Future Homes Hub

Ready for Zero

Evidence to inform the 2025 Future Homes Standard

Task Group Report

28 February 2023

Foreword

The UK has a historic opportunity to build a successful, resilient and green economy, with new homes leading the way and helping the country mitigate and adapt to climate change.

New homes are already much more energy efficient than older homes, but the sector is gearing up for significant transformation as it pushes the limits and works towards building net zero ready homes, with low carbon technology and world-leading levels of energy efficiency, over the next few years.

The Future Homes Standard, set to come into effect from 2025, is the essential regulatory framework that will provide clear direction and the consistent standards for the industry as it scales up to deliver this once-in-a-generation shift.

The importance of the Future Homes Standard is undeniable. But the development of a flagship policy is complex and challenging. Government will consult on the detail soon, but it will take the whole industry to make it reality.

To engage industry and generate practical insight, the Future Homes Hub convened over 170 experts from more than 100 organisations covering the breadth of the housebuilding sector, supply chain, consumer and public organisations, construction professions and campaign organisations. The workshops were positive, collaborative and energetic – the industry is up for this challenge.

The cross-industry engagement and thorough approach has culminated in this compelling report, the most comprehensive examination of how industry can deliver an effective net zero transition. It can inform policy at the Department for Levelling Up, Housing and Communities (DLUHC) and guide business plans as we take our next steps, together.

I would like to thank DLUHC for fully engaging with industry on this critical policy. I also want to recognise the immense efforts of the Co-Chairs David Adams and Oliver Novakovic, and the Future Homes Hub team to make this report possible.

Most importantly, I want to thank everyone who gave their time and shared their expertise: you have made an essential contribution that will help make the zero carbon homes of the future a reality, today.

David Thomas

Chair, Future Homes Hub and CEO, Barratt Developments PLC

It is tremendously helpful to set out the relevant issues and this report accomplishes that leaving no stone unturned. It is arguable whether considering the Future Homes Standard from the 'bottom up' housebuilder perspective of specifications is the right approach when the objective is unequivocal: a top-down requirement for "zero carbon ready" homes that will require no future retrofitting – but the report throws light on the issues related to both, and constructively considers the occupant perspective. For me the report highlights the priority for industry and government to address urgent challenges, including underperformance against design targets and demand reduction for peak grid load mitigation, when taking this significant step in our Net Zero transition.

Lynne Sullivan

Chair, Good Homes Alliance

The Future Homes Standard is likely to be the biggest jump in energy efficiency standards of our new homes in a generation. We need this standard to meet our Net Zero targets and to ensure we provide future generations with homes that are efficient, cost effective and healthy. Government cannot do this alone and needs to set an ambitious standard which is carefully designed so that it is realistic for the sector, as a whole, to achieve at scale, whilst ensuring the continued supply of safe, high-quality, liveable homes. This report sets out the many complex issues that need to be considered in delivering just that. It is a significant piece of work which brings together an array of evidence which Government will find invaluable as it develops the detailed technical elements of the standard for public consultation. We are very grateful for the Hub's work to facilitate this and look forward to continued cooperation as we move towards implementation.

Catherine Adams

Director Net Zero, Department for Levelling Up, Housing and Communities

Acknowledgements

We are indebted to the contributions of all those that have given up their time and contributed to the range of workgroups and the compilation of this report so energetically and constructively. A broad range of stakeholders were involved and, whilst there has been a high level of consensus, on some topics there are understandably differences of opinion which we have sought to reflect but some may hold different views on some items.

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* Separate document

Version 1

Executive summary

The Future Homes Standard is due to be introduced by the Department of Levelling Up Housing and Communities (DLUHC) by 2025. It will require new build homes to be future-proofed with low carbon heating and world-leading levels of energy efficiency.

In developing this policy, DLUHC need to understand the practical implications of delivery at scale. Under a Terms of Reference provided by DLUHC, the Future Homes Hub brought together a Task Group of over 170 expert stakeholders, organised into 20 work groups to gather evidence, culminating in a 2-day evidence session.

Technical options reviewed

The Task Group reviewed five 'Contender Specifications' (CSs) capturing the range of approaches to zero carbon ready homes. Each looked at a combination of choices across these six elements:

- **Fabric performance:** from below the 2021 standard to well above the draft notional for 2025.
- **Windows:** whether double or triple glazing.
- **Ventilation:** whether decentralised or Mechanical Ventilation Heat Recovery and the level of air permeability from 5.0 to 0.5.
- **Space heating:** generally radiators but also infra-red, and no heating source for the highest fabric.
- **Energy systems:** generally heat pumps with and without waste water heat recovery.
- **Renewable generation:** Photovoltaics for most CSs with no renewables in one case and battery and smart controls in one.

Each of the CSs were considered through a range of 'lenses' including: consumer, design, cost, planning, fabric, ventilation, heating, skills, manufacturing, maintenance, grid, metrics etc. The exam questions for each of the lenses and CS groups were: "How would the contender specification be delivered at scale?" and "What are the attributes and outcomes?" Not which was 'good' or 'bad'.

Factors determining choices

The report shares the evidence about how the range CSs perform at scale. Some of the key factors when assessing the options include:

Householder energy bills: CSs range from £190 increase to £450 saving per year compared with the 2021 regulations.

Impact on UK electricity demand at a national level: higher performing CSs would save over 600 GWh/year generation capacity.

Build cost: Stakeholders strongly disagreed on the 2022 costs of the CSs. For an end terrace house the range of costs for CS1 to CS5 in 2022, relative to Ref2025, was from £3k less to £17k more. Estimating the cost of building the CSs 'at scale' in 2026 was not attempted.

Mechanical Ventilation Heat Recovery (MVHR): the challenges and implications of step changes for builders and householders.

Air permeability level: the challenges and implications of step changes in build techniques and quality control.

Transitional arrangements: the timescales needed to secure change at scale safely for different CSs.

Recommendations for effective implementation

The report has 26 recommendations on how to secure effective implementation, irrespective of the FHS ultimately adopted. All 26 are important but these seven underpin the others:

Establish an Industry Government FHS Implementation Board with sub groups including at least: Consumer, Small Builder, Heat pump, Ventilation, Airtightness, Energy Flexibility to support robust roll out.

Announce key decisions as early as possible and include sufficient detail, to give industry time to prepare.

Provide a stable and consistent version of SAP11 in good time to enable industry to prepare and develop solutions.

Provide sufficient Transitional Arrangements based on robust understanding of the operational timescales for redesigning homes at scale and which enable a progressive implementation of the FHS.

Establish and enforce new build homes competency schemes covering airtightness, ventilation and heat pumps due to the risks highlighted in these areas.

Learn from UK and international leaders in net zero homes such as Sweden and Norway and on experience rolling out specific technologies like cMEV and MVHR.

Develop performance measurement techniques to better understand 'as built' performance as designed performance improves.

Summary, themes, recommendations

Introduction

In the 2019 Spring Statement, the Government made a commitment to introduce a Future Homes Standard by 2025 which would require new build homes to be future-proofed with low carbon heating and world-leading levels of energy efficiency.

With the short time line for developing the FHS, DLUHC need to understand the practical implications of implementation. A particular concern was to consider the impact on small housebuilders.

Under a Terms of Reference (ToR) provided by DULHC, the Future Homes Hub brought together its broad range of stakeholders and established a short term "Refining the 2025 Future Homes Standard" Task Group to support this evidence gathering.

The purpose was not to provide a recommendation on which potential technology or approach is best: rather it was tasked with helping Government understand what the practical opportunities and barriers would be if different approaches to delivering the FHS were adopted at scale.

Approach

As a device to draw out the key implications, five 'Contender Specifications' (CSs) were developed which reflected the broad spectrum of stakeholder views in response to the question "What should the Future Homes Standard 2025 look like?" Each CS had different levels of fabric performance, combinations of heating and ventilation systems, renewable generation, and energy storage.

Each of the CSs were considered through a range of 'lenses' to understand the attributes, implications and practical implementation including: design, householder, planning, fabric, ventilation, heating, skills, manufacturing, maintenance, metrics etc. Over 170 experts from over100 organisations were involved in 20 work groups, covering the development of the CSs and the more specialist areas.

Seven archetypes were selected to test the contender specifications across a broad spread of designs and sizes and not simply represent the most commonly built homes.

The exam questions for each of the work and CS groups were "How would the contender specification be delivered?" and "What are the attributes and outcomes?" Not which was the better, 'good' or 'bad'.

At the end of an intensive 6-week period, each of the work groups and CS groups presented and discussed their evidence during a two day 'in person' meeting on the 30th November and 1st December 2022, culminating in this report.

Contender specification philosophies:

CS1 to be consistent with the expectation that the FHS home should **reduce carbon emissions by a minimum of 75% from 2013**

CS2 to align closely with the current **Part L 2021** but electrify the heating

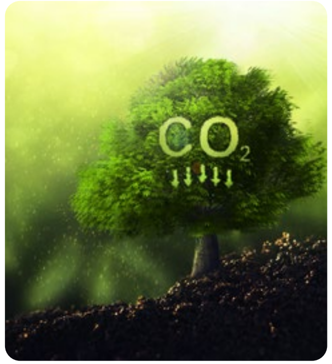
CS3 to be mainstream recognised low energy techniques and technologies for a very **low energy specification**, whilst allowing **design flexibility**

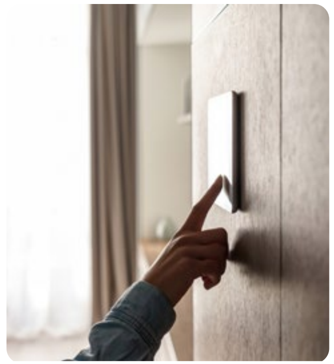
CS4 to minimise space and water heating, drawing on **UK and European low energy building best practice**

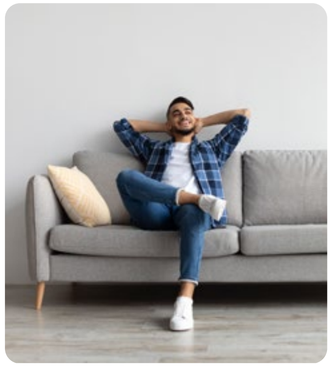
CS5 to improve the fabric efficiency to the level that a **comfortable temperature is maintained without a heating system**

Ref2021 Part L 2021 using a gas boiler

Ref2025 Draft 2025 specification published by Government







Main themes

The key considerations identified are summarised below, together with the main differences between the CSs.

Performance

- All CSs, except CS2a, meet the requirement that a FHS home should reduce **carbon emissions** by a minimum of 75% relative to one built to Part L 2013, with some significantly exceeding this.
- Householder **energy bills**:

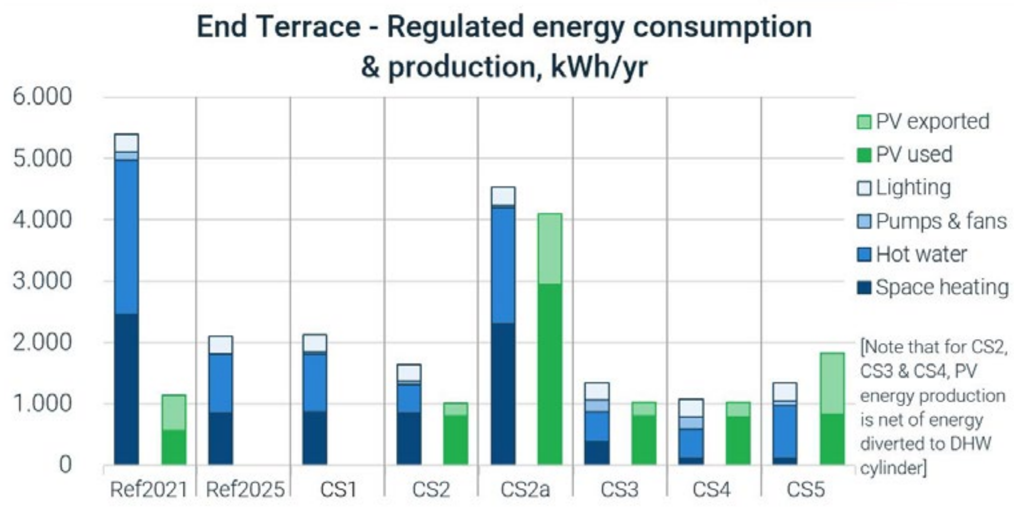
End terrace house	CS1	CS2	CS2a	CS3	CS4	CS5
Energy bills variance from Ref2021 (£700/yr)*	Circa **190**/yr **more**	Circa **£260**/yr **less**	Circa **£50**/yr **less** (Significant under-estimate)**	Circa **£360**/yr **less**	Circa **£450**/yr **less**	Circa **£410**/yr **less**

* Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid. Compared with Ref2021. £700/yr for Ref2021 is for regulated energy only.

** Under-estimate because SAP10.2 is not able to adequately model load shifting which would significantly alter the savings

Contender Specification home energy bills variance from Part L 2021 standard

- By comparison, the Government's 2025 Reference specification would increase householder energy bills by circa £190.
- Regulated energy consumption (see below)



Regulated energy consumption and production by Contender Specification

- All CSs show the same, or reductions of, **energy consumption** compared with Ref2025 except for CS2a. Ref2025 and CS1 do not have PV.
- The reduction of space heating energy consumption (Ref2021 end terrace: 46% space heating, 47% hot water and 7% lighting, pumps and fans) means **increased significance of other areas** such as: hot water (demand / efficiency of generation), ventilation heat loss, designed v built performance, and reduction of peak loads / load shifting.
- SAP10.2 is unable to calculate peak loads, assessed as (highest to lowest): CS1, CS2, CS3, CS4, CS5 (CS2a unable to estimate).
- At a development level, all CSs have similar **grid implications** except for CS2a (although peak load is minimised through smart controls and a battery).
- When viewed at a national level, there is a **significant difference in electricity demand** across the Ref2021, Ref2025 and CSs. For example, if all homes were built to Ref2025 an additional Hornsea2, the world's largest offshore wind farm, would need to be constructed every 7 or 10 years, compared with CS3/4 or CS2 (respectively) to make up for Ref2025's higher energy demand.

Costs

- Stakeholders strongly disagreed on the 2022 costs of the CSs. Estimating the cost uplift for the CSs built 'at scale' and as 'normal practice' in 2026 was not attempted
- **Build cost uplift views** for an end terrace house (not mass scale) - see table below.

End terrace house	CS1	CS2	CS2a	CS3	CS4	CS5
Arcadis Cost uplift compared with Ref2025	**- £3,110** **- 3%**	**£2,270** **2%**	**£5930** **5%**	**£11,380** **9%**	**£16,110** **13%** Relative to 2025 baseline	**£13,480** **11%**
Arcadis Cost uplift compared with Ref2021	**£2,580** **2%**	**£7,960** **7%**	**£11,620** **10%**	**£17,070** **15%**	**£21,800** **19%** Relative to 2021 baseline	**£19,170** **17%**
Other cost (builder)	**x**	**x**	**x**	**x**	**10-19%** Relative to 2021 baseline	**x**
Other cost (reports)	**x**	**x**	**x**	**x**	**12-14%** Relative to 2013 baseline	**x**

Contender Specification built cost variance

- As the level of energy performance increases, the build cost and **delivery complexity** increases.

Process

- Introduction of **Part F/L/O/S 2021** which is still underway, has been difficult and additional testing and refinement would have been beneficial. SAP10.2 outputs have continued to change.
- Many mainstream housebuilders expressed that **delivering** beyond CS2/3 was not possible at scale. Specialist housebuilders maintained it would be deliverable provided scaling up was approached in a managed way.
- **Small builders** have the least internal capacity to understand and implement the frequent regulation changes, yet often are amongst the first having to implement regulations.
- Should the same **transitional arrangements** be adopted for FHS2025 as Part L 2021, then the industry would effectively need to adopt these technologies at scale over a short 18 month period. Depending on the extent of the changes in technology and techniques, this short timescale would unnecessarily create a high risk of quality problems, inflated costs and, potentially, stalled build programmes.
- Part L 2021 used the same notional specification for all homes. Due to generally good form factors, the **space heating of apartments** tends to be a small proportion of overall consumption. With medium and high rise there are additional complexities associated with higher performance walls, compounded by the requirement to use generally thicker, non-combustible insulation.
- A Concurrent Notional does not encourage good building form. An Absolute standard increases complexity.
- The **metrics** used for Part L 2021 do not align fully with the key themes which emerged, namely: space heating demand, net energy consumption and peak load/load shifting.

Technical

- There is **technical scope** to increase the ambition of the FHS. However, with increasing standards and associated benefits, build costs, delivery risk and extent of the changes to building practice escalate.
- Recognised **techniques & technologies** exist to deliver all the CSs although manufacturing capacity and, more significantly, supply chains would need to be scaled up.
- Any difference between **designed and built performance** becomes more significant, as a proportion, as the designed energy performance is improved.
- As the energy performance increases so would the home's **embodied carbon** although this would be offset, to a greater or lesser degree, by the reduction in embodied carbon of the energy sector. Embodied carbon was excluded by the ToR, these impacts were not quantified.
- As wall thickness increases, the **plotting of homes** may be impacted. To maintain the same number of homes, more attached homes may be required. Increasing the number of attached homes would reduce the overall embodied carbon. This has not been quantified.
- The effectiveness of the current design, installation and commissioning processes and performance of al **ventilation systems** were questioned.
- The **ventilation contribution** to improved energy performance for the end-terrace house: CS2 verses CS3 (60% energy efficiency improvement) comprised: MVHR ½, fabric 1/3, air tightness 1/5.
- A key question is whether FHS should, or should not, precipitate the step change of all homes having **MVHR** with its benefits, costs and learning curve for householders (albeit common in apartments).
- Housebuilders would need to undertake a step change in techniques and quality control to **reliably reduce air permeability** (infiltration loses) below 4.5m³/m²/hr.

The table on the next page summarises the differences in specification between the CSs and sets out some additional characteristics such as: home appearance, householder comfort, maintenance requirements and future retrofit needs.

	Ref2021 Current new build home	CS1	CS2	CS2a	CS3	CS4	CS5
Fabric performance	Part L 2021, to meet FEES	Slightly below Part L 2021 Notional	Part L 2021, to meet FEES	Part L 2021, to meet FEES	Similar to Ref2025 draft notional	Very low energy fabric levels	Very low energy fabric levels (absolute metric)
Windows	Double glazing	Double glazing	Double glazing	Double glazing	Double glazing	Triple glazing	Triple glazing
Ventilation Strategy	dMEV Air permeability 4.5 – 5.0	dMEV Air permeability 5.0	dMEV [1] Air permeability 4.5 – 5.0	dMEV [1] Air permeability 4.5 – 5.0	MVHR Air permeability 3.0	MVHR Air permeability 1.0	MVHR Air permeability 0.5
Energy systems	Gas boiler (Combi, or with DHW tank for larger homes) [2]	ASHP[2] DHW tank	ASHP[2] DHW tank, WWHR	Infra-red Immersion, DHW tank	ASHP[2] DHW tank, WWHR	ASHP[2] DHW tank, WWHR	No heating system Integrated MVHR/EAHP for DHW, WWHR
Renewable generation	PV	None, unless req. for 75% CO_2 reduction	PV + diverter for houses	PV + Battery	PV + diverter for houses	PV + diverter for houses	PV
Home appearance	Similar form to Part L 2013 new build homes	Similar form to Ref2021 but typically no PV on roof	Similar form to Ref2021	Similar form to Ref2021, with max number of PV panels on roof	Similar form to Ref2021	Likely reduction in the number of dormer & bay windows; tendency for more efficient forms.	Very few dormer & bay windows; much less complex forms
Householder comfort	Similar to Part L 2013 homes	Similar to Ref2021			More consistent winter internal temperatures No draughts from window trickle vents	Stable winter internal temperatures No draughts from windows or trickle vents Very low external noise	
Healthy indoor environment	No better than the external environment	Similar to Ref2021			Better air quality than external environment		
EPC [3]	90B	84B	95A	92A	97A	99A	99A
CO_2 emissions reduction [4]	32%	78%	92%	74%	95%	98%	103%
Maintenance requirements	Boiler, cylinder – yearly service MEV – periodic cleaning of fans & ducts	Heat pump, cylinder – yearly service MEV – periodic cleaning of fans & ducts		MEV – periodic cleaning of fans & ducts	Heat pump, cylinder/ DHW heat pump – yearly service MVHR – periodic cleaning of fans & ducts; 6 monthly filter change (by householder); 5-yearly service (+ circa £80/yr from Ref2021 for service & filters)		
Future retrofit needs	Heat pump & hot water tank; Advanced controls for peak energy load shifting	Likely addition of PV; Advanced controls for peak energy load shifting	Advanced controls for peak energy load shifting	None	Advanced controls for peak energy load shifting		
Scale up complexity	---	Medium	Medium	Medium	Medium / High	High	High

Additional characteristics of Contender Specifications

[1] cMEV for apartments, air permeability 3.0 – 4.5
[2] For apartments: Panel heaters and DHW ASHP (high-rise variant with centralised ASHP)
[3] For semi detached house
[4] For semi detached house, compared to 2013 Part L

Key recommendations

The aim of the Task Group was to help the Government understand the implications and attributes of potential technologies and approaches and what it would take to deliver at scale. The Task Group were not to recommend what the FHS should be.

The report covers a lot of ground and, without knowing Government's ultimate direction of travel, a vast number of possible recommendations could be made for different FHS scenarios. As such, only the key recommendations are summarised below with some on the basis of 'if this, then that'.

Enabling FHS

1. Establishment of an Industry Government FHS Implementation Board

Whatever level of ambition the Government decides, and the extent of the subsequent implications for the wider housebuilding sector, the lesson from Parts F/L/O/S 2021 is that the implementation needs to be more actively planned, tested, communicated, and managed.

2. Early announcement of key decisions to enable industry to adequately prepare

Following the FHS consultation in the Spring, rapidly announce the key decisions in sufficient detail and clarity to enable the industry to confidently plan and prepare.

3. Early provision of a stable and consistent version of SAP11

The delay of SAP 10 until after the regulation was released has caused major issues to the sector. A readily available, stable and consistent version of SAP11 and the conventions, or an appropriate contingency, is required at least six months before FHS2025 comes into force.

4. Provide Transitional Arrangements which enable a progressive implementation of the FHS

Transitional arrangements need to be introduced which:

- provide the early start to delivery impact the Government requires
- provide a progressive scale up to enable robust uptake, not simply delaying the start
- are proportionate to the extent of the changes the industry need to implement
- are resilient to gaming
- reflect the particular challenges for the small house builder

5. Learn from UK and international leaders in this field

Best practice needs to be understood and disseminated widely to ensure an efficient transition with best outcomes for homebuyers.

6. Creation, development and promotion of a FHS brand

Government and industry to invest time and resources to establish a FHS brand as a means to stimulate consumer interest, help communicate the changes, aid understanding of what to expect and provide a common language for all to use with PR and media.

7. Formation of a Consumer Implementation Group (IG)

A Consumer IG should be established to oversee the FHS brand development and advise on the necessary actions to smooth the customer FHS journey in conjunction and with the support of Government.

8. Introduction of a Home Energy Performance Calculator

Supplement or replace the Energy Performance Certificate with a web calculator, using SAP11, to provide a personalised projection of the homebuyer's/ householder's expected energy bills for new and existing homes being sold. Validate this with research on the energy bills in a range of existing low and high performance homes.

9. Formation of a Small Builder IG

A Small Builder IG should be established to oversee the small house builders and their advisors on the FHS journey to ensure their particular needs and issues are being effectively addressed.

Ventilation & airtightness

10. Formation of a Ventilation IG

Irrespective of which ventilation system the FHS ultimately requires, improvements in ventilation general practice are necessary including the monitoring of the mass scale adoption of dMEV and, *if* the level of FHS ambition effectively requires it, overseeing the mass scale adoption of cMEV or MVHR.

11. Establishment and enforcement of a ventilation competency scheme

To ensure ventilation good practice, a comprehensive competency scheme, suitably enforced, is required covering design, installation and commissioning.

12. Undertake a rapid study of the early adopters of dMEV & MVHR

To understand better dMEV performance in the field following Part F 2021 introduction before mass scale take up and compare with MVHR experience in similar homes.

13. Review of international cMEV and MVHR roll out experience

Undertake a rapid review of international experience of implementing mass scale adoption of cMEV and MVHR.

14. Formation of an Airtightness IG

If the level of FHS ambition effectively requires a reduction in air permeability to $3m^3/m^2$pa, or less, then an IG should be established to develop and oversee an implementation plan, including: sharing of best practice, establishing a formal airtightness trade and 'champion' competency scheme.

Heat pumps

15. Formation of a Heat pump IG

Following clear early signals from Government that low carbon heating will be required from 2025, many larger housebuilders are planning or undertaking heat pump trials. A Heat Pump IG should be established to: develop and oversee an implementation plan, share best practice, support small builders on the journey.

16. Study of hot water usage

An updated study of domestic hot water usage is required to inform minimum hot water storage needs.

17. Development of new build (low energy) heat pump systems design standards

Design standards are critically required for low energy homes using low temperature heat such as heat pumps. Current standards from NHBC, MCS and CIBSE were not developed for this and have inconsistencies, resulting in confusion and potentially sub optimal designs.

18. Establishment and enforcement of a heat pump competency scheme

To ensure high standards and consistency across the sector, a new build homes orientated heat pump competency scheme for designers and installers should be established.

General

19. Introduce a dedicated Notional specification for apartments

As the fabric energy performance is improved, the more efficient form factor of apartments means only modest energy benefits result, not justifying the increased complexity. As such, apartments warrant their own Notional specification (more relaxed U values, less roof area for PV etc).

20. Undertake additional Absolute standard archetype modelling

Modelling of additional archetypes, within SAP 11, is required to better understand the implications and practicalities of an Absolute standard.

21. Develop further the idea of a Concurrent Notional standard with an Absolute backstop

Combining the Concurrent Notional and Absolute standards may provide many of the benefits of both without the main disadvantages. A full technical review including modelling of archetypes is required to explore the implications and benefits further.

22. Formation of a Grid and Energy Flexibility IG

With the significance of peak load reduction, yet a level of immaturity of the solutions, an IG is required to coordinate efforts to maximise the potential benefits for housebuilder, householders and the grid.

23. Planners, housebuilder and DNO / IDNO engagement

Increased levels of early stage engagement are required between planners and housebuilders with the DNOs / IDNOs to understand the grid capacity implications of areas under consideration, to avoid lengthy delays and excessive costs.

24. Undertake ADMD studies of existing new developments using heat pumps

Studies are required on the limited number of existing new build heat pump schemes, supplemented by data from new schemes as they come forward, to refine the power After Diversity Maximum Demand (ADMD) assumptions for development electrical grid sizing.

25. Study of the interdependencies between operational and system wide embodied carbon

As energy performance increases so does the embodied carbon of the home, however, there is a reduction at energy system level. This needs to be better understood.

26. Development of performance measurement techniques

Irrespective of the FHS level decided, as the designed energy performance further improves, any difference with the built performance becomes more significant. Appropriate performance measurement techniques are required.

Introduction

Background

In the 2019 Spring Statement, the Government made a commitment to introduce a Future Homes Standard (FHS) by 2025, requiring new build homes to be future-proofed, with low carbon heating and world-leading levels of energy efficiency. The last time Part L, the energy and carbon standards of building regulations, was updated was in 2013.

As a stepping stone to the 2025 FHS, the Government published an updated Part L which took effect from June 2022. Part L 2021 delivers a 31% reduction in carbon emissions compared with the 2013 regulation. Alongside the Part L 2021 update, the Government also updated Part F, ventilation requirements and introduced a new Part O, designed to address overheating.

At the same time as it consulted on the Part L 2021 changes, the Government sought initial stakeholder views on the approach to be taken in the FHS. In their response to that consultation, the Government confirmed its expectation that the FHS would ensure that an average home will produce at least 75% lower CO_2 emissions than one built to Part L 2013.

In addition, to illustrate what the FHS might look like, the Government published a draft notional specification with anticipated fabric, services and renewable standards. The expectation was also reiterated that heat pumps would become the primary heating technology for new homes.

The Department for Levelling Up Housing and Communities (DLUHC) is expected to issue a detailed consultation on the FHS in late spring 2023.

The Task Group

The FHS is intended to deliver 'zero carbon ready' homes, with low carbon heating and high fabric standards, that will require no future retrofitting and be net zero ready.

The timeline for developing the FHS is short. In order to carry out detailed modelling / analysis and go through the required Government procedures before the public consultation, DLUHC need to understand the practical implications of implementation, in particular, the impact on small housebuilders.

To support this evidence gathering, Future Homes Hub offered to draw on its broad range of stakeholders and establish a large-scale, short term "Refining the 2025 Future Homes Standard" Task Group.

The aim of the Task Group was not to recommend potential technologies or approaches, rather to help the Government understand the opportunities and barriers of each and what it would take to deliver at scale, the implications and the attributes.

The Terms of Reference for this Task Group were developed by DLUHC to inform the Future Homes Hub of the types of evidence that would be most useful to them as they develop their thinking in advance of the consultation (see Appendix A for the Terms of Reference).

Approach

To provide a structure for evidence gathering, the Task Group posed the question, "Future Homes Standard 2025 – what should it be?"

More than 20 different illustrative specifications were proposed. Each contender specification (CS) had different levels of fabric performance, combinations of heating and ventilation systems, renewable generation, and energy storage. Ultimately, five CSs were developed which reflected the broad spectrum of stakeholder views.

Contender specification working groups

Working groups were established to develop each of the CSs, bring together the evidence and consider the implications holistically, drawing from information provided by a series of workgroups.

Topic area working group

Technology focused working groups considered: the technical, supply, scale up etc., implications, in relation to ventilation, heat pumps and fabric. Other groups considered different aspects such as: consumer needs and wants, design implications, planning, and impact on the energy grid. These working groups provided cross-cutting insight to inform the CS discussions.

Additional working groups focused on: the lessons learnt to date from the introduction of Part L 2021, the particular needs of small housebuilders and a metrics working group on how to describe the FHS.

Lenses

To ensure that all relevant issues were discussed in working groups, participants were asked to view the CSs through a series of 'lenses', to draw out the wide range of issues, perspectives and topics which the Government might need to consider when setting the FHS.

Lenses included: skills requirements, the need for future retrofit, implications for site layout, risk of overheating, warranties, geographical differences.

The 'exam questions' for each of the topic area and CS groups were:

"How would the contender specification be delivered?"

"What are the attributes and outcomes?"

The groups were told not to make recommendations, or comment on what was 'good' or 'bad' but simply to provide evidence.

Final workshop

Following an intensive 6-week period, each of the topic area and contender specification groups presented and discussed their evidence, during a two day, 'in person' meeting on the 30th November and 1st December 2022.

The chairs of each group then developed summary notes of their key considerations and findings which were used to help prepare this report.

Fig 1: Photos from 'in-person' meeting

See:

- Future Homes Standard Task Group, Terms of Reference in Appendix A
- List of Task Group Working Groups in Appendix B

Contender specifications

Five different contender specifications were used to discuss and analyse approaches to delivering the FHS. The CSs reflect different perspectives and philosophies on the way homes in England could best be decarbonised, as we move towards net zero.

Government expects that heat pumps will become the primary heating technology for new homes under the FHS. CSs1-4 all specify a heat pump to supply domestic hot water (DHW) and, in houses, also space heating; direct electric space heating is used in apartments.

Elements	CS1	CS2 & CS2a	CS3	CS4	CS5
Fabric performance	Slightly below Part L 2021 Notional	Part L 2021, to meet FEES	Similar to Part L 2025 draft notional	Very low energy fabric levels	Very low energy fabric levels (absolute metric)
Windows	Double glazing	Double glazing	Double glazing	Triple glazing	Triple glazing
Ventilation strategy	dMEV Air permeability 5.0	dMEV[2] Air permeability 4.5 – 5.0	MVHR Air permeability 3.0	MVHR Air permeability 1.0	MVHR Air permeability 0.5
Space heating	Radiators[3]	Radiators[3] Infra-red[1]	Radiators[3]	Radiators[3]	None
Energy systems	ASHP[3]	ASHP [3], WWHR Immersion[1]	ASHP [3], WWHR	ASHP [3], WWHR	Integrated MVHR/EAHP for DHW, WWHR
Renewable generation	None, unless req. for 75% CO_2 reduction	PV PV + Battery[1]	PV	PV	PV

[1] Variant specification
[2] cMEV for apartments, airtightness 4.5 – 3.0
[3] For apartments: Panel heaters and DHW ASHP (high-rise variant with centralised AHSP)
dMEV – De-centralised Mechanical Extract Ventilation, cMEV – Centralised MEV, MVHR – Mechanical Ventilation with Heat Recovery, ASHP – Air Source Heat Pump, WWHR – Waste Water Heat Recovery, EAHP – Exhaust Air Heat Pump, PV – Photovoltaic panel

Fig 2: Summary Contender Specifications

Contender specification 1

CS1 philosophy is to be consistent with the expectation that the FHS home should reduce carbon emissions by a minimum of 75% relative to one built to Part L 2013.

Contender specification 2 and 2a

The philosophy of CS2 is to align closely with the current Part L 2021 but electrify the heating by replacing the gas boiler with a heat pump in houses and use direct electric space heating and a heat pump hot water cylinder in apartments.
As an alternative services approach, CS2a utilises infra-red space heating with PV, a battery and smart controls to load shift.

Contender specification 3

The CS3 philosophy is to mainstream recognised low energy techniques and technologies for a very low energy specification whilst allowing design flexibility.

Contender specification 4

The CS4 philosophy is to minimise space and water heating, drawing on UK and European low energy building best practice.

Contender specification 5

The philosophy of CS5 is to take “fabric first” to its logical conclusion: improving the fabric efficiency so internal heat gains balance with space heat losses, to provide a comfortable temperature without a heating system.

See table on next page for more detailed breakdown

Overview of specifications modelled - Houses								
	Ref 2021	**Ref 2025**	**CS1**	**CS2**	**CS2a**	**CS3**	**CS4**	**CS5**
Wall U-value	0.19	0.15	0.19	0.19	As per CS2	0.15	0.13	0.10 / 0.13
Roof U-value - plane	0.11	0.11	0.11	0.11	As per CS2	0.11	0.10	0.10
Floor U-value	0.15	0.11	0.15	0.15	As per CS2	0.11	0.10	0.08
Glazing	Double	Triple	Double	Double	As per CS2	Double	Triple	Triple
Thermal bridging	Psi values - Set A	y-value = 0.05	Psi values - Set A	Psi values - Set A	As per CS2	Psi values - Set B	Psi values - Set B	Psi values - Set B
Air permeability	4.5 - 5.0	5.0	5.0	4.5 - 5.0	As per CS2	3.0	1.0	0.5
Ventilation	dMEV	Natural ventilation with extract fans	dMEV	dMEV	As per CS2	MVHR	MVHR	MVHR integral with EAHP
Heating	Gas boiler	ASHP	ASHP	ASHP	IR direct elec	ASHP	ASHP	None
DHW / WWHR	Gas boiler	ASHP	ASHP	ASHP & WWHR	Immersion + smart cylinder	ASHP & WWHR	ASHP & WWHR	DHW cyl EAHP & MVHR & WWHR
PV philosophy	To achieve 2021 Part L Pass	None	None, unless req. for min. 75% redn	40% GF area, max 3.68kWp	Maximise roof area for PV	40% roof area max 3.68kWp		
Battery	No	No	No	No	6.5kWh hybrid	No	No	No

Overview of specifications modelled – Apartments								
	Ref 2021	**Ref 2025**	**CS1**	**CS2**	**CS2a**	**CS3**	**CS4**	**CS5**
Wall U-value	LR 0.19 HR 0.17	0.15	0.21	LR 0.19 HR 0.17	As per CS2	0.15	0.15	0.15
Roof U-value - plane	0.11	0.11	0.11	0.11	As per CS2	0.11	0.10	0.10
Floor U-value	0.15	0.11	0.15	0.15	As per CS2	0.11	0.10	0.08
Glazing	Double	Triple	Double	Double	As per CS2	Double	Triple	Triple
Thermal bridging	Psi values - Set A	y-value = 0.05	Psi values - Set A	Psi values - Set A	As per CS2	Psi values - Set B	Psi values - Set B	Psi values - Set B
Air permeability	4.5 Low-rise 3.0 High-rise	5.0	5.0	4.5 Low-rise 3.0 High-rise	As per CS2	3.0	1.0	0.5
Ventilation	dMEV	Natural ventilation with extract fans	dMEV	cMEV	As per CS2	MVHR	MVHR	MVHR integral with EAHP
Heating	Gas boiler	ASHP	Direct elec	Direct elec	IR direct elec	Direct elec	Direct elec	None
DHW	Gas boiler	ASHP	DHW ASHP	DHW ASHP & WWHR	Immersion + smart cylinder	DHW ASHP & WWHR	DHW ASHP & WWHR	DHW Cyl EAHP & MVHR & WWHR
PV philosophy	To achieve 2021 Part L Pass	None	None, (unless required for min. 75%)	Pro rata of 40% ground floor area	Maximise roof area for PV	low-rise: Pro rata of 40% roof area in plan high-rise: Pro rata of 20% roof area in plan		
Battery	No	No	No	No	6.5kWh hybrid	No	No	No
For more detail on each of the specifications see Appendix D								

Fig.3 Overview of specifications modelled

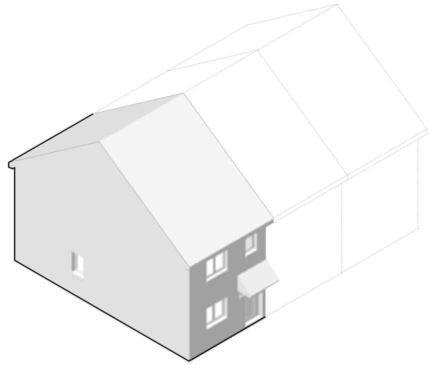
Archetypes

The different contender specifications were modelled using seven archetypes.

Archetypes were chosen to best test the contender specifications with a broad spread of designs and sizes and not simply represent the most common being built today.

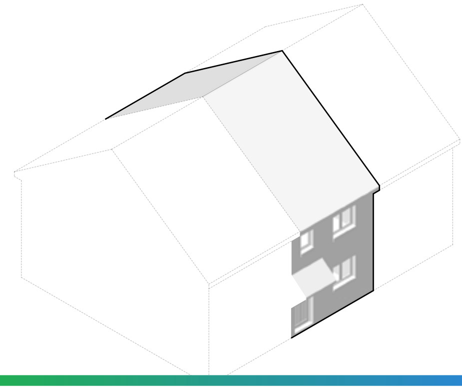
End terrace house

(2-storey, 81m^2)



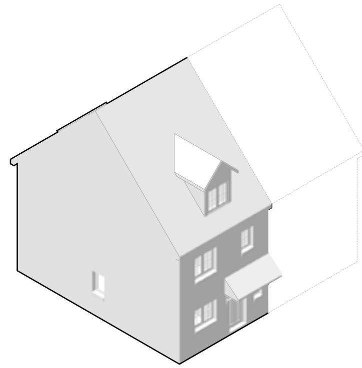
Mid terrace house

(2-storey, 81m^2)



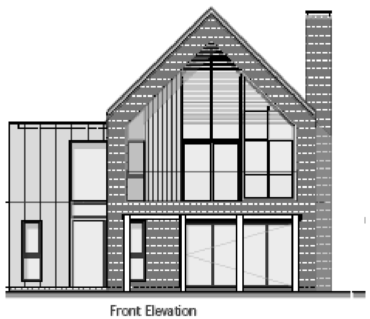
Semi-detached room-in-roof house

(2.5 storey, 112m^2)



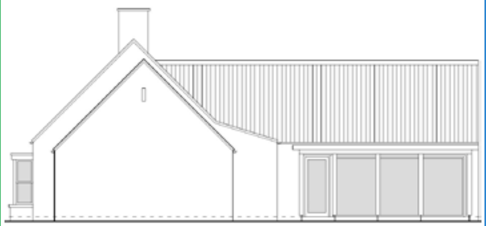
Large detached house

(2-storey, 244m^2)



Detached bungalow

(1-storey, 98m^2)



Low-rise, mid floor apartment

(59m^2) – *assumed to be part of a block with 3 floors, 3 apartments per floor*

High-rise, mid floor apartment

(52m^2) – *assumed to be part of a block with 9 floors, 9 apartments per floor*

Contender specification cost summary

Introduction and approach

Discussing costs is always difficult due to different builders having diverse baselines, price risk, learning and using different assumptions. As a result, there will be a significant range of views. To complicate matters further, the cost we 'actually need' is the cost of different CSs when delivered at scale, as 'normal practice' in 2026. These costs are unknowable. To understand the costs better, much more work would need to be undertaken.

In the absence of this, the approach taken was to understand the range of cost views for the CSs built in 2022 and then reflect on the cost reductions that have been experienced historically as delivery increases and specialist products become mainstream.

To better understand the potential uplift in costs for different contender specifications, three approaches were taken:

- The task group commissioned Arcadis to undertake an 'add and omit' exercise using 2021Ref as a baseline to produce costs for 2025Ref and the CSs using 2022 prices.
- Two main housebuilders with experience of building higher performance homes were approached for their 'view'.
- Cost analysis reports undertaken by others were reviewed.

The Arcadis costings are for a masonry End Terrace house of 81m² (NDSS) built by a medium sized housebuilder on a 200 home development in the South East in December 2022. These are developer costs, rather than contract build costs, and not sales prices. It is assumed that there is space within the home for the cylinder and the ASHP, where fitted. No learning curves have been applied to reflect any mass scale roll out savings.

The Arcadis 2021Ref cost for the home was £114,290 and £1,470/m². Whilst not unusual for this size of builder, this baseline is considerably higher than large builders' costs and less than many small builders. The percentage uplift provides an alternative representation.

The Arcadis costs have been reviewed by a range of stakeholders and the methodology and results are disputed by some. The other sources of cost information quoted, such as the data supplied by the two builders and the Passivhaus Trust report, have not been subject to detailed review and, may have different baselines, specifications, assumptions and methodologies. The validity of these costs is disputed by other stakeholders.

Observations and summary

- Arcadis 2025Ref represents the costs the housebuilders may have expected following the announcement of the FHS in the 2019 Spring Statement and publishing of the FHS draft Notional specification in Jan 2021.
- Arcadis estimated a reduction in build cost v Ref2025 for CS1 (-3%) with increased costs for CS2 to CS5 of 2% to 13% (see fig 6 for more detail).
- Passivhaus Trust have also reviewed construction costs and published a Construction Costs report in 2019[1]. This concluded that costs identified in a Passivhaus report from 2015[2] of an 18-23% uplift from a 2013 baseline had reduced. It concluded that subsequent generations of Passivhaus' had a reduced uplift in costs to 12–14% (inclusive of a 3% allowance added in each case to reflect the addition of PV onto the Passivhaus specification).
- The cost 'view' provided by two significant builders who have built a number of Passivhaus homes ranged from 10-12% to a 19% uplift of costs relative to Part L2021.
- Where land prices have been fixed, the higher CSs represent a significant increase in build costs with subsequent impact on viability, selling price or developer margin.
- The progressively higher CSs would impact the price of land, developer margins and/or selling price. Where land values are low, development may be disproportionately affected for the higher contender specification choices.
- Experience from the Code for Sustainable Homes shows certainty and volume would enable CS costs to reduce through scale efficiency gains, installation experience reducing site times, specialist products becoming mainstream, reduction in risk pricing and development of new products and techniques etc. Some elements may see significant cost reductions, others little or none.
- The Climate Change Committee commissioned Aecom and Currie & Brown to review the 'costs and benefits of tighter standards for new buildings'[3] indicating an 8% uplift in costs (inclusive of a 3% allowance added to reflect the addition of PV) Part L2013 for a specification similar to CS4 assuming mass scale delivery.

Fig 5: Overview of end terrace

- Cost uplifts.summary (not mass scale):

TOTAL UPLIFT	Ref 2025	CS1	CS2	CS2a	CS3	CS4	CS5
Arcadis from Ref2021	£5,690 5%	£2,580 2%	£7,960 7%	£11,960 10%	£17,070 15%	£21,800 19%	£19,170 17%
Arcadis from Ref2025	x x	-£3,110 -3%	£2,270 2%	£5,930 5%	£11,380 9%	£16,110 13%	£13,480 11%
PHT from 2013[1,3]	x	x	x	x	x	12-14%	x
Builder A from 2021[4]	x	x	x	x	x	19%	x
Builder B from 2021[4]	x	x	x	x	x	10-12%	x

[1] Elemental Passivhaus specification without certification which includes a FHH applied allowance of 3% for 2.68kWp PV
[2] Part L 2013 baseline, using 2018 costs, 20kWh/m²/yr specification
[3] Assumed Part L 2013 baseline but using 2018 costs
[4] Passivhaus specification without certification but with PV, 2022 costs

Fig 6: Summary of cost uplift

The following pages summarise the Arcadis calculated CS cost uplifts

[1] https://passivhaustrust.org.uk/UserFiles/File/research%20papers/Costs/2019.10_Passivhaus%20Costs(1).pdf
[2] https://www.passivhaustrust.org.uk/UserFiles/File/Passivhaus%20Capital%20Cost%20Research%20Project%20-%20Passivhaus%20Trust,%20January%202015.pdf
[3] https://www.theccc.org.uk/publication/the-costs-and-benefits-of-tighter-standards-for-new-buildings-currie-brown-and-aecom/

Change from Ref2021	Ref2025		CS1		CS2		CS2a	
	Description	£ Uplift	Description	£ Uplift	Description	£ Uplift	Description	£ Uplift
Substructure								
Substructure	70mm additional EPS insulation, 5mm additional screed, associated excavation.	£800	No change	£0	PIR insulation in lieu of EPS, 5mm additional screed.	£180	PIR insulation in lieu of EPS, 5mm additional screed.	£180
Superstructure:								
Roof	No change	£0	No change	£0	No change	£0	No change	£0
External Walls	50mm additional glass wool insulation.	£1,100	No change	£0	No change	£0	No change	£0
Windows & Doors	Triple glazed windows, enhanced entrance door U value.	£960	No change	£0	No change	£0	No change	£0
Internal Walls & Partitions	No change	£0	No change	£0	No change	£0	No change	£0
Services								
Heat Source	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit gas boiler, add electric smart cylinder with immersion.	-£230
Heat Emitter	No change	£0	No change	£0	No change	£0	Omit radiators, add IR panel heaters with all associated electrical supplies.	-£240
Specialist installations	No change	£0	No change	£0	Add Waste Water Heat Recovery	£750	No change	£0
Ventilation	No change	£0	No change	£0	No change	£0	No change	£0
Electrical (PV)	Omit PV from 2021 Baseline	-£2,190	Omit PV from 2021 Baseline	-£2,190	Add 3 additional PV panels, including diverter.	£1,820	Add 13 additional PV panels, including diverter. Add 6.5 kWh battery.	£10,770
Additional Testing & Commissioning	Additional T+C for ASHP	£180	Additional T+C for ASHP	£180	Additional T+C for ASHP	£180	Additional T+C for Smart Cylinder & Battery Storage	£180
Gaskets	No change	£0	No change	£0	No change	£0	No change	£0
Main Contractor Preliminaries								
General	Additional allowance associated with specification.	£470	Additional allowance associated with specification.	£220	Additional allowance associated with specification.	£660	Additional allowance associated with specification.	£960
TOTAL UPLIFT	**Ref 2025**		**CS1**		**CS2**		**CS2a**	
from Ref2021	5%	£5,690	2%	£2,580	7%	£7,960	10%	£11,620
from Ref2025	-	-	-3%	-£3,110	2%	£2,270	5%	£5,930

Fig 7: Cost Summary, End terrace house - CS1, CS2, CS2a.

Change from Ref2021	Ref2025		CS3		CS4		CS5	
	Description	**£ Uplift**	**Description**	**£ Uplift**	**Description**	**£ Uplift**	**Description**	**£ Uplift**
Substructure								
Substructure	70mm additional EPS insulation, 5mm additional screed, associated excavation.	£800	70mm additional EPS insulation, 5mm additional screed, associated excavation.	£800	PIR insulation in lieu of EPS (increased depth of 150mm), associated excavation	£1,440	PIR insulation in lieu of EPS (increased depth of 170mm), 30mm additional screed, associated excavation	£2,480
Superstructure								
Roof	No change	£0	Add VCL	£530	50mm additional insulation and VCL	£630	50mm additional insulation and VCL	£630
External Walls	50mm additional glass wool insulation.	£1,100	Ancon steel wall ties in lieu of wire, 50mm additional insulation, liquid VCL & independent lintels.	£2,770	Ancon steel wall ties in lieu of wire, 70mm additional insulation, liquid VCL & independent lintels.	£4,270	Ancon steel wall ties in lieu of wire, 70mm additional insulation, liquid VCL & independent lintels.	£4,820
Windows & Doors	Triple glazed windows, enhanced entrance door U value.	£960	Enhanced door U value, additional air tightness measures to openings.	£340	Triple glazed windows, enhanced door U value, additional air tightness measures to openings.	£1,510	Triple glazed windows, enhanced door U value, additional air tightness measures to openings.	£1,900
Internal Walls & Partitions	No change	£0	No change	£0	VCL to party wall	£730	VCL to party wall	£730
Services								
Heat Source	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit gas boiler, add ASHP and cylinder including associated wiring & concrete plinth.	£4,370	Omit Gas Boiler (see Ventilation for MVHR with integral Exhaust Air Heat Pump)	-£2,430
Heat Emitter	No change	£0	No change	£0	No change	£0	Omit radiators (see Ventilation for heat distribution system)	-£3,630
Specialist installations	No change	£0	Add Waste Water Heat Recovery	£750	Add Waste Water Heat Recovery	£750	Add Waste Water Heat Recovery	£750
Ventilation	No change	£0	Omit local extract fans, add MVHR including ductwork system.	£3,700	Omit local extract fans, add MVHR including ductwork system.	£3,700	Omit local extract fans, add combined MVHR / EAHP unit and ductwork system.	£10,060
Electrical (PV)	Omit PV	-£2,190	Add 3 additional PV panels, including diverter.	£1,820	Add 3 additional PV panels, including diverter.	£1,820	Add 3 additional PV panels, including diverter.	£1,310
Additional Testing & Commissioning	Additional T+C for ASHP	£180	Additional T+C for MVHR	£270	Additional T+C for MVHR	£270	Additional T+C for ASHP / EAHP.	£180
Gaskets	No change	£0	Extra over for gaskets to penetrations.	£100	Extra over for gaskets to penetrations.	£100	Extra over for gaskets to penetrations.	£100
Main Contractor Preliminaries								
General	Additional allowance associated with specification.	£470	Additional allowance associated with specification, including air tightness coordinator.	£1,620	Additional allowance associated with specification, including air tightness coordinator.	£2,210	Additional allowance associated with specification, including air tightness coordinator.	£2,270
TOTAL UPLIFT	**Ref 2025**		**CS3**		**CS4**		**CS5**	
from Ref2021	5%	£5,690	15%	£17,070	19%	£21,800	17%	£19,170
from Ref2025	-	-	9%	£11,380	13%	£16,110	11%	£13,480

Fig 8: Cost Summary, End terrace house – CS3, CS4, CS5

Contender specification energy summary

Introduction

To compare the energy and carbon performance across the CSs the End terrace archetype has been modelled in SAP10.2.

Greater detail and discussion of the outputs can be found in [CS Energy Analysis](#).

The abbreviations used in the graphs in this section refer to the following:

- Ref2021: Part L 2021 using a gas boiler
- Ref2025: Draft 2025 specification published by Government
- CS1-5: Contender Specifications as detailed in this report

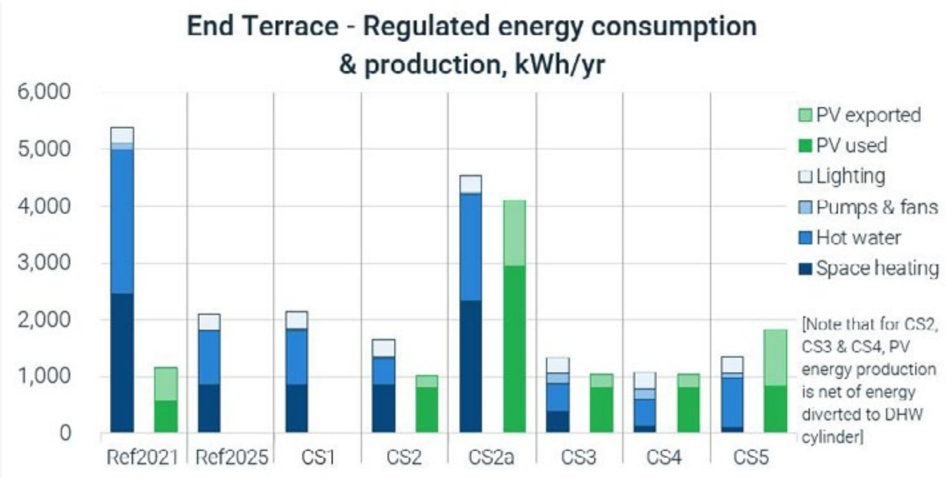


Fig 9: Regulated energy consumption & production - End terrace house

Energy consumption

The graph Fig 9 shows energy consumption by use across each of the CSs alongside PV energy production. Apart from CS2a, all specifications show a significant decrease in regulated energy consumption compared to Ref2021.

Ref2025, CS1, CS2 & CS2a have broadly the same space heating demand, and hot water energy consumption is of a similar magnitude to that for space heating. For CS3, CS4 & CS5, space heating demand is significantly reduced meaning hot water is the overriding contributor to regulated energy consumption.

The PV energy production for CS3, CS4 & CS5 is higher than the regulated energy demand of the dwelling. CS2a requires more than double the amount of energy than the other CSs but also has more than double the PV energy production.

Carbon emissions (DER)

All specifications show significant reductions in carbon emissions compared to Ref2021, with the CS2, 3, 4 & 5 end terrace house being close to zero carbon emissions for regulated energy. CS1 and CS2a carbon emissions are similar to Ref2025.

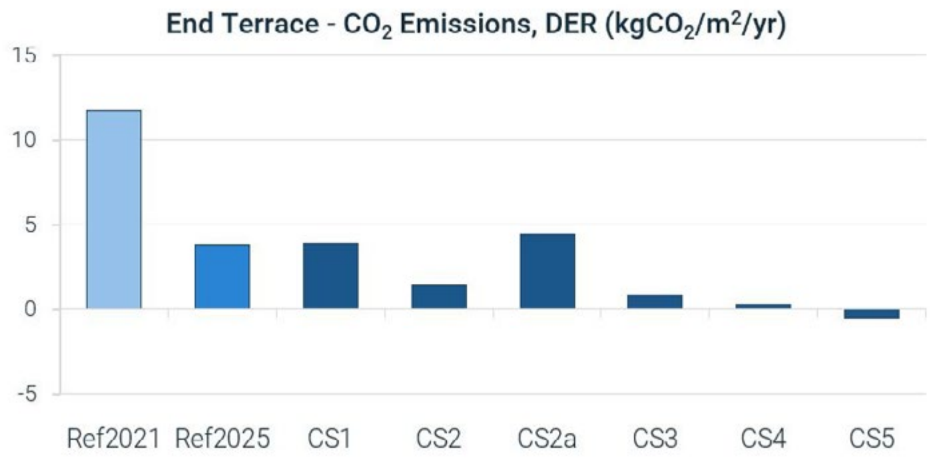


Fig 10: CO_2 emissions, DER – End terrace house

Householder aspects

For the end terrace house all CSs except Ref2025 and CS1 show reduced energy bills compared to Ref2021. The main reason Ref2025 and CS1 do not have savings is due to the lack of PV. CS2a savings are likely to be significantly understated as SAP10.2 is unable to adequately model the load shifting this specification relies on.

For CS3, CS4 & CS5 there is an additional maintenance cost of approximately £80/yr for the MVHR unit. This would make the overall savings for CS3 approximately equivalent to CS2.

All contender and reference specifications would benefit from time-of-use tariffs to reduce energy costs, particularly CS2a which includes a battery.

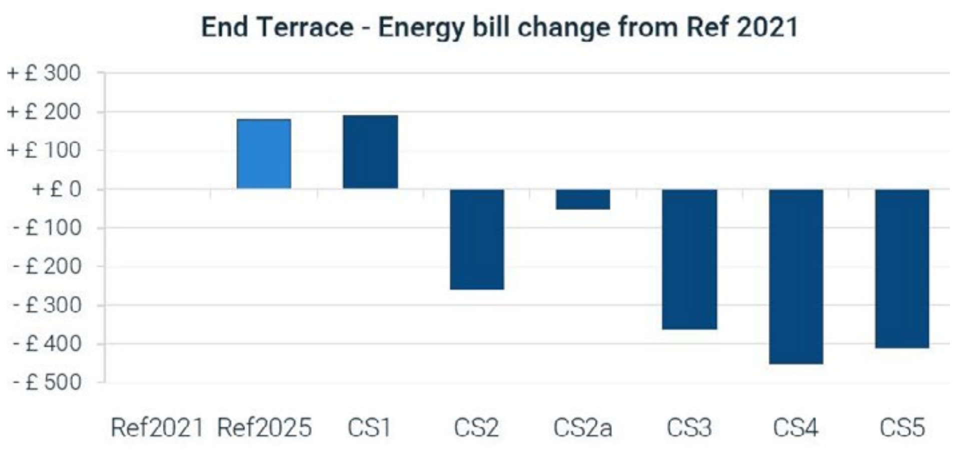


Fig 11: Energy bill change from 2021 Ref – End terrace house

The EPC rating of all end terrace properties across the specifications is B or better. A-rating is achieved for CS2, CS2a, CS3, CS4 & CS5.

** Note that CS2a & CS5 have not been modelled due to the limitations of SAP10.2*

Electricity grid

Fig 12 shows grid electrical energy demand (for regulated energy) and PV energy export across the year for the end terrace house across the different specifications.

CS1 is very similar to Ref2025 with CS2, CS3, CS4 & CS5 showing reducing grid energy requirements. CS2a has double the grid energy requirements in winter months than Ref2025 and CS1, and exports significantly during the summer months (when PV generation is high and own consumption is low).

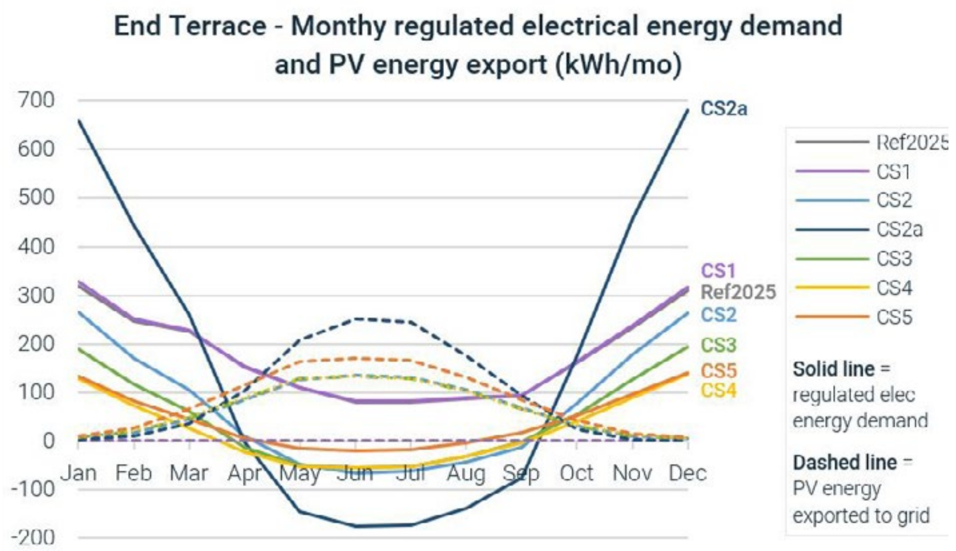


Fig 12: Monthly regulated energy demand from grid and PV energy export - End terrace house

The Grid working group also noted that the differences between CSs would have a 'considerable' energy impact at a national level.

To get a sense of what 'considerable' might be, the impact was compared with the output of Hornsea2, the world largest offshore wind farm off the Yorkshire coast. The difference in net energy demand is equivalent to constructing Hornsea2 every 10 years with CS2 and every 7 years for CS3 & 4*.

Common themes across all contender specifications

Householder perspective

Fabric standards and airtightness are significantly better than most existing homes, and properties should be warm and comfortable.

The concept of 'warming the home' with a heat pump rather than 'heating the home' will be new, with 'warm' rather than 'hot' radiators embodying this. Keeping the heating running with a setback, or reduced, temperature at night, and the heating coming on during cold nights, will also be new.

Whilst Part L 2021 introduces Photo Voltaic panels (PV), decentralised Mechanical Extract Ventilation (dMEV) and Waste Water Heat Recovery (WWHR) into new builder homes at scale, these technologies may still be unfamiliar to many householders when FHS2025 is introduced.

As with anything that is not familiar, vulnerable households, in particular, may need additional help and support initially before the new technology becomes second nature. Indeed, these homes should be easier to live in without the need for intervention but will take time to get used to.

Scale up implications and strategy

PV and dMEV will be commonly installed when FHS2025 is introduced as a result of the Part L 2021 changes. Likewise, all homes built to Part L 2021 will have designed and calculated thermal bridges with their correct construction verified on site with photos. So, whilst a considerable challenge for house builders now, these technologies and techniques will become familiar.

Overheating

Little difference expected across the range of CSs.

Future retrofitting & smart systems

All CSs could achieve additional energy bill savings with smart controls, through 'time of use' load shifting with flexible energy tariffs, of hot water and, to a greater or lesser extent depending on the level of energy efficiency, space heating.

Smart controls, optimising the use of PV generation, potentially in combination with a home battery or 'vehicle to grid', could provide further bill savings for all CSs.

Ensuring the designed performance is delivered

Past studies have shown some new homes in the UK can emit two to three times more carbon dioxide than predicted. As Part L drives further improvements in the designed performance, the relative proportion of energy/emissions associated with any underperformance, such as thermal bypass, construction faults etc., become even more significant.

Applicable to all CSs, ultimately, there is a need for a measurement of performance to validate that the homes built perform as designed.

Design implications

Where ASHP are used, appropriate external space will need to be identified to site the external unit. Internal layouts in houses will need updating to take account of DHW cylinders in properties which would typically have had combi boilers. This could particularly impact the most compact homes where the dwelling footprint may need to increase.

While East – West PV orientation has been assumed for modelling purposes, homes would benefit from optimising orientation at the development level planning stage.

Electricity grid implications

At a development level, the Grid work group advised that all contender specifications have similar grid implications except for CS2a which has a greater average demand although peak load is minimised through smart controls and a battery. The scale of the space heating demand difference across the CSs was relatively small when compared with the other loads which need to be accommodated such as PV export, plug in loads, cooking and EV charging.

Return to: CS1, CS2, CS3, CS4, CS5

Contender specification 1

Overview

To be consistent with the expectation that the FHS home should reduce carbon emissions by a minimum of 75% relative to one built to Part L 2013.

This is achieved by replacing the gas boiler with a heat-pump, slight easing of the fabric standards, dMEV, and PV introduced where required to meet the 75% reduction target.

Elements	CS1 - Houses	CS1 - Apartments
Fabric performance	Slightly below Part L 2021 draft notional	Slightly below Part L 2025 draft notional
Windows	Double glazed	Double glazed
Ventilation strategy	dMEV Air permeability 5.0	dMEV Air permeability 5.0
Space heating	Radiators	Direct electric panels
Energy systems	ASHP	DHW ASHP
Renewable generation	PV required for room-in-roof and large detached to achieve 75% CO_2 emissions reduction from 2013	PV required to achieve 75% CO_2 emissions reduction from 2013

Fig 13: CS1 Outline specification

Summary

- 75 - 78% regulated carbon emission reduction vs Part L 2013.
- Circa 10% increase in space heating demand compared with Part L 2021 and FHS2025 reference.
- Can be easily scaled up, as the only new technology introduced is a heat pump, providing a straightforward transition (although needs still to be carefully managed) and minimal change to the customer experience.
- Maintains the use of dMEV, with habitable room trickle vents and undercut internal doors as the ventilation strategy.
- Requires no change to the designs being used for Part L 2021 and allows design flexibility.
- Same footprint as Part L 2021 homes so no impact on plotting, not therefore increasing the burden on regulating authorities such as planning.
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = - £3,110 (-3%)

  Relative to Part L2021 = +£2,580 (2%)
- Householder energy bill relative to Part L 2021 end-terrace home = +£190pa (excluding the benefits of load shifting)

Fig 14: Example of homes built to similar standard as CS1 (credit: Barratt Homes)

Energy cost and carbon

The CS1 specification meets the 75% reduction in carbon emissions when compared with Part L 2013. Modelling shows this is achieved on the mid and end terrace homes and the detached bungalow. The use of solar panels (PV) is required for the room in roof semi-detached, detached, low rise apartment and high-rise apartment.

	End terrace	Mid terrace	Room in Roof semi-detached	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
% CO_2 emissions change compared with 2013 Ref	- 78%	- 77%	- 76%	- 75%	- 76%	- 76%	- 76%
% Space heating demand change compared with 2025 Ref	+ 4%	+ 6%	+ 7%	+ 20%	+ 17%	+ 34%	+ 103%
Energy cost change compared with 2021 Ref (£/yr)	+ £ 190	+ £ 210	+ £ 370	+ £ 930	+ £ 610	+ £ 120	- £ 30

*Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.

*Note that energy costs do not include savings from load shifting as this was not possible to model

Fig 15: Summary of CS1 modelling results

Space heating demand is higher than the 2025 reference ranging from a modest 4% increase to double.

Relative to a Part L 2021 home, the running costs generally increase from an additional £120 pa for the mid floor low-rise, up to an additional £930 pa for the detached dwelling. The exception was the mid floor high rise where the running costs reduced by £30 pa.

The running (regulated energy) costs calculated are substantially lower than those for a typical existing home.

When the grid is decarbonised, these homes will also decarbonise.

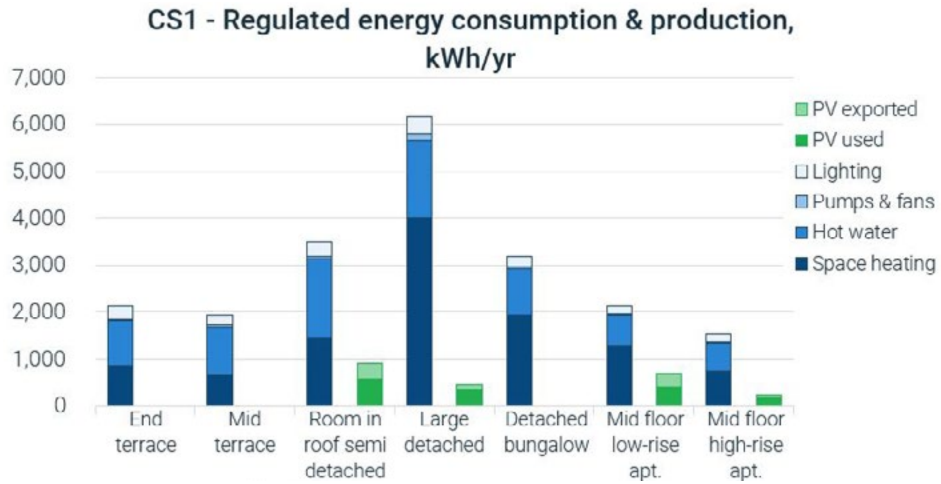


Fig 16: CS1 Regulated energy consumption & production, total per annum

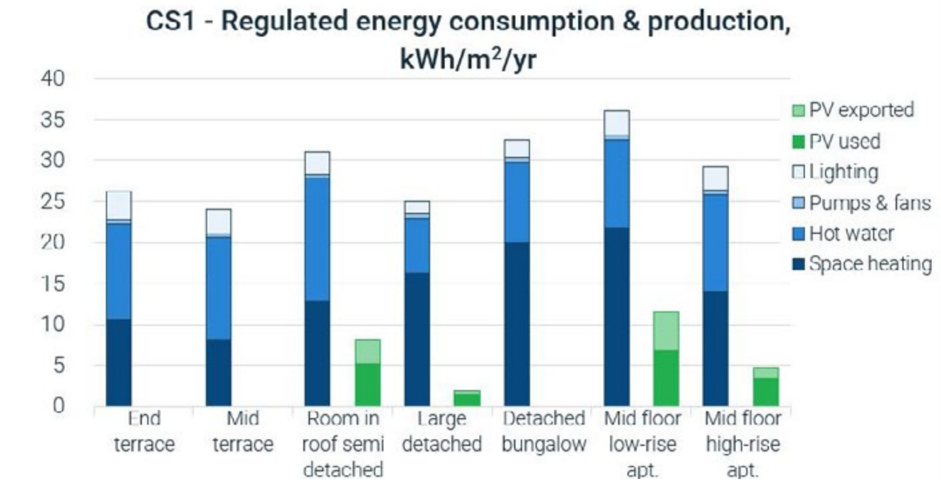


Fig 17: CS1 Regulated energy consumption & production, per m² per annum

The monthly regulated electricity demand is very similar to the 2025 reference.

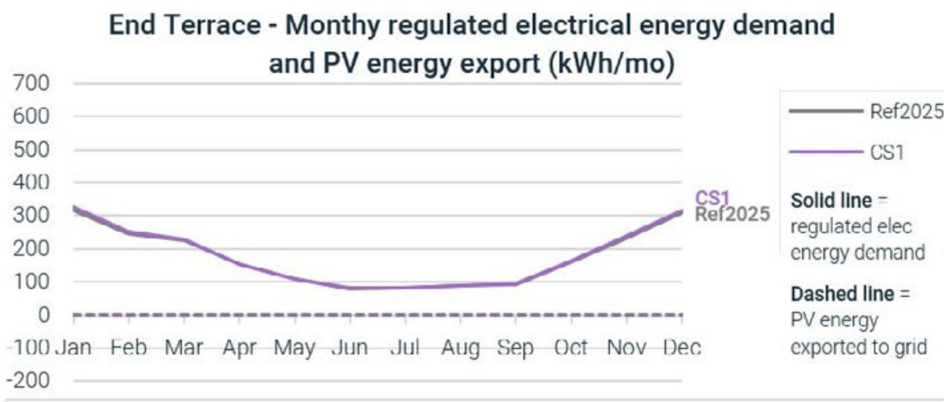


Fig 18: CS1 Monthly regulated electrical energy demand and PV energy export

Householder perspectives

CS1 specific points:

- **Typical householder bill v Part L2021, end terrace home = +£190pa**
- **Comfortable internal temperatures**

Except for the heat pump space heating (in houses), the homes will feel very similar to those built to Part L 2021.

A low carbon home is not necessarily a low running cost home; the electrification of space and water heating and reduction/ removal of PV results in higher operating costs than homes built to 2021 standards with gas boilers.

Consumers may request PVs as a priced option.

In common with other CSs, the heat pump based space heating will require changes to householder behaviour and expectations. The concept of 'warming the home' with a heat pump rather than 'heating the home' will be different. (See Common themes across all contender specifications and heat pumps chapters for detail).

Apartments may have either electric heating or a central system with Heat Interface Units (HIUs) and radiators, both being familiar technologies. With the electric space heating, the specification used a heat pump hot water cylinder to maximise efficiency although there may be longer re-charge times.

Householders are very familiar with natural ventilation and intermittent extract fans. The dMEV ventilation is somewhat different, being a continuously running fan. Mainstream householder experience of this is currently more limited but this will change with Part L 2021. (See Common themes across all contender specifications and the ventilation chapter for details).

Construction costs

End terrace house change from Ref2021	Ref2025		CS1	
	Description	£Uplift	Description	£Uplift
Substructure	Change to ground floor	£800	No change	£0
Superstructure	Change to external walls, windows & doors	£2,060	No change	£0
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360
Main contractor preliminaries	Additional allowance	£470	Additional allowance	£220
Total uplift from Red2021	5%	£5,690	2%	£2,580
Total uplift from Red2025	-	-	-3%	-£3,110

Fig 18: CS1 Monthly regulated electrical energy demand and PV energy export

There is an increase in build cost for CS1 compared with Part L 2021 circa £2,600. The cost is circa £3,100 less than the Ref2025 specification.

Scaleup implications and strategy

CS1 would require the adoption of:

- Heat pumps **in houses (DHW heat pumps or communal heat pump systems in apartments)**

CS1 scale up implications

A key advantage of CS1 is its continuity with previous standards. With the important exception of the heat pump (see Skills below), the specification does not require specific skills or supply chain development, beyond that already underway for the Part L 2021.

However, as the FHS will come shortly after Part L 2021, the current transition will be ongoing, notably the widescale introduction of dMEV, where the impact or implications may still not be known.The continuity with current fabric standards means there are no re-planning or plotting considerations.

One issue associated with this specification is regarding the PV industry. Part L 2021 will require PV on most homes to comply. CS1 only has PV on a proportion of homes and to a limited extent (see graph below). The PV industry would need to scale down as the specification is introduced.

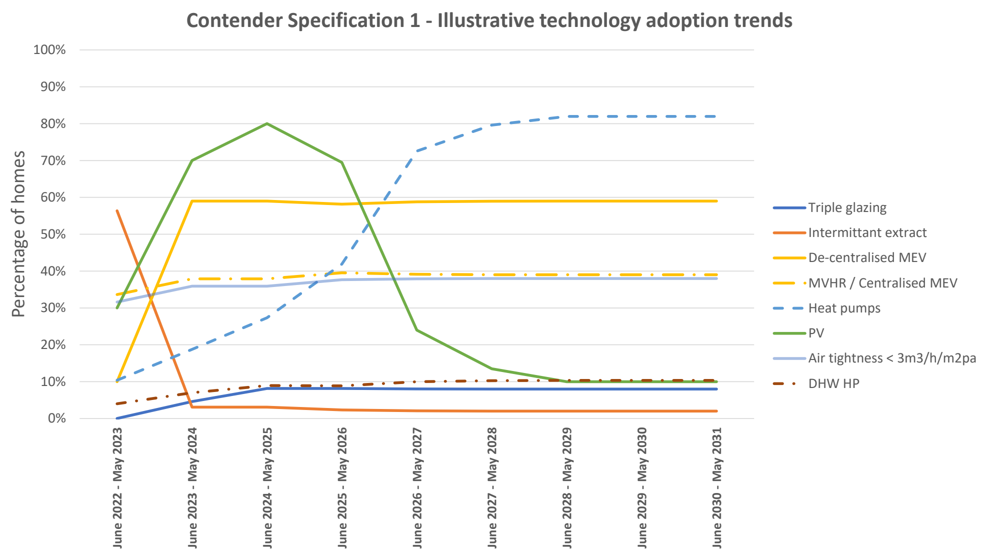


Fig 20: CS1 Illustrative technology adoption trends if there were a 12-month transitional period

Common CS1 & CS2 scaleup strategy

The introduction of the air source heat pump, as a replacement for gas heating, is common across most CSs. Upskilling will be required around heat pump design, installation, set-up and commissioning as well as new site management processes to assure quality.

Upskilling will be required around heat pump design, installation, set-up and commissioning as well as new site management processes to assure quality.

The rate of adoption of heat pumps is quite fast, especially between June 2026 and May 2027 – circa 80k heat pump installation increase, at a time when they are also being adopted in the retrofit market. In order to avoid unnecessary difficulties, the transitional arrangements could helpfully smooth the adoption of this technology.

See chapter transitional arrangement.

Further key aspects

Additional design implications

Very limited as uses the same built form as Part L 2021. For some house types, PV will be required.

Net zero / net zero ready

These homes are electrically heated so when the grid is decarbonised, they will become net zero.

Geography

With lower energy efficiency, relative to the 2025ref, the householder bill impact of the cooler weather in the North is more pronounced.

Future retrofitting & smart systems

See: Common themes across all contender specifications

Homeowners without PV may want to retrofit to reduce their energy bills and those with small PV systems may wish to increase the number of panels. Housebuilder may offer this as an option.

Skills

The specification will require:

- A programme of skills & training for heating designers.
- A significant scale up of trades trained to install and commission heat pumps.

See: Heat pump skills and training

Widespread adoption of PV and Heat Pumps will make these important controlled services on site.

Grid implications

See: Common themes across all contender specifications

Contender specification 2 & 2a

Overview

To align closely with the current Part L 2021 but electrify the heating by replacing the gas boiler with a heat pump in houses and use direct electric space heating and a heat pump hot water cylinder in apartments.

As an alternative services approach, CS2a utilises infra-red space heating with PV, a battery and smart controls to load shift.

Fig 21: Example of homes built to similar standard as CS2 (credit: Ilke Homes)

Fig 22: Example of homes built to similar standard as CS2a (credit: VerdeGO Group)

Elements	CS2 - Houses	CS2 - Apartments	CS2a
Fabric performance	Similar to Part L 2021 Notional (to meet FEES)	Similar to Part L 2021 Notional (to meet FEES)	As CS2
Windows	Double glazed	Double glazed	As CS2
Ventilation	dMEV Air perm 4.5 -5.0	dMEV Air perm 3.0 – 4.5	As CS2
Space heating	Radiators	Direct electric panels	Infra-red panels
Energy systems	ASHP, WWHR	DHW ASHP, WWHR	Immersion for DHW
Renewable generation	PV & diverter (min 40% GF area in plan, capped at 3.68kWp)	PV (min 40% GF area in plan for low-rise; min 20% roof area in plan for high-rise)	PV & battery (maximise roof area for PV installation)

Fig 23: CS2 & CS2a Outline specification

Summary - CS2

- 80-95% regulated carbon emission reduction against Part L 2013.
- Same space heating demand as Part L 2021.
- Based on current Part L2021, only introducing a heat pump as a new technology providing an easy transition.
- Maintains the use of dMEV with habitable room trickle vents and undercut internal doors.
- Continues with PV and Waste Water Heat Recovery (WWHR) technologies so does not impact the supply chain established for delivering Part L 2021.
- Allows design flexibility as elements can be enhanced to trade off if required.
- Same footprint as Part L 2021 homes so no impact on plotting.
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = +£2,270 (2%)

  Relative to Part L2021 = +£7,960 (7%)
- Householder energy bills relative to Part L 2021 end terraced home = - £260pa (excluding the benefits of load shifting)

Summary - CS2a

- 55-80% regulated carbon emission reduction against Part L 2013.
- Same fabric specification as CS2.
- Utilises infra-red (IR) space heating and smart controls. Whilst the consumer experience of radiant heating has not been tested in large scale field trials, there are positive reports from individual housebuilders (VerdeGO Group).
- Utilises an easily adoptable technology capable of being installed by any electrician, presenting fewer scaleup challenges.
- Has higher average monthly grid demand in Winter and higher export in Summer which, at scale, may have national implications.
- The current SAP version is unable to adequately model the load shifting on which this CS relies, overstating energy costs.
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = +£5,930 (5%)

  Relative to Part L2021 = +£11,620 (10%)
- Householder energy bill relative to Part L 2021 end terraced home = - £50, noting that this does not take into account cost savings from load shifting (which are expected to be significant).

Energy, cost and carbon – CS2

There are considerably more solar panels (PV) on the larger Part L 2021 homes as the amount is based on floor area, with no cap. As a consequence, the smaller homes tend to have lower running costs (approximately £250 less) and the larger homes higher ones, with the detached house almost £400 more.

In terms of carbon emissions, all exceed the minimum FHS expectation of a 75% reduction (range of 80-95%).

	End terrace	*Mid terrace*	*Room in Roof semi-detached*	*Large detached*	*Detached bungalow*	*Mid floor low-rise apt.*	*Mid floor high-rise apt.*
%CO_2 emissions change compared with 2013 Ref	- 92%	- 93%	- 82%	- 81%	- 89%	- 83%	- 79%
% Space heating demand change compared with 2025	+1%	+ 6%	+ 6%	+ 19%	+ 3%	+ 22%	+ 93%
Energy cost change compared with 2021 Ref (£/yr)*	- £260	- £250	+ £80	+ £390	+ £20	£0	- £80

*Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.

*Note that energy costs do not include savings from load shifting as this was not possible to model

Fig 24: Summary of CS2 modelling results

Energy, cost and carbon – CS2a

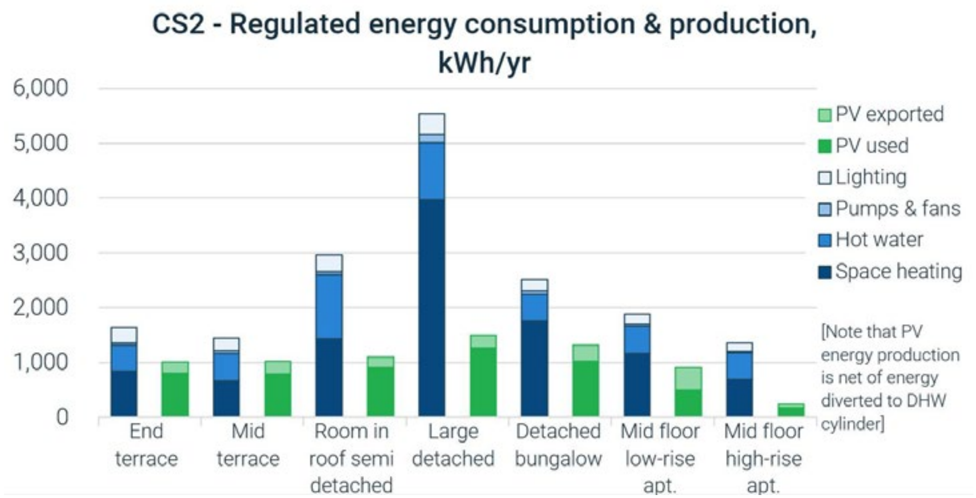


Fig 25: CS2 Regulated energy consumption & production, total per annum

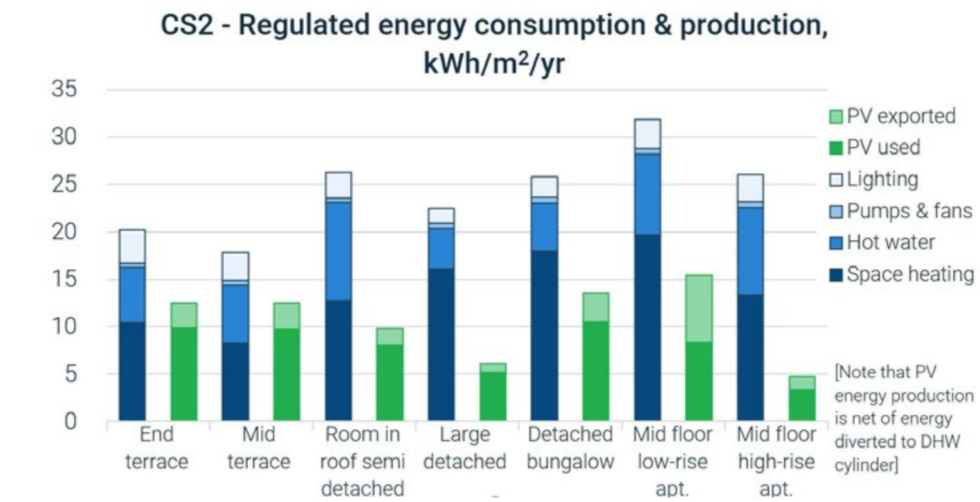


Fig 26: CS2 Regulated energy consumption & production, per m² per annum

The high proportion of PV on the homes significantly drives the energy costs in the SAP model, showing a modest saving for the mid and end terrace home. In the 'room in roof' semi' the roof area is limited relative to the size of the home and the detached home is very large, so for both, the benefits of the PV array do not mitigate the impact of the lower efficiency heating system.

SAP is currently not able to adequately model the benefit of smart controls and battery storage to demonstrate advantage of time-of-use tariffs with load shifting, so is unable to reflect these significant savings to the householder.

The benefits associated with load shifting, using technologies such as smart controls, smart hot water storage and a battery, could equally be applied to the other CSs.

	End terrace	*Mid terrace*	*Room in Roof semi-detached*	*Large detached*	*Detached bungalow*	*Mid floor low-rise apt.*	*Mid floor high-rise apt.*
%CO_2 emissions change compared with 2013 Ref	- 74%	- 78%	- 58%	- 55%	- 64%	- 67%	- 56%
% Space heating demand change compared with 2025	+ 3%	+ 9%	+ 5%	+ 7%	+ 1%	+ 14%	+ 77%
Energy cost change compared with 2021 Ref (£/yr)*	- £50	- £170	+ £950	+ £1,940	+ £790	+ £240	+ £350

*Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.
*Note that energy costs do not include savings from load shifting as this was not possible to model

Fig 27: Summary of CS2a modelling results

Carbon savings of 55-78%, versus Part L 2013, do not meet the Future Homes Standard expectation of a 75% reduction.

One of the implications of this specification is the high monthly average loads and PV export. The home draws heavily from the grid during the Winter months where PV generation is limited and exports significantly during the Summer months, when generation is strong and own consumption is low. At mass scale deployment, the implications of this need to be understood and, at a development level, the local grid capacity implications may result in export curtailment in some scenarios.

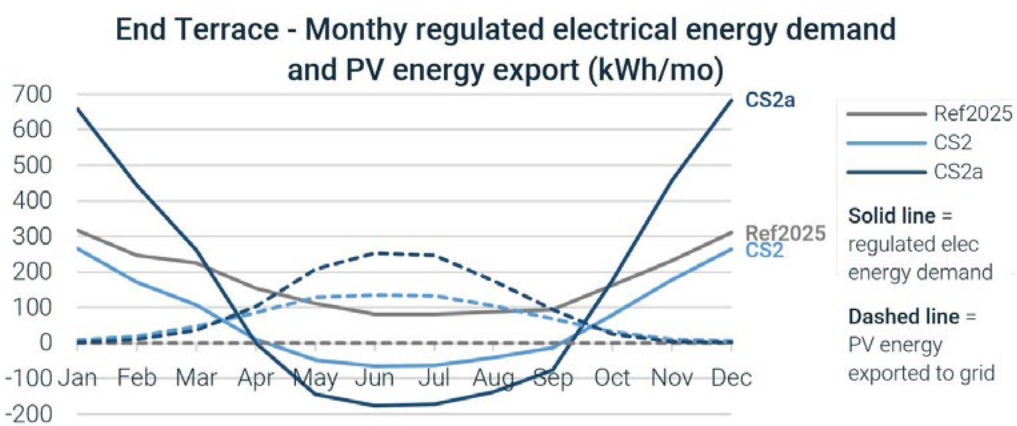


Fig 28: CS2 & CS2a Monthly regulated electrical energy demand and PV energy export

With apartments, the low level of heat loss due to the efficient form, lends itself to direct electric heating and the benefits of IR. Most energy use is hot water so householder bills could be reduced by using a heat pump hot water cylinder.

Monthly average regulated energy consumption is two to three times higher than for heat pump heated homes.

One archetype is, and another approaching, net regulated energy due to the high level of PV generation. The detached home is particularly large, with the maximum PV fixed at 10kW. PV area is limited on the Room in roof semi due to the rooflights.

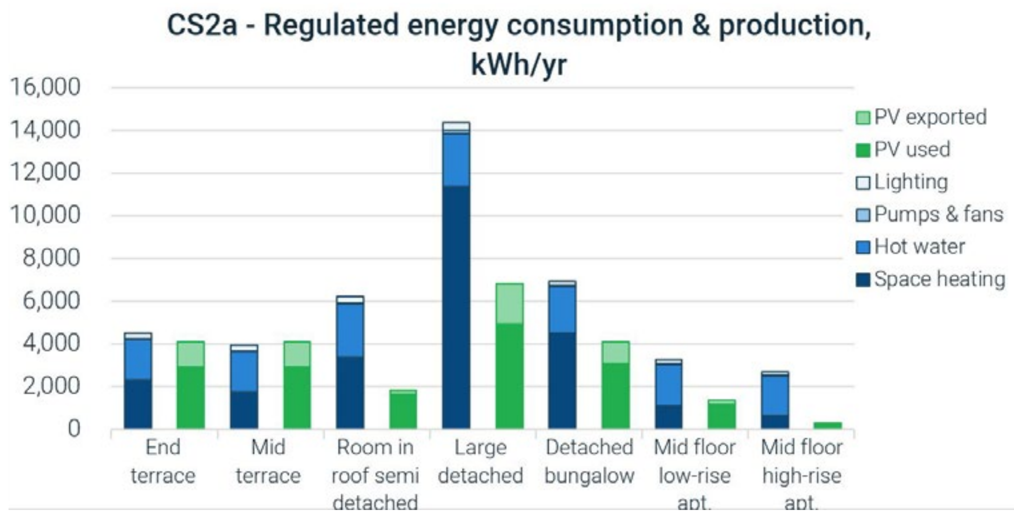


Fig 29: CS2a Regulated energy consumption & production, total per annum

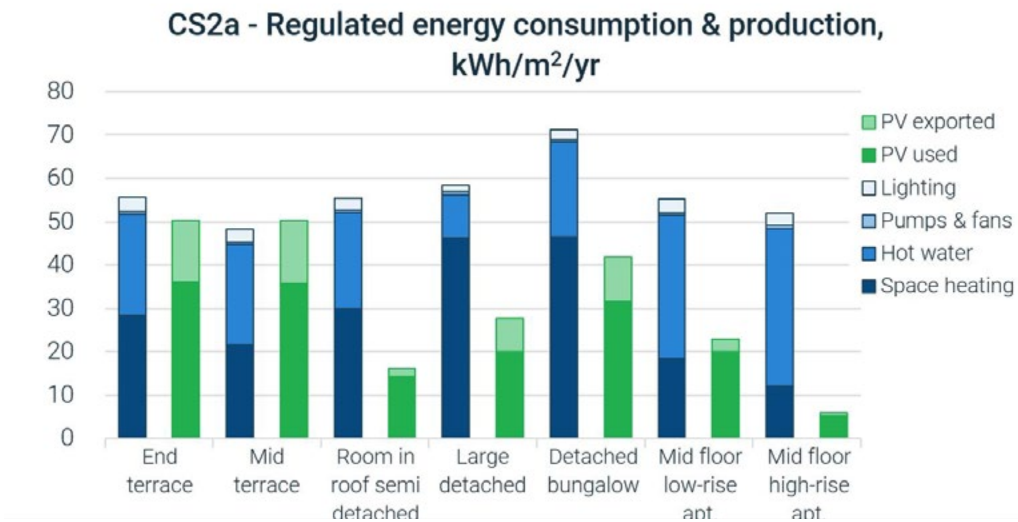


Fig 30: CS2a Regulated energy consumption & production, per m² per annum

Householder perspectives – CS2

CS2 specific points:

- **Typical householder bill v Part L2021, end terrace home = -£260pa**
- **Comfortable internal temperatures**

Except for the heat pump space heating (in houses), the homes will feel very similar to those built to Part L 2021.

In common with other CSs, the heat pump based space heating will require changes to householder behaviour and expectations. The concept of 'warming the home' with a heat pump rather than 'heating the home' will be different. (See Common themes across all contender specifications and heat pumps chapters for detail).

Apartments may have either electric heating or a central system with HIUs and radiators, both being familiar technologies. With the electric space heating, the specification used a heat pump hot water cylinder to maximise efficiency although there may be longer re-charge times.

Householders are very familiar with natural ventilation and intermittent extract fans. The dMEV ventilation is somewhat different, being a continuously running fan. Mainstream householder experience is currently more limited but this will change with Part L 2021. (See Common themes across all contender specifications and the ventilation chapter for details).

Householder perspectives – CS2a

CS2a specific points:

- **Typical householder bill v PartL2021, end terrace home = -£50pa (noting that this does not take into account cost savings from load shifting (which are expected to be significant).**
- **Comfortable internal temperatures from rapid space heating as needed**
- **Smart controls and battery storage**
- **No heat pump servicing**

The consumer experience of radiant heating has not been tested in large scale field trials, though there are positive reports from individual housebuilders (VerdeGO Group).

IR heating, linked to intelligent controls, provides instant heat so is more like the rapid heating from a gas boiler and radiators, except faster. For the householder, the controls are simple and the heating response is fast, helping to make it easy to learn. Householders need to be on flexible tariffs to benefit from lower bills associated with the load shifting.

The dMEV is the same as CS2 (See Common themes across all contender specifications and the ventilation chapter for details).

This specification includes a combination of technologies which householders will need to become familiar with but there would be very limited maintenance requirements.

Construction costs – CS2

End terrace house change from Ref2021	Ref2025		CS2	
	Description	**£Uplift**	**Description**	**£Uplift**
Substructure	Change to ground floor	£800	Change to ground floor	£180
Superstructure	Change to external walls, windows & doors	£2,060	No change	£0
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler; Add ASHP & cylinder & WWHR & addition-al PV panels & diverter & additional testing & commissioning	£7,120
Main contractor preliminaries	Additional allowance	£470	Additional allowance	£660
Total uplift from Red2021	5%	£5,690	7%	£7,960
Total uplift from Red2025	-	-	2%	£2,270

Fig 31: Capital cost uplift for End of terrace house, CS2

The increase in build cost for CS2, compared with Part L 2021, is circa £8,000 (7%). Compared with the Ref2025 specification it is circa £2,300 (2%) more

Construction costs – CS2a

End terrace house change from Ref2021	Ref2025		CS2a	
	Description	**£Uplift**	**Description**	**£Uplift**
Substructure	Change to ground floor	£800	Change to ground floor	£180
Superstructure	Change to external walls, windows & doors	£2,060	No change	£0
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler & radiators; Add smart cylinder with immersion & IR panel heat-ers & additional PV panels & battery storage & additional testing & commissioning	£10,480
Main contractor preliminaries	Additional allowance	£470	Additional allowance	£960
Total uplift from Red2021	5%	£5,690	7%	£11,620
Total uplift from Red2025	-	-	5%	£5,930

Fig 32: Capital cost uplift for End of terrace house, CS2a

The increase in build cost for CS2a, compared with Part L 2021, is circa £11,600 (10%). Compared with the Ref2025 specification it is circa £5,900 (5%) more.

Scale up implications and strategy - CS2

CS2 would require the adoption of:

- Heat pumps **in houses (DHW heat pumps or communal HP systems in apartments)**

A key advantage of CS2 is its continuity with previous standards. With the important exception of the heat pump (see Skills below), the specification does not require specific skills or supply chain development, beyond that already underway for Part L 2021. However, as the FHS will come shortly after Part L 2021, the current transition will be ongoing, notably for the widescale introduction of dMEV, WWHR and PV where the impact or implications may still not be known.

The continuity with current fabric standards means there are no re-planning or plotting considerations.

The scaleup is the same as CS1 see Common CS1 & CS2 scaleup strategy

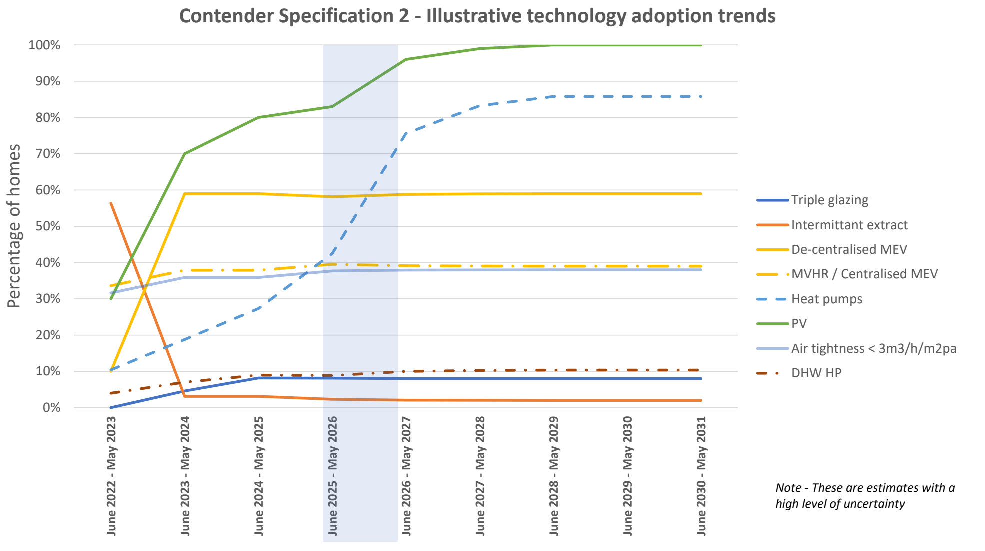


Fig 33: CS2 Illustrative technology adoption trends if there were a 12-month transitional period

Scale up implications and strategy - CS2a

A key advantage of CS2a is its continuity with the fabric of Part L 2021. The specification does not require specific fabric skills or supply chain development, beyond that already underway for Part L 2021. However, as the FHS will come shortly after Part L 2021, some of the scaling up for the current transition will be ongoing, notably for dMEV and PV.

The training involved in installing IR heating is limited, as most site electricians already have the necessary skills. Training is required for IR design and limited training to install the battery and be familiar with the smart controls.

For the majority of homes, all those where the PV is greater than 3.68kWp, a G99 licence will be required. This is applied for at the time of connection of the home and not at a development level representing some risk that the DNO/IDNO may require a load limiting device to be fitted if there is insufficient grid capacity.

Other than the G99, from a scale up perspective, there are a few implications beyond ensuring supply of IR heaters and the necessary batteries.

Further key aspects

Design implications

See: Common themes across all contender specifications

There are few design implications as CS2 uses the Part L 2021 fabric standard.

Net zero / net zero ready

These homes are electrically heated so when the grid is decarbonised these will become net zero.

Geography

With lower energy efficiency, relative to the 2025ref, the householder bill impact of the cooler weather in the North is more pronounced.

Future retrofitting & smart systems – CS2

See: Common themes across all contender specifications

Future retrofitting & smart systems – CS2a

None

Skills – CS2

The specification will require:

- A programme of skills & training for heating designers.
- A significant scale up of trades trained to install and commission heat pumps.

See: Heat pump skills and training

Widespread adoption of PV and Heat Pumps will make these important controlled services on site.

See Scale up implications and strategy – CS2a

Grid implications – CS2

See Common themes across all contender specifications

Grid implications – CS2a

CS2a does not benefit from heat pump technology. This explains the increase in demand in comparison to the 2025 Ref, as space heating and hot water heating via direct electricity alone, is less efficient than using a heat pump.

It maximises energy storage, having a battery, smart hot water cylinder and heat energy stored in the fabric. This provides the highest level of load balancing, allowing the battery and hot water to be re-energised from the solar PV system and topped up by the grid during off-peak hours. This reduces peak loads up to the capacity of the battery and subject to the size of the hot water cylinder, solar array performance and customer usage.

Ensuring the designed performance is delivered

See: Common themes across all contender specifications

The fabric standard is similar to that required for Part L 2021 and no new fabric techniques would be introduced so the delivered performance is likely to be similar.

IR heating with smart controls has not been rolled out in new homes at large scale so would need large scale monitored trials to understand performance and feedback as appropriate.

Contender specification 3

Overview

To mainstream recognised low energy techniques and technologies for a very low energy specification whilst allowing design flexibility.

Space heating demand significantly reduced through a combination of improved airtightness and MVHR. Solar panels (PV) and ASHPs further reduce grid energy demand to achieve a level of regulated carbon emissions that are close to net zero.

Elements	CS3 - Houses	CS3 - Apartments
Fabric performance	Similar to PArt L 2025 draft notional	Similar to PArt L 2025 draft notional
Windows	Double glazed	Double glazed
Ventilation Strategy	MVHR Air permeability <3.0	MVHR Air permeability <3.0
Space heating	Radiators/ underfloor	Direct electric panels
Energy systems	ASHP, WWHR	DHW ASHP, WWHR
Renewable generation	PV & diverter (min 40% roof area in plan, capped at 3.68Wp)	PV (min 40% roof area in plan for low-rise, min 20% in plan for high-rise)

Fig 34: CS3 Outline specification

Fig 35: Example of homes built to similar standard as CS3 (credit: Studio Partington Architects)

Summary

- 84-98% regulated carbon emission reduction against Part L 2013.
- Average 50% reduction in space heating demand compared with Part L 2021 and FHS2025 reference.
- Introduction of airtightness techniques that are well beyond general practice and mainstream developers expressed delivering this is not possible at scale. Specialist developers advise the air permeability level is readily achievable provided scaling up was approached in a managed way.
- There is a step change in ventilation approach as MVHR is used which, whilst common in apartments, it is not usual in low rise housing in the UK.
- The introduction of a combination of new technologies means phased transitional arrangements would be needed to steadily build up the skills and ensure quality.
- A 50-100mm increase in wall thickness, compared with the typical for Part L 2021; may require re-plotting and planning re-submission if detailed planning had been given but may be mitigated in scheme design.
- Allows design flexibility as elements can be enhanced to trade off if required.
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = +£11,380 (9%)

  Relative to Part L2021 = +£17,070 (15%)
- Householder energy bill relative to Part L 2021 End terrace home = -£360pa (excluding the benefits of load shifting)
- MVHR maintenance costs circa £80pa

Energy cost and carbon

CS3 represents a significant reduction in space heating demand against Part L 2021 and the FHS 2025 reference, driven by some improvements in U-values and improved airtightness but, principally by the introduction of MVHR. For the end terrace, CS3 gives a 57% reduction compared with the 2025Ref. By comparison CS3 with dMEV would give 16%.

The reduction in space heating demand, coupled with renewable energy generation from the ASHP and PV, reduces regulated energy costs by £360 per year in an end terrace home.

	End terrace	Mid terrace	Room in Roof semi-detached	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
% CO_2 emissions change compared with 2013 Ref	- 95%	- 98%	- 88%	- 84%	- 91%	- 94%	- 87%
% Space heating demand change compared with 2025	- 57%	- 68%	- 49%	- 32%	- 28%	- 64%	- 66%
Energy cost change compared with 2021 Ref (£/yr)*	- £360	- £360	- £130	+ £210	- £80	- £240	- £230

*Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.
*Note that energy costs do not include savings from load shifting as this was not possible to model

Fig 36: Summary of CS3 modelling results

It significantly reduces carbon emissions: achieving an 85% carbon emission reduction against current Part L in the large, detached houses and between 87%-98% in all other house and apartment types.

Hot water becomes the dominant regulated energy demand and PV broadly offsets this, except in the large detached home.

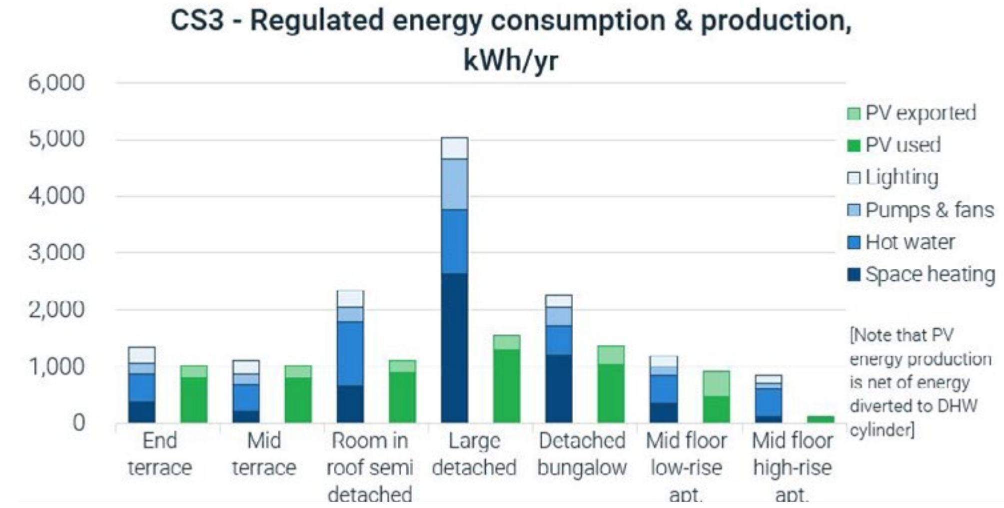


Fig 37: CS3 Regulated energy consumption & production, total per annum

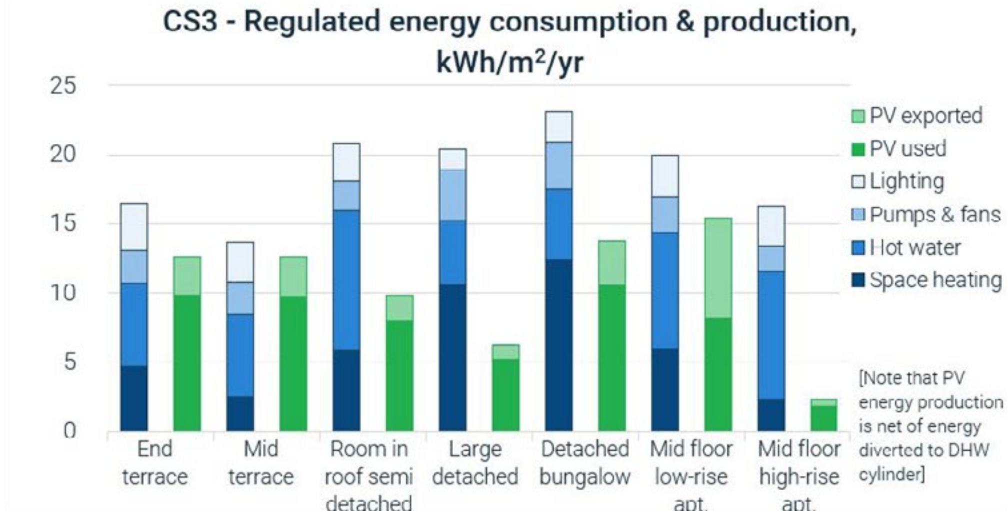


Fig 38: CS3 Regulated energy consumption & production, per m² per annum

Two of the archetypes are approaching, but not achieving, net regulated energy 'positive'. The detached home is particularly large, yet the maximum PV has been fixed at 3.68kW, hence the relative shortfall.

For the end terrace, the regulated energy costs are reduced by £360pa relative to the 2021Ref, equating to a saving of £280 after MVHR maintenance is taken into account.

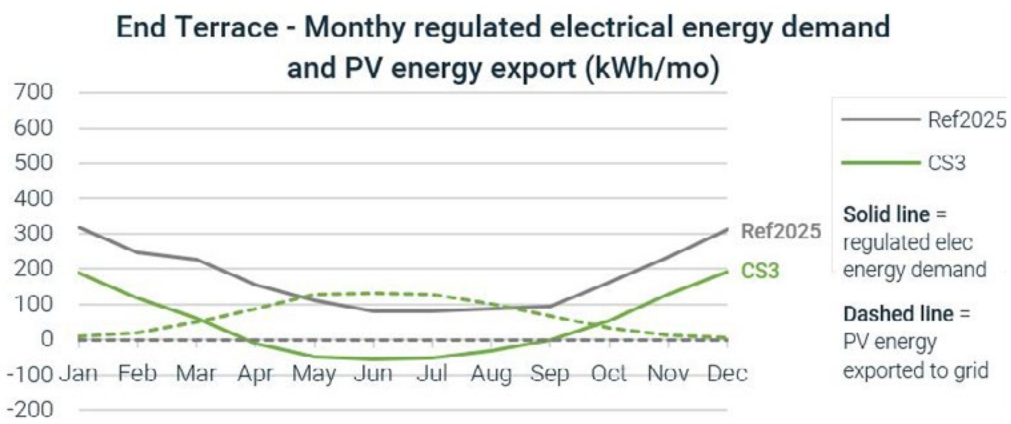


Fig 39: CS3 Monthly regulated electrical energy demand and PV energy export

Monthly peak regulated energy demand is circa 2/3 of the 2025Ref, with net monthly export from May to August.

Construction costs

End terrace house change from Ref2021	Ref2025		CS3	
	Description	**£Uplift**	**Description**	**£Uplift**
Substructure	Change to ground floor	£800	Change to ground floor	£800
Superstructure	Change to external walls, windows & doors	£2,060	Change to external walls & doors; additional airtightness measures	£3,640
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler & dMEV; Add ASHP & cylinder & WWHR & MVHR & gaskets to penetrations & additional PV panels & diverter & additional testing & commissioning	£11,010
Main contractor preliminaries	Additional allowance	£470	Additional allowance, including airtightness coordinator	£1,620
Total uplift from Red2021	5%	£5,690	15%	£17,070
Total uplift from Red2025	-	-	9%	£11,380

Fig 40: Capital cost uplift for End of terrace house, CS3

The increase in build cost for CS3, compared with Part L 2021, is circa £17,100 (15%). Compared with the Ref2025 specification it is circa £11,400 (9%) more.

Householder perspectives

CS3 specific points:

- **Typical householder bill vs PartL2021, end terrace home= -£360pa**
- **Stable internal temperatures**
- **No cold draughts above windows**
- **Good internal air quality.**
- **A stable, slightly less humid atmosphere.**
- **Filter cleaning/changing 3–24 months (dependent on external air quality - circa £50/year).**
- **Recommended MVHR service every 5 years (equivalent to circa £30pa).**

In common with other CSs, the heat pump based space heating will require changes to householder behaviour and expectations. The concept of 'warming the home' with a heat pump rather than 'heating the home' will be different, with warm rather than hot radiators. (See Common themes across all contender specifications and heat pumps chapters for details). The energy efficiency of the fabric means the heat pump is less likely to start-up in a cold Winter night to maintain the setback temperature.

Apartments may have either electric heating or a central system with HIUs and radiators, both being familiar technologies. With the electric space heating, the specification used a heat pump hot water cylinder to maximise efficiency although there may be longer re-charge times.

CS3 has an MVHR system which home buyers are unlikely to be familiar with unless they have had experience with one in an apartment where they are more common. (See ventilation chapter for details).

The lower air permeability will not be noticeable to a householder, with the ventilation system providing the fresh air required. If the ventilation was to be switched off, then the home would become stuffy although windows may still be opened to ventilate.

Scale up implications and strategy

CS3 would require the adoption of:

- **Wider cavities (circa 200mm in masonry) / lower U-value walls**
- **Heat pumps in houses (DHW heat pumps or communal HP systems in apartments)**
- **Low air permeability, 3m³/m²/hr**
- **MVHR**

CS3 scale up implications

Delivery of CS3 requires the mainstream housebuilders to embrace three significant 'new to them' technologies concurrently and the industry would require rapid and significant supply chain development.

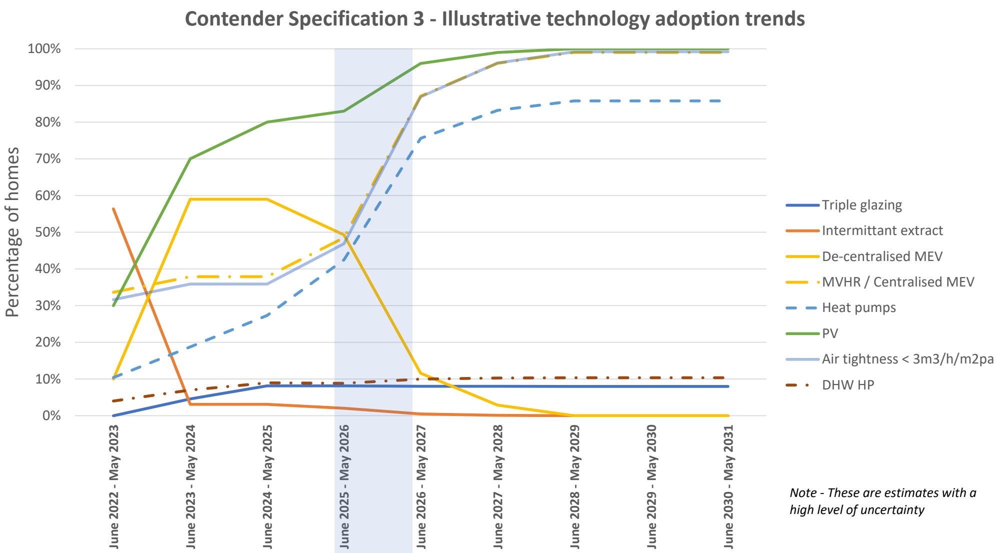


Fig 41: CS3 Illustrative technology adoption trends if there were a 12-month transitional period

For the increased airtightness, CS3 relies on the adoption of new processes and systems to deliver levels of less than 3 m³/h/m². Whilst those that build to very low levels of airtightness (<1m³/m²/hr) advise the required level of 3m³/m²/hr is relatively easy to achieve provided appropriate techniques and approaches are used, it is not simply a case of housebuilders doing what they do today, but better.

Mainstream housebuilders have expressed significant concern as they currently build less than 2% of houses at air permeabilities of less 3m³/m²/hr, with 10% below 3.5m³/m²/hr.

See the Fabric chapter, Airtightness

Common CS3, CS4 & CS5 scaleup strategy

As the FHS will come shortly after Part L 2021, some of the scaling up for the current transition will be ongoing, notably for PV and WWHR and we are not aware of the impact or implications.

The fabric U value performance is achievable using existing techniques with the requirement for designed and calculated thermal bridges already needed by Part L 2021. The insulation supply chain is substantial and also international so product supply is unlikely to cause problems. The wider cavities will require thermally broken lintels however many housebuilders anticipate adopting this for thermal bridging reasons for Part L 2021. Wall ties are a different material so the supply chain would need to be aware of the expected change in buying patterns.

The introduction of the air source heat pump, as a replacement for gas heating, is common across most CSs. Upskilling will be required around heat pump design, installation, set-up and commissioning as well as new site management processes to assure quality.

The rate of adoption of heat pumps is quite fast at a time when they are also being adopted in the retrofit market. In order to avoid unnecessary difficulties, the transitional arrangements could helpfully smooth the adoption of this technology.

Upskilling around design, installation and commissioning MHVR will be needed. MVHR must be well designed, installed and delivered to ensure good performance. Experience from installation in apartments and from passivhaus projects shows this can be achieved with the appropriate controls in place. However, several reports have highlighted the risks of incorrect installation are high and this if not addressed would have a detrimental impact.

As illustrated in the graph, the expected adoption of technologies indicated by housebuilders shows a significant ramp up rate. Should the same transitional arrangements be adopted for FHS2025 as Part L 2021 then the industry would effectively need to adopt these technologies at scale over a short 18 month period. This would create a high risk of quality problems, inflated costs and, potentially, stalled build programmes.

An approach which enables the regulations to come into force progressively would be required over a longer period to give housebuilders predictability and the supply chain the confidence to invest. Critical is to create a steady build up, flattening the adoption curve, and not simply to delay the start with the same steep rate.

A steady build-up over a longer period would allow skills to be developed, reducing the risk to housing delivery and quality.

Return to CS4 scaleup, Return to CS5 Scaleup

Further key aspects

Design implications

See: Common themes across all contender specifications

The specification intentionally does not push each element to an extreme in order to retain some design flexibility and allows trade-offs where some elements are enhanced and others reduced slightly as the design requires.

As this relies on fabric standards that are achievable using current approaches and products, it can be designed and built to a similar form to current new build homes.

The thicker walls could, in many cases, impact plotting where detailed planning has been obtained, resulting in redesign and planning re-submissions with the attendant risks and costs, unless this is accommodated by the transitional arrangements. Where outline planning has been obtained, or before, then the Design work group expects that schemes should be able to be designed to not impact the number of homes. This may increase in the number of attached homes at the expense of some detached. (See Design chapter).

In addition to the hot water cylinder required for all CSs in houses, space for the MVHR and open web joists to accommodate ductwork will be required.

Net zero / net zero ready

Some archetypes have net zero regulated carbon emissions. As these homes are electrically heated, when the grid is decarbonised the others will also become net zero. Importantly, the energy demand is very low, assisting the grid decarbonisation effort.

Geography

The high level of airtightness and insulation means there is relatively little difference in performance from the weather variations across the UK.

Future retrofitting & smart systems

See: Common themes across all contender specifications

continued...

Skills

The specification will require upskilling within the professions, site trades and management:

- A programme of skills & training for professionals.
- A significant scale up of trades trained to install and commission MVHR and heat pumps.
- Training programmes, competency schemes and new onsite processes to achieve the airtightness standard.
- A full review of capability to upgrade skills and a programme initiated to address the shortfalls.

See:

- Heat pump skills and training
- Ventilation skills and training
- Air tightness skills and training

Widespread adoption of PV, MVHR and Heat Pumps will make these important controlled services on site.

Grid implications

See: Common themes across all contender specifications

Ensuring the designed performance is delivered

See: Common themes across all contender specifications

The higher attention to detail required to achieve the air tightness has an immediate feedback loop, via the air pressure tests and through visual inspections by the air tightness coordinator, so should result in improved performance compared with Part L 2021. Experience shows these additional 'eyes' also pick up other areas that may not have been built as intended.

Contender specification 4

Overview

To minimise space and water heating drawing on UK and European best practice.

Space heating demand is significantly reduced through a combination of high airtightness and MVHR. Solar panels (PV) and ASHPs further reduce demand and regulated carbon emissions are close to zero.

Elements	CS4 - Houses	CS4 - Apartments
Fabric performance	Passivhaus fabric level	Passivhaus fabric level
Windows	Triple glazed	Triple glazed
Ventilation Strategy	MVHR Air permeability 1.0	MVHR Air permeability 1.0
Space heating	Radiators/ underfloor	Direct electric panels
Energy systems	ASHP, WWHR	DHW ASHP, WWHR
Renewable generation	PV & diverter (min 40% roof area in plan, capped at 3.68Wp)	PV (min 40% roof area in plan for low-rise, min 20% in plan for high-rise)

Fig 42: CS4 Outline specification

Fig 43: Example of homes built to similar standard as CS4 (credit: top L-R Gale & Snowden Architects; Hastoe Housing Association; bottom L-R, Gale & Snowden Architects + CG Fry; Buckrose Ecological Architects + I & C Watts, image, Green Building Store; Hastoe Housing Association)

Summary

- Very near zero regulated carbon emissions today, average circa 95% reduction v 2013, with zero regulated carbon emissions for some house types.
- Circa 80% reduction in space heating demand compared with Part L 2021 and FHS2025 reference.
- Introduction of new air tightness techniques to a stringent standard, giving builders very little margin for error. Mainstream developers are concerned that this level is not obtainable at scale. Specialist developers advise the air permeability level is achievable provided scaling up was approached in a managed way and appropriate supervision and feedback is put in place.
- There is a step change in ventilation approach as it incorporates MVHR which, whilst common in apartments, is rarely seen in houses in the UK.
- Design flexibility is somewhat constrained by good thermal bridging design rather than the standard itself.
- An 80-130mm increase in wall thickness which is likely to require re-plotting and planning re-submission if detailed planning had been given but may be mitigated in scheme design.
- Considering the extent of the specification changes, the transitional arrangements would need to provide for a progressive scaleup to address the significant delivery & quality risks.
- Homebuyers will need to be introduced to the way the home is warmed and ventilated.
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = +£16,110 (13%)

  Relative to Part L2021 = +£21,800 (19%)
- Householder bills relative to Part L 2021 end terrace home = -£450 (excluding the benefits of load shifting)
- MVHR maintenance costs £80pa

Energy cost and carbon

CS3 significantly exceeds the minimum FHS carbon reduction expectation, with all homes > 90% lower than Part L 2013 and several archetypes achieving zero regulated carbon emissions.

	End terrace	*Mid terrace*	*Room in Roof semi-detached*	*Large detached*	*Detached bungalow*	*Mid floor low-rise apt.*	*Mid floor high-rise apt.*
%CO_2 emissions change compared with 2013 Ref	*- 98%*	*- 100%*	*- 92%*	*- 89%*	*- 96%*	*- 99%*	*- 89%*
% Space heating demand change compared with 2025	*- 86%*	*- 94%*	*- 79%*	*- 65%*	*- 59%*	*- 93%*	*- 98%*
Energy cost change compared with 2021 Ref (£/yr)*	*- £450*	*- £420*	*- £250*	*- £150*	*- £250*	*- £330*	*- £270*

*Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.

*Note that energy costs do not include savings from load shifting as this was not possible to model

Fig 44: Summary of CS4 modelling results

Significantly improved fabric, MVHR, and low air permeability result in a reduction of space heating demand, ranging from 59% to over 90% compared to 2025Ref.

According to SAP, two of the archetypes are regulated energy 'positive'. The detached home is particularly large, yet the maximum PV has been fixed at 3.68kW, hence the relative shortfall.

For the end terrace, the regulated energy costs are reduced by £450pa relative to the 2021Ref, equating to -£370 after MVHR maintenance is taken into account.

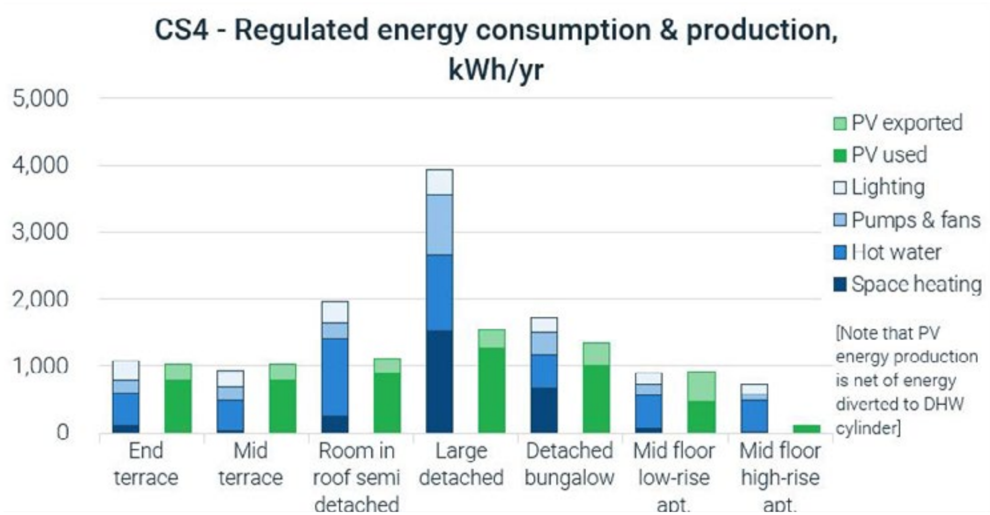


Fig 45: CS4 Regulated energy consumption & production, total per annum

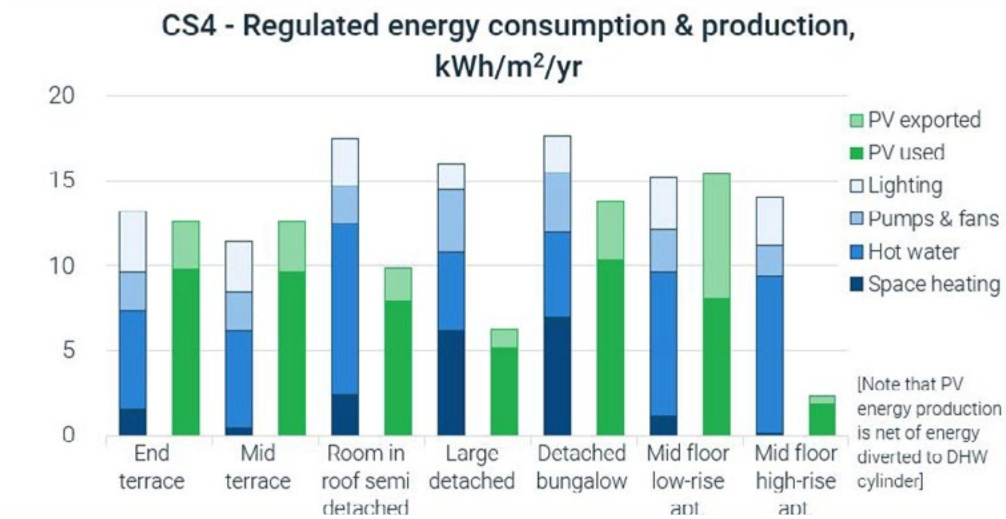


Fig 46: CS4 Regulated energy consumption & production, per m² per annum

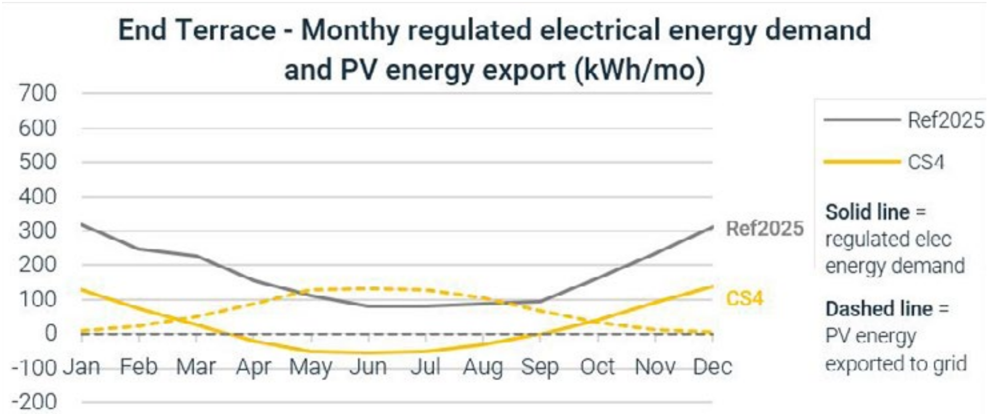


Fig 47: CS4 Monthly regulated electrical energy demand and PV energy export

Monthly peak regulated energy demand is less than half of the 2025Ref, with net monthly export from April to August.

Constructions costs

End terrace house change from Ref2021	Ref2025		CS4	
	Description	**£Uplift**	**Description**	**£Uplift**
Substructure	Change to ground floor	£800	Change to ground floor	£1,440
Superstructure	Change to external walls, windows & doors	£2,060	Change to external walls & roof & windows & doors; additional airtightness measures	£7,140
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler & dMEV; Add ASHP & cylinder & WWHR & MVHR & gaskets to penetrations & additional PV panels & diverter & additional testing & commissioning	£11,010
Main contractor preliminaries	Additional allowance	£470	Additional allowance, including airtightness coordinator	£2,210
Total uplift from Red2021	5%	£5,690	19%	£21,800
Total uplift from Red2025	-	-	13%	£16,110

Fig 48: Capital cost uplift for End of terrace house, CS4

The increase in build cost for CS4, compared with Part L 2021, is circa £21,800 (19%). Compared with the Ref2025 specification it is circa £16,100 (13%) more.

Householder perspectives

CS4 specific points:

- **Typical householder bill v Part L2021, end terrace home = -£450pa.**
- **Stable internal temperatures.**
- **No cold draughts above windows.**
- **No radiant cooling from windows to cause discomfort.**
- **Good internal air quality.**
- **A stable, slightly less humid atmosphere.**
- **Filter cleaning/changing 3–24 months (dependent on external air quality - circa £50/year).**
- **Recommended MVHR service every 5 years (equivalent to circa £30pa).**
- **Significant opportunity to load shift space heating**

In common with other CSs, the heat pump based space heating will require changes to householder behaviour and expectations. The concept of 'warming the home' with a heat pump rather than 'heating the home' will be different, with warm rather than hot radiators. (See Common themes across all contender specifications and heat pumps chapters for details).

The energy efficiency of the fabric means the heat pump is unlikely to start-up in a cold Winter night to maintain the setback temperature.

Apartments may have either electric heating or a central system with HIUs and radiators, both being familiar technologies. With the electric space heating, the specification used a heat pump hot water cylinder to maximise efficiency although there may be longer re-charge times.

continued...

CS4 has a MVHR system home buyers are unlikely to be familiar with unless they had experience with one in an apartment where they are more common. (See ventilation chapter for details).

The lower air permeability will not be noticeable to a householder, with the ventilation system providing the fresh air required. If the ventilation system were to be switched off, then the home would become stuffy although windows may still be opened to ventilate.

A design response to CS4 may emerge as a simpler aesthetic which reflects the increasing focus on low bills and low carbon, with decorative features such as layering, setbacks, bays and dormers used (sparingly) to reflect local character.

Scale up implications and strategy

Over 1,900 homes have been built in England to a certified Passivhaus standard; members of the CS4 working group estimate that ten times this have been built to low energy levels often using Passive House techniques but not certified.

Across Europe the number of Passivhaus units, predominately but not exclusively homes, being built is circa 2,000 per year. However, these are far from the only low energy homes built. Homes in Scandinavia, for example, are built to a very high level of energy efficiency.

That said, with an average build rate of 180,000 homes per year, and with an aspiration of 300,000 homes, the scale up is very significant indeed.

CS4 would require the scale up of:

- **heat pumps in houses (DHW heat pumps or communal HP systems in apartments)**
- wider cavities **(circa 230mm in masonry) / lower U-value walls**
- **very** low air permeability**, 1m³/m²/hr**
- triple glazing
- MVHR

Each of the technology groups has identified the approaches necessary to deliver at scale (see Ventilation, Fabric & Heat pump work group sections).

Delivery of CS4 would require all of these scale up approaches to be delivered concurrently.

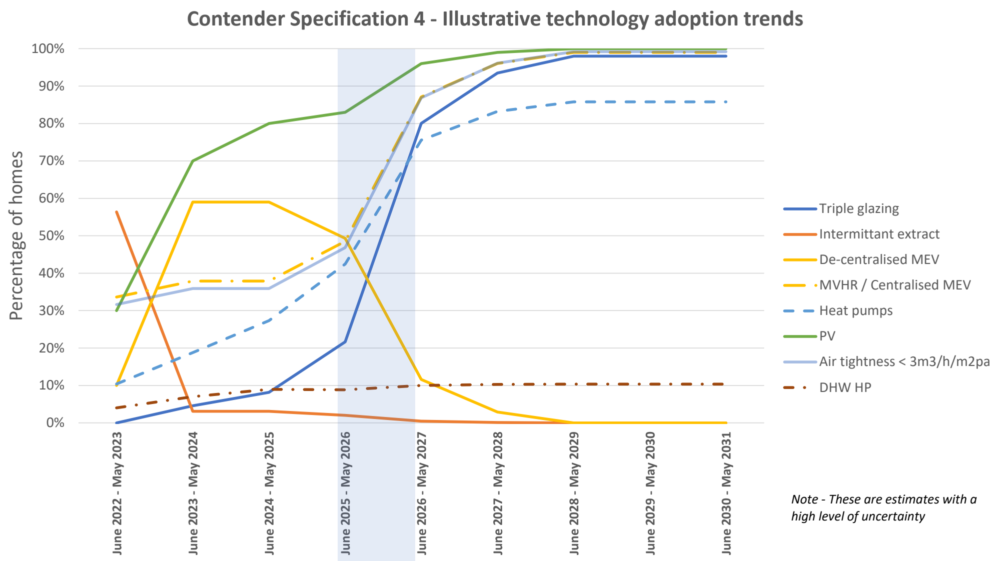


Fig 49: CS4 Illustrative technology adoption trends if there were a 12-month transitional period

See Common CS3, CS4 & CS5 scaleup strategy in Chapter CS3.

The requirement for triple glazing will also necessitate a higher capacity supply chain and circa 12 months to scale up production capacity.

Further key aspects

Design implications

See: Common themes across all contender specifications

The requirements for very high airtightness, coupled with the Part L 2021 requirement for designed and calculated thermal bridging details, is likely to result in simpler, more efficient built forms. Whilst dormer & bay windows, for example, are possible, they are likely to be less common.

The flexibility and trade-offs where some elements are enhanced and others reduced is very limited.

The thicker walls is likely to impact plotting where detailed planning has been obtained, resulting in redesign and planning re-submissions with the attendant risks and costs, unless this is accommodated by the transitional arrangements. Where outline planning has been obtained, or before, then the Design work group expects that schemes should be able to be designed to not impact the number of homes. This may require an increase in the number of attached homes at the expense of some detached. (See Design chapter).

In addition to the hot water cylinder required for all CSs in houses, space for the MVHR and open web joists to accommodate ductwork will be required.

Net zero / net zero ready

Some archetypes have net zero regulated carbon emissions. As these homes are electrically heated, when the grid is decarbonised the others will also become net zero.

Importantly, the energy demand is very low, assisting the grid decarbonisation effort.

Geography

Buildings of this standard have been delivered in all regions previously. The high fabric performance means the variance of heating costs between warmer and cooler parts of the UK is reduced compared with the 2025Ref.

Future retrofitting & smart systems

See: Common themes across all contender specifications

Skills

The specification will require upskilling within the professions, site trades and management:

- A significant national programme of skills & training for professionals.
- A significant scale up of trades trained to install and commission MVHR and heat pumps.
- Training programmes, competency schemes and new onsite processes to achieve the airtightness standard.
- A full review of capability to upgrade skills and a programme initiated to address the shortfalls.

See:

- Heat pump skills and training
- Ventilation skills and training
- Air tightness skills and training

Widespread adoption of PV, MVHR and Heat Pumps will make these important controlled services on site

Grid implications

See: Common themes across all contender specifications

Ensuring the designed performance is delivered

See: Common themes across all contender specifications

The experience from Passivhaus projects is that the significantly higher attention to detail required to achieve the air tightness, with an immediate feedback loop via the air pressure tests and through visual inspections by the air tightness coordinator, drives rapid learning and good airtightness results. Experience also suggests that these additional 'eyes' pick up other areas that may not have been built as intended.

The CS4 work group noted: a 2018 academic review of performance measurements from 50 Passivhaus and 138 other low-energy homes in the UK shows that performance of the building fabric is close to design predictions[4]. Another study[5] identified a drop in performance over time (primarily due to the deterioration of door and window seals). See also: Fabric chapter Ensuring Longevity

[4] *Gupta and Kotopouleas, 2018*

[5] http://www.wimbishpassivhaus.com/Wimbish-BPE-10-yr-Assessment-Final.pdf

Contender specification 5

Overview

To take “fabric first” to its logical conclusion: improving the fabric efficiency so internal heat gains balance with space heat losses to provide a comfortable temperature without a heating system.

Ventilation and hot water are provided using an integrated MVHR/Exhaust Air HP system. In design terms, the very high fabric performance favours significantly less complex built forms.

Elements	CS5 - Houses	CS5 - Apartments
Fabric performance	Beyond PassivHaus fabric level	Beyond PassivHaus fabric level
Windows	Triple glazed	Triple glazed
Ventilation Strategy	*MVHR* *Air permeability 0.5*	*MVHR* *Air permeability 0.5*
Space heating	None	None
Energy systems	*Integrated MVHR/EAHP for DHW, WWHR*	*Integrated MVHR/EAHP for DHW, WWHR*
Renewable generation	PV & diverter (min 40% roof area in plan, capped at 3.68Wp)	PV (min 40% roof area in plan for low-rise, min 20% in plan for high-rise)

Fig 50: CS5 Outline specification

Fig 51: Examples of homes built to similar standard as CS5
(credit L-R: Duan Fu Zedpower, HTA Design LLP)

Summary

- Zero regulated carbon emissions today
- 100% reduction in space heating demand compared with Part L 2021 and 2025Ref.
- Requires very high build standards, with stringent attention to thermal and air tightness details, particularly for poor form factor dwellings.
- Does not have a space heating system and typically uses a combined MVHR, Exhaust Air HP and DHW cylinder.
- Design flexibility is constrained by the need for good form factors and good thermal bridging design but not solar orientation.
- For individual homes, a circa 150mm increase in wall thickness would likely require re-plotting and planning re-submission if detailed planning had been given. For attached homes, the reduced plant space mitigates some, or all, of the increase in footprint.
- Considering the extent of the changes, the transitional arrangements would need to provide for a progressive scaleup to address the potentially significant delivery and quality risks.
- Homebuyers would need to be introduced to the way the home is warmed and ventilated.
- Unable to model effectively in SAP 10.2 and requires dynamic energy modelling and the regulation would need to be expressed as an absolute kWh/m² standard for space heating demand.
- Auxiliary heater is available, via the MVHR, if the home is left unoccupied for an extended period (with reduced internal gains)
- End Terrace build cost (200 home development in Dec 2022)

  Relative to FHS2025 notional = +£13,480 (11%)

  Relative to Part L2021 = +£19,170 (17%)
- Householder bills relative to Part L 2021 end terrace home = -£450

Energy cost and carbon

Properties built to this standard pay attention to dynamics and details which are not sufficiently accounted for in SAP10.2, making the modelled energy demand, running costs and emissions inaccurate at these very low energy levels. That said, the graphs and tables are generated from SAP to allow comparison and for the energy cost change, the space heating kWh has been adjusted to reflect zero space heating and is shown alongside.

Based on the SAP modelling, the specification achieves an energy positive (better than net zero regulated energy) performance for the modelled end-terrace, mid-terrace and bungalow house types. For the apartment, semi-detached and detached homes, it achieves close to net zero.

SAP10.2 was unable to model the correct size heat pump in the high rise apartment so no results are given (despite this archetype being the most common current application).

	End terrace	Mid terrace	Room in Roof semi-detached	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
%CO_2 emissions change compared with 2013 Ref	- 103%	- 105%	- 99%	- 94%	- 103%	- 97%	+
% Space heating demand change compared with 2025	- 84%	- 94%	- 78%	- 65%	- 63%	- 94%	+
Energy cost change compared with 2021 Ref (£/yr)*	- £410	- £370	- £350	- £330	- £290	- £280	+
Energy cost change compared with 2021 Ref, adjusting for zero space heating (£/yr)*	- £450	- £380	- £420	- £870	- £440	- £290	+

** Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.*

** Note that energy costs do not include savings from load shifting as this was not possible to model*

+ Unable to be modelled in SAP10.2

Fig 52: Summary of CS5 modelling results

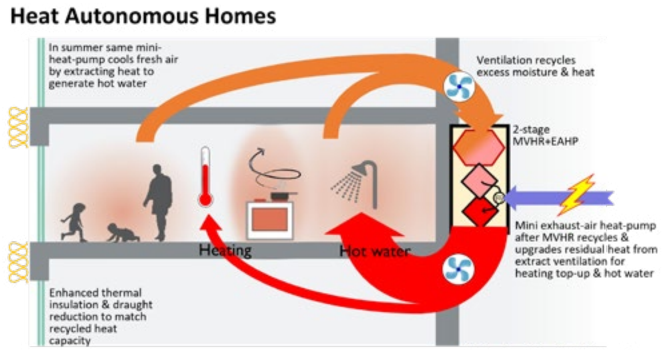


Fig 53: Illustration of heat flows in CS5 home (credit: Twinn Sustainability Innovation)

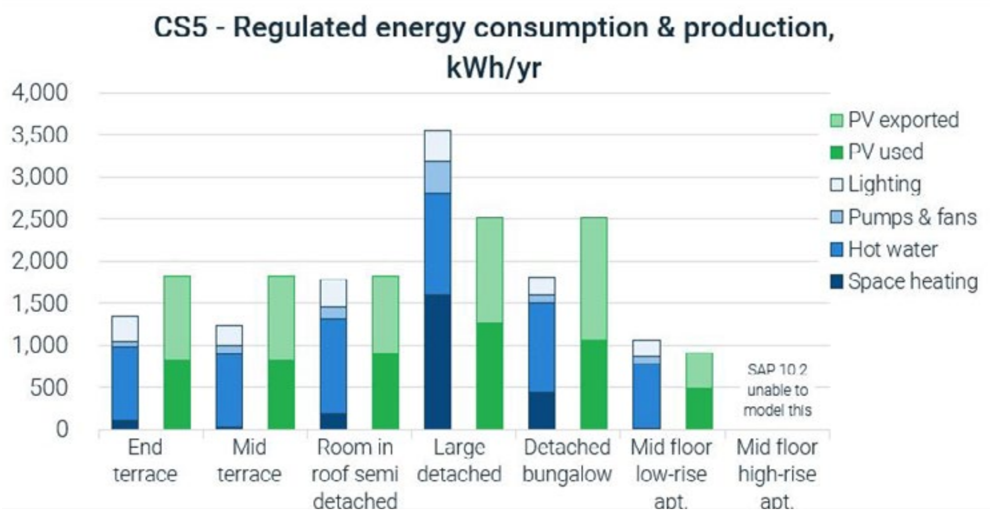


Fig 54: CS5 Regulated energy consumption & production, total per annum

The graph above shows a space heating requirement despite the very high fabric performance due to the inaccuracy of SAP10.2.

Large individual dwellings, such as the Large Detached example above, tend to have lower levels of internal gains. Solar gains can provide a suitable supplement, as solar access is more likely to be available for these homes.

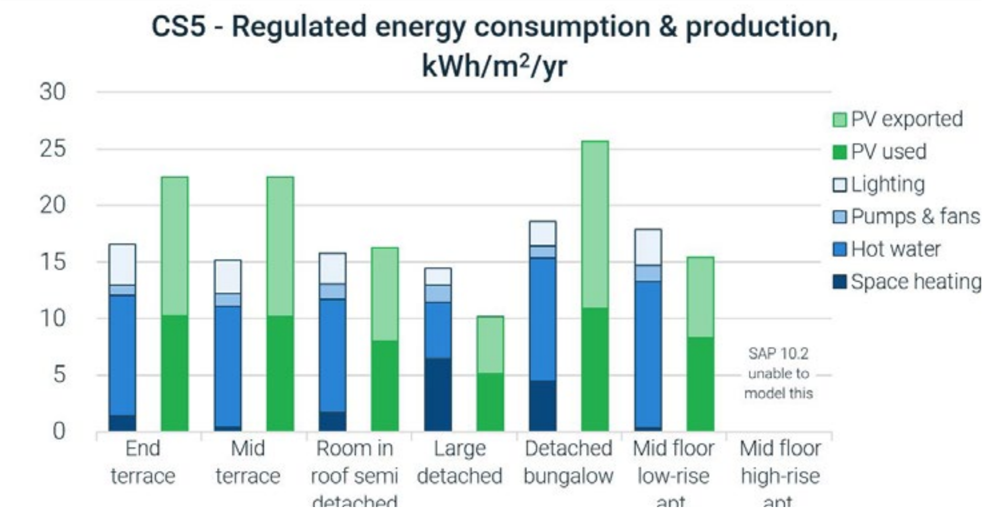


Fig 55: CS5 Regulated energy consumption & production, per m² per annum

According to SAP, four of the property types are regulated 'energy positive'. The detached home is particularly large, yet the maximum PV has been fixed at 3.68kW, hence the relative shortfall.

For the end terrace, the regulated energy costs are reduced by £450pa relative to the 2021Ref, equating to a reduction of £370 after MVHR maintenance is taken into account.

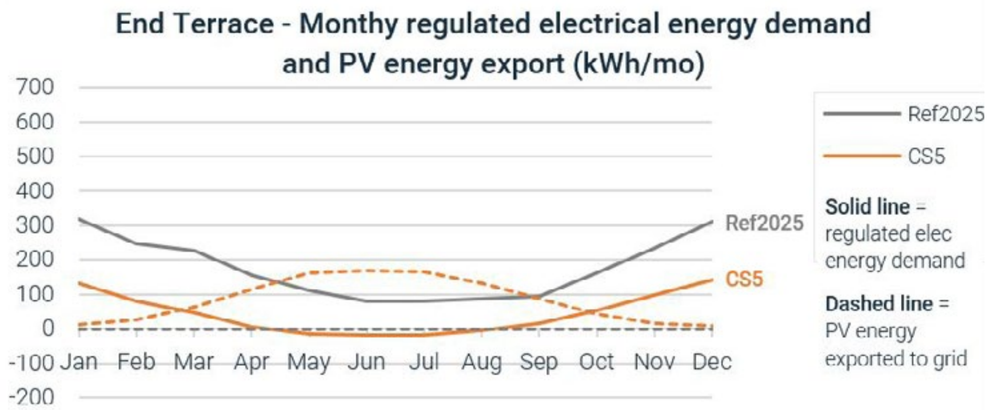


Fig 56: CS5 Monthly regulated electrical energy demand and PV energy export

CS5 monthly energy demand is likely overstated due to the limitations of SAP10.2.

Constructions costs

End terrace house change from Ref2021	Ref2025		CS5	
	Description	**£Uplift**	**Description**	**£Uplift**
Substructure	Change to ground floor	£800	Change to ground floor	£2,480
Superstructure	Change to external walls, windows & doors	£2,060	Change to external walls & roof & windows & doors; additional airtightness measures	£8,080
Services	Omit gas boiler & PV; Add ASHP & cylinder & additional testing & commissioning	£2,360	Omit gas boiler & radiators & dMEV; Add combined MVHR/ EAHP/cylinder & WWHR & gaskets to penetrations & additional PV panels & additional testing & commissioning	£6,340
Main contractor preliminaries	Additional allowance	£470	Additional allowance, including airtightness coordinator	£2,270
Total uplift from Red2021	5%	£5,690	17%	£19,170
Total uplift from Red2025	-	-	11%	£13,480

Fig 57: Capital cost uplift for End of terrace house, CS5

The increase in build cost for CS5, compared with Part L 2021, is circa £19,200 (17%). Compared with the Ref2025 specification it is circa £13,500 (11%) more.

Householder perspectives

CS5 specific points:

- **Typical householder bill v Part L2021, end terrace home = -£450pa.**
- **No heating system but stable internal temperatures.**
- **No cold draughts above windows.**
- **No radiant cooling from windows to cause discomfort.**
- **Good internal air quality.**
- **A stable, slightly less humid atmosphere.**
- **Extended hot water re-heat times.**
- **Filter cleaning/changing 3–24 months (dependent on external air quality - circa £50/year).**
- **Recommended MVHR service every 5 years (equivalent to circa £30pa).**
- **Simple control**

The absence of the heating system means households have far fewer controls to deal with. This could be particularly useful for the vulnerable, although consideration may be needed for medically vulnerable people requiring higher than typical in-home temperatures. In addition, there is no internal heat distribution system with radiators or underfloor heating and no ASHP 'outside unit' to locate and connect services to.

The homes would not need warming up and would always be at a comfortable temperature, providing significant comfort benefits. Where a home is left unoccupied for an extended period, with reduced internal gains, an auxiliary heater would be available to more rapidly warm the home. Similarly, at build completion, supplementary heaters may be required to assist the drying process during the first few months.

The higher room surface temperatures of the enhanced insulation, windows and airtightness mean that occupants comfort temperature is enhanced[6]. This allows occupants to achieve comfort at a lower temperature than could be achieved with lower fabric standards.

However, in the absence of any heating system, householders will need to be confident in the way the home behaves. As part of the home sale process, homebuyer awareness raising and expectation management will be required. (See also Common themes across all contender specifications).

CS5 has a MVHR system which home buyers are unlikely to be familiar with unless they had experience with one in an apartment where they are more common. (See ventilation chapter for details).

A design response to the specification may emerge as a simpler aesthetic which reflects the increasing focus on low bills and low carbon, with decorative features such as layering, setbacks, bays and dormers used (sparingly) to reflect local character.

[6] Ref CIBSE Guide A: Comfort temperature = Operational temperature which is a combination of air temperature, radiant temperature, and air movement

Scale up implications and strategy

BedZED is a development of 85 homes to this specification level without any installed space heating system. It has been in occupied for more than 20 years with monitored energy use and occupant satisfaction. Multiple projects amounting to about 1,300 homes are now being developed in the UK.

With an average build rate of 180,000 homes per year, and with an aspiration of 300,000 homes, the scale up is very significant indeed.

CS5 would require the adoption of:

- **Energy balance design principles**
- **Stringent on-site quality**
- **Wide cavities (circa 300mm in masonry) / lower U-value walls**
- **Very low air permeability, 0.5m³/m²/hr**
- **Triple glazing**
- **Mechanical ventilation with heat recovery**

Each of the technology groups has identified the approaches necessary to deliver at scale (see Ventilation, Fabric & Heat pump work group sections).

Whilst CS5 doesn't have a typical heat pump and heat emitters to skill up to design, install and commission, the other aspects are very significant step change. Should the same transitional arrangements be adopted for FHS2025 as Part L 2021 then the industry would effectively need to transform over an 18month period. This would create a very high risk of quality problems, inflated costs and, likely, stalled build programmes.

To mitigate these risks a phased transition would be required to deliver a steady build-up of professional and trade skills and experience over a multi-year period.

The main scale up challenge is achieving the very low airtightness. However, the principles/testing is the same once below 3m³/hr.m². Feedback from those delivering Passivhaus is the site learning curve is quick because site testing allows rapid feedback to site operatives although there is an ongoing need for close supervision.

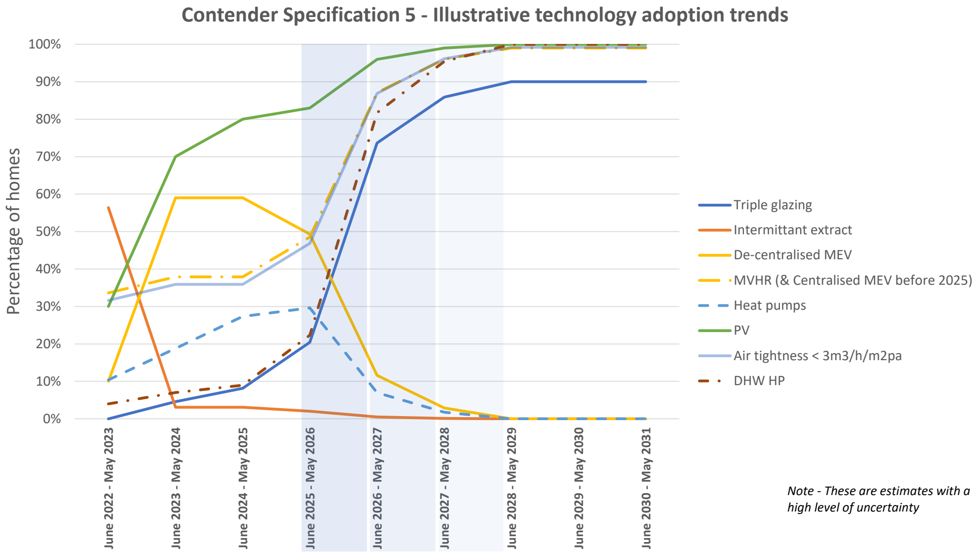


Fig 58: CS5 Illustrative technology adoption trends if there were a 12-month transitional period

See Common CS3, CS4 & CS5 scaleup strategy in Chapter CS3

There will be significant upskilling requirement for architects, architectural technicians and energy modellers. A move to an energy balance approach will require a whole new level of detailing and likely wholesale move away from the typical mainstream housebuilder home designs.The requirement for triple-glazing will also necessitate a higher capacity supply chain and circa 12 months to scale up production capacity.

The building components are already available.

In terms of the required M&E technologies, the MVHR+EAHP+DHW monoblock type unit is available from at least 5 suppliers in the UK tapping into large Europeans supply chains. Site scale up is less of an issue because factory tested mono-block means no site interfacing between normally separately supplied components. Site testing and commissioning is by supplier certified staff.

Where the form factor is poor, making it difficult to meet the required absolute energy standard, extremely high airtightness standards are required but are less stringent where the form factor is good. A major national focus on training programmes, and competency schemes will be required together with new onsite processes (see Fabric chapter).

Further key aspects

Design implications

See: Common themes across all contender specifications

A key evolution since this standard was first developed some 25 years ago has been the analysis using DSM (dynamic simulation modelling). This has demonstrated access to solar heat gains is not necessary to achieve the gains and losses heat balance for most archetypes. This means dwellings can be oriented in any direction and is suitable for high density developments where many dwellings may be without access to mid-winter solar gain.

Fig 59: Example of MVHR+ EAHP+ DHW monoblock type unit (credit: Twinn Sustainability Innovation overlay on Nilan image)

The principles are applicable for all archetypes and recent experience shows it to be a good match with high density high rise and low rise. Good form factor has a major impact on cost and the thermal performance required of components and tends to encourage simpler built forms.

Space is required for the off-the-shelf mono-block MVHR+EAHP+DHW unit inside each dwelling, typically requiring a single 60x60cm footprint full height unit containing all the components and controls interfaces.

No external heat pump is needed, so it is well suited to apartments as well as low rise housing developments with limited gardens. There are no requirements for roof top heating plant on flats and, therefore, more room for PV.

There are likely to be very few dormer windows and bay windows. A lobby between the front door and the rest of the dwelling is ideal to minimise heat loss, but not essential. This may cause some divergence with Government drivers around creating great places.

The thicker walls likely to impact plotting where detailed planning has been obtained. This may result in redesign and planning re-submissions with the attendant risks and costs, unless this is accommodated by the transitional arrangements.

Where outline planning has been obtained, or before, then the Design work group expects that schemes should be able to be designed to not impact the number of homes. This will likely require an increase in the number of attached homes at the expense of some detached. (See Design Chapter).

Overheating

See: Common themes across all contender specifications

The mono-block MVHR+EAHP+DHW has the potential facility to generate some summer cooling of the supply air. It can provide a modest level of cooling without any extra energy use. The finite MVHR air flow defines the extent of cooling potential.

Net zero / net zero ready

Some archetypes have net zero regulated carbon emissions. As these homes are electrically heated, when the grid is decarbonised the others will also become net zero.

Importantly, the energy demand is very low, assisting the grid decarbonisation effort.

Geography

Homes of this standard have been built and operate in Scandinavia, colder climates than the UK. The high level of airtightness and insulation means that weather variations across the UK are a second order influence compared to dwelling size.

Future retrofitting & smart systems

Time-shifting of demand for space heating is not a relevant consideration. With hot water, the extended recharge time mitigates against peak loads.

Continued...

... Further key aspects continued

Skills

Whilst there is one less technology to introduce, the design, installation/build and commissioning standards required are very high and comprehensive onsite construction verification and feedback is key to accelerate learning.

The specification will require significant upskilling within the professions, site trades and management.

- A national programme of skills & training for professionals.
- A significant scale up of trades trained to install and commission MVHR+EAHP+DHW units.
- Training programmes, competency schemes and new onsite processes to achieve the airtightness and construction detailing standards.
- A full review of capability to upgrade skills and a programme initiated to address the shortfalls.

See: Heat pumps, Ventilation, Air tightness skills and training

Widespread adoption of PV, MVHR and Heat Pumps will make these important controlled services on site.

Ensuring the designed performance is delivered

See: Common themes across all contender specifications

The experience from Passivhaus projects is that the significantly higher attention to detail required to achieve the air tightness, with an immediate feedback loop via the air pressure tests and through visual inspections by the air tightness coordinator, drives rapid learning and good airtightness results. Experience also suggests that these additional 'eyes' pick up other areas that may not have been built as intended.

The CS4 work group noted: a 2018 academic review of performance measurements from 50 Passivhaus and 138 other low-energy homes in the UK shows that performance of the building fabric is close to design predictions[7]. Another study[8] identified a drop in performance over time (primarily due to the deterioration of door and window seals).

See also: Fabric Chapter Ensuring Longevity

[7] *Gupta and Kotopouleas, 2018*

[8] *http://www.wimbishpassivhaus.com/Wimbish-BPE-10-yr-Assessment-Final.pdf*

Consumer perspectives

Summary

- The consumer acceptance of any new standard is paramount for them to buy new homes.
- Acceptability will need to be driven by consumer education led by Government, housebuilders, manufacturers, finance providers and infrastructure agencies.
- Initiatives such as: FHS brand, FHS show home 'open days', home energy performance calculator, the Energy Saving Stamp Duty Incentive could help to increase consumer / market awareness and drive aspiration.
- Whilst sustainability and energy efficiency are of increasing interest to house buyers (65%), the highest priority was still location and quality of build (96% and 95%).
- Only 13% of the public knew their home's EPC rating but 40%, up from 30% a year earlier, advised the EPC rating was 'very important'.
- Easy-to-use controls coupled with good consumer handovers and customer care will help customers become familiar with their new home and optimise their energy use.
- A Consumer Implementation Group should be established to oversee the necessary actions to smooth the customer FHS journey in conjunction and with the support of Government.

Needs and Wants

Interviews with residents in low carbon homes as part of the Building for 2050[9], research project showed that location, size and design (interior and external) were the principal drivers for choosing their home, with sustainability, quality and low running costs important but of lower concern. This finding is supported by market research by Space & Time[10] of 2000 new homebuyers. This showed that 96% considered location an important influence on their purchasing decision, (49% considered this the most important factor), 95% the quality of the build and 55% whether it had a dedicated office space. 65% considered sustainability an important factor, but only 4% considered this the most important factor.

Fig 60: Main drivers for residents (credit: Building for 2050 report)

BEIS Public Attitudes Tracker (PAT, Spring 22)[11] from the Winter 2021 survey (ie before the Ukraine invasion) found 71% paid a fair, or a lot of attention to the amount of heat used in their homes.

The PAT survey identified 36% of people had a lot, or fair amount of knowledge of the need to change the ways homes are heated to reach net zero.

[9] https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/1121448/Building_for_2050_Low_cost_low_carbon_homes.pdf
[10] Space&Time (Summer 2022), Sustainability & the Homebuyer

[11] www.gov.uk/Government/statistics/beis-public-attitudes-tracker-spring-2022
[12] https://www.natwest.com/mortgages/greener-homes-attitude-tracker.html

Only 13% of the public in the PAT survey knew exactly what their EPC rating was but 76% had awareness of the EPC. However, in the NatWest Greener Homes Attitude Tracker Oct 2022[12], 40% of prospective homebuyers said the EPC rating was 'very important' up from 30% the year before.

Consideration of sustainability is increasing, particularly for those with larger budgets. However, key factors such as energy bills and running costs are at the forefront of consumers' minds now more than ever. A Santander report[13] found 79% saying increases in energy cost made them think about the importance of energy efficiency.

Space & Time research identifies that homebuyers are attracted to low carbon homes, that cost less to run. The concept is often associated with technologies being a marker of a low carbon home such as Solar PV, heat pumps and EV charging. However, insulation (84%) and triple glazing (63%) were reported by more homebuyers as important features compared to Solar PV (46%) and heat pumps (41%).

Over 50% of estate agents in the Santander report found home buyers were prioritising energy efficiency over proximity to transport, open plan living and additional space, with over a third prioritising energy efficiency over a large garden or a home office.

The same survey asked people who were looking to buy a new home in the next 5 years to rank the top three features that would be important to them. Energy efficiency featured in the top three, alongside a large garden and off-street parking, with 40% saying they would definitely or very likely look for specific details relating to energy efficiency when looking at an advert for a new home.

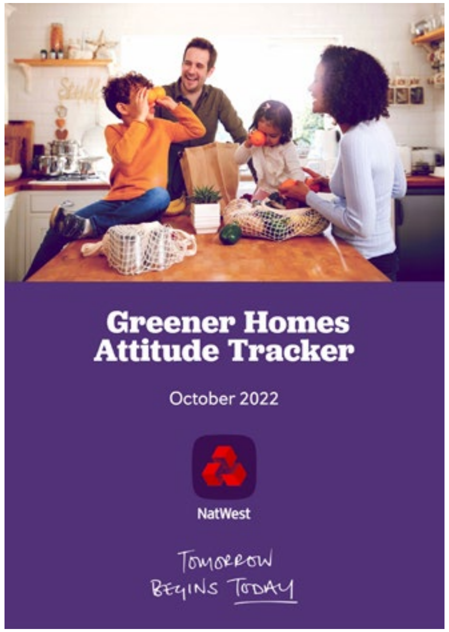


Fig 61: Greener homes attitude tracker

Fig 62: Buing into the Greener homes Revolution report

[13] Santander, Buying into the Green Revolution report Oct 2022, https://www.santander.co.uk/assets/s3fs-public/documents/buying_into_the_green_homes_revolution_report.pdf

Design features

The Building for 2050 consumer survey investigated whether the aesthetics of a property creates a barrier to purchase or rent. 59% of consumers said they would be happy to accept sustainable homes looking a little different to a typical home, 12% said it would deter them.

Concerns about interior space and the visibility of technology were highlighted by residents prior to occupancy. However, visibility was not an issue during occupancy, but residents did report lack of storage space. The size and location of low carbon features reduced their accessibility to areas of their home (e.g. attic spaces) where ventilation units and duct work were located.

End user experience of the home

Awareness raising

Education and awareness of how to use and the benefits of low carbon homes, is needed before purchase. For example in the BEIS PAT survey only 20% of the public knew a lot or a fair amount about heat pumps.

After purchase, help familiarising homebuyers with the control and maintenance of systems is particularly important. A digital passport that contains all guides and pre-set settings for technology could be used by first and subsequent occupants. Large housebuilders already offer digital home user guides, smaller builders may require assistance to manage this.

Show homes could be a valuable tool to promote the benefits low carbon homes and demonstrate how they operate. Housebuilders could invite not just potential buyers but homeowners looking to retrofit, and those that are curious, to see the new low carbon homes and to understand what they look like, how they feel, the technologies, the products and how to get the most from them.

If this were coordinated across the UK, as a low carbon show homes national event, this could be a powerful means of raising consumer awareness and encouraging people into show homes who were not even considering buying a new home.

Future Homes Standard 'Brand'

It is likely that the asset value of low carbon homes, with low running costs will increase in the future. A survey of 2,000 homebuyers by Space and Time (Sustainability and the homebuyer report) revealed that 57% are willing to pay more for a home that supports a sustainable lifestyle (i.e. solar panels, electric car port, triple glazed windows, etc.) 84% said that insulation levels would influence whether to buy a home.

Whilst Part L 2021 homes are an enhancement to the 2013 standards, changes in specification have previously not been advertised to home buyers. Government has stated that the changes in 2025 will be more significant and the last major change in Part L regulations on the path to zero carbon. Creating a recognised brand, or mark, for homes meeting the Future Homes Standard would provide a consumer-friendly label to identify the step change in performance, help communicate the changes, aid understanding of what to expect and provide a common language for industry wide PR and media.

Working with the finance community, the FHS brand might also be used to attract green mortgage offers.

Promoted via the national low carbon show homes events, the 'FHS home', may help grow recognition that visitors with existing homes will need to invest in substantial improvements over the next years. Alternatively, they could simply buy a FHS home, enjoy the benefits and avoid the hassle.

Understanding energy performance

Whilst the BEIS PAT Survey last winter showed 71% had heard of an Energy Performance Certificate, only 13% knew what the rating was of their own home. Indeed, even knowing the A to G rating does not actually tell you much about its energy performance.

The problem is the EPC A to G rating is a measure of the running cost per m² under standardised weather and occupancy for heat, hot water, light and fans utilising standardised, historic energy costs. It ignores plug in loads which can constitute half of the energy costs. The energy use indicated on the EPC does not readily relate to what householders actually pay, causing confusion. It does not alert a home buyer to the expected size of their energy bill. As agile tariffs become more common, especially for electrically heated zero carbon ready homes, the standard EPC format becomes positively unhelpful.

In short, if we drive up home buyer interest in the EPC, as many problems are created as solved.

The energy performance of a home is complicated to describe. A fixed piece of paper, or more likely a PDF, is not up to the job any more.

BEIS have launched an EPC Action plan to make improvements. From a homebuyer's perspective, critically it should be relevant and accurately reflect the home's performance as if they were living in it. For the home buyer it is not an 'asset rating'.

A helpful tool that emerged from the Green Deal Finance initiative was an energy calculator which used the home's own EPC data to calculate the bespoke savings associated with user selected retrofit options.

Along similar lines, a dynamic, web based EPC portal, drawing on the SAP data held on all homes, could be developed which allowed a home buyer or householder to input their own lifestyle, contain up to date energy prices, and reflect the tariff type they are actually using. Providing a more accurate view of their expected energy bills would both engage householders and provide a real opportunity to compare the running costs of the different homes they may be considering. All the home buyer /householder would need to do is look up their home via address or EPC unique reference number, as they can today, but rather than viewing a static screen, have options to tailor it to their own circumstances. This could also form a much better basis for mortgage companies to determine energy bill outgoings and affordability.

For the EPC rating itself, a kWh/yr absolute scale, translated to A -G rating would provide a better rough indicator of a home's performance.

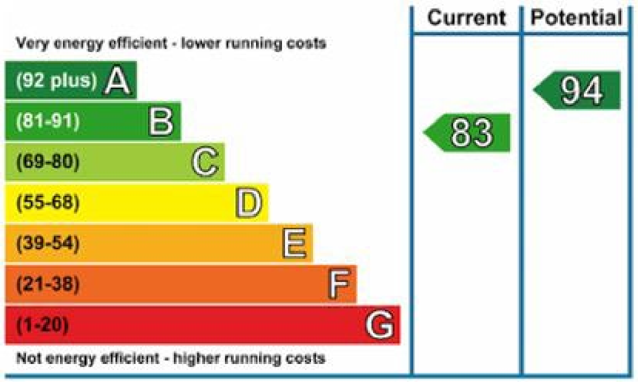


Fig 63: Example EPC rating

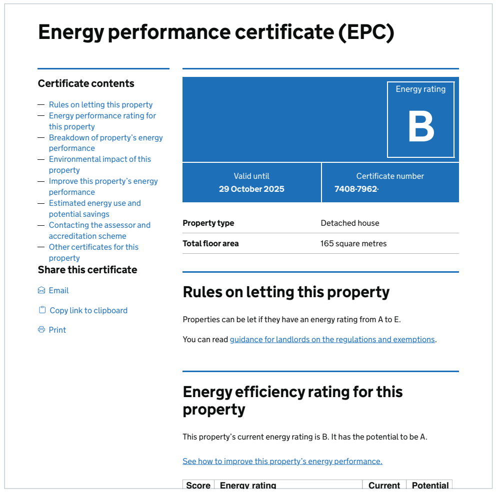


Fig 64: An online Energy Performance Certificate

Incentivising low energy homes purchase

Whilst there is increasing evidence to show that better performing homes command a higher price and the recent spike in energy bills may accelerate this, there are no Government drivers which surveyors can reference to justify higher valuations for more energy efficient homes. Surveyors reflect the market, so as the market evolves, so will valuation. A structural driver could accelerate this process. The Energy Efficiency Infrastructure Group and UKGBC, with broad backing, has proposed an Energy Saving Stamp Duty Incentive[14] whereby the Stamp Duty is nudged down and up based on the energy performance of the home. Existing homes that are improved within 2 years get reassessed and a rebate paid. New homes, which are inherently higher performing, stand to benefit both directly and indirectly as the market more rapidly values lower energy homes. It is revenue neutral to the Treasury.

Fig 65: Companies supporting the Energy Saving Stamp Duty Incentive

[14] https://www.theeeig.co.uk/stamp-duty/

Running costs

All of the CSs should have lower running costs compared with typical existing homes.

For the benefit to be realised in full, the as-built performance must match the design performance. Case studies conducted as part of the Building for 2050 project show that this was not always the case. Some form of process to demonstrate real performance could link to a Future Homes brand to ensure the brand does not get undermined by cases of claimed poor performance.

The Building for 2050 report showed that survey respondents and case study residents anticipated that their energy costs would be lower as a result of moving into an energy efficient home. However, moving from gas heating to an electric heat pump may not mean low heating costs, due to the difference in cost per unit of energy, if there is still significant demand for space and water heating. Experiences of higher than anticipated fuel costs would impact negatively on the public perception of low carbon homes.

Energy tariffs

To maximise the benefits of all of the CSs, 'time of use' or 'agile' energy tariffs are likely to be needed. Using energy when it is less expensive knowing that the home cools down slowly, heating hot water and storing it or even charging a battery. These tariffs can be confusing and make energy bills somewhat more complicated. This will need careful explanation to home buyers and potentially additional support will be required for some vulnerable households who may find it particularly challenging.

Freehold / leasehold

Most, but not all, of the CSs for apartments include technologies which may be situated in common areas such as PV, Heat Pumps or communal heating systems. Whilst not a new issue to accommodate, it may be more complicated regarding responsibilities for control, maintenance, access and sharing of the benefits of different technologies between the freeholder and leaseholders or tenants.

Technologies and consumers

Controls

As well adapting to the lived experience of new energy technologies, householders will need to learn the new technologies' control and maintenance requirements. Prior to moving in, householders in the Building for 2050 study, had concerns they would have difficulty understanding unfamiliar technologies. In practice, many struggled and some had no wish to interact with the technology. There were fewer issues for householders in homes with communal heating system.

Householders said there was a lack of training and information about how to optimise their systems and tailor them to their needs. Most commented that information was not user-friendly, with some only receiving installer guides. This underlines the importance of good consumer education and awareness raising around expectations, controls and maintenance with good handover processes and user guides.

There was insufficient forethought to ensure the controls were simple to understand and operate. While some homes offered apps to control the systems, residents had issues accessing and using these.

A quality mark around controls usability could link to a Future Homes brand to ensure usability.

Heat Pumps

(See also householder section of the Heat pump Chapter).

Heat pumps are installed in each contender specification, with the exceptions of apartment buildings, CS2a and CS5.

The main concern for householders will be adapting to lower flow temperatures than gas central heating. With homes that maintain heat for longer, the concept of 'warming the home' with a heat pump rather than 'heating the home' from cold will be new. This will require an understanding of how the system operates including: optimising the control of a less responsive heating system and taking the opportunity to use flexible tariffs to warm the home when the energy prices are lower, knowing that heat will be retained.

Householders not understanding the system may think that if their radiators are not hot, then the heating system is not working correctly.

An integrated DHW heat pump should require limited attention, however, the longer recharge times may need explaining. In three of the four case study homes in the Building for 2050 report, residents reported having insufficient hot water. The case which did not have complaints had larger capacity cylinders (see heat pump chapter).

Ensuring there is adequate room-space for dining tables and storage are major concerns which are particularly acute in smaller homes. Extra internal space will be required for hot water cylinders in homes that previously used combi boilers. Alternatively, space saving technologies exist and could become more common such as phase change heat batteries. With CS1&2 radiators may be larger although underfloor heating can mitigate against the space this can take up.

For terraced homes, in particular, some of the limited outdoor space will be used by the heat pump outside unit. These archetypes may also have limited options for positioning a heat pump.

Return to the Heat pump Chapter

Fig 66: Example ASHP outside unit (credit: Dr J Wingfield)

Fig 67: Example DHW HP installation (credit: Vaillant)

Direct electric heating

There are various forms of direct electric heating from panel heaters installed like radiators on walls, to Infra-red panels installed on the ceiling embedded in the plaster. All of the contender specifications assumed direct electric heating in the apartments, apart from CS5, and CS2a used Infra-red. Typically, they are easy to control and providing instant heat, they can be cost effective, if matched with high performing fabric and time of use tariffs.

Fabric

All CSs should provide significantly improved thermal comfort compared with most existing homes. As the fabric performance improves across the CSs, the temperature variation within the home decreases, as does the time taken for the home to cool.

Triple glazing, in some of the specifications, minimises the radiant cooling from windows which may cause discomfort, particularly where there are large, glazed areas.

The “no-space-heating” CS5 standard offers the highest levels of indoor temperature stability but householders would need to be confident that a heating system was not required. Being new to consumers, they are likely to need some convincing of a home which is always warm, rather than requiring heating. Additional consideration may be needed for medically vulnerable people who need higher than typical in-home temperatures.

Ventilation

(See also householder section of the Ventilation chapter).

The majority of new houses to date have typically used intermittent extract fans, trickle vents in the window frames and undercut internal doors. Part L 2021 is likely to change that, with many housebuilders opting for decentralised continuously running mechanical extract fans (dMEV) in place of the intermittent fans.

It could be argued that for natural ventilation and dMEV there is little to no householder interaction. However, in reality this may not be the case when it comes to the background trickle vents and noise intrusion from local fans. For natural ventilation, trickle vents tend to be quite large and can create unwelcome draughts which can prompt householders to close the vents and, therefore, disrupt the ventilation strategy and impact indoor air quality.

Past studies[15] have shown that 60% of trickle vents were found to be closed and 67% of fans switched off. Whilst it is rarely undertaken, householders should periodically clean the extract fan / ductwork as well as the trickle vents.

The same limited householder interaction point could be made for dMEV regarding draughts and noise, prompting householders to close vents and switch fans off, but possibly to a lesser degree regarding draughts as the trickle vents are smaller.

There are limited studies on homes with dMEV so additional evidence gathering is required, particularly as householders are generally unable to recognise poor air quality.

Many apartments have centralised mechanical extract systems either with or without heat recovery. It is estimated of all houses built, 25% have these systems[16].

CS1 and CS2 maintain the dMEV approach to ventilation in houses, with centralised MEV used in the apartments. CS3,4 & 5 adopted mechanical ventilation with heat recovery (MVHR).

A well designed and installed cMEV system can be very quiet, reducing one of the potential issues with dMEV. For cMEV, a professional service is typically required approximately every 5 years but there are no filters to change.

[15] BSRIA

[16] BEAMA

MVHR extracts stale air and uses this to pre-warm incoming fresh air which is ducted into the habitable rooms so there are no window trickle vents.

Filters need cleaning/replacing, typically every 6 months which is an additional maintenance task for the householder. However, these filters are collecting the airborne dirt that is otherwise breathed in. If needed, different standards of filter can be installed. Should the householder have particular allergies then specialist filters can be installed to remove pollen, for example, for hay-fever sufferers. A professional service is recommended approximately every 5 years.

With MVHR, there is also a risk of being switched off if the consumer is disturbed by the noise, draughts, or as mistaken action to save energy which likewise can lead to poor internal air quality and moisture issues. It is important, therefore, for good design to address the former and effective training to avoid the latter.

Well designed and installed, the systems are quiet and do not cause draughts. However, the householder may find the air drier, with an MVHR system.

With all ventilation systems, the undercuts of internal doors are important. Householders will need to be aware to ensure these are maintained, for instance, when new carpets are installed.

Most case study residents in the Building for 2050 report said the air quality in their homes was good and did not report any issues with mould, damp, or condensation. Three of the studies had MVHR and one MEV. Householders in two of the sites with MVHR reported that the air was dry and investigation found they were being over ventilated. A few commented about how they felt their health had improved as a result of MVHR in their new homes, particularly for those with respiratory issues having experienced damp in previous homes.

Fig 68: Example MVHR installation (credit: Zehnder)

Return to the Ventilation chapter

Design

Implications of contender specifications on meeting the design standards

DLUHC are pressing for better housing quality – higher performance as well as aesthetically pleasing. The National Model Design Code and Guidance points to tropes such as layering, setbacks, bays, dormers and chimneys as aesthetic devices. These can be, and have been readily achieved, even within the very low energy build 'passivhaus' standard performance envelope. There is also an emerging simpler aesthetic - which reflects the increasing focus on low bills and low carbon – with such decorative features used (sparingly) to reflect local precedent.

Some of the high-performance window companies showcase bays and roof windows on their websites as a selling point.

Fig 69: Ditchingham Passivhaus, Hastoe (Credit: Hastoe Housing Association)

Increasingly, the robustness of high performance fabric is evolving its own aesthetic, such as:

- substantial windows set deeply into reveals (in line with the insulation layer).
- shading devices and ventilation grilles integrated into window design.
- roofs designed for integrated photovoltaics (and in some cases heat pumps).
- mechanical systems 'pods' integrated into streetscape design.
- front door porches with cycles and storage.

This new design vocabulary is now increasingly recognised at design review and in planning pre-application discussions as an added opportunity to enhance the aesthetic quality of housing.

Fig 70: (L) The Old Forge Cottage Passivhaus, Leeds (Credit: Green Building Store); (R) Passivhaus Bungalow (Credit Internorm)

Compliance

Given that the design and form of homes greatly impacts on their thermal performance, this raises the question of whether it is sensible to have the same notional dwelling specifications for different house types and apartments. Dense apartments have significantly different profiles in terms of internal gains, heat losses and risks to overheating, compared to detached houses.

Achieving greater improvements in fabric performance becomes increasingly difficult in apartments with limited wall space when relying on non-combustible insulants. Shelf angles to support masonry also interfere with treatment of thermal bridges. Furthermore, the profile of energy demand from communal heating, cooling and ventilation systems, looks very different and can be shifted using different strategies compared to individual homes.

Householder and planning perspectives

Daylight and overheating

Daylight is desired by households, more so now with greater numbers of people working from home. However, from a building regulation viewpoint, windows are sources of heat-loss in cold periods, or problematic solar gain in summer. Planning authorities tend to favour designs that maximise daylight but have been less concerned with overheating.

Increasingly, overheating is a concern for dense apartments, many of which are in cities subjected to urban heat island effects that are not accounted for in weather files used for overheating risk analysis. Overheating regulation is now dominating specifications for window size and type – favouring smaller windows. Similarly, concerns around acoustics are driving designs in the same direction.

Acoustics and space for mechanical systems

Heat pumps have a different noise profile to boilers. They are typically quieter but run for longer periods. ASHPs, but not all heat pumps, take up external space and need clear space around them which may alter the space available to householders. Similarly, hot water cylinders and heat batteries used with heat pumps take up internal space.

As covered in the ventilation chapter, more maintenance is required for homes with improved air tightness, whether they have natural ventilation, MEV or MHVR. These systems need to be designed for easy accessibility.

Geography and Renewable Energy

Homes in the Southwest will gain substantially more benefit from renewables than homes in the Northeast and will also benefit from lower heating demand. Homes in the Northeast have lower risk of overheating and are less likely to need cooling in the long term. Land values are generally higher in the South, meaning it is easier for land prices / developers to absorb the costs of enhanced regulation compared to the North.

Site and development with thicker walls

Housebuilders, particularly those building standard house types on large sites, are understandably concerned that increased wall thicknesses reduce overall development capacity for new housing. CS3, CS4 and CS5 have significantly wider masonry walls, ranging from 400mm to 500mm, compared to 330mm to 380mm for a typical home built to Part L 2021 building regulations.

An existing site with detailed planning consent may need to be re-designed or re-plotted to accommodate houses with a larger footprint, together with associated risks and costs of going back for planning. Better would be for the transitional arrangements to allow homes with detailed planning to proceed under the original building regulations.

Should re-plotting be required for larger footprint homes, this could mean unit numbers are reduced if all the homes retain the internal area and are predominately detached. However, with design consideration, it is probable that numbers can be maintained on any site by fine-tuning the site layout, adjusting the house design or by using more terraces and semi-detached homes.

However, it should be noted that, for a new scheme designed from the outset with larger footprint homes, the impact is likely to be small compared with Part L 2021 (150mm cavity) for CS3 (200mm cavity), if there were no design mitigations and modest with CS4 (230mm cavity). Indeed, other design considerations may have a more noticeable impact on housing density than wall thicknesses namely: viability, design, unit mix, unit tenure, topography, landscape as well as other regulatory requirements such as parking standards, highways requirements, unit mix, biodiversity, and SUDS.

The illustration below compares a theoretical worst case row of 30 detached houses, narrow frontage and minimum distance between them. For the 200mm cavity, compared with the 100mm, approximately ½ a house is lost. However, the same number is maintained if 4 detached homes become 2 pairs of semi-detached.

The scheme illustrated on the right had planning consent. It had a dense and compact layout. However, it was then required to be re-plotted with house types with larger footprints to achieve a higher level of external wall thermal performance. Whilst the homes in the replotted site had a larger footprint, the total number of homes increased thanks to more use of terraced and semi-detached homes. The houses were designed to meet specific market housing and affordable housing requirements not accounted for in the outline approval.

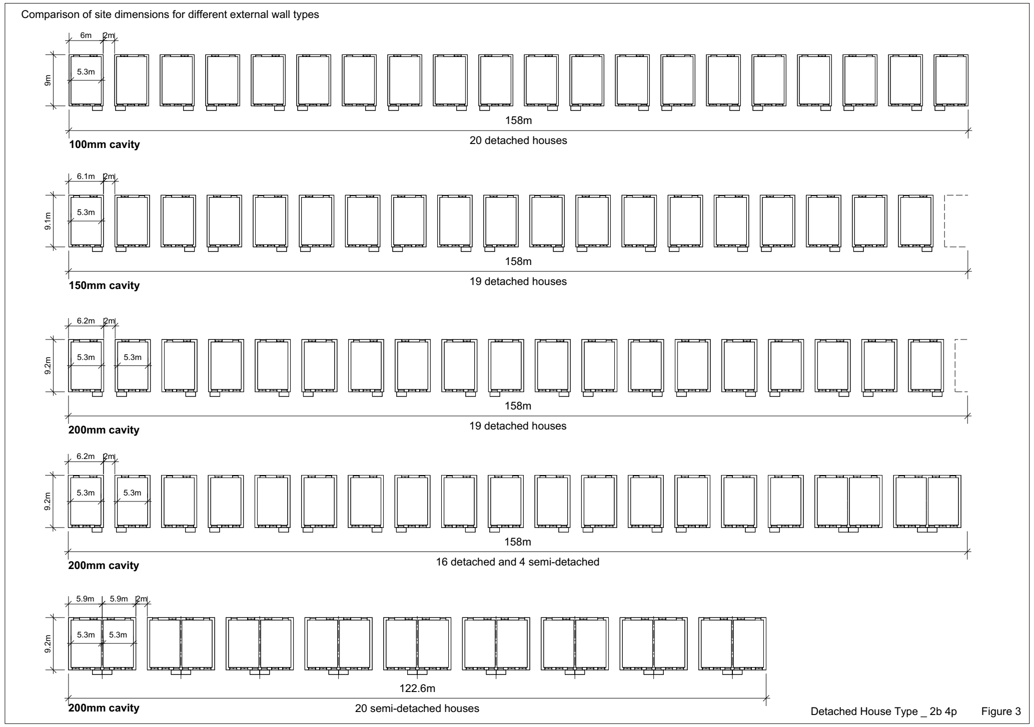


Fig 71: Comparison of site dimensions for different external wall thicknesses

Original planning application
- 32 detached
- 40 semi-detached
- 72 homes in total

Revised planning application
- 14 detached
- 61 semi-detached
- 75 homes in total

Fig 72: Comparison of different layouts for same site (differing wall thicknesses)

See appendix G (separate document) for more details.

High rise

Summary

- For high-rise apartments, due to generally good form factors, increasing complexities and diminishing returns of further improvements to fabric standards, no CSs proposed to go beyond those already required in London (wall U-value=0.15).
- The requirement for non-combustible cladding materials has additional implications for lower U-value wall design.
- Thermal bridging needs careful consideration to reduce overall heat loss and ensure reductions in U-values are not offset by increased bridging.
- At these fabric performance levels, hot water demand is by far the dominant requirement for heat.
- There are a number of ways in which heat can be delivered efficiently to apartments including: via centrally located heat pumps; via a communal ambient loop; or by decentralised heat pumps for DHW only, plus electric panel heaters.
- Each option has different implications for space requirements within the block and individual apartments.
- Ventilation strategies go hand in hand with overheating considerations, increasingly leading to many high-rise schemes requiring active cooling to comply with AD Part O.
- With the use of heat pumps, the energy cost to the occupant across all CSs is reduced compared to Part L 2021 (gas combi) solutions.
- The CSs for apartments were sufficiently different to their low rise housing equivalents in all CSs for a separate notional specification to be required.

Fabric performance

Given the reduced exposed surface area of high-rise apartments, annual space heating demand represents a smaller fraction of overall energy demand of between a quarter and one sixth of the hot water demand. As such, improving fabric standards was less of a focus, as these increase embodied carbon and capital cost with diminishing returns. Each contender specification proposed separate fabric standards for apartments and these have not gone beyond what is currently required by the GLA in London.

It is, however, noted that for medium and high-rise apartment blocks, the requirement to use non-combustible cladding materials reduces the options available for achieving very low fabric standards.

To ensure good overall fabric performance there are also implications for thermal bridging, which will need careful consideration.

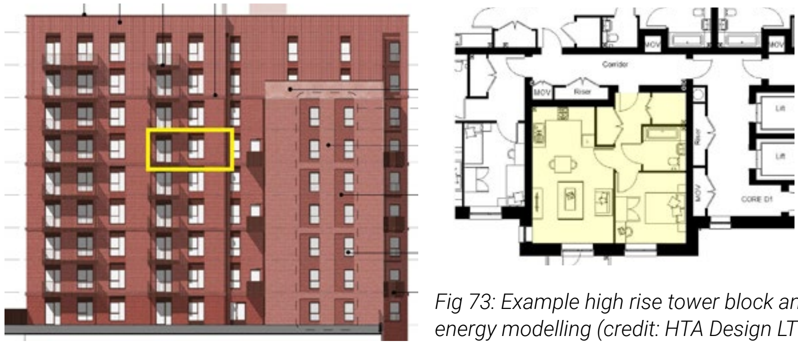


Fig 73: Example high rise tower block and apartment used for energy modelling (credit: HTA Design LTD)

Electrifying heat

Presently mid- and high-rise apartments are generally built using a centralised plant to generate “low” temperature hot water distributed to individual Heat Interface Units (HIUs) within the apartment. These deliver instantaneous hot water and heat to radiators and /or underfloor emitters. HIUs take up only a limited amount of space as does underfloor heating. The low space heating demand for apartments means that the energy solution should be geared toward efficient production of hot water. Across the CSs, the DHW demand as a proportion of the total heat demand varied from 69% to 99% for a mid floor apartment.

There are three main approaches to consider when efficiently electrifying heat to apartments:

Centrally located ASHPs

These can be used in place of a central boiler plant, retaining the same spatial efficiency and topology within the apartment. A plant on the roof typically requires over 150m² of space for a 300 unit scheme (less for ground floor plants). On mid-rise and high-rise schemes, biodiversity planting, photovoltaics and other necessary safety equipment vie for roof space alongside amenity space. Siting constraints, system efficiencies and cost factors mean that other approaches are often considered.

Centrally located ambient heat pump with apartment heat-pump

A smaller, central HP plant delivers ambient temperature water (150- 300C) to apartments. A heat-pump within each apartment raises temperatures to usable levels to store DHW ready for use. These units are typically the size of an upright fridge-freezer, some requiring an external buffer vessel, which combined, takes significantly more space than a single HIU.

Decentralised air to water DHW heat pump with electric panel heaters

This approach eliminates the need for a central plant with distribution pipework by using a decentralised air to water heat pump mounted on top of the cylinder to generate hot water. Space heating is provided by direct electric panel heaters or IR panels. This solution demands the equivalent volumetric space to the apartment as the second approach. Furthermore, furniture layout may be restricted by panel heaters although IR panels may help mitigate this. DHW ASHPs also require ducts from the unit to the façade that can increase the congestion in ceiling voids.

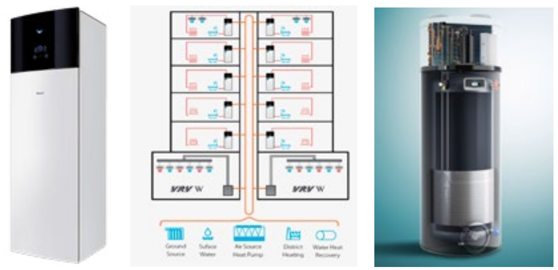


Fig 74: (L-R) Example heat pump (credit: Daikin); communal heat network schematic (credit: Daikin); DHW ASHP (credit: Vaillant)

Ventilation

The ventilation strategies differ between each contender specification. dMEV was proposed for CS1. CS2 uses cMEV, requiring minimal internal equipment and ducting running from bathrooms and kitchens to the façade.

The MVHR proposed for CS3 and CS4 increases the number of ducts required in the ceiling void. Inline duct attenuators and possible NOx filtration systems add to space requirements. These may be accommodated in dropped ceiling zones, usually outside the utility cupboard, providing the additional benefit of easier access.

Cooling

Awareness of overheating risk in apartments has greatly increased recently underlined by the release of Part O of the Building Regulations.

The inferred internal acoustic criteria contained within regulation guidance means developments close to any transport infrastructure will likely not pass the assessment if using openable windows as an overheating mitigation strategy. This effectively mandates active cooling for a large proportion of apartments, as other forms of mitigation are generally not viable. The issue is exacerbated by higher fabric performance, greater noise levels and more demanding local weather conditions with schemes in the South-East most acutely affected.

Cooling solutions must respond to energy strategy and context but will usually involve refrigerant based cooling boxes working in conjunction with the MVHR, supplementary extract ventilation systems, or chilled water coils added after the MVHR supply ductwork. Underfloor cooling is possible but is severely limited by condensation issues and the thermal resistivity of floors.

The latter solutions are dependent on an infrastructure in place capable of delivering chilled water, such as the ambient loop. The former two solutions work independently of energy strategy but will involve higher running costs and higher operational carbon impact.

Each solution, except underfloor cooling, exert additional spatial pressures within ceiling voids. Bulkheads will need extending significantly and ceiling heights may need to be dropped if the slab-slab dimension remains the same.

Energy costs

There is a perception that electrification of heat will translate to significantly higher running costs to the customer. This certainly has been the case historically thanks to direct electric immersion heating for DHW, poor performing night storage heaters, or combining direct electric panel heaters with poor fabric performance.

With the solutions proposed above, combined with modern fabric performance, running costs are expected to be lower than for current specifications, as can be seen from the table above for most contender specifications. Whilst CS2a is an anomaly, the running costs are likely overstated due to the inability to model the benefits of load shifting in SAP10.2 and a DHW Heat pump within this specification could be used instead of an immersion heater.

Annual space heating demand is minimal thanks to fabric performance, build form and MVHR (where installed). Whether delivered via panel heaters or through heat pump-derived LTHW, the heat output required from these systems is small compared to the DHW demand. DHW generated by heat pumps derives three times more useful heat than an electric immersion heater. The solutions also deliver significantly more usable heat for DHW than a central boiler or CHP plant.

	CS1	CS2	CS2a	CS3	CS4	CS5
Modelled assumption	Panel heaters & individual DHW HPs		IR panel heaters & DHW cylinder with immersion	Panel heaters & individual DHW HPs		
Energy cost change compared with 2021 Ref (£/yr)*	- £30	- £80	+ £350 See note 1	- £230	- £270	+
Space heating requirement (kWh/yr)	730	690	640	120	10	+

Note 1: This is likely to be significantly over estimated as energy costs do not include savings from load shifting as this was not possible to model

* Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.

+ Unable to be modelled in SAP10.2

Fig 75: Summary of modelling results for high-rise mid floor apartment

Planning

Summary

- Local Planning Authorities (LPAs) are stretched and under resourced.
- Careful design of transitional arrangements is required to deliver the outcomes Government requires without creating significant re-design and resubmission where detailed planning had been received.
- Some LPAs continue to be reluctant to permit PV and heat pumps.
- CS1,2 & 3 had no particular planning issues raised.
- CS4 &CS5 prompted concerns about re-plotting of existing permissions and, for CS5, the implications for features such as dormer windows and archetypes such as bungalows.
- Design Codes were seen as necessary to show how the Government's 'Building Beautiful' agenda could be realised in practice particularly with CS4 & CS5.
- Training for local planners to increase understanding of regulations is needed.
- With all CSs, LPAs understanding the grid capacity implications of areas under consideration is critical to avoiding lengthy delays and excessive costs.

Local planning authorities and building regulations

The working group considered the planning implications for each contender specification.

Concern was expressed that the planning system was not flexible and not set up for change. As such, careful design of transitional arrangements was key in accommodating building regulations that may impact detailed plans already submitted without placing additional load on Local Authority Planners, who are already stretched beyond capacity. This recognises the timescale for planning to be obtained can be longer than the timeline for the development and implementation of building regulations.

Members of the work group noted that some local planning authorities set additional energy standards and go as far as pushing for Net Zero. This raised the question whether, alongside the introduction of the FHS, there was an intention to preclude LPAs setting even higher standards or not.

LPAs knowledge of grid constraints, and working closely with network operators, is critical to avoid delays and facilitate necessary grid reinforcements in the context of the significant competing demands for connections (See Grid chapter). Examples were quoted where planning permissions had been obtained but development could not proceed due to lack of local electricity capacity for installation of heat pumps, with upgrade/ reinforcement works prohibitively expensive and/or causing considerable delays.

Some members of the work group noted the potential for changes to building regulations to run up against other local planning priorities such as numbers of homes built. Also noted was many LPAs did not seem to give any advantages to schemes that were proposed to be net zero.

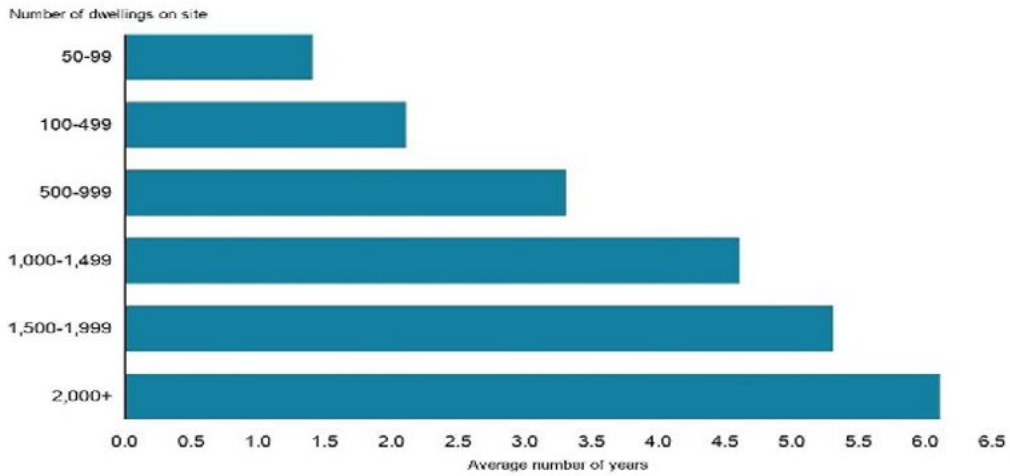


Fig 76: How many years does it take to get planning permission for different sized developments? (credit: Lichfields/ BBC, 2020)

Contender specification implications

Common to all contender specifications, the group reported that some local planning authorities had been reluctant to permit developments with PV and heat pumps for a range of reasons including: perceptions of noise, an assumption of a predominance of particular roof orientations and aesthetic reasons. Additionally, there can be limited recognition that features such as chimneys and dormers, which may be required by planning, have an impact on the useable roof space for PV which may create a conflict with building regulations.

CS1 was considered to have no significant changes to present regulations apart from the addition of an air source heat pump and, on some homes, solar PV. Likewise, CS2 and CS3 aligned with what the work group anticipated home builders were assuming for 2025 regs with no additional planning concerns highlighted.

Concerns were raised regarding CS4 and CS5 requiring thicker walls, thus affecting the building footprint which could reduce the number of house plots possible within a development. Where outline planning has been obtained, or before, then the Design work group expects that schemes should be able to be designed to not impact the number of homes. This, however, may require an increase in the number of attached homes at the expense of some detached. See Design chapter section on plotting.

The focus on thermal bridging (all CSs) and airtightness (CS4&5 in particular), favours simple build forms. Concern was expressed that this could limit diversity of building designs and may present challenges to design in line with the Government's *Building Beautiful* agenda. The increased emphasis on Design Codes was seen as an opportunity to show how this might be mitigated and this was also picked up by the design group (see Design chapter).

From a planning and design point of view, CS5, based on an energy balance philosophy where the losses equal the gains, effectively restricts the use of energy inefficient features such as dormer windows and inefficient forms such as bungalows. This could give rise to design outcomes that run contrary to local design requirements.

Role of Design Codes in creating strong links between Planning and Building Regulations

National planning policy is placing increasing importance on the role of Design Codes in setting out clear design parameters to help local authorities and communities decide what good quality design looks like.

All local planning authorities are now required to prepare Design Codes. Given this enhanced emphasis on the role of Design Codes, and the opportunities they present to integrate the delivery of the FHS into the architectural design of proposals and master planning, it will be important to consider how the final specification for the FHS can be reflected in Design Codes both national and local. Doing so would ensure that the delivery of the FHS contributes to the delivery of high quality, sustainable designs that respond to context, speeding up the planning application process where applications are in line with Design Codes.

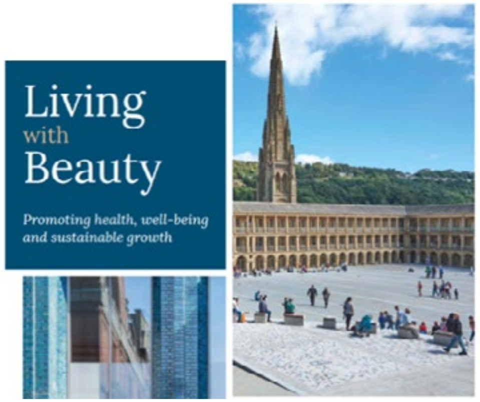


Fig 77: The Building Better, Building Beautiful Commission's 2020 report

Example considerations include:

- The implications more efficient forms have on functional design of those homes, such as space for bikes, cars and space for ASHPs. Design Codes can be used to show how these can be successfully delivered for different housing typologies.
- Responding to context, a key consideration for planning, Design Codes can be an opportunity to show how context requirements can be achieved while still enabling considered articulation of buildings.
- Design Codes can help deliver optimisation of roof design to support delivery of PV, even where those roofs are responding to context (for example, hipped roofs).

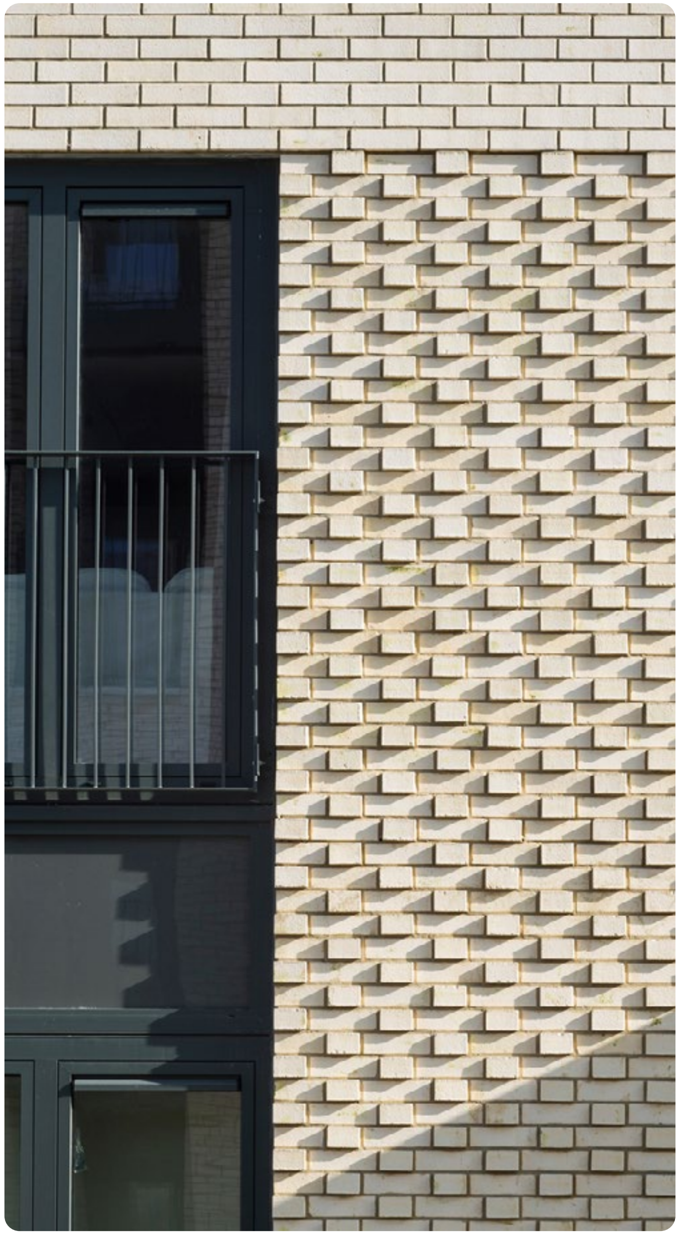
For further details and examples of the role of Design Codes see Appendix H in a separate document.

Fabric

Summary of key findings

Return to: CS1, CS2, CS3, CS4, CS5

- Build-ups exist for walls, roofs and floors utilising a range of insulants for masonry, timber construction, SIPs, ICF etc.
- Wall thickness ranges from 350mm (typical Part L 2021) to 505mm.
- CS 3, 4 & 5 require higher airtightness (≤3m^3/h.m^2) meaning a significant change in techniques and site practice. The training associated would need to be reflected in the transitional arrangements to avoid significant cost, quality and delivery risks. A robust and detailed implementation plan would need to be developed and implemented.
- Many mainstream housebuilders are concerned at delivering air permeability of 3m^3/h.m^2 and do not believe it is possible to deliver 1–0.5 m^3/h.m^2.
- Those housebuilders familiar with the necessary airtightness techniques advise these can be learnt within the timescale of a project and are not problematic provided detailed attention is paid.
- For CS3 to CS5 airtightness, 3,000 to 6,000 additional trades needed for installation and supervision.
- Part L 2021 already effectively requires all significant thermal bridges to be calculated and constructed correctly on site.
- Thermal bridge calculations are valid for a small range of U-values and would need to be updated for the lower U-values associated with CS4 and CS5.
- The wider cavities in masonry walls require different wall tie materials and can be built to current regulations provided the cavity is below 300mm.
- Windows and doors may need to be repositioned within the wall build-up to be within the insulation layer.
- Should a contender specification require triple glazing, this will require a sufficient lead in time, advised as one year, for suppliers to ramp up manufacturing capacity.
- ***If*** the level of FHS ambition effectively requires a reduction in air permeability to 3m^3/m^2pa, or less, then an Implementation Group should be established to develop and oversee an implementation plan.



Analysis of standards required by fabric element

Floors

Several options are available for floors and all five CSs could be achieved using suspended slab and insulated beam and block. Uninsulated beam and block could only be used to meet the U-values required for CS1 and CS2.

Higher performing insulants are used in some build ups to reduce the overall thickness. Deeper ground floors may result in walls effectively over 2.7M high, which would fall outside AD-A and required specific calculations.

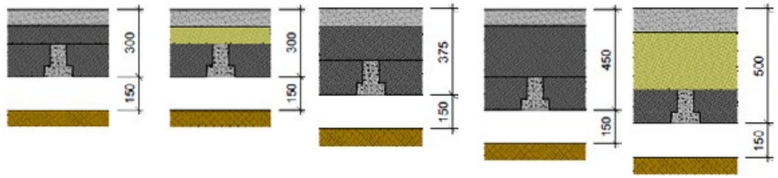
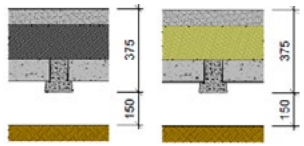
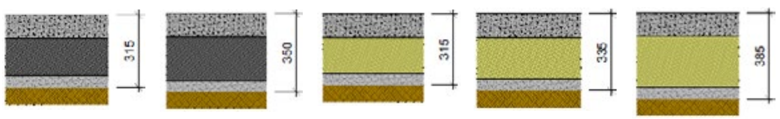
Contender Specification	CS1 & CS2	CS2 Bungalow	CS3	CS4	CS5
U-value	0.15	0.13	0.11	0.10	0.08
Insulated beam and block					
Uninsulated beam and block					
Suspended slab					

Fig 78: Example build-up options for ground floors (EPS – Grey, PIR – yellow)

Roofs

See Fig 79.

The required U-values for cold and warm roof construction are similar to those of Part L 2021, with the exception of CS5, where U=0.1, a considerably thicker build up is required to deliver the warm roof U-value = 0.10.

CS3 – CS5 includes a VCL and service void to meet the enhanced airtightness requirements.

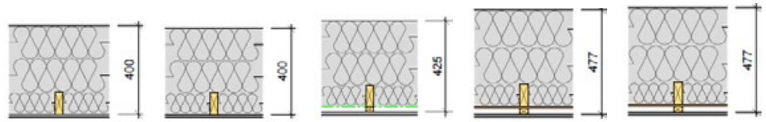
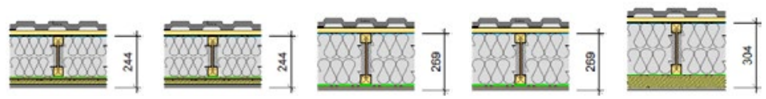
Contender Specification	CS1	CS2	CS3	CS4	CS5
Air permeability	5.0	4.0 – 5.0	3.0	1.0	0.5
Cold roof					
Insulation depth	400mm	400mm	400mm	450mm	450mm
U-value	0.11	0.11	0.11	0.10	0.10
Warm roof					
U-value	0.16	0.16	0.15	0.15	0.10

Fig 79: Example build-up options for cold and warm roofs

Walls

Masonry

All U-values are achievable with full fill and partial fill insulation using a standard brick and light weight block with plasterboard on dabs. Internal laminated insulated plasterboards were not considered to maximise the potential for the thermal mass effect of the masonry in increasing comfort.

The examples given here are just two wall constructions out of many. A thinner overall solution can be achieved with better performing insulation materials, albeit at a potential higher cost. There are also better performing block types that will reduce the thickness of the insulation although these are not permitted in all exposure zones. Newer forms of insulation include those that are effectively full fill with a 5 to 10mm airgap between the insulation and the outer skin. Whilst brick outer skins are shown, these can be replaced by rendered blockwork, for example, which in some cases may reduce the thickness of insulation required.

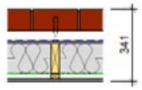
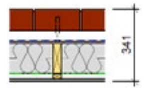
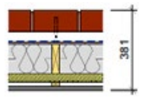
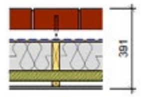
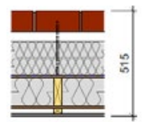
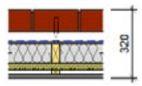
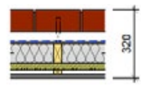
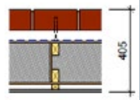
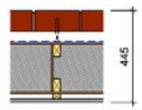
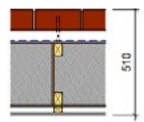
Contender Specification	CS1		CS2		CS3		CS4 & CS5*		CS5 *	
Air permeability	5.0		4.0 – 5.0		3.0		1.0		0.5	
U-value	0.19		0.19		0.15		0.13		0.10	
Full fill (mm) (mineral wool, λ)	150 (0.034)		150 (0.034)		200 (0.034)		230 (0.034)		285 (0.032)	
Part fill (mm) (PIR, λ)		85 (0.022)		85 (0.022)		115 (0.022)		135 (0.022)		185 (0.022)
Cavity width (mm)	150	135	150	135	200	165	230	185	285	235
Wall zone (full fill, mm)	 380		 380		 430		 460		 515	

* CS5: detached houses, U-value=0.10; attached houses, U-value=0.13
Note: Calculations based on brick outer leaf, lightweight aggregate block inner leaf (λ=0.6) except CS1 & CS2 (λ=0.15). Cavities up to 150mm can use wire ties; cavities from 151-225 require steel ties, cavities over 225mm require basalt fibre ties.

Fig 80: Example build-up options for masonry walls

Timber Frame

All U-values can be achieved with timber-frame solutions with similar widths to masonry walls. All build-ups utilise a service void to improve the U-value performance as well as simplify the air-tightness detailing. Below are a few examples of wall makeups and there are many other systems with different attributes and benefits.

Contender Specification	CS1	CS2	CS3	CS4 & CS5*	CS5*
Air permeability	5.0	4.0 – 5.0	3.0	1.0	0.5
U-value	0.19	0.19	0.15	0.13	0.10
Option 1 (wall zone, mm)	 341	 341			
Option 2 (wall zone, mm)	 320	 320			

* CS5: detached houses, U-value=0.10; attached houses, U-value=0.13

Fig 81: Example build-up options for timber frame walls

Thermal bridging

Part L 2021 effectively requires all significant thermal bridges to be calculated. As thermal performance increases, the relative proportion of heat loss through bridges increases. Manufacturers and industry have published values up to 150mm cavities. Thermal bridges will require recalculating for wider masonry cavities (CS4 &CS5). Shelf angles, required on taller buildings will increase thermal bridging requiring consideration in the design. For masonry walls with wider cavities, some junctions worsen due to geometry of the junction.

Thermal bridging values for timber frame walls are available from manufacturers for all CSs.

Windows and doors may need repositioning to be within the insulation layer, noting the additional support required if triple glazed windows are installed.

Thermal bypass

Where there is potential discontinuity of insulation, such as gaps in insulation, or where insulation is not in intimate contact with the vapour control layer, thermal bypass can occur. In low energy buildings, the proportion of losses associated with thermal bypass are potentially significant but these are currently poorly tackled in Part L and this needs addressing and accounted for in the thermal models.

Airtightness

Air permeability of between 4 and 5 $m^3/h/m^2$ (required for CS1 &CS2) is general practice. A move to an air permeability of less than 3 $m^3/h/m^2$ is significant and requires different techniques, designed joints and close attention to detail on site.

Techniques and materials used to achieve an air permeability of 3 $m^3/h/m^2$ or less are broadly the same but with ever increasing attention to detail the lower you go.

Delivering air permeability of less than 3

Designing-in airtightness at the beginning of the process and careful detailing on site improves both energy efficiency and quality. The purpose is to reduce as much as possible the unintended air leakage around gaps, cracks, holes, splits and tears. Simple form works better for airtight homes (good form factor) as this reduces the number of complex junctions to think about and seal. The air tightness level targeted by the design is zero, with degradation from this a result of detailing on site and the quality of materials chosen.

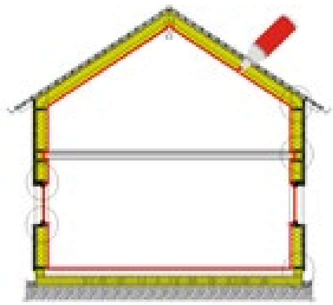


Fig 82: Ensuring continuity of airtightness layer (credit: Passipedia)

Step 1 Design stage

Airtightness is a critical concept at the design stage with architects trained to incorporate airtightness in their design and not at later stages.

Airtightness designers should be trained via accredited certified airtightness training programmes (to be developed).

Step 2 Construction stage

Airtight materials are used to create the airtight layer and connect with appropriate tapes/ materials.

Masonry construction might be:

- Concrete floor
- Parge plaster or liquid membrane to blockwork taped to:
- taped certified airtight board or membrane to ceiling
- Window and doors taped to parge plaster or liquid membrane
- All service penetrations sealed

Timber frame construction might be:

- Concrete floor taped to:
- taped certified airtight board or membrane to walls taped to:
- taped certified airtight board or membrane to ceiling
- Window and doors taped to the wall certified airtight board
- All service penetrations sealed

Fig 83: Taped junctions (credit: Ecological Building Systems)

Fig 84: Liquid VCL being sprayed (credit: Intelligent Membranes)

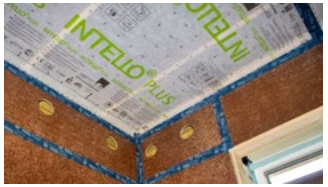


Fig 85: Taped airtight board (credit: Ecological Building Systems)

To assure performance, every site would benefit from a trained airtightness coordinator to instruct and oversee the works. The **airtightness coordinator** could be trained and certified via accredited certified airtightness training programmes (to be developed).

They would provide training to all construction teams (toolbox talks) prior to commencing the works, as the sequence of works is very important. This approach allows the scale up of airtightness awareness on each site.

The airtightness works can be delegated to different construction teams/ subcontractors accordingly and be part of their work (e.g., window fitters can do window taping, brick layers/joiners can seal wall to floor, wall to ceiling junctions etc.), or one single team can be appointed to do the whole work as a separate package.

Step 3 Testing

In the early stages of delivering airtight homes, they may need more than one air test and typically this can be two or three, when targeting the highest levels of airtightness. The first test is critical and should be taken when the shell is airtight and the airtight layer exposed; this allows identification and sealing of any leaks. Later tests will ensure the airtight layer has not been compromised.

Masonry: The walls should be plastered or sealed with a sprayed liquid applied membrane, overlapping the tapes at the junctions prior to the first test. The second test can be carried out after the final fixings.

"The airtight ones achieved 2.4. We used: a polymer spray (Blowerproof Liquid), airtight board at ceiling level, joists on hangers etc. We missed a few tricks that could have got us closer to the 1.5 such as: the seals to the windows and doors, and the proper detailing of penetrations and services (i.e. airtight gromets for service penetrations, airtight housing for electrical back boxes etc.)." Project 80 Team

Timber frame: Provided the service battens have been installed prior to the first test and any decoration/final board etc. is fixed on to the service battens without affecting the membrane, the second test could be the final test.

Ensuring longevity

Whilst there is evidence of the longevity of airtightness, it is recognized by the industry that the air tightness product quality is key. A robust certification scheme would be required to ensure that air tightness products are fit for use and match the 'building lifetime'.

Scale-up

CS1 and CS2

CS1 and CS2 are based on Part L 2021 fabric and air permeability so no materials or skills scale up is required.

CS3, CS4 & CS5 - Fabric

CS3, CS4 & CS5 have enhanced U-values, although use readily available buildups and techniques.

CS3, CS4 & CS5 - Airtightness

The increased airtightness of CS3, CS4 & CS5 would require the adoption of new techniques, additional site airtightness trades and airtightness champions (estimated: CS3=2,100 + 800, CS4= 3,100 + 1,600, CS5 4,200 + 2,600) with associated training.

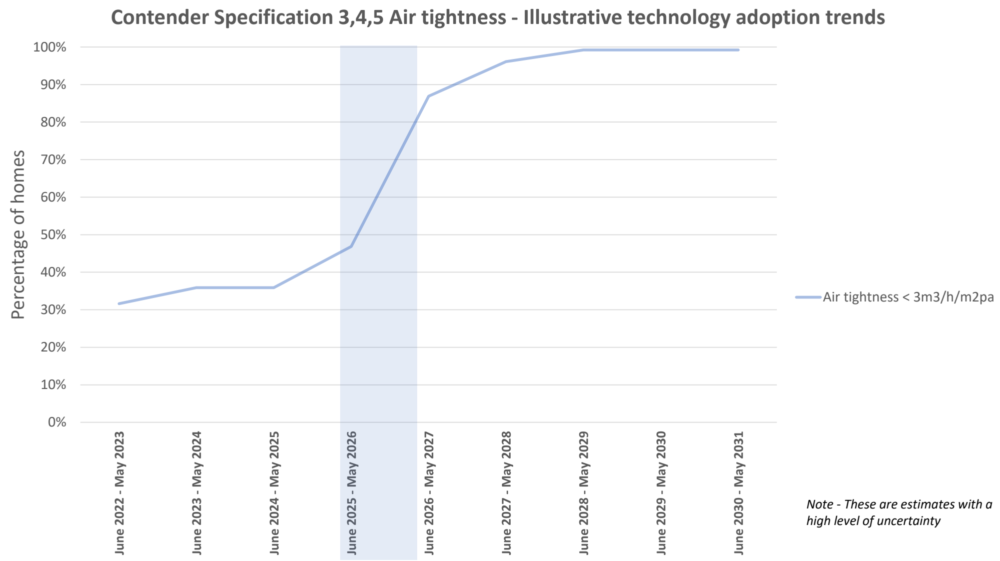


Fig 86: Illustrative CS3, CS4 & CS5 airtightness adoption trends if there were a 12-month transitional period

CS3 relies on the adoption of new processes and systems to deliver levels of air tightness of less than 3 $m^3/h/m^2$. Whilst those that build to very low levels of airtightness (<1$m^3/m^2/hr$) advise the required level of 3$m^3/m^2/hr$ is relatively easy to achieve provided appropriate techniques and approaches are used, it is not simply a case of housebuilders doing what they do today, but better.

Mainstream housebuilders have expressed significant concern as they currently build less than 2% of homes at air permeabilities of less 3$m^3/m^2/hr$, with 10% below 3.5$m^3/m^2/hr$, although most agree the sector should further consider the feasibility of pushing airtightness using new techniques and skills.

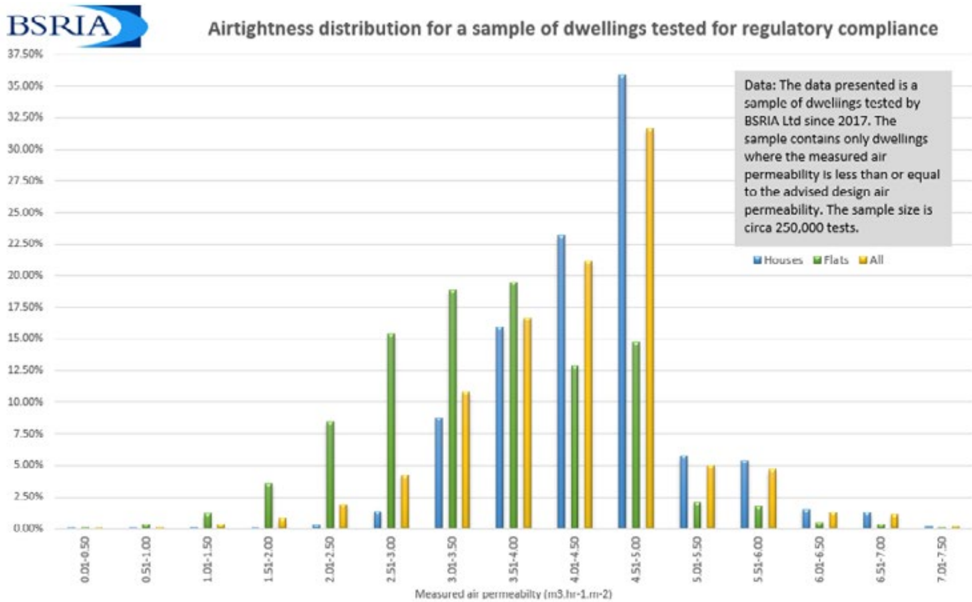


Fig 87: Airtightness distribution for a sample of dwellings tested for regulatory compliance (credit: BSIRA)

With transitional arrangements similar to those adopted for Part L 2021, a significant proportion of this upskilling would need to occur over a 12 month period. This would be extremely challenging and represent a significant risk of underperformance, particularly for CS4 & CS5.

The main scale up challenge is achieving the very low airtightness. However, the principles/testing is the same once below $3m^3/hr.m^2$. Feedback from passivhaus experience is the learning curve is quick because site testing allows rapid feedback to site operatives.

Part of the approach might, therefore, be to stage the level of ambition of the regulations coming into force to, for example, allow industry to introduce fabric, MVHR and a more relaxed air permeability of $3m^3/hr.m^2$ first, with the introduction of the strict air tightness requirement coming into force a couple of years later.

Achieving an airtightness of $3m^3/h/m^2$ (CS3), using techniques and controls designed to deliver 0.5 $m^3/h/m^2$, has a sufficient margin to not represent a delivery risk but still requires scale-up time to allow the industry to obtain the necessary skills.

To avoid the same lessons being learnt simultaneously across multiple sites, the second part of the approach might be to allow builders to progressively transition and meet increasing percentages of production to the new standards across multiple years (see Transitional arrangements chapter 26). Critical would be to create a steady build up, flattening the adoption curve, and not simply delay the start but maintain the same steep rate of adoption.

This way designers and housebuilders would have predictability and the supply chain would have the confidence to invest.

CS3, CS4 & CS5 - Glazing

Production capacity is currently focused on double glazing so a wholesale shift to triple glazing would require re-tooling for most manufacturers of windows. From the point the manufacturers have confidence in the future demand, the minimum lead time to increased capacity is circa 12 months from tooling design to product launch.

Particularly with the increased value of triple glazing, careful consideration is needed for the protection of the glass.

Return to: CS Chapter, CS1, CS2, CS3, CS4, CS5

Further considerations

Site health and safety implications

The increased weight of triple glazed windows over double glazed was raised as an additional health and safety concern. Appropriate safe systems of work would need to be introduced but this was felt to be manageable.

Skills & training

Little additional fabric skills and training are required beyond that required for Part L 2021, except for airtightness.

Airtightness training for a designer is typically via an online two-day course. Airtightness coordinator training can be carried out partially online, partially live with appropriate kits for demo and practice (one day each, two in total). Trades airtightness training is typically via onsite toolbox talks given by the airtightness coordinator.

Meeting air tightness targets – Training

Training timings	Certified training	Delivered
Airtightness designer	2 days	Online
Airtightness Co-ordinator on site	2 days	1 day online 1 day on site
Airtightness team on site	Toolbox talks	On site

Fig 88: Training timings (provided by the specialist developers)

Construction / installation and supervision

Resources required to successfully deliver Part L 2021 on site plus the following for airtightness:

Airtightness Co-ordinators		CS4	CS5	CS5
Airtightness Co-ordinator on site	Hours per home	6hrs	12hrs	20hrs
	Number required[1,2]	800	1,600	2,600
Airtightness team on site	Hours per home	16hrs	24hrs	32hrs
	Number required[2]	2,100	3,100	4,100

[1] Reduced number required as airtightness becomes normal practice

[2] 200,000 homes per year, 40 hr week, 70% of time 'on the job'

Fig 89: Airtightness resourcing needs (provided by the specialist developers)

Moisture implications & mitigations

No issues with regards to moisture ingress. AD C provides guidance for wider cavities. The usual details for window head, wider cavity trays/DPCs are required. Deeper ground floor build-ups will need to be considered to ensure detailing at external walls is robust and takes account of moisture below ground level.

Structural implications & mitigations

Cavities up to 300mm are covered by AD A, BS5628-1 and BS8103-2 and Eurocode 6 does not have a limit. The cavity wall ties are upgraded as the cavity width increases.

Insulated lintels, increasingly required for Part L 2021, are likely to be required.

Fire compliance

For timber, SIPS, LGSF etc wall and roof systems solutions, fire testing of new makes will be needed to endorse compliance.

Track record of technologies / evidence base

CS1 & CS2 construction is the same, or very similar, to the Part L2021 requirements.

Project 80 (Midland Heart HA in Birmingham) is an example of how to achieve the broadly CS3 U-values and thermal performance with masonry - using 150mm cavities and U-values around 0.15 to 0.13.

Whilst many housebuilders expressed concern about building cavity walls that are greater than 150mm, and it is not general practice, a number of housebuilders reported they built to this width without issues and it is more common in London.

Passive houses have been built in masonry construction with cavities, typically, between 150 and 300mm, as well as using timber frame and other systems. In the UK, circa 1,950 homes have been built to a certified Passivhaus standard, approximately 200 per year, and an estimated 10x more that were not certified.

Unintended consequences

Without mitigations, increased wall thickness of CS3, CS4, & CS5 can have implications on the number of plots achievable on some sites where there is a predominance of detached homes. Detached homes may need a slight adjustment to their proportions to ensure the same number on a site or the proportion of semi-detached or terraced dwellings increased. See the Design chapter.

Ventilation

Summary

- Adequate ventilation solutions are a critical element of a 'net zero' ready home to ensure good indoor air quality as well as enable energy efficiency.
- Circa 62% of new homes are naturally ventilated, 22% MEV and 16% MVHR. The assumption is most MVHR is in apartments.
- All ventilation systems need to be correctly designed, installed, and commissioned with internal door undercuts not closed off by floor coverings.
- Home layouts should be planned considering MVHR /cMEV to minimise space taken, costs and give best performance.
- All ventilation strategies need some form of maintenance but there is increased maintenance requirements for Mechanical Ventilation with Heat Recovery (MVHR).
- Natural ventilation (with intermittent extract fans) relies on trickle vents being open and extract fans operating.
- Mechanical extract ventilation (cMEV and dMEV) rely on trickle vents being open and fans kept switched on. MVHR must be kept switched on.
- Studies have shown problems with all ventilation strategies in delivering adequate indoor air quality for householders primarily linked to poor design/installation/commissioning or householder switching parts of the system off.
- Ongoing evidence gathering from all ventilation approaches is needed to ensure system performance is improved and lessons fed back and actioned.
- A robust Competent Persons scheme is needed with installation and commissioning responsibilities separated and the designer taking responsibility for performance.
- Skills training is critical for design, installation, commissioning, and verification of all systems.
- For CS3 to CS5 an additional 900 ventilation engineers are required for installation and commissioning.
- Homebuyers need to be familiar how the homes ventilation system works, why it is important and how to ensure best performance.
- Whilst some studies suggest that MVHR provides the highest indoor air quality and highest dwelling energy performance, it is considerably more expensive to install and has higher maintenance costs.
- Irrespective of which ventilation system the FHS ultimately requires, improvements in ventilation general practice are necessary.

Return to: CS Chapter, CS1, CS2, CS3, CS4, CS5

Ventilation systems

Adequate ventilation solutions are fundamental to delivering net zero ready homes. With higher levels of insulation and airtightness levels, the importance of the ventilation solution increases and should not be underestimated.

There are broadly four ventilation strategies:

Natural ventilation with intermittent extract fans

Intermittent fans in wet rooms, trickle vents in habitable rooms and wet rooms, internal doors undercut. Suitable in properties with an air permeability: design > $5m^3/(h{\cdot}m^2)$, as built > $3m^3/(h{\cdot}m^2)$.

Decentralised Mechanical Extract Ventilation (dMEV)

Continuous running fans in wet rooms, trickle vents in habitable rooms, internal doors undercut.

Suitable for properties with any air permeability (higher than $3m^3/(h{\cdot}m^2)$ in Scotland).

Centralised Mechanical Extract Ventilation (cMEV)

Centralised unit with continuous extraction from wet rooms, trickle vents in habitable rooms, internal doors undercut.

Suitable for properties with any air permeability (higher than $3m^3/(h{\cdot}m^2)$ in Scotland).

Mechanical Ventilation with Heat Recovery (MVHR)

Centralised unit with balanced supply and extract air with heat recovery, internal doors undercut.

Suitable for properties with any air permeability but most energy efficient with low permeabilities.

Fig 90: Ventilation strategies

Natural ventilation with intermittent extract fans

This has been the predominant form of ventilation for dwellings in the UK where the air permeability is higher than 5m³/m²/hr. However, as fabric performance standards improve, ventilation heat losses increase as a proportion and are now dominant, hence the need to review.

Whilst it might be argued that with natural ventilation there is little, to no, occupier interaction, in reality, this may not be the case. Trickle vents tend to be quite large and can create unwelcome draughts which can prompt occupants to close them. Noise intrusion from local fans can result in fans being switched off, altering the ventilation strategy and impacting indoor air quality.

A BSRIA study[17] found only 40% of trickle vents were open and the same study found 67% of fans were switched off.

Householders living in naturally ventilated homes are often unaware that these systems need maintenance (e.g. cleaning of trickle vents and extract fans), that these vents should be left open and that internal doors should have a 10mm gap above floor finishes.

Natural ventilation in Part F 2021 has been updated to nearly double the size of the trickle vents in response to indoor air quality studies. It is too soon to have feedback on the impact of this change.

This said, housebuilders do not typically have customers expressing concerns about natural ventilation or indoor air quality in new homes. However, humans tend not to be very good at assessing air quality unless it is particularly poor.

Mechanical Extract Ventilation (MEV)

As air permeability reduces, controlled ventilation becomes more necessary. The 2021 update to Building Regulations (especially Parts L&F) seems to have intentionally, or otherwise, precipitated a move away from natural ventilation. Many housebuilders (especially the larger ones) are moving to installing decentralised MEV (dMEV) and taking benefits within SAP, avoiding larger trickle vents in windows and some taking the advantage of a designed air permeability of slightly less than 5m³/m²/hr.

Like natural ventilation, the argument could be made that with dMEV householder interaction is limited, however, the same concerns of local fan noise and draughts may exist.

cMEV, with the centralised fan, typically has lower fan noise but still creates unwelcome draughts from trickle vents. Various studies have identified problems with ductwork installations: inadequate flow rates due to poor commissioning, increased fan noise due to various factors.

Homes should be designed with cMEV in mind to ease installation, minimise costs and optimise performance.

For cMEV, a professional service is typically recommended approximately every 5 years but there are no filters to change.

Mechnical Ventilation with Heat Recovery (MVHR)

MVHR is often specified in apartments and dwellings which aim for very high levels of energy efficiency such as those built to Passivhaus standards. When designed, installed and commissioned correctly, the system should provide good indoor air quality (filtering the external air) and increased occupant comfort as there are no cold drafts from window trickle vents.

As with cMEV, home layouts should be planned considering MVHR. The size and location of the MVHR needs to be carefully designed, located in the warm envelope and sized in order to minimise costs and optimise performance. Duct runs to outside must be kept short which requires the fan box to be on, or close to, an external wall. These ducts must be insulated. Adequate space must be provided around a fan box for maintenance i.e. filter replacement.

The problem most frequently identified with MVHR systems is poor commissioning resulting in poor performance. Poor installation of flexible ductwork, poor design/sizing, and lack of maintenance are also cited. A fundamental starting point is to design the house with MVHR in mind.

The filters need cleaning/replacing, typically every 6 months, although can be as long as 2 years. A professional service is recommended approximately every 5 years.

[17] *BSRIA*

Performance

Studies have shown problems with all ventilation strategies in delivering adequate indoor air quality for householders, particularly linked to poor design/installation/commissioning or householder switching parts of the system off[18].

The Building for 2050 report[19] showed cases where MVHR and cMEV provided good air quality despite, in some cases, being poorly design and installed. Some of the homes were over-ventilated.

The meta study on MVHR performance, characteristics and performance of MVHR systems[20] concluded, 'the study indicates that the rationale behind the use of MVHR systems is borne out – the rates of ventilation as evidenced very generally by CO_2 levels are better, and the energy use overall is lower.'

With MEV, the need to rely on trickle vents, and thus ventilation rates in individual rooms being subject to natural driving forces, is exacerbated as airtightness increases.

Concern was raised about what happens to air quality, particularly in very airtight homes, if the MVHR is switched off. Relatively little research was identified but Sassi (2013)[21] presents some evidence that homes which switch off the MVHR do not necessarily have poor air quality if windows can be opened.

Enforcement of ventilation as a controlled service

Poor ventilation outcomes can occur through lack of design, poor installation, poor commissioning or by unwise user actions.

The work group agreed that there was a need for better training for ***all*** ventilation systems: natural, MEV and MVHR, and not only for installers, but designers and commissioners alike. It was observed that too often, systems are installed with insufficient design input or, the designers did not possess sufficient knowledge or, designs are not followed or, design changes made on site which are not referred to back the original designer for approval.

The existing Competent Persons Scheme training can be completed in only 2 days, however, there is minimal hands-on installation training, and generally without commissioning fault finding / diagnosis assessment as part of the training. There are no ongoing checks of competency after training. It is recommended that the approach to ventilation as a service must be overhauled.

Given that an installer is trained to install, commission and sign-off their own works, responsibility for performance is removed from the system designer. The work group proposed that the installing and commissioning processes are separated, with the designer taking responsibility for installed performance.

Scale-up

Natural ventilation, with intermittent extract fans, has been the predominant ventilation system in houses, with cMEV and MVHR relatively rare in houses but common in apartments.

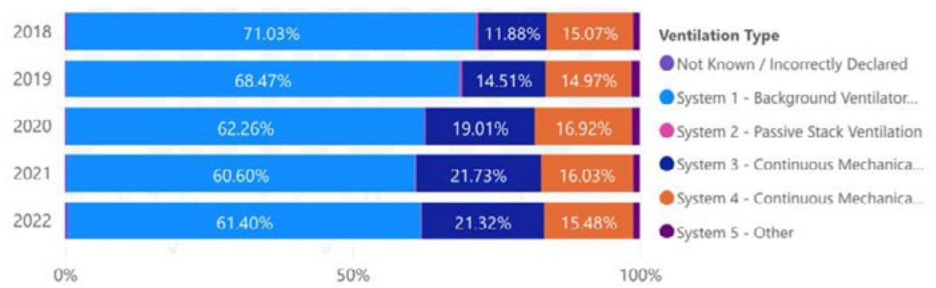


Fig 91: ATTMA tests on homes by system (System 3 is assumed to be cMEV)

[18] DULHC Ventilation and Indoor Air Quality in New Homes https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/835208/Research_-_ventilation_and_indoor_air_quality.pdf

[19] BEIS https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/1121448/Building_for_2050_Low_cost_low_carbon_homes.pdf

[20] By Sharpe, T., Mawditt, I., Gupta, R., McGill, G., & Gregg, M. (2016). http://radar.gsa.ac.uk/4073/1/MVHR%20Meta%20Study%20Report%20March%202016%20FINAL%20PUBLISHED.pdf

[21] A Natural Ventilation Alternative to the Passivhaus Standard for a Mild Maritime Climate https://www.mdpi.com/2075-5309/3/1/61

With the introduction of Part L & F 2021, the direction of travel as indicated by housebuilders is a move away from natural ventilation towards decentralised MEV, and for certain building types moving towards centralised MEV and MVHR.

CS 1 & 2 would be expected to continue the trend.

CS 3, 4 & 5 use MVHR and if similar transition arrangements were to be introduced for FHS, then the adoption rate to meet housebuilding delivery might be illustrated below.

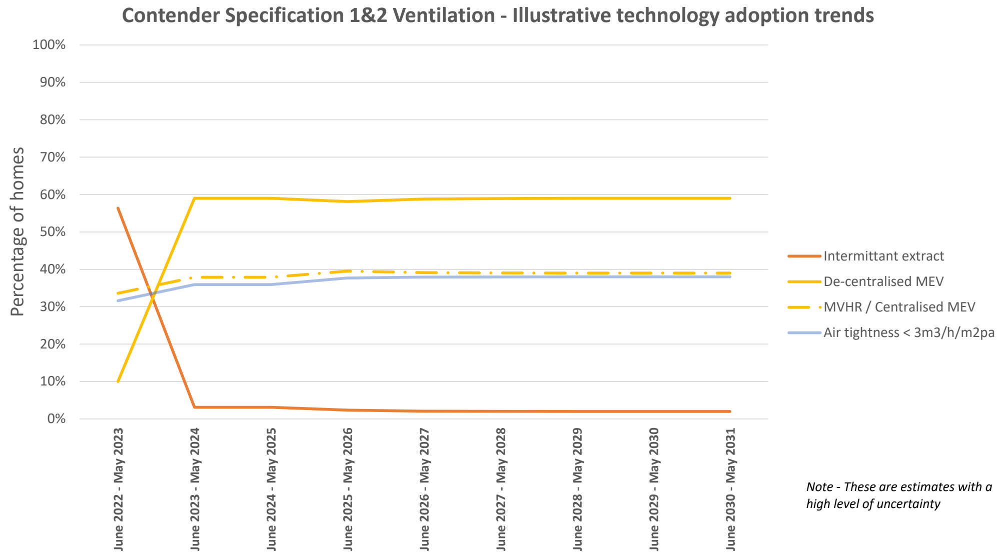


Fig 92: CS1 & CS2 Illustrative ventilation system adoption trends if there were a 12-month transitional period

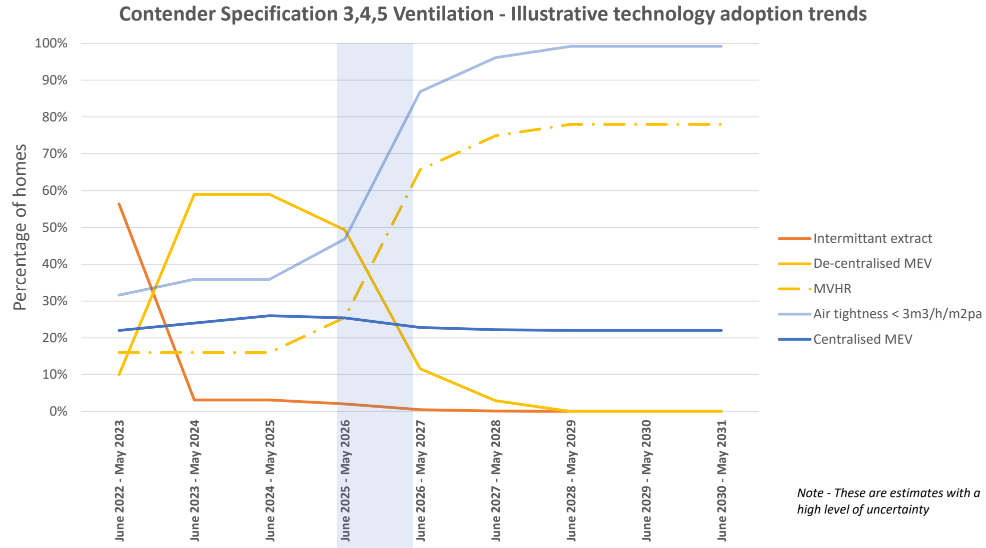


Fig 93: CS3, CS4 & CS5 Illustrative ventilation system adoption trends if there were a 12-month transitional period

The dMEV would peak and then fall away, replaced by a steep rise in MVHR. Whilst product availability should not be an issue for any ventilation system, as the UK and European market is vertically integrated very well, different technologies will have different scaling up timeframes due to differing upskilling requirements.

The illustrative curves below suggest how each technology might be scaled in terms of the product (kit) and the skills & training.

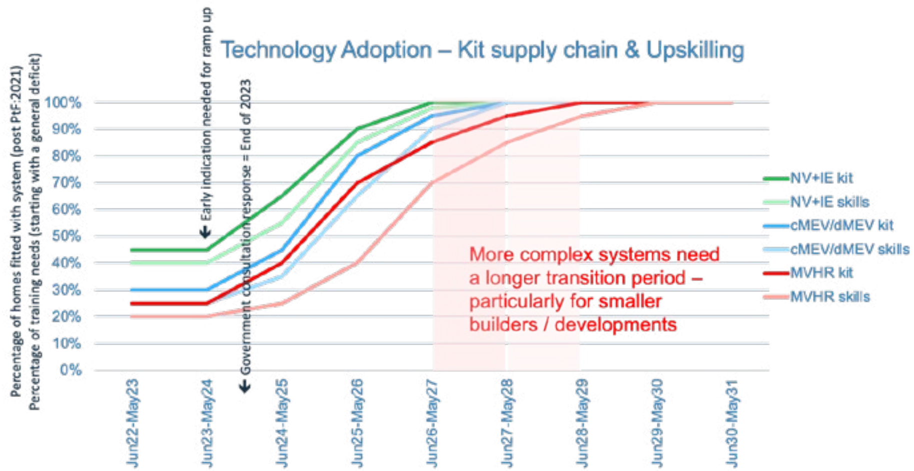


Fig 94: Illustrative adoption trends for ventilation technologies and skills Credit: WG6

It is expected that Part L 2021 will drive the adoption of dMEV over the next few years in any event.

An industry wide move to cMEV or MVHR, at scale, would be a very considerable shift is expected that Part L 2021 will drive the adoption of dMEV over the next few years in any event, requiring careful planning and significant upskilling across design, installation and commissioning. It would require the introduction of a robust Competent Person Scheme (as discussed above) and many house types would need a level of redesign to accommodate the components.

MVHR Additional ventilation installation & commissioning labour requirement			
House type	No. of plots	extra over time (hrs/dwelling)*	total extra over time (hrs)*
Mid terrace house	27,000	4.86	131,220
End terrace house	49,950	4.86	242,757
Semi-detached 2.5 storeys	5,550	12.18	67,599
Small detached house	49,400	10.18	502,892
Large detached house	2,600	22.75	59,150
Detached bungalow	2,500	7.78	19,450
Low rise apartment	17,000	5.75	97,750
High rise apartment	26,000	5.05	131,300
Total homes built during year	180,000		1,252,118
Additional engineers needed (40 hr week, 70% of time 'on the job')			860
** between natural ventilation / dMEV and MVHR*			

Fig 95: Additional installation and commissioning labour time for MVHR (Supplied by a ventilation contractor)

The Work group advise that scaling for cMEV or MVHR would need to be spread over a significantly greater time period than the Part L 2021 transitional arrangement would allow and requires a progressive scaling of demand. This would require careful design of the transitional arrangements.

The risk of poorly managing any transition are well documented on NHBC Foundations / ZCHub report: Mechanical Ventilation With Heat Recovery In New Homes22 together with additional recommendations which still apply.

Return to: CS Chapter, CS1, CS2, CS3, CS4, CS5

[22] https://www.nhbcfoundation.org/wp-content/uploads/2016/05/RR8-Mechanical-ventilation-with-heat-recovery-in-new-homes.pdf

cMEV & MVHR design and delivery

For good outcomes, experience has shown:

1. Keep the duct **air speed** as low as possible (noise) and for more air to large spaces, double up ducts rather than increase speed.
2. Keep the distance from the **main uni**t to the **outside air** short. Ideally, the main duct(s) (for MVHR – from and to outside) 1-2m each (and must be insulated).
3. Ensure there is a **good commissioning** process with the system balanced (supply to extract sides of MVHR) to reduce noise and energy use.
4. Allow enough room maintenance / replacement of the MEV / MVHR fan box – whilst being somewhat counter cultural, good accommodation of services is a key part of ensuring an energy efficient house performance.

The cMEV and MVHR systems must be fully designed by a competent and knowledgeable person and followed on site and without site modifications being made without reference to the designer. Many designs are undertaken by the manufacturers. Approved for Construction design drawings must be provided to the installers, with as-built drawings produced on completion. (See fig 96).

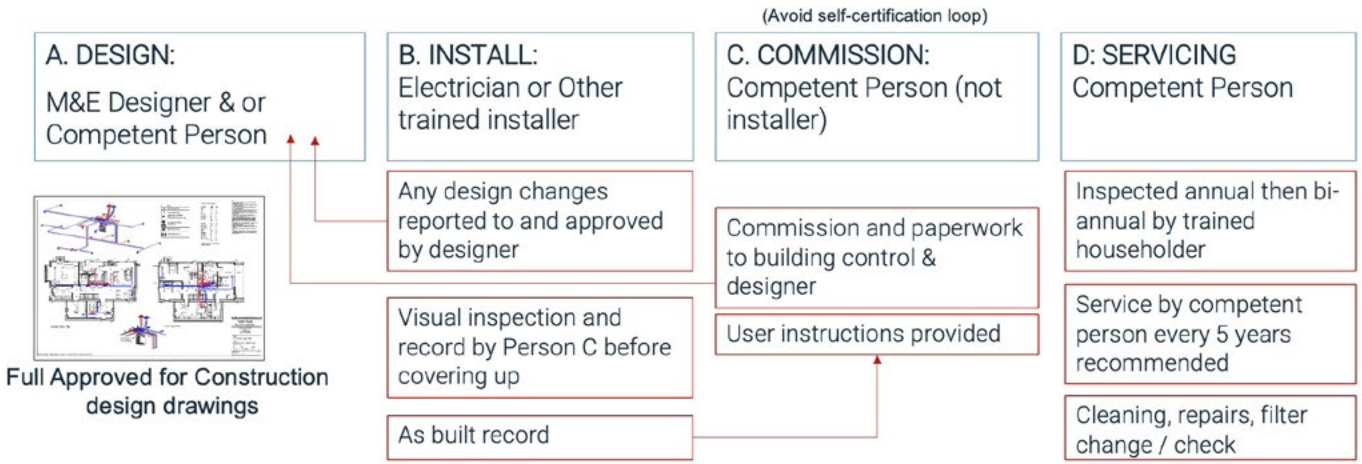


Fig 96: Proposed ventilation design, installation, commissioning, and maintenance process credit: WG6

Buildability

dMEV is little different to natural ventilation extract fan installation and, in any event, is being installed in increasing numbers due to Part L 2021 and Part F 2021.

Where the FHS solutions use cMEV or MVHR, then the home layouts should be planned considering these systems. Installation can be greatly simplified if the early dwelling design incorporates appropriate service riser and duct routes. Particular care is required with 2.5 / 3 storey dwellings to ensure the fire requirements are fully considered at the design stage to avoid buildability difficulties.

On site deviations from design need approval from the designer, whilst current installation checklists capture this, it is rarely reported.

Householder perspectives

See also ventilation section in the Consumer chapter

CS1,2 & 2a

The homes benefits from:

- Adopting the same ventilation approach as Part L 2021 (and the same as the 2025 Reference) so familiar with trades and householders.

Like all mechanical ventilation systems, they should not be turned off and trickle vents should be left open, otherwise indoor air quality would be impacted. Trickle vents tend to be quite large, in particular natural ventilation, and may create unwelcome draughts. There can be noise intrusion from local fans.

The air quality is no better than the external air.

Householders need to periodically clean trickle vents / extract fan ducts and ensure internal doors maintain a 10mm gap above floor finishes.

CS3,4&5

An airtight home with MVHR benefits from

- Reduced energy costs
- Increased thermal comfort through the elimination of cold drafts from the top of windows
- Improvement of indoor air quality via filtered air and fresh supply independent of external conditions

Householders would have a most stable indoor temperature which is slightly dryer than a home with MEV and something the householder may notice. In combination with a highly energy efficient fabric, the winter indoor temperatures would be more stable.

The lower air permeability would not be noticeable to a householder, with the ventilation system providing the fresh air required.

Common with all the mechanical extract ventilation systems, MVHR needs to be kept running. In practice, any mechanical ventilation (MEV or MVHR) should be a 'fit and forget' solution for households, with the exception of routine maintenance.

The householder would need to clean / replace the filters, typically every 6 months, although can be up to 2 years. Whilst this is an additional maintenance task for the householder, these filters are collecting the airborne dirt from the outside air that is otherwise breathed in. Similar to all the CSs ventilation systems, the undercuts of internal doors are important and householders will need to be aware to ensure these are maintained when new carpets etc are installed/replaced.

Air quality is better than the external air. Should the householder have particular allergies then specialist filers can be installed, such as for pollen.

The householder would need to arrange for a professional service which is recommended approximately every 5 years.

It was reported that some social housing providers specify that MEV and MVHR should not be installed due to the risks of tenants turning units off and the maintenance costs. However, others, such as Exeter City Council specify MVHR in their homes. Householder education is key to avoiding problems occurring.

Indoor air quality (IAQ)

Adequate IAQ is critical to the health of occupants. Continuously running mechanical systems where designed, installed, commissioned and maintained correctly give a better chance of good outcomes, especially in homes with an airtightness level below 5.

Noise

Noise is often cited as a reason intermittent extract, dMEV, cMEV and MVHR units are turned off. Mechanical ventilation correctly designed, installed and maintained should not result in a noise nuisance.

Running costs

All of the CS ventilation systems rely on continuously running fans which, although low power, use electricity so have a cost to run.

MVHR typically costs more to run than cMEV and dMEV / IE, but if designed and installed correctly, significantly more energy is recovered than used to power the fans.

For all CSs, except CS1 when PV is not installed, circa 1/3 of the energy used by the fans, irrespective of the system, will be supplied from the PV (currently not reflected in SAP10.2).

The additional running cost of the MVHR system is reflected in the energy cost modelling and is offset against the savings associated with the reduced heating demand achieved through the system's heat recovery.

Maintenance

Accountability for maintenance in communal systems and in rented properties must be established.

The table below illustrates the relative maintenance requirements of the various ventilation options.

Maintenance requirements	Natural ventilation	dMEV	cMEV	MVHR
Duct cleaning	✓	✓	✓✓	✓✓✓
Fan/ valve cleaning	✓	✓	✓	✓✓
Filter replacement	x	x	x	✓
Heat recovery cell cleaning	x	x	x	✓

Fig 97: Maintenance requirements of different ventilation systems

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Heat pumps

Summary

- Government have an objective of 600,000 annual heat pump installations from 2028 (existing and new build homes).
- MCS / NESTA estimate an additional 4k – 6k trained heat pump engineers are required each year for 6 years to 2028 (new & existing home installations).
- Similar transitional arrangements to Part L 2021 would likely result in a rapid significant increase in adoption of heat pumps over a short period risking: supply chain shortages, increased costs and potentially leading to lower quality installations.
- Transitional arrangements that provided a progressive scale up of demand would de-risk the expansion of skills, training, supply chains providing better outcomes.
- Clear and timely decisions by Government are needed to provide the confidence the heat pump industry needs to invest in capacity and provision of training to the level required.
- With market demand, manufacturers advise that heat pump manufacturing and skills training capacity are unlikely to be a limiting factor.
- A new build homes orientated heat pump competency scheme for designers and installers would help ensure quality across the industry.
- There are inconsistencies between NHBC and MCS standards and there is an absence of guidance for low temperature and/or heat pumps systems in low energy homes.
- Home buyers and householders will need introductory training to ensure they know what to expect from lower-temperature heating, and how best to use the controls to maximise comfort and minimise running costs.
- A Heat Pump Implementation Group should be established to: develop and oversee an implementation plan, share best practice, support small builders on the journey.

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Introduction

Heat pumps feature in houses across most of the contender specifications, benefiting from the increased efficiency.

Direct electric heating was assumed in apartments, where the fabric heat loses are lower, with in most cases a hot water heat pump. Centralised heat networks, driven by a common heat pump, were recognised as options but not modelled due to the tight timeframes.

For ease of analysis, individual air source heat pumps are used as a proxy for the range of heat pump technologies which might be considered including: ground source, exhaust air and communal heat pump approaches (for houses and apartments).

CS5 uses an exhaust air heat pump for hot water heating only in both houses and apartments. CS2a did not use a heat pump, instead using IR heating and direct electric for the hot water.

Scale-up

National context

The heat-pump supply chain will, over the next few years, be shaped by the very large planned increase in the market for heat pumps in existing buildings: the Government's Heat and Building Strategy sets out an ambition of 600,000 heat pumps to be installed annually by 2028, from a base of around 55,000 currently.

To drive this market, a planned market-based policy mechanism will require heating manufacturers to sell a minimum proportion of heat-pumps. In addition, the Government has a 'Boiler Upgrade Scheme' which is providing grants to 90,000 existing buildings, principally to install ASHPs or GSHPs in existing homes and a proposed Heat Pump Investment Accelerator Competition[23].

FHS

A range of housebuilders were asked their expected adoption rate of heat pumps with the implementation of FHS from 2025. Whilst only an illustration, the feedback suggests a significant ramp-up of installations, particularly in the period 2026-27 with a corresponding reduction in gas boilers.

The skills development is significant covering: design, installation, setup and commissioning.

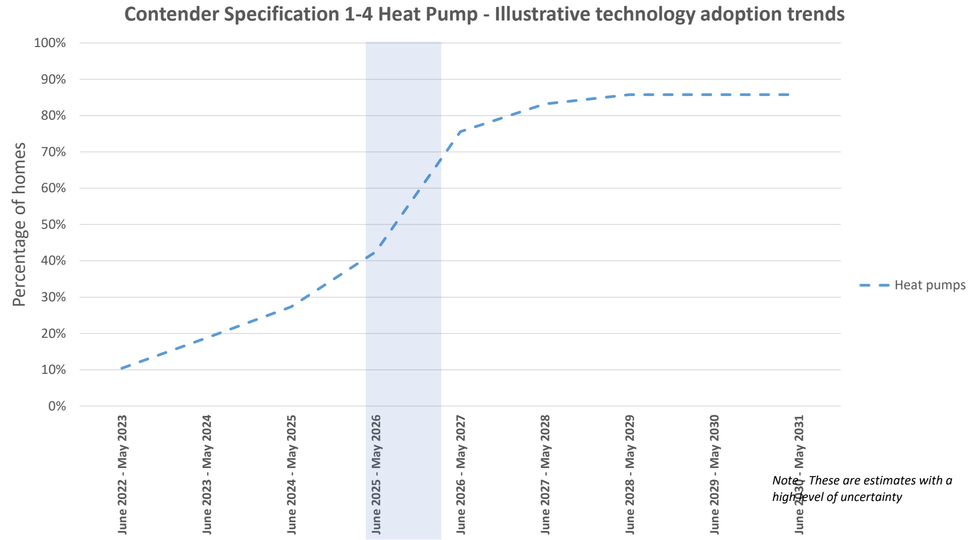

Fig 98: CS1-4 Illustrative heat pump adoption trends if there were a 12-month transitional period

The scale up rate indicated by industry, if the same transitional arrangements are used as Part L 2021, suggests a transition which would be difficult to deliver. To ensure a successful, industry wide move to heat pump technology at scale, the transitional arrangements need to ensure a progressive ***buildup of skills*** and experience.

[23] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943712/heat-pump-manufacturing-supply-chain-research-project-report.pdf

Risks – the ramp up of production has the following industry challenges:

- Supply chain – worldwide call for components could impact on UK volumes.
- Labour – lack of training, installer age v experience gap, availability of skilled manufacturing production operatives for new/expanding manufacturing sites.
- Production Expansion - availability of land and buildings, long lead type manufacturing equipment.
- Systems – component substitutions with associated performance risks.

Mitigations - Whilst the risks apply to the ramp up of heat pump installations generally, from a new build homes perspective, clear and timely decisions by Government would provide the confidence the industry needs to invest. As heat pump manufacturing is a global business, product can be imported to support a transition as necessary. Clearly this is a significant opportunity to encourage domestic production. Manufacturers advise that heat pump manufacturing capacity is unlikely to be a limiting factor[25].

It is worth emphasizing, whilst the focus has been on individual ASHPs, other technologies and approaches are available with different skills and product requirements: Ground source HPs, Exhaust Air HPs, communal heat pumps supplying low temperature networks with HIUs retained for instance or an ambient loop configuration.

Product availability and supply chain issues

A range of coordinated actions would assist scale up:

- **Specification** - House types to include key commissioning data, flow rates etc. Plot template to determine min performance for SAP (PCDB No).
- **Manufacturing capacity** – supported by long term planning.
- **Route to market** – currently through national/regional merchants. With increased volumes this would require larger investment in stock and warehousing.
- **Stock** – early visibility of site plans and start dates, volumes, house types to optimise manufacturing scale up, stock holding forecasting, system plot type call offs. Regular forecasts to update site scheduling.
- **Installation** - Industry wide recognised heat pump installations and commissioning where consistency facilitates easy maintenance and supports the influx of new less experienced installers entering the market.

Design standards

The mainstreaming of heat pumps highlights some inconsistencies in industry guidance and standards, e.g. NHBC and Microgeneration Certification Scheme (MCS) standards.

NHBC's standards, which are very familiar to all housebuilders, have historically focused on higher temperature heating systems such as gas boilers and not specifically low temperature heat pumps. MCS standards were developed for installation of heat pumps into existing, lower performing homes, generally with relatively high heating requirements.

Examples of inconsistences include: hot water cylinder sizing where MCS uses 45l per bedroom plus 45l whereas NHBC guidance sets a minimum requirement based on number of bathrooms and showers and has a minimum cylinder recovery time.

Neither currently has a standard published specifically for low energy new build homes, although this is under development by MCS and CIBSE are undertaking a specific "low temperature" update to their Domestic Heating Design Guide.

As a matter of urgency, the inconsistencies between differing sources of industry guidance, need to be resolved and a common set of standards agreed together with any normative documents which underpin them. This is required to facilitate the transition to heat pumps and low temperature heating systems at scale and help ensure that householders are protected and performance is optimised.

As historically industry standards were based on high temperature heating, and typically an assumption of baths, the work group recommended research to determine current DHW consumer behaviours.

Updating the standards and guidance should include: considerations of hot water storage for load shifting purposes (in dwelling and communal), smart hot water cylinders and the interaction with wastewater heat recovery systems.

With the Government's drive for increased water efficiency, a holistic view needs to be taken to also reflect the drive for reduced consumption.

Design, installation and commissioning

Where homes have previously had a combi boiler, suitable space will need to be found for an outdoor heat pump, and indoor cylinder, manifold and potentially a buffer vessel. The slight trade-off from the addition of a cylinder is gaining some kitchen cupboard space.

It is important that installation of these systems are 'as designed'. If there are performance gaps then this will lead to low comfort, high running cost and poor reliability. The current condensing boiler technology is better able to compensate for underperformance of other elements of the build, such as fabric or sub optimal pipework installation, than a low carbon heating system.

Correct system design – room by room heat loss calculations based on geographic conditions, position, height and exposure are required. This is separate from SAP compliance and produces three key design elements: emitter sizing, maximum heat loss and distribution pipe sizing (flow rates and volumes). Inputs are: fabric materials, construction, orientation and location. The output will be typically a 2D drawing showing pipe runs, pipe dimensions, external heat pump positions and any auxiliary required components such as buffers of divertor heating valves. Correct system design for sizing of storage/buffer vessels will also need to consider daily use profiles, especially for communal systems.

Build and install as per design – fabric should be 'as designed' otherwise a risk of 'greater than designed' winter heat requirement creating a performance gap and resulting in: homeowner discomfort, complaints and remedial work.

External positioning of heat pump - to minimise cost and improve performance, long flow and return pipe work between the outdoor unit and home should be avoided. The outdoor unit should be installed on a base, with provision for condensate soak away. To reduce vibration and noise, flexible hoses and acoustic insulated mounting feet should be used. The outdoor unit should be installed in compliance with clearances for air circulation, maintenance, and safety zones with regard to refrigerant type. Electrical isolation should be installed adjacent to the outdoor unit. Full consideration should be given to positioning the outdoor unit to minimise noise to the home and surrounding dwellings.

Internal pipe work – internal pipe work and fitting should be installed and insulated in compliance with the design and/or manufacturer's instructions.

Electrical – electrical connection should be selected and installed to comply with manufacturer's instruction, in particularly RCD capacity and type.

BREL Report – may provide a thread for confirming that design through to install, setup and commissioning was followed, assuring system performance.

Responsibility - House builders and installers must be responsible for the installation. Any design supplied to the house builder is to aid and support the installers which, when combined with manufacturer's instructions and guides, form the base for a high performing and reliable installation.

Skills and training

Manufacturers are already gearing up in anticipation of significant increase in demand. However, industry still requires upskilling in both the design installation, commissioning and maintenance.

MCS / NESTA[24] estimate 4k to 6k trained heat pump engineers need to be trained each year for 6 years to meet the Government's new & existing home heat pump installation target of 600,000 installations per year by 2028.

Nearly all manufacturers offer training courses for designers and installers on new build installations. The uptake of these training schemes is anticipated to increase in line with demand for heat pump installations. The Heat Pump Association estimates the industry has training capacity for 7,000 heat pump installers per year[25].

This 'skills scale up' needs to be planned, progressively rolled out and monitored. The transitional arrangements need to be designed to soften the rate of adoption and not simply delay the start.

To help manage the scaleup, the work group discussed splitting the installation between:

- one team using current skills focused on pipework and emitter installation; and
- another team focused on installation, setup and commissioning of the heat pump

This would help reduce the immediate level of training and certification required during the transition. Indeed, some heat pump manufacturers might offer the design and heat pump installation/commissioning as a service.

A competent person's scheme, with minimum technical competencies and a level of professional oversight and tailored for new build homes, would help ensure good installation, set-up and commissioning.

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Householder perspectives – HP

See also heatpump section in the Consumer chapter

'Warming' the home

A heat pump based space heating will need some changes to householder behaviour and expectations. This will require consumer education and awareness, to ensure householders know what to expect from lower-temperature heating, and how best to use controls to maximise comfort and minimise running costs.

The concept of 'warming the home' with a heat pump rather than 'heating the home' will be new. Warm rather than hot radiators will be the embodiment of this or the home may have underfloor heating. A slow heat which takes longer to build up but, due to the low heat losses, also takes much longer to cool down.

The slow heat means keeping the heating running but with a 'setback' temperature at night to prevent the temperature falling too low, on a very cold night, ready to be warmed up again in the morning.

Depending on the level of fabric performance, the radiators may be larger than homes with gas boilers.

Energy tariff

What will also be new is the opportunity to use flexible tariffs to heat the home when energy prices are low, knowing the home will retain its heat for a considerable period of time. To take advantage, the heating controller would need to be set appropriately to pre-warm the home during low tariff periods or, being developed, are smart services that manage the home's energy use for the householder.

Annual maintenance and care

Like boilers, heat pumps will require annual maintenance which takes a similar amount of time and typically a similar cost.

[24] https://media.nesta.org.uk/documents/How_to_scale_a_highly_skilled_heat_pump_industry_v4.pdf

[25] https://www.heatpumps.org.uk/wp-content/uploads/2020/06/Building-the-Installer-Base-for-Net-Zero-Heating_02.06.pdf

For the householder, care needs to be taken to ensure that there is free airflow to the outside unit of an ASHP so plants should not be grown up against it nor items stored in very close proximity.

Noise
Heat pumps are generally fairly quiet but do produce some noise. As such their proximity, particularly to bedrooms, needs consideration. Fully enclosing ASHPs to omit all noise risks is not possible due to the amount of free air circulation required. Larger central plants will need acoustic attenuation.

Hot water
Many householders are effectively used to an unlimited supply of hot water from either a combi boiler or from a cylinder that re-charges very quickly from a large gas boiler. With a small heat pump, this is quite different. If the hot water is all used, the re-heat times are much longer than with a gas boiler.

As FHS homes will be highly energy efficiency the space heating requirement is quite low. The hot water demand becomes the dominant energy requirement. Sizing a heat pump for rapid hot water recharging may oversize the heat pump for space heating. This can be undesirable if it leads to short cycling, when the heat pump switches on and off after short periods, significantly impacting the efficiency.

A larger hot water cylinder, able to supply more of the immediate demand without re-charging, is an alternative, although these are typically taller, taking more space. The Buildings for 2050 report[26], commissioned by BEIS, studied 4 large new build developments using heat pumps and found only one development did not have complains about hot water and this development had large hot water cylinders.

A further benefit to the householder of a larger cylinder is it allows greater load shifting flexibility – where hot water is predominately heated during low tariff periods and there is sufficient hot water to avoid heating during peak periods.

Other approaches for optimising hot water for the householder include:

- Shower fittings have a flow rate of 8L/min or less
- Waste water heat recovery
- Highly stratified cylinders (which minimise mixing)
- Smart hot water cylinders which are able to heat the top of the cylinder and intelligently optimise storage to actual consumption
- Utilise instantaneous heating e.g. from a heat pump heat network

Controls
Key for a householder is simply to set desired the temperatures and the setback schedule and not adjust commissioning settings.

Where smart thermostats, or electronic TRVs are installed, these can be helpful to pre-heat the home recognising the longer warm up times.

Householder perspectives – HP DHW

Most of the contender specifications for apartments utilised heat pump hot water cylinders. These have the benefit of not having an outside unit but, being small heat pumps, have long hot water recharge times.

Site health and safety implications

Transportation, siting, and installation of heat pumps must be carefully considered due to their weight and the potential for leakage of refrigerant in the event of material damage.

Installation, maintenance, and decommissioning must be undertaken by qualified, competent persons in accordance with manufacturer's instruction.

The refrigerant vessel must be disposed of appropriately to avoid atmospheric escape at end of life.

[26] https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/1121448/Building_for_2050_Low_cost_low_carbon_homes.pdf

Grid load

Summary

- New loads like heat pumps and EVs in the home, will significantly increase average household electricity demand so grid capacity will need considerable reinforcement.
- The ability to load shift and reduce peaks is as important as reducing the average demand in new homes.
- Adoption of smart technologies, with home management systems and energy storage, can provide significant support for local and national networks by reducing loads during peak periods and can reduce householder energy bills.
- SAP capabilities, and the dwelling design metrics, need to reflect the overarching Smart/ Flexibility ambitions and recognise a broad range and combinations of flexible energy solutions (such as fabric, hot water, battery approaches) and credit smart solutions that improve grid capacity.
- All contender specifications could shift space heating and hot water heating demand to a varying degree. Whilst only one CS included a smart hot water tank and battery storage, these technologies would have benefited them all.
- All contender specifications have similar 'development level' grid implications, except for CS2a which has a greater average demand, although peak load is minimized through smart controls and a battery.
- The higher performing CSs have a lower winter energy demand which is significant when considered at the national level of housing delivery.
- Customers need to be incentivised during the adoption phase of technology to encourage changes in behaviour that maximises the benefits and use of smart systems.
- There is high competition for grid connections so early engagement with network operators is critical and planning departments should prioritise areas with strong infrastructure.
- Investment is vital for both grid development and low carbon technology (LCT) adoption to help reduce costs to customers
- Studies are required on the limited number of existing schemes, supplemented by data from new schemes as they come forward, to refine the 'after diversity maximum demand'.
- With the significance of peak load reduction, yet a level of immaturity of the solutions, an Implementation Group is required to coordinate efforts to maximise the potential benefits for housebuilder, householders and the grid.

Future grid challenges

BEIS indicates that electricity demand could double from 300 to 600 TWh by 2050, leading to estimated reinforcement costs between £28bn to £64bn. New housing makes up only part of the demand on electricity networks, but new connections will compete with new concentrated grid demands including: increased electrified heat, renewable generation, EV charging, new data-centres and hospitals etc.

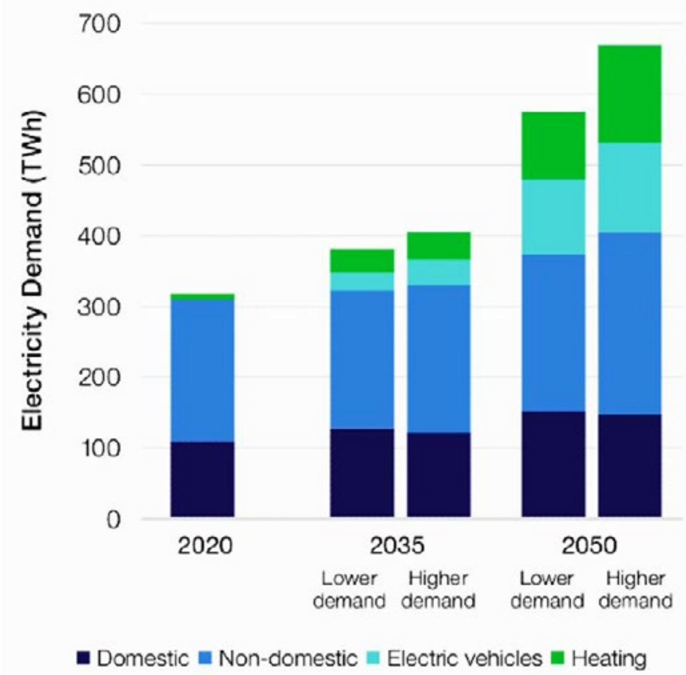

Fig 99: Electricity demand, net zero scenarios (source: BEIS Energy white paper: Powering our net zero future, 2020)

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Grid transition

To enable the growth of electrification, the grid is in a transition period from a traditional centralised network with a single direction of energy transmission, to a new decentralised, bidirectional, smart and flexible grid to meet the 2050 demands.

The transition means changes in the investment, operation and management of generation, transmission and distribution of electricity and a transition at all levels from the national, regional, local to micro.

The impacts of new connections must be considered at all levels and areas of the network. Increasingly, for homes and householders, questions around electricity use will have an increased emphasis on the time of demand, and how flexibly this can be managed and shifted. National and local peaks in demand and supply are not always co-incidental.

Creating a FHS homes 'brand' would help with the transition process giving the industry a common/shortcut language to aid understanding and help raise awareness across industry / networks DNOs, IDNOs.

Such a label would make it easier to communicate the expected outcomes which in turn helps to increase understanding of impacts and to inform specifications.

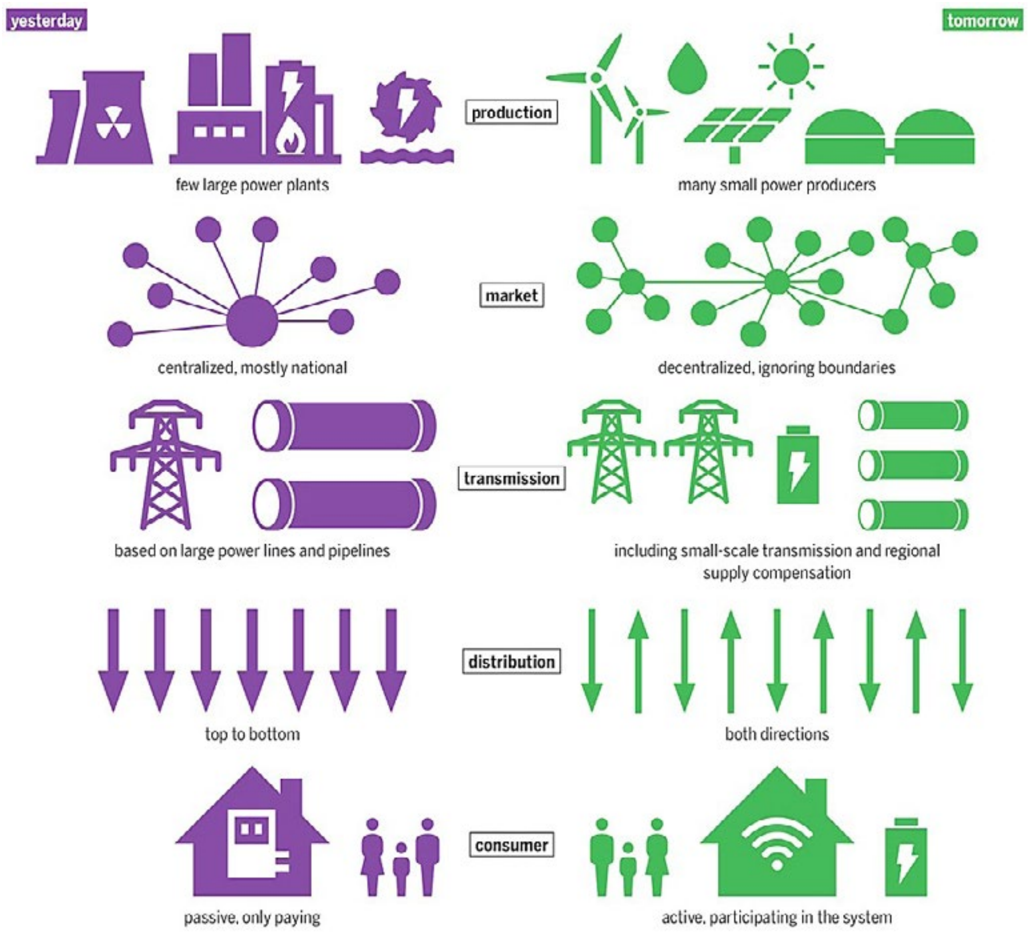


Fig 100: Expected structural changes in the energy system made possible by the increased use of digital tools (source: Energy Atlas 2018)

Implications for new developments

Reinforcement planning horizons at the distribution level can be up to 5 years and up to 10 years for transmission. The feasibility of new connections is very site-dependent and considered in line with existing application queues. With increasing competition on the grid, connection lead in times for new developments could take longer. Noting, without network and supply chain constraints, the lead time from design to energisation is typically two years.

Developers must engage early with network operators to identify possible constraints that may impact the planned development. Early communication also allows DNOs/IDNOs and developers to be able to identify possible alternative connection options which potentially can have a positive impact on the lead times for connections and may help avoid costly design changes and/or connection charges.

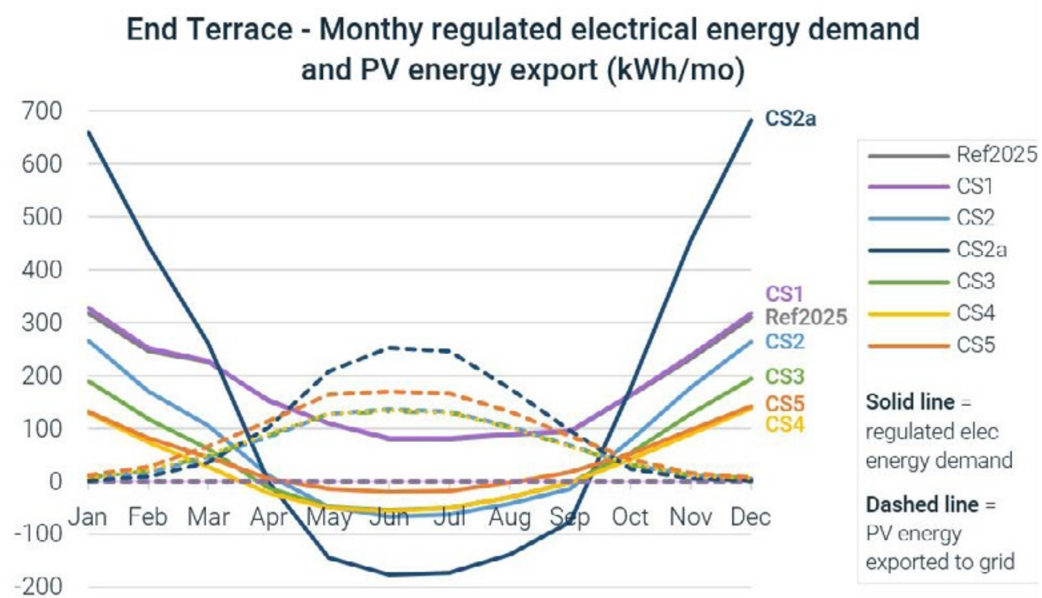


Fig 101: Monthly regulated energy demand from grid and PV energy export - End terrace house

Development level grid implications - CS1,2,3,4&5

The main difference from CS1 to CS5 is a reduction in space heating demand, with CS2 to 5 also providing substantial generation. At a development level, the scale of the space heating demand difference makes relatively little difference when compared with the other loads which need to be accommodated. This said, the aggregate impact across all homes built nationally would be considerable (see section below: Grid implications – National scale)

Development level grid implications - CS2a

Whilst CS2a benefits from battery storage, smart hot water and intelligent controls, the winter months' average power consumption, as indicated in the graph above, is significantly higher than the 2025ref specification.

CS2a is the only specification not benefiting from heat pump technology which accounts for the increase in demand in comparison to the other CSs, as space heating and hot water heating via direct electricity alone is less efficient than by heat pump.

The use of energy storage in CS2a, with its battery energy storage system and smart hot water allows for the highest level of load balancing of the contender specifications allowing the battery and hot water to be re-energised from the solar PV system and topped up by the grid during off-peak hours (Subject to the size of the battery/hot water cylinder, solar array performance, customer usage and so on).

In archetypes where a heat pump is not suitable, and the benefit of their efficiency is not available, load management and generation will be vital to offset the impact of the demand.

Balancing demand and reducing demand

The contender specifications considered have limited energy storage options that enable balancing. Most emphasis is on reducing space heating rather than hot water and unregulated electricity demand. CS1 to 5 successively lower demand thanks to increasing levels of thermal efficiency. CS2a is the only one to incorporate battery storage technologies although all would benefit from the technology.

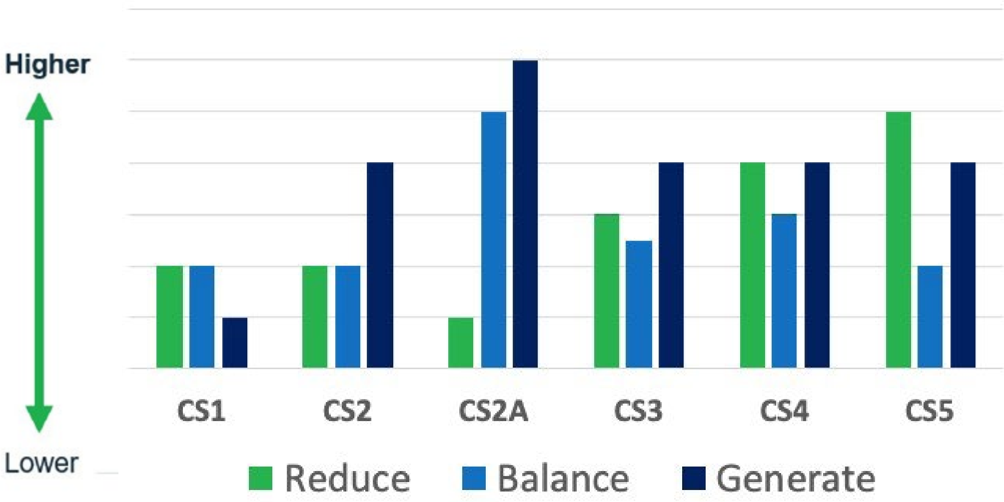


Fig 102: Capacity of different CSs for reducing, balancing and generating electricity

Building regulations could consider, not only reducing demand, but also the capacity for homes to generate electricity and balance demand and supply. Balancing involves utilisation of energy storage devices for electricity and heat, smart, efficient, and flexible appliances, such as smart dishwashers, and low carbon technologies.

Smart technologies and controls

AKA Demand side reduction

The difference between the CSs in terms of their impact on the grid, is limited in comparison to the difference between a home with or without smart technologies and controls built to any of the standards.

Smart technologies and home management systems will be able to optimise household demand and reduce it during peak periods, which will significantly support local and national networks. Noting that some technologies last the lifetime of the building, such as the fabric itself. Others have a shorter lifespan and may require many replacements over the lifetime of the building and these replacements would be at the discretion of the householder e.g. smart cylinders, battery storage.

Implications of increases in solar PV

Regarding the increase of domestic solar, the Networks have committed to the Net Zero targets set by Government, and the potential for domestic solar generation to play a sizable contribution towards that target. The Networks must also consider the safety and resilience of the network, therefore, new connections and newly connected assets must adhere to the relevant regulations and standards. This may mean that, under certain circumstances, a load or generation-limiting device needs to be installed at the point of connection for the installation to go ahead, in order to protect the consumer and the grid. Homebuyers would need to be made aware of this.

Managing the transition

To facilitate the adoption of smart flexible controls, SAP must have the capability to reflect the overarching Smart/Flexibility ambitions recognising the broad range, and combinations, of flexible energy solutions and include smart solutions that reduce grid capacity. The metrics chosen for the regulations could encourage housebuilders to build homes that require reduced grid capacity.

There is a scarcity of data on full developments of low energy homes with heat pumps, PVs and car chargers. The data that exists is primarily from existing homes with significantly higher heating loads. Studies are required on the limited number of existing schemes, to be supplemented by data from new schemes as they come forward, to build understanding, refine the 'after diversity maximum demand' (ADMD) calculations being used, build confidence and shape future policy.

Come 2025, there will still be a sizeable number of homes planned on sites with gas networks already laid to them, as many as 500,000. There needs to be a transition plan for these developments.

The implications of electrifying heat, increased PV generation and vehicle charging pose potential risks of delaying some developments. To mitigate these risks, clear and timely decisions by Government are required. Planning needs to be cognisant of grid restrictions and opportunities and housebuilders must engage very early with DNOs / IDNOs.

Householder perspectives

Transitioning to a smart grid will require education and engagement with all households, not merely those in new homes. Standardisation and consumer understanding of smart controls will need to improve. Who pays, and who benefits and how smart demand is managed will require clear signal from Government.

To get the best from their new homes, homebuyers will need to become familiar with energy in a way they have not needed to before.

Housebuilders will need to help householders along this journey to ensure best outcomes and also to avoid misunderstandings. An example of the latter is ensuring that householders are aware if there is a limiting device on their PV generation, export may be curtailed in situations where this is required to protect the customer and the grid.

Grid implications – National scale

It was noted that the differences between CSs would have a considerable impact at a national level. The modelling group calculated, if all homes were built to Ref2025, an additional Hornsea2 offshore wind farm would need to be constructed every 7 or 10 years compared with CS3/4 or CS2 (respectively) to make up for the Ref2025's higher energy demand.

See Energy analysis section – national scale grid implications

Lessons so far from 2021 Part F/L/O implementation

Introduction

We are mid-way through the 2021 Part F/L/O transition, with few if any homes built so far to these regulations, however, there are early lessons to be learnt.

Building net zero ready homes necessarily requires changes to build practices. Whilst issues cannot be fully avoided in the 2025 Part L introduction, lessons can be applied in order to make the transition to FHS 2025 as efficient and smooth as possible.

Housebuilders were asked for feedback on some of the principal challenges they had faced so far in the transition from the 2013 regulations to the 2021 Part L/F/O regulations. Responses from small and volume housebuilders were gathered separately to ensure the small housebuilder concerns were given a clear voice.

A wide range of concerns and issues were reported, with a smaller number of underlying causes namely:

- Issues relating to the **development and introduction timeline** of the new regulations and compliance tools.
- Implications of the new **transitional arrangements**.
- **Awareness and understanding** of the regulatory requirements among housebuilders, their suppliers/contractors and building control.
- **Availability of skilled staff and contractors** able to design and build homes to the standards.
- **Design of regulatory methodologies**: aspects of the regulations perceived to be poorly designed; inconsistencies between different regulations, inadequate guidance.

The full details of the issues, underlying causes, immediate solutions and lessons for FHS 2025 can be found in Appendix C.

Learnings for the FHS 2025 introduction

Development and introduction timeline

Whilst the time between the first announcement of new regulation and its introduction is considerable, this is only advanced warning rather than anything that the industry can act on, or reasonably prepare for. At consultation stage, a better picture of what might occur is given but this is subject to change in light of feedback given so is also not a basis on which to act. Additionally, as there is a one-shot consultation, any significant changes do not have the benefit of a second consultation round. A good example of this was Part O which, when published, had sections that had substantial changes with significant implications.

Only when the Approved Documents are published does the industry get a clearer view. However, even this is only partial since it does not, rightly, prescribe solutions so, ultimately, it is not until the compliance software is released that the actual combination of optimised solutions are known. It is after this point housebuilders can start working through and finalising dwelling designs. Manufacturers then know how their products compare and compete and this trickles down into the wider supply chain. It is only now developers know how much a compliant home will cost to build and finally know what to pay for land.

So, whilst it may feel like there is a considerable period of notice, in reality this is not the case. Any slippage, which is not reflected in the implementation date, causes significant difficulties, and imposes additional costs.

For Part L 2021, the SAP10.2 delay implications were compounded by the move to plot-by-plot transitional arrangements. The former site-by-site transitions' naturally slower introduction was more resilient to these problems. However, even this only helped those with landbanks, typically the larger builders and not the majority of small builders.

The timeline for FHS2025 has already been set and there is pressure, from some quarters, to accelerate the implementation. The delayed introduction of SAP10.2 has created the most problems and is still not stable. SAP11 is a very important development but, with the track record of compliance tool delays, it must represent a considerable risk.

Lessons for 2025:

- Linking the date Part L 2025 comes into effect, to the release of commercially available, stable and robust SAP11 tool with associated conventions.
- Application of key changes that were not fully consulted upon, example being PV ratio at 40%.
- Clarifying more rapidly, after the consultation closes, all the key decisions taken and the expected impacts (effectively what Government suggests housebuilders might want to assume when buying land, whilst not accepting liability).

Implications of the new transitional arrangements

The transitional arrangements for Part 2021 are different from previous Part L changes, with the 2021 changes requiring works to have substantially begun on each plot, a year after the regulations' introduction in June 2022 – a plot-by-plot transition. This change was introduced to prevent large sites continuing to be built out, over many years, to older Part L regulations and accelerate the adoption of the new regulations.

With the introduction of the plot-by-plot transitional arrangements, sites where land price had been fixed but homes now need to be built to Part L 2021 standards, meant there is a significant cost impact which cannot be recovered.

Similarly, where detailed planning permission had been obtained, but the homes could not be started within the transition period, design changes resulting from Part L and O result in planning having to be resubmitted with all the costs, risks and planning capacity issues this entails.

Lessons for 2025:

- Have transitional arrangements that reflect the extent of the change in regulations and allow 'phasing in' to avoid re-designs, and resubmissions to planning (where detailed planning had previously been obtained).
- Extended transitional arrangements period for small housebuilders to ensure they follow, rather than lead, the introduction of regulations, giving time for the supply chains to train and scale up with larger housebuilders.

Awareness and understanding

There was, and still is in some areas, widespread lack of awareness of Part L, F and O by housebuilders, architects, designers, energy modellers, supply chain, manufacturers, planners and even building control. The mechanisms used to get the message across to those that need to be aware, enable them to prepare, train, implement new systems etc were not sufficiently effective.

This must be transformed for the 2025 FHS introduction, particularly as it could, potentially, represent an even more significant change in regulation.

Lessons for 2025:

- A formal industry – Government Task Group structure to oversee, report and coordinate the implementation of FHS2025.
- A short study to understand and map how information flows through the construction sector, its supply chain and public organisations that are involved with housebuilding.
- A formal programme of stakeholder engagement and FHS awareness raising.
- Particular support for small housebuilders and those that advise them.
- Tracking and reporting of required activities.

Availability of skilled staff and contractors

Supply chains take time to respond to changes in regulations. There are particular concerns that an insufficient number of heat pump, PV and other specialist installers will result in skills shortages causing delays, poor quality and higher costs.

A decade ago, publicly available thermal bridging details were identified as being required. Experience already from Part L 2021 introduction shows a low level of understanding and awareness of thermal bridges and their implications and there is limited availability of details, many of which were produced in the last few months. This situation could and should have been avoided and represents an ongoing problem for small builders, in particular, because of the bespoke home designs they often undertake.

Smaller builders are reporting skills shortages associated with the transitional arrangements, encouraging larger housebuilders to start plots in advance of June 2023.

Albeit relatively modestly at this stage, the increasing adoption of heat pumps, and other low energy technologies, has highlighted local shortages of appropriately skilled contractors, leading to delays and complications on site.

Lessons for 2025:

- A full understanding / study of the available skills and training requirement to deliver the necessary design and construction skills is required.
- A progressive build-up of Part L adoption, to support skilling up, through re-designed transitional arrangements.
- Development and monitoring of a resourcing plan to ensure bottlenecks are not caused.
- A review of what supporting guidance is needed.
- Potential development of a database of commonly used thermal bridges (donated by larger housebuilders to assist smaller housebuilders).

Design of regulatory methodologies

Issues were raised about poorly designed or inadequate regulation/regulatory tools, inadequate assessment of impacts and conflicts and contradictions.

Insufficient assessment of impacts

Too limited testing of new requirements within the context of consequential impacts on other Building Regulations, Material/Skill availability, integration into current approaches and buildability.

Insufficient robust testing of approaches

The approach of developing regulation relying on a single consultancy, with limited engagement of different stakeholders in the detail, resulting in issues coming to light as the standard was rolled out.

Conflict and contradiction with other parts of the regulations

Compliance is made significantly more difficult when having to decide which regulation takes precedence over another, when there are apparently contradictory standards for the same requirement

SAP 10.2

This was excluded from the Task Group ToR. All the same, there were many concerns expressed about SAP. These, and future recommendations, were captured in the detailed notes see Appendix C.

Part O

There were many issues regarding the introduction of Part O extending to most aspects of the regulation. (see Appendix C for the full details).

A good example of a 'good idea' not working as anticipated is the 'simplified method of compliance' which seems to have limited use. Most larger housebuilders, with fairly standard house types which suit the simplified model, use the TM59 method to minimise the necessary design changes to comply. Those smaller housebuilders, that are aware of Part O, use the costly TM59 approach because the simplified model has too few overheating mitigation options so is not suitable for the bespoke homes they build.

The Part O simplified model needs substantial improvements to become fit for use as a matter of urgency.

Lessons for 2025:

- Either: Large regulation changes be co-designed with industry and then consulted on high risk when single consultant develops such complex regulation as no single entity has enough breadth.
- Or: a need for significantly more active industry engagement and wider industry testing during its development prior to consultation and, if substantial changes are made after the initial consultation, then industry is involved and a further consultation undertaken.
- Introduction of new regulations needs to be more actively managed, with significantly more support provided to ensure an effective and smooth uptake.

Small builder FHS 2025 implications & recommendations

The Task Group brought together small builders to discuss the issues of Part F/L/O/S 2021 transition from their perspective and lessons for FHS 2025.

Challenges and impacts of the Part L 2021 transition

Small builders:

- do not have the purchasing power to compete with large housebuilders so must respond to local need and tend to be highly innovative and market responsive, producing aspirational homes.
- bespoke designs typically are more difficult to meet Part L and will require bespoke detailing (new) with bespoke thermal bridging calculations (new).
- tend to build a high percentage of different house types compared to larger developers, such as bungalows, which can struggle to meet new regulations.
- are distinct and varied in: the types of homes they build, the techniques used, and how they work with their professional advisors and supply chain.
- are impacted by regulations earlier because they are typically unable to 'start additional plots', for a range of reasons, within the transition period to delay, and smooth, the switch to the new regulations.
- generally have limited internal capacity to understand the details of the frequent regulation changes.
- are generalists, having multiple responsibilities, so do not necessarily see information advising regulation is / has changed.
- tend to build with techniques they used before. When regulations change there is a danger of being caught out.
- rely on designers to advise on changes so trust they are up to speed but these are not necessarily architects with formal CPD routes.
- tend to engage designers and then get energy calculations undertaken directly or via a material supplier. Designers are not typically liaising with energy assessors, creating problems.
- may not be readily able to respond to onerous planning conditions but neither have the option to build elsewhere, unlike larger builders.
- do not have the purchasing power when skills or materials are tight so tend to be 'at the back of the queue' and in a poor position if regulations changes create shortages.

Implications for FHS 2025 implementation

The number of homes built by small housebuilders has been in steady decline over many years. Yet, to achieve the Government's ambition of increasing the number of homes built, it is through these companies expanding where sizeable growth can come from. Further, their local roots, specific parts of the market they serve and, ability to build on smaller parcels of land, means the introduction of the FHS step must help them flourish and not undermine them.

Key recommendations to support small housebuilders:

- Provide an extended transitional arrangements period for small builders to shield them until the supply chain has been established by the medium and larger housebuilders (see Transitional arrangements chapter).
- Consideration of an elemental standard (effectively a more detailed notional specification) as alternative route to compliance for the small builder.
- Actively support existing communication routes / channels that inform and advise small housebuilders and, critically, their professional advisors.
- Inform, advise and encourage planners to focus sustainability clauses on larger housebuilders initially, rather than impose on small builders, until the supply chain is established and experience is gained.
- Support the development of appropriate skills & training designed specifically for small builders.
- Allocate parcels of Government land specifically for small builders that wish to build early to the FHS.

Transitional arrangements

Introduction

Return to: CS Chapter, CS1, CS2, CS3, CS4, CS5

With the heating and powering of homes representing 20% of UK emissions, and new homes being additional, the change in transitional arrangements for the 2021 changes to facilitate earlier application of the new regulations was understandable.

Fig 103: Currently assumed transitional arrangements

The early indications are that similar transitional arrangements are suggested for FHS2025. However, with CS3-5, in particular, the task group advised modified transitional arrangements would be required which allowed a progressive build-up of skills and experience.

Unintended consequences

Identified during the course of the Task Group process, and discussed at the transitional arrangements workshop, were the following issues:

- Where detailed planning permission had been obtained, re-designs of homes to comply with new regulations that then require resubmission to planning - with risks, costs and increased planning department burden.
- Changes of regulations typically impact small housebuilders in advance of larger housebuilders who are more able to make starts on multiple plots before the end of the transitional period.
- Where substantial changes are brought in, the time over which to train new techniques and gain experience is short, increasing quality and delivery risks and increasing costs.
- Energy infrastructure that has already been laid to larger sites which will continue being built out beyond 2025. Gas infrastructure capacity could be underutilised with the potential that gas infrastructure rebates will need to be repaid. Further, the installed electrical grid infrastructure may be under capacity for the increased new loads and require additional cost to upgrade.
- Potential of sites already being built out not having the grid supply capacity locally to accommodate the additional load in the short term.
- Potential for two neighbouring homes having different performance specifications / appearance / character within a phase.
- The continuous stream of regulations changing which can require repeated design changes, for example: Part F/L/O/S Jun 2022, Part J Oct 2022, Part B Dec 2022, Part R into force 26th Dec 2022.
- Ongoing, multiyear contracts with sub-contractors and energy suppliers requiring renegotiation with incumbent increasing costs.
- Housebuilders starting multiple homes, by putting down bases, in advance of the June 2026 cut off.

Desirable Attributes

- Progressive scale up (not simply delayed)
- Delayed start for small builders who are resource limited
- Flexible implementation (by housebuilder)
- Clear outcomes
- Certain
- Low administration
- Auditable

Alternative Transitional Approaches

Long list brainstorm:

1. **Cities lead**
   Identified city areas come into effect on one date and other areas at a later one
2. **Voluntary early**
   Housebuilder electing to go early
3. **Site-by-site, time limited**
   Revert to site by site but have a maximum period by which FHS must be adopted
4. **Adaptive 'into effect' date**
   Rather than being a fixed date, the 'into effect date' is a defined period after specific milestones are met. Such: as a commercially available version of SAP11.
5. **Phase by phase**
   Each phase (to be defined) can continue on the previous regulations
6. **Housebuilder ratio**
   Date set as now but each housebuilder may register to postpone the new regulation on a decreasing proportion of their annual build volume (such as FHS: yr1=25%, yr2=50%, yr3=75%, yr4=100%) on plots of their choice.
7. **Small builder site derogation (limited time)**
   Small sites (eg <30plots) given an additional 2 years after 'into effect date'
8. **Small builder volume derogation (limited time)**
   Adaption of housebuilder ratio. Date set as now but housebuilder building less than a defined number of homes per year may register to postpone the new regulation completely initially and then a decreasing proportion of their annual volume (such as FHS: yr1=0%, yr2=0%, yr3=50%, yr4=100%) on sites of their choice.
9. **Detailed planning 'into effect' delay (limited time)**
   Where plots have detailed planning permission then the 'into effect' date for these plots is postponed by a defined time period.
10. **Section 73**
    Design amendments due to regulation changes dealt with using Section 73 rather than full planning
11. **Balancing**
    Allow some sites/plots to delay adoption of the FHS provided other sites/plots start early
12. **Carrot**
    'Help to buy scheme' type approach where Government funding is made available but only for those plots that adopt FHS
13. **Incentive based**
    Early adoption of FHS benefits from a streamlined planning process. Potential linked with the Design Code/no-preconditions
14. **FHS Transparency**
    Housebuilders have to state which Part L regulation year the home is built to (eg 2021, FHS 2025) when marketing/selling the home.
15. **As Built energy monitoring (time limited)**Housebuilders can delay the 'into effect' date (up to a maximum to be defined) on phases where a % of homes are performance monitored to defined standards
16. **Public land 'go early'**
    Projects on public funded land required to adopt FHS early
17. **Technology phased**
    Specific technologies/approaches allowed to be adopted progressively such as: air tightness yr1<4, yr2<3, yr3<2, yr4<1$m^3/m^2/hr$

Metrics

Summary

- Two aspects have been considered, the 'metrics' to be used (such as kWh/m²/yr) and the 'target setting approach' (i.e. concurrent notional approach or absolute targets).
- For a particular archetype, the level of energy ambition set has a significantly greater impact on energy demand than driving more efficient forms.
- The concurrent notional allows the same elemental specification across different archetypes where the absolute energy target does not.
- Both the concurrent notional approach and absolute target can be compared with actual performance. However, the absolute target relates dwelling performance to net zero.
- No single metric positively drives all the likely policy objectives (e.g. reduced heat demand, load shift) nor has ***all*** the desired attributes that a metric would ideally have (e.g. easy to understand, measurable etc).
- Whilst more than one metric will be required, there should be as few as possible and it is more manageable if they can be applied in a sequence: first meet A, then focus on B (which does not negatively impact A), then focus on C (which does not negatively impact A or B).
- The metrics used for Part L 2021 do not align fully with the key themes which emerged, namely:
  - space heating demand,
  - net energy consumption
  - peak load/load shifting.
- As the energy performance increases, the absolute difference in performance between archetypes reduces, however, identifying an appropriate absolute target level is not straightforward and would require substantial work.
- Householders are likely to be more interested in the expected energy bills than any other metric. However, the variables that exist such as: energy price changes, different ways people live in the homes mean the expected energy bill is bespoke to the householder. An online estimate could be generated based on SAP, with the prospective purchaser selecting options appropriate for them (e.g. with different inputs to the standardised compliance ones, such as: occupancy and heating patterns, energy tariffs).

Introduction

The ToR asked specific questions around metrics, in terms of how the FHS might be described. The metrics used to describe targets are as important as the level of ambition set, as the metric will materially affect the outcomes of the policy.

There are two parts to this – the **metrics** themselves (e.g. carbon emissions, $kgCO_2/m^2/yr$) and the **targeting approach**. Currently the target is set by a 'concurrent notional dwelling'. Alternatives include: an absolute target, a combination of both or something else such as minimum elemental standards.

Each of these parts were considered in turn together with the impact of location.

Metrics

Three metrics are used within Part L 2021:

- Fabric Energy Efficiency (per m²)
- CO_2 emissions from regulated energy (per m²)
- Primary Energy from regulated energy (per m²)

There are a significant range of possible metrics with a variety of attributes. Not knowing the specific policy objectives, a matrix was developed to compare a long list of metrics with potential outcomes and other attributes. (A summary of the matrix is shown in fig 104).

There is not a single metric which positively drives all likely policy objectives so a combination will be required. Multiple metrics can be very complicated and confusing to meet. From experience, multiple metrics are more manageable if there is a clear order to follow and subsequent metrics do not negatively impact a previous one. E.g. first meet A, then meet B (which does not negatively impact A), then meet C (which does not negatively impact A or B).

Some metrics would be helpful to report on, but not set a target for, e.g. energy costs and regulated energy consumption.

Potential metrics Note that many of these could be set either per m² or per dwelling, with differing outcomes		**Policy objective. Does it incentivise…**								**Other attributes:**			
Type	**Specifics**	**energy efficient fabric? Specifics**	**efficient services provision?**	**reduction of householder energy use?**	**Lower householder Costs?**	**reduction of carbon emissions?**	**renewable energy generation?**	**peak demand reduction?**	**load shift-ing?**	**Ability to measure actual performance**	**Under-stand-ability by house-holder**	**Stability over time**	**House builder ability to influence**
FABRIC	Heat Transfer Coefficient (HTC)												
	Heat Loss Parameter (HLP)												
	Fabric Energy Efficiency Standard (FEES)												
ENERGY	Space heating demand (fabric, airtightness, ventilation)												
	Space heating and cooling demand												
	Space heating, cooling & DHW demand												
	Energy consumption for space heating												
	Energy consumption for space heating & cooling												
	Energy consumption for space heating, cooling & DHW												
	Total regulated energy consumption (into meter)												
	Total energy consumption												
	Renewable energy generation (on-site) e.g. PV & solar thermal												
	NET energy consumption (i.e. net of on-site generation)												
PRIMARY ENERGY	For all regulated energy consumption												
	For all energy consumption												
CARBON EMISSIONS	For all regulated energy consumption												
	For all energy consumption												
DEMAND MAN-AGE-MENT	Peak load (kW)												
	Peak load & kW being shifted (heat)												
	Peak load & kW being shifted (heat & power)												
	Energy storage being shifted (kWh)												
COST	Energy bills - regulated energy only												
	Energy bills £/yr - total energy												
EPC RATING	Main EPC rating (Energy Efficiency Rating, based on £/m²)												
	Secondary EPC rating (Environmental Impact Rating)												

KEY: Policy objective	+ve effect	Less impactful +ve effect	Slight or indirect +ve effect	Has no effect	-ve effect in certain cases	-ve effect

KEY: Other attributes	+ve impact	Some impact	Little impact	No impact	-ve impact	Strong -ve impact

Fig 104: Metrics matrix (suggested target metrics shown a solid blue rectangle and potential metrics to report identified with a dashed rectangle)

The matrix gives some pointers to the combination of metrics that may be appropriate:

- space heating demand
- net energy consumption
- peak load/load shifting

Which do not align fully with the metrics used for Part L 2021. Further reflection and analysis on this important aspect of the regulations will be required. Unintended consequences would need to be comprehensively checked, especially the net energy consumption metric, to determine which technologies and desirable outcomes would and would not be driven.

Target setting approach

Within Part L 2021, the target for each of the three metrics used is set via a concurrent notional dwelling. This a dwelling of the same size, shape and orientation as the actual dwelling, but with an elemental reference specification applied. A concurrent notional dwelling was also used for Part L 2013.

Part L 2010 & 2006, by contrast, used a historic notional dwelling, with the target set by applying a percentage improvement. The work group agreed that using a historic notional is not a useful way to create the target, as a percentage improvement disadvantages the most efficient forms (eg apartments) and is typically easier to meet by the least efficient forms (detached homes).

A Task Group run by the Zero Carbon Hub[29] has previously recommended that Part L targets should be set in absolute terms. This recommendation was not implemented at a national level. However, there are examples of Local Authorities setting local targets this way, Passivhaus performance is set as an absolute standard, and LETI, RIBA, CIBSE (and others) have all recently promoted the move towards energy use intensity (EUI) in kWh/m².yr

A key difference between the two approaches is the absolute approach takes into account the form and orientation of the dwelling and the concurrent notional does not.

[29] *Carbon Compliance for tomorrow's new homes: A review of the modelling tool and assumptions – Overview of findings and recommendations, Zero Carbon Hub, July 2010*

Form factor

Whilst the absolute metric encourages an efficient form, what is the magnitude of this effect? There are some observations in an NHBC Foundation document looking at shape and form[30].

Different archetypes inherently have different form factors as illustrated in Fig 105.

	Type	Form Factor	Efficiency
	End mid-floor apartment	0.8	Most efficient
	Mid-terrace house	1.7	
	Semi-detached house	2.1	
	Detached house	2.5	
	Bungalow	3.0	Least efficient

Fig 105: Illustration of change in form factor by dwelling type (source: NHBC Foundation, NF72)

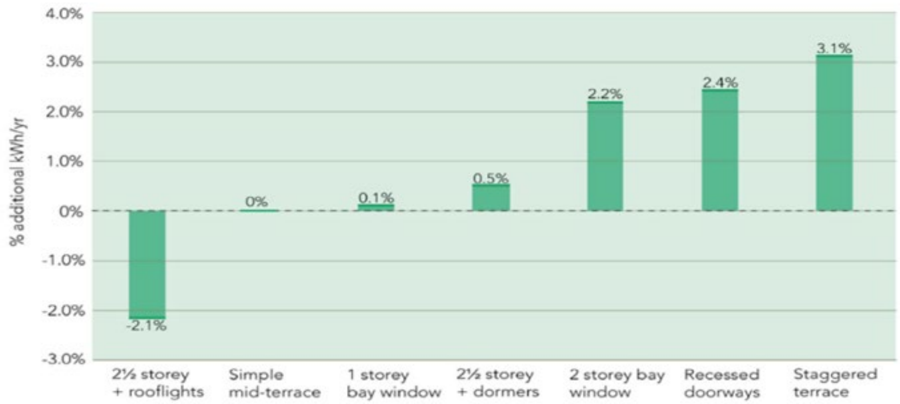
As the form factor increases across different archetypes, the energy efficiency decreases.

Within a particular archetype, design choices will drive a slightly higher or lower form factor, which also influences the space heating demand.

For a mid terrace home, the percentage change in space heating demand caused by incorporating different design elements is illustrated in the following page.

[30] *NF72 - The challenge of shape and form: Understanding the benefits of efficient design, NHBC Foundation, 2016*

Mid terrace home: percentage change in space heating demand with different design elements



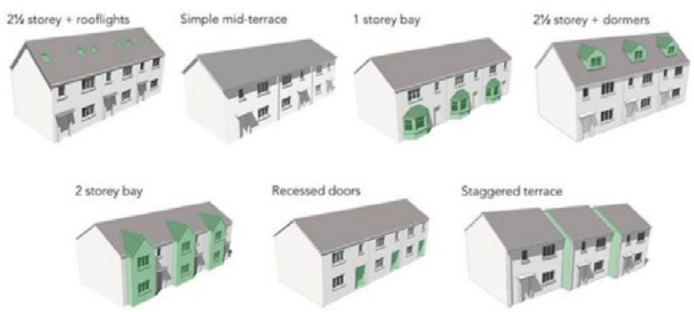


Fig 106: Change in space heating demand with different design elements, mid terrace house (source: NHBC Foundation, NF72)

This shows just over 5% variation in space heating demand across the different mid terrace home designs as measured by SAP.

To help understand the significance, the graph below shows the space heating demand variation across Contender Specifications, compared to CS3, including some variants to CS3.

These variants are:

- CS3 Square = same m² but with a square footprint
- CS3 Wide = footprint rotated by 90deg so is wide and shallow(the original CS3 is narrow and long) increasing the exposed area.
- CS3+air4 = CS3 with air permeability at 4 (rather than 3)
- CS3+air5 = CS3 with air permeability at 5 (rather than 3)
- CS3+dMEV = CS3 with MVHR replaced by dMEV (air permeability at 3)
- CS3+dMEV+air4.5 = CS3 with MVHR replace by dMEV and air permeability at 4.5 (rather than 3)

This shows, for this particular dwelling:

- the inefficiencies created by moving from a narrow to a wide end terrace are approximately equivalent to increasing the air permeability by 1m³/hr.m²@50Pa, circa 20% increase in space heating demand.
- the differences in specification between CS2, CS3 & CS4 have a far more significant effect on space heating demand than the change in form.
- The 5% reduction associated with dormers and bay windows is small in comparison.
- However, the impact of form will become increasingly more significant for higher performing homes.

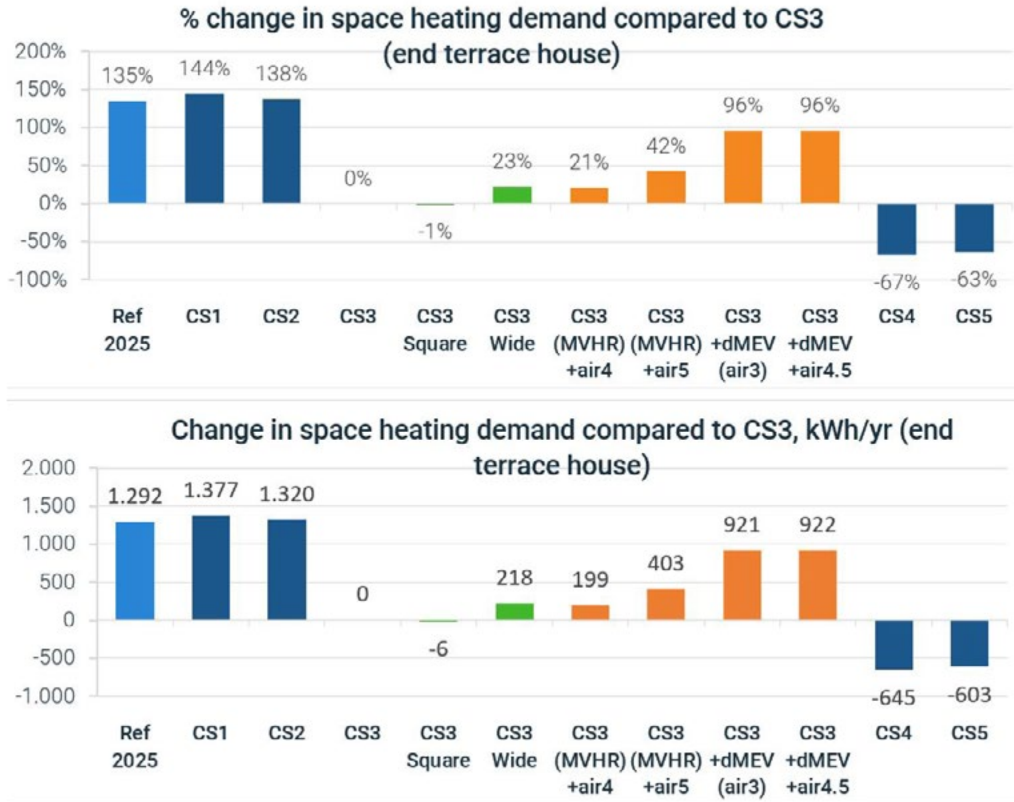


Fig 107: Percentage and absolute change in space heating demand compared to CS3 - End terrace house (SAP10.2 modelling results)

Attributes of different ways of setting the target

The advantages and disadvantage of setting the target via either a concurrent notional dwelling or at an absolute level were brainstormed by the group and shown in the tables below.

Concurrent Notional Standard

Where the target is derived from an elemental specification applied to a building of the same size, shape and form as the actual dwelling design.

Advantages	Disadvantages
• Flexibility for constrained sites & planning requirements (bay windows & dormers not penalised) • Allows same spec across house types – standardisation for construction • Known to be achievable as it is an actual specification. • Notional dwelling is itself a compliant solution (helps small builders?) – but only if all elements are achievable e.g. psi values & system efficiencies etc. • In combination with the model, can give an output which could be measured post-construction • Reduces the impact of input error in SAP (error is on both the target setting and means to achieve so broadly cancel out) • Familiar approach – used in current regulations [maintain status quo to allow continuity and direct comparability]	• No benefit for inherently more efficient built forms, so does not encourage this • Not intuitive. Concept which only experts understand • Does not use a stable metric for target setting • Cannot be measured directly post-construction (but a measure that could be measured, can be an output from SAP) • Not easy to predict delivered outcome (e.g energy/ carbon outcome). Lack of precision inhibits local energy planning. • Less compatible with absolute zero carbon target (less visibly consistent with policy objectives) • Complex to derive all aspects of notional dwelling (e.g. where to set system efficiencies, psi values etc) • Applying a % reduction to drive higher standards can be problematic

Absolute Standard

Where the target is the target

Advantages	Disadvantages
• Promotes efficient form (but differences between different house types larger than differences within a house type, so depends how level(s) are set) • Understandable – a single figure(s) • Greater perceived flexibility to meet the target • Able to link to national targets/ standards • Easy to state targets (& provide trajectory for change) • Energy metric measurable in use (link to householder expectations) • Easy to derive overall energy performance of dwelling • Stable metric	• Different element specifications required for different forms & house types – more difficult to manage across a site • Depending on level set, may be some forms which cannot be built • Hard to set level simply and fairly (but less variance across house types as performance increases) • If the calculation method changes then the target may need adjusting • Any calculation input errors may be problematic

Setting an absolute standard

One of the reasons the Zero Carbon Hub, recommendation for an absolute standard was not taken forward was the difficultly in defining where the level should be set so it was 'fair' across the range of archetypes. A single level was problematic as it was either too hard for one archetype or too weak for another although guidance has been produced to assist this[31].

The graph below shows how the space heating demand per m² varies between house types for four different specifications modelled in SAP10.2. This demonstrates that the difference between archetypes reduces as the absolute performance improves. However, house types with more extreme form factors, such as a bungalow, may still require particularly high performing fabric to comply or start to rely on solar orientation.

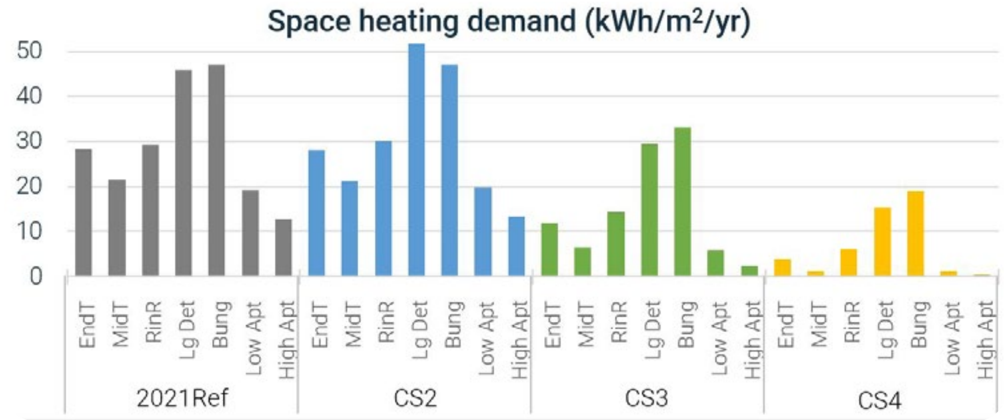


Fig 108: Space heating demand of different archetypes for selection of specifications (SAP10.2 modelling results)

As the graph above shows, selecting a particular kWh means some archetypes would need to 'work harder' and others may 'take a step back'.

For example, if a single level of 15kWh/m²/yr were chosen: the end terrace would be approaching CS3 performance, the mid terrace halfway between CS2 and CS3, the Room in Roof at CS3, large detached at CS4 & bungalow possibly at CS5 (or possibly solar orientated with CS4), the low apartments at the 2021Ref and the high rise may be at 2013 levels of performance.

If an absolute standard were to be considered for FHS2025, further work would need to be undertaken to derive a target, or set of targets for different archetypes, once the desired general level of energy performance is decided.

Setting and concurrent notional standard

If the concurrent notional approach to setting the standard were to be taken forward for FHS2025, then any one of the contender specifications used as part of this work (or indeed a hybrid) could be turned into a notional dwelling with due consideration to the values of certain critical items (such as psi values, efficiencies, PV area, etc). Medium and high-rise apartment blocks should have a different notional building due to differences in the construction type, services strategy, and restrictions on materials which can be used compared to low-rise properties.

Setting a concurrent notional standard with an absolute backstop

To address some of the inherent complexities of setting absolute standard whilst also tackling the concurrent notional approaches inability to encourage better form factors, a combination of the two might be considered. Examples:

- a concurrent notional based on CS2 with an absolute limit of 30kWh/m²/yr

The End Terrace, Mid Terrace, Room in Roof, Low-rise Apartment, High-rise Apartment would see space heating limited by the concurrent notional and the Large Detached and Bungalow space heating would be limited by the absolute limit.

[31] https://www.cibse.org/media/hbhlcx3t/2205-cibse-briefing-setting-energy-targets-in-planning-policy-rev1.pdf

Householder perspective

Most householders are likely to be much more interested in the home's energy performance in terms they understand - the expected size of their energy bills. The current EPC rating attempts to present a standardised energy cost, utilising a simple A to G scale. There are several immediate problems with this: it only takes into account regulated energy, uses out-of-date energy cost data, and is based on 'average' usage. This means that the costs derived for the rating bears no relation to the energy bills a householder will receive from their provider.

With energy price volatility, increasing use of 'time-of-use' tariffs overlayed onto the varied ways people live in their homes, the amount of hot water used, how much they cook and devices they plug in means energy use is very complicated to convey.

However, energy modelling will exist and could be made available to all home buyers to choose their own use and tariff assumptions and utilise current energy costs. The output would be very simple and clear – an expected total energy bill. It would be robust and be based on the homebuyer's inputs. A standardised EPC output could still be generated for Government's 'stock' reporting.

The 'expected energy bill' calculation could also be available for existing homes with similar functionality based on the RdSAP model (used to generate the EPC) to provide fair comparison.

This would both inform the home buyer and protect the housebuilder from the misunderstandings the current 'static' EPC creates. (See also 'Understanding energy performance' section of the consumer chapter 17 for further information).

National 'average' vs Regional weather

All new dwellings are currently modelled with the assumed weather of the East Pennines region for compliance purposes (national 'average' weather). This is also the case for the EPC[32].
This makes it easier to compare the specification of dwellings in different locations, from a policy perspective, and allows national housebuilders to have a single specification across the country. However, for the householder, the actual performance at the real location could be very different (e.g. NE England vs SW England), and the current set up does not encourage housebuilders to consider the impact of specification choices at the local level.

Three combinations were considered:

National Standard & National Weather (current situation)

- Same specification no matter which region
- Different experiences for householder (energy cost) – higher bills N, lower bills S

National Standard & Regional Weather

- Specification would differ regionally (less onerous S, more onerous N)
- More comparable experience for householder (energy cost)

Regional Standard & Regional Weather

- Impact would depend on how regional standards are set

The work group observed that deciding which combination is best depends on the desired outcome. Is the purpose to maintain the same dwelling specification across all geographies or is it to deliver the same energy bills? Different work group members had different views.

Where there was agreement, was the EPC should reflect the energy performance of the particular dwelling in its actual location.

[32] *although the recommendations / potential cost savings do use the actual location*

CS energy analysis

Introduction

Return to: Grid Chapter

To provide easy comparison between the Contender Specifications, this section takes the example of the end terrace archetype and a series of results from the SAP10.2 modelling across all specifications.

Note: the final modelling for FHS2025 will use SAP11, rather than SAP10.2, which will allow additional factors to be considered such as load shifting. SAP11 will produce different results for all CSs to a greater or lesser extent. CS2a and CS5s, in particular, are poorly represented in SAP10.2 so the information shown here should be considered with these limitations in mind.

Modelling work undertaken

Specifications

All Contender Specifications (CS1, CS2, CS2a, CS3, CS4 & CS5) needed to be modelled, along with reference specifications for 2021[33] & 2013[34] Part L compliance, plus the draft notional 2025 specification published in the Government's response to the Future Homes Standard consultation[35] .

(An overview of each of these specifications can be found in Approach. Full details of each specification can be found in Appendix D).

Archetypes

WG1 came up with a shortlist of dwelling archetypes to model, which were then prioritised into primary, secondary and tertiary types. Given the timescales of this project, only the primary set of archetypes have been modelled. They have been chosen not to represent the average of what is being built, but to test the contender specifications with a broad spread of designs and sizes. (Details of the archetypes modelled can be found in Approach).

All dwellings modelled were checked against Part O 2021 compliance using either the simplified or dynamic method.

Construction type

It was intended to model houses and low-rise apartments in both masonry construction and timber frame, with high-rise apartments modelled in RC frame. The timber frame modelling was not undertaken due to time constraints.

Variants to heat delivery in high-rise apartments

Modelling of a communal system variant to heat delivery for the high-rise apartments was planned, but due to time constraints it was not possible to include.

SAP tool

Elmhurst Design SAP 10 was used for the modelling work. Results have been updated following software update of 23rd Jan 2023.

Results

This chapter summarises the results from the energy modelling work.

Consolidated tables of outputs for each specification and archetype can be found in Appendix F.

The abbreviations used in the graphs in this section refer to the following:

- Ref2021: Specification which achieves compliance with Part L 2021 using a gas boiler (based on example specifications in Part L 2021 Where to Start guide by the Future Homes Hub)
- Ref2025: Draft 2025 specification as published by Government in the consultation response to the Future Homes Standard
- CS1-5: Contender Specifications as detailed in this report

[33] *To allow comparisons with current regulations*

[34] *To allow comparisons with the Government's published ambition of the FHS achieving at least a 75% reduction in CO2 emissions compared with 2013 standards*

[35] *Specification taken from Table A in: The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings, Summary of responses received and Government response, January 2021*

Metrics used in current Part L regulations

Fabric energy efficiency (DFEE)

CS1, CS2 & CS2a have a DFEE broadly the same as Ref2021. Ref2025 and CS3 have similar DFEE, slightly reduced from Ref2021. CS4 & CS5 show the greatest improvement in DFEE of approx. 33% from Ref2021.

Within any given specification there is significant variation in DFEE across the archetypes.

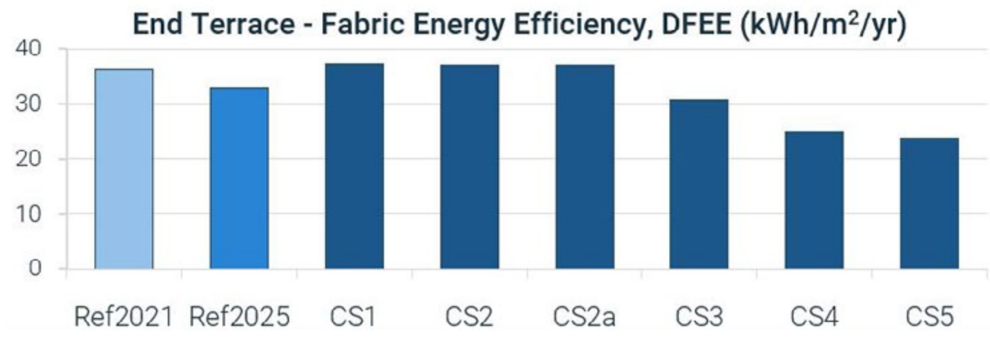


Fig 109: Fabric Energy Efficiency, DFEE - End terrace house

Fabric Energy Efficiency, DFEE (kWh/m²/yr)							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	36.3	29.2	38.2	52.1	55.9	27.3	19.3
Ref 2025	32.9	25.1	32.5	43.6	51.0	21.0	13.5
CS1	37.4	29.8	38.7	52.5	61.5	29.0	21.4
CS2	37.0	30.0	38.2	52.1	55.9	27.3	19.3
CS2a	37.0	30.0	38.2	52.1	55.9	27.3	19.3
CS3	30.8	24.9	33.5	46.7	53.3	22.3	18.0
CS4	25.0	20.0	27.9	39.1	43.3	18.3	14.1
CS5	23.9	18.6	25.6	36.1	39.2	17.6	*

Note that the calculation of Fabric Energy Efficiency does not take into account the effect of any mechanical ventilation systems in the design.
* Unable to be modelled in SAP10.2

Fig 110: Fabric Energy Efficiency, DFEE, for all archetypes and specifications

Carbon emissions (DER)

All specifications show significant reductions in carbon emissions compared to Ref2021, with CS5 being net zero carbon for regulated energy for this end terrace house, and CS4 & CS3 being practically zero and CS2 not far off. CS1 emissions are similar to Ref2025, with CS2a marginally higher.

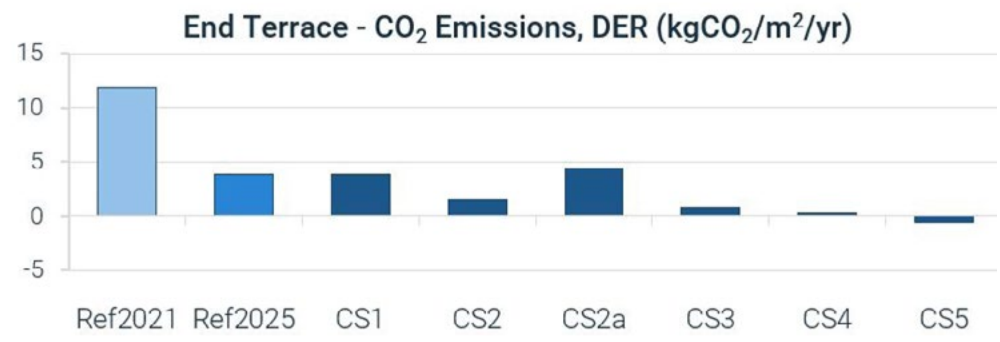


Fig 111: CO2 emissions, DER - End terrace house

Across the archetypes modelled, emissions are very low for all CSs compared to Ref2021. There is slight variation in emissions across architypes within each specification

Fabric Energy Efficiency, DFEE ($kWh/m^2/yr$)							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	11.8	10.2	10.8	10.3	11.8	11.9	12.1
Ref 2025	3.8	3.4	4.4	3.3	4.5	3.5	3.0
CS1	3.9	3.5	3.6	3.5	4.9	4.0	3.7
CS2	1.4	1.1	2.7	2.7	2.2	2.8	3.3
CS2a	4.4	3.4	6.4	6.5	7.2	5.5	6.9
CS3	0.8	0.4	1.8	2.3	1.7	1.0	2.0
CS4	0.3	0.0	1.3	1.6	0.9	0.2	1.7
CS5	- 0.5	- 0.7	0.2	0.9	- 0.6	0.6	*
* Unable to be modelled in SAP10.2							

Fig 112: CO2 emissions, DER, for all archetypes and specifications

Primary Energy

All specifications show at least a 33% reduction in primary energy rate from Ref2021 for the end terrace house. CS1 has a DPER broadly the same as Ref2025. CS2a shows a further reduction, with CS2 approximately half of CS2a. CS3 is lower still, with CS4 & CS5 showing the greatest improvement in DPER of approx. 93% from Ref2021.

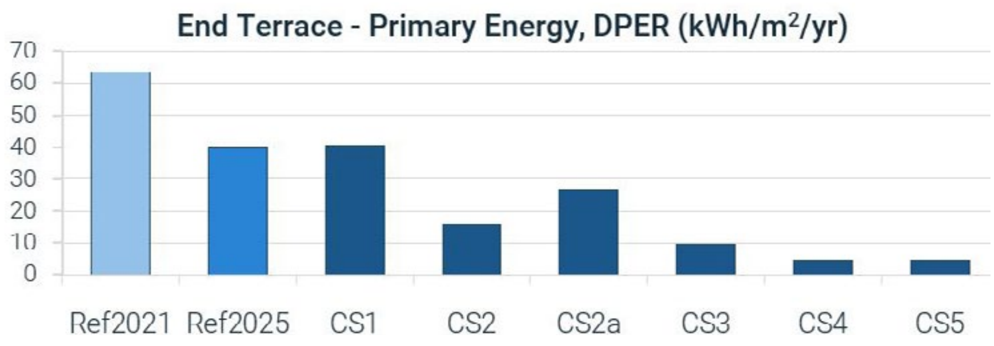


Fig 113: Primary energy, DPER - End terrace house

Level of ambition

Carbon emissions reduction from 2013 regs

For the end terrace house, all specifications broadly meet or go further than the Government's previously stated ambition of a minimum 75% carbon emissions reduction from 2013 regulations.

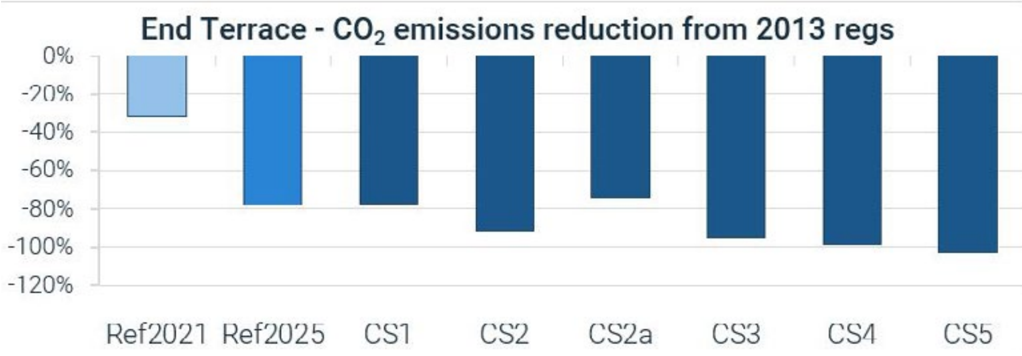


Fig 114: CO2 emissions reduction from 2013 regs - End terrace house

Apart from CS2a, all CSs meet the 75% ambition across all archetypes modelled.

CO2 emissions reduction from 2013 regs *							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	32%	34%	28%	28%	41%	28%	23%
Ref 2025	78%	78%	71%	77%	78%	79%	81%
CS1	78%	77%	76%	75%	76%	76%	76%
CS2	92%	93%	82%	81%	89%	83%	79%
CS2a	74%	78%	58%	55%	64%	67%	56%
CS3	95%	98%	88%	84%	91%	94%	87%
CS4	98%	100%	92%	89%	96%	99%	89%
CS5	103%	105%	99%	94%	103%	97%	*

* 2013 Ref CO2 emissions figure obtained by modelling each housetype in SAP2012 to achieve compliance (with gas boiler) and then modelling that 2013 specification in SAP10.2 (with shower flow rate of 11l/min).
* Unable to be modelled in SAP10.2

Fig 115: CO2 emission reduction from 2013 regs, for all archetypes and specifications

Energy demand and consumption

Space heating demand

In this context, space heating demand refers to the required kWh heat input into a dwelling in order to maintain the comfort temperature (as per SAP methodology).

Space heating demand is broadly the same for Ref2021, Ref2025, CS1, CS2 & CS2a. CS3 shows a significant reduction of almost 60% from Ref2021. CS4 & CS5 reduce space heating demand to very low levels, showing approx. 85% reduction from 2021Ref.

To investigate the impact of the ventilation heat recovery used on CS3, CS4 & CS5, three variants on CS3 spec are shown in the second graph. The base CS3 specification has an air permeability of 3m³/hr.m² @50Pa. Variants are shown with this increased to 4 and 5. A variant is also shown to the base CS3 specification with MVHR replaced by dMEV (as used in CS1 & CS2).

This indicates that the space heating demand reduction seen for CS3 is primarily due to the use of heat recovery ventilation rather than improved air permeability or fabric U-values. This is demonstrated by CS3 with dMEV rather than MVHR, giving an 18% demand reduction from Ref 2021 (compared to 58% for the base CS3 spec with MVHR).

As would be expected, CS3 with worse air permeability correlates with slightly increased space heating demand. Stepping from CS2 to CS3, the fabric changes make up approx. 30% of the difference, heat recovery ventilation makes up approx. 50% and air tightness makes up approx. 20%.

Note that although CS5 is a "no heating" specification, SAP10.2 is not able to reflect this.

Fig 116: Space heating demand - End terrace house

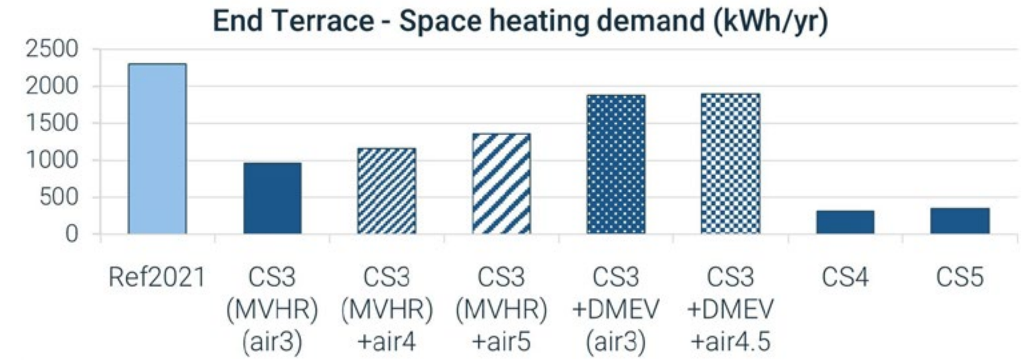


Fig 117: Space heating demand for variant specifications - End terrace house

Space heating demand (kWh/yr)							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	2,301	1,751	3,295	11,299	4,606	1,136	671
Ref 2025	2,251	1,617	3,200	10,660	4,483	957	360
CS1	2,335	1,707	3,428	12,841	5,248	1,285	732
CS2	2,279	1,720	3,378	12,722	4,601	1,165	694
CS2a	2,315	1,765	3,375	11,393	4,530	1,093	636
CS3	958	525	1,619	7,246	3,231	349	124
CS4	313	95	685	3,768	1,848	67	7
CS5	355	103	712	3,681	1,660	59	*
* Unable to be modelled in SAP10.2							

Fig 118: Space heating demand, for all archetypes and specifications, total per annum

Space heating demand (kWh/m²/yr)							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	28	22	29	46	47	19	13
Ref 2025	28	20	28	43	46	16	7
CS1	29	21	30	52	54	22	14
CS2	28	21	30	52	47	20	13
CS2a	28	22	30	46	46	18	12
CS3	12	6	14	29	33	6	2
CS4	4	1	6	15	19	1	0
CS5	4	1	6	15	17	1	*
* Unable to be modelled in SAP10.2							

Fig 119: Space heating demand, for all archetypes and specifications, per m² per annum

Regulated energy consumption, kWh/yr

This graph shows energy consumption by use across each of the Contender Specifications alongside PV energy production. Apart from CS2a, all specifications show a significant decrease in regulated energy consumption compared to Ref2021.

Ref2025 and CS1 have very similar energy consumption. CS2 has slightly reduced energy consumption, with CS3, CS4 & CS5 lower still. The PV energy production for CS5 is higher than the regulated energy demand of the dwelling. CS2a requires more than double the amount of energy than the other CSs, and has more than double the PV energy production.

As you move across the specifications, it can be seen that hot water becomes the overriding contributor to regulated energy consumption for CS3, CS4 and CS5 (reflecting the reduced space heating demand for these specifications).

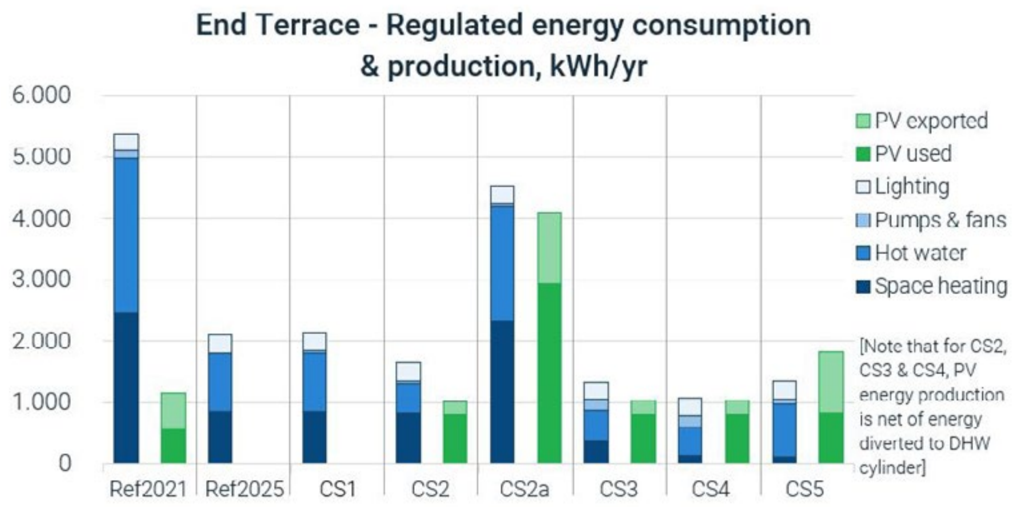


Fig 120: Breakdown of regulated energy consumption & production - End terrace house

Energy consumption (regulated energy only), kWh/yr *							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	5,390	4,760	7,060	16,270	7,930	3,730	3,080
Ref 2025	2,100	1,910	3,340	5,320	2,910	1,430	1,080
CS1	2,130	1,950	3,500	6,170	3,180	2,140	1,520
CS2	1,640	1,450	2,960	5,530	2,520	1,890	1,360
CS2a	4,530	3,930	6,240	14,000	6,950	3,270	2,710
CS3	1,340	1,110	2,350	5,030	2,260	1,180	850
CS4	1,070	930	1,960	3,930	1,720	900	730
CS5	1,350	1,230	1,780	3,560	1,820	1,060	**

* Includes energy for space heating, hot water, pumps & fans and lighting
* Includes gas & electricity consumption for Ref 2021; the other specs are all electric
** Unable to be modelled in SAP10.2

Fig 121: Regulated energy consumption, for all archetypes and specifications, total per annum

Energy consumption (regulated energy only), kWh/m²/yr *							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	66	59	63	66	81	63	59
Ref 2025	26	23	30	22	30	24	21
CS1	26	24	31	25	33	36	29
CS2	20	18	26	22	26	32	26
CS2a	56	48	55	57	71	55	52
CS3	16	14	21	20	23	20	16
CS4	13	11	17	16	18	15	14
CS5	17	15	16	14	19	18	**

* Includes energy for space heating, hot water, pumps & fans and lighting
* Includes gas & electricity consumption for Ref 2021; the other specs are all electric
** Unable to be modelled in SAP10.2

Fig 122: Regulated energy consumption, for all archetypes and specifications, per m² per annum

Householder aspects

Energy bill implications

All specifications except Ref2025 and CS1 show reduced energy bills compared to Ref2021 for the end terrace house. This is primarily due to there being no PV on Ref2025 or CS1 for this archetype.

For CS2a, the savings are minimal compared with the savings for CS2, CS3, CS4 & CS5.

Note that for CS3, CS4 & CS5 there would be an additional maintenance cost of approx. £80/yr for the MVHR unit, compared to the other specifications. This would mean that for these CSs the overall cost savings to the householder would be less than the bill change shown in the graph. This would make the overall savings for CS3 approximately equivalent to CS2, with CS4 & CS5 still giving the lowest overall cost.

Note that all contender and reference specifications would benefit from time-of-use tariffs to reduce energy costs, particularly CS2a which includes a battery. However, this cannot be modelled within SAP10.2.

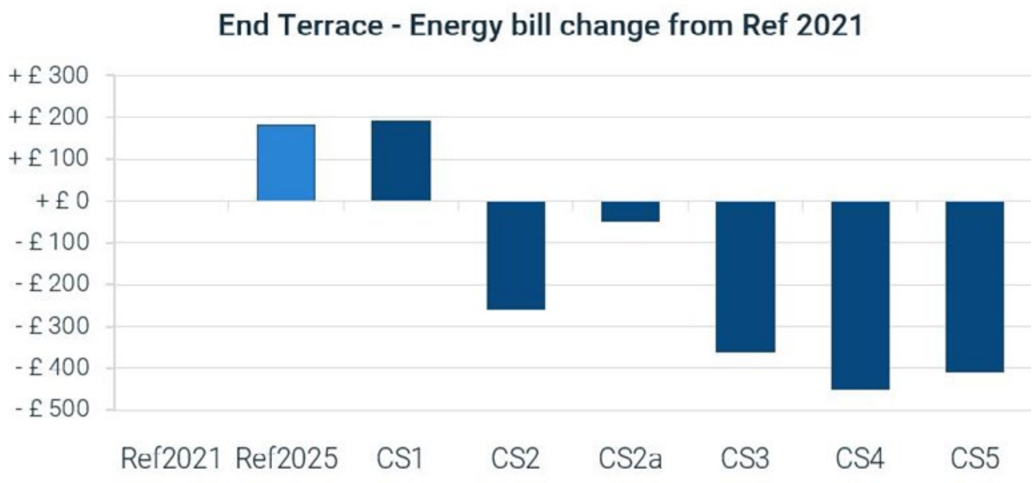


Fig 123: Energy bill change compared to Ref2021 - End terrace house

Energy bill (regulated energy only), £/yr *							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	£ 700	£ 630	£ 780	£ 1,210	£ 650	£ 620	£ 650
Ref 2025	£ 880	£ 820	£ 1,300	£ 1,980	£ 1,160	£ 650	£ 530
CS1	£ 890	£ 830	£ 1,140	£ 2,140	£ 1,250	£ 750	£ 620
CS2	£ 440	£ 380	£ 860	£ 1,610	£ 660	£ 620	£ 570
CS2a	£ 650	£ 460	£ 1,730	£ 3,150	£ 1,430	£ 870	£ 1,000
CS3	£ 340	£ 260	£ 650	£ 1,430	£ 570	£ 380	£ 420
CS4	£ 250	£ 200	£ 520	£ 1,060	£ 390	£ 290	£ 380
CS5	£ 290	£ 260	£ 420	£ 890	£ 350	£ 340	++

* Energy costs calculated based on SAP10.2 energy consumption figures at October 2022 Price Guarantee tariffs and standing charges, with smart export guarantee for PV exported to grid.
* Includes energy for space heating, hot water, pumps & fans and lighting, plus benefit from PV used in dwelling and PV exported (where included in spec)
* Note that Ref 2021 values are relatively low for Large detached and Bungalow. This is due to Part L 2021 requiring very large PV arrays on these particular dwellings as they have a large ground floor area.
* Note that energy costs do not include savings from load shifting as this was not possible to model
\+ CS2a is particular impacted by the limitations of SAP10.2 as the philosophy relies on load shifting and PV to reduce householders bills so these costs will be over stated.
++ Unable to be modelled in SAP10.2

Fig 124: Predicted energy bill (regulated energy only) for all archetypes and specifications

EPC Rating

The EPC rating of all end terrace properties across the specifications is B or better. A-rating is achieved for CS2, CS2a, CS3, CS4 & CS5.

The table below shows that the majority of the archetypes achieve A or B-rating across the specifications, except for CS1, where the bungalow is C-rated and for CS2a where the room-in-roof semi, large detached, bungalow, and high-rise apartment are C-rated.

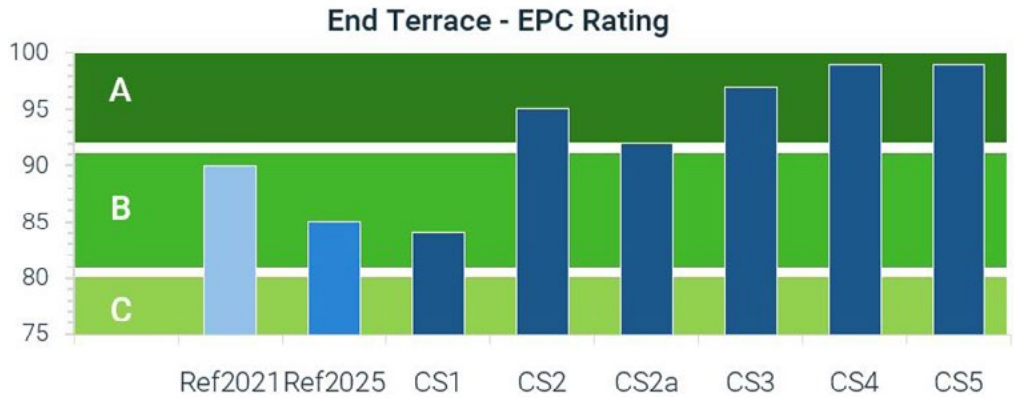


Fig 125: EPC Rating - End terrace house

EPC Rating							
Spec	End terrace	Mid terrace	Room in Roof (semi)	Large detached	Detached bungalow	Mid floor low-rise apt.	Mid floor high-rise apt.
Ref 2021	90 B	92 A	92 A	96 A	97 A	85 B	86 B
Ref 2025	85 B	86 B	80 C	83 B	81 B	87 B	90 B
CS1	84 B	86 B	83 B	81 B	79 C	86 B	86 B
CS2	95 A	96 A	88 B	86 B	91 B	90 B	88 B
CS2a	92 A	96 A	74 C	73 C	78 C	83 B	74 C
CS3	97 A	98 A	92 A	88 B	93 A	96 A	92 A
CS4	99 A	100 A	94 A	92 A	96 A	98 A	93 A
CS5	99 A	100 A	97 A	94 A	99 A	96 A	*

* Unable to be modelled in SAP10.2

Fig 126: EPC Rating, for all archetypes and specifications

Grid

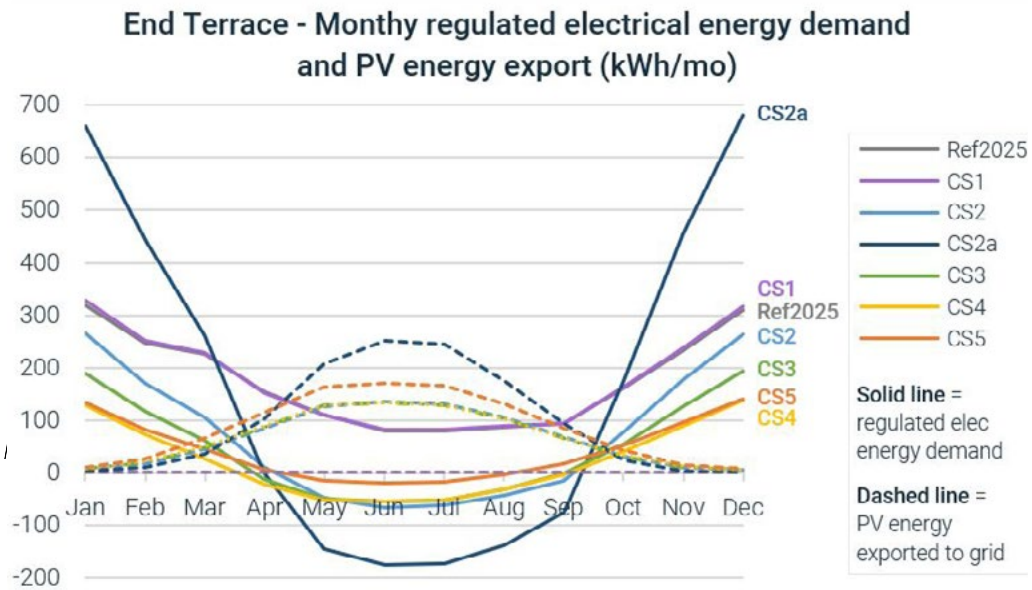
Dwelling level implications

The Grid work group advised that, at a development level, the scale of the space heating demand difference across the CSs makes little difference when compared with the other loads which need to be accommodated such as PV export, dwelling small power and EV charging.

The graph below shows grid electrical energy demand (for regulated energy) and PV energy export across the year for the end terrace house across the different specifications.

CS2a has double the grid energy requirements in winter months than Ref2025 and CS1, and exports significantly during the summer months (when PV generation is high and own consumption is low).

CS3, CS4 & CS5 show the lowest overall grid energy requirements. CS5 energy demand is likely overstated due to the limitations of SAP10.2 to model very low energy homes.



National scale grid implications

The Grid work group noted that the differences between CSs would have a considerable impact at a national level. In order to understand what 'considerable' might be, the energy consumption of a representative mix of homes for each contender specification was compared with the 2025 Ref, scaled up to the Government's aspiration of 300,000 new homes per annum. This was then compared with the output of the proposed Sizewell C nuclear power station and the output of the world's largest offshore wind farm (Hornsea2, off the Yorkshire coast in the North Sea).

All contender specifications make savings over 2025 Ref by varying degrees.

CS2a and CS5 have not been modelled due to the limitations of SAP10.2

	CS1 compared with Ref2025	CS2 compared with Ref2025	CS3 compared with Ref2025	CS4 compared with Ref2025
National electricity generation savings compared with 2025 Ref (GWh/yr)	46	424	577	617
Number of years to save equivalent energy to one Sizewell C power station	376	41	30	28
Number of years to save equivalent energy to Hornsea2 offshore wind farm	88	10	7	7

* Modelled based on Government's new homes aspiration of 300,000 built per year
* Uses an illustrative build mix
* Sizewell C has stated capacity of 3.2GW, sufficient to supply 6m homes (EDF web statement) – converted to GWh/yr output using OFGEM average household elec energy use of 2,900kWh/yr
* Hornsea 2 offshore wind farm is the world's largest and consists of 165 no. 8MW turbines, sufficient to supply 1.4m homes (Orsted web statement) – converted to GWh/yr output using OFGEM average household elec energy use of 2,900kWh/yr.

Fig 128: Electricity demand compared with Ref2025, at a national scale

Glossary

ADMD - After Diversity Maximum Demand
After Diversity Maximum Demand calculation used by DNO/IDNO to estimate the required load from housing developments.

Air Barrier
An air barrier controls air leakage into and out of the building envelope. This is usually in the form of a membrane. (ADL)

Air permeability
The measure of air flow which passes through a given area of fabric.

ASHP - Air Source Heat Pump
A renewable energy technology which uses the warmth from external air to provide space and water heating in the home.

Airtightness
The resistance of the building envelope to infiltration when ventilators are closed. The greater the airtightness at a given pressure difference across the envelope, the lower the infiltration. (ADL)

Ambient Loop
A pipe network transporting low temperature heat between multiple dwellings or premises in a building or area.

Building automation and control system
A system comprising all products, software and engineering services that can support energy efficient, economical and safe operation of heating, ventilation and air conditioning systems and on-site electricity generation through automatic controls and by facilitating the manual management of those building systems. (ADL)

Building envelope
Physical barriers which separate the internal dwelling and the outside environment (walls, floor, roof, windows etc.).

Built form
The shape of the building. Buildings with more complex geometries can have higher rates of heat loss, making it harder to achieve high levels of fabric energy efficiency.

CHP – Combined heat and power or 'Cogeneration'
A process to use the heat arising from electricity generation, sometimes at building or community scale.

COP - Coefficient of performance
A measure of the efficiency of a heat pump at specified source and sink temperatures.

Heating COP = heat output / power input.
% COP (COP x 100) is the heat generator efficiency. (ADL)

Commissioning
When, after all or part of a fixed building service or on-site electricity generation system has been installed, replaced or altered, the system is taken from a state of static completion to working order. Testing and adjusting are carried out to ensure the system uses no more fuel and power than is reasonable in the circumstances or, in the case of on-site electricity generation systems, that electricity generation is maximised. (Adapted from ADL)

Community heating scheme
A system that supplies heat from a central source to more than one dwelling or premises within a single building. (ADL)

Contender Specification
In the context of this report, a set of specifications in terms of fabric standards and defined technologies that stakeholders believe could be used as the basis of setting the level of ambition for the 2025 Future Homes Standard regulations.

Controlled service or fitting
Defined in regulation 2(1) [of building regulations legislation] as a service or fitting in relation to which Part G [sanitation, hot water safety and water efficiency], H [drainage and waste disposal], J [combustion appliances and fuel storage systems], L [conservation of fuel and power] or P [electrical safety] of Schedule 1 imposes a requirement. (ADL)

Cooling load
The rate at which heat is removed from the space to maintain a desired air temperature. (ADL)

District heat network
A system to supply heat from a central source to consumers, via a network of underground pipes carrying hot water. Heat networks can cover a large area or even an entire city, or can be relatively local, supplying a small cluster of buildings. (ADL)

DHW - Domestic Hot Water
The system which delivers hot water to fixtures such as sinks and showers.

dMEV – Decentralised Mechanical Extract Ventilation
A whole house ventilation method which consists of low energy, continuous running fans and background ventilators.

Dwelling
A self-contained unit designed to accommodate a single household. (ADL)

EAHP - Exhaust Air Heat Pump
A renewable energy technology which uses the warmth from a ventilation system to provide heat in the home

EPC - Energy performance certificate
A regulated document that must be produced at home sale or rental. It summarises and rates the home's energy efficiency – identifying areas in which it can be improved.

Envelope area
The total area of all floors, walls and ceilings bordering the internal volume. (ADL)

Fixed building service
Any part of, or any controls associated with: fixed internal or external lighting systems; fixed systems for heating, hot water, air conditioning or mechanical ventilation (adapted from ADL)

Form Factor
The building's surface to volume ratio. Buildings with a higher ratio of thermal envelope surface area to floor area will tend to have a higher rate of a heat loss compared to other buildings of the same construction.

G99 Licence
A G99 license is required when connecting applications over 3.68kW to the grid

HIUs - Heat Interface Units
A set of controls that control interactions between a central boiler and any outlets in a heat network.

Heating zone
A conditioned area of a building which is on a single floor and has the same thermal characteristics and temperature control requirements throughout. (ADL)

IR - Infra-red heating or radiant heating
A heating method using infra-red radiation. Radiant heating directly warms objects or bodies, rather than the air around them.

Load compensation
A control function that maintains internal temperature by varying the flow temperature from the heat generator relative to the measured response of the heating system. (ADL)

Load switching
Using a mechanical or electronic system, to distribute the amount of power being used within a building throughout the day.

MVHR - Mechanical Ventilation with Heat Recovery
A system to provide fresh filtered air into a building whilst retaining most of the energy that has already been used in heating the building.

Notional building
A hypothetical building of the same type, size and shape as the building being designed. Building regulations Part L .guidance sets the fabric standards and energy related features of the notional building which is used to produce the TFEE, TER and TPER (calculated using SAP) which the actual dwelling needs to comply with.

PV – Solar photovoltaic panels
A renewable energy technology which uses sunlight to create electricity through solar cells.

Performance gap
The gap between the designed energy or carbon performance of the building, and its measured, in-use performance.

Primary energy
Energy, from renewable and non-renewable sources, that has not undergone any conversion or transformation process. (ADL) The Target Primary Energy Rate is set using the notional building approach

Regulated energy
Energy consumption resulting from fixed building features or fittings, such as heat pumps, hot water, ventilation, and lighting. (ADL)

Renewable technology
Technology that uses renewable resources, which are naturally replenished on a human timescale, to produce electricity. Resources include wind, wave, marine, hydro, biomass and solar. (ADL).

SAP – Standard Assessment Procedure
The official calculation methodology used in building regulations to measure home energy and carbon performance

TER – Target Emissions Rate
The TER is the maximum CO2 emission rate for the dwelling in Part L 2021. It is determined through SAP modelling of the notional building.

TFEE – Target Fabric Energy Efficiency
The TFEE is a measure of fabric energy efficiency of the dwelling in Part L 2021. It is determined through SAP modelling of the notional building.

Thermal bridging
Transfer of heat which occurs when part of a thermal element has significantly higher conductivity than surrounding materials. Identification, modelling and design of thermal bridges as part of house design improved fabric energy efficiency and helps prevent in-use cold and moisture problems.

TPER – Target Primary Energy Rate
The TPER is the maximum primary energy rate for the dwelling in Part L 2021. It is determined through SAP modelling of the notional building.

Transitional arrangements
The phasing around the timing of the introduction of new or updated building regulations requirements. Transitional arrangements are put in place by the Government to reduce the need for redesign of planned or in-construction buildings due to changed regulatory requirements.

Trickle vents
An opening in a window or other building envelope component to allow small amounts of ventilation in spaces intended to be naturally ventilated.

Seasonal Coefficient of performance
A measure of the efficiency of a heat pump over the designated heating season. (ADL)

Seasonal energy efficiency ratio
The total amount of cooling energy provided by a single cooling unit over a year, divided by the total energy input to that single cooling unit over the same year. (ADL)

Space cooling system
A system for cooling the temperature of the air in a space (ADL)

U-value
A measure of the ability of a building element or component to conduct heat from a warmer environment to a cooler environment. It is expressed as the quantity of heat (in watts) that will flow through 1m² of area divided by the difference in temperature (in degrees K) between the internal and external environment. The unit is W/(m² ·K). (ADL)

WWHR – Waste Water Heat Recovery
A system that transfers heat from outgoing, waste hot water used in showers etc., allowing the heat to be retained within the hot water system.

Weather compensation
A system which enables the operating flow temperature of a heating system to be varied. An external sensor communicates with one inside the boiler. (Adapted from ADL)

Wet heating system
When a heating appliance (usually a boiler) produces hot water which is distributed around the dwelling to heat emitters. (ADL)

Acknowledgement

Definitions identified as (ADL) are reproduced wholly or in part from Appendix A of the 2021 edition of Approved Document L, published by HM Government[36], available at: https://assets.publishing.service.gov.uk/Government/uploads/system/uploads/attachment_data/file/1099626/ADL1.pdf

Appendices

- **A** Terms of Reference [included in this document]
- **B** List of Work Groups [included in this document]
- **C** Large and small housebuilders 2021 challenges, solutions and 2025 lessons – full list [included in this document]
- **D** Detailed specifications modelled [included in this document]
- **E** Build cost data – Elemental analysis [included in this document]
- **F** SAP10.2 modelling results – by contender specification; by archetype; variants modelled [separate document]
- **G** Plotting implications analysis [separate document]
- **H** Role of Design Codes [separate document]

Appendix A - DLUHC Terms of Reference

Future Homes Hub FHS request**Refining the 2025 Future Homes Standard**

Future Homes Hub Task Group

Terms of Reference

25th August 2022

Introduction

The Government has committed to consulting on the Future Homes Standard in Spring 2023. The Government have committed that the Future Homes Standard will deliver zero carbon ready homes, with low carbon heating and high fabric standards, that will require no future retrofitting.

The development of such a flagship policy is necessarily complex and challenging, and there are many different aspects and questions to be explored and understood in order to support the development and refinement of a standard for consultation. Input from all stakeholders is crucial to achieving this.

The Future Homes Hub is proposing the establishment of a task group to consider and collect evidence to inform some of these questions and this paper outlines the key questions and context the Department for Levelling Up, Housing and Communities (DLUHC) would like support with and the proposed terms of reference.

Context

The timeline for developing the FHS specification is short. The DLUHC intend to launch a public consultation in Spring 2023. As part of the preparation for the consultation and the wider changes, DLUHC need to gather evidence and information which will inform policy proposals. DLUHC are looking to gather as much information as possible before the end of this year in order that there is adequate time to carry out detailed modelling and analysis and go through the required Government procedures before the public consultation.

As part of this information gathering, DLUHC are seeking evidence on particular questions and objectives that are integral to the policy development process, and obtaining this evidence by consulting stakeholders. The Hub can have a particular role to play in drawing on its sector representation to provide an evidenced view on the reality of implementation at scale, with a particular focus on the impact on SMEs. Details of each individual aspect are laid out below.

Questions / objectives for the Task Group and timings

1. Summarise what new technologies and approaches homebuilders are considering using to deliver the Future Homes Standard and the benefits and challenges of each.
    a. Have any homebuilders begun early designs of possible FHS homes? What technologies do these designs include?
    b. What technologies would you suggest are integrated into the notional building specification for the Future Homes Standard?

c. Using supporting evidence, provide a summary of the views of all stakeholders relating to the key technologies and techniques that could be used to meet the FHS. Provide insights on, but not limited to, the following areas:

i. The benefits (perceived and real)

ii. Consumer desirability

iii. Issues, impacts & potential solutions associated with:

1. Design
2. Installation
3. Skills
4. Supply chain
5. Upfront cost
6. Energy costs
7. Unintended effects

including, but not limited to, the following technologies:

8. Heat pumps
9. MVHR
10. Triple Glazing
11. Airtightness
12. Batteries (including electric & heat storage)
13. Smart Meters
14. PV
15. WWHR
16. MEV

2. What would the impact be, including pro and cons, for homebuilders of using form factors or absolute targets vs using a notional building specification?

a. How would a form factor make you design your house differently?

b. How would an absolute target make you design your house differently?

c. How challenging is it to redesign house types to make them more efficient, removing common aspects that are less efficient, such as dormers for example?

d. How could designs reduce complexity of form while retaining design freedom and in-keeping with the Government's aims of quality and building beautiful?

3. What are the key challenges you envisage in delivering 2025 FHS homes (over and above Part L 2021) In particular, are there any key risks around:

a. Consumer understanding?

b. Commissioning and installing services correctly?

c. Other?

4. Consider the impact of the 2021 uplift, in particular answering the following questions:
    a. How is the 2021 uplift landing with industry, outside of the issues we've experienced with SAP 10.2?
    b. What type of concerns have been raised?
    c. What lessons can we learn ahead of the 2025 Future Homes Standard?
    d. How have housebuilders responded to the introduction of the Pulse airtightness test? Have there been any issues or concerns raised?
5. Present your understanding of the 'needs' and 'wants' of consumers of modern newbuild housing.
    a. What new technologies are consumers looking for?
    b. What design features?
    c. Other elements?
    d. What consumer barriers are there to some of the technologies that could be in 2025 FHS?
    e. How can we better educate today's consumers about energy efficient homes and the technologies within them?

Out of Scope

6. The following areas are out of scope:
    a. Detailed modelling work or proposed detailed specifications although it is recognised that modelling may be required for sensitivity analysis to inform discussion. The key interest is the insight that the sector can provide around practical constraints and opportunities.
    b. Embodied and up-front carbon.
    c. Macro-level considerations beyond the housebuilding sector such as impact on the national grid although load shifting benefits inform discussion and sensitivity analysis.

Task Group structure

In order to provide a robust and considered view the Task Group should include a wide cross section of the house building industry including environmental, supply chain and consumer representatives.

Deliverables required

There are two deliverables to be produced by the Task Group:
    1. Factual notes following workshops / meetings as appropriate
    2. Final report by 15 December 2022

Appendix B - List of Work Groups

WG1	Lenses
WG2	2021 challenges & solutions (Large HB)
WG3	Consumer desirability/ expectations
WG4	FHS 2025 build profile
WG5	Design
WG6	Ventilation technology group
WG7	Heat pump technology group
WG8	Fabric
WG9	Grid load (development)
WG10	Small builder implications
WG13	Planning
WG14	Costing
WG15	Energy modelling
WG16	Metrics
WG17	High Rise

CS1	Contender spec 1
CS2	Contender spec 2 & 2a
CS3	Contender spec 3
CS4	Contender spec 4
CS5	Contender spec 5

Appendix C - Large and small housebuilders 2021 challenges, solutions & 2021 lessons

Aggregated issues from Small builder meeting on 14th Nov & 22nd November 2022 and Large Builder meeting on 12th October 2022 and the reviewing the evidence workshop on 30th November 2022

1) Problems with Part L introduction and compliance requirements

The issues

- Custom and practice for smaller builders is to 'build what the built last time' and unaware of the impact of the changes.
- Significant design changes required to meet the new FEES. (Coupled with the Part O effect).
- General lack of understanding of how to meet new FEES especially regarding thermal bridging.
- Lack of standard thermal bridging details freely available to use
- Architects have typically designed separately from the energy assessor and M&E designer etc so designs are being produced that tend to fail or pass with re-work.
- Small builders particularly impacted as tend to rely on others for technical advice who are ill-equipped to provide it leading to confusion.
- Industry unable to produce house designs before the regulations came into force with subsequent knock-on effect on supply chains.
- Re-plotting of homes to accommodate design changes, or pushing other elements significantly and staying with 100mm cavities.
- Lack of appreciation of the implications of lower flow temperatures
- Photographic report requirements not well understood.
- Conflicts between different regulations and between planning requirements.

Underlying causes

- Short timescale between regulation details being know and introduction.
- Limited awareness raising about the regulatory changes and new requirements.
- Industry generally not aware of, and not used to, considering thermal bridge details so significant change of practices (see later).
- When detailed planning had been obtained, re-plotting and re-submission to planning necessary due to the plot-by-plot transitional arrangements.

Solution to address immediate issues

- Enhanced awareness raising programmes.
- Rapid additional professional skills training.

Lessons for 2025

- Strengthened awareness raising programmes.
- If a significant change in regulations is undertaken which fundamentally impacts dwelling design:
    - a planned and monitored 'change management' programme is required including a better understanding, and utilisation, of existing knowledge development methods used by professions, supply chains, planners, building control etc to accelerate understanding.
    - modified transitional arrangements for plots where detailed planning has been obtained.
- Proactive awareness and skills training requirement.

Residual issues

- It should be possible to avoid residual issues if well planned.

2) Challenges in using the current iteration of SAP

The issues

- SAP changes from the 'consultation' version to a settled 'commercial' BRE approved and settled version have meant that house designs could/cannot be finalised some months after regulations go live, let alone before, creating considerable work and difficulties for housebuilders.
- Without settled designs supply chain are unable to prepare.
- Issues, and possible inaccuracies, relating to modelling thermal bridges, window orientation, PV, district heating, FGHR.
- SAP inability to adequately reflect technologies that provide load shifting advantages.
- SAP does not reflect claimed benefits of radiant heating.
- Carbon factors and energy costs are out of date.
- Extensive modelling with consultation SAP is useful – informs consultation response and supports business looking ahead (does not inform exact specifications).
- Appendix Q does not have enough products in it!
- Server based tool takes longer to perform calculations.

Underlying causes

- Delayed release of a commercially available, stable, BRE approved of SAP.
- Changes in SAP methodology between consultation version and final introduction.
- Need for methodological improvements.

Solution to address immediate issues

- No additional actions

Lessons for 2025

- Developers need 12 months to update designs once a stable commercial version of SAP is available.
- Need for sufficient time between release of a finalised SAP and Part L going live.
- Improvements to the model required (SAP11).
- If software is still evolving, introduce a mechanism whereby the software version can be fixed for a development to provide stability (GLA president).
- Test a broader range of archetypes and cases for unintended consequences not just major housebuilder standard designs (particularly important for small builders).
- Key dates cannot slip.

Residual issues

- There will always be a challenge for SAP in incorporating new technologies that have not been thoroughly tested in field trials. This needs a wider policy solution (of support for field trials).

3) New overheating regulations introduction

The issues

- Introduction has/will result in significant changes to designs particularly for smaller housebuilders that tend to build with larger glazed areas.
- Too many small housebuilders, smaller architects / architectural technicians do not appear to be aware of Part O or currently do not appreciate its significance simply designing/building to what they built before.
- A short/medium 'interim' issue is Part O requiring redesigns of homes/sites that were designed to the 2013 regs and have existing detailed planning permission. As a consequence of the redesign for Part O, and to a lesser extend Part L, these sites need to go back to planning - risking objections, CIL changes and new planning conditions. Section 3 is creating a significant proportion of the problems – 15k + drawings being amended and sent back to planners.
- Inadequate/over-simplified/ too general "Simplified Model" isn't working as intended ie providing a simplified route to compliance. Small builders reported that, compared to volume housebuilders, they are often building bespoke homes which are more likely to require the dynamic model to reflect the overheating mitigation measures they are using (such as shading, solar controlled glass etc) but are far less able to bear costs and complexity of dynamic modelling.
- The TM59 dynamic modelling takes into account more nuanced geographical regions where as the simplified model could but does not, often developers going straight to TM59.
- High rise + acoustic limitations tends to result in active cooling (which will be used more than the calculations would suggest, because it is there…).
- Cost and quality assurance of consultants undertaking simplified Part O calculations.
- Even dynamic approach may need further refinement/ consideration: difficulty of getting dense urban developments through under TM54; interaction with acoustic regulations.
- Guarding rail unintended consequences in Part O.
- Part O Simplified model guidance interpreted differently by different people.

Solution to address immediate issues

- See separate FHH reports.

Lessons for 2025

- The simplified model needs substantial improvements to become fit for use as a matter of urgency.
- Large regulation changes:
  - Should be co-designed and then consulted on when there are large changes of regulation.
  - need to be introduced more carefully and with significantly more support – a professional change management process.

Residual Issues

- Climate change. Warming is changing the way we need to design homes.
- How to continue to have good daylighting in homes whilst not succumbing to overheating.

4) Combined effect of regulatory issues, Part L and Part O changes are pushing developers to standardised designs and undermining bespoke design:

The issues

- Part L pushes companies to adopt standardised design solutions and will stifle design variation and innovation.
- Part O requirements will prevent designs that create light-filled homes.
- Challenges reported getting idiosyncratic, bespoke designs (e.g. larger, more glazed, homes with individual design features) - to meet FEES within SAP. Easier to get 'small boxes' to achieve compliance.
- Difficulties are compounded by the slow pace of BRE's process to add new products to the list of those which can be used under SAP.

Underlying causes

- Lack of the skills.
- Building low/zero carbon homes is more technically complex and may dictate certain forms/approaches given certain technologies.
- Do homes with larger glazed areas struggle to meet FEES due to the 25% limit of glazing within the notional dwelling?

Solution to address immediate issues

- Enhanced awareness raising programmes.
- Rapid additional professional skills training.

Lessons for 2025

- Recognition that as the fabric standards become more stringent, the opportunity to trade off one element against another reduces, impacting design flexibility.
- Enhanced skills and awareness is necessary to be able to deliver bespoke designs within a more complex regulatory environment.
- The need to check the impact of regulations on house types commonly built by small housebuilders not only the standard 'main housebuilder' typical homes.

Residual Issues

- Low/zero carbon homes bring more build complexity.
- Policy decision around the balance between flexibility and hitting low/zero carbon standards.
- Climate change implications may require us to build homes that are of a different design and potentially construction and change market arrangements such as some build techniques gaining in popularity and some reducing.

5) Higher build costs leading to reduced profit margins

The issues

- Short/medium term issue - land price paid was based on cost calculations for building to 2013 regs (2021 changes might lead to fewer plots etc) or the 2021 Part L consultation (whichever depending on when the land was purchased). With plot-by-plot transitional arrangements the assumed cost of compliance becomes a significant factor.
- With much higher awareness of energy efficiency, there is now house buyer and finance provider demand for homes that go beyond 2021 regs (eg for EPC 'A' homes). These cost more to build.
- Landowners – particularly in areas of the country with strong demand/limited supply – may not accept a lower price, preferring to delay sale for a higher price.

Underlying causes

- Land prices being agreed with limited knowledge of the regulatory requirements that will apply.
- Changing consumer expectations.

Solution to address immediate issues

- No additional actions

Lessons for 2025

- Need sufficient clarity, confidence in and notice of required standard to build into land bids.
- Adapt transition arrangements where detailed planning has been obtained prior to regulation details being announced.

Residual issues

- Powerful market position of landowners in areas of short supply/high demand.

6) Many unaware of the significance of thermal bridging details

The issues

- Few publicly available thermal bridge calculations available.
- Particular lack of small builder / designer / energy assessor awareness / understanding.
- Smaller builders more often build bespoke house types with bespoke bridges.
- Industry capacity to calculated psi-values.

Underlying causes

- Lack of awareness.
- Lack of coordinated effort to address the lack of details until late in the day and still only partial.
- Without a business model to create details in advance and speculatively provision relies on customer pressure on product manufacturers to develop which by definition is very late in the day.

Solution to address immediate issues

- Enhanced awareness raising programmes.
- Rapid additional professional skills training.
- Potential creation of a database of commonly used thermal bridges used by larger housebuilders to assist smaller housebuilders.

Lessons for 2025

- A more systematic process to identifying and resolving expected issues resulting from the introduction of regulation.
- Ensure that PSI values are readily available to suit the likely U values.

Additional FHS 2025 concerns

7) Real or perceived customer acceptance challenges

The issues

- Customers turning off MVHR systems – complaining about the noise. Noise from batteries; noise from ASHPs.
- Concern householders not understanding how heat pumps work (space warming not space heating), cool radiators not hot.
- Concern that households will need to be educated how to work their household, otherwise they will be dissatisfied. Needs a wider push for education beyond SME housebuilders.
- Customer education – how to use systems and ensuring customers know importance of maintenance and fans and filters.
- Costs of long-term maintenance.
- Increasing consumer and finance providers' interest in EPC ratings which are not aligned to the direction of travel of newbuild standards.

8) Design and construction implications

The issues

- Plotting reduced with thicker walls.
- Skills
- Fire performance associated with higher performance insulants.
- Local Authorities will continue to ask for a myriad of higher standards.

9) Supply chain shortages and delays – materials and sub-contractors

The issues

- Supply chain reconfiguration in response to the regulations takes time.
- Lack of knowledge/preparedness from the supply chain for the regs change.
- Global interruptions to all supply chains, caused by Covid19, war in Ukraine. New energy technologies more reliant on materials with complex global supply chains, eg semi-conductors.
- Heat pumps and other new energy technologies require new workforce configurations on site, eg problems of commissioning issues between plumbers and electricians not understanding how system operates –eg electric controls not wired correctly to work with distribution system.
- Training/retraining programmes to bring heat pump and other specialist energy tech installers into the market hasn't kept pace with demand/the need created by regs changes.
- Concern the supply chain would not be able to meet the air tightness requirements.

10) Limited energy systems capacity on site

The issues

- Short/medium term issue with regs transition - if you've already put in the mains for a development you're restricted with what loads you can take off or put in.
- Installation of PV over 3.68kWp need a specific permission to feed in which is time limited so a delay may result in the permission being withdrawn.
- Lack of grid capacity locally for heat pumps and PV.

11) Maintenance

The issues

- Will there be sufficient supply chain to maintain the new equipment?
- Will householders maintain the essential systems (such as all ventilation fans, intermittent, continuous extract, MVHR)?

Appendix D - Detailed specifications modelled

HOUSES: Detail of specifications modelled (page 1 of 2)								
	Ref 2021	**Ref 2025**	**CS1**	**CS2**	**CS2a**	**CS3**	**CS4**	**CS5**
Wall U-value	0.19 [1]	0.15	0.19	0.19 [1]	As per CS2	0.15	0.13	Detached 0.10
Roof U-value - plane	0.11	0.11	0.11	0.11	As per CS2	0.11	0.10	0.10
Roof U-value - slope	0.16	0.11	0.16	0.16	As per CS2	0.15	0.15	0.10
Floor U-value	0.15 [2]	0.11	0.15	0.15 [2]	As per CS2	0.11	0.10	0.08
Glazing	Double	Triple	Double	Double	As per CS2	Double	Triple	Triple
Window U-value / centre pane g-value	1.3/ 0.73 [3]	0.8/ 0.57	1.3/ 0.73 [3]	1.3/ 0.73 [3]	As per CS2	1.2/ 0.53	0.8/ 0.5	0.8/ 0.5
Front door U-value	1.2	1.0	1.6	1.2	As per CS2	1.0	0.8	0.6
Half-glazed door U-value	1.3	1.0	1.3	1.3	As per CS2	1.0	0.8	0.8
Roof window U-value	1.4 [4]	0.8	1.4	1.4 [4]	As per CS2	1.2	1.0	1.0
Thermal bridging [5]	Psi values - Set A	y-value = 0.05	Psi values - Set A	Psi values - Set A	As per CS2	Psi values - Set B	Psi values - Set B	Psi values - Set B
Resultant y-value End Terrace	0.035	0.05	0.035	0.041 [6]	As per CS2	0.028	0.028	0.028
Resultant y-value Mid Terrace	0.046	0.05	0.046	0.055 [6]	As per CS2	0.037	0.037	0.037
Resultant y-value Room in Roof	0.039	0.05	0.039	0.039	As per CS2	0.035	0.035	0.035
Resultant y-value Large Detached	0.039	0.05	0.039	0.039	As per CS2	0.033	0.033	0.033
Resultant y-value Bungalow	0.031	0.05	0.031	0.031	As per CS2	0.024	0.024	0.024
Air permeability	4.5 - 5.0 [7]	5.0	5.0	4.5 - 5.0 [7]	As per CS2	3.0	1.0	0.5
Ventilation	dMEV	Natural ventilation with extract fans	dMEV	dMEV	As per CS2	MVHR	MVHR	MVHR integral with EAHP
Heat emitter type	Radiators (55deg flow)	Radiators (45deg flow)	Radiators (45deg flow)	Radiators (45deg flow)	Infra red direct elec heaters	Radiators (45deg flow)	Radiators (45deg flow)	None

continued...

HOUSES: Detail of specifications modelled (page 2 of 2)									
		Ref 2021	**Ref 2025**	**CS1**	**CS2**	**CS2a**	**CS3**	**CS4**	**CS5**
Heating		Gas boiler + compensator [8]	ASHP	ASHP	ASHP	IR direct elec	ASHP	ASHP	None
DHW		Gas boiler + compensator [8]	ASHP	ASHP	ASHP	Immersion + smart cylinder	ASHP	ASHP	DHW cylinder integral with EAHP & MVHR
WWHR		No [9]	No	No	Yes	No	Yes	Yes	Yes
Shower flow rate [10]		8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min
PV philosophy		To achieve Part L 2021 Pass	None	None, unless req. for min. 75% carbon emissions reduct. from 2013	40% ground floor area, capped at 3.68kWp	Maximise roof area for PV	40% roof area in plan, capped at 3.68kWp	40% roof area in plan, capped at 3.68kWp	40% roof area in plan, capped at 3.68kWp
PV (kWp) [11]	End Terrace	1.68	0	0	2.68	6.00	2.68	2.68	2.68
	Mid Terrace	1.68	0	0	2.68	6.00	2.68	2.68	2.68
	Room in Roof	2.68	0	1.34	2.68	2.68	2.68	2.68	2.68
	Large Detached	9.72	0	0.67	3.68	10.00	3.68	3.68	3.68
	Bungalow	5.70	0	0	3.68	6.00	3.68	3.68	3.68
PV Diverter		No	No	No	Yes	No	Yes	Yes	No [12]
Battery		No	No	No	No	6.5kWh hybrid	No	No	No

[1] 0.18 for Bungalow

[2] 0.13 for Bungalow

[3] 1.27/ 0.59 for Large Detached & Bungalow as these archetypes require lower g-value glazing for Part O compliance.
To meet TFEE, Bungalow also required triple glazing (0.8/ 0.5) for rear glazed wall to lounge.

[4] 1.3 for Large Detached

[5] To be compatible with U-value combinations, two different sets of psi values were used. See separate psi-value table.
Resultant y-value for each archetype from these psi-value sets is shown in rows below.

[6] With standard insulated lintel instead of thermally broken lintel

[7] 4.5, except 5.0 for Room in Roof & Large Detached

[8] Combi boiler, except System boiler & DHW tank for Room in Roof & Large Detached

[9] Yes for Room in Roof due to limited roof area for PV

[10] CS3 and above would have liked to use 6l/min but not possible in SAP10.2

[11] E/W facing, none/very little overshading, 45deg pitch

[12] Wanted to model with PV diverter, but not possible in SAP10.2 for this spec

U-values are stated in W/m²K; air permeability is stated in m³/hr.m²@50Pa

APARTMENTS: Detail of specifications modelled (page 1 of 2)								
	Ref 2021	**Ref 2025**	**CS1**	**CS2**	**CS2a**	**CS3**	**CS4**	**CS5**
Wall U-value	0.19 Low-rise 0.17 High-rise	0.15	0.21	0.19 Low-rise 0.17 High-rise	As per CS2	0.15	0.15	0.15
Roof U-value - plane	0.11	0.11	0.11	0.11	As per CS2	0.11	0.10	0.10
Floor U-value	0.15	0.11	0.15	0.15	As per CS2	0.11	0.10	0.08
Glazing	Double	Triple	Double	Double	As per CS2	Double	Triple	Triple
Window U-value / centre pane g-value	1.27/ 0.59 Low-rise 1.2/ 0.4 High-rise [1]	0.8/ 0.57	1.27/ 0.59 Low-rise 1.2/ 0.4 High-rise [1]	1.27/ 0.59 Low-rise 1.2/ 0.4 High-rise [1]	As per CS2	1.2/ 0.53 Low-rise 1.2/ 0.4 High-rise [1]	0.8/ 0.5 Low-rise 0.8/ 0.4 High-rise [1]	0.8/ 0.5 Low-rise 0.8/ 0.4 High-rise [1]
Front door U-value	1.2	1.0	1.6	1.2	As per CS2	1.0	0.8	0.6
Thermal bridging [2]	Psi values - Set A	y-value = 0.05	Psi values - Set A	Psi values - Set A	As per CS2	Psi values - Set B	Psi values - Set B	Psi values - Set B
Resultant y-value: Low-rise	0.075 [3]	0.05	0.064	0.075 [3]	As per CS2	0.058	0.058	0.058
Resultant y-value: High-rise	0.166	0.05	0.166	0.166	As per CS2	0.132	0.132	0.132
Air permeability	4.5 Low-rise 3.0 High-rise	5.0	5.0	4.5 Low-rise 3.0 High-rise	As per CS2	3.0	1.0	0.5
Ventilation	dMEV	Natural ventilation with extract fans	dMEV	cMEV	As per CS2	MVHR	MVHR	MVHR integral with EAHP
Heat emitter type	Radiators (55deg flow)	Radiators (45deg flow)	Direct elec heaters	Direct elec heaters	Infra red direct elec heaters	Direct elec heaters	Direct elec heaters	None
Heating	Gas combi boiler + compensator	ASHP	Direct elec	Direct elec	Direct elec	Direct elec	Direct elec	None
DHW	Gas combi boiler + compensator	ASHP	DHW ASHP	DHW ASHP	Immersion + smart cylinder	DHW ASHP	DHW ASHP	DHW cylinder integral with EAHP & MVHR
WWHR [4]	No	No	No	Yes	No	Yes	Yes	Yes
Shower flow rate [5]	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min	8 l/min

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APARTMENTS: Detail of specifications modelled (page 2 of 2)									
		Ref 2021	Ref 2025	CS1	CS2	CS2a	CS3	CS4	CS5
PV Philosophy	Low-rise	To achieve Part L 2021 Pass7	None	None, unless req. for minimum 75% carbon emissions reduction from 2013	Pro rata of 40% ground floor area	Maximise roof area for PV	Pro rata of 40% roof area in plan	Pro rata of 40% roof area in plan	Pro rata of 40% roof area in plan
	High-rise						Pro rata of 20% roof area in plan	Pro rata of 20% roof area in plan	Pro rata of 20% roof area in plan
PV (kWp) [6]	Low-rise	0.67	0	1.0	1.34	2.0	1.34	1.34	1.34
	High-rise	0.36	0	0.36	0.36	0.42	0.18	0.18	0.18
PV Diverter	Low-rise	No	No	No	No [9]	No	No [9]	No [9]	No [9]
	High-rise	No	No	No	No	No	No	No	No
Battery		No	No	No	No	6.5kWh hybrid	No	No	No

[1] High-rise apartment required lower g-value glazing for Part O compliance

[2] To be compatible with U-value combinations, two different sets of psi values were used. See separate psi-value table.
Resultant y-value for each archetype from these psi-value sets is shown in rows below.

[3] With standard insulated lintel instead of thermally broken lintel

[4] Appropriate system for apartments modelled

[5] CS3 and above would have liked to use 6l/min but not possible in SAP10.2

[6] E/W facing, none/very little overshading, 45deg pitch

[7] Individual supply

[8] Landlord supply

[9] Wanted to model with PV diverter, but not possible in SAP10.2 for this spec

U-values are stated in W/m²K; air permeability is stated in m³/hr.m²@50Pa

NOTE: For CS5, SAP10.2 was unable to model the correct size heat pump in the high-rise apartment so no results were able to be output for this combination

Summary of psi-values used in modelling work

	Construction type:		Masonry		Concrete frame	
	Applicable to:		Houses & Low-rise apartment		High-rise apartment	
	Junction detail	Ref	Set A	Set B	Set A	Set B
Junctions with an external wall	Lintel (standard)	E2	0.175	-	-	-
	Lintel (thermally broken)	E2	0.050	0.050	0.050	0.038
	Sill	E3	0.038	0.028	0.040	0.039
	Jamb	E4	0.041	0.024	0.071	0.051
	Ground floor (beam & block)	E5	0.060	0.047	-	-
	Intermediate floor within dwelling	E6	0.002	0.002	-	-
	Party floor between apartments	E7	0.037	0.037	0.060	0.046
	Balcony between dwellings	E9	-	-	0.040	0.040
	Eaves (insulation at ceiling level)	E10	0.097	0.034	-	-
	Eaves (insulation at rafter level)	E11	0.041	0.024	-	-
	Gable (insulation at ceiling level)	E12	0.059	0.059	-	-
	Gable (insulation at rafter level)	E13	0.058	0.058	-	-
	Flat roof with parapet	E15	0.160	0.160	-	-
	Corner (normal)	E16	0.046	0.046	0.097	0.081
	Corner (inverted)	E17	-0.082	-0.082	-0.030	-0.055
	Party wall	E18	0.036	0.036	0.060	0.060
	Exposed floor (normal)	E20	0.160	0.160	-	-
	Exposed floor (inverted)	E21	0.160	0.160	-	-
	Eaves (insulation at ceiling level - inverted)	E24	0.240	0.240	-	-
	Staggered party wall between dwellings	E25	0.036	0.036	0.120	0.120

	Construction type:		Masonry		Concrete frame	
	Applicable to:		Houses & Low-rise apartment		High-rise apartment	
	Junction detail	Ref	Set A	Set B	Set A	Set B
Junctions with a party wall	Ground floor	P1	0.059	0.059	-	-
	Intermediate floor within dwelling	P2	0.000	0.000	-	-
	Intermediate floor between dwellings	P3	-	-	0.000	0.000
	Roof (insulation at ceiling level)	P4	0.045	0.045	-	-
	Roof (insulation at rafter level)	P5	0.058	0.058	-	-
Junctions within a roof or with a room-in-roof	Head of roof window	R1	0.120	0.120	-	-
	Sill of roof window	R2	0.120	0.120	-	-
	Jamb of roof window	R3	0.120	0.120	-	-
	Ridge (vaulted ceiling)	R4	0.060	0.060	-	-
	Flat ceiling (inverted)	R7	0.060	0.060	-	-
	Roof to wall (flat ceiling)	R9	0.160	0.160	-	-

Appendix E - Build cost data - Elemental analysis

The cost analysis was carried out by Arcadis on behalf of the Future Homes Hub in January 2023

Elemental Cost Analysis, End terrace house (page 1 of 2)

End terrace house	Ref 2021		Ref 2025		CS1		CS2		CS2a		CS3		CS4		CS5	
Element	Cost	£/m²	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost
0: Facilitating Works																
Facilitating works	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Element Total	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
1: Substructure																
Substructure	12,996	167	803	13,799	-	12,996	182	13,178	182	13,178	803	13,799	1,442	14,437	2,476	15,472
Element Total	**12,996**	**167**	**803**	**13,799**	**-**	**12,996**	**182**	**13,178**	**182**	**13,178**	**803**	**13,799**	**1,442**	**14,437**	**2,476**	**15,472**
2: Superstructure																
Frame	400	5	-	400	-	400	-	400	-	400	-	400	-	400	-	400
Upper floors	3,556	46	-	3,556	-	3,556	-	3,556	-	3,556	-	3,556	-	3,556	-	3,556
Roof	11,433	147	-	11,433	-	11,433	-	11,433	-	11,433	530	11,963	626	12,059	626	12,059
Stairs and Ramps	750	10	-	750	-	750	-	750	-	750	-	750	-	750	-	750
External Walls	23,674	304	1,098	24,772	-	23,674	-	23,674	-	23,674	2,772	26,447	4,270	27,945	4,820	28,495
Windows and External Doors	4,676	60	956	5,632	-	4,676	-	4,676	-	4,676	336	5,012	1,506	6,182	1,899	6,575
Internal Walls and Partitions	8,449	109	-	8,449	-	8,449	-	8,449	-	8,449	-	8,449	735	9,184	735	9,184
Internal Doors	2,780	36	-	2,780	-	2,780	-	2,780	-	2,780	-	2,780	-	2,780	-	2,780
Element Total	**55,718**	**716**	**2,502**	**57,773**	**-**	**55,718**	**-**	**55,718**	**-**	**55,718**	**3,639**	**59,358**	**8,138**	**62,856**	**8,081**	**63,800**
3: Internal Finishes																
Wall Finishes	1,880	24	-	1,880	-	1,880	-	1,880	-	1,880	-	1,880	-	1,880	-	1,880
Floor Finishes	3,830	49	-	3,840	-	3,830	-	3,830	-	3,830	-	3,830	-	3,830	-	3,830
Ceiling	2,945	38	-	2,945	-	2,945	-	2,945	-	2,945	-	2,945	-	2,945	-	2,945
Element Total	**8,655**	**111**	**-**	**8,655**	**-**	**8,655**	**-**	**8,655**	**-**	**8,655**	**-**	**8,655**	**-**	**8,655**	**-**	**8,655**

continued...

Elemental Cost Analysis, End terrace house (page 2 of 2)

End terrace house	Ref 2021		Ref 2025		CS1		CS2		CS2a		CS3		CS4		CS5	
Element	Cost	£/m²	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost	Add/ omit	Cost
4: Fittings, Furnishings & Equipment																
Fittings, furnishings and equipment	5,500	71	-	5,500	-	5,500	-	5,500	-	5,500	-	5,500	-	5,500	-	5,500
Element Total	**5,500**	**71**	**-**	**5,550**	**-**	**5,500**	**-**	**5,500**	**-**	**5,500**	**-**	**5,500**	**-**	**5,500**	**-**	**5,500**
5: Services																
Sanitary Installations	1,350	17	-	1,350	-	1,350	-	1,350	-	1,350	-	1,350	-	1,350	-	1,350
Disposals	1,550	20	-	1,550	-	1,550	-	1,550	-	1,550	-	1,550	-	1,550	-	1,550
Water Services	1,612	21	-	1,612	-	1,612	-	1,612	-	1,612	-	1,612	-	1,612	-	1,612
Heat Source	2,477	32	4,374	6,851	4,374	6,851	4,374	6,851	-230	2,247	4,374	6,851	4,374	6,851	-2,427	50
Space Heating	3,630	47	-	3,630	-	3,630	-	3,630	-242	3,388	-	3,630	-	3,630	-3,630	-
Ventilation	406	5	-	406	-	406	-	406	-	406	3,699	4,105	3,699	4,105	10,056	10,462
Electrical	7,406	95	-2,190	5,216	-2,190	5,216	1,817	9,223	10,770	18,176	1,817	9,223	1,817	9,223	1,314	8,720
Fuel Source	200	3	-	200	-	200	-	200	-	200	-	200	-	200	-	200
Communications	1,388	18	-	1,388	-	1,388	-	1,388	-	1,388	-	1,388	-	1,388	-	1,388
Specialist installations (WWHR)	-	-	-	-	-	-	750	750	-	-	750	750	750	750	750	750
Testing, Commissioning, BWIC	1,962	25	180	2,142	180	2,142	180	2,142	180	2,142	370	2,332	370	2,332	280	2,242
Element Total	**12,981**	**283**	**2,264**	**24,345**	**2,364**	**24,345**	**7,121**	**29,102**	**10,478**	**32,459**	**11,010**	**32,911**	**11,010**	**32,991**	**6,343**	**28,324**
Building Works Total	**104,850**	**1,348**	**5,221**	**110,071**	**2,364**	**107,214**	**7,303**	**112,153**	**10,660**	**115,510**	**15,452**	**120,302**	**19,590**	**124,439**	**16,900**	**121,750**
9: Main Contractor's Preliminaries																
Main Contractor's Preliminaries 9%	9,436	121	470	9,906	213	9,649	657	10,094	959	10,396	1,616	11,052	2,213	11,650	2,271	11,708
Element Total	**9,436**	**121**	**470**	**9,906**	**213**	**9,649**	**657**	**10,094**	**959**	**10,396**	**1,616**	**11,052**	**2,213**	**11,650**	**2,271**	**11,708**
10: Main Contractor's O/H & Profit																
Main Contractor's O/H & Profit	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.	excl.
Element Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL	**114,286**	**1,469**	**5,691**	**119,977**	**2,577**	**116,863**	**7,960**	**122,246**	**11,619**	**125,905**	**17,067**	**131,354**	**21,803**	**136,089**	**19,171**	**133,458**

Ready for Zero

Evidence to inform the 2025 Future Homes Standard

28 February 2023