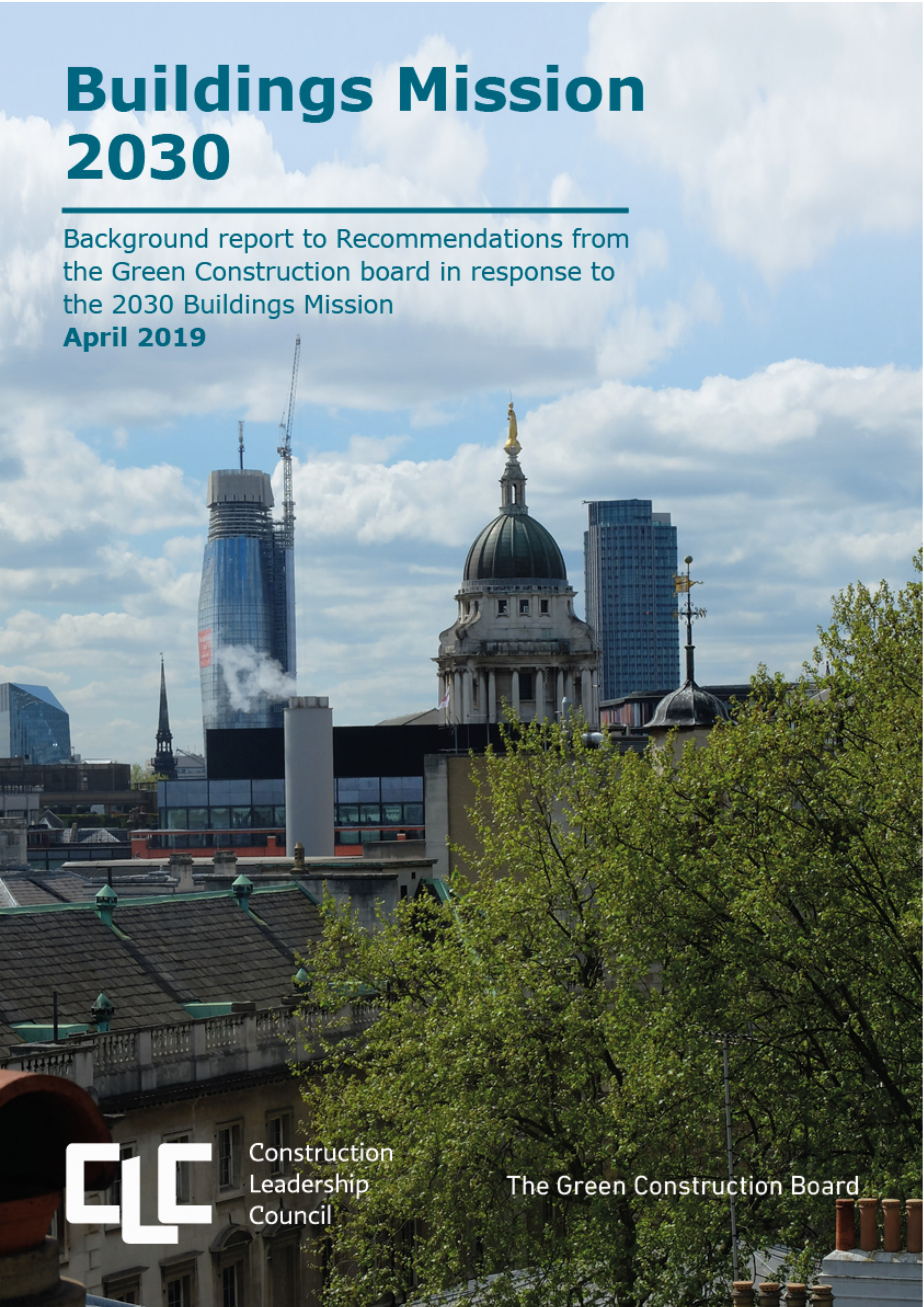
Buildings Mission 2030

Background report to Recommendations from the Green Construction board in response to the 2030 Buildings Mission

April 2019



Construction Leadership Council

The Green Construction Board

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Finally, we want to thank the clients, architects and design teams, contractors and occupants of all 15 case studies selected. They are not named in this report but their work has been instrumental in delivering buildings which are so energy efficient. Should you want to have the names of the client, design team and contractor for any of the case study buildings, please do not hesitate to contact us.

FOREWARD

David Pinder
Chair of the Green Construction Board

Since I was appointed Chair of the Green Construction Board (GCB) in March 2018, I am proud to be part of a group that is championing the delivery of a more environmentally sustainable construction agenda, which is fundamental to the UK achieving its clean growth goals. It is a privilege to work with industry experts with such a wealth of knowledge, and also the vision and passion to deliver a future with zero carbon buildings and a cleaner environment. I would like to extend my sincere thanks to the team, chaired by Lynne Sullivan, who have worked hard to gather all the supporting evidence and produce this excellent report of practical recommendations.

Lynne Sullivan, OBE
Architect, Green Construction Board Member
Chair of the GCB Buildings Mission Taskgroup

The Green Construction Board was invited to respond to the government's 2018 Grand Challenge to use new technologies and modern construction practices to "at least halve" the energy usage of new buildings by 2030, and I agreed to chair a time-limited Taskgroup to this end. It has been a privilege for me to convene a group of industry experts who have in-depth knowledge on energy efficiency in new buildings and to draw together, in collaboration with these Taskgroup members and my GCB colleagues, a set of recommendations which we believe are both visionary and achievable over the next ten years or sooner. As a Board, much of our previous work (eg on better data and closing the 'performance gap') has focussed on the importance of better performance in use, and the need to accelerate the industry's ability to predict and learn from real outcomes of building projects, in order to improve sustainability and climate resilience. This is essential for the Construction Grand Challenge "Buildings Mission" to be met and our Recommendations together with this background report strongly reinforce this case.

This report was initiated by the GCB Taskgroup and ably delivered by Julie Godefroy Sustainability and Etude. It provides background evidence for our Recommendations, which are positioned in the context of the longer-term objective of Net Zero Carbon buildings, and whilst we do not address them here, pertinent issues of Existing Buildings, Whole Life and Embodied Carbon, Energy supply and management, and Offsetting will all need to be addressed. We have focussed, as a nearer term objective, on reducing energy demand and improving energy and systems efficiencies. Along with process efficiencies including better quality management and procurement practices, we demonstrate how the Challenge can be tackled pragmatically, building on current best practice.

Our Recommendations unequivocally support the Mission objective and this report demonstrates that it is realisable. We call for urgent and consistent action on three fronts - regulation, incentives and supporting research – and whilst the government's Challenge was framed in the context of new technologies and modern construction practices it is notable that the exemplars cited in this report do not suggest that these are a significant pre-requisite. However, to achieve the Mission for all new buildings and all building energy uses then to operationalise at scale the industry needs mass production of high performance fabric and systems, and this will bring economies of scale as well as continuous improvement. 'New' technologies in the form of sensors and diagnostics are key enablers but we have these already at our disposal - just needing to be put to better use to make in-use performance transparent, and to ensure related performance issues (eg good ventilation and indoor air quality) are part and parcel of the quality improvements we seek. Moving to a culture of reliability of performance will incentivise investors and provide a new platform upon which to engage building users and owners with the narrative of building performance, emissions reduction, healthy indoor environments, and a future where growth is 'clean' and 'green'.

1.0 EXECUTIVE SUMMARY

The Green Construction Board was asked to respond to the 2030 Buildings Energy Mission currently led by the Department for Business, Energy & Industrial Strategy (BEIS).

This background report to the Green Construction Board's recommendations in response to the Buildings Mission 2030 (new buildings) has been prepared by Etude with Julie Godefroy Sustainability and its main purpose is three-fold:

- to indicate the feasibility of achieving a 50% (or greater) reduction in energy use of new buildings by 2030 based on an initial building energy data research undertaken on key new building typologies (offices, primary schools and housing);
- to provide a related commentary on the approach, methodologies, and out-turn performance of case study buildings;
- to provide a commentary on other characteristics relevant to the mission in relation to the case studies e.g. cost, occupant health, industrialisation and digital potential.

Case study buildings have been identified which use less than 50% of the energy use compared with similar buildings, suggesting that the **Energy Mission's aim can be achieved** in the near term.

There are recurring approaches, techniques and/or systems used by most or all of the case study buildings:

1. Contractual energy performance targets.
2. Prediction of future energy use at the design stage and during construction[1].
3. Optimisation of form to reduce energy, allow comfortable conditions and save capital costs.
4. "Fabric first" approach with a very energy efficient envelope.
5. Openings for a passive ventilation strategy in summer <u>and</u> Mechanical Ventilation with Heat Recovery (MVHR).
6. Low total energy consumption with consideration of all energy uses (not just the uses currently covered by Building Regulations).
7. Energy performance quality assurance during construction and comprehensive commissioning, with follow-up checks.
8. Aftercare to deliver low energy consumption in operation with mechanisms for performance monitoring and evaluation integrated at design stage and followed-through during operation.

This initial report provides more details on the case studies as well as on the above commentary. It indicates that **achieving at least a 50% reduction in the energy use of new buildings is technically and financially feasible**.

[1] This went far beyond carrying out calculations for Building Regulations purposes by including anticipated unregulated energy uses <u>and</u> by trying to understand and represent the building's actual operations rather than using standard occupancy and use profiles.

In order to find these case studies of buildings which are currently using at least 50% less energy than their peers, we undertook research using the Display Energy Certificate (DEC) database (Landmark Register), CIBSE Building Performance awards, Passivhaus database, Low Energy Buildings database, CarbonBuzz, BREEAM case studies and awards, Innovate UK Building Performance Evaluation programme, other industry publications and data submitted by individuals, as well as a selective search of buildings occupied by organisations with environmental credentials e.g. WWF, National Energy Foundation, Environment Agency.

This search has highlighted the **limited amount of reliable, publicly available data on actual energy use in buildings**. This is very much an issue in itself. Significantly improving the approach to building energy data disclosure and analysis is therefore urgently required. It is also an area of **potential for digital innovation**.

In order for the reduction of energy use by 50% across all buildings by 2030, significant work is also required to support and incentivise the building industry. Potential further work is therefore identified at the end of each of the recommendations.

In summary:

1. Contractual energy performance targets
2. Prediction of future energy use (kWh/m^2)
3. Optimisation of form to reduce energy use and capital costs
4. "Fabric first" approach
5. Opening windows and MVHR
6. Consideration of all energy uses
7. Quality assurance for construction / commissioning
8. Aftercare to deliver low energy use

50% reduction in energy use

2.0 INTRODUCTION: THE ENERGY MISSION

The Industrial Strategy sets out a number of key challenges to put the UK at the forefront of the industries of the future. The Department for Business, Energy & Industrial Strategy (BEIS) is currently developing Grand Challenge missions to tackle key challenges, with the objective of bringing government, businesses and organisations across the country together to make a difference.

One of these challenges is Clean Growth, which includes the mission **to achieve at least a 50% reduction in the energy use of new buildings by 2030** through the use of new techniques and technologies. It is supported by £170 million of public money through the Transforming Construction Industrial Strategy Challenge Fund. The ambition is that it will be matched by £250 million of private sector investment, resulting in a total investment of over £400 million.

BEIS have outlined a number of ways to achieve the 50% reduction in the energy use of new buildings by 2030. These include:

- making sure every new building in Britain is safe, high quality, much more efficient and uses clean heating;
- innovating to make low energy, low carbon buildings cheaper to build;
- driving lower carbon, lower cost and higher quality construction through innovative techniques;
- giving consumers more control over how they use energy through smart technologies;

The Mission also aims to halve the cost of reaching the same standard in existing buildings.

3.0 THIS REPORT

An evidence-based approach was adopted throughout this work. The main purpose of this initial report is therefore to summarise the building energy data research undertaken on typical building typologies (offices, primary schools and housing) in order to indicate whether achieving at least a 50% reduction in the energy use of new buildings by 2030 appears to be feasible. The research was restricted to these typologies at this stage given the limited timeframe.

There are a number of common traits between the buildings identified which achieve at least a 50% reduction in energy use compared to the average equivalent building. We have summarised them in key messages.

4.0 ENERGY USE: DEFINITIONS

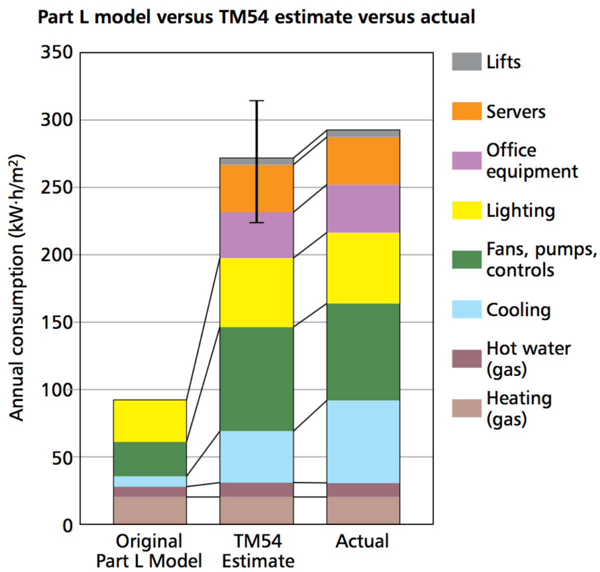
4.1 The limitations of regulated energy and why we need to predict total energy use

Energy modelling during the design of new buildings is normally restricted to Building Regulations Part L assessments of regulated energy uses, using the National Calculation Methodology (NCM). This approach is meant to be used only for demonstrating compliance with building regulations; rather than predicting energy use, it is based on standardised and simplified inputs and assumptions. The output is therefore not an 'actual' energy estimate, and is not meant to be one, but it is unfortunately used as one.

This is often due to the lack of awareness of energy modellers who assume that a Part L model can accurately predict heating, hot water, lighting and fans and pumps energy uses (as these generally fall under the 'regulated' energy use category) and that 'unregulated' energy uses just need to be added. This is not correct. There are many reasons why Part L assessments do not predict energy use accurately (even regulated energy use), and this alone can result in the initial design stage calculation underestimating actual energy use by a factor of 20% to 600%.

"In the UK, energy models are used at the design stage to compare design options and to check compliance with Building Regulations. These energy models are not intended as predictions of energy use, but are sometimes mistakenly used as such."

CIBSE TM54 – Evaluating operational energy performance of buildings at design stage
(published in 2013)



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tract from CIBSE TM54 – Evaluation of operational energy performance of buildings at design stage

In the domestic sector, estimating 'unregulated' energy loads has routinely been carried out by interrogating total energy use (e.g. electricity, and gas used for heating and hot water) and subtracting regulated loads. Recent approaches show reasonable confidence in the estimate can be achieved: for example, the Energiesprong approach to retrofit, now being applied to new build, guarantees total energy performance (net zero over the year) including establishing typical small power usage on average and developing a 'reasonable' allocation per property, reflecting occupancy, that is enshrined in an annual contract with the user. Where small power 'allocation' is exceeded, an additional tariff is applied, and this methodology has now been verified by 4,000 Energiesprong homes delivered in the Netherlands.

	Before (per sqm)	**After** (per sqm)	**Before** (house)	**After** (house)
Space heating (kWh)	162	25	14,723	2,275
Hot water (kWh)	24	19	2,145	1,729
Lighting, pumps and fans (kWh)	7	6	654	546
Electric (home) appliances (kWh)	24	20	2.200	1,820
Total (kWh)	117	70	19,722	6,370

Example of prediction of unregulated energy loads in residences: Table showing assumed energy split before and after retrofit works - Energiesprong Transition Zero document 2015

A key recommendation of this report is to **progress from the current 'compliance' approach towards prediction of energy 'performance' during the design and construction**, and verification on completion.

4.2 Energy use at the meter

When assessing the performance of buildings, a number of metrics are possible which have been proposed and used over the years in response to different objectives:

- Evaluating the performance of the building itself, or as part of a wider system including factors such as inefficiencies of the electricity grid
- Focusing on energy or carbon
- Facilitating monitoring and comparisons over time and between buildings
- Raising awareness and communicating with end users.

In the context of this study, it is important to adopt a performance metric which can not only be used during the design and construction but also measured during operation, in order for the energy performance of buildings to improve constantly over time. This will enable a **feedback loop and continuous improvement, which are essential conditions for success in delivering the objective of the Buildings Energy Mission**.

We have adopted here **'kWh at the meter'** as the metric as it facilitates year-on-year comparisons, and as it can easily be measured and understood by all stakeholders, most importantly the people running and occupying the building. In the context of this study, this metric offers benefits compared to alternatives, for example:

- EPC ratings do not relate to operation, and do not include all energy uses;
- Annual carbon emissions ($kgCO_2$) change over time with carbon factors;
- Primary energy changes overtime and requires correction factors which add a level of technical complexity.

In a wider context, for example for Building Regulations Part L, a 'kWh at the meter' metric could be used alongside other metrics such as carbon or primary energy, which are useful to reflect the impact on climate change and other system/grid efficiency considerations.

We have nonetheless carried out a sense check on the case study buildings to test their relevance if an approach based on primary energy use or carbon emissions was adopted instead, using 2018 factors (from SAP 10): under a primary energy approach, two of the case studies would exceed the benchmark limit; the others would meet the target 50% improvement on to new buildings, or only exceed it marginally; under a carbon emissions approach, all case studies would meet the target or only exceed it marginally. The choice of metric would not therefore significantly alter the selection of case studies nor the recommendations of the report, which would remain valid under approaches using primary energy or carbon emissions as metric.

Overall, for the purposes of this exercise and in view of the above explanation, we consider 'kWh at the meter' (per m^2) is the right metric looking ahead – see methodology details in section 5.0. The case studies provide the breakdown into electric and thermal uses, where data is available – see details in section 10.0

5.0 METHODOLOGY

The core of this initial work consisted in researching buildings which could be used as case studies and form the evidence base required to indicate whether achieving at least a 50% reduction in the energy use of new buildings by 2030 is possible and how.

The research needed to establish what the average energy consumption was for three key types of buildings: offices, primary schools and domestic buildings.

For commercial offices and primary schools, in the absence of widespread reliable benchmarks for new buildings, the following CIBSE Guide F[2] 'typical practice' energy benchmarks were used, where floor area is expressed in terms of gross floor area:

- Offices[3]: 224 kWh/m^2/yr
- Primary schools: 196 kWh/m^2/yr.

For domestic buildings, according to Ofgem's Typical Domestic Consumption Values (TDCVs)[4], the energy use of 'low' consumers is:

- Domestic: 9,900 kWh/yr/dwelling[5], corresponding to 146 kWh/m^2/yr[6].

Our data research therefore focused on finding case studies which would achieve the following levels of energy consumption (or less):

- Offices: **112 kWh/m^2/yr**
- Primary schools: **98 kWh/m^2/yr**
- Domestic: **73 kWh/m^2/yr** (+ check against whole dwelling consumption below 4,950 kWh/yr)

In order to find these case studies, we undertook a search using the Display Energy Certificate (DEC) database (Landmark Register), BREEAM case studies and awards, CIBSE Building Performance awards, Passivhaus database, Innovate UK Building Performance Evaluation programme, Low Energy Buildings database, CarbonBuzz, other industry publications and a selective search of buildings occupied by organisations with environmental credentials e.g. WWF, National Energy Foundation, Environment Agency.

For each of these case studies, the following information was gathered (when available):

1. **Name**
2. **Location**
3. **Floor area** (m^2 GIFA)

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[2] CIBSE Guide F, Energy Efficiency in Buildings, CIBSE, 2012

[3] This represents the 'typical practice' energy benchmark for naturally ventilated open plan offices. The 'typical practice' benchmark for air conditioned offices is much higher than this (423 kWh/m^2/yr). However, it relies on relatively old data, before significant improvements in plant efficiency (especially cooling) and significant reductions in loads from lighting and IT were made. Selecting the benchmark for naturally ventilated offices means selecting a relatively demanding target, however this is the 'typical practice' benchmark, which is in fact not too dissimilar to the 'good practice' one for air conditioned offices (249 kWh/m^2/yr); this therefore seems a reasonable assumption. Furthermore, this has allowed us to focus on best performing offices, and the case studies demonstrate it is achievable.

[4] Industry standard "low" values for the annual gas and electricity usage of domestic consumers, from Ofgem. This value was used instead of the "average" value on the assumption that new dwellings should consume less than the average building stock, and in order to set an ambitious target. A check was also done against the dwellings of the recent Innovate UK Building Performance Evaluation programme; on average they consumed approximately 9,540 kWh /year, i.e. a value very close to the Ofgem "low" dwelling consumption value.

[5] When looking for residential case studies, while the overall target was expressed in kWh/m^2 as for the other building types, it was considered important to also check the total dwelling consumption, due to large variations between dwelling sizes but not necessarily large variations in numbers of occupants. This is particularly the case with early « low energy » homes, which were often one-off projects and generous in size.

[6] Assuming an average size of 68 sqm for dwellings built in the UK since 2010, according to LABC warranty data: https://www.labc.co.uk/news/what-average-house-size-uk?language_content_entity=en.

4. **Client occupier?** yes/no
5. **Occupancy** (m^2 GIFA/occupants)
6. **Project cost** (£/m^2 GIFA)
7. **Construction end year** (e.g. 2014)
8. **Contractual energy performance target?** yes/no
9. **Energy performance standard achieved (if any)** (e.g. NABERS, Passivhaus, DEC A)
10. **Design prediction of energy performance?** yes/no
11. **Construction type**
12. **Indicative simplified form factor** (from GIFA and Google Maps)
13. **Envelope performance** (e.g. U-values, windows, airtightness,)
14. **Main ventilation type** (e.g. Natural Ventilation, MVHR)
15. **Overheating mitigation** (e.g. Natural Ventilation or mechanical cooling)
16. **Health and Wellbeing aspects** (e.g. air quality)
17. **Heating system** (e.g. gas boiler or ground source heat pump)
18. **DHW system type** (e.g centralised/decentralised)
19. **Quality assurance during construction/commissioning?** yes/no
20. **Aftercare and post-occupancy monitoring?** yes/no
21. **Others** (e.g. incentives, relevant project information)
22. **Energy consumption** in kWh/m^2/yr[7] (and, for dwellings, total kWh/yr).

[7] We took account of energy consumption before renewable energy systems (i.e. gross at the meter). Carbon savings and further reductions in net energy consumption are therefore present in practice in some of the case studies due to on-site renewable energy systems (typically PVs in our case studies).

6.0 EVIDENCE BASE – SELECTED CASE STUDIES

The following case studies were selected on the basis that they achieved at least a 50% reduction in energy use compared to the assumed baseline, as noted in the previous section.

Whilst the sample of case studies is relatively small, this was necessary in the given timeframe in order to be able to study project characteristics in some depth. It should also be noted that:

- Passivhaus buildings represent a very large proportion of the case studies, even though the case studies were identified as a result of a wide-ranging search (see section 5.0 for sources we reviewed). There are in fact more Passivhaus examples than the ones selected which would meet the 50% criterion. This is likely to be due to the quality of the Passivhaus certification, and to the public availability of in-use data.
- Whilst the benchmark for offices represents existing offices (rather than only new offices), the level of energy used chosen as criterion for offices is demanding (see details in section 5.0 Methodology). Raising the energy target for offices would capture many more buildings.

From the information available, the construction costs of these case studies vary between 1,800 (2009 costs) and 3,400 £/m^2 for offices and 1,900 and 3,000 £/m^2 for primary schools[8]. Insufficient data was available on the costs of residential projects for a meaningful comparison.

[8] Note there is some degree of uncertainty as, when made public, costs are not necessarily reported accurately or consistently. Some office buildings were also built at least 10 years ago, which may affect the comparison.

6.1 Offices

National Energy Foundation, Milton Keynes

430 m² GIFA

Built in 2004

Total energy consumption

81 kWh/m²

Improvement on typical

64%

Canolfan Hyddgen, Macchynleth, Wales

400 m² GIFA

Built in 2009

Total energy consumption

95 kWh/m²

Improvement on typical

57%

Enterprise Centre Norwich

3,400 m² GIFA

Built in 2015

Total energy consumption

70 kWh/m²

Improvement on typical

68%

Keynsham Civic Centre Bristol

6,365 m² GIFA

Built in 2015

Total energy consumption

107 kWh/m²

Improvement on typical

52%

BSD Office Kettering

420 m² GIFA

Built in 2017

Total energy consumption

104 kWh/m²

Improvement on typical

54%

6.2 Primary schools

Rogiet Primary School
Monmouthshire

1,660 m² GIFA — Built in 2009

Total energy consumption 93 kWh/m²
Improvement on typical **53%**

St Lukes CoE Primary School Wolverhampton

2,600 m² GIFA — Built in 2009

Total energy consumption 99 kWh/m²
Improvement on typical **49%**

Bushbury Hill Primary School
Wolverhampton

1,808 m² GIFA — Built in 2011

Total energy consumption 73 kWh/m²
Improvement on typical **63%**

Montgomery Primary School Exeter

2,786 m² GIFA — Built in 2012

Total energy consumption 60 kWh/m²
Improvement on typical **69%**

Wilkinson Primary School Wolverhampton

2,610 m² GIFA — Built in 2014

Total energy consumption 60 kWh/m²
Improvement on typical **69%**

6.3 Domestic

Rowner Renewal Phase 2
Hampshire

2 Blocks; 5 units (out of total 24) — Built in 2011

Total energy consumption — 60 kWh/m^2
Improvement on typical — **59%**

Wimbish
Essex

14 units — Built in 2011

Total energy consumption — 75 kWh/m^2
Improvement on typical — **48%***

Lancaster cohousing
Lancastershire

41 units — Built in 2012

Total energy consumption — 61 kWh/m^2
Improvement on typical — **59%**

Racecourse estate
Durham

25 units — Built in 2012

Total energy consumption — 70 kWh/m^2
Improvement on typical — **53%**

Lark Rise
Buckinghamshire

1 detached house — Built in 2015

Total energy consumption — 32 kWh/m^2
Improvement on typical — **78%**

* This is close to a 50% and was therefore still included as a case study with interesting findings

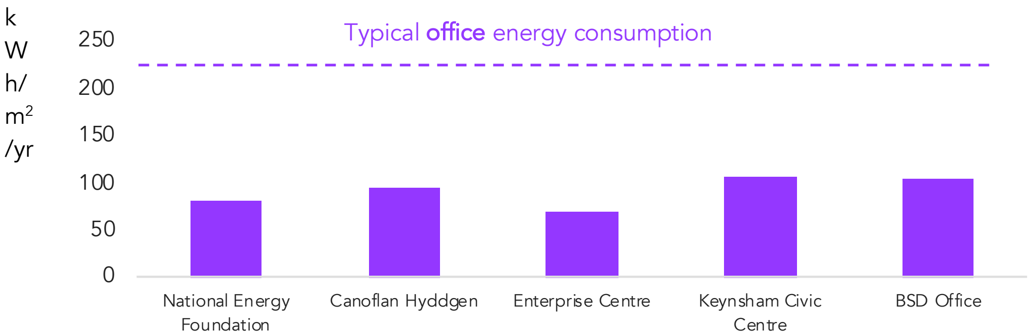
7.0 KEY MESSAGES

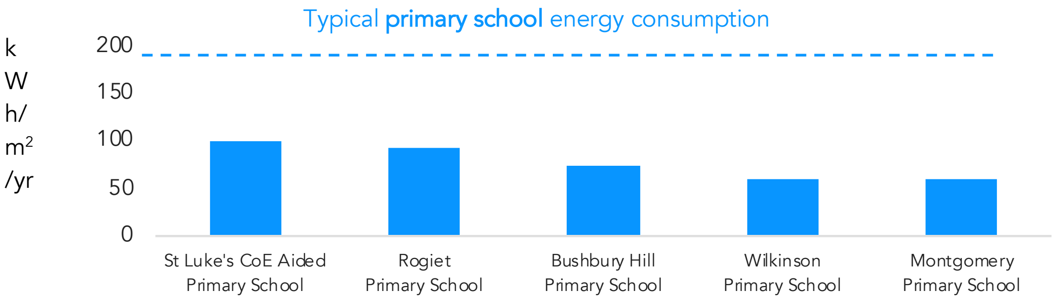
See following pages.

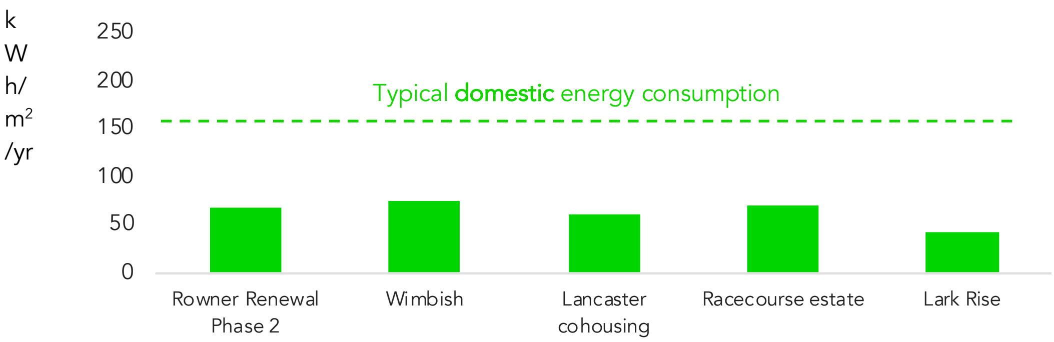
0

Halving energy consumption is possible

Based on the initial research undertaken, reducing energy consumption in new buildings by at least 50% is possible now, as the summary figures below show:







It is clear that whilst achievable, and cost-efficient at scale, significant work is required to support and incentivise the building industry to deliver on this target in the near term, and to move to the measurement of out-turn performance as part of the journey to 2030, 2050 and net zero emissions targets. Potential further work is therefore identified at the end of each of the following summary pages.

Note that, as described in the methodology, for some buildings further NET energy and carbon savings were available through on-site renewable energy systems (PVs, solar thermal panels) – see more information in Section 9.0.

1

Setting a contractual energy performance target

The large majority of buildings identified in this initial research share an approach: a contractual energy performance target was set for them as part of the design process. This was done either directly in the form of a particular energy performance to achieve, or indirectly through the requirement to achieve an energy standard which itself required a particular energy performance.

Offices	Contractual energy target	Primary schools	Contractual energy target	Domestic	Contractual energy target
NEF	-	Rogiet Primary School	-	Rowner Renewal Phase 2	No – but fabric efficiency target[3] for half of the units
Canolfan Hyddgen	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	St Luke's CoE Primary School	-	Wimbish	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]
Enterprise Centre	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	Bushbury Hill Primary School	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	Lancaster cohousing	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]
Keynsham Civic Centre	DEC A rating	Montgomery Primary School	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	Racecourse estate	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]
BSD office	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	Wilkinson Primary School	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]	Lark Rise	< 120 kWh/m²/yr[1] < 15kWh/m²/yr [2]

[1] Primary energy [2] Heating demand [3] Target defined using Fabric Energy Efficiency Standard (FEES) from SAP

There are a number of ways to set a contractual energy performance target, for example targets can be set as an improvement on energy benchmarks or emerge from data owned by an organisation and particularly buildings which the organisation consider 'exemplar'. The important aspect is that it should aim at delivering real (i.e. in use) energy performance.

Setting an operational energy performance target can also be done through compliance with an energy standard, as long as the standards used are robust and with a proven track record. Some of the most successful and efficient energy standards are based on clear, transparent and absolute performance metrics: NABERS (being trialled in the UK under Design for Performance pilots), DEC A rating performance contracts, Better Buildings Partnership Landlord Energy Rating, AECB Silver and Passivhaus. Whilst Passivhaus certification is strictly speaking based on as-built checks rather than operational performance, evidence available from monitored schemes shows that, on average, it acts as such, with operational performance very close to the original target.

Further work recommended:

→ Further research and examples of operational energy targets for a number of sectors would facilitate their implementation in design and construction contracts.

→ Performance requirements could be adopted, with ambitious but gradual improvements towards a 50% improvement. This would help to educate project teams about 'actual energy performance' and build over time a culture of energy performance and disclosure/transparency in the industry, and develop the associated skills and products. This could be supported initially by adopting it on public projects, and lead to a change in regulatory requirements.

2 Energy predictions during design and construction (in kWh/m²)

As explained in the previous section (Recommendation 1), most case study buildings pursued contractual operational energy performance targets. In order for these targets to be achieved, most buildings estimated their predicted energy performance frequently during design and construction to inform design choices and ensure quality during construction.

Most buildings used a simple, transparent and 'tangible' energy use metric such as 'kWh/m^2' throughout design and construction. This metric generally included estimates of all energy uses (regulated and unregulated). One of the key advantages is that this very basic metric can easily be related to by occupiers, compared against post occupancy surveys of similar buildings during the briefing stage, evaluated during the design, checked during operation and translated into both carbon and financial costs and savings throughout the process. It is also the metric used by energy suppliers for billing purposes.

Offices	**Energy use predicted during design/construction?**	**Offices**	**Energy use predicted during design/construction**	**Domestic**	**Energy use predicted during design/construction?**
NEF	-	Rogiet Primary School	-	Rowner Renewal Phase 2	No
Canolfan Hyddgen	Yes	St Luke's CoE Primary School	-	Wimbish	Yes
Enterprise Centre	Yes	Bushbury Hill Primary School	Yes	Lancaster cohousing	Yes
Keynsham Civic Centre	Yes	Montgomery Primary School	Yes	Racecourse estate	Yes
BSD Office	Yes	Wilkinson Primary School	Yes	Lark Rise	Yes

This would require an evolution of the current energy modelling approach, away from simple Building Regulations compliance towards better predicted energy assessment, and more generally better performance modelling (to also include other aspects of building performance, such as thermal comfort modelling). Methodologies and tools are available (e.g. CIBSE TM54, Design for Performance, PHPP, Energiesprong) but a step change is required to generalise their use and/or to develop additional tools.

Further work recommended:

→ CIBSE TM54 is a methodology which can be adopted and used alongside any modelling software; the existing methodology could also evolve, for example in commercial buildings it could be informed by the Better Buildings Partnership's Design for Performance scheme. PHPP is an open source spreadsheet developed by the Passivhaus Institute. Energiesprong guarantees energy performance. Innovation could be encouraged and supported to improve the prediction of energy use and link it to other efforts on digitalisation and BIM.

→ Associated with a mandatory disclosure of data, a 'kWh/m^2' indicator measured consistently at each stage and during operation would be very helpful at identifying the most successful approaches and eradicate over time the least successful.

→ Peak demand assessment (for a better integration with the electricity grid) should be considered.

3

Efficient form

Efficient form factors offer a simple and cost effective way to achieve low energy buildings.

For new buildings, a first step towards reducing energy demand is therefore to design a form which is as efficient as possible. In many of the case study buildings, this was expressed as a relatively compact form. The obvious reason for this is that when two buildings with similar specifications are compared, the one with the smaller envelope to floor area ratio will have a reduced heating demand.

This tended to be adopted particularly in primary schools and domestic buildings, where heating requirements are often the main energy use.

In order to avoid the negative consequences of deep plan buildings (e.g. increased lighting and cooling needs), in most office buildings, energy considerations led to relatively narrow plans or rooms (under 15m), allowing natural ventilation in the summer, and ideally cross ventilation with openings on both sides (or onto one side and an atrium).


Geometric variations in sections are particularly problematic as they do not only add heat loss area but also important thermal bridges as the thermal insulation line and the structural line are not consistent.

The case studies demonstrate that taking account of form does not hinder architectural expression.

This could be further supported by improved quality of detailing and construction, and innovation in high-performance products and techniques.

Further work recommended:

- → Simpler forms may also make Modern Methods of Construction (MMC) more suitable, although this would depend on other factors, such as the amount of repetitive elements.
- → Form efficiency can also work hand in hand with capital cost efficiency by reducing the amount of external envelope – this is why it was possible to deliver some Passivhaus primary schools with a normal budget.
- → We would recommend working with MHCLG to further encourage considerations of form in Building Regulations Part L. In the current approach, buildings are assessed against a notional building of the same form and layout; there is not a significant incentive to improve the energy efficiency of the building shape, and to optimise the internal layout.

4 Adopting a 'Fabric first' approach

There is a growing consensus that the building fabric represents a significant and essential opportunity to save energy and carbon for the lifetime of a building and improve its resilience. The risk of 'locking in' inefficiency and high emissions is also much higher with the building fabric than with its services and 'getting it right' is much less challenging than 'fixing it' later. This is already well-documented and is confirmed in this initial research as all case studies have adopted a 'Fabric first' approach. The table below shows the external wall U-value, the window U-value and the air permeability rate as proxies for fabric performance. In addition, the design teams paid attention not only to the performance of individual elements, but also to the envelope as a whole, including percentages of glazing and thermal bridging.

There is untapped potential, with the advent of universal acceptance of the need for higher performance fabric, for an enhanced UK supply chain offering.

Offices	**Fabric performance**	**Primary schools**	**Fabric performance**	**Domestic**	**Fabric performance**
NEF	-	Rogiet Primary School	External wall: 0.20 W/m².K Windows: 1.30 W/m².K Air permeability rate: 4.4 m³/h/m²	Rowner Renewal Phase 2	External wall: - Windows: - Air permeability rate: 3.7-4.0 m³/h/m²
Canolfan Hyddgen	External wall: 0.18 W/m².K Windows: 0.79 W/m².K * Air permeability rate: 0.37 m³/h/m²	St Luke's CoE Primary School	External wall: 0.13 W/m².K Windows: 0.9 W/m².K Air permeability rate: 2.6 m³/h/m²	Wimbish	External wall: 0.15 W/m².K Windows: 0.8 W/m².K Air permeability rate: 0.6 m³/h/m²
Enterprise Centre	External wall: 0.12 W/m².K Windows: 0.80 W/m².K Air permeability rate: 0.35 m³/h/m²	Bushbury Hill Primary School	External wall: 0.13 W/m².K Windows: 0.9 W/m².K Air permeability rate: 0.5 m³/h/m²	Lancaster cohousing	External wall: 0.12 W/m².K Windows: 0.9 W/m².K Air permeability rate: 0.5 m³/h/m²
Keynsham Civic Centre	External wall: 0.20 W/m².K Windows: 1.40 W/m².K Air permeability rate: 3 m³/h/m²	Montgomery Primary School	External wall: 0.15 W/m².K Windows: 1.0 W/m².K Air permeability rate: 0.7 m³/h/m²	Racecourse estate	External wall: 0.12 W/m².K Windows: 0.8 W/m².K Air permeability rate: 1.3 m³/h/m²
BSD Office	External wall: 0.12 W/m².K Windows: 1.0 W/m².K Air permeability rate: 0.5 m³/h/m²	Wilkinson Primary School	External wall: 0.12 W/m².K Windows: 1.0 W/m².K Air permeability rate: 0.8 m³/h/m²	Lark Rise	External wall: 0.13 W/m².K Windows: 0.7 W/m².K Air permeability rate: 0.4 m³/h/m²

Further work recommended:

→ We would recommend working with MHCLG to further encourage a fabric first approach in Building Regulations. This would contribute to better aligning the objectives of the Energy Mission with those of Part L of the Building Regulations.

- → This could go hand-in-hand with support to supply chains in order to develop better and cheaper UK products, including:
  - **Insulation:** for external walls, roofs, floors, etc.
  - **Windows:** frame as well as glazing performance.
  - **High thermal efficiency products**: balcony thermal breaks, efficient brackets, masonry support systems, brick ties, etc.
  - **Airtightness products**: membranes, tapes, gaskets.
- → Modern Methods of Construction (MMC) could add further benefits, with assemblies off-site allowing better quality detailing and less thermal bridging.
- → Fabric first also reduces peak demand, a crucial element for meeting future UK energy demand in the context of the electrification of heat and transport.
- → Airtightness is not only key to low energy and zero carbon buildings, but also a key indicator of construction quality. A greater focus on airtightness (in design <u>and</u> checked at completion) would help to drive quality during construction.

5

Heat recovery ventilation and openable windows

Another consistent point across the case studies is the approach to ventilation: all buildings have openable windows or vents for summer ventilation and to help mitigate overheating risk in the summer (this can also be used for purge ventilation). In addition, all dwellings and a large proportion of the non-domestic buildings have a mechanical ventilation system with heat recovery (MVHR).

Offices	MVHR?	Openable windows / vents?	Offices	MVHR?	Openable windows / vents?	Domestic	MVHR?	Openable windows / vents?
NEF		•	Rogiet Primary School		•	Rowner Renewal Phase 2	•	•
Canolfan Hyddgen	•	•	St Luke's CoE Primary School		•	Wimbish	•	•
Enterprise Centre	•	•	Bushbury Hill Primary School	•	•	Lancaster cohousing	•	•
Keynsham Civic Centre		•	Montgomery Primary School	•	•	Racecourse estate	•	•
BSD Office	•	•	Wilkinson Primary School	•	•	Lark Rise	•	•

MVHR provides fresh air to occupants by supplying and extracting minimum amounts of air mechanically throughout the year and recovering heat from the air extracted in the process. It can also offer significant air quality benefits, particularly in cities, by filtering the outside air before supplying it to the space. However, the MVHR unit location, specifications, installation, commissioning and the insulation around intake and exhaust ductwork are critical to achieve energy savings, sufficient ventilation rates for good indoor air quality, and low noise levels. In domestic buildings, MVHR is often considered negatively by consumers but this is due largely to the fact that many are poorly designed, installed and commissioned[9]. A step change in quality is required.

Where natural ventilation is employed for purge and summer ventilation, experience suggests that simple manual controls that can be easily operated by the user are the most effective e.g. a traditional approach of simple opening windows[10]. Additional measures (e.g. brise-soleils, external shutters, external blinds), or specific solutions (e.g. louvres in front of windows to enable a wider opening) are also employed to further mitigate the overheating risk.

Further work recommended:

→ MVHR is likely to be an essential equipment for buildings to use at least 50% less energy. A review of currently available British MVHR products and how they compare with their best European competitors would help to drive improvements and greater success of British products both for the domestic and non-domestic sectors. Skills required for high quality design, installation and commissioning of these systems also need to be improved.

→ Solutions for natural ventilation and overheating mitigation also represent a growth and innovation opportunity, not only to reduce energy use but also for climate change adaptation.

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[9] Zero Carbon Hub, Mechanical Ventilation with Heat Recovery in New Homes, Interim Report, 2012

[10] Additional provision is required where natural ventilation is also used for background ventilation, to ensure permanent ventilation regardless of user operation e.g. trickle vents

6

All types of energy uses matter

Most buildings identified as case studies have considered all energy uses in the building rather than focusing on 'regulated' energy uses only (which was the focus of previous 'Zero Carbon' regulatory efforts).

This includes uses often thought about, such as kitchen equipment and IT, but also uses particular to the building, and plant often ignored, such as fire suppression systems. This section illustrates it with just two examples. It is important to note that this does not cover 'unregulated' energy uses only as 'regulated' energy uses will also be impacted by these, e.g. IT equipment will have an impact on heating requirements.

School kitchen equipment. There is less energy wasted with induction hobs compared to gas hobs (approximate food energy efficiency of 88% vs 30% according to CIBSE TM50). There are also savings associated with ventilation as the air volumes are lower than with traditional gas cooking reducing the need to pre-heat large quantities of external air in the winter. Induction hobs can also use electricity generated during the day by the PV system and it also helps the kitchen to be safer through the absence of gas, naked flames and hot working surfaces. Post occupancy monitoring has shown energy use of 6-7kWh/m²/yr in energy efficient school kitchens.

Sprinkler systems. Many schools have dedicated standalone plant rooms for their sprinkler systems. These structures are typically built from prefabricated composites and are often uninsulated, yet they are heated with electrical resistance heaters to prevent freezing in winter. Post occupancy studies have shown these can account for around 10-14kWh/m² which is very significant. When such problems have been identified the tanks had to be retrofitted with insulation.

Typical commercial induction cooktop Prefabricated sprinkler tank

These are only examples but they highlight the need to pay attention to all energy uses during design and construction which would promote the need for energy efficient products to enable a reduction in energy use of at least 50%. Effective and simple energy efficient monitoring solutions are also required to identify issues and drive improvements. These efforts can even be translated into a contractual requirement / assumption, e.g. Energiesprong takes a typical domestic small power use and incorporates it into the contract which the resident then agrees to.

Further work recommended:

- A review of key energy efficient products manufactured in the UK with a view of improving them further or developing them could identify innovation opportunities for the supply chain, for the UK and also with export potential.
- Incentivising and standardising the development of better and simple energy monitoring / data solutions is also key.

7 Quality assurance during construction and commissioning

Most case study buildings adopted a specific quality assurance process during construction and commissioning aimed at delivering a good energy performance. Where this was not the case, this was highlighted as a hindrance to an even better energy performance[11]. The latest CCC report on the future of housing[12] states that: *it is recognised that the way average new buildings are built often falls short of design standards and that this is unacceptable: greater levels of inspection and stricter enforcement of standards are required*. Quality assurance would enable to improve this through regular monitoring and checking.

The importance of commissioning has also been highlighted in numerous reports over the past decades, including the initial PROBE studies and more recently the Innovate UK Building Performance Evaluation programme, including the meta study of MVHR systems[13]. This is essential not only for the main plant items but also for associated controls and BMS, both of which are regularly highlighted as too complex and poorly set for building users to operate.

Offices	Energy QA process (Stage 5)[1]	Energy QA process (Stage 6)[2]	Offices	Energy QA process (Stage 5)[1]	Energy QA process (Stage 6)[2]	Domestic	Energy QA process (Stage 5)[1]	Energy QA process (Stage 6)[2]
NEF	Unknown, but likely	•	Rogiet Primary School	-	•	Rowner Renewal Phase 2	-	(partial)
Canolfan Hyddgen	•	•	St Luke's CoE Primary School	-	•	Wimbish	•	•
Enterprise Centre	•	•	Bushbury Hill Primary School	•	•	Lancaster cohousing	•	•
Keynsham Civic Centre	•	•	Montgomery Primary School	•	•	Racecourse estate	•	•
BSD Office	•	•	Wilkinson Primary School	•	•	Lark Rise	•	•

[1] RIBA Stage 5 – Construction [2] RIBA Stage 6 – Handover and close out (this includes commissioning)

Further work recommended:

- → This stream of work would align well with the government's implementation of the Hackitt Review, which highlights the need for a more consistent approach to quality and detail during design, construction and handover, and the need for better enforcement (e.g. commissioning is in theory required by Building Regulations, but is notably poorly enforced).
- → It would also align well with lessons from the Each Home Counts review for retrofits, including the need for a government-endorsed quality mark (now TrustMark) based on compliance with standards and codes of practice for design, construction, coordination, and overall quality checking.

[11] Rogiet Primary School; some of the dwellings in the Rowner Phase II scheme

[12] UK housing: Fit for the future? Committee on Climate Change report, February 2019

[13] Characteristics and performance of MVHR systems A meta study of MVHR systems used in the Innovate UK Building Performance Evaluation Programme, Innovate UK, Sharpe, Tim, Mawditt, Ian, Gupta, Rajat, McGill, Grainne and Gregg, Mat (2016)

8 Aftercare for low energy consumption

Commissioning, handover and monitoring. Case studies, particularly in the non-domestic sector, were supported by thorough processes of quality checks, handover, and aftercare, often with monitoring. This was sometimes the result of adopting a Soft Landings approach, but it also took other forms e.g. an internal research programme, or monitoring to verify compliance with the energy performance target.

Aftercare and monitoring are essential to ensure that the building operates as intended and to identify needs for fine-tuning and user training, but also to gather lessons learnt for future projects. For example, early projects relied more on BMS and automation of systems (e.g. rainwater sensors that prevented operation of windows). Monitoring and experience showed these could confuse users, who often thought the systems were broken as they did not understand the control logic. More recent projects have reported higher success rates with simple and intuitive control systems, and a reduced reliance on automation and BMS.

Managing for performance. This is important not only in the first few months and years of operation, but also in the longer-term as part of building management. There needs to be a focus away from simple maintenance and reaction to user complaints, towards management for operational performance. This is where contractual targets and disclosure can help.

Please also refer to Recommendation 10 for an overview of the number of buildings which were DEC A-rated on the 2016 national register, and no longer were in January 2019: energy performance is not a given without continued attention.

In addition to energy performance, this can be part of a wider trend, including providing indoor environments which better support the health, comfort, satisfaction and productivity of occupants.

Further work recommended:

- → This stream of work would align well with the government's implementation of the Hackitt Review, which highlighted the need for a bigger focus on the operational stage
- → See also section our recommendations on energy performance targets and disclosure, which will drive more attention to good operation

9 Upskilling for better energy performance

The case studies demonstrate that achieving a 50% reduction in energy consumption is possible. However, in order for it to be widespread it will require significant upskilling and a change of culture across the industry.

This has already happened to some extent thanks to the development of Passivhaus in the UK in the past 10 years, with a growing number of qualified designers, experienced contractors, and schemes of varied typology. Due to the overlap with construction quality, lessons from these projects are then often used in other projects, even if these do not seek Passivhaus certification.

A number of areas remain in order to achieve a widespread uptake of these techniques, deliver energy savings and ensure acceptability by occupants, including:

1. Prediction of energy performance
2. MVHR design, installation and commissioning
3. Learning to simplify systems for ease of use and operation, as highlighted by successive post-occupancy evaluation studies
4. Quality assurance during construction
5. Detailed design and commissioning of BMS, controls and complex systems; these are notorious common areas of problems in operation. Upskilling is required among designers to avoid supply chain-driven solutions, without overall coordination and consideration of the desired end outcome.
6. Energy performance culture: learning from past projects, including post-occupancy evaluation; designing with the future user in mind, and engaging with them where possible.

Further work recommended:

- → Following recommendations elsewhere in this report should help create requirements and incentives for the industry to upskill.
- → Broader industry initiatives such as the new TrustMark (which responds to the Each Home Count's recommendation to create a government-endorsed quality mark), which is targeted at the domestic retrofit sector but could potentially have wider impacts, and the Hackitt Review recommendations should also lead to upskilling and a culture change towards quality and performance.

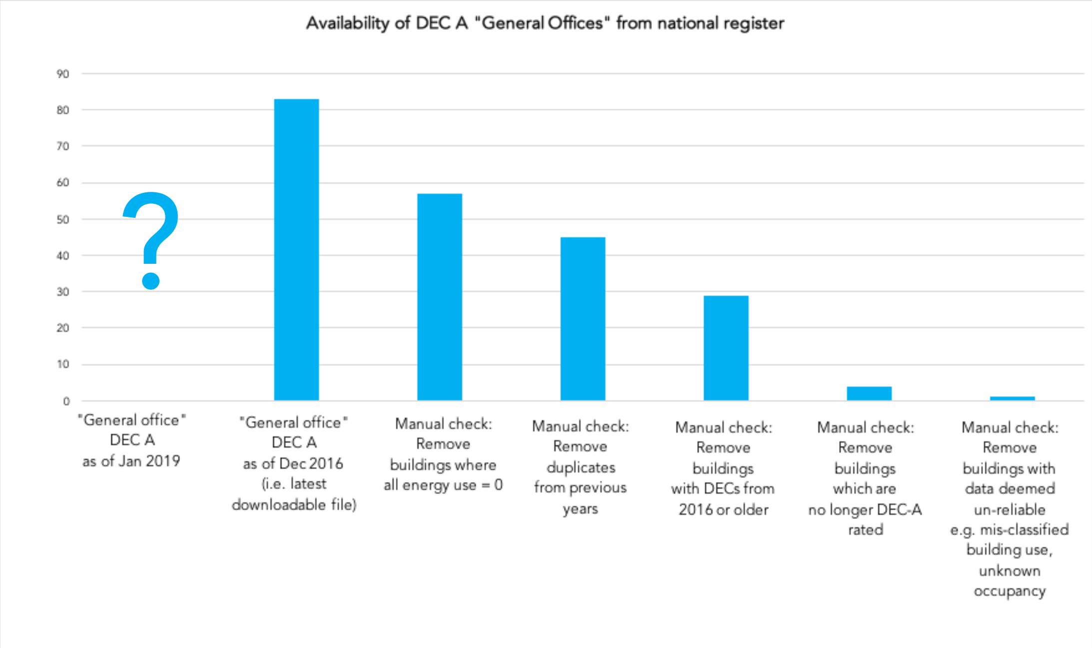
10

Better data

There is a growing consensus in the UK [14] and abroad that the building industry should move to an energy use metric in kWh/m^2. This would enable a 'single' and 'consistent' language on energy throughout design, construction and operation.

Although CIBSE energy benchmarks exist and there are a few energy databases and disclosure initiatives, the building industry has not embraced a data-led culture to drive down energy use. Operational energy data is typically not disclosed and there are very few meaningful energy databases available on public data stores.

The national register of public Display Energy Certificates (DECs) is currently the most important by far (in numbers and potential significance); however, it is vastly less useful and informative than it could be: its data can be unreliable, not often updated, and not easily accessed in bulk to allow analysis and turn data into information. This is illustrated in the figure below.



Similarly, the data generated and gathered by the Innovate UK Building Performance Evaluation programme, hosted by the Digital Catapult, is now difficult to access other than in a very high level summary form. This could be a very useful resource.

In turn this means that design and construction are not enough informed by performance data. This limits innovation triggered in other sectors by access to relevant data.

Understanding current performance. A more ambitious use and approach of available energy data could have significant benefits. One of them relevant to the Energy Mission is to quantify and measure what current 'typical' energy performance is and to evaluate it over time. Data gathered by smart meters also offer the potential to recognise differentiated loads.

[14] see for example the London Energy Transformation Initiative (LETI) https://www.leti.london/declaration and CIBSE position paper on Building Regulations https://www.cibse.org/getmedia/4a601f5c-a866-41a2-8cf7-1bab17f4f57e/Position-Paper-on-Building-Regulations-Part-L-F.pdf.aspx

Identifying what is working. Successful dynamic systems and programmes often rely on their ability to identify successes / promote them and identify failures / learn from them / discourage them. BEIS Energy Mission data should seek to enable the same virtuous continuous development.

Disclosure of energy data. For a data driven culture to benefit the design, construction and operation of buildings, the culture needs to evolve and energy data need to become more open and publicly available. Energy data disclosure and its technological dimension (e.g. platform) have a significant role to play in changing the energy consumption culture and achieve a reduction of 50% or more in the next 12 years.

Further work recommended:

- → Add an energy data dimension to the Energy Mission including energy data disclosure, protocols and artificial intelligence. especially that of unlocking the construction's digital potential through BIM and innovations in digitisation.
- → Ensure that domestic smart meters fulfil their promise to empower consumers through better knowledge of their home energy usage.
- → Improve the usability and reliability of the data currently held in the Landmark Register and other sources of information generated through public funds e.g. the Digital Catapult.
- → Work with other government departments to improve the DEC regime in terms of reliability of data, frequency of updates. We would also recommend expanding requirements to commercial buildings: the last consultation on this issue, a few years ago[15], showed overwhelming support in favour of this.
- → Review examples of organisations encouraging energy data disclosure, such as some local authorities as part of the planning system; ultimately this would work hand-in-hand with a move to contractual and, ultimately, regulatory energy performance targets (see point 2).

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[15] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/8556/37907201.pdf

11 Tenanted commercial buildings pose a particular challenge

Most of the non-domestic case studies identified in this report had public sector clients and were often owner-occupied, or tenanted with the public sector tenant likely to remain responsible for energy bills and maintenance.

Although this could also be due to the fact that **little data is available on the performance on non-public buildings**, it is more likely to be the result of public owner-occupiers and tenants wanting to achieve an exemplar energy performance.

There is currently a **lack of incentives for low-energy multi-tenanted buildings** since the investors, owners and occupiers are often different entities. In addition, enforcement of Building Regulations Part L in fit-outs can be very loose; 'core and shell' submissions by the developer are typically based on assumed fit-outs by their future tenant, and the actual fit-out is rarely subject to thorough energy compliance checks.

Some initiatives have emerged to help with:

- benchmarking (i.e. helping to define what good performance is) with one of the approaches to separate consumption associated with the landlord (e.g. main heating and cooling plant, lifts) and the tenants (e.g. lighting, IT);
- guidance and examples of incentives between investors, clients and tenants.

One such initiative is the Design for Performance pilots, led by Better Buildings Partnership (BBP), which seek to learn from Australia's NABERS programme and is trialling its implementation in the UK.

NABERS is based on a number of characteristics also identified in this report's case studies: contractual energy performance target; energy prediction from the design stage; attention to handover and commissioning. It was originally adopted by public sector occupiers, which allowed the market to upskill and helped energy performance be increasingly seen as a mark of good quality and good building management, encouraging the private sector to adopt it too.

Further work recommended:

→ Work with MHCLG to review the treatment of core and shell and fit-out in Building Regulations. Core and Shell submissions should be more strictly evaluated on their own merit (without relying on assumed fit-outs), and compliance of fit-out schemes should be more consistently enforced.

→ Trial the adoption of contractual energy performance arrangements on buildings where the public sector is either a tenant or a landlord.

→ Data disclosure: consider expanding the requirements for DEC to all non-domestic buildings[16]. If carried out alongside improvements to the disclosure regime, this could help the industry identify best practice trends, increase awareness among investors, landlords and tenants, and lead to the wider adoption of market-led measures, such as contractual energy performance arrangements between landlords and tenants.

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[16] Previous consultation showed a large support for this: in 2010, 93% of respondents agreed that DECs should be required for commercial buildings https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/8556/37907201.pdf

8.0 COMMENTARY ON CONSTRUCTION METHODS AND COST

In addition to their procurement, their delivery processes and their technical performance characteristics (e.g. fabric first approach), many case study buildings also share construction characteristics, such as the use of wood (e.g. timber cladding, timber frame). We do not think these should be seen as required for energy performance though: they are more likely to be an expression of the buildings' wider sustainability and embodied carbon aspirations.

Modern Methods of Construction (MMC) do not appear to be a common feature of the selected case studies. This may be related to the time lag between design and completion (typically 3-5 years): for a building to have been operational for at least two years and have monitoring data to demonstrate compliance with the level of energy required, it is likely to have been designed in 2012-2013 at a time when Modern Methods of Construction were less popular.

It is also important to highlight that from the list of key traits of an energy efficient building, only four of them (those highlighted in bold below) would be more easily achieved (directly or indirectly) with MMCs:

1. Contractual energy performance target
2. Future energy consumption (in kWh/m^2) estimated at design stage
3. **Relatively simple form/shape**
4. **Very energy efficient envelope**
5. Mechanical Ventilation with Heat Recovery (MVHR) and openable windows
6. **Low energy consumption as details were captured during the design process**
7. **A specific quality assurance process associated with energy performance**
8. Comprehensive commissioning
9. Mechanisms for future performance monitoring and evaluation
10. Aftercare

9.0 COMMENTS ON CARBON REDUCTION AND SUPPLY SIDE MEASURES

On-site renewable energy systems

Many buildings in this initial report incorporate a solar photovoltaic system (PVs). However, their contribution was not counted towards the energy consumption reported here, as the aim was to show buildings that could significantly reduce their energy consumption in the first place. Given the substantial savings needed, and the availability of renewable energy supply and seasonal disparities, it is paramount to reduce demand first, before contributions from renewable energy are taken into account.

This should not be considered as a reason not to install PVs, quite the contrary. PVs are a mature technology which delivers low carbon and cheap electricity. It should be taken advantage of wherever possible and would achieve further reductions in net energy consumption, and in carbon savings.

Energy efficiency will help renewable systems achieve higher savings at lower capital costs.

Community heating

It should be noted that a number of schemes we identified had the potential to be used as case studies as their energy *demand* was very low, but that this low demand was met by inefficient community heating schemes with high distribution losses[17]. It is essential to ensure that community heating schemes are low carbon and efficient. BEIS should continue to support efforts in that direction (e.g. Codes of Practice development and adoption).

Low carbon heat

The decarbonisation of the electricity grid is likely to lead to a transition towards electric-based heating systems, primarily heat pumps in new buildings. Heat pump systems reduce energy consumption further and are the single most important technology identified to decarbonise heat.

As many of the case studies selected in this initial report were built between 2009 and 2015, prior to recent decarbonisation of the electricity grid, we could not identify an evidence-based pattern of the use of heat pumps. Early heat pump installations were also often of lower efficiency but this is understood to have improved due to a combination of factors such as the Renewable Heat Incentive (RHI) requirements for efficiency and metering, new guidance and codes of practice, and general upskilling of the supply chain.

However, we mention heat pumps in this report as they are expected to play a significant role in the reduction of energy use in new buildings from now to 2030 and beyond, and for which consistently good performance coefficients will be demanded.

10.0 CASE STUDIES - FACTSHEETS

See following pages:

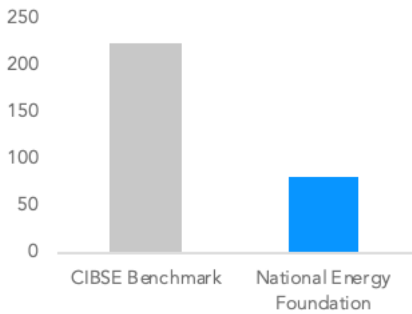
- Offices
- Primary Schools
- Domestic

[17] For example, a large apartment building with more than 150 units has a mean electricity consumption of 46kWh/m^2/yr and a mean heat demand of 33kWh/m^2/yr (i.e. 79 kWh/m^2/yr in total). However, this was equivalent to an energy consumption of more than 140 kWh/m^2/yr once plant and distribution inefficiencies are accounted for.

National Energy Foundation Phase 2 Office

Location	**Milton Keynes**	
Year of completion	**2004**	
Floor area	**430**	m²
Approximate occupancy	**9.6**	m²/person
Client occupier?	**Yes**	
Contractual performance target?	**Unknown – probably not**	
Design prediction of energy performance?	**Unknown – probably yes**	

Energy consumption	**81**	kWh/m²/year
Heating energy consumption	**-**	kWh/m²/year
Electrical energy consumption	**-**	kWh/m²/year
Annual carbon emissions	**-**	$kgCO_2/m^2$

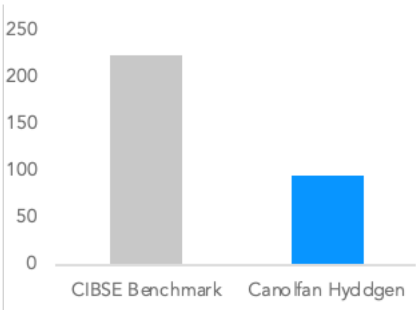


Approximate form factor	**-**	External envelope area/floor area	
Quality assurance during construction?	**Probably yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	**Unknown**		
Heating system description	**Mostly electric**	*Ground source heat pump; top-up 3kW immersion heater and local stove for very cold days; back-up biomass boiler*	
Hot water generation description	**Mostly electric**	*Top-up by solar thermal panels*	
Main ventilation type	**Natural ventilation**		
Other information	*By nature a client motivated to lower energy consumption; this was their 2nd phase building, and presumably took account of learnings from Phase 1 building.*		
References	*DEC 2018 for energy data; NEF webpage*		

Canolfan Hyddgen — Office

Location	**Macchynleth, Wales**	
Year of completion	**2009**	
Floor area	**400**	m^2
Approximate occupancy	**9.6**	m^2/person
Client occupier?	**Part yes, part tenanted**	
Contractual performance target?	**yes**	
Design prediction of energy performance?	**yes**	

Energy consumption	**95**	kWh/m^2/year
Heating energy consumption	**15**	kWh/m^2/year
Electrical energy consumption	**80**	kWh/m^2/year
Annual carbon emissions	**-**	$kgCO_2/m^2$

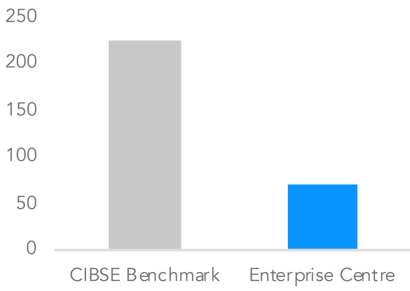


Approximate form factor	**-**	External envelope area/floor area	
Quality assurance during construction?	**yes**	After care and post occupancy monitoring	**yes**
Envelope performance	Airtightness: 0.37m^3/(h.m^2)@50Pa Exterior wall : 0.183 W/m^2/K Roof: 0.125 W/m^2/K Floor : 0.122 W/m^2/K		
Heating system description	**Gas**	*Boiler*	
Hot water generation description	**Electric**	*Point of use water heaters*	
Main ventilation type	**MVHR**		
Other information	*Summer daytime natural ventilation. Secure night time ventilation via MVHR in summer bypass mode with external & internal temperature sensors.*		
References	*Passivhaus Trust case study*		

Enterprise centre, University of East Anglia — Office

Location	**Norwich**	
Year of completion	**2015**	
Floor area	**3,400**	m^2
Approximate occupancy		m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**70**	kWh/m^2/year
Heating energy consumption	**30**	kWh/m^2/year
Electrical energy consumption	**40**	kWh/m^2/year
Annual carbon emissions		$kgCO_2/m^2$



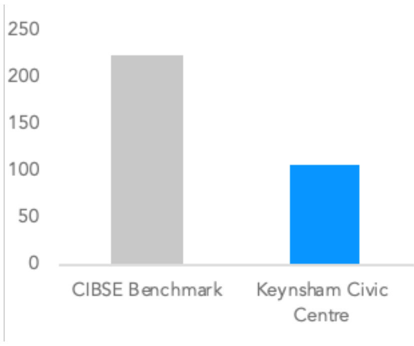
Approximate form factor		External envelope area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	Airtightness @ 50 Pa: 0.21 ACH Ground floor 0.128 W/m^2/K Walls 0.122 W/m^2/K Windows 0.77-0.81W/m^2/K Roof 0.132 W/m^2/K		
Heating system description	**District heating**		
Hot water generation description	**Unknown**		
Main ventilation type	**MVHR**	*natural cross ventilation possible in the summer*	
Other information	*narrow wings so many rooms have natural cross ventilation; some localised cooling e.g. auditorium; low VOC materials for air quality*		
References	*DEC August 2018 for energy data; Architype case study*		

Keynsham Civic Centre

Office

Location	**Bristol area**	
Year of completion	**2015**	
Floor area	**6,363**	m^2
Approximate occupancy		m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**107**	kWh/m^2/year
Heating energy consumption	**44**	kWh/m^2/year
Electrical energy consumption	**63**	kWh/m^2/year
Annual carbon emissions		$kgCO_2/m^2$



Approximate form factor		External envelope area/floor area	
Quality assurance during construction?		After care and post occupancy monitoring	**Yes**

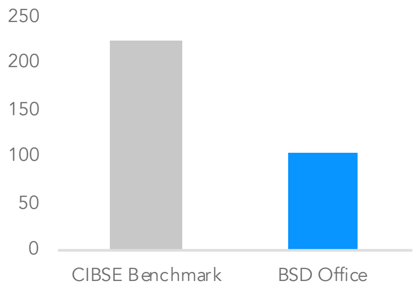
Envelope performance	Airtightness target $3m^3$:hr/m^2 @ 50Pa, actual unknown Walls: 0.20 W/m^2/K Roof 0.15 W/m^2/K Floor 0.15 W/m^2/K Window / Glazing 1.4 W/m^2/K Curtain windows 1.4 W/m^2/K	
Heating system description	**Gas**	Boiler
Hot water generation description	**Gas**	Boiler; some rooms (e.g. tea points) have local electric water heaters
Main ventilation type	**Natural**	*Predominantly passive stack ventilation, using high and low level vents and a mix of manual and BMS controls; some local mechanical ventilation, some with Heat Recovery; fans top-up depending on CO2 levels*
Other information	*Overheating mitigation: mix of BMS control for high-level vents, which allow night-time cooling, and manual control of openings*	
References	*DEC January 2018 for energy data; Max Fordham & AHR case study, Max Fordham case study for Banes; building log book*	

BSD Office, Kettering

Office

Location	**Kettering**	
Year of completion	**2017**	
Floor area	**418**	m^2
Approximate occupancy	**16.7**	m^2/person
Client occupier?	**Owner-occupied**	
Contractual performance target?	**Passivhaus**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**104 (excluding PVs)**	kWh/m^2/year
Heating energy consumption		kWh/m^2/year
Electrical energy consumption		kWh/m^2/year
Annual carbon emissions	**0 (including PVs)**	$kgCO_2/m^2$



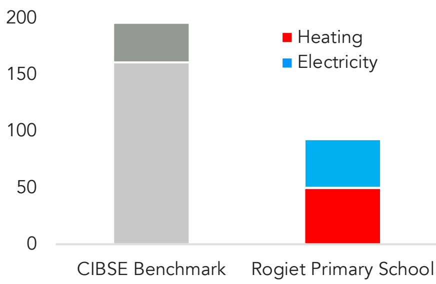
Approximate form factor		External envelope area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	Airtightness: 0.52m^3/(h.m^2) @ 50Pa External wall: 0.12 W/m^2.K Windows: 1.0 W/m^2.K		
Heating system description	**Electricity (split system)**		
Hot water generation description	**Electric at point of use**		
Main ventilation type	**Mix**	*mixed mode with mechanical ventilation, with cross-ventilation through windows in the summer*	
Other information	*Potential for passive cooling through night-time ventilation in the summer*		
References	*CIBSE Awards submission, data provided by BSD*		

Rogiet Primary School

School

Location	**Monmouthshire**	
Year of completion	**2009**	
Floor area	**1660**	m^2
Approximate occupancy	**7.90**	m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**No**	
Design prediction of energy performance?	**No**	

Energy consumption	**93**	kWh/m^2/year
Heating energy consumption	**50**	kWh/m^2/year
Electrical energy consumption	**43**	kWh/m^2/year
Annual carbon emissions	**21.20**	$kgCO_2/m^2$

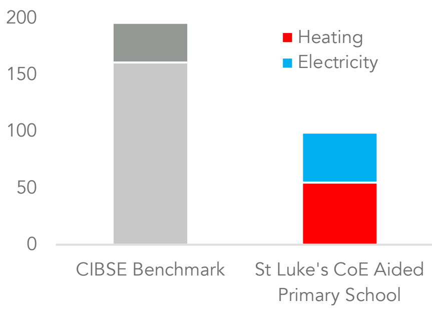


Approximate form factor	**2.94**	Surface area/floor area	
Quality assurance during construction?	**Unknown**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Unknown*		
Heating system description	**Gas**	*Gas boiler with underfloor heating*	
Hot water generation description	**Gas**	*Gas boiler supplemented with solar thermal*	
Main ventilation type	**Natural ventilation**		
Other information	*Uses recycled cellulose insulation*		

References

St Luke's CoE Aided Primary School		School	
Location	**Wolverhampton**		
Year of completion	**2009**		
Floor area	**2600**	m^2	
Approximate occupancy	**5.42**	m^2/person	
Client occupier?	**Yes**		
Contractual performance target?	**No**		
Design prediction of energy performance?	**No**		

Energy consumption	**99**	kWh/m^2/year
Heating energy consumption	**55**	kWh/m^2/year
Electrical energy consumption	**44**	kWh/m^2/year
Annual carbon emissions	**34.62**	$kgCO_2/m^2$

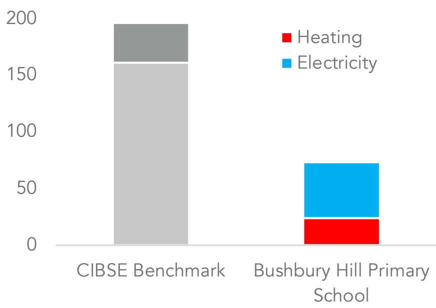


Approximate form factor	**2.59**	Surface area/floor area	
Quality assurance during construction?	**Unknown**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Opaque envelope uses 300-400mm cellulose insulation. Airtightness of 2.12ACH. Air permeability approximately 2.62m³/h.m²*		
Heating system description	**Biomass/gas**	*Biomass boiler with underfloor heating*	
Hot water generation description	**Biomass/gas**	*Assumed heated from biomass boiler*	
Main ventilation type	**Natural ventilation**		
Other information	*Designed by Architype prior to experience with Passivhaus schools. Timber framed windows*		
References	*https://www.sustainabilitywestmidlands.org.uk/resources/st-lukes-ce-primary-school-wolverhampton-winner-of-bcse-*		

sustainable-school-of-the-year-2010/

Bushbury Hill Primary School		School
Location	**Wolverhampton**	
Year of completion	**2011**	
Floor area	**1808**	m^2
Approximate occupancy	**6.70**	m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**73**	kWh/m^2/year
Heating energy consumption	**24**	kWh/m^2/year
Electrical energy consumption	**49**	kWh/m^2/year
Annual carbon emissions	**16.23**	$kgCO_2/m^2$

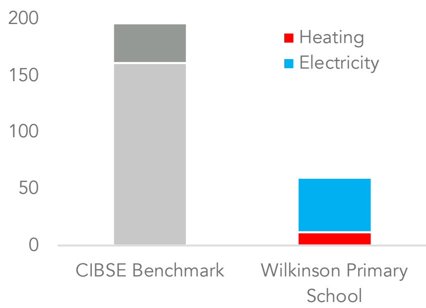


Approximate form factor	**2.27**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Walls 0.13W/m²K, roof 0.10W/m²K, floor 0.06W/m²K. Windows 0.9W/m²K. Doors 1.0W/m²K. Air permeability 0.53m³/h.m²*		
Heating system description			
Hot water generation description		*Compact - no hot water to individual classrooms*	
Main ventilation type	**Mechanical with heat recovery**		
Other information	*Designed by Architype, as their first generation of Passivhaus schools. Uses recycled cellulose insulation*		
References	*https://www.designingbuildings.co.uk/wiki/CIBSE_Case_Study_Bushbury_Hill_Primary_School*		

Wilkinson Primary School School

Location	**Bilston**	
Year of completion	**2014**	
Floor area	**2610**	m^2
Approximate occupancy	**6.21**	m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**60**	kWh/m^2/year
Heating energy consumption	**12**	kWh/m^2/year
Electrical energy consumption	**48**	kWh/m^2/year
Annual carbon emissions	**13.13**	kgCO_2/m^2

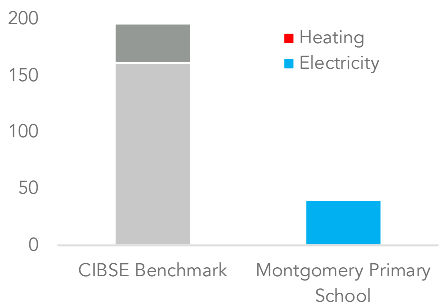


Approximate form factor	**2.06**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Walls 0.12W/m²K, roof 0.12W/m²K. Windows and doors triple glazed. Airtightness 0.48ACH. Air permeability approximately 0.75m³/hm²*		
Heating system description	**Gas**	*Single Gas Boiler. Single zone with TRV's*	
Hot water generation description	**Other**	*Gas instant in kitchen. Elsewhere small electric storage, microbore, low flow-rates*	
Main ventilation type	**Mechanical with heat recovery**		
Other information	*Designed by Architype, as their second generation of Passivhaus schools. Uses recycled cellulose insulation.*		
References	*Nick Grant - Building a better Passivhaus school. http://cygnum.co.uk/case-study/wilkinson-primary-school-wolverhampton/*		

Montgomery Primary School — School

Location	**Exeter**	
Year of completion	**2012**	
Floor area	**2774**	m^2
Approximate occupancy	**6.60**	m^2/person
Client occupier?	**Yes**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**60**	kWh/m^2/year
Heating energy consumption	**-**	kWh/m^2/year
Electrical energy consumption	**-**	kWh/m^2/year
Annual carbon emissions	**8.54**	kgCO_2/m^2

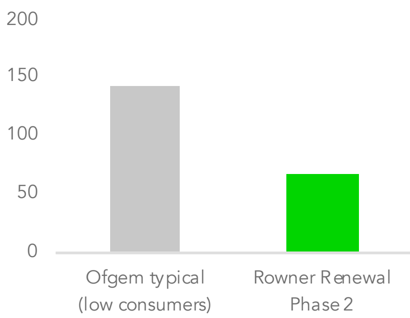


Approximate form factor	**1.79**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Opaque envelope U-value of 0.15W/m²K. Air permeability 0.68m³/h.m²*		
Heating system description	**Electric**	*Electrical*	
Hot water generation description	**Electric**	*Air source heat pump*	
Main ventilation type	**Mechanical extract**		
Other information	*Five years of monitoring was undertaken by Exeter Univeristy. Demonstrated that 96% of the school's energy was provided by the solar PV from 2012 to 2017.*		
References	*https://www.exetercityfutures.com/programme/partners/montgomery-primary-school/*		

Rowner Renewal Phase 2 — Domestic

Location	**Hampshire**		
Year of completion	**2011**		
Floor area	**24 units**		
Approximate occupancy	**-**	m²/person	
Client occupier?	**-**		
Contractual performance target?	**No**		
Design prediction of energy performance?	**No**		

Energy consumption	**67**	kWh/m²/year
Heating energy consumption	**37**	kWh/m²/year
Electrical energy consumption	**30**	kWh/m²/year
Annual carbon emissions	**18**	$kgCO_2/m^2$



Approximate form factor	**-**	Surface area/floor area	
Quality assurance during construction?	**No**	After care and post occupancy monitoring	**No**

Envelope performance: *Walls 0.18W/m²K, Windows 1.50W/m²K, Air permeability rate approximately 3.7-4.0m³/hm²*

Heating system description: *Individual gas boiler*

Hot water generation description

Main ventilation type: **Mechanical with heat recovery**

Other information

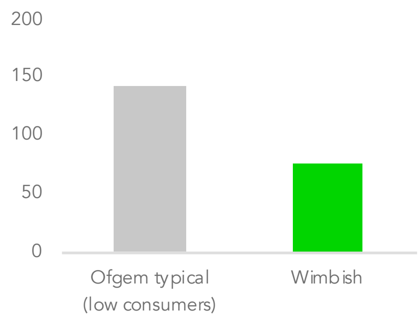
References: *http://www.zerocarbonhub.org/sites/default/files/resources/reports/ZCH-RownerResearch-Phase-II.pdf*

Wimbish

Domestic

Location	**Essex**	
Year of completion	**2011**	
Floor area	**14 units**	
Approximate occupancy	**-**	m^2/person
Client occupier?	**-**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**75**	kWh/m^2/year
Heating energy consumption	**38**	kWh/m^2/year
Electrical energy consumption	**37**	kWh/m^2/year
Annual carbon emissions	**-**	$kgCO_2/m^2$

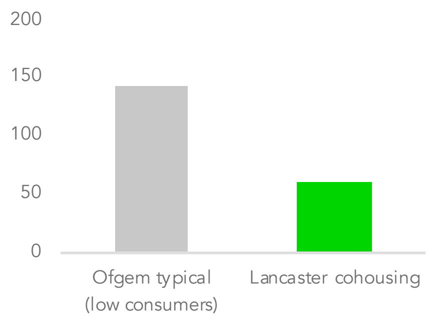


Approximate form factor	**-**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Walls 0.11W/m^2K, Windows 0.80W/m^2K, Air permeability rate approximately 0.6m^3/hm^2 (airtightness 0.6ACH)*		
Heating system description	**-**	*Individual gas boiler with solar water heating*	
Hot water generation description	**-**		
Main ventilation type	**Mechanical with heat recovery**		
Other information			
References	*http://www.hastoe.com/page/760/Wimbish-passivhaus-performs--Hastoe-releases-results-of-two-year-study.aspx*		

Lancaster cohousing — Domestic

Location	**Lancashire**	
Year of completion	**2012**	
Floor area	**41 units**	
Approximate occupancy	**-**	m²/person
Client occupier?	**-**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**61**	kWh/m²/year
Heating energy consumption	**39**	kWh/m²/year
Electrical energy consumption	**22**	kWh/m²/year
Annual carbon emissions	**-**	$kgCO_2/m^2$



Approximate form factor	**-**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**

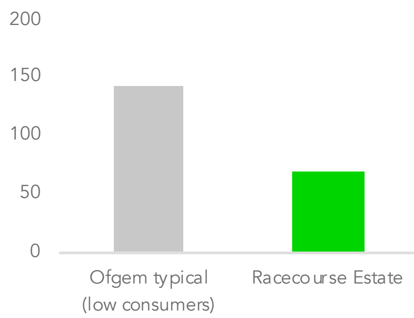
Envelope performance	*Walls 0.12W/m²K, Windows 0.9W/m²K, Air permeability rate approximately 0.5m³/hm² (airtightness 0.5ACH)*
Heating system description	*Community heating (biomass boiler, solar water heating)*
Hot water generation description	
Main ventilation type	**Mechanical with heat recovery**
Other information	
References	*http://www.passivhaustrust.org.uk/UserFiles/File/UK%20PH%20Awards/2013/Posters/UKPHAwardsPoster_social%20housing_Lancaster.pdf*

Racecourse Estate

Domestic

Location	**Durham**	
Year of completion	**2012**	
Floor area	**25 units**	
Approximate occupancy	**-**	m^2/person
Client occupier?	**-**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**70**	kWh/m^2/year
Heating energy consumption	**-**	kWh/m^2/year
Electrical energy consumption	**-**	kWh/m^2/year
Annual carbon emissions		kgCO_2/m^2



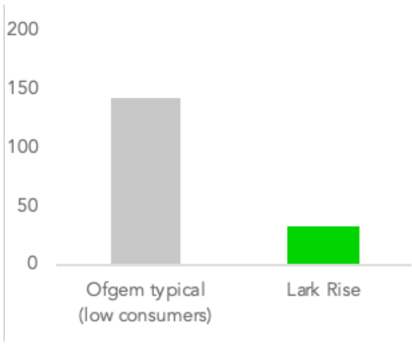
Approximate form factor		Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**

Envelope performance	*Walls 0.12W/m²K, Windows 0.8W/m²K, Air permeability rate approximately 1.4m³/hm² (airtightness 0.6ACH)*
Heating system description	
Hot water generation description	
Main ventilation type	**Mechanical with heat recovery**
Other information	*Monitored data to be confirmed*
References	*http://goodhomes.org.uk/wp-content/uploads/2017/05/gha-case-study-racecourse-full.pdf*

Lark Rise — Domestic

Location	**Buckinghamshire**	
Year of completion	**2015**	
Floor area	**175 m²**	Single house
Approximate occupancy	**2**	persons
Client occupier?	**Tenanted**	
Contractual performance target?	**Yes**	
Design prediction of energy performance?	**Yes**	

Energy consumption	**32**	kWh/m²/year
Heating energy consumption	**11**	kWh/m²/year
Electrical energy consumption	**21**	kWh/m²/year
Annual carbon emissions	**Carbon negative**	$kgCO_2/m^2$



Approximate form factor	**2.9**	Surface area/floor area	
Quality assurance during construction?	**Yes**	After care and post occupancy monitoring	**Yes**
Envelope performance	*Walls 0.13W/m²K, Windows 0.7W/m²K, Roof 0.07W/m²K, Air permeability rate approximately 0.4m³/hm² (airtightness 0.4ACH)*		
Heating system description	**Air source heat pump**		
Hot water generation description	**Air source heat pump**		
Main ventilation type	**Mechanical with heat recovery**		
Other information	**Large PV array** (not included in energy data above)		
References	*https://www.bere.co.uk/architecture/lark-rise/*		

Construction Leadership Council

The Construction Leadership Council (CLC) draws together Government with business leaders from across the sector with the aim of reducing the time to build and the cost whilst also improving sustainability outcomes. Through the Construction Sector Deal it has identified three key enablers to deliver this transformation: digitalisation to deliver better, more certain outcomes, off-site manufacturing to improve productivity, quality and safety, and by addressing whole life performance to improve energy performance, lower emissions and reduce running costs. The Council has Co-Chairs, one a leader from industry and the other the government Construction Minister. The CLC works through a number of different workstreams and task groups.

www.constructionleadershipcouncil.co.uk

Green Construction Board

The Green Construction Board (GCB) is the sustainability workstream of the Construction Leadership Council. Participants are key members of the UK construction and property industry. Its main role is to advise government and the built environment industry on the regulatory and policy framework and actions required to overcome barriers to the delivery of green buildings and infrastructure as well as to promote the commercial opportunities of sustainable construction. Progress on activities is reported via the GCB Chair into the Construction Leadership Council.

www.constructionleadershipcouncil.co.uk/workstream/sustainability/

For further information contact:

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