhaus Trust report 'Passivhaus: the route to zero carbon?, March 2019, where it is noted 'the **quality assurance process** that is part of the Passivhaus standard ensures that what is designed is what gets built and the actual energy performance of Passivhaus homes is, on average, exactly as predicted by the design stage modelling'.

Passivhaus is a voluntary buildings' performance standard that can be used to deliver buildings with highly reduced energy demand requirements (operational). It incorporates high levels of airtightness and a mechanical ventilation heat recovery system. Following a fabric first approach, the resulting energy demand for heating is extremely low compared to current minimum building regulations standards.

The steady state predicted heat loss associated with each of the Passivhaus-certified dwellings is obtained from the Passive House Planning Package (PHPP) predictions. PHPP is a planning tool that enables a number of energy balance calculations to be undertaken for a proposed building. As part of the Passivhaus certification process, it is a mandatory requirement that each Passivhaus dwelling is modelled and verified using PHPP[40].

In previous work undertaken by the Zero Carbon Hub on the performance gap, the Standard Assessment Procedure (SAP), the government-approved methodology for assessing the predicted energy and carbon performance of new homes in the country, was considered as a potential contributor to the performance gap. This was noted to be because of assumptions used within the calculation methodology.

Additional research undertaken on SAP has identified potential weaknesses in accurately predicting the energy and carbon performance of homes, usually by

[40] The Building Fabric Thermal Performance of Passivhaus Dwellings—Does It Do What It Says on the Tin? January 2016

underestimating the amounts of operational energy required. On a number of published reports, it is mentioned that PHPP might be able to predict with greater accuracy the expected building's energy and carbon performance.

SAP10.1 is the new trial version of SAP that the government has produced in preparation of the new Part L 2020. Whether or not issues around performance predictions have been sufficiently addressed is currently unclear.

Whether or not PHPP can better predict the regulated energy consumption of a new building than SAP, dissociated from the robust quality assurance (QA) processes in place is not clear. The Passivhaus standard requires a robust QA process with constant checks to be followed that ensure actual design delivery.

Human error, quality of inputs and level of expertise are all interlinked with the use of predictive software applications and are additional impacting factors in the cases of both SAP and the PHPP tools.

A potential requirement of PHPP analysis reports on top of the legally required SAP/EPC report outputs could translate into additional developer cost and is likely to create challenges in terms of the reports' outputs interpretation by the planning officers (conflicting predictions between the legally required SAP and the PHPP outputs).

Irrespective of whether Passivhaus certification is sought, there is a need to improve QA processes. This was clearly demonstrated in the majority of research undertaken on the performance gap.

Since the use of the PHPP is voluntary for developers, it is advised that if the different districts consider it as a beneficial additional planning requirement, appropriate training and information is provided to the planners in support of the evaluation of PHPP reports and outputs.

This could include marked areas of reporting differentiation, likelihood of deviation and potential reasoning as well as identification of construction elements that are considered as main contributors to these differences (along with an indication of the accuracy of the model).

It is advised that further research is undertaken into the implementation of additional PHPP requirements to the GMSF policy. This could be conducted during 2020-2025 for an introduction into policy as soon as possible. On-site trials followed up by performance monitoring can be used in the GM region to produce additional information in terms of the predicted benefits.

Quality assurance processes are of utmost importance in terms of reducing the potential performance gap and should be demonstrated in all new developments. Additional QA policy requirements should be considered if deemed necessary.

2.6 Monitoring and post-occupancy evaluation

Key findings: **2.6 Monitoring and post-occupancy evaluation**
▪ Visibility over buildings' actual operational energy and carbon performance is key to understanding inefficiencies relating to construction standards applied or operational inefficiencies. ▪ Soft landings, smart meters and requirements for post-occupancy evaluations for large developments can all support extracting additional knowledge over delivered/actual performance of buildings.
Recommendations:
▪ The carbon and energy policy of the GMSF refers to carbon performance improvements as evaluated in SAP. The policy trajectory also includes meeting actual net-zero carbon for new developments from 2028. A stronger focus on actual energy performance and demand of buildings is advised which should include an explicit reference to the need for post-occupancy evaluations. ▪ Major developments should be expected to monitor and report their energy performance as per the guidelines provided within the new draft London Plan Policy SI2, paragraph B[41].

The industry is increasingly recognising the impact of new-build performance not matching design intent, and the problem of a performance gap. Industry bodies and authorities such as Innovate UK and the UK GBC are working to address this through task groups and workstreams.

[41] https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan/draft-new-london-plan/chapter-9-sustainable-infrastructure/policy-si2-minimising

The draft London Plan Policy SI2 requires that major developments monitor and report on energy performance for at least five years via an online portal. This monitoring will allow the Greater London Authority to identify good practice and report on the operational performance of new development in London.

The 'performance monitoring' workstream in the recent review of London Plan policies by the London Energy Transformation Initiative was the first to propose the 'Be Seen' element of the London energy hierarchy, which is now included in the current draft of the new London Plan.

The opportunities that are to be developed by this workstream include recommendations on the energy and contextual data that should be reported; providing advice on the practicalities of setting up metering; monitoring and reporting systems; and demonstrating some of the uses of the data and the opportunities it brings[42].

Monitoring through post-occupancy evaluations (POEs) is essential for creating the evidence base for tracking product and design efficiency, as well improving the building user experience. Building Services Research and Information Association (BSRIA)[43] and Government Soft Landings (GSL) can be used to ensure quality of projects' delivery.

Soft landings is a building delivery process which runs through the project, from inception to completion and beyond, to ensure that all decisions made are based on improving the operational performance of the building meeting the client's expectations. It can also include POEs.

When applied, POEs should be considered at the outset of the project in order to fully maximise data collection, implement appropriate monitoring strategies and technologies and fully engage with the building users. Permission to capture data from homes and commercial buildings has to be agreed with residents and businesses and will be subject to data protection regulations, which includes informing that their personal data is being processed, clearly stating the purpose of using this data and their personal information, and an instruction on how they can

[42] London Energy Transformation Initiative (2019) LETI 2019 Workstreams https://www.leti.london/2019-workstreams
[43] https://www.bsria.com/uk/consultancy/project-improvement/soft-landings/

subsequently opt out[44]. POEs can be used to satisfy the GMSF policy requirement for developments' energy performance monitoring. With POEs there are usually two evaluation approaches:

- User experience-based – using tools such as building user surveys; focus groups to understand how the space works for its occupants.
- Energy performance-based – using tools such as BMS/ sub-meter data analysis looking at building services systems and energy consumption.

Through collection of operational data from metering systems such as building management systems (BMS) and qualitative feedback on building user experience, lessons learnt can be identified and a wider evidence base for improving future similar buildings can be produced. Since April 2016, the requirement to carry out government soft landings has been mandatory for all publicly funded buildings. However, there is still huge uncertainty in the industry over what is meant by soft landings and how to fully implement and embed this effectively on a project[45].

During 2018, the government extended the Smart Meters Act 2018 to ensure the full roll-out of energy meters. In September 2019, the deadline for supplier roll-out was extended to 2024. Although installation is not mandatory, energy firms must have offered meters to all UK households by this new deadline, encouraging a sense of accountability in monitoring building performance. The smart meter roll-out is estimated to deliver a net benefit to consumers of £5.7 billion over the lifetime of the programme[46]. It is estimated that smart meters will take £300 million off consumers' bills in 2020, rising to more than £1.2 billion a year by 2030 – an average annual saving of £47 per household. A smart metering data access and privacy framework has been established to ensure the safeguarding of consumers' privacy (domestic and microbusiness level) while not inhibiting access to energy consumption data for government records[47].

[44] Old Oak and Park Royal Development Corporation, Post Occupancy Evaluation Study, Local Plan Supporting Study, Mayor of London, June 2018, https://www.london.gov.uk/sites/default/files/39._post_occupancy_evaluation_survey.pdf
[45] The RIBA Journal (2017) All you need to know about soft landings https://www.ribaj.com/intelligence/government-soft-landings-gsl-digital-process
[46] BEIS (2016) Smart meter roll-out (GB): cost-benefit analysis 2016 https://www.gov.uk/government/publications/smart-meter-roll-out-gb-cost-benefit-analysis
[47] BEIS (2018) Smart metering implementation programme – Review of the Data Access and Privacy Framework

It is understood that there are current limitations in terms of post-project completion evaluations from a planning perspective (disconnect of approval from performance) and a complex regulatory environment in terms of local authorities' authority over such data handling. Nonetheless there is precedent within London, local authorities and internationally (eg Boston) for capturing both planning stage and in-use performance data to monitor responses to energy/carbon legislation.

Capturing this data through deployment of smart meters, and quantitative and qualitative analysis of post-completion building performance is essential to evaluating the success of set carbon reduction requirements and monitoring overall progress. POEs not only provide information on aspects such as air quality, thermal performance, acoustics and daylighting but provide a narrative around user experience and their safety, security and wellbeing.

2.7 Low-carbon economy and tackling fuel poverty

Key findings:

2.7 Low-carbon economy and tackling fuel poverty

- A household is considered to be fuel poor if they have required fuel costs that are above average and if they were to spend that amount, they would be left with residual income below the official poverty line.
- Energy-efficient installations are the major contributor to the change in the proportion of households in fuel poverty between 2018 and 2019.
- Carbon performance improvements realised through a carbon performance target alone do not necessarily translate into low running costs.

Fuel poverty in England is defined using a low income high costs (LIHC) indicator. Under this indicator, a household is considered to be fuel poor if they have required fuel costs that are above average and if they were to spend that amount, they would be left with residual income below the official poverty line.[48]

According to the Department for Business, Energy and Industrial Strategy's 'Sub-Regional Fuel Poverty in England, 2019 (2017 data)' statistics "Local authorities in the South East of England and East Midlands generally have below average fuel poverty levels, while households in the West Midlands and the North West generally have the highest levels of fuel poverty[49].

- While the proportion of fuel poor households is projected to decrease, the average gap is projected to increase – also a result of price changes.
- Ofgem estimates the default tariff price cap will reduce bills for 11 million households. Due to the scale of this cap, it will have less of a downward effect on fuel poverty headline figures than the prepayment cap, as prepayment customers are more overrepresented in the fuel poor population.

[48] Government (2019) Fuel poverty statistics https://www.gov.uk/government/collections/fuel-poverty-statistics
[49] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/808295/Fuel_poverty_sub_regional_2019__2017_data_.pdf

- Energy efficiency installations are the major contributor to the change in the proportion of households in fuel poverty between 2018 and 2019, while projected price increases across all payment types in 2019, contribute to the increase in the average gap”

Higher energy-efficient new domestic buildings have the ability to reduce the energy demand requirements for running the property.

This could lead to substantial energy cost savings. This is explored in more detail within section 6.2 of the report, but it needs to be noted that there is a disassociation between carbon savings and energy cost savings, especially when high cost but low-carbon energy types are proposed (electricity).

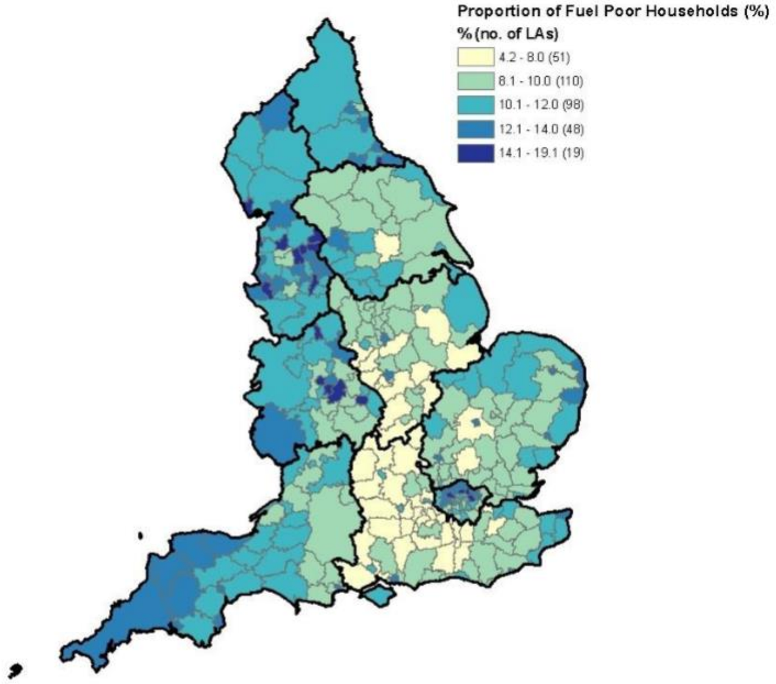


Figure 3 - Proportion of fuel poor households (%)

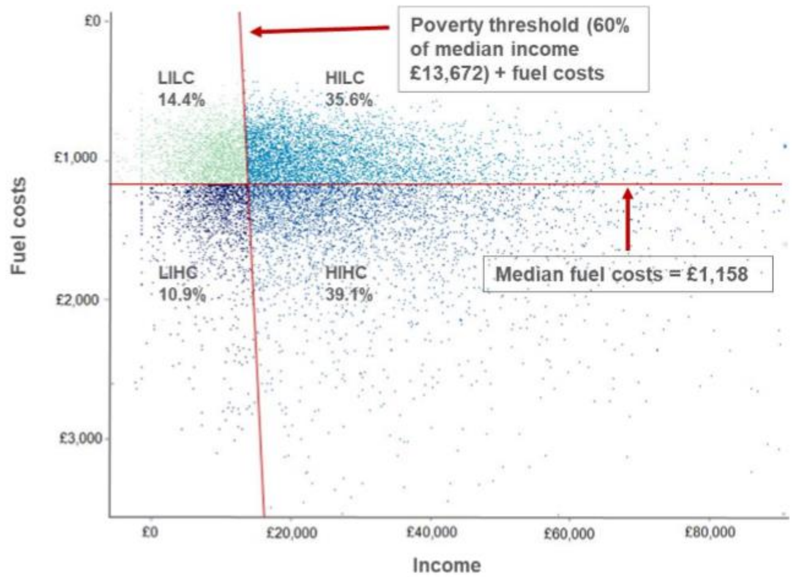


Figure 4 - 10.9 per cent of all households classified as fuel poor (LIHC) in 2017[50]

[50] BEIS 2019, Annual Fuel Poverty Statistics in England, 2019 (2017 data) , https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/829006/Annual_Fuel_Poverty_Statistics_Report_2019__2017_data_.pdf

3. Domestic models development

Key findings:

3.1 Development of the domestic archetypes – sizes and typologies

3.2 Development of the domestic archetypes – energy performance specifications

3.3 New domestic buildings – energy types

- There were six prevailing housing typologies within Greater Manchester that were selected for modelling. These included a detached house, an end-terrace house, a mid-terrace house, an end-terrace townhouse, a small flat (one bedroom) and a large flat (two-bedrooms).
- Floor areas for the housing model were produced by analysing nationally prescribed minimum gross internal floor areas and recent planning applications from the ten Greater Manchester districts.
- The six archetypes produced from the six housing typologies, typical for the Greater Manchester floor areas, and in-house Currie & Brown construction data were evaluated using SAP 2012 of the Building Regulations.
- The release of the Future Homes Standard consultation document, and the introduction of new carbon factors within SAP10 and later SAP10.1, complicated the modelling approach as the new SAP versions were neither finalised nor used for compliance purposes yet.
- Modelling the housing archetypes to achieve an interim 19% $CO2_e$ emissions reduction targets as per the draft GM Spatial Framework raised a question as to whether or not this would be superseded by the potential higher performance standards discussed for Part L 2020 within the Future Homes Standard consultation (20% or 31% improvement).
- Carbon emissions as an appropriate evaluation metric was analysed. The results demonstrated the potential impact of the grid decarbonisation in meeting the net-zero carbon target – as this could be driven by a transition to all electric solutions only.

- Such a move could hinder as noted the take-up of renewable electricity generating technologies, as in the case of PV, because of the limited ability in the future to offset carbon.
- Specifications in terms of fabric and services performance assigned to the six archetypes were developed for modelling following the GMSF energy hierarchy.
- In terms of fabric specifications, seven improvement scenarios were introduced for each one of the six archetypes.
- Two energy demand reduction technologies were selected for the models, mechanical ventilation heat recovery (MVHR) and waste water heat recovery systems (WWHR).
- Two services options were selected for the modelling. These included gas boiler and air source heat pump (ASHP) systems.
- Photovoltaics were used as a proxy for renewable electricity generation on site.
- More than 300 models were selected to be assessed using SAP 2012 – through combinations of all of the above parameters for energy and carbon performance assessment.
- All options selected for the improvement of the six archetypes are considered as technically feasible and potentially cost-effective.

3.1 Development of the domestic archetypes – sizes and typologies

New domestic buildings performance, in terms of energy and carbon, were analysed using SAP 2012. The six archetypes produced were based on preliminary analysis conducted on representative regional housing typologies (across the ten Greater Manchester districts).

3.1.1 Archetype typologies

Housing models were developed based on prevailing housing typologies within Greater Manchester. The following information was extracted and utilised for the construction of the new domestic building archetypes:

- 93% of the domestic buildings in Greater Manchester fall within one of the following categories: flats, detached, terraced and semi-detached housing properties.
- The majority of domestic buildings within Greater Manchester consist of two- to three-bedroom properties.
- Floor areas of typical domestic buildings were not readily available, but such information was extracted by sampling recent new domestic development planning applications within the ten districts.

Table 3 shows the number of archetypes developed and agreed for modelling by the GMCA.

Table 3 - New domestic buildings – typologies selected for modelling

Archetype	**Number of bedrooms**	**Number of storeys**	**Construction**
Detached house	4	2	Traditional
End-terrace house	3	2	Traditional
Mid-terrace house	3	2	Traditional
Small flat	1	1	Traditional/high rise
Large flat	2	1	Traditional/high rise
End-terrace townhouse	3	3	Traditional

3.1.2 Floor areas in domestic models

Nationally prescribed minimum gross internal floor areas, in conjunction with information extracted from planning applications of recent developments within Greater Manchester, were used to identify appropriate floor areas for the selected archetype models (Table 4).

All data sets were used in conjunction with work undertaken by Currie & Brown on producing archetypes for the Approved Document L of the Building Regulations to finalise the geometric characteristics of the domestic models. The following floor areas were selected for the six (6) archetypes.

Table 4 - Floor areas of selected new domestic buildings archetypes

Archetype	**Number of bedrooms**	**Number of storeys**	**Gross internal floor area (m^2)**
Detached house	4	2	117
End-terrace house	3	2	84
Mid-terrace house	3	2	84
End-terrace townhouse	3	3	90
Small flat – midfloor	1	1	43
Large flat – midfloor	2	1	70

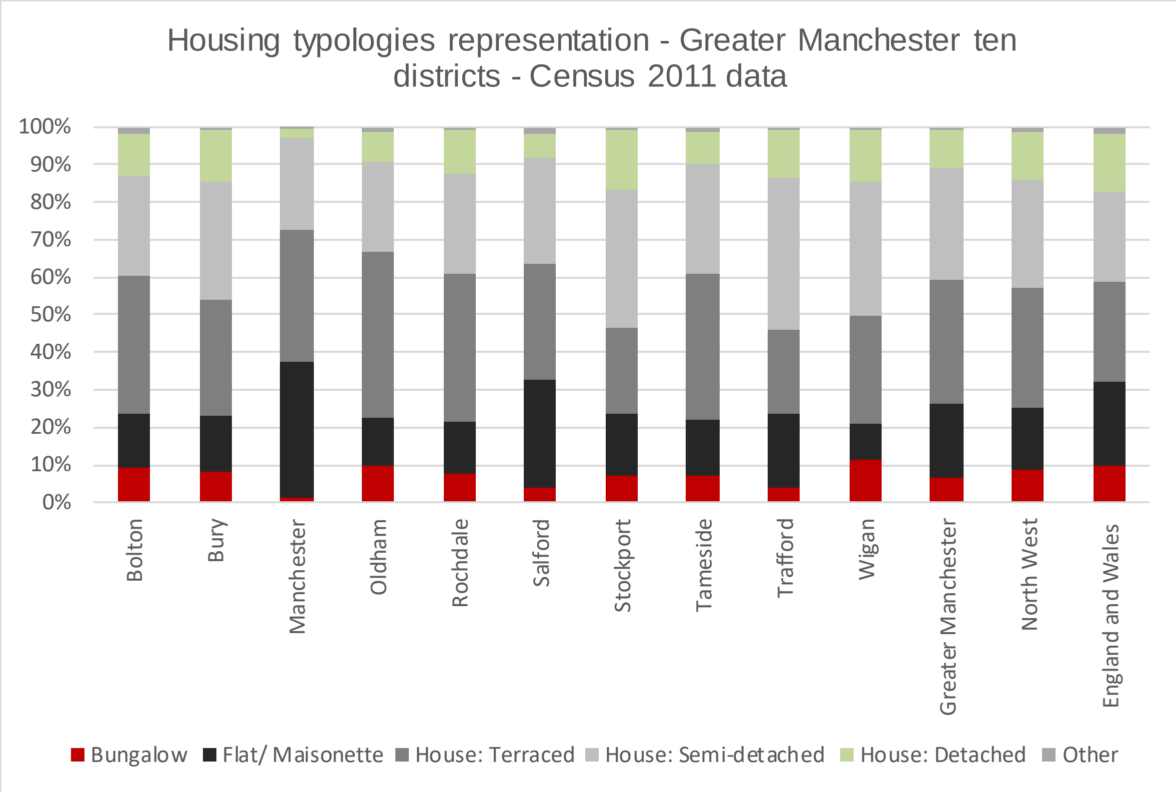


Figure 5 - Housing typologies and sizes - representation within Greater Manchester

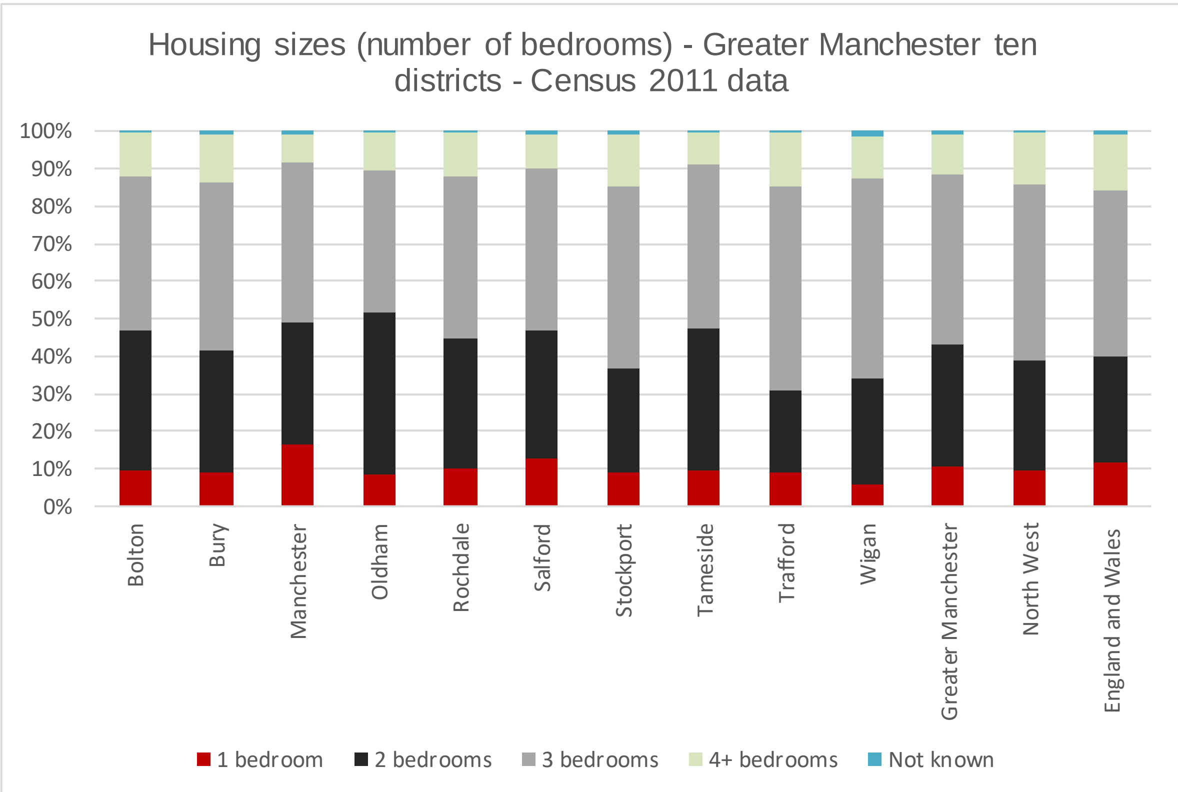


Figure 6 - Selected archetypes floor areas - supportive information

Minimum space national requirements for domestic buildings

Number of bedrooms (b)	Number of bed spaces (persons)	1 storey dwellings	2 storey dwellings	3 storey dwellings
1b	1p	39		
	2p	50	58	
2b	3p	61	70	
	4p	70	79	
3b	4p	74	84	90
	5p	86	93	99
	6p	95	102	108
4b	5p	90	97	103
	6p	99	106	112
	7p	108	115	121
	8p	117	124	130
5b	6p	103	110	116
	7p	112	119	125
	8p	121	128	134
6b	7p	116	123	129
	8p	125	132	138

Technical Housing Standards – nationally described space standard, March 2015

Department for Communities and Local Government

Space standards used within GM districts

- Oldham, Bury, Salford, Trafford, Stockport, Manchester
- 3-4 planning applications per area
- Size of new developments ranging from 10s to 100s of new houses
- All building typologies represented
- Average floor areas calculated
- Actual and common compliance fabric and services specifications identified
- High-rise examples provided

Evaluation of floor areas and designs used within the domestic building modelling work were cross-checked against real life projects within Greater Manchester. Information on planning application numbers was provided by the Greater Manchester Combined Authority project manager.

3.1.3 The Standard Assessment Procedure and the new Part L 2020 changes

The research work included the modelling of new domestic building typologies through the usage of the government-approved Standard Assessment Procedure (SAP). At the time of the report writing the version of SAP used for compliance purposes was SAP 2012.

An interim SAP specification (SAP10) was released by BRE during July 2018. It included proposed changes within the methodology as well as an update in terms of primary energy and fuel carbon factors in light of new evidence produced relating to the decarbonisation of the electricity grid.

Furthermore, on 1 October 2019 a new SAP specification was released, SAP10.1, by BRE. Additional proposed changes were introduced, which included a further modification of the carbon intensity factors in reference to the electricity grid.

On the same date (1 October 2019) the *Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings* (FHS) consultation document was released from the Ministry of Housing, Communities and Local Government (MHCLG). Guidance for non-domestic buildings was not released at the time of the report writing.

Critical elements within the new consultation document include the following[51]:

- An expectation that an average home built to the Future Homes Standard 2025 will have 75 - 80% less carbon emissions than one built to current energy efficiency requirements (Approved Document L 2013).
- An intention to make new homes more energy efficient and to future-proof them in readiness for low-carbon heating systems.
- An interim uplift in terms of energy efficiency standards and requirements for new homes, through a new Part L 2020 containing two potential options:
  - Option 1: 20% reduction in carbon emissions compared to the current standard for an average home. This could[52] be delivered by very high

[51] Extracted from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835536/Future_Homes_Standard_Consultation_Oct_2019.pdf
[52] It would be possible to meet these standards via other solutions, for example, through the introduction of an ASHP and without improvements in energy efficiency.

fabric standards (typically with triple glazing and minimal heat loss from walls, ceilings and roofs).

- Option 2: 31% reduction in carbon emissions compared to the current standard. This could[52] be delivered based on the installation of carbon-saving technology such as photovoltaic (solar) panels and better fabric standards, though not as high as in option 1 (typically double not triple glazing).

Other recommended changes include simplification of the language, structure and presentation of the Approved Document L and F of the Building Regulations and changes within the transitional arrangements for compliance purposes of new developments.

The possible Future Homes Standard (2025) has the potential to support GMCA with meeting the 2028 new development targets. This is mainly due to the level of carbon emissions reductions expected to be achieved in the construction of new homes. No additional information is provided in terms of the performance of non-domestic construction projects.

What needs to be noted is that the Building Regulations address only the 'regulated' carbon emissions. The FHS in that sense is not expected to address whole-life carbon requirements. Furthermore, it is unclear if minimum renewable energy generation thresholds will be introduced.

3.1.4 The carbon emissions ($CO2_e$) metric effect – conceptualising results

Energy demand from new buildings is converted into $CO2_e$ (CO2 equivalents) through the usage of appropriate factors (commonly referred to as carbon factors).

These derive from government predictions in terms of the carbon intensity of various fuel mixes and the carbon intensity of the electricity grid.

In fact, while carbon emissions are predicted based on energy requirements, this is not necessarily true the other way around. Predicted carbon emissions cannot provide enough information in terms of energy efficiency or energy demand reductions achieved by a building.

This can be easily demonstrated by using the following two examples:

- If a building was to consume the amount of energy required to run 20 houses but all the energy used was from a renewable/carbon-free energy source the carbon emissions during operation of that building would be predicted to be zero.
- If a new domestic building was to use substantially less energy than an all-electric house but the energy source used was gas, then in terms of carbon emissions it would perform worse that the more energy-demanding all-electric house.

As Figure 7 demonstrates, the carbon intensity of the electricity grid has recently decreased and will continue to decrease moving forward. Data presented derived from:

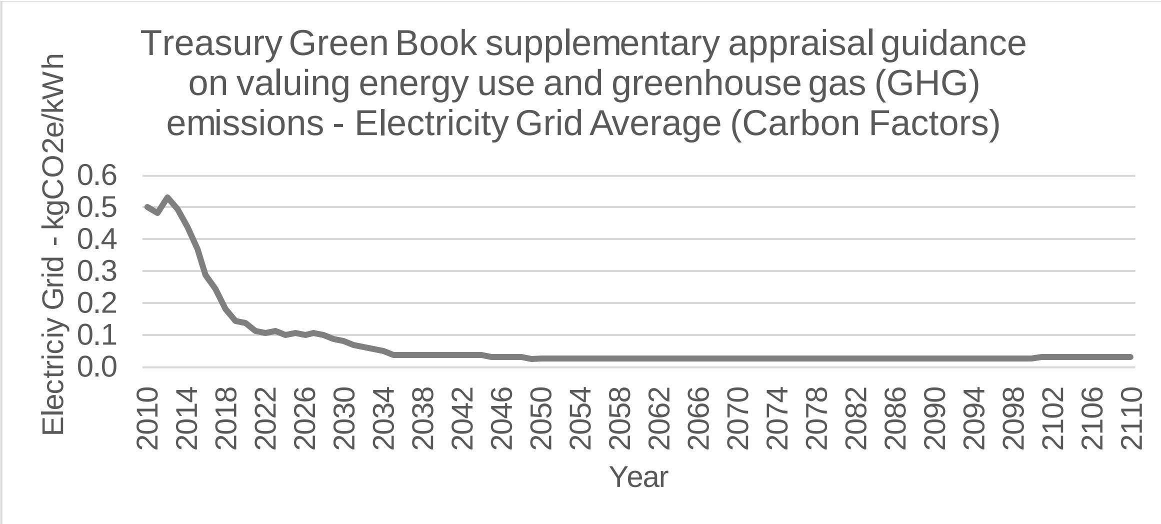
- Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions - Electricity Grid Average: showing year by year the predicted carbon intensity of the electricity grid.
- The Standard Assessment Procedure historic and future forecasts of the carbon intensity of the electricity grid – running up to 2035[53].

In Table 5 the history and the predicted carbon performance of the gas network is provided.

If current predictions in terms of the carbon intensity of the electricity grid are accurate, then by the end of 2035 a house constructed today utilising only electricity will perform almost 50% better in terms of carbon, even if the exact amount of energy is still required to run the building at that time.

Figure 9 to Figure 11 provide information on minimum fabric and services performance parameters as shown within the new Part L consultation document.

[53] Emissions predictions for 2025-2035 were supplied by the BRE



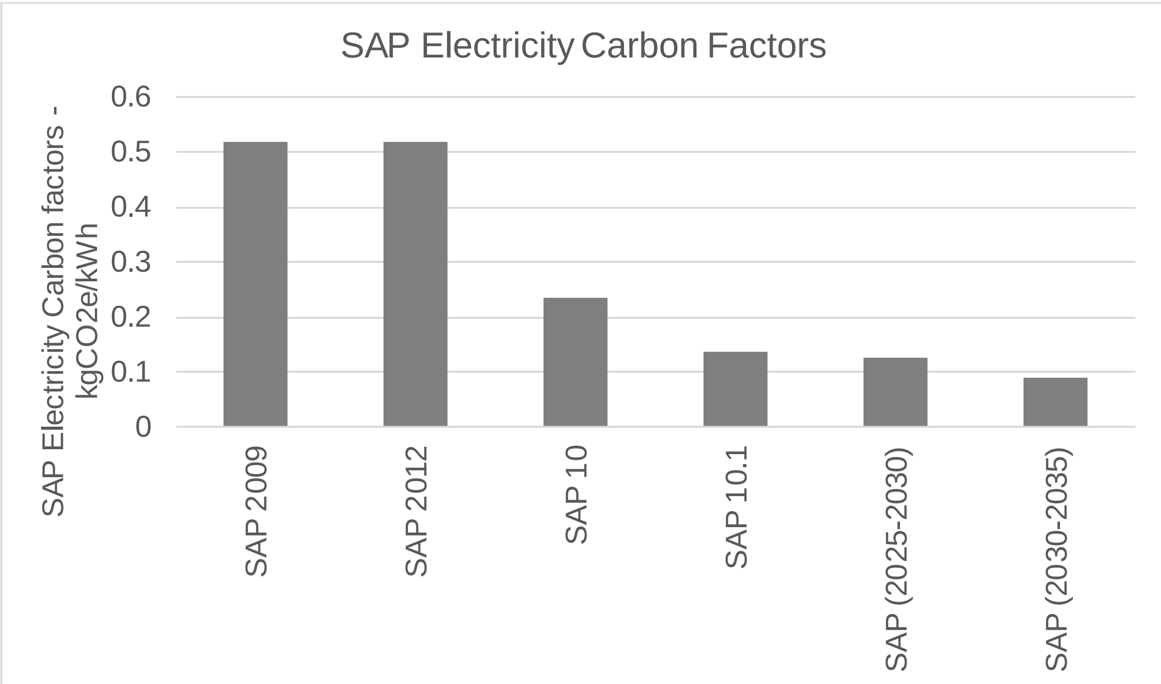


Figure 7 - Electricity carbon factors

Table 5 - SAP current and future carbon factors - gas

$kgCO_{2e}/kWh$	SAP 2005	SAP 2009	SAP 2012	SAP 10	SAP 10.1	SAP (2025-2035)
Gas (Grid)	0.194	0.198	0.216	0.21	0.21	Likely 0.21

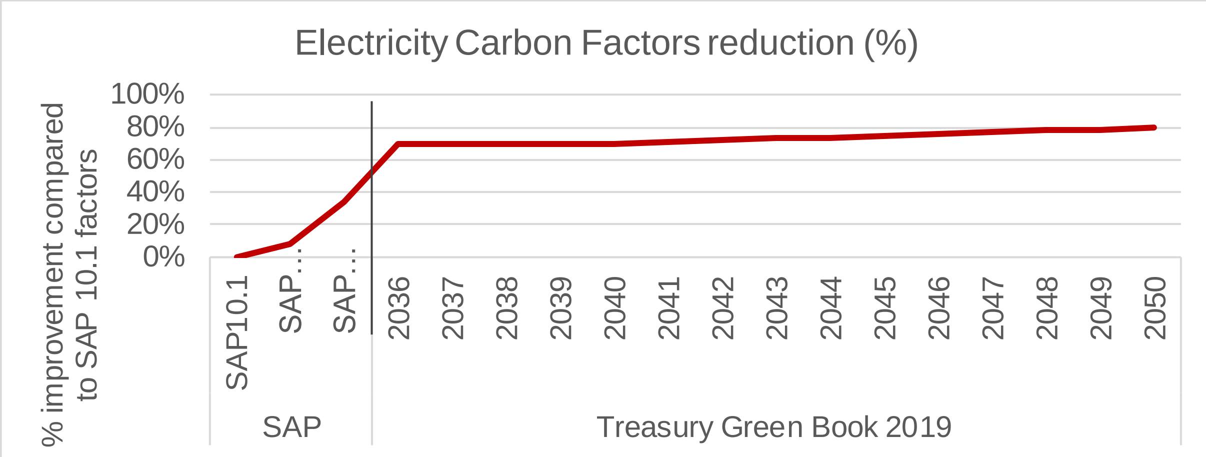


Figure 8 - Reductions in carbon emissions from the electricity grid -% of change

Table 2 Limiting fabric parameters

Roof	0.20 W/(m²·K)
Wall	0.30 W/(m²·K)
Floor	0.25 W/(m²·K)
Party wall	0.20 W/(m²·K)
Swimming pool basin[1]	0.25 W/(m²·K)
Windows, roof windows, glazed roof-lights[2], curtain walling and pedestrian doors	2.00 W/(m²·K)
Air permeability	10.0 m³/(h·m²) at 50 Pa

Notes:

1. Where a swimming pool is constructed as part of a new building, reasonable provision should be made to limit heat loss from the pool basin by achieving a U-value no worse than 0.25 W/(m²·K) as calculated according to BS EN ISO 13370.
2. For the purposes of checking compliance with the limiting fabric values for roof-lights, the true U-value based on aperture area can be converted to the U-value based on the developed area of the roof-light. Further guidance on evaluating the U-value of out-of-plane roof-lights is given in *Assessment of thermal performance of out-of-plane rooflights*, NARM Technical Document NTD 2 (2010).

Figure 9 - Part L 2013 - Minimum fabric performance parameters

Table 3.1 - Minimum standards for fabric performance	
External walls	0.26 W/m².K
Party walls	0.20 W/m².K
Floor	0.18 W/m².K
Roof	0.16 W/m².K
Windows	1.6 W/m².K
Roof-lights[1]	2.2 W/m².K
Door	1.6 W/m².K
Air permeability	8m³/m².K at 50Pa

[1] The U-value of upstands and builders' kerbs is subject to the limiting U-value for external walls.

Figure 10 - Part L 2020 - Consultation documents proposed minimum fabric performance parameters

Table 3.2: Proposed revisions to minimum building services efficiencies and controls for new dwellings			
Application	**Current Part L 2013 standard**	**Proposed Part L 2020 standard**	**Comments**
Gas boiler efficiency	88% SEDBUK 2009	92% ErP	Consistent with Boiler Plus measures for existing dwellings
Heat pump efficiency	SCOP 'D' if ≤12kW COP 2.5	SCOP 2.80	Consistent with Ecodesign standard
Comfort cooling efficiency	EER 2.4 (air cooled) EER 2.5 (water cooled)	SEER 3.87	Consistent with Ecodesign standard
Lighting	45 lamp lumens per circuit-watt	60 lamp lumens per circuit-watt	Uplift to reflect common practice

Figure 11 - Part L 2020 - Consultation documents proposed building services efficiencies and controls

3.2 Development of the domestic archetypes – energy performance specifications

In order to assess the impact of the energy hierarchy on the new domestic archetypes' baseline energy and carbon performance (Part L 2013 compliant), a series of 'improved performance' scenarios were developed for each one of them.

This included a stepped improvement in terms of fabric performance (against a Part L 2013 notional model), two different options in terms of installed services provisions (gas boiler and an all-electric air source heat pump), two options of heat recovery (MVHR, WWHR) and renewable energy generation through the use of PV.

More than 300 models – variations of the six archetypes - were produced and analysed.

The fabric specifications used in each one of the archetypes were modified to reflect a range of advanced fabric performances. These included:

- Three naturally ventilated models
- Four mechanically ventilated models

The naturally ventilated models commonly referred to as N1 to N3 models in the report follow a stepped improvement with N3 getting close to Passivhaus standards in terms of levels of insulation and thermal performance of windows achieved.

The mechanically ventilated models commonly referred to as M1 to M3 and 'Very High' also follow the same improved fabric stepped approach.

The main differences when compared to the naturally ventilated models include the high airtightness levels achieved in all mechanically ventilated models and the use of mechanical ventilation heat recovery systems (MVHR).

The ‘Very High’ model is separated from the other mechanical models as its specification competes with, and exceeds in occasions, the fabric specifications commonly used in Passivhaus projects. It needs to be noted that M3 is also very close to the Passivhaus standard specifications.

In all cases, the solutions utilised to improve the performance of the thermal envelope (fabric) were deemed technically feasible and not ‘uncommon’ by the researchers.

It is recognised that high levels of airtightness would require specific provisions in terms of sequencing of works on site, detailed design elements and special care provided on site (skills and knowledge applying).

The specifications used in terms of thermal bridging, elemental U-values and airtightness levels in all archetypes are provided in detail in Tables 7 and 8 below. Energy-efficient lighting was used in all models.

Table 6 - Archetypes - fabric performance classification

Archetype Code	Description
N1	Naturally ventilated house/flat – small improvement of fabric performance compared to Part L 2013 minimum requirements
N2	Naturally ventilated house/flat – medium improvement of fabric performance compared to Part L 2013 minimum requirements
N3	Naturally ventilated house/flat – high improvement on fabric performance compared to Part L 2013 minimum requirements (close to a Passivhaus fabric performance)
M1	Mechanically ventilated house/flat – small improvement on fabric performance compared to Part L 2013 minimum requirements, high airtightness and installed mechanical ventilation heat recovery system (MVHR)
M2	Mechanically ventilated house/flat – medium improvement on fabric performance compared to Part L 2013 minimum requirements, high airtightness and MVHR
M3	Mechanically ventilated house/flat – high improvement on fabric performance compared to Part L 2013 minimum requirements (close to Passivhaus), Passivhaus airtightness levels and MVHR
Very High	Mechanically ventilated house/flat – extreme improvement on fabric performance compared to Part L 2013 minimum requirements - Passivhaus airtightness and MVHR – potentially exceeding Passivhaus performance

Table 7 - Domestic building archetypes – thermal bridging

Thermal bridging (Y-value)	Part L 2013 Notional	N1 and M1	N2 and M2	N3 and M3	Very High
Detached House	0.048	0.045	0.040	0.035	0.025
End-terrace House	0.057	0.050	0.045	0.040	0.030
Mid-terrace House	0.068	0.065	0.060	0.055	0.030
End-terrace Townhouse	0.070	0.060	0.050	0.035	0.025
Small flat – Midfloor (TM)	0.083	0.125	0.105	0.085	0.050
Large Flat – Midfloor (TM)	0.087	0.115	0.105	0.095	0.050

Table 8 - Domestic buildings archetype fabric specifications

U-Values (W/m².K) Airtightness (m³/h.m² @50pa)			Natural ventilation			Mechanical ventilation			
	Element	Part L 2013 Notional	N1	N2	N3	M1	M2	M3	Very High
Detached house	External wall	0.18	0.18	0.15	0.12	0.18	0.15	0.12	0.095
	Ground floor	0.13	0.13	0.12	0.11	0.13	0.12	0.11	0.076
	Roof	0.13	0.11	0.09	0.09	0.11	0.09	0.09	0.074
	Door	1.20	1.20	1.10	1.00	1.20	1.10	1.00	1.00
	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5
End-terrace house	External wall	0.18	0.18	0.15	0.12	0.18	0.15	0.12	0.095
	Ground floor	0.13	0.15	0.13	0.11	0.15	0.13	0.11	0.076
	Roof	0.13	0.11	0.09	0.09	0.11	0.09	0.09	0.074
	Door	1.20	1.20	1.10	1.00	1.20	1.10	1.00	1.00
	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5
Mid-terrace house	External wall	0.18	0.18	0.15	0.12	0.18	0.15	0.12	0.095
	Ground floor	0.13	0.15	0.13	0.11	0.15	0.13	0.11	0.076
	Roof	0.13	0.11	0.09	0.09	0.11	0.09	0.09	0.074
	Door	1.20	1.20	1.10	1.00	1.20	1.10	1.00	1.00

	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5
End-terrace townhouse	External wall	0.18	0.17	0.15	0.12	0.17	0.15	0.12	0.09 5
	Ground floor	0.13	0.14	0.13	0.11	0.14	0.13	0.11	0.07 6
	Roof	0.13	0.11	0.09	0.09	0.11	0.09	0.09	0.07 4
	Door	1.20	1.20	1.10	1.00	1.20	1.10	1.00	1.00
	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5
Small flat – midfloor (TM)	External wall	0.18	0.18	0.15	0.12	0.18	0.15	0.12	0.09 5
	Walls to corridor	0.18	0.21	0.18	0.15	0.21	0.18	0.15	0.12
	Door	1.20	1.20	1.00	0.80	1.20	1.00	0.80	1.00
	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5
Large flat – midfloor (TM)	External wall	0.18	0.18	0.15	0.12	0.18	0.15	0.12	0.09 5
	Walls to corridor	0.18	0.21	0.18	0.15	0.21	0.18	0.15	0.12
	Door	1.20	1.20	1.10	1.00	1.20	1.10	1.00	1.00
	Windows	1.40	1.30	1.00	0.80	1.30	1.00	0.80	0.80
	Airtightness	5	5	4	4	3	3	1	0.5

3.3 New domestic buildings – energy types

3.3.1 Energy demand types – regulated and operational unregulated energy demand analysis

The GMSF current energy and carbon policy (19% DER/TER Part L 2013) includes regulated energy only. Regulated energy is the one currently assessed against legal Part L compliance requirements.

- **Regulated energy use**: Part L considered energy use and associated carbon emissions. This currently includes heating, generation of domestic hot water (DHW), installed services energy requirements (including ventilation) and fixed lighting.

- **Operational unregulated energy use**: Occupant lifestyle-based energy demand predictions as produced currently by SAP 2012. Referred to commonly as plug-loads.

Both types of energy demand were estimated and considered within the new domestic buildings' archetype models.

Technically feasible solutions were assigned to the archetype models to address the energy requirements.

The models used include both passive and active technologies and systems to reduce energy demand.

Figure 12 measures refer to energy demand reduction provisions.

Energy demand	Energy needed for	Measures to reduce energy consumption
Regulated	Heating	Fabric performance Energy recovery ventilation (MVHR) Increased efficiency of services
	Domestic Hot Water generation (DHW)	Waste water heat recovery (WWHR) Photovoltaic/solar panels and thermal store Increased efficiency of services
	Installed lighting systems	Energy-efficient lighting
Operational unregulated	User Appliances	Better-rated appliances User behaviour change

Figure 12 - Regulated and operational unregulated energy demand reduction approaches

4. New domestic buildings archetypes - energy demand

Key findings:

4.1 Space heating and DHW requirements (no services efficiency considered)

4.2 Energy-efficient services, impact on space heating and DHW energy demand

4.3 Operational unregulated energy demand

- The energy hierarchy provides a non-prescriptive optimised preferred approach that delivers a net-zero carbon development from 2028.
- Space heating demand reduction was demonstrated through the introduction of advanced fabric specification including both natural ventilation and mechanical ventilation options.
- SAP 2012 Box 98 space heating demand requirements indicated the performance of the new domestic buildings in terms of required energy for space heating excluding the contribution of the efficiency of the heating services installed (fabric only).
- Domestic hot water (DHW) generation demand only relied on occupancy levels and generation services efficiencies (heat pumps).
- The introduction of highly energy-efficient services, eg heat pumps in combination with passive heat recovery systems (waste water heat recovery systems) can contribute to DHW energy demand reductions.
- Operational unregulated energy demand does not rely on building standards but occupant preferences and can only be offset utilising on-site energy generation means (such as PV).

Recommendations:

- Consider the introduction of requirements referring to space heating demands as assessed prior to considering the efficiency of services providing the heating.
- Space heating demand thresholds of 30 kWh/m^2 for houses and 25 kWh/m^2 for flats per year would be easily achievable in most instances by using an N2/N3 natural ventilation fabric specification or an M2/3 mechanically ventilated fabric specification (MVHR included). The thresholds can be reassessed and reduced in 2025 and be tightened to 20 kWh/m^2 for houses and 15 kWh/m^2 for flats (achieved through an M2/3 mechanically ventilated fabric specification, no naturally ventilated solutions).
- Domestic hot water energy demand from the grid can be reduced to 15 kWh/m^2 per year (houses and large flat) and 20kWh/m^2 per year (smaller flat) by utilising an energy-efficient DHW generating system such as an ASHP and WWHR systems.
- Complete operational unregulated energy use and carbon offsetting through the utilisation of PV might not be feasible on top of additional requirements for energy generation through PV on site. Depending on energy generation requirements, consider the inclusion of operational unregulated energy use to the target upon the introduction of the Future Homes Standard to ensure alignment with current policy requirements and the option to offset through the Carbon Offset Funds.

4.1 Space heating and DHW requirements (no services efficiency considered)

4.1.1 Regulated energy demand (space heating)

The space heating demand requirement was calculated for all models and all archetypes. SAP 2012 version was used for these predictions.

The results of the impact of the advanced fabric standards on space heating requirements, when solar and internal gains are considered, along with the impact of the ventilation systems is shown in Figure 13.

All models achieved space heating levels of < 15kWh/m^2.year when the M3 fabric specification was utilised. In terms of the Very High fabric specification, this led to even greater reductions in space heating energy demand of <10 kWh/m^2.year.

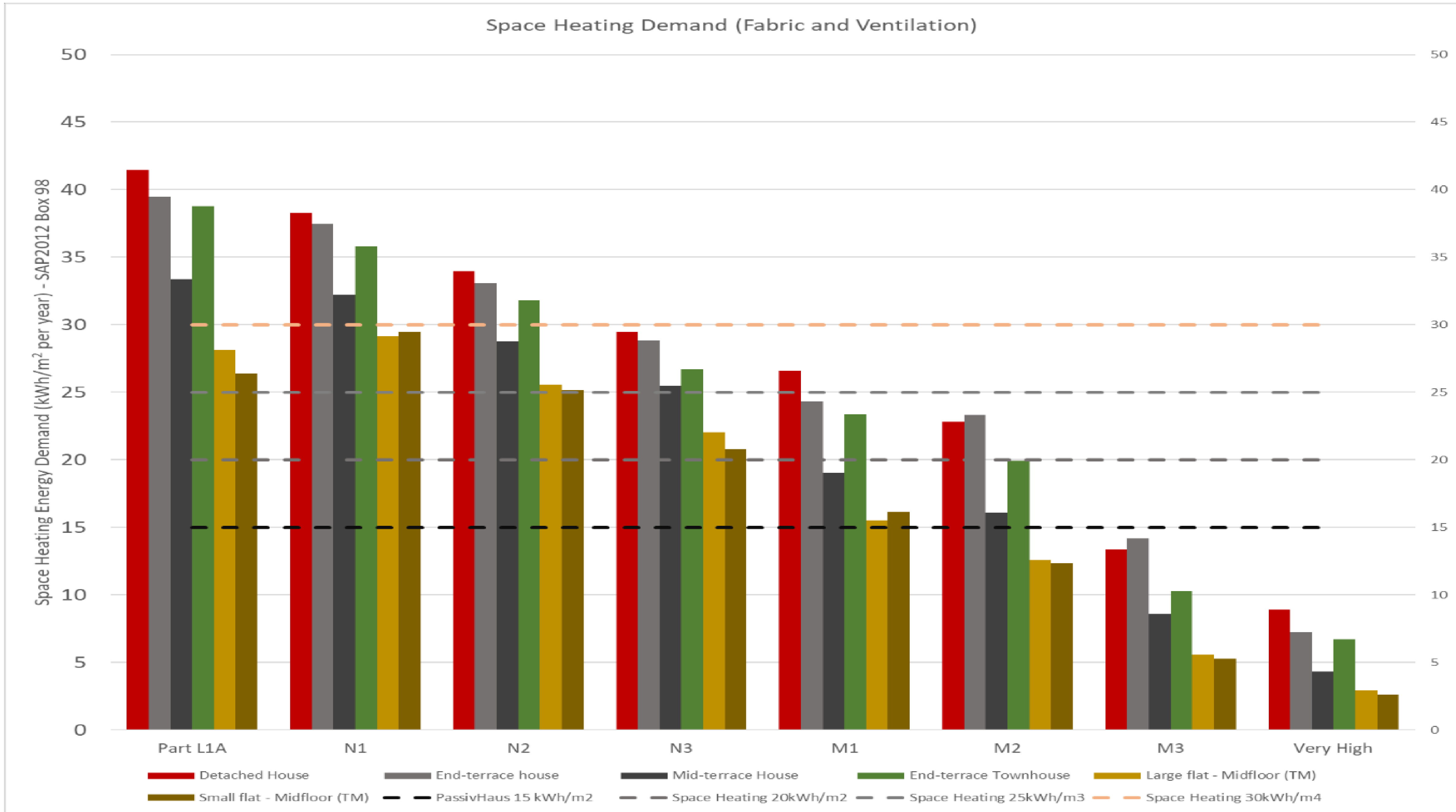


Figure 13 - Space Heating Demand (kWh/m2.year) – SAP 2012 Box 98

SAP Box 98: The 'useful' energy required from the heating system each month is calculated from internal and external temperatures and the heat transfer coefficient allowing for internal and solar gains. Totalled over one year this quantity is known as the dwelling's space heating requirement and is calculated at SAP worksheet Box 98. [54]

[54] The Government's Standard Assessment Procedure for Energy Rating of Dwellings, Version 10.1 https://www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-10-10-2019.pdf

As the fabric specifications improved, a big portion of the regulated energy consumption was attributed to domestic hot water (DHW) generation requirements (Table 9).

Table 9 - DHW demand – services efficiencies not included (includes distribution and storages loss calculations)

Occupancy	SAP 2012 (people)	DHW (l/day)	Floor areas (m^2)	DHW (kWh/year)	DHW (kWh pp.year)	DHW (kWh /m^2. Year)
Detached house	2.85	101.9	117	2161	758	18
End-terrace house	2.54	94.5	84	1626	640	19
Mid-terrace house	2.54	94.5	84	1626	640	19
End-terrace townhouse	2.62	96.4	90	2103	803	23
Small flat – midfloor	1.48	69.5	43	1232	832	29
Large flat – midfloor	2.25	87.6	70	1517	674	22

4.2 Energy-efficient services, impact on space heating and DHW energy demand

All models were assigned and assessed using two different energy delivery systems in terms of supplying space heating and DHW requirements. These included the utilisation of a gas boiler system (SEDBUK 89.1%) and an air source heat pump (ASHP) with a coefficient of performance 2.5 (COP 2.5).

The efficiency of the services used will dictate energy demand required from the gas and electricity grids.

The energy demand reduction as calculated for the same detached house archetype using different services to supply space heating and DHW to the property is shown in Table 10.

Table 10 – Detached house -Part L 2013 model - boiler and ASHP grid energy demand

kWh/year	Space heating	DHW generation	Pumps and fans	Lighting	Total gas	Total electricity	Total energy
Part L 2013 boiler 89.5%	5179	2578	75	443	7757	518	8275
Model (actual) boiler – 89.1%	5189	2555	75	443	7744	518	8262
Model (actual) ASHP (LT COP2.5)	2816	1271	30	443	-	4560	4560

The utilisation of a very energy-efficient service as in the case of the ASHP, compared to the use of a boiler led to a grid energy demand reduction of almost 45%.

Main impacts in terms of utilising an ASHP instead of a boiler:

- Reduction in the energy required from the grid to deliver the space heating.
- Reduction in the energy required from the grid to deliver the DHW.
- Reduction in the energy required from the grid in terms of pumps and fans.
- All the **energy required from the grid switched to electricity**.

It needs to be noted that the price of electricity moving forward is predicted to be on average almost four times higher per kWh than gas.

4.2.1 Heat recovery systems – MVHR and WWHR

Both MVHR and WWHR systems were utilised in the models.

MVHR systems can be applied to domestic buildings meeting high airtightness standards (< $3m^3/m^2h$ @50Pa, present in all M-fabric specification and almost a default option for 'Very High' standards).

MVHR energy demand reduction is achieved through an 'energy needed for heating' reduction. As MVHR systems are embedded, they are considered as part of the fabric option.

While the space heating energy demand reductions due to the effect of the MVHR systems was already included within the mechanically ventilated models results, this was not true for the WWHR.

WWHR can be installed in main and en-suite bathrooms. The energy demand reduction is achieved through an 'energy needed for DHW' reduction.

- The use of the ASHP led to a DHW grid energy demand reduction of 35-50%.
- The use of a WWHR system in all models provided an additional 10-20% DHW grid energy demand savings.

4.2.2 Renewable heat and renewable energy generation

Renewable energy contributions to the energy and carbon performance of the models were considered both in the sense of renewable heat generation, through the utilisation of heat pumps, as well as renewable energy generation (electricity) through the use of PV.

The impact of both elements was reviewed within the context of regulated and operational unregulated energy demand.

It needs to be clarified that the use of renewable energy technologies does not necessarily associate with impact on the buildings' energy demand. In the case of electricity generation, as achieved for example through the installation of PV systems, the energy generated offsets the energy that would have been used from the grid to cover for the particular need.

In the case of ASHP, the renewable heat generated is calculated based on COP of the heat pump. As this is more than 100%, 1 unit of electricity produces x amounts of heat (>1).

It is that difference (COP-1) produced for the sake of the RHI that is the potential domestic renewable heat generation.

While this is a method commonly used to identify the carbon impact contributions of the ASHP to the final as-built, from an energy demand perspective, the impact of utilising an ASHP is already considered in the models in the sense of a space heating and DHW energy demand reduction, but not within the concept of renewable heat generation.

- Renewable electricity generation (PV) is dissociated from the performance of the building, and as discussed later should be disassociated in terms of policy requirements in the form of DER/TER Merton Rule types. While it will be accounted within potential carbon savings it should be set apart as a minimum energy generation requirement.
- Heat pumps contribution to renewable energy/heat generation can be accounted in the sense of energy/carbon savings. Avoiding a DER/TER Merton type of rule will allow for more appropriate evaluation of energy generation.

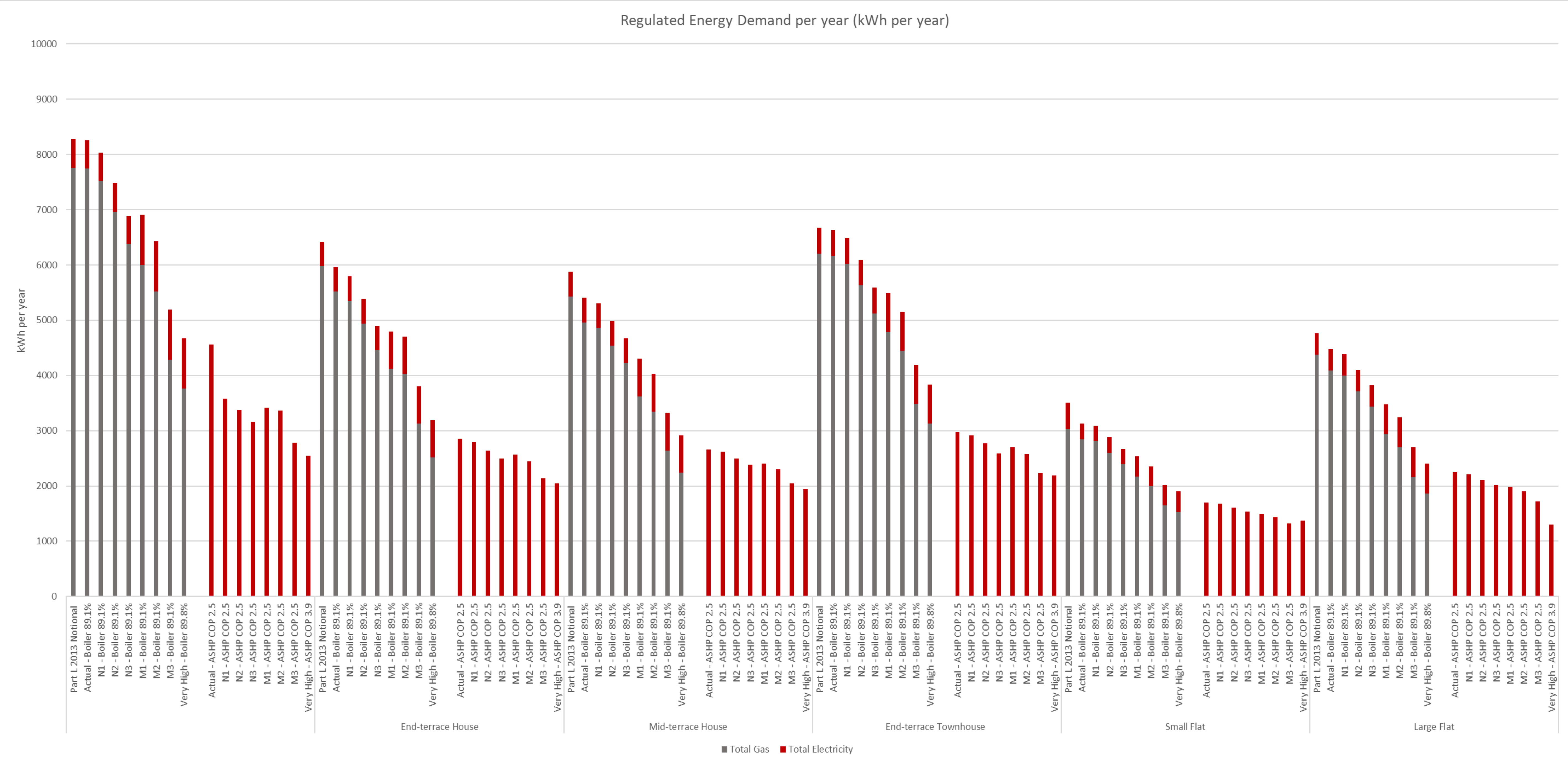


Figure 14 - Annual regulated energy demand - archetype models

4.3 Operational unregulated energy demand

The operational unregulated energy demand, for all different new domestic building archetypes was predicted by utilising SAP guidance.

Table 11 – Operational unregulated energy demand and PV generation

Unregulated energy (SAP 2012)	Cooking (kWh/m^2 per year)	Appliances (kWh/m^2 per year)	Total per year (kWh/m^2 per year)	Total per year (kWh per year)	PV required to offset energy demand (kWp)	PV required to offset energy demand (% of floor area)
Detached house	7.4	27.5	34.9	4079	4.7	59%
End-terrace house	9.9	30.9	40.8	3428	4.0	69%
Mid-terrace house	9.9	30.9	40.8	3428	4.0	69%
End-terrace townhouse	9.4	30.4	39.8	3579	4.1	101%
Small flat – midfloor	16.7	34.3	51	2191	2.5	43%[55]
Large flat – midfloor	11.6	32.2	43.8	3063	3.5	37%[55]

In terms of accuracy of operational unregulated energy demand predictions produced, information extracted from the Energy Follow-Up Survey 2011[56] appeared to be in agreement with SAP estimates.

[55] Note that the available roof area per flat will diminish as the number of stores increases, therefore for the small/large flat options modelled there would be insufficient roof space for the necessary PV if the block was more than two storeys.
[56] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/274778/9_Domestic_applianc

'*The median electricity consumption of the data is 3,914 kWh/year (mean = 4,628 kWh/year). Analysis of the data shows that around 30% of homes consume between +/- 10% of the median*.'

'*Electricity is the dominant fuel used in ovens (almost 70% of households with ovens have electric ovens and just under 30% have gas ovens). For hobs, the prevalence of fuels is reversed with gas being the dominant fuel (38% of households have electric hobs, whereas 61% have gas hobs).*'

Unregulated energy demand was on average almost 50% more than the energy required for DHW generation. In terms of demand per m^2 it was also similar to the space heating demand prior to adapting the models to higher fabric specifications.

It needs to be noted that while the carbon emissions from cooking are calculated within SAP 2012 using a function of occupancy and total floor area variables, the emissions calculated are not assigned to a specific fuel type used.

For the generation of the cooking energy demand within the research work, the predicted carbon emissions were converted to energy demand by utilising the gas carbon emission factors.

An all-electric unregulated energy demand would require the same amount of energy generation from a PV installation in order to offset all associated emissions. It became apparent that all electric housing will require an additional installation of 2.5-5kWhp PV (18-37m^2) to cover the operational unregulated energy use of the different archetypes.

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New domestic buildings archetypes - carbon emissions

5.1 Energy demand and carbon performance of the models

Key findings:

5.1 Energy demand and carbon performance of the models

5.2 Models predicted carbon emissions

5.3 Renewable energy impact on predicted carbon emissions

- The 20 and 31% DER/TER improvement targets over the Part L 2013 baseline were achieved by almost all models utilising N2, N3, M1, M2 and M3 fabric specifications and a gas boiler even without the use of PV.
- All the models that utilised an ASHP met the Part L 2020 target irrespective of the fabric specifications used (even minimum Part L 2013 fabric specification complied).
- Heat pumps impact on carbon emissions reductions was significant as the model's performance was compared against the Part L 2013 notional building which utilises a gas boiler as the main energy source. Being all electric, heat pumps hugely benefited from the reduced carbon emissions of the electricity grid. Energy demand reductions were also achieved because of the heat pumps embedded increased efficiency.
- Because of the ever-decreasing carbon intensity of the electricity grid, the contribution of renewables to carbon reductions depended on the technology used.
- Heat pumps energy displacement and energy savings due to their increased efficiency are compared to the energy requirements of a gas-based solution (the Part L 2013 notional building), and therefore the carbon savings could be overestimated as the gas carbon factors are used (energy displacement – gas).
- PV energy generation displaces electricity energy demand of the models, to which case the electricity carbon emission factors are used to estimate the impact of PV onto predicted model carbon emissions. This means that from a carbon emissions perspective, the renewable energy contribution to

predicted carbon emissions reductions would constantly reduce when another fuel is also used in the model and remain constant in terms of models utilising all electric solutions.

Recommendations:

- While carbon emissions are a recognised metric for assessing the environmental impact of new buildings, it is recommended that predicted energy demand is also utilised as part of the GMSF carbon and energy policy.
- A potential carbon performance improvement requirement from renewable and low-carbon energy solutions might become challenging to satisfy through the usage of PV due to the ever-decreasing carbon intensity of the electricity grid. Pending confirmation on how this assessment will be conducted through the introduction of the new Part L 2020 and associated SAP, a target based on energy generation or amount of energy displacement could be a better proxy to enable further PV installations.
- A potential introduction of a 20% PV coverage of roof space of domestic buildings during 2020-2025 as a minimum, tightened to 40% for 2025-2028 can be considered. It needs to be noted that in the case of high-rise and flats the contributions to the overall block energy consumption will be much smaller when compared to houses.

5.2 Models predicted carbon emissions

All archetype models assessed in terms of carbon performance were reviewed utilising the expected carbon factors at the time of the policy implementation.

SAP10.1 factors (expected for Part L 2020) were used to cover the 2020-2025 period. Carbon performance was compared against a Part L 2013 new domestic building built to the minimum requirements.

The assessment of compliance with the Future Homes Standard 2025 was done using the SAP 2025-2030 carbon emission factors.

All results are shown in Table 12.

	Light green indicates those options meeting Part L 2020 consultation Option 1 (20% improvement)
	Darker green indicates those options meeting Part L 2020 consultation Option 2 (31% improvement)
	Grey indicates options compliant with the target performance range for the FHS (~70-80% improvement)

- The majority of the naturally ventilated models met the 20% improvement standard utilising the N2 and above specification and a gas boiler.

- The majority of the naturally ventilated models met the 31% improvement standard utilising the M2 and above specification and a gas boiler (no PV).

- No change was required in meeting the Part L 2020 targets in all models utilising heat pumps.

- The Future Homes Standard 2025 was only met by models utilising heat pumps and with a natural ventilation specification of N2 and above. Almost all mechanically ventilated models using a heat pump met the target even with the lowest M1 specification used (M1).

Figure 15 to Figure 17 demonstrate the impact of the grid carbon emission factors moving forward. It became apparent that the all-electric solutions are hugely benefited by the decarbonisation of the grid in terms of the predicted carbon performance of the properties.

This is the case for operational unregulated energy use too. In effect, while the predicted energy demand requirements of the archetypes remain constant in time, at the time of the evaluation the carbon intensity of the grid will dictate their predicted carbon performance.

From an environmental perspective, it is positive to showcase the continuously reduced carbon impact of electricity generation.

Nevertheless, the energy demand indicates not only the carbon performance of the property but also its associated running costs, impact on grid capacity and other parameters that should not be hindered by a strong focus on carbon performance only.

Table 12 – Housing models DER/DER Actual* improvement (% reduction) - compared to Actual - SAP 2012 CO2e factors

			Percentage improvement on Part L 2013					
			SAP10.1 factors	SAP 2025-2030 factors			SAP10.1 factors	SAP 2030-2035 factors
Detached house	Gas boiler solution	Actual	0%	0%	ASHP solution	Actual	68%	71%
		N1	15%	15%		N1	75%	77%
		N2	21%	21%		N2	76%	78%
		N3	27%	28%		N3	78%	80%
		M1	29%	29%		M1	76%	78%
		M2	34%	34%		M2	76%	78%
		M3	47%	48%		M3	80%	82%
		Very High	53%	53%		Very High	82%	84%
End-terrace house	Gas boiler solution	Actual	0%	0%	ASHP solution	Actual	73%	75%
		N1	17%	17%		N1	73%	75%
		N2	23%	23%		N2	75%	77%
		N3	30%	30%		N3	76%	78%
		M1	33%	33%		M1	75%	77%
		M2	34%	35%		M2	77%	79%
		M3	47%	48%		M3	80%	81%
		Very High	56%	57%		Very High	80%	82%
Mid-terrace house	Gas boiler solution	Actual	0%	0%	ASHP solution	Actual	72%	75%
		N1	17%	17%		N1	73%	75%
		N2	22%	23%		N2	74%	76%
		N3	27%	28%		N3	75%	77%
		M1	35%	35%		M1	75%	77%
		M2	39%	40%		M2	76%	78%
		M3	50%	51%		M3	79%	80%
		Very High	57%	57%		Very High	80%	81%
End-terrace townhouse	Gas boiler solution	Actual	0%	0%	ASHP solution	Actual	74%	76%
		N1	16%	16%		N1	75%	77%
		N2	21%	21%		N2	76%	78%
		N3	28%	28%		N3	78%	79%
		M1	30%	31%		M1	77%	79%
		M2	35%	35%		M2	78%	80%
		M3	47%	48%		M3	81%	82%

			Percentage improvement on Part L 2013					
			SAP10.1 factors	SAP 2025-2030 factors			SAP10.1 factors	SAP 2030-2035 factors
		Very High	**52%**	**53%**		Very High	**81%**	**83%**
Small flat (TM)	Gas boiler solution	Actual	**0%**	**0%**	ASHP solution	Actual	**70%**	**72%**
		N1	**17%**	**18%**		N1	**70%**	**72%**
		N2	**23%**	**24%**		N2	**71%**	**74%**
		N3	**29%**	**29%**		N3	**73%**	**75%**
		M1	**34%**	**39%**		M1	**73%**	**75%**
		M2	**39%**	**39%**		M2	**74%**	**76%**
		M3	**48%**	**48%**		M3	**76%**	**78%**
		Very High	**51%**	**52%**		Very High	**75%**	**89%**
Large flat (TM)	Gas boiler solution	Actual	**0%**	**0%**	ASHP solution	Actual	**68%**	**74%**
		N1	**15%**	**18%**		N1	**75%**	**74%**
		N2	**21%**	**24%**		N2	**76%**	**76%**
		N3	**27%**	**29%**		N3	**78%**	**77%**
		M1	**29%**	**37%**		M1	**76%**	**77%**
		M2	**34%**	**41%**		M2	**76%**	**78%**
		M3	**47%**	**52%**		M3	**80%**	**80%**
		Very High	**53%**	**58%**		Very High	**82%**	**85%**

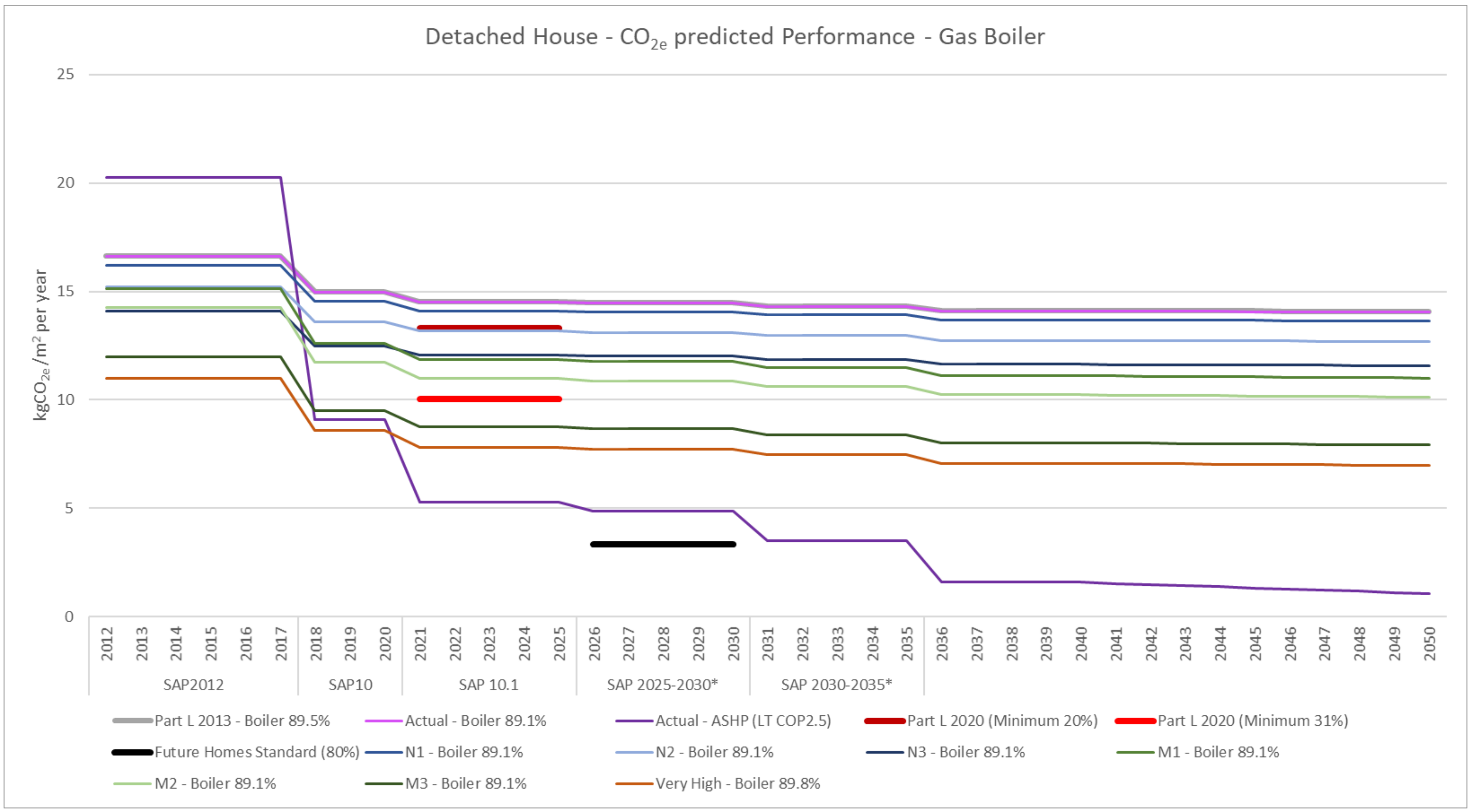

Figure 15 - Detached house carbon performance – gas boiler

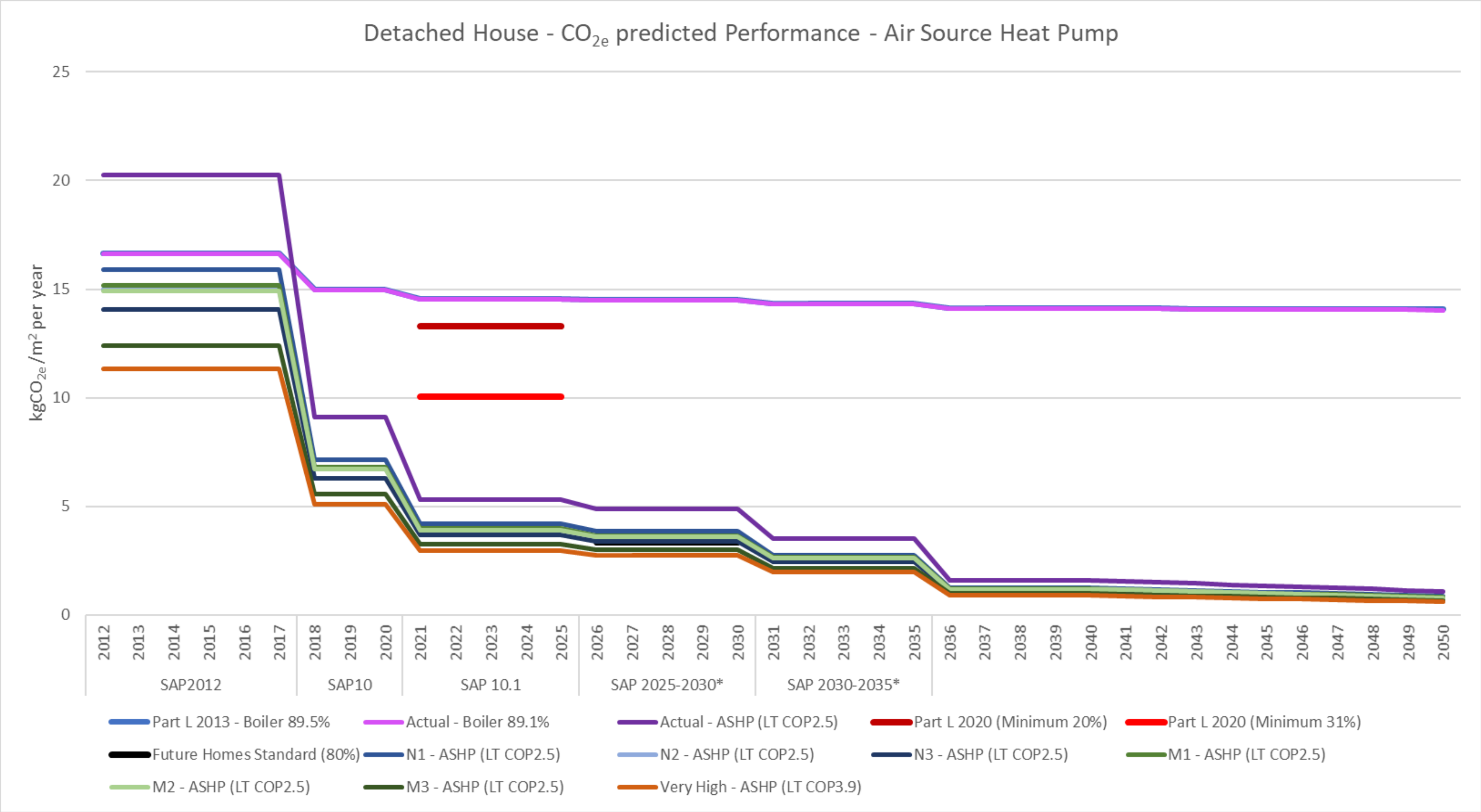

Figure 16- Detached house carbon performance – air source heat pump

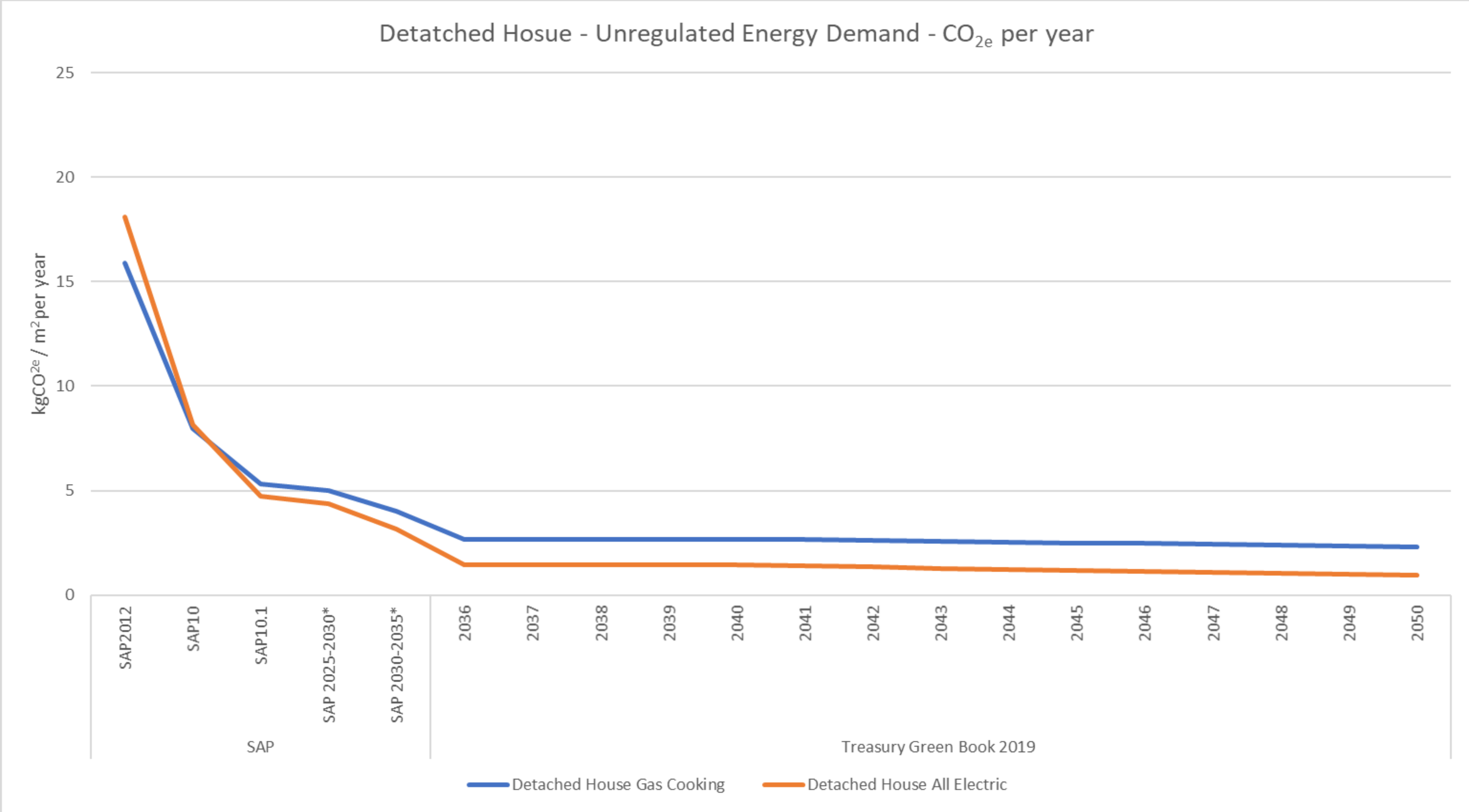

Figure 17 - Detached house carbon performance – operational unregulated energy use related emissions

5.3 Renewable energy impact on predicted carbon emissions

5.3.1 The effect of heat pumps on carbon reductions through renewables

Heat pumps are classified as a means for renewable heat generation. Appropriate guidance is provided by Ofgem. Heat pumps qualify for the new domestic renewable heat incentive (existing domestic buildings only).

In order to assess the impact of the heat pump in terms of renewable heating, and to assess its contributions to overall carbon performance improvement, the following method was selected.

- Utilise the gas boiler models as the baselines – their DERs (Nx, Mx and Very High variations of all archetypes).
- Compare the DER/TER (TER based on Part L 2013 concurrent notional building).
- Calculate the carbon savings as a percentage of carbon emissions decrease for the same models if an ASHP was to be used instead of the gas boiler system.

This method is also demonstrated graphically in Figure 18.

Figure 19 shows the carbon emission reductions attributable to the use of an air source heat pump based on the detached new domestic building archetype.

As it can be observed, the continuous decarbonisation of the electricity grid, and the comparison of an all-electric solution to the Part L 2013 concurrent notional specification that includes a gas boiler system, provides an ever-increasing carbon benefit associated with the use of heat pumps.

Heat pumps with higher efficiencies would have led to even higher predicted carbon savings in the models.

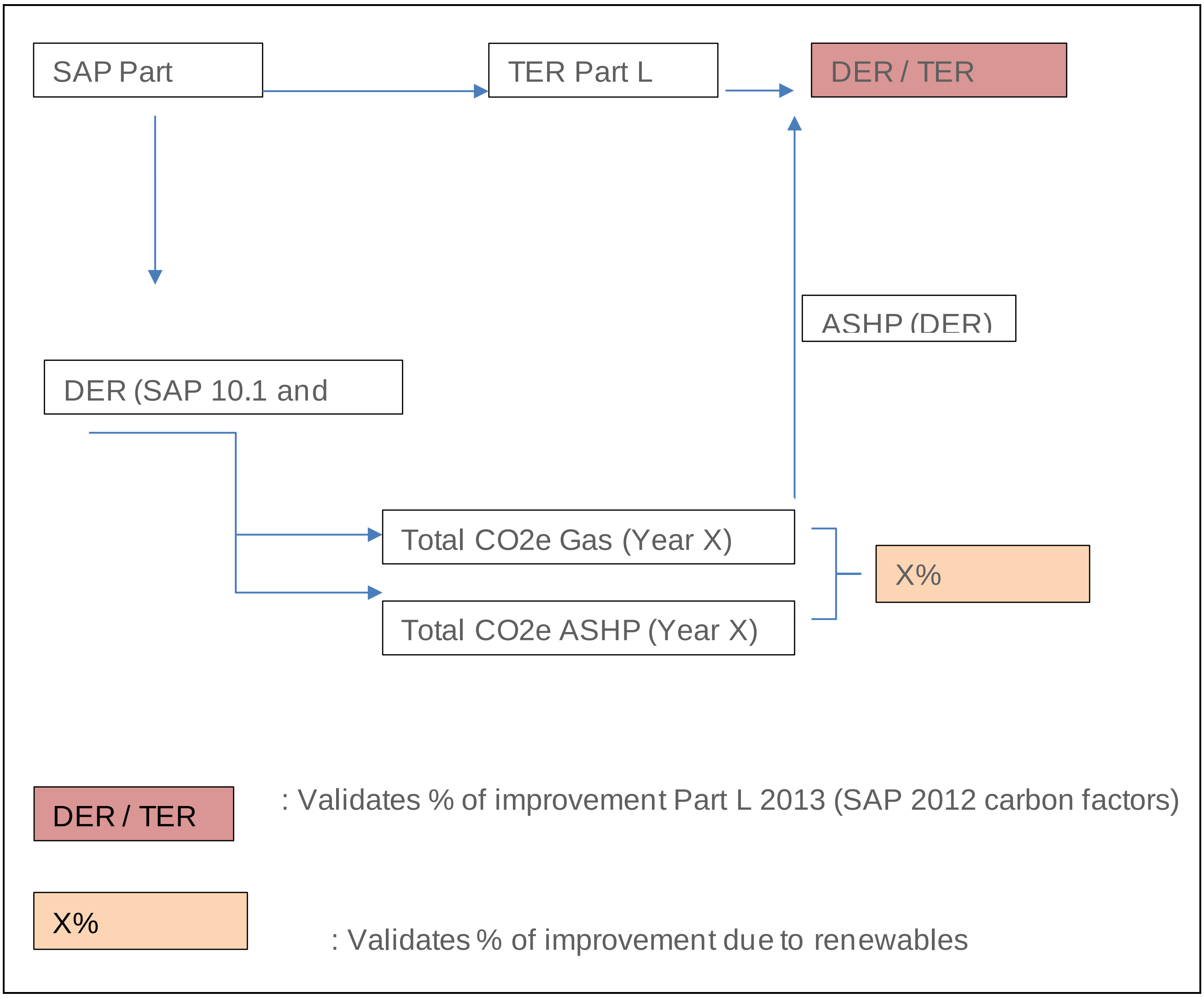

Figure 18 - ASHP carbon emissions reductions contributions calculation method

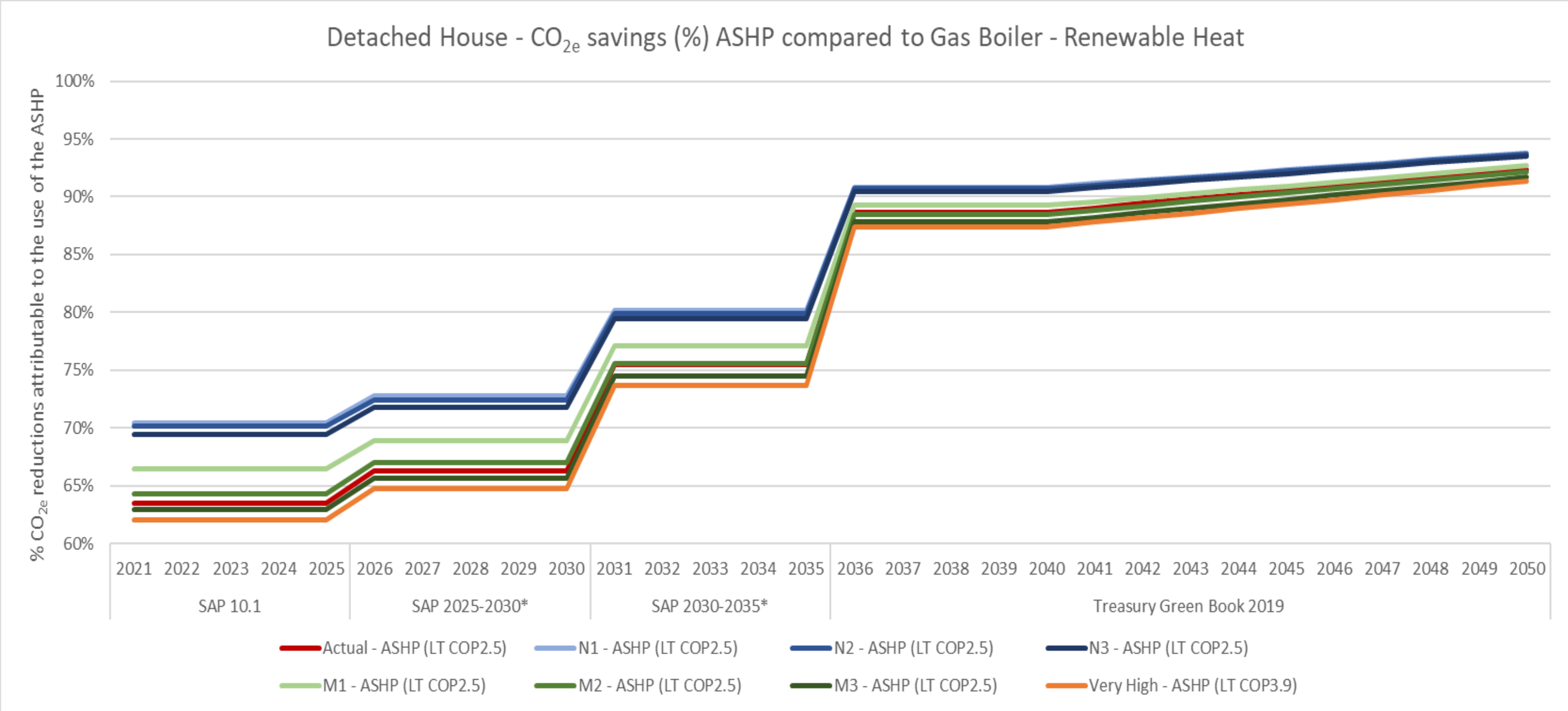

Figure 19 - Detached house - carbon savings attributable to the use of an air source heat pump (ASHP)

5.3.2 The effect of PV

The impact of PV energy generation on predicted carbon emissions was evaluated for all models both in terms of regulated and operational unregulated energy use.

The contributions of PV on energy demand and carbon performance is threefold. It includes the following:

- Electricity energy generation, depends on the size of installation and technology used – contributes to domestic hot water generation as well as reduced running costs.
- Reduction in regulated energy use deriving carbon emissions (DER), depends on the carbon emission factors of the electricity grid and amount of electricity generated.
- Reduction in operational unregulated energy use deriving carbon emissions, depends on the carbon emission factors of the electricity grid and amount of electricity generated.

The impact of PV installations on the carbon performance of the different models was evaluated against different points in time, following the decarbonisation of the electricity grid.

The energy generated by a PV installation in SAP is considered as energy displaced from the electricity grid, and therefore the same carbon intensity factor to that of the electricity grid is assigned to the PV generated energy.

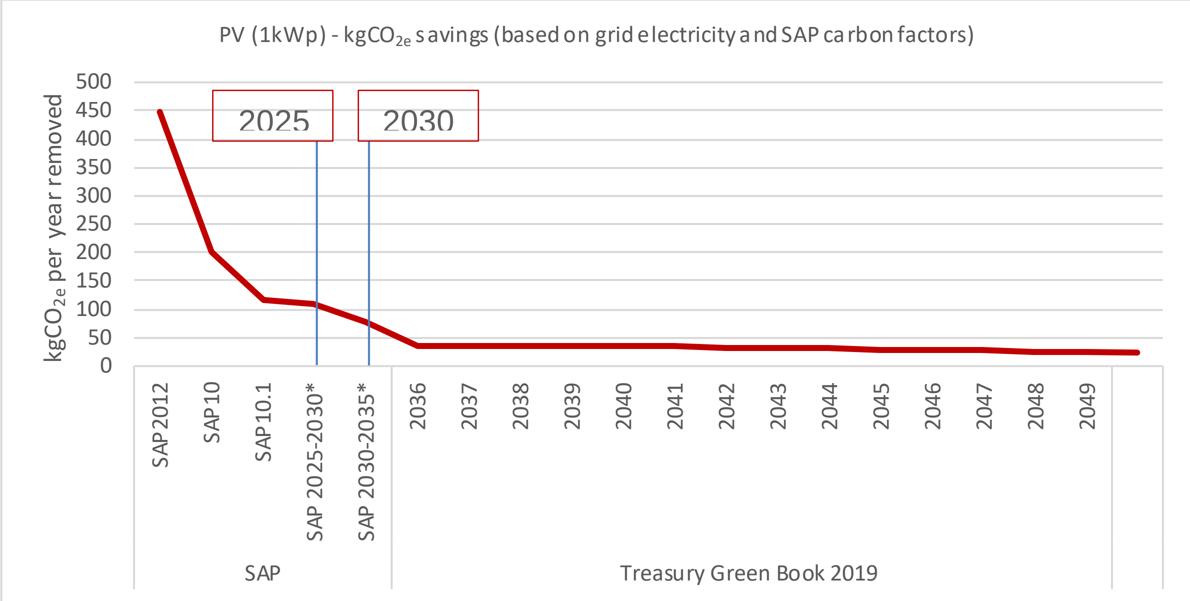

Figure 20 - Impact of electricity grid decarbonisation on PV (1kWp) installation

As shown in Figure 20 the ability of the PV generation to improve the carbon performance of the house continuously decreases as the electricity grid becomes more decarbonised.

Main observations include:

- Ever-increasing amount of PV installations will be required in the future to compensate for the same amount of carbon emissions produced.
- The impact of PV energy generation on carbon emissions is expected to become insignificant as the electricity grid decarbonises.
- The amount of PV required to offset carbon emissions produced by the use of carbon-intense fuel might become prohibiting in terms of available roof space for installation on buildings.

5.3.2.1 PV offset – regulated energy demand

The research looked into all three influencing factors. As a proxy, a 2kWp PV installation was assumed for houses and 0.75kWp for flats.

The amount of energy generated by the installations, as estimated using SAP 2012, was removed from the total energy demand predicted for all archetypes and specification variations (Nx, Mx and Very High produced). Results are shown in Figure 23 - Figure 28.

While the energy demand reductions for each model were substantial, upon PV installation the impact on the overall predicted carbon emissions of the building (DER) was not equally affected.

The carbon emissions reductions achieved with a 2kWp PV installation, using the detached house as a proxy, are shown below in Figure 21 and Figure 22.

As it can be observed, the ability of the PV to offset carbon emissions is reducing in time due to the fact that the displaced grid electricity is of a low carbon intensity.

In the case of ASHP options, the displaced electricity counters the carbon deriving from the energy consumption of the system, on the basis that the energy consumption is based on an all-electric solution (Figure 22).

This is not the case in the options utilising gas boilers, since the carbon intensity is considered stable during the period of time under evaluation (Figure 21).

Nevertheless, the contribution of PV to energy demand reduction and running costs offsetting becomes significant as services move to all electric options.

Table 13 - PV installation as a portion of ground floor area (proxy for roof space area)

Archetype	PV (kWp)	% of GFA[57]
Detached house	2	25
End-terrace house	2	35
Mid-terrace house	2	35
End-terrace townhouse	2	49
Small flat – midfloor	0.75	13
Large flat – midfloor	0.75	8

[57] Ground floor area can be assumed to be equal to total roof area in the case of houses with flat roofs and same floor plans across the different storeys

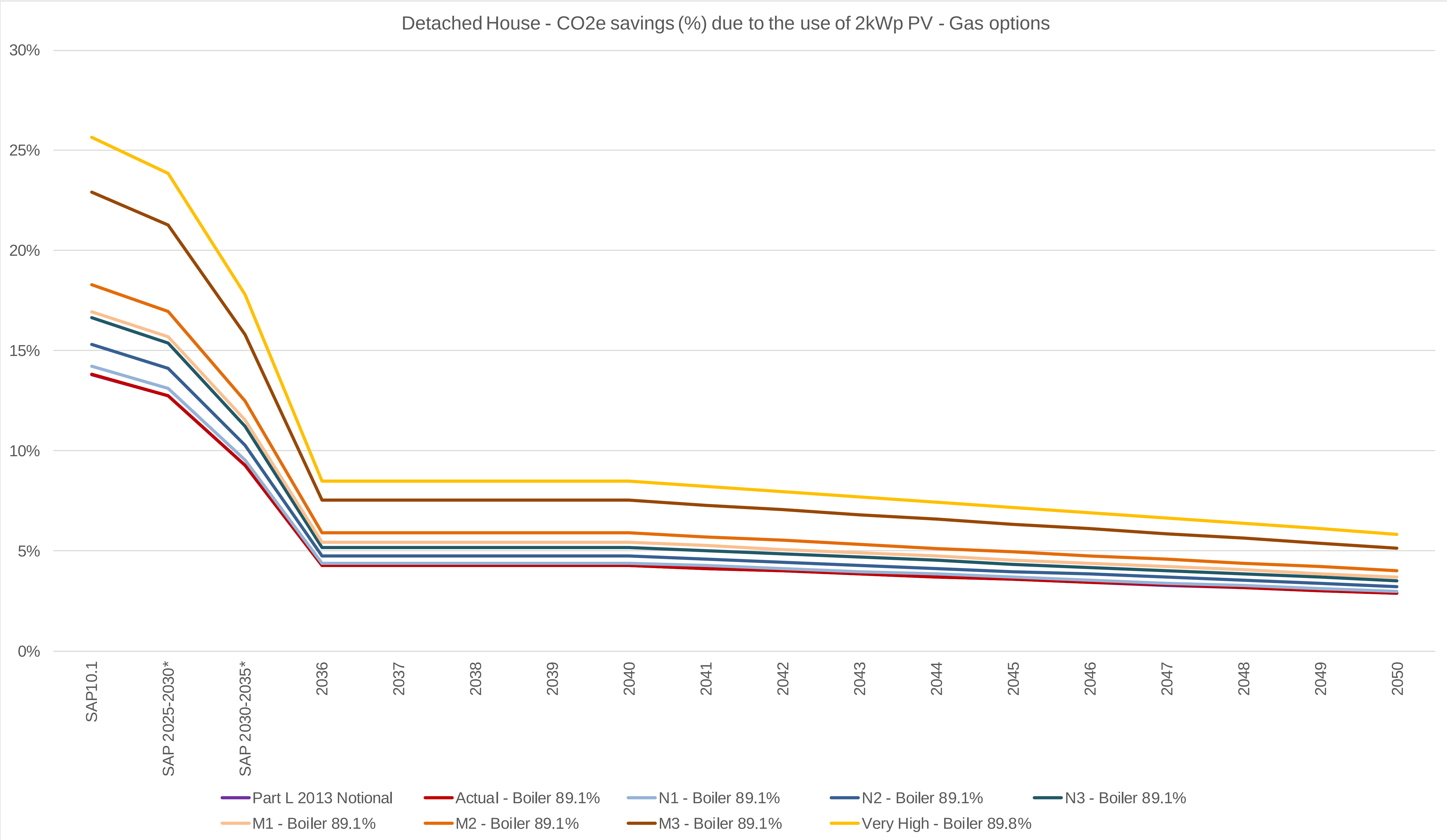

Figure 21 - Detached house - regulated energy use - CO_{2e} reductions (%) through 2kWp PV – gas boiler

Figure 22 - Detached house - regulated energy use - $CO2_e$ reductions (%) through 2kWp PV – air source heat pump

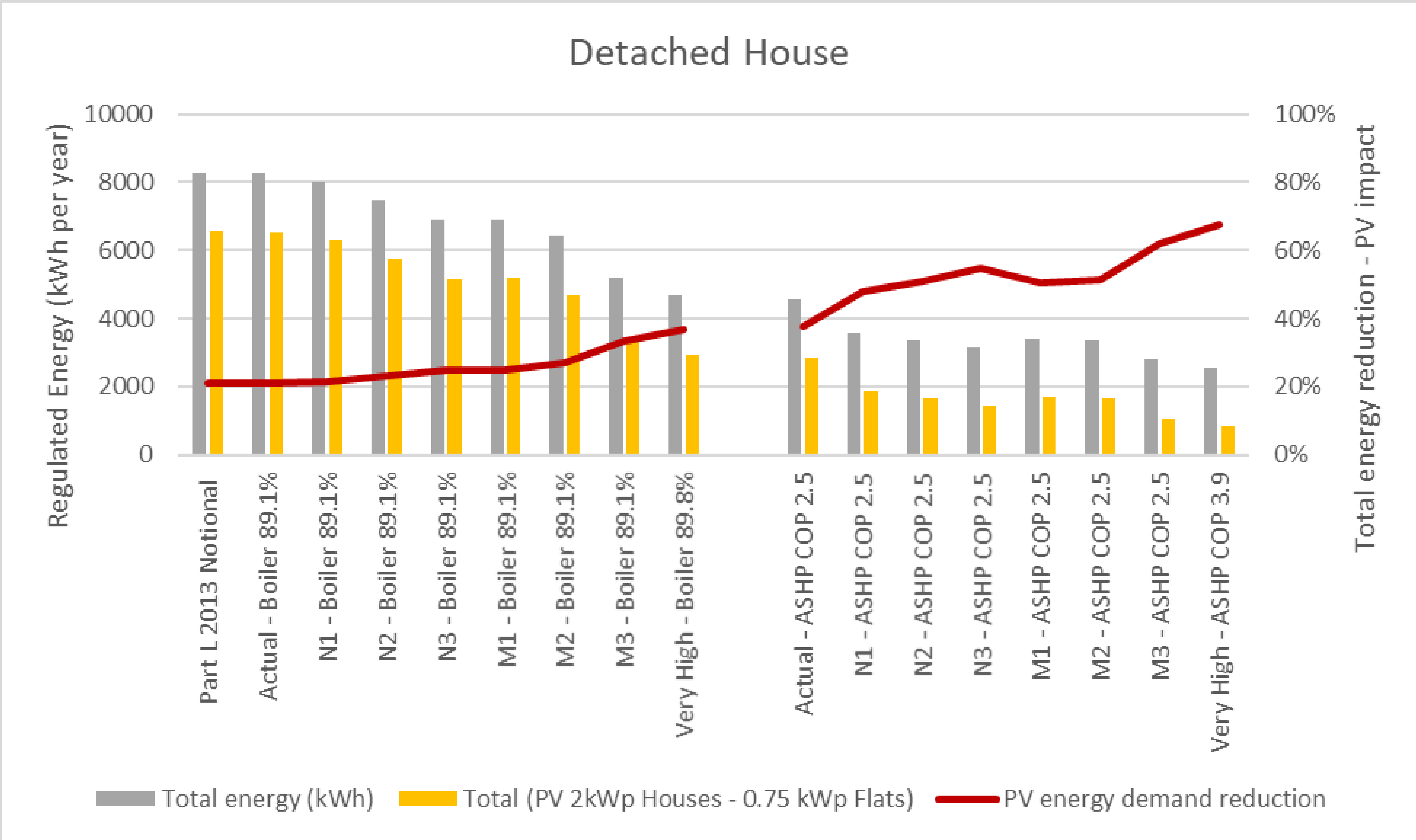

Figure 23 - Detached house - regulated energy demand reduction due to PV (2kWp)

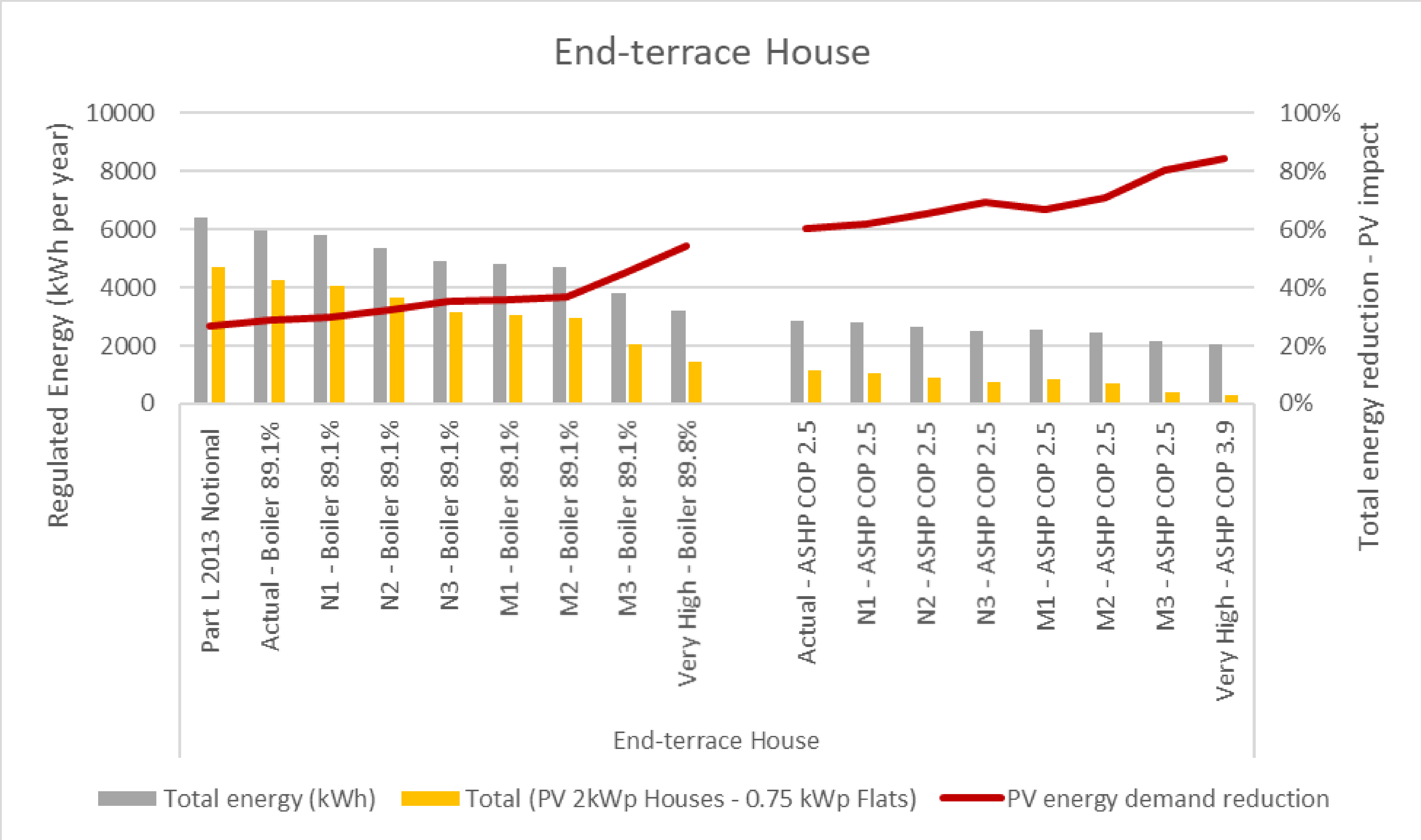

Figure 24 - End-terrace house - regulated energy demand reduction due to PV (2kWp)

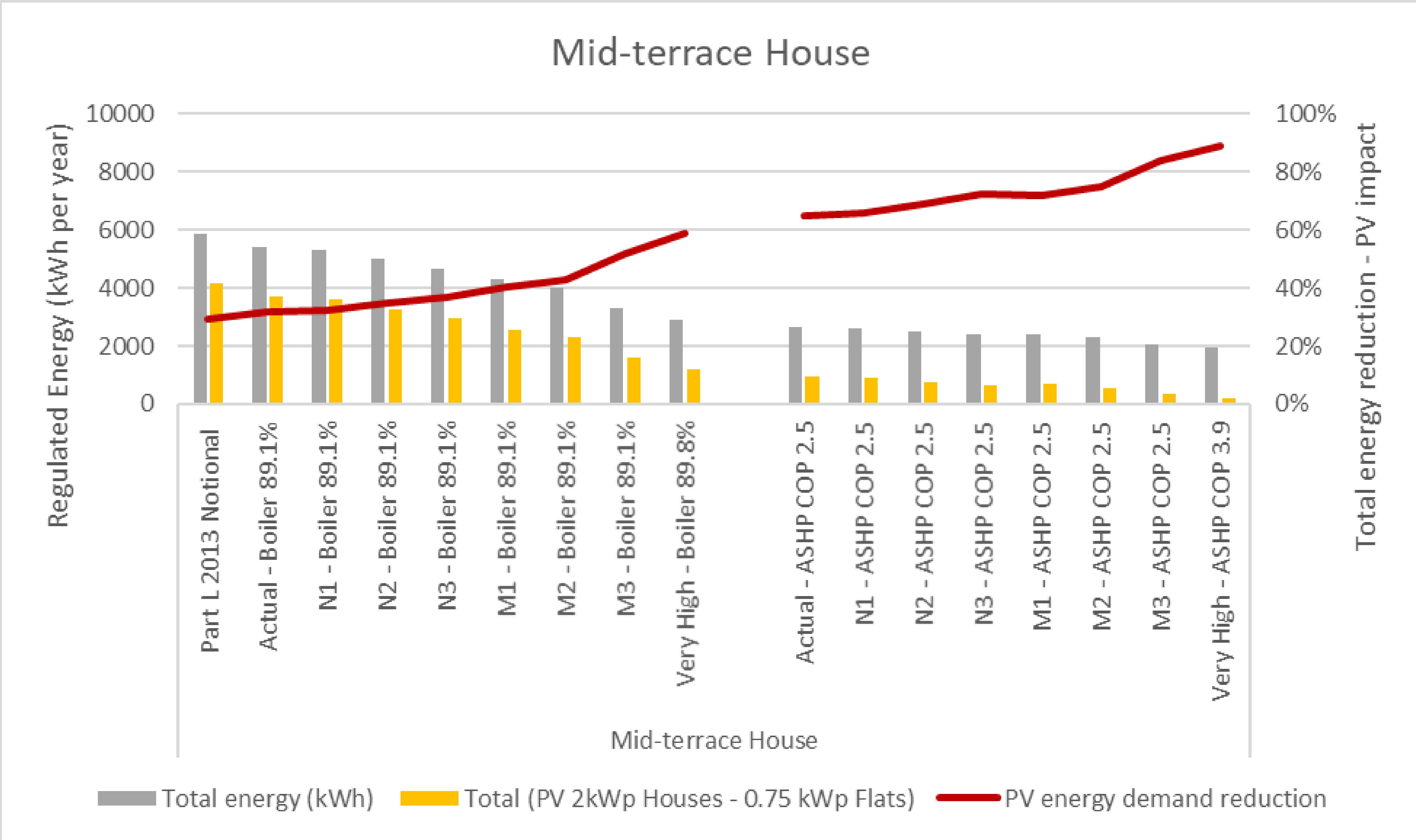

Figure 25 - Mid-terrace house - regulated energy demand reduction due to PV (2kWp)

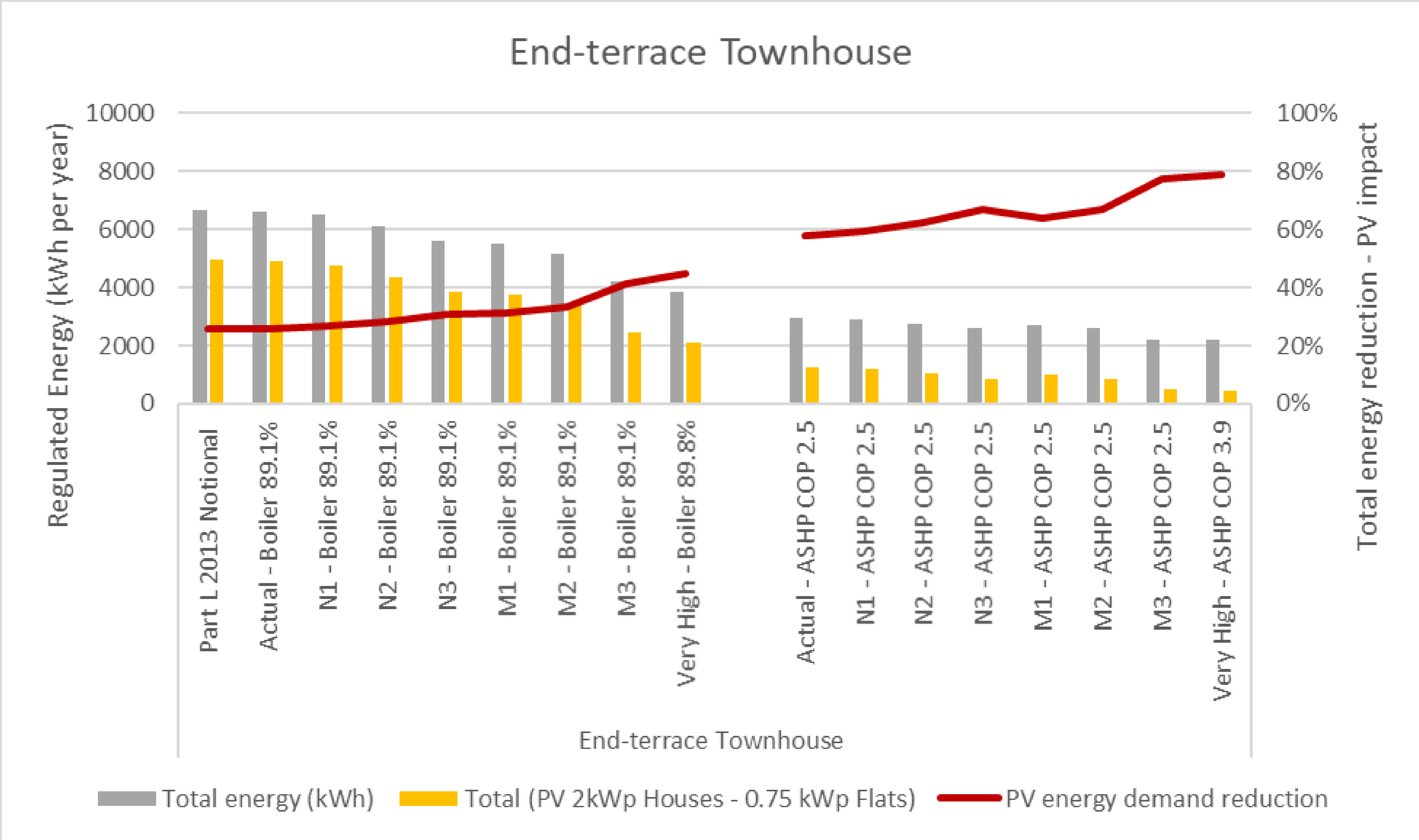

Figure 26 - End-terrace townhouse - regulated energy demand reduction due to PV (2kWp)

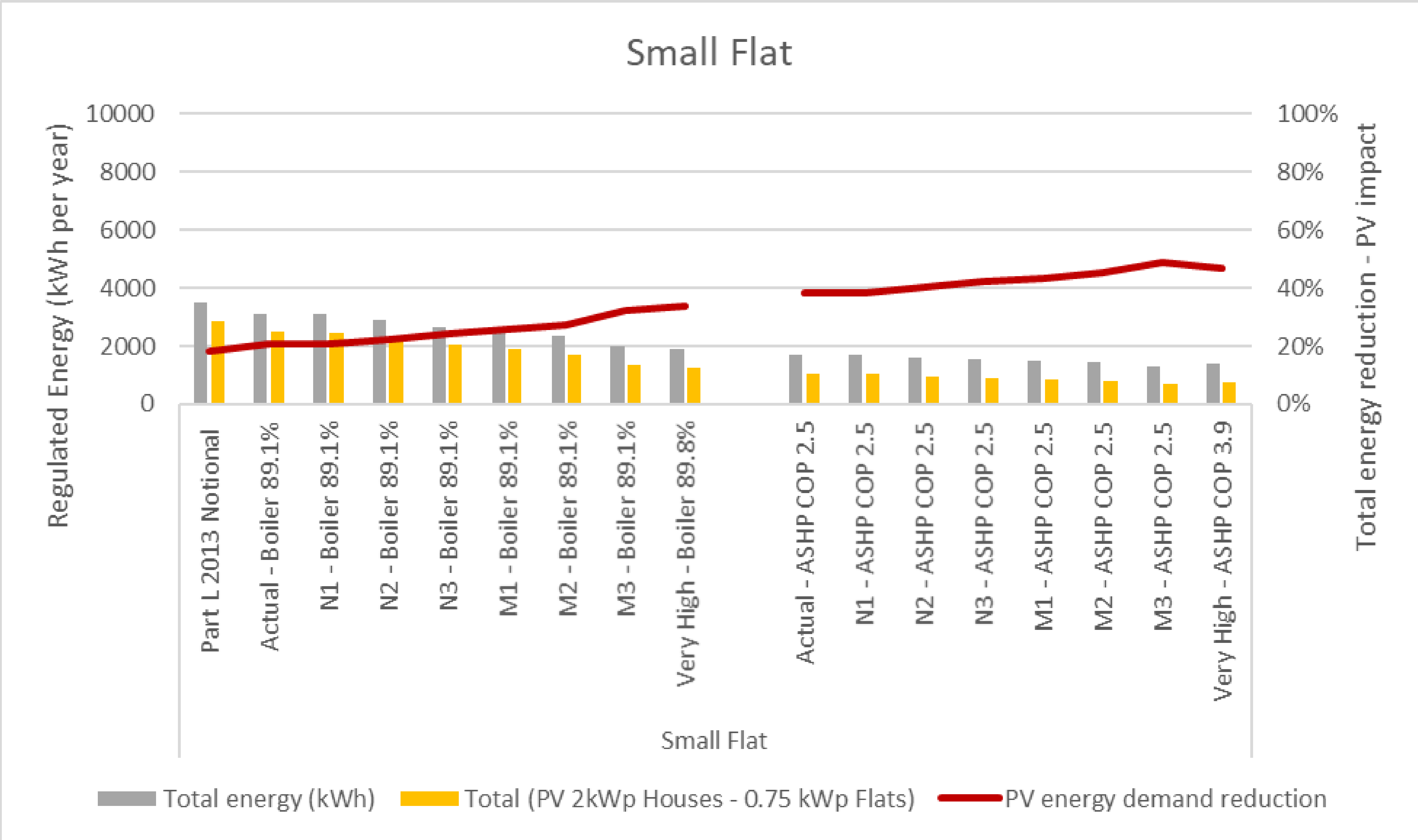

Figure 27 - Small flat - regulated energy demand reduction due to PV (0.75kWp)

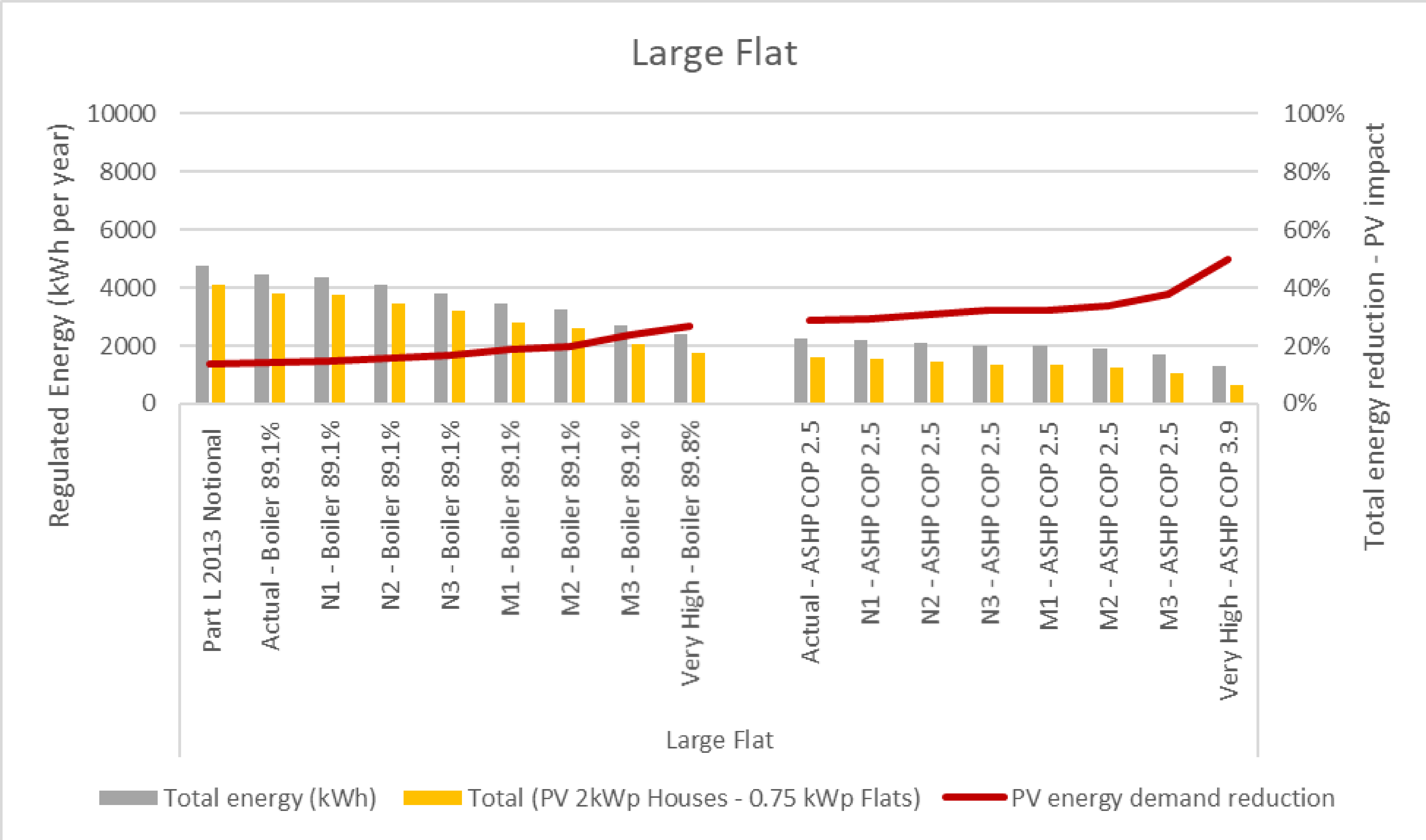

Figure 28 - Large flat - regulated energy demand reduction due to PV (0.75kWp)

5.3.2.2 PV offsetting unregulated energy demand

A mixed (gas and electricity) unregulated energy demand would require additional installation of PV to offset the gas-associated carbon emissions. The amount of PV required would be ever-increasing as carbon emissions saved are attributed to the PV energy generation based on the ever-decreasing carbon intensity of the electricity grid.

This would remain true in all electricity-generating renewable energy technologies, if the methodology used to estimate the carbon savings was to align savings to grid electricity displacement.

Previous work on setting the carbon compliance levels undertaken by the Zero Carbon Hub[58] demonstrated a PV to floor area ratio of 40% as the limit for coverage of the roof, after which additional PV installations increase the technical risk of the project (space limitation, access, layouts and design). In that sense and considering the limited floor space of the small flats it needs to be noted that a maximum of 0.75 kWp could be used if the flats were part of a three-storey building. In the housing models a 20% roof coverage (flat roofs) would translate into 0.8 to 1.6 kWp and for 40% into 1.6 - 3.2 kWp PV installed capacity.

The PV installation space requirements (as a % of floor area) of the detached house, are provided below as a reference (Figure 29) if all operational unregulated energy associated carbon emissions were to be offset using PV. It becomes obvious that this would be unachievable after 2035 in gas cooking options while all electric system solutions would require almost 60% of the roof area to be covered in PV. No regulated energy carbon emissions were considered.

58 http://www.zerocarbonhub.org/sites/default/files/resources/reports/Carbon_Compliance_What_is_the_Appropriate_Level_for_2016.pdf

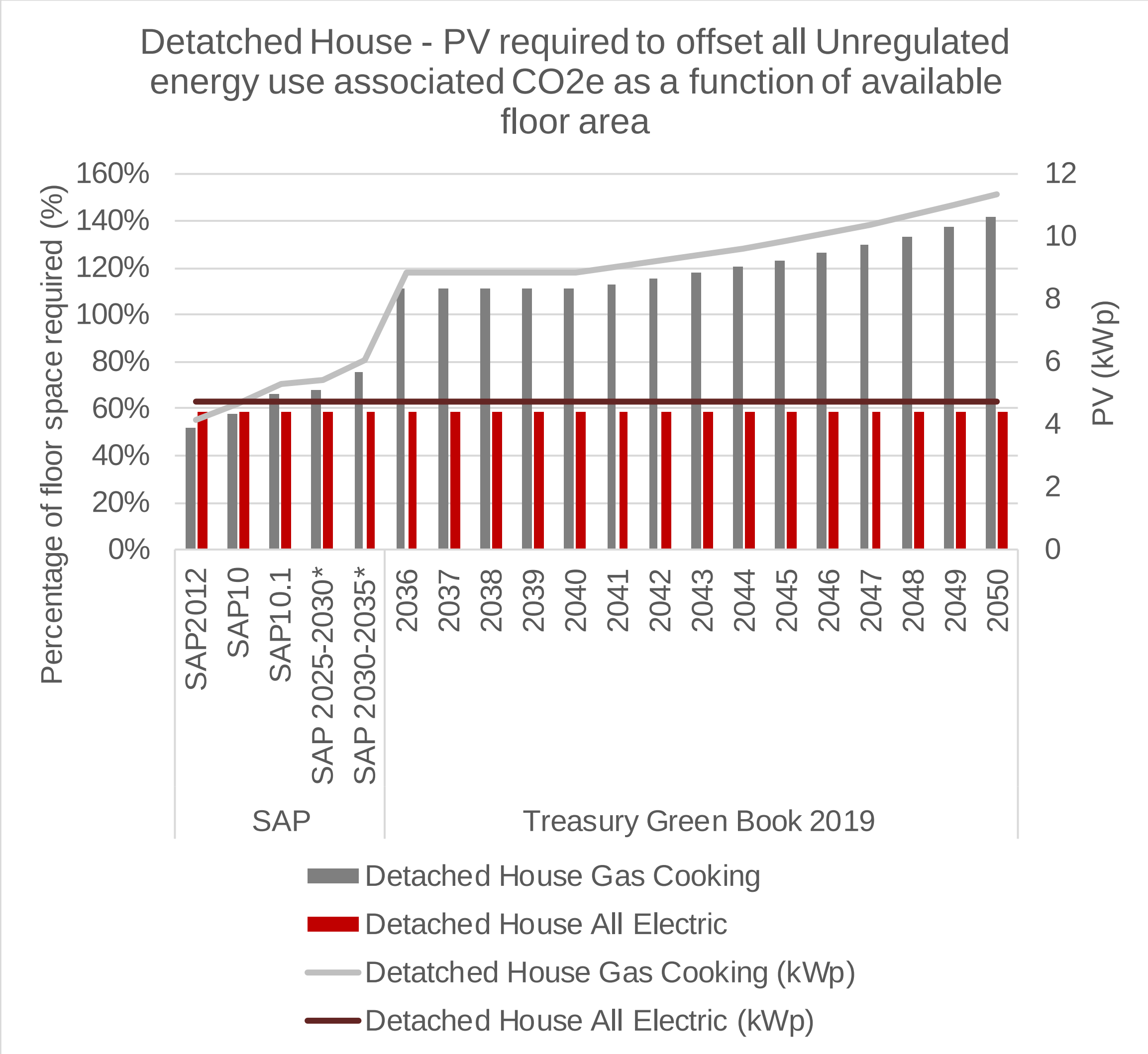

Figure 29 - Detached house - PV requirements for carbon offsetting – operational unregulated energy use

New domestic buildings - cost

Key findings:

6.1 Cost analysis basis

6.2 Occupant running costs

- Meeting the highest modelled fabric standard and including 1.25 kWp of PV and both WWHR and ASHP does not increase the construction costs in any of the models by more than 6%.
- In general, the fabric upgrades required in the case of the more thermally efficient archetype forms of mid-terrace properties and flats were substantially less than archetypes with a lot of exposed elements (detached and end-terrace properties).
- In absolute terms, meeting the Very High standard at the detached archetype new domestic model was the most expensive uplift, with additional construction costs of around £9000 predicted (excluding installation of PV).
- Operating costs including maintenance and running costs are affected by both the fabric performance standards used as well as the type of services selected to supply the new domestic buildings with space heating and DHW generation. Additional running costs could be incurred if all-electric solutions were to be occupied due to the higher cost of electricity if appropriate energy demand reduction provisions are not in place.
- In the case of all-electric solutions, costs savings could be achieved through the implementation of passive and active heat recovery services, on-site energy generation and the removal of the gas standing charge.

Recommendations:

- The cost uplifts associated with the different levels of energy and carbon performance improvements are expressed in current cost terms and can be utilised in the GMSF viability assessment work.
- Consideration should be given when specifying high levels of energy and carbon performance from a capex perspective. This is because specialist skills, technical knowledge and expertise might be required to deliver the projects. Such costs were not included in the current research work.
- For certified houses, such as Passivhaus, additional costs will be incurred for the certification process. Whether or not a Passivhaus or similar standard is introduced within the GMSF, as mentioned earlier in the report, introducing QA processes are key to delivering the targets.
- While the cost upgrade is not prohibiting to requiring some of the highest specifications' standards, consideration should be given as to the local skills and knowledge, quality of housing and summer overheating. A stepped approach in meeting high-end standards might be required prior to implementing a very strict carbon and energy policy.
- The cost of moving to heat pumps and mechanical ventilation systems is similar to the cost of achieving similar fabric performance levels with naturally ventilated buildings. This is because of the benefit of smaller heating distribution networks and number of radiators required. Such service solutions (heat pumps and similar technologies), categorised as active measures, would require additional provisions in terms of commissioning and maintenance routines, part replacements and controls. Additional user guidance might be required in terms of operating such properties and accessing local technical support.
- Attention should be given to expected annual bills for the residents when all electric solutions are considered. Special recommendations should be provided from a policy perspective in terms of energy demand reductions and appropriate levels of energy generation negating additional costs expected from the higher electricity price of electricity.

6.1 Cost analysis basis

Cost analysis considered the additional costs of improving the fabric specification in the different new domestic building archetype models produced, the incorporation of passive energy saving measures such as the MVHR and WWHR systems, the installation of ASHP and the use of PV in all models.

Costs are based on Currie & Brown's professional experience of project costs and are developed from detailed specifications of the full range of cost implications for each element. Cost uplifts were reviewed against a current Part L 2013 new domestic building, reflective of the shape and form of each new domestic building archetype produced as part of the research.

For the high-rise small and large flats, it was expected that the fabric specifications thermal performance uplifts required to achieve the Nx-Mx and Very High series would be similar to those of traditionally constructed low-rise flats. This assumption was considered as valid when addressing fabric elements and the thermal performance uplift requirements.

The reason for this is that the construction materials used would need to be replaced with similar materials of a 'better' performance, with a proportionate cost uplift to those of traditional construction materials, as this could involve better insulation or windows upgrades. Nevertheless, it needs to be noted that these assumptions would only apply in the case of high-rise flats with similar proportions of materials used, with similar windows-to-walls surface ratios and thermal bridging details.

A cost differentiating factor between low- and high-rise flats is usually the installed services selected and the way energy and heat is distributed around the building. Variations in the technological solutions used (air source heat pumps, ground source heat pumps, district heating systems), distribution networks, controls and building management system changes can largely vary based on location, building type and M&E design factors.

Such additional costs are not accounted for within the research. While energy standards can be applied to high-rise projects in a similar fashion to low-rise in terms of cost, high-rise projects are more bespoke with potential unique features that could greatly affect overall construction and services installation costs. These are not necessarily associated with energy and carbon savings.

Potential cost variations, using an elemental fabric costing approach for high-rise new domestic buildings' energy and carbon efficiency uplifts are detailed as follows:

- Cost of windows and large glazed surface: The costs of moving to highly performing windows and glass façades would include both the cost increase in terms of materials used as well as potential changes in terms of structural reinforcements that may be required to accommodate the load bearing changes of the frame. Additional components in terms of fixtures might be required.
- Cost of achieving high airtightness levels: This will depend on the overall airtightness strategy and structural details (based on construction solutions and joint details).
- Cost of installing mechanical ventilation heat recovery systems: Costs may vary in terms of required electrical capacity, or potential changes in the layout of services and commissioning. In some instances, high-rise buildings may pose additional challenges in accommodating solutions due to layout or special requirements.
- Thermal bridging: Special provisions may be required to optimise heat loss from junctions. While main junctions may be limited to external walls to floors and ceiling/roof components, different construction materials choices and the complexity of the layout will heavily affect the overall construction time, or design costs.
- The overall cost uplift as a function (%) of overall construction costs: The overall construction cost of a high-rise building can vary significantly between different design and construction approaches when compared to new low-rise buildings.

In essence, while traditional construction cost uplifts are shown within this section of the report and may be close to the actual costs faced by a developer delivering these solutions, a similar exercise including the high-rise new domestic buildings could have introduced a higher level of risk in terms of the accuracy of the estimates.

Therefore, caution is advised in terms of applying provided data to new domestic high-rise projects.

Putting cost estimates in context

The costs presented in this report are for a medium-sized developer, building several hundred to a thousand homes per year.

It is important to remember that the costs of developing new homes can vary widely for a range of factors, not least: location, ground conditions, site constraints, access, topography, quality of finishes, design complexity, supply chain and management.

Construction costs can also be subject to sudden and significant change because of market or economic factors, for example varying exchange rates, skills or materials shortages and interest rates. In the 12 months from May 2017 to May 2018, average housing materials costs increased by around 5%. However, this number is likely to conceal larger variations in specific items.

These extensive factors mean that a benchmark cost analysis is only indicative of overall cost implications of different energy and carbon performance improvement options and their relative significance.

Analysis of the potential for reduced costs associated with achieving higher standards of energy efficiency suggest that the cost premium associated with the most energy-efficient standards may fall by around 20-30% between 2020 and 2030. This is as project teams become more familiar with achieving high levels of air tightness and the markets for new technologies become more established. In addition, it is likely that there will be further reductions in the costs of PV with costs falling by a further 35% on 2020 levels by 2030.

These cost trajectories mean that it is likely to become less expensive to build to lower carbon and high-energy efficiency standards over time. However, the scale and speed of changes in costs associated with different technologies is relatively small and slow in comparison to other factors such as the changes to the modelling method and carbon factors that might affect the predicted carbon performance of the new buildings.

Changes in the electricity grid carbon factors will have a very material impact on the total estimated carbon emissions of new homes and the effectiveness of different options used for their reduction. They will act to favour the use of heat pumps and will reduce the carbon savings delivered by PV arrays.

The costs of meeting a specific standard will change markedly when modelling methods and emission factors are changed.

These changes, which may be introduced within the next two years, are likely to have a more material effect on the costs of meeting a target than changes in the capital costs of specific materials and technological solutions (services).

6.1.1.1 Cost modelling assumptions

In the case of photovoltaics, the initial installation was costed at £1,470 for 0.5kWp installed
with an incremental cost of £185 per additional 0.25kWhp PV required added to the model.
Associated heating system sundries costs were reduced in the case of models with lower than 25kWh/m^2/year space heating demand following the rules described in Table 14.
The reason for this reduction was that a smaller amount of heat distribution network and number of radiators would be required to deliver the space heating requirement.
The assumptions were based on evidence obtained from previous research projects undertaken by Currie & Brown including '*The costs and benefits of tighter standards for new buildings'* Committee on Climate Change report.[59]

Table 14 – Heating system sundries cost reductions associated with reduced space heating demand

Space heating demand (Box 98 (kWh/m2/year)	Reduction in heating systems radiators and distribution pipework cost (%)
< 25	25
< 20	50
< 15	75[60]

[59] Currie & Brown and Aecom (2019) The costs and benefits of tighter standards for new buildings. Accessed at: https://www.theccc.org.uk/publication/the-costs-and-benefits-of-tighter-standards-for-new-buildings-currie-brown-and-aecom/
[60] Not applied to small flats due to an already reduced internal space heating network and small number of radiators required. For flats a maximum reduction of 50% was considered.

6.1.1.2 Cost modelling results

The following cost graphs were produced based on an elemental cost analysis of all models, their fabric specification variations and the potential cost uplift incurred. These costs refer to additional capital expenditure cost (capex).

The construction cost uplift does not include changes in labour time on site, design/planning or any other costs associated with the delivery of the new domestic buildings.

Figure 30 to Figure 35 provide the additional costs of meeting the different model fabric and services specifications as compared to a new domestic building complying with the minimum Part L 2013 requirements, 'Actual', used as the baseline. Tabulated detailed cost data can be found in Appendix C – Tabulated domestic models cost data.

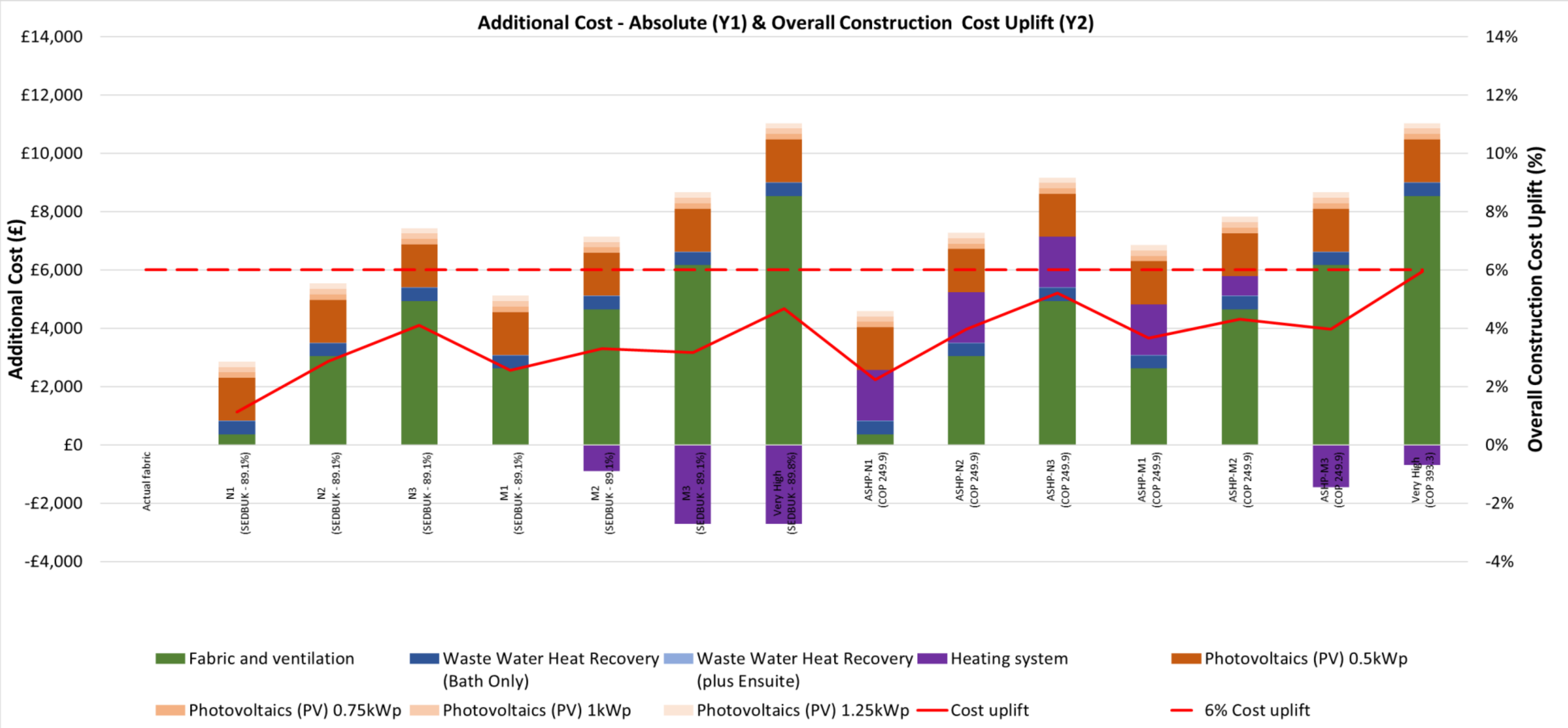

Figure 30 - Detached house construction cost uplift to different standards

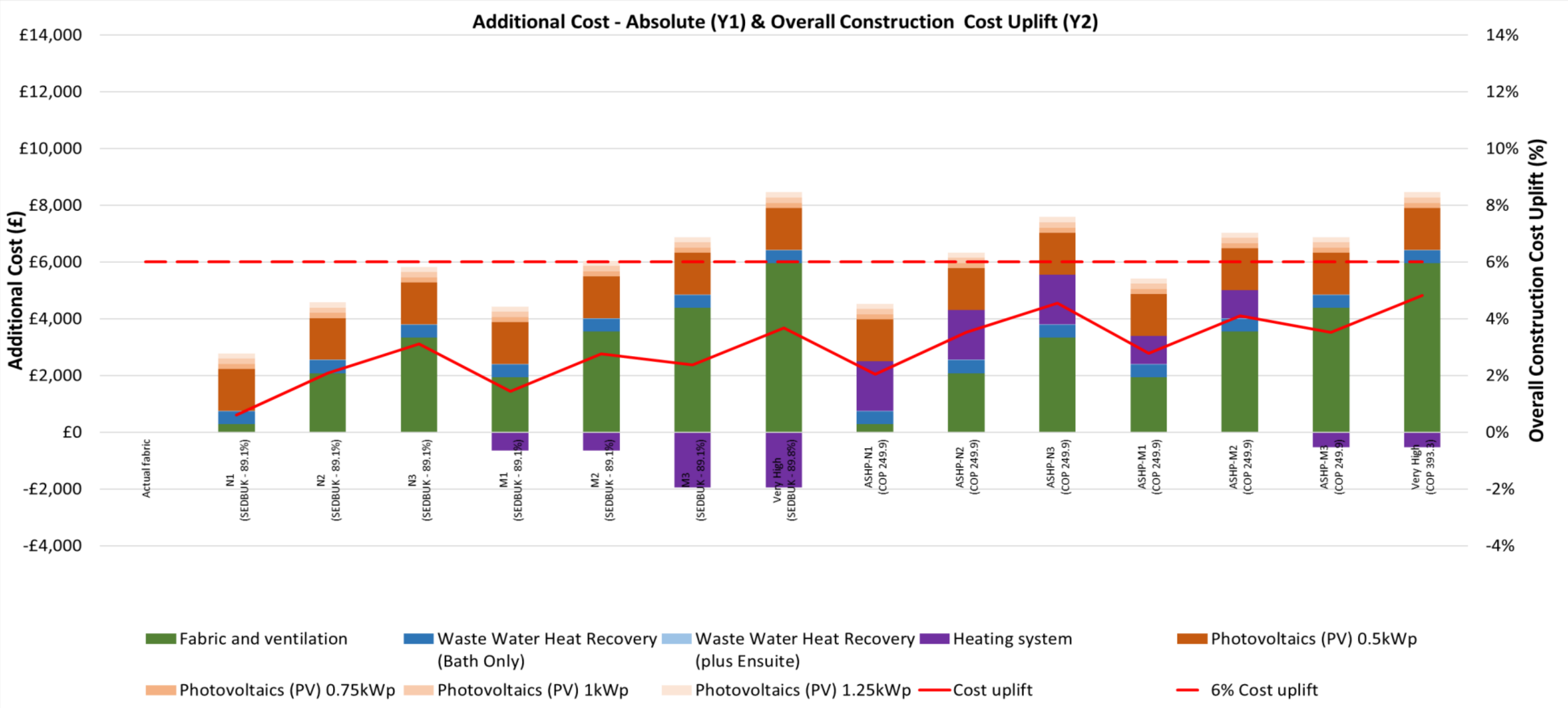

Figure 31 - End-terrace house construction cost uplift to different standards

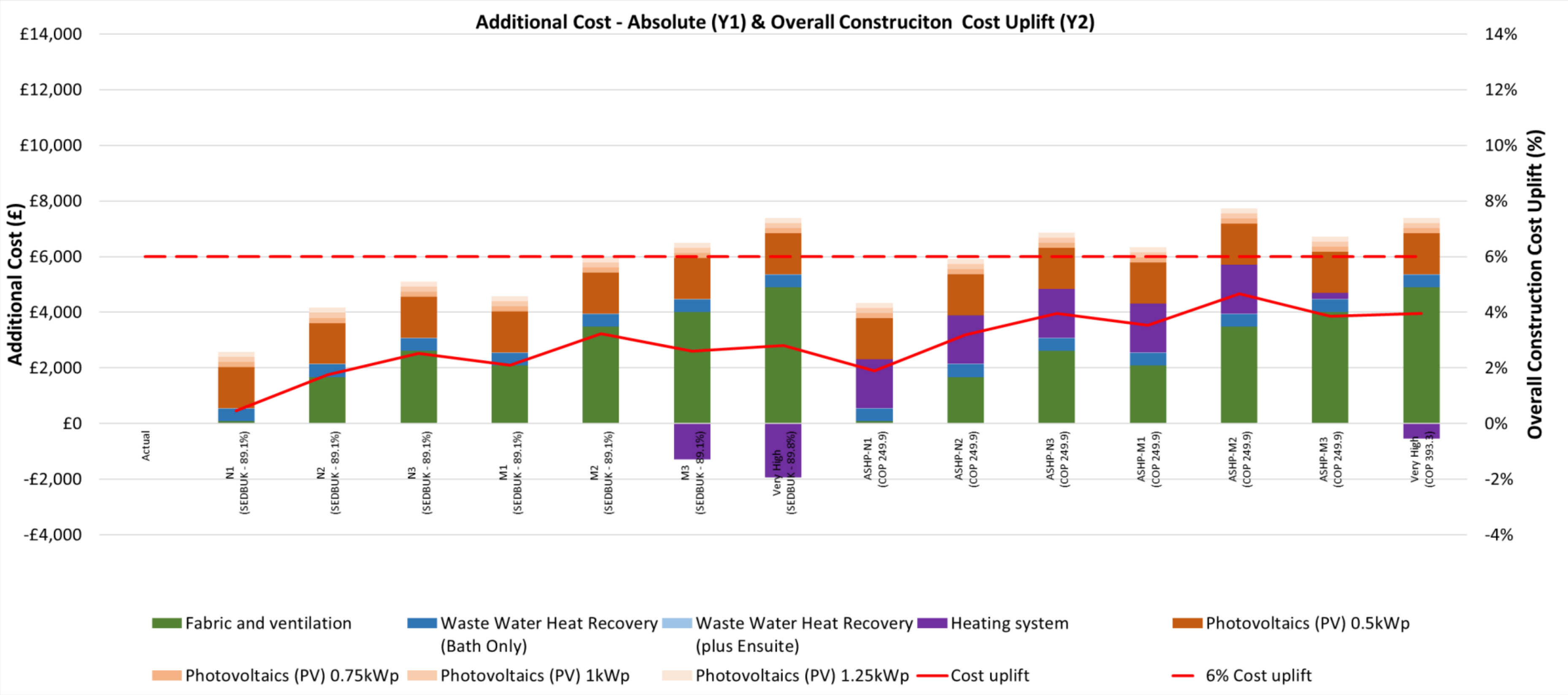

Figure 32 - Mid-terrace house construction cost uplift to different standards

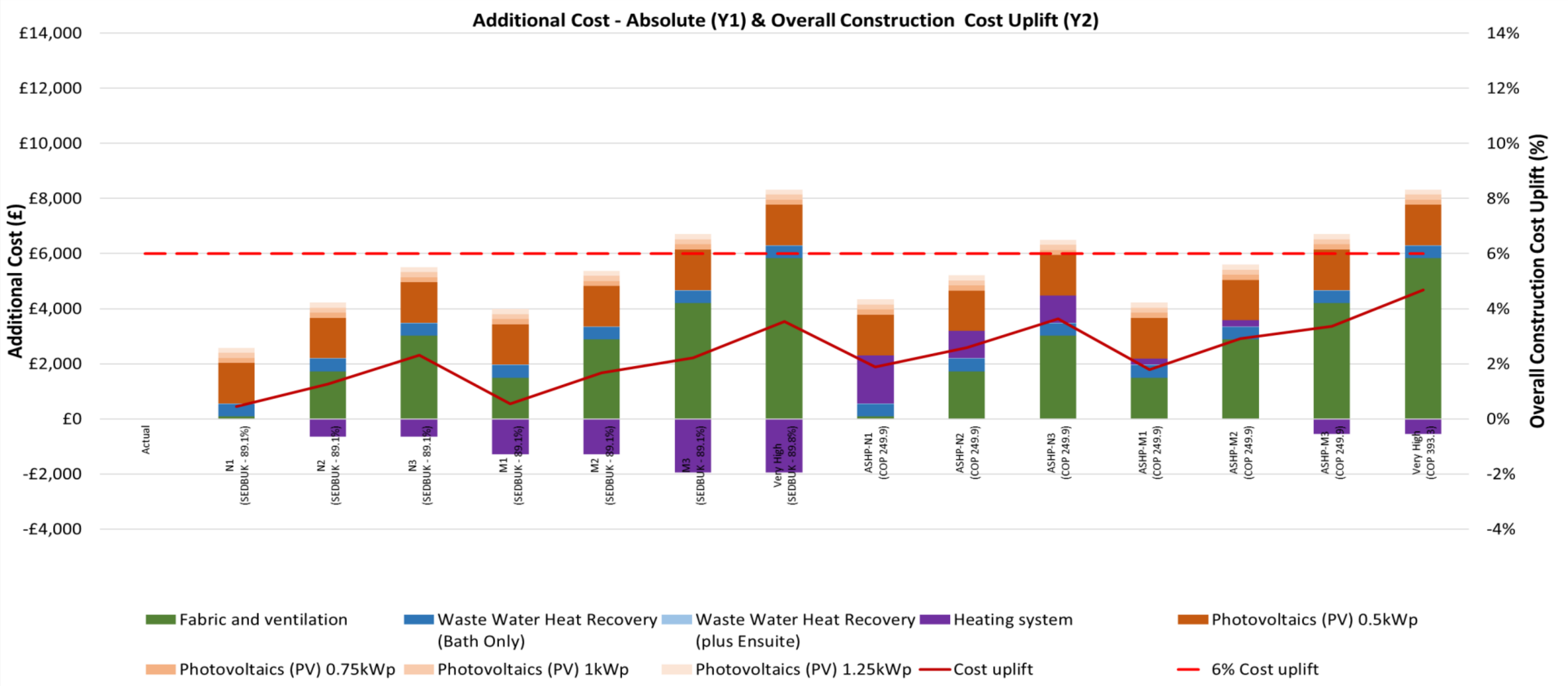

Figure 33 - End-terrace townhouse construction cost uplift to different standards

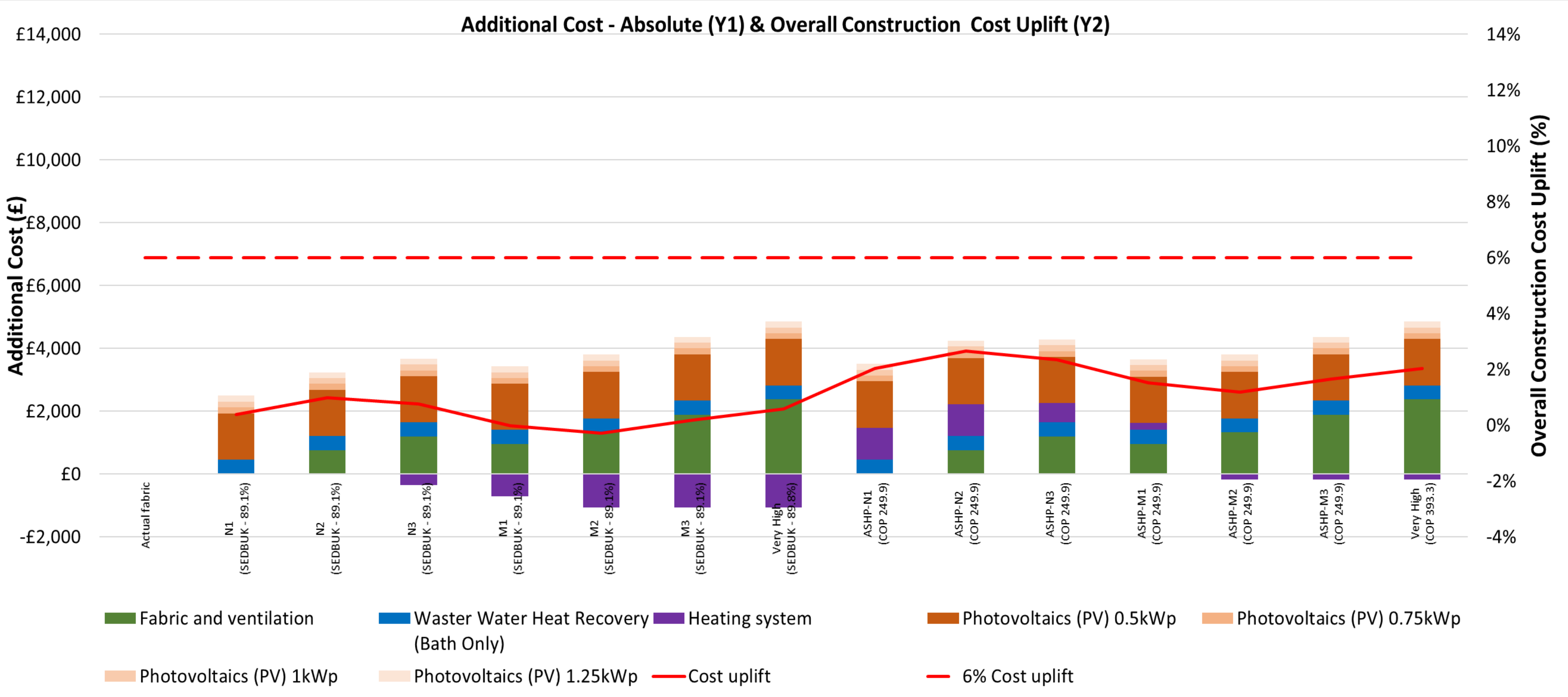

Figure 34 - Small flat construction cost uplift to different standards

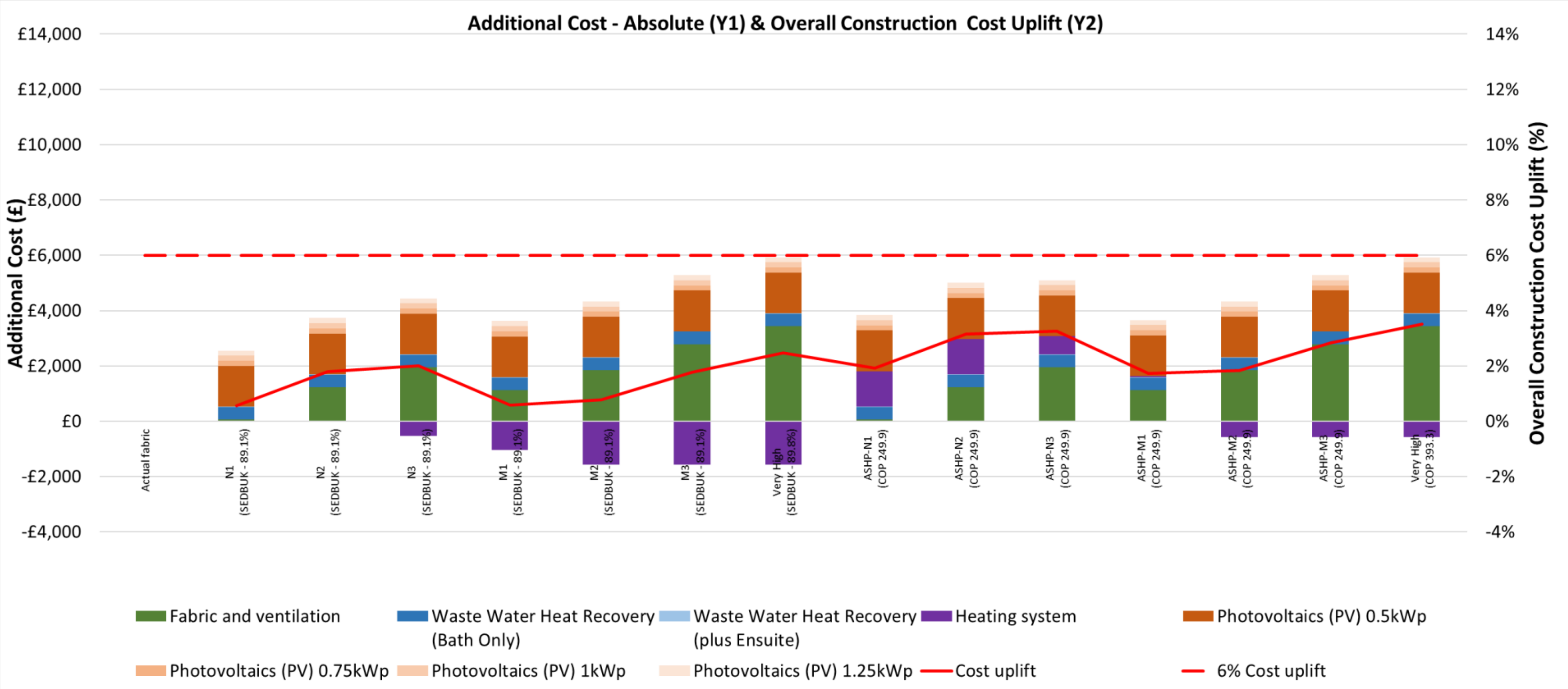

Figure 35 - Large flat construction cost uplift to different standards

6.2 Occupant running costs

Upgrades in terms of the fabric and services specifications used in the models meant that gradual performance improvements in terms of energy demand and carbon performance of the new domestic buildings are achieved.

Capital costs associated with such improvements were described in the previous section. While these costs would be incurred by the developer, attention was given to the potential operational costs incurred by the occupants. More information on how running costs can be affected based on energy and carbon performance changes are provided within Table 15.

All new domestic building models were analysed in terms of annual energy costs. Predicted energy use was based on SAP 2012 energy demand prediction for regulated energy use. The predicted energy use, and type of energy use, was then translated into running cost estimates utilising Treasury Green Book 2018 central energy price predictions running to 2050 (Figure 37).

The annual running costs of the models were averaged across 30 years of operation (2020-2050) and are presented in Figure 38. These are based on a gas boiler system of around 89% efficiency (SEDBUK 2009) and use of an ASHP (COP 2.5). The ASHP solutions are all electric, with no gas connection. The gas boiler supported models were assumed to utilise gas for cooking, which was estimated within the operational unregulated energy cost estimated.

The standing charges for electricity and gas were extracted from the SAP10.1[61] manual and may vary in the future on a year-by-year basis (SAP commonly utilises an average figure over the five years of Part L duration, or gets updated when a major shift occurs based on policy objectives).

The performance of the new domestic buildings fabric, and systems' efficiencies, was maintained the same for the period of time under evaluation (same with first day of operation). Maintenance costs were not assigned into the cost models which only reflect energy costs in terms of annual energy bills.

[61] https://www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-10-10-2019.pdf

Furthermore, while it is recognised that a building's fabric may degrade as it ages, and that the installed systems' efficiency may also be compromised due to the same reason, it was not part of this research work to evaluate such elements. Currently, compliance with Part L does not require lifecycle analysis elements of construction standards and services used.

Photovoltaic systems were assumed to export 50% of the total generation, sold to the grid at the price per kWh indicated within the SAP10.1 manual (5.3 p/kWh).

In all models, the move to an ASHP COP 2.5 led to higher annual energy bills. This was roughly £150-200 per year in houses for regulated energy use and £50-150 in the case of flats for regulated energy use.

It is worth noting that heat pump efficiencies are constantly improving and evidence from the RHI premium payment scheme suggest that a heat pump COP of around 3 is possible. The use of heat pumps with a high COP would mean than even less energy would be required from the electricity grid directly translating to lower operational energy costs.

When all electric cooking was utilised in the properties an additional £100-120 per year was estimated in most cases.

Removing the gas standing charge, no longer required for all-electric solutions, would lead to annual savings of around £88.

PV electricity generation based on 2kWp for houses and 0.75kWp installed capacity in flats would lead to additional annual savings of £206 and £77 accordingly[62].

If waste water heat recovery systems were to be installed in the properties, additional annual savings of £15-25 could be achieved in the case of gas-supported properties, and £35-55 in the case of all-electric properties.

[62] Please note that based on a 7.3m^2 per kWp PV that would equate to almost 5.5m^2 of flat roof area per flat. Depending on the total roof area and the number of flats it may not be feasible in the case of high-rise developments to allocate the required PV amount per flat.

Moving from N1 to Very High in the housing models led to annual energy savings of around £90 for gas boiler-based houses and £55 for flats. The same upgrade in ASHP-supported models (N1 to Very High) led to annual savings of around £150 in both houses and flats.

The **cost of electricity (retail) is expected to be four times more than that of gas**. As research results indicated in the case of all-electric solutions, a combination of WWHR, PV and the lack of a gas standing charge could lead to up to £225 annual savings in the case of houses and up to £160 in the case of flats. A combination of such solutions could offset the additional costs incurred due to moving to all-electric.

Additional costs incurred due to unregulated energy use annual costs increase, moving to all-electric cooking, was not covered in all model cases through the annual savings achieved through regulated energy running cost reduction measures.

The effect of the advanced fabric specifications to predicted regulated costs is shown in Figure 36.

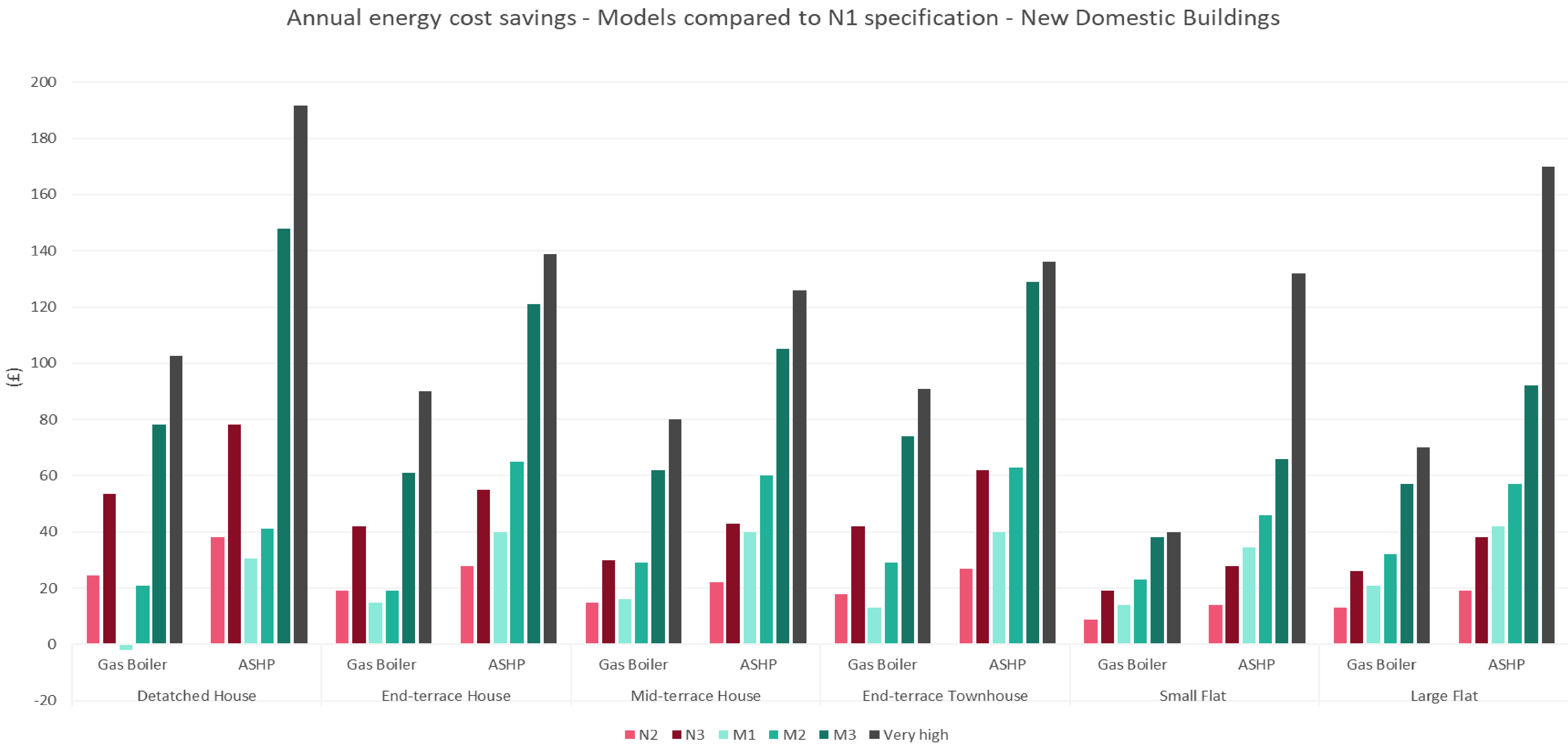

Figure 36 - Annual energy cost savings for gas boiler and ASHP models based on improvements N1-3 and M1-3, Very High, additional compared to N1 models

Main cost savings achieved through fabric improvements were noted in detached and end-terrace properties. This was expected as fabric specification affects the space heating energy demand. Highly thermally efficient forms with few heat losing elements, such as mid-terrace properties and flats, achieved more savings through a DHW energy demand reduction.

Table 15 - Impacting factors on running costs of new domestic buildings

Observation	Impact
Overall energy demand decrease	▪ If energy type (price/kWh) and ratio of energy use between different energy types used is retained the annual bills should be lower. ▪ The reduction will be proportional to the decrease of the specific energy type demand.
Change in energy type used	▪ The energy type utilised to cover the energy needs of the occupant will affect comparative running costs between identical homes. ▪ Standing charges, operators pricing tariffs and changes of energy prices in the future will all affect the running costs.
Installed services	▪ The service life of different technologies installed in buildings will vary. Replacement costs need to be considered at the design stage (eg through options appraisal). ▪ Maintenance frequency and requirements may lead to additional expenditure incurred by the occupant during operation. ▪ Combination of services, and complexity of controls and installation may require specialist support.
Renewable energy generation	▪ Energy generation on site, such as in the case of PV will lead to annual energy costs reductions. ▪ Energy savings achieved will depend on the amount of energy generation, as well as on the level of energy utilisation on-site. Energy used directly on-site would lead to higher cost savings than energy exported as it directly contributes to less electricity used from the grid (high price). The electricity price for exporting to the grid is significantly lower than the retail electricity price demanding energy from the grid (SAP10.1 export price was 5.3p/kWh and standard tariff 17.56p per kWh).

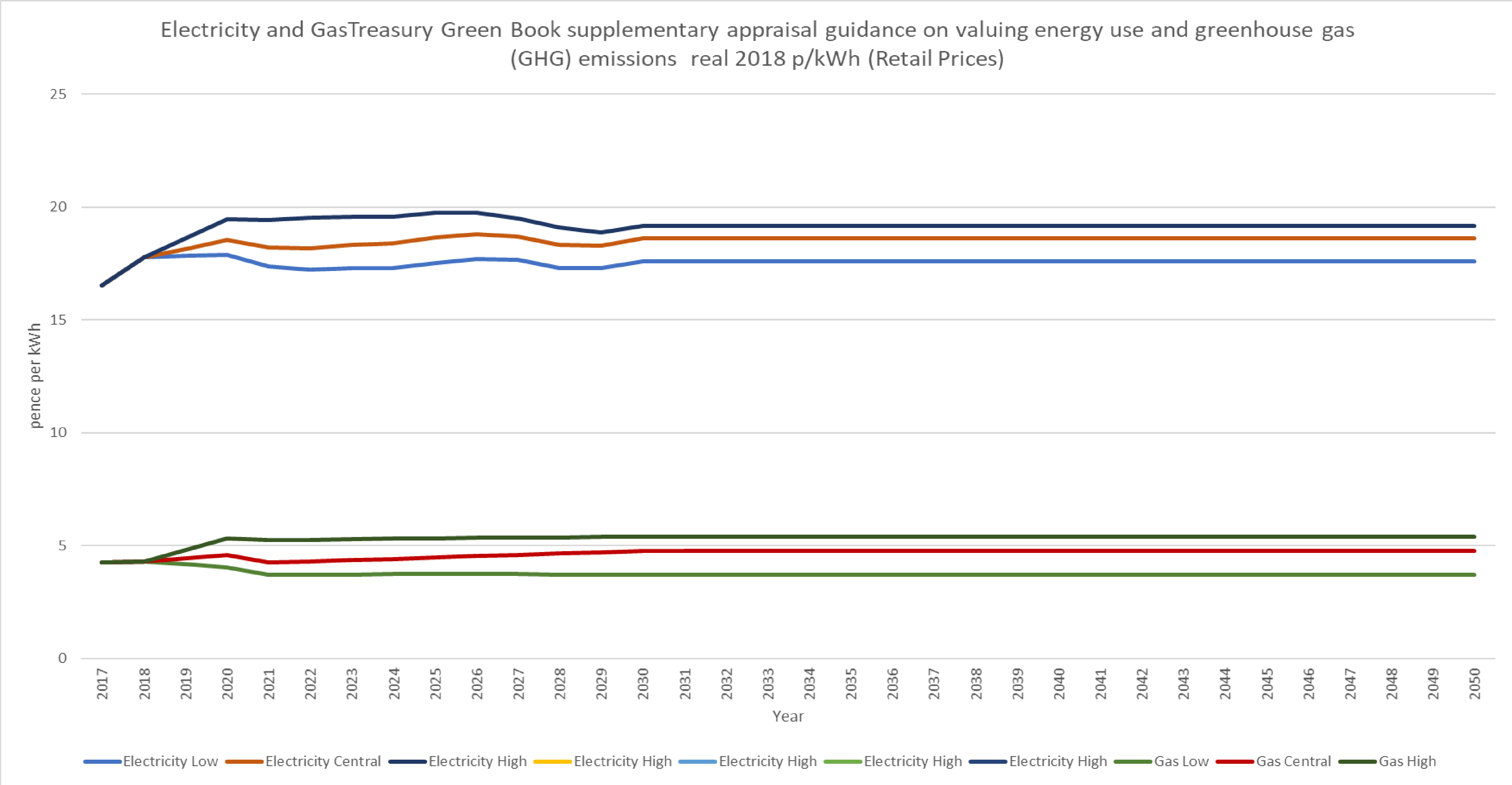

Figure 37 - High, medium and low costs of electricity and gas - projections to 2050 based on the Treasury Green Book data (2018 prices in p/kWh - Retail for domestic buildings

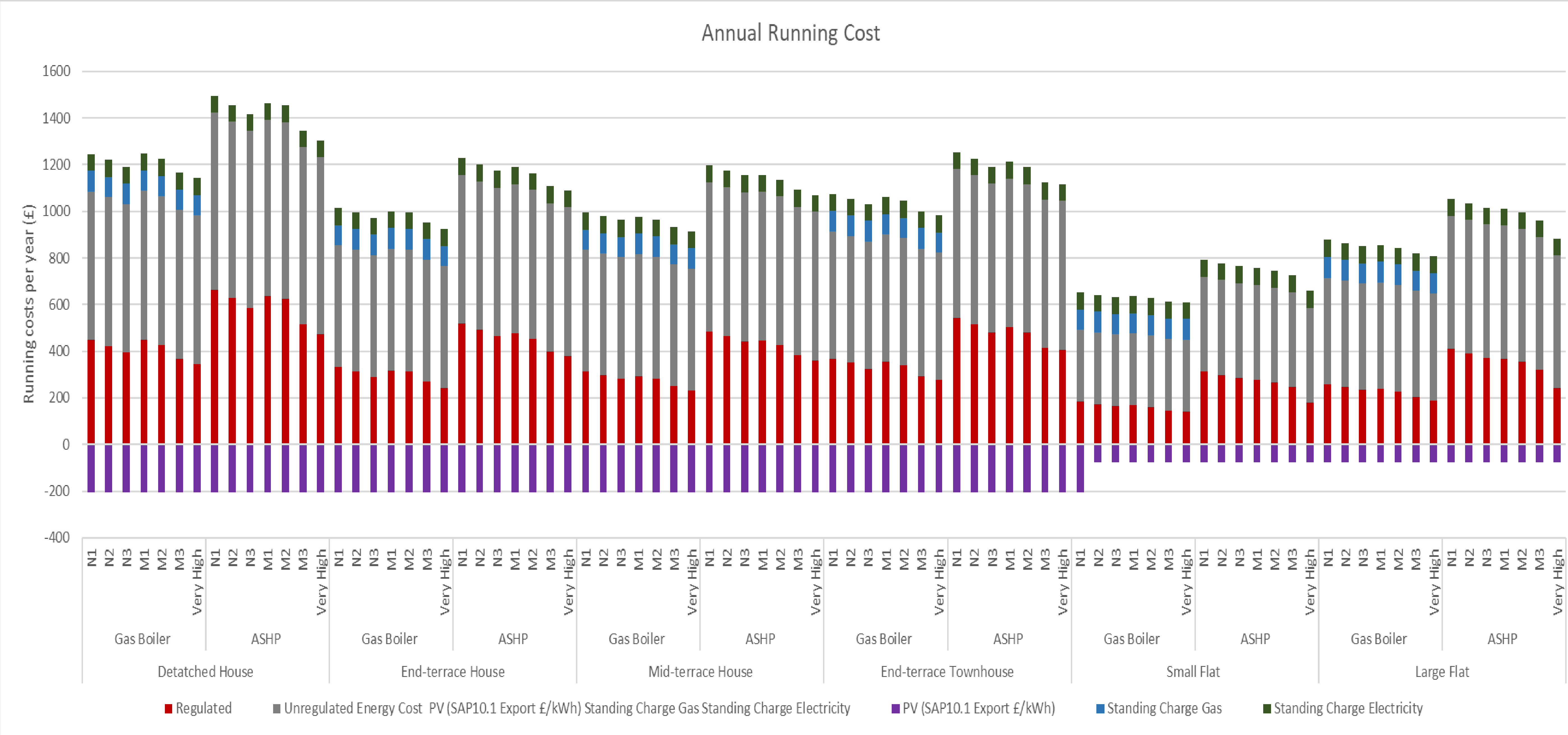

Figure 38 - Predicted annual energy running costs for gas boiler and ASHP-supported new domestic building models – including unregulated energy use, standing charges and PV

Non-domestic buildings

Key findings:

7.1 Non-domestic buildings – energy efficiency

7.2 BREEAM rating

Key findings:

- Meeting tighter carbon performance requirements in non-domestic will affect mainly buildings that utilise non-electric solutions for space heating and hot water generation.
- There is a huge variation in the form and use of non-domestic buildings and this results in a wide range of energy demands and varying potential for increased efficiencies.
- Energy efficiency, energy demand and carbon performance can all be used to evaluate climatic, social and economic impact. A carbon-based target and only may diverge attention from energy demand reduction measures.
- The variability of the design, type and intended use of non-domestic buildings indicates that special consideration should be provided for different building types as to their potential to reduce their operation carbon footprint.
- BREEAM certification was identified as a good performance validator and evaluation method.

Table 16 summarises the cost uplifts of the potential standards to reduce carbon emissions. As stated previously there will inevitably be variation around these levels depending on the type and design of non-domestic building being proposed so these uplifts should be taken as indicative of scale only.

Table 16 - Indicative cost uplifts of the potential standards to reduce carbon emissions

Standards	Target	Percentage of construction cost
Energy efficiency	Minimum carbon reduction of 15%	<2%
BREEAM	BREEAM 'Excellent' rating	1-2%
Total		<2%-4%

The additional cost of BREEAM 'Excellent' certification may be a 1-2% for measures not associated with delivering energy requirements. In many buildings this additional cost could be under 1% subject to its location, the base design and experience of the design and construction team.

Recommendations:

- The utilisation of certification methods such as BREEAM is advised.
- Setting energy demand and carbon performance targets will ensure that best solutions are used.
- For buildings with high energy demand requirements due to space heating and hot water, fabric upgrades and district heating connections would be beneficial.
- Not all non-domestic buildings need to follow a fabric first approach, but all buildings should pursue energy demand reductions and utilise low-carbon energy types (including electricity).
- Renewables can be utilised as in the case of domestic buildings.

7.1 Non-domestic buildings - energy efficiency

While the assessment of the new non-domestic buildings was conducted through a literature review study, findings from the evaluation of the new domestic building models provided valuable insights in terms of similar trends applying to both building types.

The effect of the ever-decarbonising electricity grid will affect all building types, including existing and new (Figure 39).

Buildings covering a substantial amount of their energy utilising electricity will be affected the most (lighting, direct electric radiators/heat pumps or spaces utilising all-electric thermal stores).

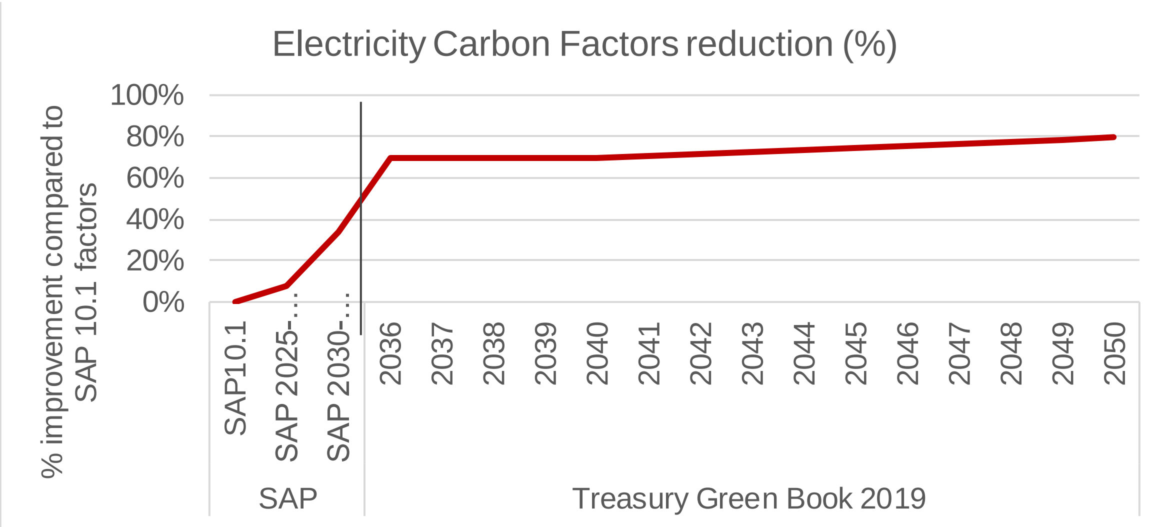

Figure 39 - Reductions in carbon intensity of the electricity grid, translating to similar reductions in carbon performance estimates of all electric solutions

- Non-domestic buildings with a heating requirement will benefit from a fabric first approach.
- For non-domestic buildings mainly utilising energy for other than space heating purposes, carbon reduction targets are expected to be achieved through the introduction of more energy efficient services and all electric systems rather than a fabric first approach.

- With both domestic and non-domestic buildings transitioning to all electric solutions, a question should be raised in terms of the capacity and performance of the current electricity grid.

Recent studies by Buro Happold (ref 7) and Aecom (ref 1) (both supported by Currie & Brown) for the Greater London Authority considered the potential and associated costs from achieving carbon reductions in non-domestic buildings.

These studies considered the implications of setting tighter energy efficiency standards for non-domestic buildings as part of the formulation of the draft new London plan.

In addition, work by Buro Happold (with Currie & Brown) for the Old Oak Park Royal Development Corporation specifically considered how energy and carbon savings can be achieved in higher-rise and mixed-use developments (ref 8).

Key findings from these studies included:

- The correlation between energy efficiency/carbon performance (excluding PV and heat networks) and capital cost is weak or absent with a range of factors influencing both cost and performance including:
  - Building form
  - Glazing ratio
  - 'Good passive design' that balances glazing area and energy demands
- Energy use in non-domestic buildings can vary greatly based on intended use and building typology. The cost and potential for achieving savings beyond the Part L 2013 requirements will therefore depend on building type, design and intended use.

- Substantial energy efficiency savings are typically achievable in office and retail buildings, but other building types such as schools and particularly hotels may find it more difficult to achieve energy efficiency savings because of the specific nature of their demand, for example the dominance of hot water supply as an energy source in hotels.

- Efficient lighting and control systems are a major contributor to energy efficiency in office and retail spaces with the potential to deliver substantial savings in lighting energy demand compared to that required by Part L 2013.
- Substantial energy efficiency savings can be achieved purely with highly efficient lighting (i.e. LED) and controls, in some situations these could be sufficient to achieve savings of 10-15% or more on the requirements of Part L 2013.
- More efficient lights and controls are still more expensive than traditional systems (approximately a further £20/m^2 depending on design) but are becoming standard in new buildings as developers and occupiers realise their significant performance benefits and reduced maintenance and energy costs.
- Cost uplift associated with energy efficiency measures varies considerably because of differing building designs. The Part L Notional specification was set at £0 but in practice there is a substantial variation in the costs of building to this specification depending on design considerations.
- The uplift associated with achieving a 15% energy efficiency target was between £37 and £59 m^2 which when compared with overall development costs of between £2,000 and £3,000 m^2 is under 2% of the capital cost.
- Nearly 60% of non-domestic developments in London achieve a 10% energy efficiency saving, with a little under half achieving a saving of 15% in comparison to Part L 2013.
- In 2017, the average energy efficiency saving in non-domestic buildings in London was 19.2% beyond the requirements of building regulations (ref 17). This suggests that while certain buildings may not be able to achieve a 15% requirement it is widely achievable in new non-domestic buildings.

Policy consideration: Energy efficiency

Most existing non-domestic buildings can achieve 10-15% energy efficiency improvements on current regulations, but there are some buildings that might find this standard more difficult due to the energy associated with their type and operational demand, for example hotels.

Evidence suggests that 15% is widely achievable on new non-domestic buildings.

7.2 BREEAM rating

Currie & Brown's research with BRE (ref 5, 6), together with previous studies for the British Constructional Steelwork Association, shows that, if delivered efficiently by experienced design and construction teams the additional costs of meeting the 2011 BREEAM 'Excellent' ratings are in the order of a 1-2% of capital costs for most buildings but can be higher, in the order of 3-5% for some buildings (such as healthcare buildings) and locations.

The most significant costs associated with achieving higher BREEAM ratings are often associated with meeting minimum energy requirements.

This means that where a planning requirement also exists for carbon/energy efficiency measures beyond the requirements of building regulations then the net impact of an additional BREEAM requirement would be reduced.

Where a contractor is inexperienced in delivering BREEAM, it is possible for additional costs to be incurred in setting up processes to ensure that their site management and supply chain activities are BREEAM-compliant.

Similarly, for very small projects the costs of assessment and certification, which do not scale linearly with project size, may result in disproportionately higher costs. For example, assessment costs might be 0.1% or less of the cost of a 10,000m^2 office but around 1% of the costs of a 1,000m^2 retail unit.

BRE have recently introduced the BREEAM 2018 standard which includes a range of new or amended requirements.

Some of these new criteria are deemed to be cost-free albeit they may require additional consultant's input and considerations at early design stage. BREEAM 2018 is a recently introduced standard and evidence of sufficient data on its implications is not yet available for a substantial cost analysis.

However, Currie & Brown's initial review suggests that while the 2018 standard requires more time input from the project team, its implications for capital costs are relatively small.

Policy consideration: BREEAM

While the costs of BREEAM ratings are typically in the range of a few per cent of capital cost, the implications for specific buildings, development locations (eg greenfield sites, away from transport links and amenities) may be higher and the costs of the certification itself become considerable for smaller developments.

A size threshold and viability assessments may help to reduce costs for smaller projects.

2020-2025:

It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Very Good' is considered.

Carbon requirements-wise, within the 'Very Good' target, a mandatory requirement for achieving the BREEAM 'Excellent' minimum standards, 4 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.

2025-2028:

It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Excellent' is considered.

Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Excellent' with at least 6 credits for Energy Performance within the 'Ene 01 – reduction of energy use and carbon emissions' is advised to be implemented.

It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy efficient equipment'.

Please note that Ene08 refers only to operational energy use and does not include embodied carbon or whole lifecycle carbon.

2028-onwards:

It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Excellent' is considered.

Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Outstanding', 9 credits for Energy Performance and 4 for energy modelling and reporting within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.

It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy efficient equipment'.

Results overview

8.1 Scoping activity

A review of background information in terms of energy and carbon policy across all ten districts revealed discrepancies in the energy efficiency and carbon performance targets set for new developments.

Most importantly, these included out-of-date content, unclear references to standards and variations in terms of the size of development applying to.

Furthermore, carbon and energy improvements expected were expressed in both metrics, but not in a uniform, unifying matter. In some instances, the requirements could refer to one or the other metric in such a way that compliance with minimum set requirements would be challenging for planners to evaluate.

International and national drivers for moving into a carbon-neutral built environment were identified. Recent government announcements, the release of a new consultation document '*The Future Homes Standard: changes to Part L and Part F of the Building Regulations for new dwellings*' and suggested changes within the Standard Assessment Procedure currently create additional challenges in setting targets based on minimum regulatory carbon performance requirements as presented within Part L 2013.

Fuel poverty, energy conservation and actual delivered performance of new buildings are key considerations in establishing a robust energy and carbon policy. Research undertaken showcased the importance of delivering high-quality standards upon project completion, the necessity of feedback collection in terms of delivered energy and carbon performance of new buildings and the importance of linking energy and carbon policy with operational and running costs.

Finally, in terms of the exact 'carbon-neutral', 'net-zero carbon' buildings definitions, literature review indicated that these terms can be used within a variety of contexts. The UK GBC framework provides a number of carbon attributable construction activities, while Part L of the Building Regulations only considered the regulated energy emissions (operational).

The UK GBC Net zero carbon – operational definition was considered as the most appropriate proxy for delivering the different net-zero carbon requirements until 2025, within the gradual implementation of additional elements of the UK GBC Net zero carbon – construction considered from 2025 and onwards.

8.2 New domestic buildings energy and carbon performance

Because of recent changes in national policy, and in light of the new consultation document suggesting potential changes within Part L 2020, a thorough review of the GMSF carbon and energy policy alignment was undertaken. This revealed that current GMSF guidance including an interim 19% carbon performance improvement over Part L 2013 could be deemed redundant.

The potential Future Homes Standard requirements from 2025, for an almost 80% reduction in carbon emissions compared to Part L 2013, indicated 2025 as an appropriate intermediate step for the GMSF policy.

The target for new developments to be net-zero carbon from 2028 could include further improvement recommendations. In both scenarios the introduction of appropriate offsetting mechanisms could be considered. It is advised that a Carbon Offset Fund mechanism is introduced from 2025.

Six new domestic buildings archetypes were identified through the review of national minimum space standards, as well as Greater Manchester planning applications for new domestic developments. All archetypes were modelled using SAP 2012 so regulated energy demand predictions can be produced. The number of models created including different levels of fabric and services performance followed the current GMSF energy hierarchy.

An analysis conducted on the stepped approach suggested within the energy hierarchy, identified areas of wording open to interpretation, as well as overlapping terminology used between the different tiers. While clear in terms of the end goal, the hierarchy would benefit from further details provided on the preferred compliance approach when submitting supportive information to planning authorities.

The interim 19% improvement over current Part L 2013 guidance provided by the GMCA, along with a recommendation for 20% of these savings to come through renewable and low carbon energy sources was reviewed. Due to the inherited interdependence of such a threshold with the carbon intensity of the grid and the SAP version used, it was not utilised as the baseline for the research modelling results review. In contrast, specific renewable energy generation targets in terms of installed capacity was advised.

Current and future predicted grid carbons were analysed, prior to reviewing the new domestic modelling archetype results. These was considered as important to demonstrate how energy type (gas/electricity) would affect any carbon-based performance predictions.

Main challenge identified with the use of carbon performance improvement targets was the accelerated decarbonisation of the electricity grid. As it was demonstrated, sought levels of carbon performance improvements will vary in time based on assessment tools used and the time of the assessment. In support of this analysis the models were assessed both in terms of carbon and energy demand performances.

A breakdown of energy demand in terms of regulated and operational unregulated energy use demonstrated the impact of operational unregulated energy (plug loads) on overall predicted operational energy consumption. Operational unregulated energy use included mostly electrical energy demand. Main impacting factors in both energy categories were explained for policy wording clarity purposes and provided within the report.

Considering space heating energy demand, an analysis conducted using the Box 98 SAP outputs demonstrated the impact of the higher performing fabric specifications used in the naturally and mechanically ventilated models. Most housing models were able to achieve space heating energy demand requirements of 30 kWh.m^2 per year by introducing medium impact (cost and technical) fabric upgrades. In the case of flat models, the relevant threshold was established as 25 kWh.m^2 per year. Both limits were recommended as policy targets for the period of 2020-2025. Equally both limits were reduced to 20 and 15 kWh.m^2 per year respectively for the period 2025 and onwards.

DHW generation energy requirements varied between the archetypes. This depended on predicted levels of occupancy. Main difference between energy demand in terms of delivered energy and energy demand as required from the grid was the efficiency of the service used to deliver the energy to the DHW.

Heat pumps due to inherited energy efficiency achieved substantial energy reduction requirements in producing the DHW energy required. It was identified that DHW demand from the grid can be reduced to 15 kWh.m^2 per year (houses and large flats) and 20kWh/m^2 per year (smaller flats) by utilising an energy-efficient DHW generating system such as an ASHP and WWHR systems.

An initial consideration for a 20% DHW energy demand reduction when compared to Part L 2013 notional building was suggested for the policy period of 2020-2025. This could become mandatory for 2025 and onwards, depending on feedback received during Stage 1.

Renewable energy generation as a compensator for carbon emissions produced from new domestic buildings was evaluated against proposed changes within future SAP carbon emission factors and predicted carbon emissions of the electricity grid produced by using the Treasury Green Book guidance. As identified, the contributions of PV generation in such a manner would be ever-reducing as a result of the small carbon content attributable to exported energy.

On the other hand, heat pumps have a high impact in meeting ‘renewables’ target as far as renewable heating is concerned due to the methodology occupied by the government in evaluating carbon emissions mitigation through energy displacement (due to the systems efficiency).

Finally, the analysis of operational unregulated energy demand predictions, and complete offsetting through the introduction of PV systems on the roof of the models, indicated that the use of PV for covering the totality of regulated and operational unregulated carbon emissions would be non-feasible. A stepped approach to minimum amount of installed PV generation based on roof areas, with remaining emissions required to be offset through a Carbon Offset Fund was suggested.

The overall review of the carbon performance of all six archetype models revealed that an interim 19% improvement in carbon emissions compared to Part L 2013 baseline was achievable using the SAP10.1 carbon factors both with naturally ventilated and mechanically ventilated gas boiler-supported solutions with medium fabric specifications upgrades required. This revealed that such a target would be ‘too easy’ to meet.

The effect of heat pumps efficiency, combined with the predicted decarbonisation of the electricity grid, led to all models complying with the 20% and 31% carbon improvement requirements proposed for Part L 2020. This was irrespective of the fabric specifications used (no worse than Part L 2013 minimum requirements), even though further fabric performance improvements may be introduced within Part L 2020.

The use of heat pumps also led to compliance with the potential Future Homes 2025 targets of around 80% carbon performance improvements compared to Part L 2013 when future SAP electricity carbon factors were used, with fabric specifications used similar to the ones used for the compliance with Part L2020.

8.3 New domestic buildings – cost

All domestic models were assessed in terms of capital cost uplifts required to achieve the modelling specifications. They were also assessed in terms of running costs predictions.

The capital cost uplifts to achieve the highest specifications (Very High) did not exceed £10,500 in any of the archetypes (costs incurred to deliver the ‘Very High’ detached house archetype was the highest). Costs included the ASHP, installations of PV up to 1.25 kWp and WWHR. Based on overall construction costs this would translate into a less than 6% uplift in all cases.

In terms of running costs, the use of all-electric solutions had a high impact on running cost predictions. This was due to the high price of electricity compared to that of gas (almost fourfold increase).

With the implementation of appropriate systems to compensate for the increase in costs for models utilising the same fabric specifications (heat pumps, MVHR, WWHR and PV) it was possible to deliver annual savings of £160-£225.

These savings were not driven by carbon performance targets per se, but appropriate provisions to negate the high impact of electricity prices on the different models are explained in more detailed in the relevant section.

8.4 Non-domestic buildings

Non-domestic buildings' carbon end energy performance potential uplifts were evaluated through a desk-based literature review study.

As it was identified, similarly to domestic models, the potential decarbonisation of the electricity grid will have a big impact on the carbon performance assessment of non-domestic buildings.

The type of use, design and services installed can vary greatly in non-domestic buildings which need to be fit for purpose. All-electric solutions would lead to a rate of decarbonisation of the buildings under evaluation similar to the rate of the decarbonisation of the electricity grid.

Using carbon performance as the main metric, it was showcased that the carbon performance of these new all-electric non-domestic buildings would improve in time even if their fabric specifications and energy demand requirements were to remain steady.

The type of main energy use, for lighting, heating and generation of hot water, would dictate the preferred construction standards used. Non-domestic buildings with very small requirements for space heating for example would not necessarily benefit from a fabric upgrade as the main energy consumption does not derive from heat energy loss through the building's elements.

Furthermore, and as far as energy efficiency is concerned. Appropriate energy performance baselines will differ between the different building typologies. In order to maintain a proper baseline, it was suggested that appropriate certification tools and frameworks are used for the non-domestic buildings assessments as in the case of BREEAM.

Literature review evidence demonstrated that achieving a BREEAM ‘Excellent’ in non-domestic buildings would not lead to substantial construction cost uplift, as estimated to around 5% increase. The cost uplift increase also included a 15% reduction in energy demand requirement.

Conclusions and recommendations

9.1 Conclusions

- Current research included a thorough examination of potential current and future GMSF carbon energy policy requirements, in achieving the net-zero carbon for new development targets from 2028. Main milestones and alignment with central government direction was considered.
- Advanced carbon energy models produced for new domestic buildings, indicated the importance of considering energy demand when evaluating the roadmap to 2028.
- Main impacting factors in terms of the predicted carbon performance of new domestic buildings were the assessment methodology used and the potential decarbonisation rate of the electricity grid.
- The introduction of all-electric solutions, and more energy-efficient installed services for space heating and domestic hot water generation requirements would produce favourable results and are expected to be some of the first measures undertaken by the construction industry.
- The impact of a fabric first approach, one of the most robust methods to secure energy and carbon savings through space heating demand reduction, as well as to secure a comfortable and affordable-to-run internal environment for the occupant, was obvious especially in less efficient form (detached, end-terrace).
- The impact of fabric performance improvements on space heating, for extremely advanced fabric standards used, was substantial but at that level of performance the energy demand is dominated by the DHW energy requirements as well as operational unregulated energy use (if to be considered), therefore, proper consideration should be given to the supportive policy documents produced to assist with a carbon performance-centric policy requirement. Energy demand targets in the case of energy demand for heating in new homes will need to be introduced as per the research findings.
- Utilisation of PV for carbon offsetting, and the impact of their use on the predicted carbon performance of buildings, may not be substantiated from a

carbon performance perspective in the future. This is mainly due to the impact of the predicted decarbonisation of the electricity grid.

- The impact of PV in terms of additional electrical energy generation, and from a running costs perspective, is significant and ongoing. Depending on primary energy factors and the Part L 2020 baseline (concurrent notional), it might be the case that the PV argument remains central to main government policy requirements and therefore transferred as such in local policy if carbon and only metrics are to be used.
- Non-domestic buildings, in a similar matter to that of domestic, will benefit from the electricity grid decarbonisation, especially in the case of all-electric solutions when assessed against a carbon performance metric.
- Carbon performance of new buildings in the future (2025 step) is expected to be assessed using a new assessment tool, methodologies and carbon and primary energy performance targets. It is important that any local policy introduced today in terms of energy and carbon is reassessed in the future.
- Running costs for the occupants and residents of new buildings will be dictated by the energy required from the gas and electricity grids. As all-electric and mainly electric solutions are expected to receive greater appreciation from a carbon performance perspective in the future, for the same energy demand requirements between a gas supported building and an all-electric building the annual energy expenditure is expected to increase. Nevertheless, with the introduction of more energy-efficient systems (heat pumps and the likes), energy recovery and energy generation systems these can be offset. This is the case for buildings with the same fabric specification used.

9.2 Recommendations

- The new Part L 2020 is expected to introduce new requirements in terms of the fabric performance of a new building, improvements in terms of carbon performance (20 or 31%) and changes in the way buildings are evaluated through SAP (method and metrics). The current interim 19% DER/TER GMSF carbon improvement requirement – over the Part L 2013 – will need to be revised upon confirmation of the Part L 2020 changes.
- Informed from new central government guidance provided, and findings deriving from this report, the GMSF net-zero carbon definition will need to be clarified. The description ideally will include information on energy and associated carbon metrics used and clarification over types of carbon emissions considered. It is expected that initially (2020-2025) this will align with the UK GBC net-zero carbon buildings – operational energy principles, and later it will transition to include elements of the UK GBC net zero carbon buildings – construction definition (2025-2028 and later)
- The local carbon and energy requirements of the ten districts will need to be unified under the GMSF target. Old and redundant policies and references will need to be removed (archived). New guidance should be produced and provided for planners and developers to fully comprehend the policy in terms of compliance requirements. Any supportive documentation produced should be updated at each stage of the policy implementation pathway. In addition, based on interim feedback received and shared between the ten districts, wording corrections and additional supportive information should be kept up to date.
- Energy (Merton Rule) and carbon policy targets expressed as stacked percentages of CO_2 improvements over new and past minimum regulatory requirements lead to complications. This should be abandoned or further enhanced (an initial alignment with Part L2020 and the Future Homes Standard, 2025 is recommended in the sense of DER/TER and regulated energy consumption predictions). Specific requirements in terms of energy demand and generation are recommended.

a. **New domestic buildings**: Priorities should be to combine the carbon-saving opportunity presented by low-carbon heating systems with the need to maintain affordable running costs and minimise external impacts on the energy system.

This requires a combination of energy efficiency targets and the use of low-carbon heating. This should be achieved while minimising the potential for complication and performance issues in use and so it is prudent to avoid introducing too many new systems and building methods at the same time. The introduction of requirements in terms of a strong QA framework used by the developers is strongly recommended and will support minimising the potential performance gap.

Maximum space heating demand targets of 30kWh/m^2.year for houses and 25kWh/m^2.year for flats (maximum space heating energy demand requirement prior to considering any system efficiencies', SAP Box 98) are achievable in all archetypes tested with natural ventilation and are considered a proportionate initial step in reducing energy use, supporting the use of low carbon heating while minimising short-term impact of adopting and integrating too many new technologies.

In combination with the space heating target, the introduction of a requirement to avoid the use of fossil fuels and to ensure that modelled energy bills (via SAP) are no higher than that of an home built to the 2013 Part L standard using gas would ensure that an efficient low-carbon heating system (eg an ASHP) is used rather than gas or a direct electric system.

Once there is experience in delivering more energy-efficient homes using low-carbon heating systems, a sensible further step would be to tighten the energy performance standards. This would have a relatively small impact on operational carbon emission but would reduce running costs for residents and help minimise any impacts on the wider energy system associated with the increased consumption of electricity.

Tightening up the maximum space heating demand targets from 2025 at 20kWh/m^2.year for houses and 15kWh/m^2.year for flats (maximum space heating energy demand requirement prior to considering any system efficiencies', SAP Box 98) are achievable in all archetypes tested with mechanical ventilation and are considered a proportionate initial step in further reducing energy use, in line with the Committee on Climate Change recommendations.

In term of the additional construction cost expected to be incurred by meeting the suggested thresholds, this was calculated based on a Part L 2013 notional building (meeting minimum regulatory requirements). The average fabric upgrade cost for each housing model archetype is provided below.

Please note:

- Efficient forms such as the mid-terrace house and mid-floor flats can meet the Stage 1 standards using an N2 specification (naturally ventilated).

- The use of mechanically ventilated systems to meet Stage 1 thresholds led to substantial cost reductions in the case of the least efficient housing archetype forms (detached and end-terrace properties).

- On a number of occasions, a range of fabric improvements is noted as applicable (eg N2 to N3). This is because marginal improvements over the lower specification indicated can meet the standard. Therefore, the upgrade cost is expected to be somewhere between the range provided and closer to the lower end of the range.

Cost associated with increased standards

	Stage 1 <30kWh/m2 Houses <25kWh/m2 Flats				**Stage 2 <20kWh/m2 Houses <15kWh/m2 Flats**			
Archetype	**Naturally ventilated**		**Mechanically ventilated**		**Naturally ventilated**		**Mechanically ventilated**	
	Fabric standard (FS)	Additional cost (AC)	FS	AC	FS	AC	FS	AC
Detached	N3	~ £4,900	M1	~ £2,600	-	-	M2 to M3	~ £4,650 to £6,200
End-terrace	N3	~ £3,300	M1	~ £1,950	-	-	M2 to M3	~ £3,550 to £4,400
Mid-terrace	N2	~ £1,700	M1	~ £2,100	-	-	M1	~ £2,100
End-terrace townhouse	N2 to N3	~ £1,700 to £3,000	M1	~ £1,500	-	-	M2	~ £2,900
1B flat	N2	~ £800	M1	~ £950	-	-	M1 to M2	~ £950 to 1,300
2B flat	N2	~ £1,250	M1	~ 1,150	-	-	M1 to M2	~ 1,150 to 1,800

PV capacity can increase, if feasible, at very little additional cost. An introduction of a Merton Rule for PV can be based on available roof space. An initial introduction of a 20% coverage can be introduced in 2020-2025 followed by an increase to 40% during 2025-2028.

It needs to be noted that the cost implication of such a requirement will vary based on the available roof space of the new houses or flats and the amount of PV that this translates into. As an example, in the case of the detached house (based on ground floor area as a proxy, 58.4m^2) 20% would translate into ~1.6kWp PV installed and 40% into ~3.2 kWp PV installed at ~£2,285 and £3,470 respectively.

b. **New non-domestic buildings**: Consider introducing a minimum overall sustainability performance requirement through appropriate accreditation which includes energy efficiency.

This could include the following:

2020-2025:
It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of ‘Very good’ is considered.
Carbon requirements-wise within the ‘Very Good’ target a mandatory requirement for achieving the BREEAM ‘Excellent’ minimum standards, 4 credits for Energy Performance within the ‘Ene 01 - reduction of energy use and carbon emissions’ is advised to be implemented.

2025-2028:

It is recommended that in terms of sustainability targets a non-domestic BREEAM minimum rating of 'Excellent' is considered.

Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Excellent' with at least 6 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.

It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'. Please note that Ene08 refers only to operational energy use and does not include embodied carbon or whole lifecycle carbon.

2028-onwards:

It is recommended that in terms of sustainability targets a Non-domestic BREEAM minimum rating of 'Excellent' is considered.

Carbon requirements-wise a mandatory requirement for achieving the BREEAM 'Outstanding' 9 credits for Energy Performance and 4 for energy modelling and reporting within the 'Ene 01 - reduction of energy use and carbon emissions' is advised to be implemented.

It is also recommended that a level of performance for unregulated energy (operational) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'.

Please note that any cost uplift will heavily depend on the size, location and type of non-domestic buildings delivered. Post-2028 recommendations, cost impact will need to be reassessed as more information becomes available.

- Carbon emissions deriving from operational unregulated energy use should be considered from 2025 and onwards, with appropriate guidance provided on the calculation method to be used. The majority of these emissions will derive from the use of electrical energy and will continue to reduce as the electricity grid is getting decarbonised. It is recommended that a Carbon Offset Fund is set up and used to deliver the net-zero carbon requirements. It is recommended that such a fund is introduced as early as 2025.

- As the electricity grid is expected to continue to decarbonise, it is also expected that a lot of new buildings will be employing all-electric solutions to achieve the different sustainability standards. This could lead to a strong focus on energy-efficient heating and hot water generation services. It is recommended that additional research is conducted on how best to accommodate these new technological needs locally (skills, knowledge, grid capacity) as well as to ensure that the construction quality remains of a high standard. A carbon-only metric can mask knock-on effects including increased operational costs, electricity grid upgrade requirements and evaluation of performance of fabric and services in-situ (performance gap).

- Special provisions shall be made within local policy in terms of affordability, fuel poverty and impact of new buildings' specifications on occupants' bills. In terms of new domestic buildings, it is recommended that consideration is given as to the level of running costs expected. One approach to introducing such thresholds could be an expectation of new domestic buildings to achieve not only any energy and carbon improvement targets, but also a predicted running cost reduction compared to the Part L 2013 concurrent notional (pending confirmation of introduction of the new regulatory requirements). Such a requirement can be superseded or become redundant if appropriate provisions within the new Part L are identified and considered as sufficient.

- Actual delivered quality of buildings should be of prime focus. New buildings within the area should be delivered following robust QA frameworks. For public buildings, energy and carbon performance monitoring is advised. Planning requirements for developers including a request for description of methods and processes in place to reduce a potential performance gap could be considered.

9.3 Accelerating the 2028 net-zero carbon development requirements

In terms of accelerating the policy pathway, delivering the objective of net-zero carbon developments from 2028 was considered as rational by the research team.

Delivering net-zero carbon buildings is not an easy task. As discussed previously, while the carbon metric can be easily addressed, due to the impact of the grid decarbonisation and the use of new technologies, other factors come into play when trying to quickly deliver high standards that the industry might not have a lot of experience with.

In the case of housing, the standards proposed within the report are considered as cost-effective and technically feasible. At the same time the stepped approach will allow for the phased adaptation of the construction industry and the planning system to the new standards required.

In the case of non-domestic buildings, similarly, and while it is appreciated that larger developments might strive to exceed the standards suggested, the approach recommended allows again for the gradual adaptation of the different stakeholders to the new requirements.

The staged implementation of the policy objective allows for evaluation of policy success, optimisation of policy wording and the stepped introduction of the advanced requirements.

It also allows for the better understanding of the impact of new national standards, construction technologies and systems on this journey.

Some of the main challenges in terms of bringing the timeline forward would include:

- Upskilling planners and involved parties to assess and address the stricter requirements.

- Reduced time to collect performance-based feedback, potentially leading to buildings that ill-perform, leading to an increasing number of complaints and affecting the user experience. Claims and retrofit actions might also increase in numbers.

- Quick introduction of a variety of new systems and potentially untested solutions. Knock-on effects can include lack of local support, issues with systems operation and maintenance and the introduction of a larger ‘performance gap’.

- Sudden increase in development costs that can deter developers, limiting delivery due to identified risks leading to slower assessment of policy success.

- Not allowing the time to develop robust control QA frameworks and system solutions.

- Updates in performance standards may end up in disarray with main cycles of Building Regulation updates introducing legal challenges.

The research team realises the additional greater benefits and opportunities that might arise if the net-zero carbon objective was to be met earlier.

Nevertheless, in-house experience with policy implementation and industry adjustment rates indicate that the phased improvement of standards, and the 2028 target are appropriately timed to allow for adaptation to new measures.

To conclude, while the risk of accelerating the 2028 net-zero carbon development requirements is not quantified or within the scope of this report, caution is advised in terms of bringing the timeline forward. A more conservative approach would allow for GM to explore the net-zero carbon developments landscape and support and ensure the policy’s appropriate implementation.

Appendices

Appendix A – References

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Appendix B – Glossary

Actual

This term is used within the domestic energy modelling section of the report as a way to describe a new built property currently delivered within TWBC. In effect the Part L 2013-compliant model was adjusted to reflect minor variations in terms of the fabric elemental performance, as extracted from new built planning applications within the TWBC, In all models it was noted that the ‘Actual’ had a similar (less than 1% improvement) fabric performance to the minimum Part L 2013 requirements.

Airtightness

Airtightness is a general descriptive term for the resistance of the building envelope to infiltration with ventilators closed. The greater the airtightness at a given pressure difference across the envelope, the lower the infiltration.

Emission factor

Emission factors are the amount of carbon emitted to supply a given quantity (eg 1 kWh) of energy. Emission factors exist for a wide range of fuels and also for electricity. In recent years the emission factor for electricity has reduced considerably as a result of increased use of renewable energy and of lower carbon sources of power generation. Emission factors for fuels are largely unchanged. The reducing emission factor for electricity means it is becoming an increasingly low carbon source of energy, particularly when used within highly efficient technologies such as heat pumps.

Fabric first

A ‘fabric first’ approach to building design involves maximising the performance of the components and materials that make up the building fabric itself, before considering the use of mechanical or electrical building services systems. This can help reduce capital and operational costs, improve energy efficiency and reduce carbon emissions. A fabric first method can also reduce the need for maintenance during the building’s life[63].

Heat pumps

Heat pumps typically use electricity to compress and thereby increase the temperature of air or water and then extract the heat to provide space heating or domestic hot water. Common heat pumps are either air source (ASHP) that extract heat from the air or ground source (GSHP) where heat is extracted from water that has absorbed heat from the ground. Because some of the heat suppled is already present in the air or water, the energy used by the heat pump is only a fraction of the useful heat supplied to the building. For example, an ASHP may output over three times more heat energy than it requires to in the form of electric power.

Infiltration

The uncontrollable air exchange between the inside and outside of a building through a wide range of air leakage paths in the building structure.

[63] https://www.designingbuildings.co.uk/wiki/Fabric_first

Kilowatt peak (kWp) capacity

In the context of photovoltaic panels, the peak capacity is the maximum theoretical output of the system under standardised test conditions. In practice, the output of a fixed PV array will vary throughout the day according to its orientation and incline, presence of oversharing, the position of the sun and weather conditions.

LEAN

London Plan Policy SI2 Minimising greenhouse gas emissions. Be lean: use less energy and manage demand during construction and operation.

Mechanical ventilation and heat recovery (MVHR)

MVHR is a mechanism for providing ventilation that provides a controlled supply of outside air that has been warmed by recovering heat from the stale air being extracted from the property. In this way the unit provides the necessary ventilation with minimal loss of heat in the home. When external temperatures are higher, the MVHR is capable of operating in 'bypass' mode whereby there is no heating of the incoming air. The system uses electric fans and so has running costs and associated carbon emission but in a well-insulated and air-tight home the saving in heating energy use is greater than that required to operate the MVHR unit.

Merton Rule

The Merton Rule is a term used to describe planning requirements to incorporate a minimum level of renewable energy within a development. The concept was first popularised by its introduction in, and advocacy by, the London Borough of Merton.

Natural ventilation

Natural ventilation is driven by pressure differences between one part of a building and another, or pressure differences between the inside and outside. Natural ventilation tends to cost less to build, operate and maintain than mechanical ventilation, and so this is generally the first option investigated during the design process[64].

[64] https://www.designingbuildings.co.uk/wiki/Natural_ventilation_of_buildings

Net-zero carbon building

There is no single definition for a net-zero carbon building. This is mainly due to the fact that the boundary conditions for associated carbon emissions are not always very clear (as to from which point ones starts calculating the impact of the new building in terms of carbon emissions to the environment).

The recent UK GBC publication '*Net Zero Carbon Buildings: A Framework Definition*' provides the following information:

Net zero carbon – construction (1.1):

"When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."

Net zero carbon – operational energy (1.2):

"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

'*Net zero carbon for both construction and operational energy represents the greatest level of commitment to the framework.'* [65]

Notional dwelling

A notional dwelling is a dwelling that is of the same size and shape as the actual dwelling (model) reviewed under the Standard Assessment Procedure (SAP) 2012. The performance of the modelled dwelling is compared against that of the notional dwelling (gas boiler-based) in terms of carbon performance through the use of the target emission rate (TER) (notional) and the dwelling emission rate (DER) (model). If the actual dwelling is constructed entirely to the notional dwelling specifications it will meet the CO2 and the fabric energy efficiency targets and the limiting values for individual fabric elements and buildings services[66].

Passivhaus

Passivhaus is an international energy standard that was originally developed for housing and is now applied to a range of building types. A building certified to the Passivhaus standard must meet stringent standards for energy consumption for heating (15kWh per m^2) and for overall energy demand. In addition, there are design requirements to control the quality of the internal environment, for example by controlling internal surface temperatures and the risk of overheating to provide a comfortable living space.

Performance gap

There is growing evidence of a gap between the as-designed and as-built energy/carbon performance of new buildings. This gap might arise in a number of ways within the overall building process and, if significant and widespread, may constitute a considerable risk to meeting environmental targets.

Photovoltaics

Photovoltaics (PV) are renewable energy technologies that generate electricity from solar energy. There are a range of PV technologies ranging from thin film solutions that can be overlain on existing surfaces (eg glass) through to discrete panels made

[65] UK GBC, Net Zero Carbon Buildings, A Framework Definition, April 2019
[66] Approved document L1A, 2013 edition incorporating 2016 amendments – for use in England

of a mono or polycrystalline silicon substrate. The electricity generated by a PV is direct current (DC) so it needs to pass through an inverter to be converted into the alternating current (AC) that can be used within a home.

Regulated energy

Energy use that is regulated by Part L of Building Regulations. This includes energy used for space heating, hot water and lighting together with directly associated pumps (for circulating water) and fans (eg for ventilation).

Standard Assessment Procedure (SAP)

SAP is a procedure by which the energy performance of a home is assessed. It is the typical method used for the purposes of assessing compliance with Building Regulations Part L1a. SAP calculates the energy use, cost of energy and carbon emissions of a home, the last of which (the dwelling emission rate) must be lower than the calculated target emission date. The target emission rate is calculated by modelling a home of the same form and size but built to the minimum standards required by Building Regulations. The version of SAP used to assess compliance for new homes is currently SAP 2012; a more recent SAP10 has been published by BRE on behalf of the government but this has not yet been adopted for use in assessing Part L1A compliance.

U-value

A u-value is a measure of the rate of heat transfer across a structure divided by the temperature difference (in Kelvin) across the structure. It is measured in watts per m^2 per Kelvin of temperature difference or Wm^2K. Lower u-values equate to better insulative properties and reduced heat loss. Part L of the Building Regulations sets minimum standards for the u-values of different building elements (eg floor, window, roof or external walls) but building to lower u-values is one method that can help to reduce energy consumption.

Unregulated energy

Energy use that is not controlled by Part L of the Building Regulations. In homes this includes energy use for cooking, white goods and small power (eg, TVs, kettles, toasters, IT, etc). The quantity of unregulated energy in a home is estimated in SAP 2012 using information on the building area.

In non-domestic buildings unregulated energy also includes that used for vertical transportation (lifts and escalators) and process loads such as industrial activities or server rooms.

Ventilation

The removal of ‘stale’ indoor air from a building and its replacement with ‘fresh’ outside air.

Appendix C – Tabulated domestic models cost data

		Gas boiler solutions						
	Cost (£)	N1	N2	N3	M1	M2	M3	Very High
Detached house	Fabric and ventilation	358	3,035	4,936	2,616	4,649	6,161	8,538
	Heating system	0	0	0	0	-906	-2,719	-2,719
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,853	5,530	7,431	5,111	6,237	5,937	8,314
		N1	**N2**	**N3**	**M1**	**M2**	**M3**	**Very High**
End-terrace house	Fabric and ventilation	278	2,078	3,328	1,933	3,546	4,376	5,958
	Heating system	0	0	0	-648	-648	-1,944	-1,944
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,773	4,573	5,823	3,780	5,393	4,927	6,509
		N1	**N2**	**N3**	**M1**	**M2**	**M3**	**Very High**
Mid-terrace house	Fabric and ventilation	84	1,668	2,610	2,086	3,483	4,005	4,897
	Heating system	0	0	0	0	0	-1,296	-1,944
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,579	4,163	5,105	4,581	5,978	5,204	5,448

		Gas Boiler Solutions						
	Cost (£)	N1	N2	N3	M1	M2	M3	Very High
End-terrace townhouse	Fabric and ventilation	82	1,727	3,018	1,495	2,881	4,205	5,831
	Heating system	0	-648	-648	-1,296	-1,296	-1,944	-1,944
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,577	3,574	4,865	2,694	4,080	4,756	6,382
		N1	N2	N3	M1	M2	M3	Very High
Small flat	Fabric and ventilation	17	764	1,192	953	1,326	1,895	2,377
	Heating system	0	0	-354	-708	-1,062	-1,062	-1,062
	Waster water heat recovery (bath only)	450	450	450	450	450	450	450
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,492	3,239	3,313	2,720	2,739	3,308	3,790
		N1	N2	N3	M1	M2	M3	Very High
Large flat	Fabric and ventilation	61	1,229	1,949	1,123	1,838	2,786	3,436
	Heating system	0	0	-525	-1051	-1576	-1576	-1576
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	2,556	3,724	3,919	2,567	2,757	3,705	4,355

		ASHP solutions						
Detached house	Cost (£)	**N1**	**N2**	**N3**	**M1**	**M2**	**M3**	**Very High**
	Fabric and ventilation	358	3,035	4,936	2,616	4,649	6,161	8,538
	Heating system	1,737	1,737	1,737	1,737	674	- 1453	-694
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1470	1470	1470	1470	1470	1470	1470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	4,590	7,267	9,168	6,848	7,818	7,203	10,339
		N1	**N2**	**N3**	**M1**	**M2**	**M3**	**Very High**
End-terrace house	Fabric and ventilation	278	2078	3328	1933	3546	4376	5958
	Heating system	1755	1755	1755	990	990	-540	-540
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1470	1470	1470	1470	1470	1470	1470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	4,528	6,328	7,578	5,418	7,031	6,331	7,913
		N1	**N2**	**N3**	**M1**	**M2**	**M3**	**Very High**
Mid-terrace house	Fabric and ventilation	84	1,668	2,610	2,086	3,483	4,005	4,897
	Heating system	1,755	1,755	1,755	1,755	1,755	224	-541
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	4,334	5,918	6,860	6,336	7,733	6,724	6,851

		ASHP Boiler Solutions						
	Cost (£)	N1	N2	N3	M1	M2	M3	Very High
End-terrace townhouse	Fabric and ventilation	82	1727	3018	1495	2881	4205	5831
	Heating system	1755	990	990	225	225	-540	-540
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	4,332	5,213	6,503	4,215	5,601	6,160	7,786
		N1	N2	N3	M1	M2	M3	Very High
Small flat	Fabric and ventilation	17	764	1192	953	1326	1895	2377
	Heating system	1012	1012	619	226	-167	-167	-167
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Photovoltaics (PV) 0.5kWp	1470	1470	1470	1470	1470	1470	1470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	3,504	4,251	4,286	3,654	3,634	4,203	4,685
		N1	N2	N3	M1	M2	M3	Very High
Large flat	Fabric and ventilation	61	1,229	1,949	1,123	1,838	2,786	3,436
	Heating system	1,279	1,279	660	41	-579	-579	-579
	Waste water heat recovery (bath only)	450	450	450	450	450	450	450
	Waste water heat recovery (plus en-suite)	20	20	20	20	20	20	20
	Photovoltaics (PV) 0.5kWp	1,470	1,470	1,470	1,470	1,470	1,470	1,470
	Photovoltaics (PV) 0.75kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1kWp	185	185	185	185	185	185	185
	Photovoltaics (PV) 1.25kWp	185	185	185	185	185	185	185
	Total cost uplift on 'actual'	3,835	5,003	5,104	3,659	3,754	4,702	5,352

Appendix D – Carbon and Energy Policy Final Outputs (Presentation)

Greater Manchester Combined Authority

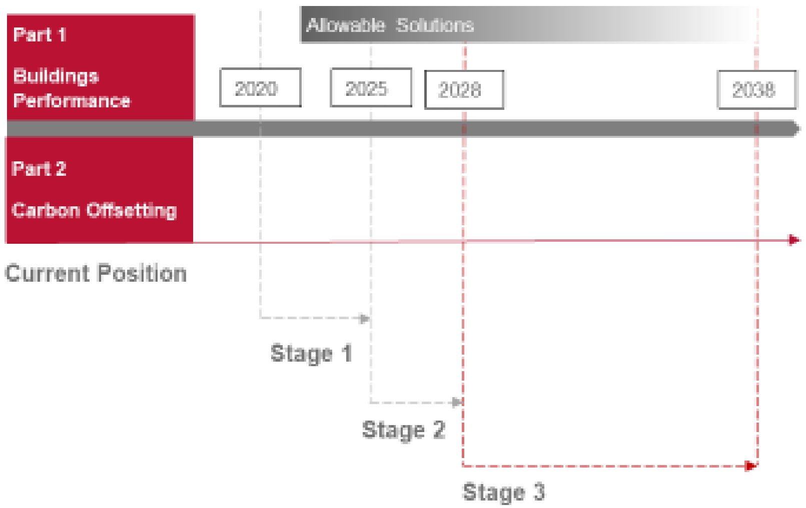
Carbon and Energy Policy Implementation Study - 06.03.2020

Currie & Brown

Content


Bury
Rochdale
Bolton
Oldham
Wigan
Salford
Tameside
Manchester
Trafford
Stockport

Timeline



Greater Manchester Spatial Framework

Policy GM-S 2 Carbon and Energy

All new developments need to be zero net carbon from 2028 following the energy hierarchy (with any residual carbon emissions offset)

A staged approach is proposed, this includes:

- Introduction of immediate requirements for new developments from 2020 – cost effective measures that will allow for business adaptation. The consideration of an early set-up of a Carbon Offset fund (~2022, see Part 2 report*)
- Improvement over 2020 requirements on 2025, in light of the potential introduction of the Future Homes Standard. Inclusion of additional policy objectives.
- 2028 inclusion of all policy items delivering a net zero carbon development as per the UK-GBC framework definition

* net-zero carbon policy kicks in 2028. While the Carbon Offset fund must be activated then, it raises the question as to how best to prepare for this and if its establishment can be brought forward

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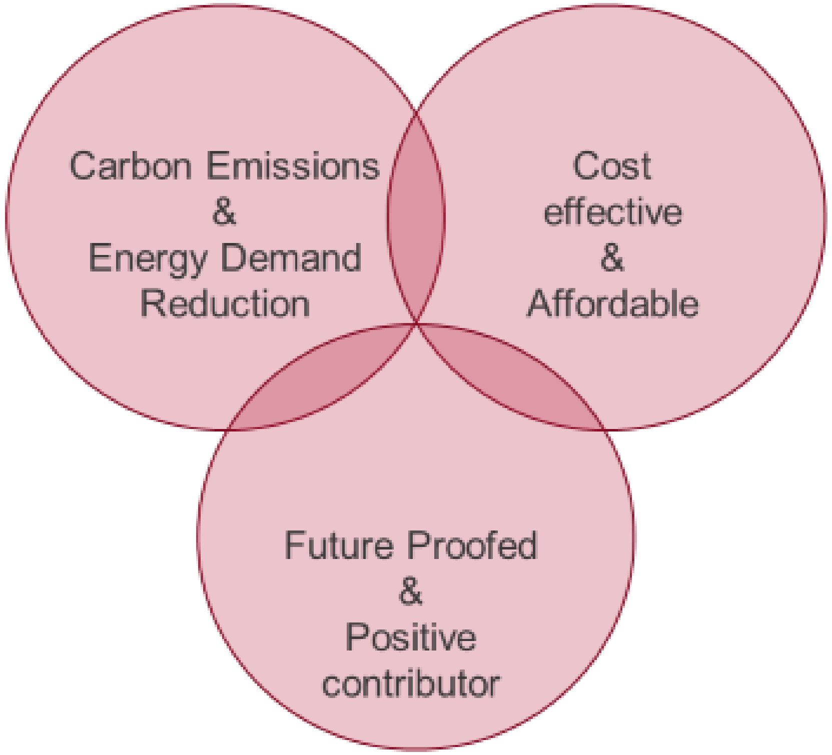
Hierarchy

Carbon and Energy Policy Implementation Study, Currie & Brown 2019 Research Principles

- Energy and carbon emissions reductions needs to be considered together at all stages of the transition. Focusing on carbon emissions and only risk resilience of solutions proposed
- Measures implementation pace should allow for stakeholders to adjust, while targets are not compromised. Measures integration is based on cost-effectiveness of solutions both in terms of construction as well as operational costs
- Measures evaluated and recommendations offered must ensure foresight. Energy generation and carbon offsetting are key steps to meeting the goal. The solutions should be set up in such manner that the new buildings are future proofed and contribute positively to both environmental protection and social values



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Research Boundaries

Carbon and Energy Policy Implementation Study, Currie & Brown 2019

- Construction stage, embodied carbon and demolition emissions are not currently considered within the building regulations. These are also omitted from the costing presented within the research project
- Performance of domestic buildings based on gradual improvements is established through the review or archetypes of housing typologies representative for the area
- The development of archetype based improvement scenarios uses current best construction practice and standards. Model energy and carbon performance outputs are produced using the government's approved method (SAP)
- Cost uplifts are estimated using current prices. Domestic building costs are estimated through modelling. Non-domestic buildings costs are estimated using standards such as BREEAM data and literature review information on cost up-lifts
- Carbon Offset guidance produced is based on literature review and actual carbon offsetting schemes and LA initiatives information.
- All advice and recommendations within the report are based on best practice and current knowledge
- The Part 1 and 2 reports provide the evidence base for appropriate policy development. Recommendations offered are based on findings and in-house experience and expertise on the matter. Alignment with local policies and selection of appropriate policy wording prior to direct implementation is advised. It is not within the scope of the report to produce the policy itself but to inform the policy maker

Part 1

Buildings Performance

Part 2

Carbon Offsetting

Main energy and carbon areas of consideration

Current Implementation Study

Currie & Brown, 2019

Operational Energy Use – Definitions

Regulated energy demand:

As calculated for compliance with the building regulations. Includes energy used for heating, hot water, installed services and lighting

Unregulated energy demand (report context):

In the case of residential buildings this includes the energy used by the occupant during the operation of the house for everyday needs such as computer/phone charging, refrigerators, washing machines etc.

In the case of commercial buildings this refers to small power (includes computers, server, and on-board specialist equipment and other)

Net zero carbon – construction (1.1):

"When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."

Net zero carbon – operational energy (1.2):

"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

UK-GBC

Net Zero Carbon Buildings: A Framework Definition, 2019

Net zero carbon – operational energy is defined as:

"When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."

Energy demand and carbon emissions should be treated together. Setting only a carbon target, against Part L notional, leads to the following knock-on effects:

1) It is not very clear as to where the carbon emission savings come from (fabric, installed services and/or energy generation).
2) Carbon emissions are calculated based on the carbon intensity of the energy type required (gas, electricity or other). The carbon intensity of electricity is ever changing as the electricity grid decarbonises and therefore such targets become a moving target
3) The comparison is conducted with a specific version of PartL1A where minimum requirements also change every 5 years

Net-Zero Carbon Building – *Definition*

The following recommendations are made in terms of adopting a GMCA transition period to net zero carbon – to be completely adopted from 2028 (following a stepped approach), with interim stages required to reflect, adjust and enhance requirements.

Stage 1) 2020-2025 covers predicted operational energy demand – excludes unregulated energy use

Stage 2) 2025-2028 includes unregulated energy, energy storage options, operational energy monitoring

Stage 3) 2028-onwards includes embodied carbon, whole life carbon calculations (including construction) and carbon offsetting allowances

At Stage 3 the Net-Zero Carbon target will align with the objectives of the UK-GBC publication 'Net Zero Carbon Buildings: A framework definition'

Policy
Guidance
Quality Assessment
Research

Pathway – Net Zero Carbon

Stage 1

2020-2025

Introduce mandatory policy elements:

- ✓ Domestic Regulated Energy and Carbon requirements
- ✓ Non-Domestic BREEAM or similar 'Very Good', min energy and carbon 'Excellent' requirements
- ✓ Renewable energy generation targets
- ✓ Legal 2028 net-zero carbon definition

Prepare the Pre-2025 Targets (favourable):
(Domestic and Non-Domestic)

- ✓ Sample site monitoring
- ✓ Unregulated energy use calculation guidance
- ✓ Energy generation monitoring
- ✓ Performance gap minimisation

Initiate work on these Post-2025 targets:
(Domestic and Non-Domestic)

- ✓ Energy Storage research
- ✓ Embodied carbon research
- ✓ Whole life carbon methods and cost research
- ✓ Carbon offset fund structure – discussion initiation

Stage 2

2025-2028

Update:

- ✓ Domestic Regulated Energy and Carbon limits
- ✓ Non-Domestic BREEAM or similar to '**Excellent**', min energy and carbon requirements uplift applies (slide 16)
- ✓ Renewable energy generation targets
- ✓ Local to national policy alignment

Introduce mandatory policy elements :

- ✓ Sample site monitoring rules established (size dependant)
- ✓ Unregulated energy use calculation guidance confirmed - allowance
- ✓ Performance gap minimisation standards implemented - framework

Prepare the Pre-2028 Targets (favourable):
(Domestic and Non-Domestic)

- ✓ Energy storage policy target and planning guidance produced
- ✓ Embodied carbon policy and planning guidance produced
- ✓ Whole life carbon policy and planning guidance produced
- ✓ Carbon Offset fund operational*

Stage 3

2028-onwards

Analyse effectiveness of:

- ✓ Sample site monitoring rules
- ✓ Unregulated energy use allowance
- ✓ Performance gap standards

Update:

- ✓ Domestic Regulated Energy and Carbon limits to **net-zero carbon**
- ✓ Non-Domestic BREEAM or similar to '**Excellent**', min energy and carbon requirements uplift to 'Net Zero' and BREEAM 'Outstanding'
- ✓ Renewable energy generation targets
- ✓ Local to national policy alignment

Introduce mandatory policy elements:

- ✓ Minimum energy storage requirements
- ✓ Minimum embodied carbon requirements
- ✓ Whole life carbon policy and planning requirement
- ✓ Introduction of limits for investment within the Carbon Offset fund

* net-zero carbon policy kicks in 2028. While the Carbon Offset fund must be activated then, it raises the question as to how best to prepare for this and if its establishment can be brought forward

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Policy Pathway and Evidence from the reports

Information provided should be read in conjunction with the reports produced

Furthermore:

- Detailed **energy and carbon targets are provided as per the reports' outputs**
- **Recommendations** on the pathway to net zero carbon **includes elements where further research will be required**
- **Policy targets** are suggested as per the latest guidance in terms of Building Regulations and current GMCA commitments and **may require revising as such elements get updated**
- Domestic buildings research was conducted using a modelling approach and therefore outputs are far more detailed than non-domestic buildings
- **Non-domestic buildings** can follow a similar domestic buildings trajectory in terms of underlying principles. Due to stock variability and future Greater Manchester growth plans, **if necessary and desirable, additional detailed research will need to be conducted for the establishment of numerical thresholds** for all metrics concerned for different building typologies
- Cost impact of non-domestic building upgrades is expressed as an average construction cost uplift percentage associated with BREEAM. This is due to the inherited variability in terms of construction types, sizes and intended use
- Guidance referenced within the research is up to date, but updates will be required by 2028

Domestic Buildings – Stage 2

Stage	Action	Comments
STAGE 2 2025-2028	Sample site monitoring review	**It is recommended that the post-occupancy evaluation standards for major developments are reviewed and the adjusted accordingly. This might include extending the approach to smaller scales of development.**
	Performance gap minimisation standards implemented - framework	**It is recommended that policy requires for Performance Gap minimisation to be demonstrated by the developer though a written statement.** **Guidelines should be updated based on feedback received**

Other areas of interest

Energy storage policy target and planning guidance produced:

Energy storage has the potential to enable greater amounts of renewable energy to connect to the distribution grid, thereby enabling carbon savings to be achieved, however more work would be needed to develop a methodology to predict and attribute such savings to a particular scheme.

Please note that such technologies can be used as part of the Carbon Offset fund but also it would be useful to consider minimum on-site requirements. That will assist in optimising storage and use of on-site generation and minimising occupant expenditure. Additional research on technological solutions, stand-alone or communal systems, insurances and warranties is required.

Embodied carbon policy and planning guidance produced

It appears that there is a current lack of knowledge in the built environment industry around embodied carbon. To meet the net zero carbon new development target, appropriate policy will need to be developed. Guidance on the matter is currently being produced and needs to be researched in terms of planning purposes. The LETI Embodied Carbon Primer could be a good starting point (https://www.leti.london/ecp)

Whole life carbon policy and planning guidance produced
The whole life approach would cover all stages of a structure's life (cradle to grave) – and better align with the UK-GBC Net-Zero Carbon construction. Further research into standards will need to be performed to allow for appropriate planning and policy guidance development. Recent work by LETI (Embodied Carbon Primer) provides some guidance on how developers can achieve zero operational and embodied carbon buildings.

Non Domestic Buildings – Stages 1-3 Targets

Stage	Action	Policy Target
STAGE 1 2020-2025	BREEAM 'Very Good' Requirement	It is recommended that in terms of sustainability targets a Non-domestic BREEAM minimum rating of 'Very good' is mandated. Carbon requirements wise within the 'Very Good' target, a mandatory requirement for achieving the BREEAM 'Excellent' minimum standards, 4 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is implemented. *Please note that BREEAM accreditation does not exclusively refer to energy efficiency and carbon performance of non-domestic buildings, but covers a range of sustainability measures scored to reduce environmental impact.*
STAGE 2 2025-2028	BREEAM 'Excellent' Requirement	It is recommended that in terms of sustainability targets a Non-domestic BREEAM minimum rating of 'Excellent' is mandated. Carbon requirements wise a mandatory requirement for achieving the BREEAM 'Excellent' with at least 6 credits for Energy Performance within the 'Ene 01 - reduction of energy use and carbon emissions' is implemented. It is also recommended that a level of performance for unregulated energy (**operational**) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'. *Please note that Ene08 refers only to operational energy use and does not include embodied carbon or whole lifecycle carbon.*
STAGE 3 2028-onwards	BREEAM 'Excellent' Requirement	It is recommended that in terms of sustainability targets a Non-domestic BREEAM minimum rating of 'Excellent' is mandated. Carbon requirements wise a mandatory requirement for achieving the BREEAM 'Outstanding' 9 credits for Energy Performance and 4 for energy modelling and reporting within the 'Ene 01 - reduction of energy use and carbon emissions' is implemented . It is also recommended that a level of performance for unregulated energy (**operational**) use is implemented based on the different building typologies. This can be found under BREEAM criteria for 'Ene 08 Energy Efficient Equipment'. *Please note that BREEAM 9 credits for Energy Performance in latest guidance translate into a Net-Zero regulated energy carbon emissions building.* *Please note BREEAM provide updated schemes every four years with interim updates, so specific criteria may be subject to change.*

Non Domestic Buildings – Stages 1 - 3 Targets

Other areas of interest

Stage 1:

- Due to the variability in non-domestic buildings type, size and use, introducing exact thresholds for heating, hot water generation and fixed services was not possible. In fact in terms of energy and carbon performances of new non-domestic building energy efficiency performance improvement over standard construction (%) is a common metric of describing improvement. **It is recommended therefore that BREEAM accreditation is used to evaluate energy and carbon performance improvements**.

- Minimum renewable energy generation targets are not prescriptive, but rather are translated through interpretation of the technology in terms of energy and carbon savings. **If policy wants to consider particular energy generation thresholds for non-domestic, further research will be required.**

- While the costs of BREEAM ratings are typically in the range of a few percent of capital cost, the implications for specific buildings, development locations (e.g. greenfield sites, away from transport links and amenities) may be higher and the costs of the certification itself becomes considerable for smaller developments. **A size threshold may help to reduce costs for smaller projects.**

Stage 2:

- **It is recommended that the policy wording ensures that there is an energy consumption monitoring requirement for new non-domestic buildings**. The draft London Plan Policy SI2 requires that major developments monitor and report on energy performance for at least five years via an online portal, a similar approach can be followed within the GMCA.

- Using Soft Landings*, smart meters and requirements for Post Occupancy Evaluations for large developments can all support extracting additional knowledge over delivered / actual performance of buildings minimising the Performance Gap. **It is recommended the policy introduces a requirement for reporting on actions and measures in place, for all new non-domestic developments, targeting the avoidance of a Performance gap including considerations around as-designed to as-built (construction) and as-build to in-use (operation).**

- **It is recommended that whole life carbon policy and planning guidance is produced.** The whole life approach would be all stages of a structure's life (cradle to grave) – and better align with the UK-GBC Net-Zero Carbon construction. Further research into standards will need to be performed to allow for appropriate planning and policy guidance development for non-domestic buildings.

Stage 3:

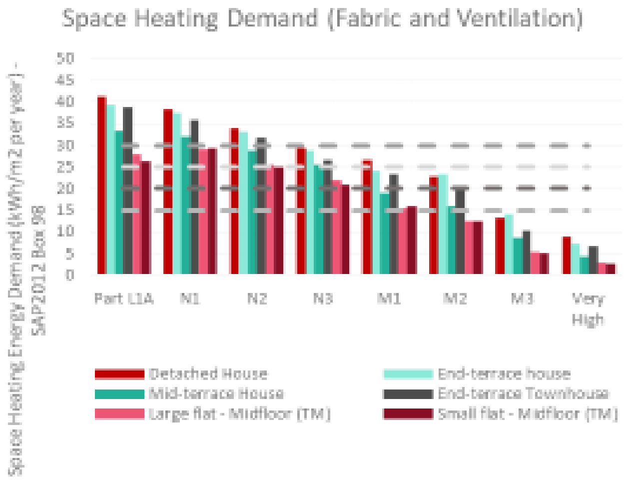
- **As in the case of domestic buildings it is recommended that minimum energy storage requirements for non-domestic buildings are introduced.** This can be set up as a requirement for both buildings generating energy but also for buildings that can act as interim energy storage units for energy generation in the area. Further research will need to be conducted in terms of the capacities required from different building types and sizes.

- **It is recommended that whole life carbon policy and planning policy is introduced. This should include thresholds for embodied carbon following industry guidance.**

- **It is recommended that the policy considers reduction of allowances for carbon offsetting to support more on-site delivery**

* https://www.bsria.com/uk/consultancy/project-improvement/soft-landings/guides/

Construction costs



Domestic Archetype costs (Fabric Only)

Model	Stage 1 <30kWh/m2 Houses <25kWh/m2 Flats		Stage 2 <20kWh/m2 Houses <15kWh/m2 Flats	
	Nat. Vent	MVHR	Nat. Vent	MVHR
Detached	£4,900	£2,600	-	£6,200*
End-terrace	£3300	£1,900	-	£4,400*
Mid-Terrace	£1,700	£2,100*	-	£2,100
Townhouse	£3,000	£1,500*	-	£2,900
1B Flat	£900	£1,000*	-	£1,000
2B Flat	£1,250	£1,100*	-	£1,150*

* Meets lower heating energy demand targets – see graph

Non-Domestic costs

Standards	Achieves	Cost
Energy Efficiency	Minimum carbon reduction of 15%	<2%
BREEAM	BREEAM Excellent rating	1-2%
Total	<2-4%	

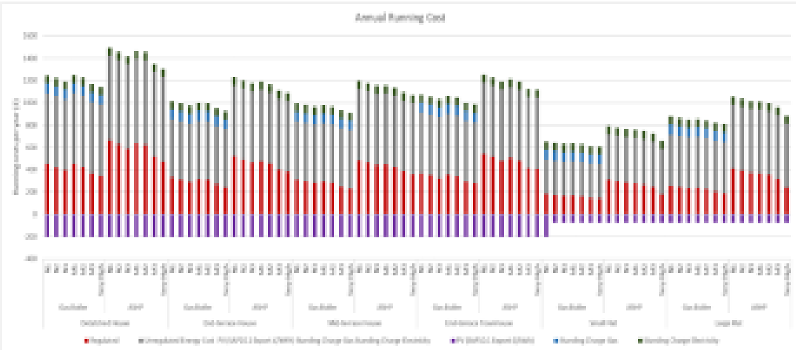
Domestic :

- Meeting the highest modelled fabric standard and including 1.25 kWp of PV and both WWHR and ASHP does not increase the construction costs in any of the models by more than 6%.
- In absolute terms, meeting the 'Very High' standard at the detached archetype new domestic model was the most expensive uplift, with additional construction costs of around £9000 predicted (excluding installation of PV)
- At standard 'Very high' all types require less that 10kWh/m2 per year for heating (specs exceed the current Passivhaus minimum standards)

Non-Domestic:

- The additional cost of BREEAM Excellent certification may be a 1-2% for measures not associated with delivering energy requirements. In many buildings this additional cost could be under 1% subject to its location, the base design and experience of the design and construction team.

Occupant running costs



Domestic Archetype costs (Fabric Only)

- In all models, the move to an ASHP Coefficient of Performance (COP) 2.5 led to higher annual energy bills. This was roughly £150-200 per year in houses for regulated energy use and £50-150 in the case of flats for regulated energy use.

Policy recommendation: if heat pumps are to be used in a development for Stage 1 the system should be designed to operate at low temperatures and to achieve a minimum heating COP of 3.0

- PV electricity generation based on 2kWp for houses and 0.75kWp installed capacity in flats would lead to additional annual savings of £206 and £77 accordingly.

Ties in with the policy recommendation in terms of minimum PV installation (Stage 1 and 2) with generation benefits attributed to the occupants

- If Waste Water Heat Recovery Systems were to be installed in the properties additional annual savings of £15-25 could be achieved in the case of gas supported properties, and £35-55 in the case of all electric properties.
- Moving from N1 to Very High in the housing models led to annual energy savings of around £90 for gas boiler based houses and £55 for flats. The same upgrade in ASHP supported models (N1 to PH) led to annual savings of around £150 in both houses and flats.
- The cost of electricity (retail) is expected to be 4 times more than that of gas.

The cost of all electric solutions will require an introduction of 'affordability' within the energy and carbon policy wording.

That could include a statement that no new home would be expected to be more expensive to operate (regulated energy) when compared to the notional building used for minimum regulatory compliance.

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End

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