Passivhaus Trust

The UK Passive House Organisation

Passivhaus Construction Costs

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Contents

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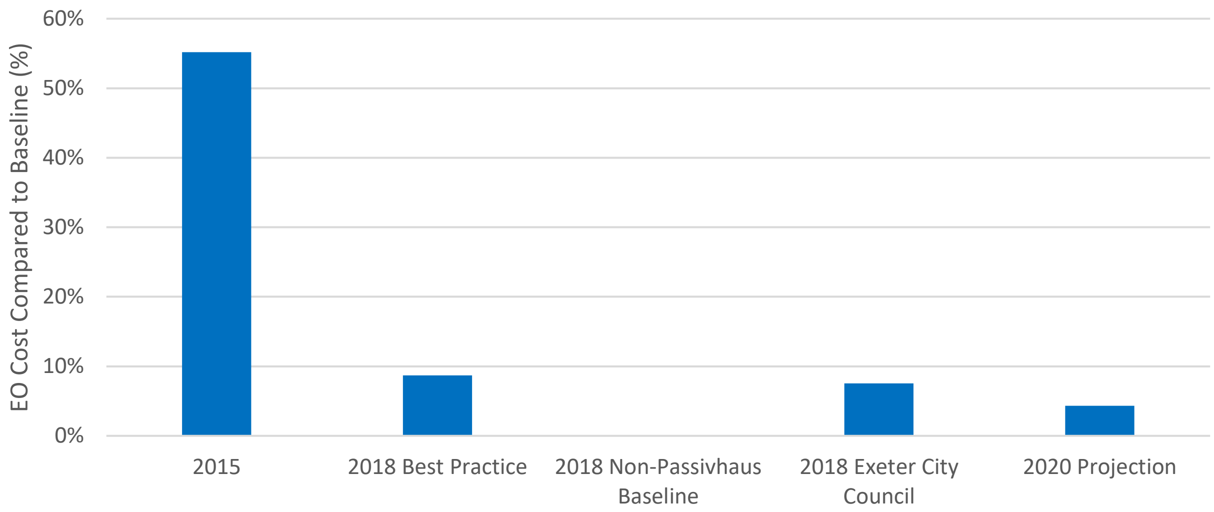
Executive Summary

This study has looked at several historical Passivhaus developments to derive the cost premium, or extra over cost, of building to the Passivhaus standard. It has then compared these results with previous analysis and other reports to demonstrate the cost trend and where it is likely to settle should Passivhaus be adopted at scale in the UK.

The overall summary of this trend is shown in the chart below and demonstrates current best practice is at 9% extra over costs. However, Exeter City Council, with nearly 9 years' experience, are now building Passivhaus at a premium of just 8% over baseline and that the steady-state projection of Passivhaus adoption at scale is around 4%.



To achieve this there are several key success factors which sets a Passivhaus development apart from a typical project:

1. Passivhaus needs to be part of the initial brief
2. Employ an experienced Passivhaus Designer or Consultant
3. Keep it simple
4. Ventilation design is important
5. Overheating control is part of the standard
6. Airtightness is key
7. Everybody needs to know
8. It isn't just about design
9. Designer and Contractor working together
10. Get the certifier onboard early

It should also be noted that there are several additional benefits of building to the Passivhaus standard including reduced life cycle costs, increased comfort and health benefits (such as warmer homes, better air quality and less risk of mould) which have not been accounted for in this study but will be the subject of future work.

Overall, this analysis has shown that by following some key principles and leveraging prior experience, Passivhaus projects in the UK can be achieved for a modest extra over cost likely to be around 4% or less once adopted at scale.

Introduction

This study has examined a range of different Passivhaus residential developments which, bar one, were completed between 2014 and 2018, to determine the extra over costs when compared to a non-passivhaus equivalent. The majority of the developments were built for social landlords and are of modest size of between 3 and around 90 units. They comprise some low-rise developments of 2-3 bed apartments and terraced and sometimes semi-detached mainly 3-bedroom houses, often for a mix of tenures e.g. 'social rent', 'affordable rent', shared ownership – and sometimes a portion for private sale. There was also one development for the private market and to a considerably higher specification.

Construction methods varied between timber frame faced with brick or render, masonry cavity, and solid masonry; with insulation within the frame, integral to the masonry, in a cavity, or externally, or a combination of these.

From the (differing) information available about these projects it has been possible to arrive at some indicative costs per square metre for the additional cost of Passivhaus, broken down into the various elements or stages of the construction process to which they apply. From this we have arrived at a potential range of extra-over costs per m^2, and a range of factors that appear to enable these costs to be kept at the lower end.

Project Summary

No.	No. Units	Date of Tender	Tenure	Building Form	When was PH adopted?	Construction Method	Corrected Build Cost (£/m^2) exc externals and fees
1	1-9	2018	Private Sale	Terraced	Outset	porotherm block	1,529
2	10-30	2018	Affordable council homes	Terraced	Outset	Porotherm block	1,296
3	10-30	2018	Affordable council homes	Flats	Outset	Porotherm block	1,453
4	1-9	2018	Affordable council homes	Terraced/Semi	Outset	Porotherm block	1,751
5	10-30	2018	Affordable council homes for over 60s	Flats	Outset	Porotherm block	1,807
6	10-30	2016	Private Sale	Terraced	Outset	Porotherm block	2,070
7	10-30	2010	Affordable council homes for over 60s	Flats	Outset	Concrete Block and EWI	1,542
8	1-9	2015	Affordable council homes	Terraced	Outset	Porotherm block	1,517
9	1-9	2015	Affordable council homes	Terraced	Outset	Porotherm block	2,035
10	31+	2017	Social Rent	Mixed Terrace/Flats	After 1st Design	Timber Frame	1,966
11	1-9	2016	Affordable Rent	Semi	After 1st Design	Timber Frame	1,927
12	31+	2016	Mix of rent and shared ownership	Terraced	Outset	Concrete Block and EWI	1,954

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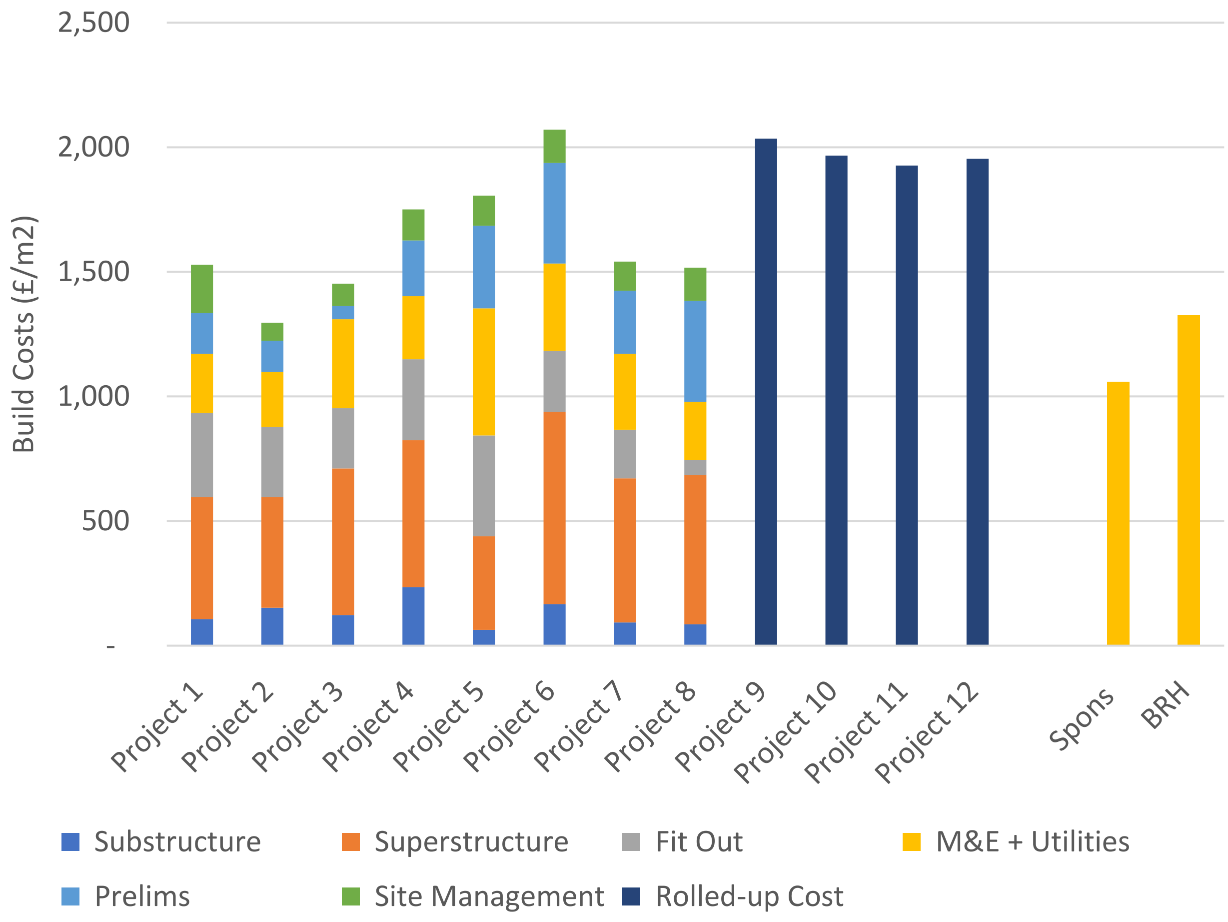
Cost Comparison

The chart below shows the overall cost per m^2 of each project. Elemental costs are shown where they were available. In other cases, only the overall rolled-up cost has been shown. The average cost of the equivalent normalised project (taken from SPONS 2018) and an alternative average suggested by Baker Ruff Hannon are shown as comparators[1].



The extra-over percentage costs against the SPONS UK average and the average suggested by Baker Ruff Hannon are as follows:

	1	2	3	4	5	6	7	8	9	10	11	12
Compared to Spons	31%	18%	27%	39%	41%	49%	31%	30%	48%	46%	45%	46%
Compared to BRH average	13%	-2%	9%	24%	27%	36%	14%	13%	35%	33%	31%	32%

[1] This figure derives from a number of non Passivhaus 'Design & Build' projects Baker Ruff Hannon have undertaken with Housing Associations in the South West region, ranging in size between 9 and 60 homes (for regional cost variation, SW construction costs are at 100% i.e. baseline): the average was £1,325/m^2. We have used this as a comparator. In comparison the Passivhaus projects that BRH have been involved had an average of £1,465/m^2. (NB this represents a ~11% uplift for this small, unadjusted group of projects)

Costing Methodology

The build costs per m^2 shown have been derived from cost data provided by the project teams. In order to provide an equitable comparison, this source data has been adapted using the following methodology:

- In some projects, the majority of the elemental costs were available, but one or two were not. Rather than exclude the entire project from the analysis, the missing elemental costs have been extrapolated from averaged costs for this element from the other projects

- Where more than two elemental costs were unavailable, only the overall rolled-up costs have been shown

- External works (landscaping etc) have been excluded

- Professional fees relating to Passivhaus have been excluded as they are not generally a valid cost per m^2 of build and, for larger projects will tend to be a relatively small contributor

- Costs have been corrected to be equivalent to a common baseline of a 2018 terraced build, in order to eliminate so far as possible the variations due to date, project size and composition, etc. The detail of how the correction factors have been arrived at is shown in Annex A.

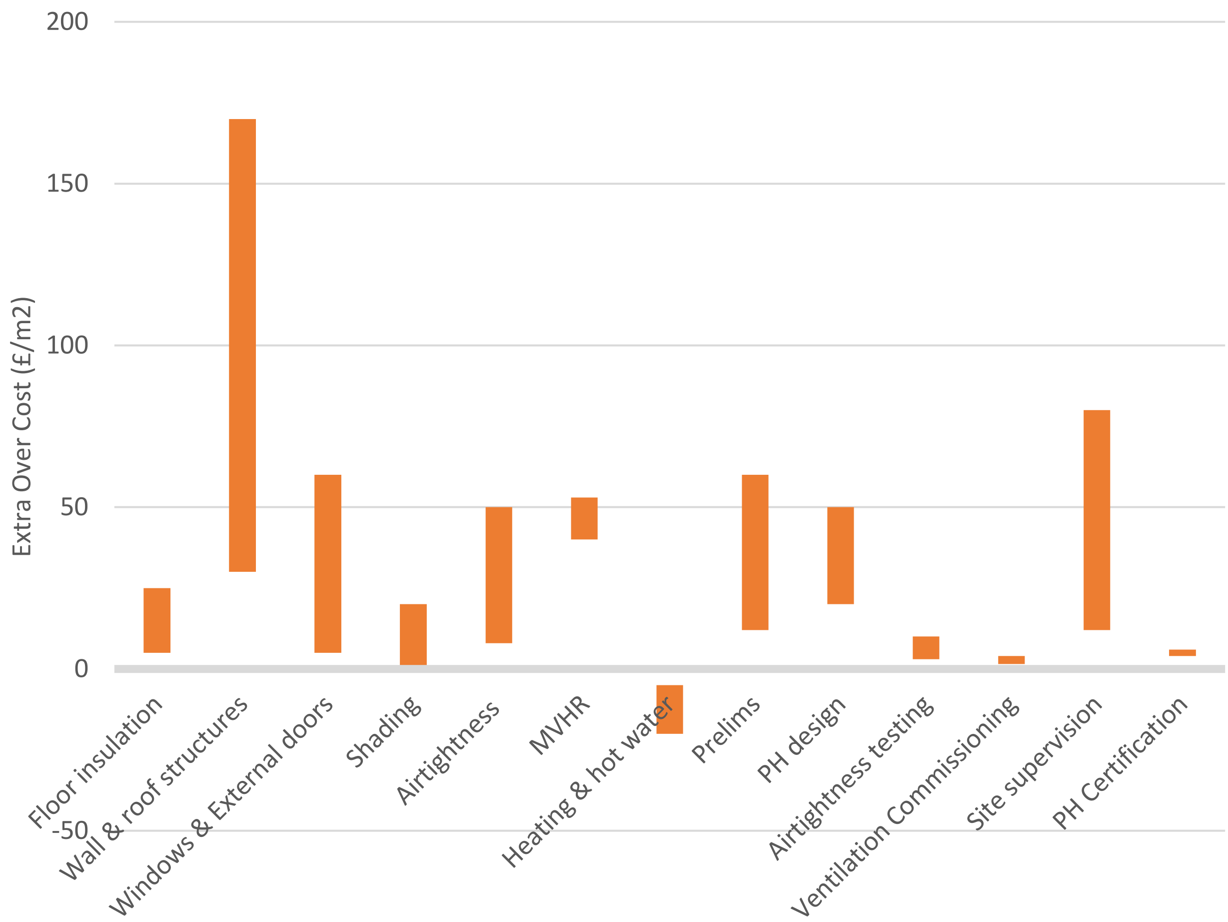
- Correction factors applied are as follows:
    - Year of build
    - Size of development
    - Mix of build types
    - Location

Analysis of Extra Over Costs Identified

Element	Possible PH EO element(s)	Detail/examples/commentary
Substructure	Floor insulation	Floor constructions included insulated slab, and beam and block floor with additional insulation, but as there are many other factors affecting substructure cost (relating to site conditions), extra-over costs specific to Passivhaus can be difficult to identify.
Superstructure (above dpc)	Wall & roof structures	Basic construction may be similar to a standard build, or modified e.g. using thermal-bridge free and/or wider cavity ties, wider i-beams, lightweight blockwork etc
	Wall & roof insulation	Whether this is a minor or major extra cost will depend on wall construction, but the biggest variations have been seen due to building form and in particular, complexity such as setbacks, cantilevers etc, requiring specialist structural thermal breaks
	Windows & external doors	Extra-over cost rises with glazing area, and steeply with very large glazed openings such as patio doors. These are heavy and therefore expensive to install, also requiring specialist hinges/rails etc. Also, a high glazing ratio is more likely to lead to the need for shading/shutters.
	Shading	Generally only required when glazing design has not been optimised for summer performance – e.g. through poor design (or adoption of Passivhaus too late in the design process), or for reasons of luxury. Therefore no 'reference' figure is given, but indicative costs only. It can also be argued that this is not really a Passivhaus cost as overheating should be addressed in a non-passivhaus building as well.
	Airtightness	May be via tapes, parge, membrane, board – or combination.
Mechanical and electrical services	MVHR	Always required in UK Passivhaus. Usual option is a passivhaus certified unit, system always designed and commissioned by specialists. Strictly, a small amount can be subtracted from the MVHR cost to account for a non-PH system that would otherwise have been installed. The trivial price of many of these reflects, sadly, their trivial ability to move air. NOTE: if it is already expected that MVHR would be used for example to meet local codes (as seen with the zero-carbon requirements in London for example), or to achieve better SAP ratings, then the uplift to Passivhaus standards will be less that that identified in this analysis
	Heating and hot water	Usually a net saving in Passivhaus as smaller heat source and fewer heat emitters required, compared to a standard build.
	Renewables	Only required when needed to balance the primary energy for the PER target, if used, or for more advanced levels of Passivhaus such as Plus or Premium. Not included in comparison.
Preliminaries	May include EOs for supervision and risk	Depending on the individual procurement/contract approach, may also include some or all fees - listed separately below.
	Airtightness testing	Each unit is tested at completion and it is also usual to perform earlier tests to inform construction process
	Ventilation commissioning	Ensures MVHR is giving correct flow in all rooms and is acceptably quiet. Commissioning is theoretically required in conventional construction, but self-certification is permitted, and evidence suggests it is seldom carried out adequately outside of Passivhaus.
	Site supervision/clerk of works/training	Apportioned differently in different contracts. EO element for Passivhaus not often broken out, but sometimes for example an airtightness champion is specifically identified.
	Passivhaus Certification	Essential – good certifiers offer advice throughout the design and construction process.

Range of Extra Over Costs

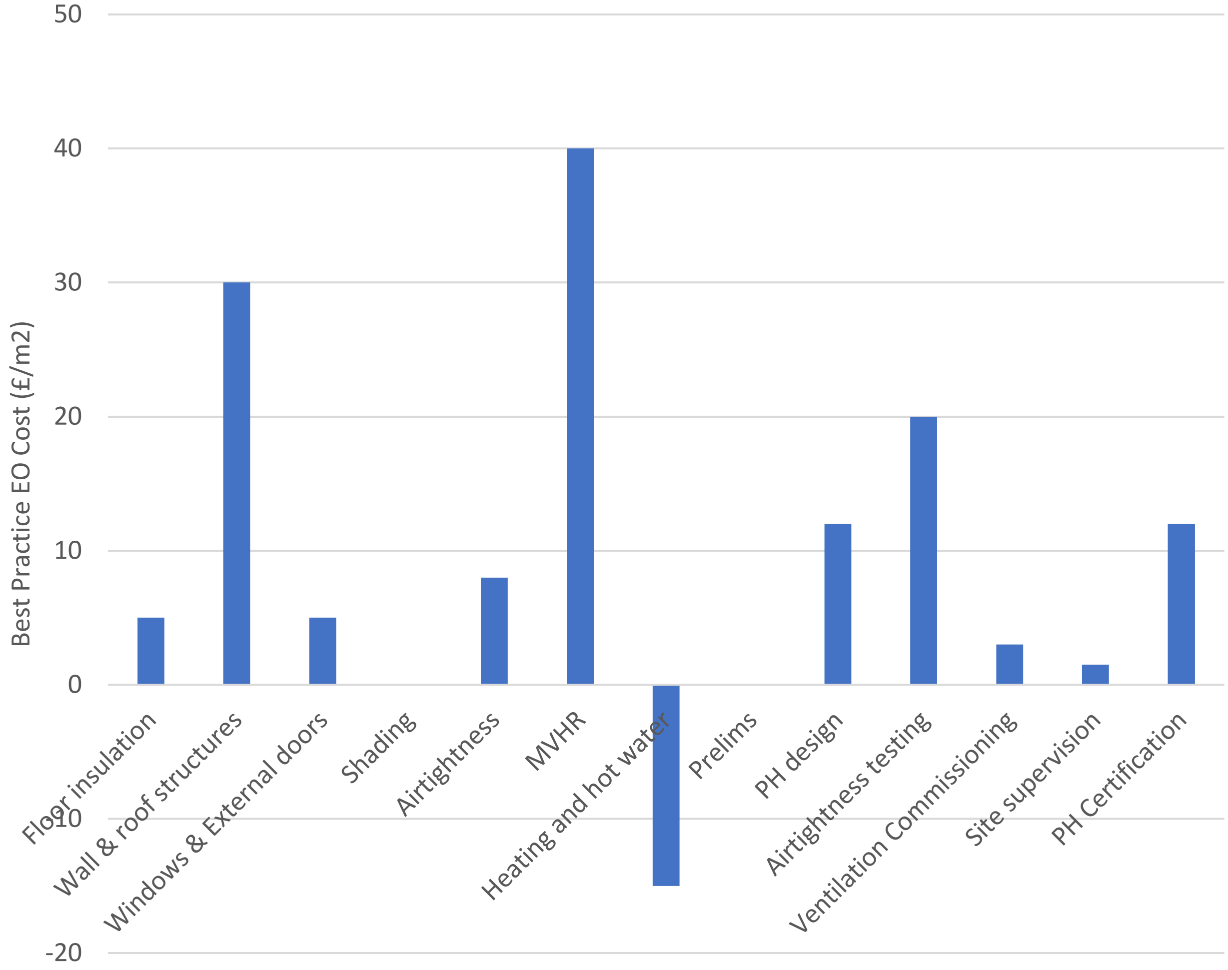
The range of extra-over costs noted for each project has been examined and shows a wide variation in some cases. Often these areas are where either better/earlier design decisions or better on-site practices would result in costs towards the lower end of the cost ranges identified – though in some cases they arose through deliberate design decisions, e.g. for 'luxury' features. The range of extra-over costs observed relating to Passivhaus are shown below. Note that there may be some overlap or interdependence between categories. For example, the costs for wall and roof structures may include some elements of airtightness that it has not been possible to break out as a discrete cost. However, this analysis still gives a good indication of the relative impact of the various Passivhaus related elements.



Best Practice Extra-Over Costs

The lower end of each extra-over element has been used to provide an indicative breakdown of a notional project where best practice has been used in all cases. This is simplistic in some ways as it ignores potential interaction between categories – i.e. the cheapest option in one area could result in increased costs somewhere else. However, in general, the projects analysed showed that lower costs were achieved through good, simple design supported by rigorous on-site practices during the construction phase. This suggests that it would be feasible to achieve close to best practice extra-over costs in each category.

Applying this methodology produces an indicative best practice Passivhaus extra-over cost of £115/m^2, which is 11% of the average Spons UK build cost for terraced housing, or 9% of the Baker Ruff Hannon average (which relates to projects that are more comparable to our sample).



The Cost of Quality Assurance

It can be seen that the costs of additional site supervision can be a considerable (up to £80 per m^2). One of the key features of the Passivhaus standard is that the associated certification and quality assurance process ensures that the project is built as designed, and thus there is little or no performance gap. In comparison, the average UK home exhibits energy consumption of at least 40% more than the design would predict[2]. Future standards and legislation will seek to close this performance gap[3] and thus additional quality assurance mechanisms will need to be implemented at a national level. This could take the form of an enhanced Building Control regime or perhaps see the actual performance of buildings being monitored with punitive measures for those that do not perform as their design predicts. For a Passivhaus project, the additional costs of an enhanced inspection regime are currently considered as part of the associated extra-over costs.

It is therefore questionable whether, in the future, the additional quality assurance costs associated with Passivhaus should be included as genuine Passivhaus extra-over costs as this level of supervision will be required for all projects if the performance gap is to be successfully closed. For the purposes of this analysis, they have been included, but their omission would further reduce the Passivhaus extra over costs.

[2] Passivhaus: the route to Zero Carbon?, March 2019, Appendix 2

[3] See for example recommendations to Government of the Hackitt Report (written at the request of Government, in response to the Grenfell fire) and of the Committee on Climate Change. The latter made closing the energy performance gap it's top recommendation in the 2019 report "UK Housing: Fit for the Future", in response to government's request for a road map for decarbonisation up to 2050, in order to meet its legal obligations. https://www.theccc.org.uk/wp-content/uploads/2019/02/UK-housing-Fit-for-the-future-CCC-2019.pdf

Passivhaus as a driver for skills and quality uplift

One of the main concerns about improving building performance in the UK is the skills gap in design and construction. The success of these Passivhaus projects suggests both that the skills are all achievable given the right context – and that designing and building to Passivhaus is a good way to embed these skills in future practice.

The following examples illustrate this happening in practice:

Quality & learning: design

On a project that had originally been designed without Passivhaus specifically in mind, but was adapted to reach Passivhaus, the designer explained that they had reduced the size of some large north-facing windows in order to reduce heat loss. "We realise now that this is not just good practice for Passivhaus, it is good practice for all our builds."

Quality & learning: construction

On a site of mixed Passivhaus and Code homes, the contractor explained how learning had passed from the Passivhaus portion to benefit the non-PH builds:

"We found that what the subcontractors learned on the Passivhaus builds, they took into the rest of the site. For example there was a tricky bit of sequencing where the vapour check membrane had to be wrapped around some joists, and this was not always being done properly. We picked this up and resolved it on the Passivhaus builds, and after that, the same detail was done properly on the rest of the site too**."**

On another, all-Passivhaus site, the QA process adopted by the contractor led to a significant drop in defects, and now informs all their builds:

"Defects and legacy are so frustrating for a contractor – you lose a lot of money and tie good people down going back to sort stuff out. The (QA) sign-off process has been a good lesson and reaped rewards in our business. It has been a good learning process for us."

Through-life and broader benefits

Whilst this report concentrates on the initial capital costs of a Passivhaus development, any discussion of costs should also consider the impact on through-life costs.

It is no accident that many Passivhaus projects are being taken forward by Local Authorities and Housing Associations. This is likely to be because, unlike market housing development, the client gains long-term benefit from lower voids, rent arrears, operational costs and fewer defects. In effect, higher up-front investment is made in return for longer term benefits.

Typical benefits which attract landlords and local authorities include:

- Energy Saving leading to fuel poverty eradication
- Reduced maintenance and lifecycle costs
- Reduced rent arrears & voids
- Fewer complaints arising from noise issues
- Market value increase (rent & sale capital)
- Future-proofed – less ongoing capital investment

There are also broader quality considerations which reduce through-life costs. Passivhaus buildings will have been checked (and certified) for internal surface temperatures and condensation risk which ensures that the building fabric is not at risk. In contrast, in buildings which have at-risk construction build-ups, moisture issues often take several years to come to light, and then can be expensive to repair.

Furthermore, the quality of components (e.g. windows) is likely to be higher in a Passivhaus as the thermal conductivity and airtightness properties will need to be of a good standard. The net result is that these components will last longer than inferior alternatives thus, again, reducing through-life costs.

There are also broader health and wellbeing benefits which go beyond purely financial considerations. The Passivhaus Trust will be exploring these further in a future publication.

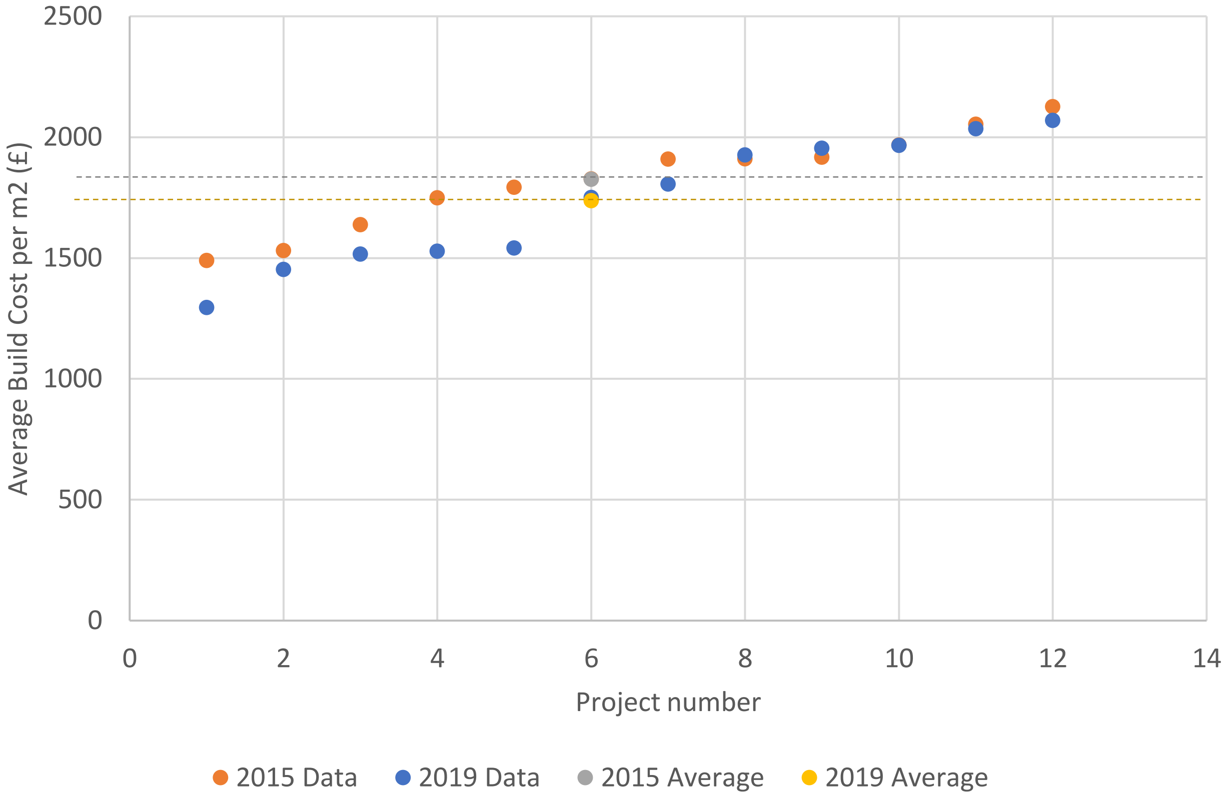
> “OUR OLDEST PASSIVHAUS DWELLINGS ARE ALMOST 10 YEARS OLD AND SO FAR, WE HAVEN’T HAD TO REPLACE A SINGLE COMPONENT … WE HAVE ALSO NOTICED WE GET LOW RATES OF ANTI-SOCIAL BEHAVIOUR ON OUR PASSIVHAUS DEVELOPMENTS. WE LOOKED INTO IT AND THE SUGGESTION IS THAT THE IMPROVED NOISE ABATEMENT WITH AIRTIGHT AND HIGHLY INSULATED DWELLINGS IS HELPFUL IN THIS REGARD.”
>
> *Emma Osmundsen, Managing Director of Exeter City Living Ltd*

Future Trajectory

Whilst there are now over 1200 certified Passivhaus dwellings in the UK, this is still a small fraction of the total number of new homes (circa 165,000[4] in England alone) built in the UK each year. The costs presented in this analysis should therefore be considered as early adoption costs; extra over costs for Passivhaus as a mainstream building standard are likely to be significantly lower.

Previous Passivhaus Trust Analysis

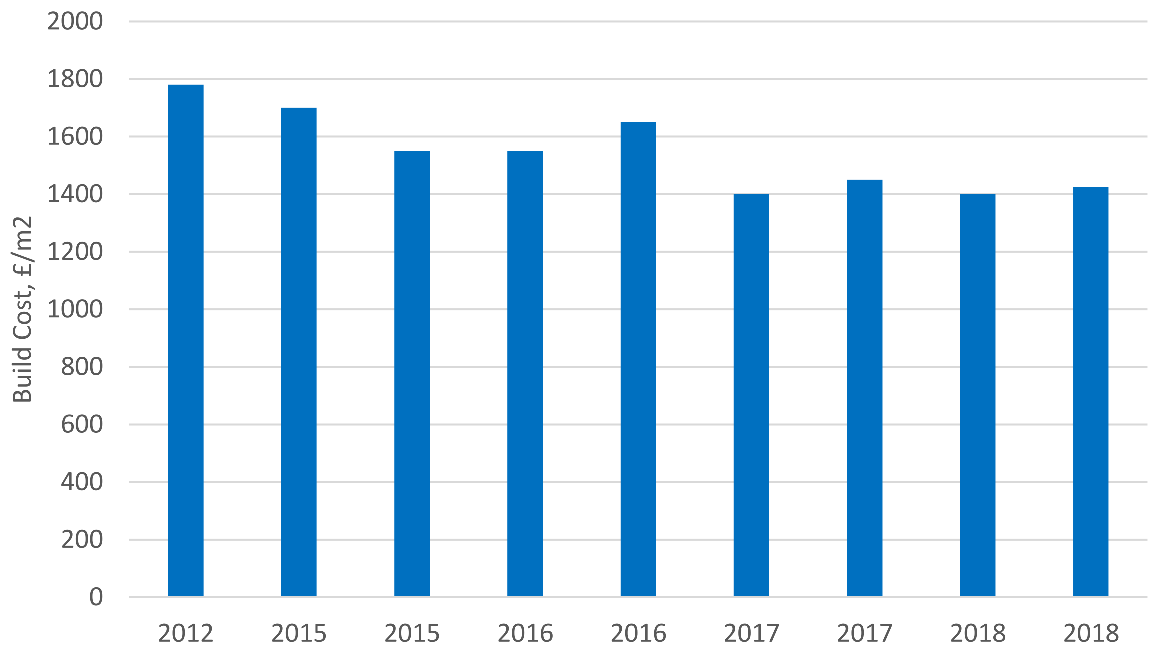
The Passivhaus Trust published a research paper[5] in 2015 which identified Passivhaus build costs per m^2 and concluded that, at that point, the extra over costs were between 15 and 20%. The chart below, corrected for build-cost inflation and external works[6] shows that there is a consistent trend of reducing costs from 2015 to 2018 over the period. In general, the cheaper projects have become even cheaper whilst the more expensive projects are more consistent.



Exeter City Council Build Costs

Further evidence of decreasing costs are evident in build costs from Exeter City Council who have now been building Passivhaus projects since 2010. Again, corrected for inflation (but not for location and other factors, so not comparable with other figures in this analysis), the chart below shows that build costs by project have reduced by 25% over 5 years. This reflects Exeter's growing experience as a client, alongside maturing supply chains and more experienced designers and contractors. Further details about how this has been achieved is included in the Case Study section of this report.

[4] New starts from Dec 17 to Dec 18 taken from MHCLG Publication "House Building; new build dwellings, England, December Quarter 2018"
[5] Passivhaus Capital Cost Research Project, January 2015
[6] The 2015 study included external works. An average elemental cost of 18% has therefore been deducted to achieve an equitable comparison



Currie and Brown Analysis for the UKCCC

Whilst this study has looked at historic build costs, an analysis by Currie and Brown in support of the UK Committee on Climate Change[7] looked at the likely future costs of building to a very high fabric standard at scale in the UK. Whilst the standard was not expressly specified as Passivhaus, the space heating demand metric of 15 kWh/m^2.year was included and this is typically not achievable without Passivhaus levels of fabric performance. This study found that, once the costs of supporting materials and technologies had stabilised at volume, the extra over cost of building to this standard was an estimated £4,800 for an 84m^2 semi-detached property, which is equivalent to an extra over cost of £57 per m^2. This is just 4.3% of the current Baker Ruff Hannon average build cost.

Factors influencing future Passivhaus Build Costs

Project and Cost Managers Baker Ruff Hannon have experience working with registered social landlords to procure Passivhaus and have examined ways in which costs vary between Passivhaus and mainstream construction.[8]

Passivhaus is still young, and to date projects have tended to be scattered one-offs. As BRH point out:

- There is insufficient volume from any single source (commissioning body) to drive a standard design or a standard approach.
- The geographic spread of projects across the country has not exposed the supply chain to the practice required, so there is very limited skills-building, experience or learning being generated.

These factors inevitably increase costs in the short term – costs that will naturally decline as the market expands and experience multiplies and spreads.

Bespoke projects for, in the main, social landlords as clients, represent a very different commercial set-up compared to mainstream commercial house-building. BRH highlights economies available in the mainstream commercial house-building sector, including:

[7] The Costs and benefits of tighter standards for new buildings, Currie and Brown, February 2019, Page 37

[8] **Procurement, costs & risks; Nigel Marsh, Baker Ruff Hannon, UK Passivhaus Conference 2017 https://ukphc.org.uk/speaker/nigel-marsh**

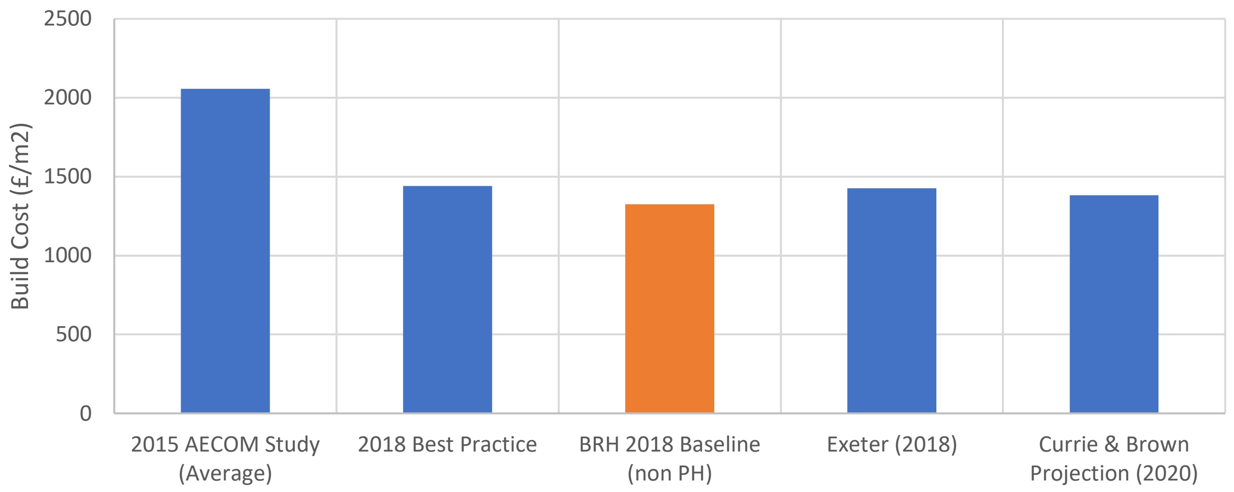
- A systematised approach: build, repeat, move on
- Using common components
- Repeat layouts in different 'skins'

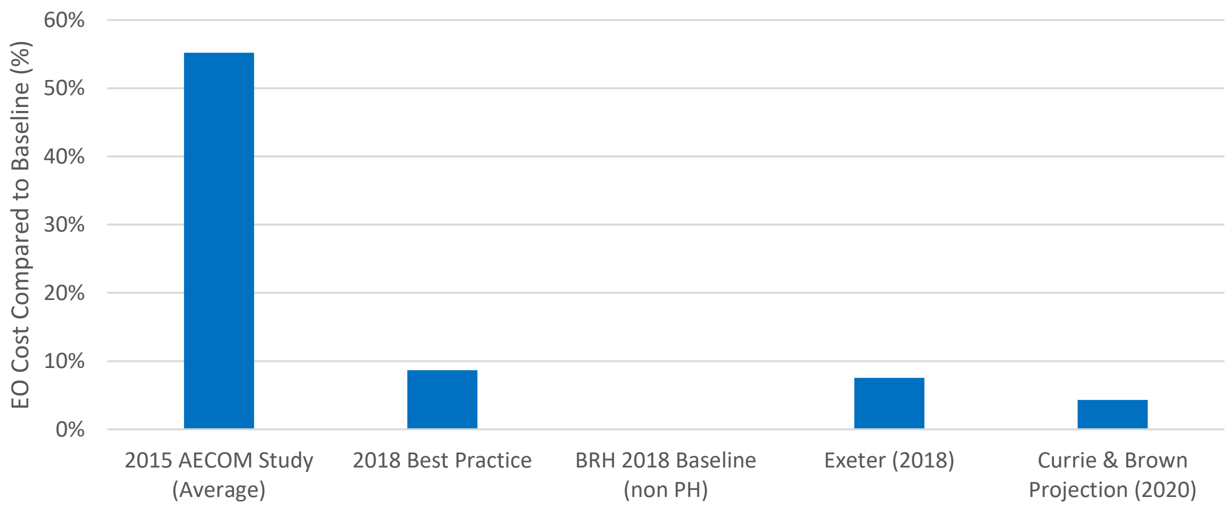
There is no reason why the economies of scale available in the commercial housebuilding model would not be equally applicable to mass construction to Passivhaus, provided Passivhaus became the norm.

It is also worth noting that profit is not part of the build costs cited for mainstream commercial housebuilding, as it is recovered via the sales price. (In the overall build costs quoted for Passivhaus in this report, profit is included).

Summary of Extra Over Cost Trends

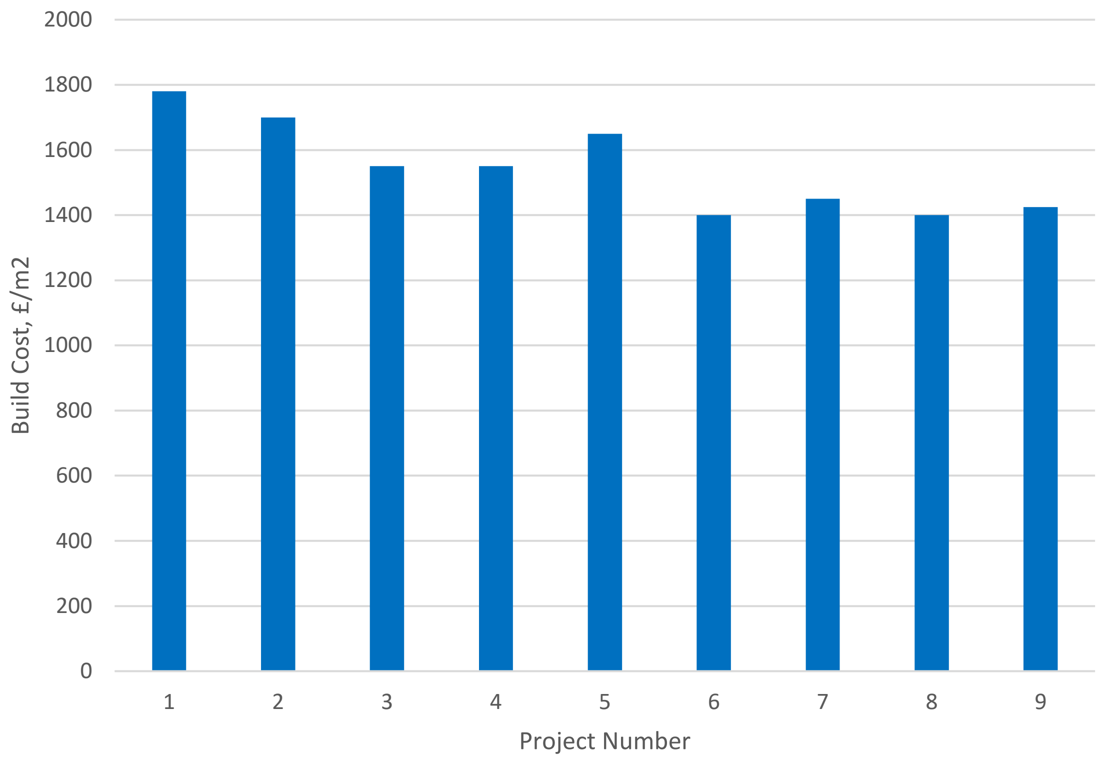
The charts below show the reducing trend in Passivhaus extra-over costs as detailed in the various sources above. Passivhaus costs are shown in blue and equivalent non-Passivhaus baseline cost from Baker Ruff Hannon in orange. It shows that Exeter's Passivhaus build costs are now only 8% above the Baker Ruff Hanon average non-Passivhaus costs for the South West and that Currie and Brown's projection, when added to the BRH baseline, shows costs only 4% above baseline.





Case Studies

Case Study 1 - Exeter's story: as experience grows, costs fall



Costs of Exeter's Passivhaus housing developments over time, in £/m2, adjusted for date, project size, and composition

Exeter city council procured its first Passivhaus housing in 2010 and has now completed or initiated 10 Passivhaus social housing developments, along with a leisure centre and extra care centre (currently on site), with over 500 certified Passivhaus homes in the pipeline.

Build costs for the housing (houses and/or flats) have progressively reduced as the procurement team, and the designers and contractors they work with, have refined the specifications and designs, step by step, to make it easier to deliver Passivhaus economically. Costs still vary within that trend, depending on project-specific factors (e.g. project no. 5 has a curved wall, to fit the shape of the site).

All dwellings are for social or affordable rent, or mixed tenure but tenure blind - apart from No 6, which is all-private.

1st generation (Knight's Place & Rowan House, 1 & 2)

- Standard concrete block construction with EWI
- Some dormers and step-backs

2nd generation (Barberry & Silverberry Close, 2 & 3)

Simplified form at Silverberry Close

- Simplified form (no dormers etc)
- Used generic details, so easier to get right quickly, meaning more repetition and easier estimating- less risk to contractor.
- Different build system (Porotherm blocks) with less wet cement/mortar. This enabled a faster build and faster drying-out times (this can be an issue for winter builds with very airtight buildings like Passivhaus, especially in higher-rainfall areas like SW England
- Leaner specification: smaller MVHR unit
- Approaching a generic house type – realising some economies of scale in design etc

3rd generation (Reed Walk & Chester Long Court, 4 & 5)

- Simplified services: no solar thermal: small gas boiler instead.
- Few radiators, (none really needed in practice).
- MVHR moved from loft to kitchen – minimises duct runs

4th generation (6-9)

(9 is a flatted development that includes balconies – this increases costs, but they are included as they are important for occupant quality of life)

- Reduced "PH specialist" areas to just a few trades (e.g., plasterers) to minimise the need for training – other trades operate as normal

Next steps for Exeter

New Vaughan Rd flats – future development

By building on all this learning, and working closely the designers and contractors, Exeter City Council hope to reduce build costs further again in the next phase of construction: the hope is that the (unadjusted) cost for a development of 92 apartments will be 18% lower than the previous phase (Chester Long Court).

"COSTS ARE STILL FALLING. PASSIVHAUS STARTED EXPENSIVE, BUT THAT'S BECAUSE WE WERE EARLY PIONEERS OF THE STANDARD, THE SUPPLY-CHAIN FOR COMPONENTS WAS IN ITS INFANCY AND WE LACKED THE EXPERIENCE WE HAVE AMASSED TO DATE."

Emma Osmundsen, Managing Director of Exeter City Living Ltd

Emma Osmundsen, Managing Director of Exeter City Living Ltd believes one of the main reasons Passivhaus has been perceived as expensive is because it is so new and unfamiliar. "Costs are still falling. Passivhaus started expensive, but that's because we were early pioneers of the standard, the supply-chain for components was in its infancy, and we lacked the experience we have amassed to date. And we are still learning!"

Case study 2 – First Time Contractor

A development of Passivhaus homes: first-time Passivhaus for the contractor, with assistance from experienced Passivhaus consultants. The project was completed at close to the average adjusted cost for the 12 projects analysed here, and with an estimated extra-over for Passivhaus of around 7%.

- **Collaboration from the outset** The contractor was familiar with to-and-fro to refine a design with subcontractor and architects, so adding in the discussions with Passivhaus consultants in the pre-contract stage was not a big jump in their normal process, and allowed good decisions that worked for all concerned to be taken while there was still maximum flexibility.

- **Simplification** Discussions with the client, planning authorities and Passivhaus consultants led to a number of design simplifications:
  - Unfamiliar SIPs system exchanged for familiar masonry build;
  - More expensive finishes were replaced by simple variations in render colour;
  - fenestration simplified so that many of the windows are identical, meaning that manufacturing costs fell, and one breakage would not hold up the build;
  - windows were manufactured locally, at a lower cost than imported Passivhaus windows.

- **Quality Control** A systematic approach was implemented, with staged payments for the subcontractors related to quality hold points. This proved popular and effective – subcontractors were given confidence about when they would be paid for what.

Case study 3 – Comparing two developments

These are two Passivhaus developments for the same client. They had an identical core specification (space standards, internal finishes etc). But with different constraints, costs were quite different.

Cheaper project: (close to the average of our sample) - planning constraints required a very simple form, in order to fit with the look of neighbouring housing.

- No dormers, step-backs or recesses. Ideal for Passivhaus

Dearer project: planning conditions required a much "fussier" look

- Windows were required to be "old fashioned" looking with glazing bars – hence larger frame area increasing heat loss and requiring windows to be larger to admit same daylight.
- Sub-optimal window design had to be compensated by more expensive thermal specifications

> "FOR THE FIRST PROJECT, WE HAD TO DO REMEDIAL WORK AFTER THE AIR TESTS ON A NUMBER OF UNITS. WE IDENTIFIED SOME WEAK POINTS AND CHANGED SOME ASPECTS OF THE CONSTRUCTION FOR THE SECOND PROJECT, AND HAD MODIFICATIONS MADE BY OUR SYSTEM SUPPLIER.
>
> ON OUR NEXT PROJECT, ALL THE UNITS PASSED FIRST TIME. THE WHOLE BUILD HAS GONE A LOT MORE SMOOTHLY."
>
> *Contractor constructing two successive Passivhaus projects for the same client*

- Higher form factor on this development added to the pressure on fabric performance, adding more expense.

Case study 4 - An up-market Passivhaus development

For this development, build costs were high overall: it was a luxury project in a high-price location. (Full build cost not known)

- Design was not optimised for Passivhaus but for aesthetic and amenity considerations; Passivhaus performance just one element included to achieve a price premium.
- Recesses, balconies and protruding windows, some made with pre-cast concrete, necessitated specialist thermal breaks;
- Overall fabric performance had to be very high as a consequence;
- Upgrading the wall construction for improved thermal performance was expensive, because the construction system was expensive.

The total cost for upgrading the structure and adding extra insulation and specialist thermal breaks alone, was around £230/m^2.

Homes were relatively highly glazed, meaning:

- absolute extra cost for Passivhaus-certified glazing also high (around £50/m^2),
- shutters were required (£20/m^2)

Despite the apparently high costs/m^2 of some aspects of Passivhaus uplift, because the overall build was expensive, as a percentage of overall build costs the Passivhaus uplift was relatively low, estimated at less than 5%.

It is worth noting that the aspects considered for Passivhaus (e.g. overheating, thermal bridging etc) – and addressed as required - would not necessarily have been considered in so much detail for the sister block (very similar-looking, but not Passivhaus).

Getting it Right

Looking at the stories behind the headline figures in this report has revealed that there are several key factors which consistently contribute towards a successful and on-budget Passivhaus project.

> "ADDING IN PASSIVHAUS REQUIREMENTS LATER IN THE PROCESS, PARTICULARLY AFTER PLANNING, LIMITS THE ELEMENTS OF THE DESIGN THAT YOU CAN CHANGE, TO THE MORE EXPENSIVE OPTIONS - SUCH AS HIGHER PERFORMING WINDOWS, SOLAR SHADING AND SO ON. IF PASSIVHAUS IS INTRODUCED AT AN EARLIER STAGE THEN COST-EFFECTIVE SOLUTIONS CAN BE FOUND IN ORIENTATION, FORM FACTOR ETC"
>
> *Scott Moore (QS at Baker Ruff Hannon with Passivhaus experience)*

1. Passivhaus needs to be part of the initial brief. Considering Passivhaus as an integral deliverable right at the start of the project means that factors such as building orientation, form factor (efficient building shape) and the proportion of glazing can all be designed optimally. Getting these factors right makes the remainder of the project easier and cheaper.

2. Employ an experienced Passivhaus Designer or Consultant. Somewhere on the delivery team, there needs to be an individual who understands the Passivhaus standard in some detail. This doesn't mean that you need to employ an architectural practice that has Passivhaus experience, but you should ensure that there is a suitable consultant as part of the design team.

3. Keep it simple. Passivhaus does not need to be complicated. Junctions and airtightness strategies which are simple and use familiar materials and techniques are more likely to be successful on site.

> "WITH A SIMPLE WELL-DEVELOPED DESIGN WE CAN GO IN WITH A SMALL RISK REGISTER. NORMALLY AS CONTRACTORS WE GET NOTHING LIKE THAT – YOU CAN EVEN JUST GET THE PLANNING DRAWINGS!"
>
> *Passivhaus Contractor*

4. Ventilation design is important. Mechanical Ventilation and Heat Recovery (MVHR) is not a common technology in the UK. It can be designed well – or it can be designed badly. Poor designs will be noisy and inefficient. Use a designer who understands the Passivhaus criteria and how MVHR systems differ from commercial ventilation requirements.

5. Overheating control is part of the standard. Modelling the risk of overheating is an important part of the process and clients need to be realistic about how much cooling can be achieved by opening windows. External shading and glazing orientation needs to be carefully considered – listen to your Passivhaus designer. The impact of severe summer overheating is significant (and the risk is increasing) so, in this instance, function needs to take precedence over form.

6. Airtightness is key. Many aspiring Passivhaus projects have failed to achieve certification due to poor airtightness. Passivhaus levels of airtightness are more than 15 times more demanding than the minimum required by Building Regulations, and thus a dedicated airtightness strategy will need to be used. This may require specialist materials, but in general should be as simple and robust as possible. This is the most difficult part of delivering a Passivhaus and needs careful planning and attention. On small projects where the fabric can be tested as a whole, you will need to allow for several additional air tests to check for leaks. On larger projects there will need to be a more advanced airtightness testing strategy which confirms the required standards are being met as the build progresses. In either case, a simple, robust airtightness strategy that is easy to implement is likely to be the most successful.

7. Everybody needs to know. Delivering a Passivhaus is a team effort. Everybody in the design team, and everybody on site needs to be educated in Passivhaus principles and understand what it means for their part in the project.

8. It isn't just about design. A perfect Passivhaus design can be implemented badly. Ensure that you have Passivhaus expertise on site to monitor quality and ensure the key elements of the design are being properly enacted.

9. Designer and Contractor working together. For first time contractors, it is vital that they understand the implications of building to the Passivhaus standard. This is achieved by providing ready access to the design team and also talking to other contractors who have gone through the process. A contractor who does not understand what they are being asked to deliver is a recipe for disaster. For Passivhaus designers, it is invaluable to listen to contractors and establish early on what is going to work on site, and what would lead to problems.

10. Get the certifier onboard early. The certifier is a key part of the process. The earlier they are involved, the better, and they should set out exactly what their requirements are at each stage. They should be seen as a helpful advisor and an integral part of the team.

"THE MAIN DESIGN CHANGE ON ONE LOW-BUDGET PASSIVHAUS PROJECT WAS PROBABLY TO REPLACE THE CATHEDRAL CEILINGS WITH NORMAL FLAT CEILINGS. ALL THE JOBS I'VE WORKED ON THAT HAD A BUDGET USED TRUSSES, WHICH ARE MUCH CHEAPER AND SIMPLER THAN CONSTRUCTING A ROOF OVER A CATHEDRAL CEILING, AND A FLAT CEILING LEAVES YOU WITH A SMALLER HEAT LOSS AREA, AND A SMALLER AREA TO INSULATE."

Alan Clarke, Passivhaus Designer

"WITH A LESS DEVELOPED DESIGN, YOU WILL GET A MUCH WIDER RANGE OF PRICES BACK. THUS, THERE IS ALWAYS THE RISK EITHER THAT CLIENT PAYS TOO MUCH, OR CONTRACTOR BIDS TOO LOW - WHICH WILL LEAD TO PROBLEMS FOR EVERYONE."

Passivhaus Contractor

Summary and Conclusions

This study has shown that the extra over costs associated with building to the Passivhaus standard has reduced over the past three years and, as of 2018, best practice was around 8% when set against comparable projects.

However, removing the costs associated with quality assurance (as this should be done regardless) and considering further development of skills, expertise and supply chain maturity, indicates that extra over costs could come down to around 4%. In the context of other factors which result in higher build costs (quality of materials, design form, ground conditions etc), this is a very minor uplift.

To achieve this sort of level of extra over cost, there are several key success factors which need to be considered. If typical design and construction techniques are followed it is likely that either the Passivhaus Standard will not be achieved or will result in significant additional cost. Unfortunately, it is often this sort of project that makes headlines when things go wrong.

It also needs to be considered that, for this 4% uplift, the result is a far superior product in terms of running costs, carbon emissions, comfort levels and health benefits.

Overall, this study has shown that the Passivhaus standard in the UK can be achieved now for a modest extra-over cost and this is likely to reduce to nominal levels if adopted at scale.

Annex A – Discussion of Correction Factor Methodology

Assumptions and Exclusions

The figures used in our analysis are contract sums excluding external works, as externals can vary considerably between projects, and are not relevant to the Passivhaus standard. Contingency sums are excluded as they may or may not have been used and it is not possible to allocate them to Passivhaus elements.

Professional fees are excluded as they will vary significantly depending on the size/type of development, and also how many unique designs were provided. It is therefore misleading to compare professional fees across projects.

Preliminaries are expressed in £/m^2 of the gross internal floor area.

Correcting for Build Cost Inflation

The annual change in construction costs have been taken from ONS statistics[9] and can be summarised as follows:

Year	Correction	Percentage	Cumulative Difference from 2018
2013	96.1	-3.90%	14.200%
2014	98.8	-1.20%	11.500%
2015	100	0.00%	10.30%
2016	103.2	3.20%	7.10%
2017	106.8	6.80%	3.50%
2018	110.3	10.30%	0

Correcting for Development Size

Because of economies of scale, a larger development with more similar housing units on it will usually work out cheaper, per unit and per m^2, than a small one. An attempt to quantify this effect was made in a 2015 report for the Federation of Small Businesses by RICS, by looking at the project details of around 2,000 residential developments.[10] This analysis has been used to derive correction factors to adjust the normalise dwelling size to 1-10 dwellings:

Development Size	Median Cost (£/m2)	Adjust to 2018/19 equivalent	Correct Factor to normalise to 1-10 dwellings (£/m2)
1-5 Dwellings	1077	1187	-56
1-10 Dwellings	1026	1131	0
>10 Dwellings	978	1078	+52

Correcting for Building Form

Building form also has an impact on costs, with terraces being more cost-effective than semi-detached, which are again more cost-effective than detached houses (however, no detached houses have been analysed for this paper).

Information from Spon's architects and builders price book 2018 gives an approximate uplift for semi-detached homes (and also apartments) over a terraced development, again in £/m2. Costs shown relate to Local Authority and Housing Authority developments.

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[9] Office for National Statistics, Monthly construction output prices indices from Jul 14 to March 2019

[10] The effect of Project Size on cost of housing construction: Report for The Federation of Small Businesses August 2015

Development Type	Median Cost (£/m2)	Correction Factor to normalise to Terraced
Terraces	1060	0
Semi-detached	1210	-150
Low-rise apartments	1300	-240
Medium Rise apartments	1570	-510

Correcting for Location

The cost of development varies across the country and the build costs therefore need to be adjusted to reflect this.

Location	Index	90% confidence interval	Standard deviation	Range	Sample
North East	105	104 - 106	13	79 - 187	459
North West	91	91 - 92	10	61 - 150	980
Yorkshire and the Humber	92	92 - 93	11	70 - 174	630
East Midlands	105	104 - 106	12	68 - 149	633
West Midlands	93	93 - 94	10	65 - 158	897
East of England	100	99 - 101	11	66 - 149	973
London	112	111 - 113	15	75 - 182	1001
South East	112	111 - 112	13	80 - 170	1466
South West	100	99 - 101	12	69 - 221	853
Wales	92	91 - 93	11	70 - 143	397
Scotland	101	100 - 102	14	67 - 201	1211
Northern Ireland	56	55 - 56	6	43 - 74	194
Islands	115	113 - 117	12	89 - 157	131

This table is taken from the RICS study[11]. The projects analysed in this review all fall in regions which have an index of 100 or 112

[11] The effect of Project Size on cost of housing construction: Report for The Federation of Small Businesses August 2015