Passivhaus Trust

PASSIVHAUS BENEFITS

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EXECUTIVE SUMMARY

The Climate Crisis has highlighted the urgency with which we need to cut carbon emissions across all sectors - with buildings being a big culprit. Often considered primarily as the exemplar standard for producing high-performance buildings, Passivhaus does indeed minimise energy demand, but it delivers much more, including health and well-being of occupants; our ability to meet climate targets; construction quality; and commercial benefits to owners, employers and lenders, to name just some. Passivhaus can allow us to thrive, not merely survive, by slashing energy use without compromising our health & wellbeing - factors put into sharp focus during the pandemic.

The multi-faceted benefits offered by Passivhaus resonate with different stakeholders. Homeowners may be interested in superior quality & comfort whilst lowering energy bills. Eliminating fuel poverty, reducing rent arrears, and achieving zero carbon targets will attract local authorities. The government may focus on the potential to lower peak demand and amplify grid capacity for a smooth transition to renewable energy. This guide sets out the benefits offered by Passivhaus in several groups to allow different stakeholders to quickly focus on the aspects of most interest to them.

With 30 years of international evidence, and a decade of UK specific data, there is considerable research now available which demonstrates how Passivhaus buildings perform. In many areas it is possible to make a direct comparison against a typical new-build or an existing building. It is particularly true for quantitative data such as energy demand or costs. However, when it comes to health, commercial productivity or subjective wellbeing, the data is less extensive - or there may not yet be enough Passivhaus-specific data. In this case, we have therefore set out the evidence linking outcomes with qualities of buildings and then shown how Passivhaus can improve those qualities.

This guide, relevant UK wide[1], is a reference for anyone wishing to understand more about what Passivhaus can deliver and will be a valuable resource for organisations seeking to assemble a business case in support of a Passivhaus strategy or project. This guide forms part of the Passivhaus Trust's wider cost-benefits research.

Sarah Lewis, Research & Policy Director, Passivhaus Trust

Bowman's Lea EnerPHit: Harry Paticas © Agnese Sanvito

INTRODUCTION

Our research identified almost fifty types of benefits relating to Passivhaus which have been categorised into six distinct areas. When taken together, they make a compelling case for the adoption of Passivhaus. Each of these six areas is backed by detailed research papers, and they are available to download on the Passivhaus Trust website.

1. BUILDING PERFORMANCE
Understand what Passivhaus achieves in terms of a building's energy demand, performance gap, comfort and quality.

2. CLIMATE EMERGENCY
Decarbonisation is a critical part of our journey to net zero. Learn how Passivhaus enables the levels of demand reduction that we will need to achieve net zero.

3. HEALTH & WELLBEING
Explore how Passivhaus can address the root causes of poor housing and thus improve health outcomes.

4. PEOPLE PERFORMANCE
The improved living and working environments offered by Passivhaus can improve productivity, learning outcomes and reduce absenteeism.

5. THE FINANCIAL BENEFITS OF PASSIVHAUS
A Passivhaus building isn't just more affordable to run - it can also offer lower maintenance costs, reduced fuel poverty, and open access to green finance or better rates on mortgages.

6. SOCIAL RETURN OF INVESTING IN PASSIVHAUS
Improved wellbeing and productivity reduce the load on health and social care and gives people better life chances. These are potentially some of the biggest and most far-reaching benefits. While they are often difficult to quantify, they cannot be ignored.

Categorising the Benefits of Passivhaus

BUILDING PERFORMANCE
- Low energy demand
- Reduces performance gap
- High levels of comfort
- Effective and healthy ventilation
- Higher performance building components
- Better site QA procedures resulting in better construction quality
- Lower risk of building fabric damage
- Resilient and future-proofed buildings

HEALTH & WELLBEING
- Eliminates cold homes – and associated health impacts
- Guarantees good levels of ventilation – essential for health
- Reduces internal pollutants such as VOCs
- Deals with internal humidity - eliminates condensation and mould
- Improves quality of life for people with chronic illness or disabilities
- Protects against external air pollutants
- Reduces risk of airborne infection
- Reduces the impact of external noise

CLIMATE EMERGENCY
- Lower carbon emissions
- Lowers peak demand
- Lowers the overall requirement for renewable energy
- More economical to save energy than to generate it
- Gives us the best chance of achieving net zero in buildings
- Enables decarbonisation without increasing fuel bills
- Robust in the face of short-term extremes and longer-term climate changes
- Ability to support demand response
- Lower cooling requirement in a future warmer climate

PEOPLE PERFORMANCE
- Reduced absenteeism
- Improved productivity
- Improved learning outcomes
- Attract and retain staff

SOCIAL
- Improved health& wellbeing of communities
- Reduced demand on health and social services
- Improved learning outcomes for children
- Economic stimulus of construction
- Upskilling of the construction workforce
- Clear statement of intent for transition to a net zero economy
- Demonstrates compliance with social value policies and targets
- Aligns with several UN Sustainable Development Goals

FINANCIAL
- Lower energy bills
- Rental - fewer and shorter void periods
- Reduces the extent and depth of fuel poverty
- Higher capital value 5-7%
- Lower maintenance costs
- Lower management costs
- Ability to access cheaper time of day tariffs
- Lower whole life costs
- Lower borrowing costs / Green mortgages
- Ability to access cheaper green finance
- Holds value in the event of future carbon or efficiency legislation
- Lower risk of defects litigation
- Lower risk of repetitive damage due to quality issues

Quantifying the Benefits of Passivhaus

When examining the potential benefits of Passivhaus, it is useful to understand the order of magnitude of these benefits relative to each other and put them into context. Some benefits are 'hard' - they are direct costs or savings which can be accurately predicted. Others are 'soft' – i.e. indirect effects where the savings have been estimated using the findings set out in this guide. Whilst hard and soft savings can't be added together to get an overall net benefit, it is possible to use these figures to compare the relative impact and understand where Passivhaus could have the most effect.[2]

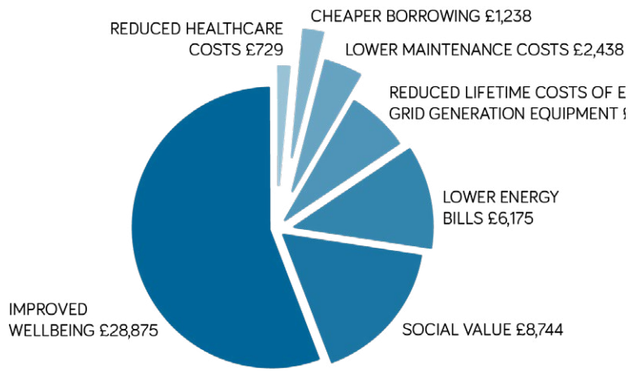

FIGURE 1
Living in a Passivhaus home over 25 years

This scenario sets out the individual and social benefits for three people living in a 90m² Passivhaus home over 25 years, compared to a typical new house built to the 2021 English Building Regulations.

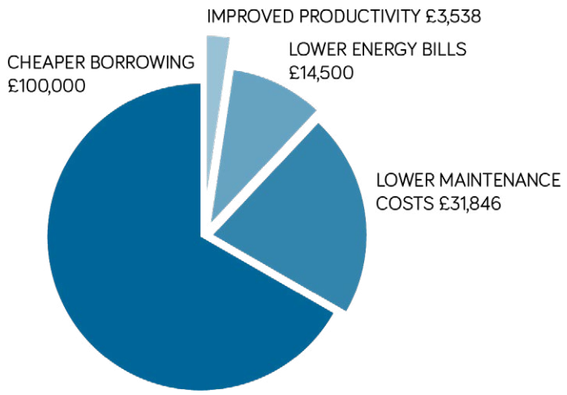

FIGURE 2
Working in a Passivhaus office over 10 years

This scenario sets out the commercial benefits from a team of fifty people working in a 500m² Passivhaus office over ten years compared to a typical new-build UK office.[3]

Kintyre Passivhaus: Tate + Co © Kilian O'Sullivan

BUILDING PERFORMANCE

KEY BENEFITS

- Low energy demand
- Reduces performance gap
- High levels of comfort
- Effective and healthy ventilation
- Higher performance building components
- Better site QA procedures resulting in better construction quality
- Lower risk of building fabric damage
- Resilient and future-proofed buildings

1. BUILDING PERFORMANCE

1.1 Criteria for Whole Building Performance

Passivhaus sets out measurable criteria which must ALL be achieved to meet the standard. Whilst prioritising low energy, many of the criteria ensure a comfortable and healthy internal living environment. These aims often go together. For example, setting a maximum fan power for ventilation systems reduces energy consumption but also means that fans are of better quality - designed to operate at their optimum speeds with minimal pressure resistance. Thus, they are also quieter.

CRITERION (For Passivhaus Classic standard)	LIMITING VALUE	COMFORT & HEALTH RELATED	ENERGY RELATED
Airtightness (as built tested)	0.6 air changes per hour @50Pa	X	X
Internal Surface Temperatures	>17ºC at all times	X	
Summer overheating	No more than 10% of the year >25ºC. The UK guideline for this limit is 5% with a best practice target of 0%*	X	
Ventilation Air (as built tested)	30m³ of fresh air per person per hour	X	
Ventilation System Noise	<25dBa in living and sleeping areas	X	X
Heating Demand Heating Load (One or other of these criteria has to be met)	<15 kWh/m².year or <10 W/m².year		X
Primary Energy	135 kWh/m².year		X
Or ... Primary Energy Renewable	<60 kWh/m².year		X

TABLE 1
Primary Passivhaus Criteria

* PHPP (the Passivhaus design and calculation software) requires designers to model the impact of glazing areas, window openings, shading, internal gains and ventilation options so they can minimise the risk of overheating. New guidance developed by the Passivhaus Trust now requires Passivhaus designers to “stress test” designs in future climates and situations where, for example, occupants may fail to open windows in hot weather.

1.2 Passivhaus Quality Assurance and Certification

Alongside stringent performance criteria, the Passivhaus standard is renowned for a robust quality assurance process that helps to meet the targets in practice.[4] All certified Passivhaus buildings undergo this compliance process, and research proves that Passivhaus buildings consistently perform remarkably close to their design targets.[5] [6]

As the authors of a recent study on indoor air quality in Passivhaus dwellings put it, "Passivhaus' rigorous design and construction methods, along with post-completion testing and verification… are key components in ensuring that energy targets are achieved.… The strict controls in the construction phase are a form of warranty that the building will perform as designed." [7]

The certification process helps to ensure that the targeted high performance is achieved in the finished building. This quality assurance contrasts with most mainstream construction in the UK, where there is no comparable process, and 'performance gaps' in energy use in the finished buildings are commonplace.

1.3 Addressing the Performance Gap

Energy Performance Gap

From the monitoring of thousands of built Passivhaus buildings, energy use on average is extremely close to the amount that the modelling predicts. In an average new home, by contrast, heating demand can be 60% more than forecast using SAP modelling.

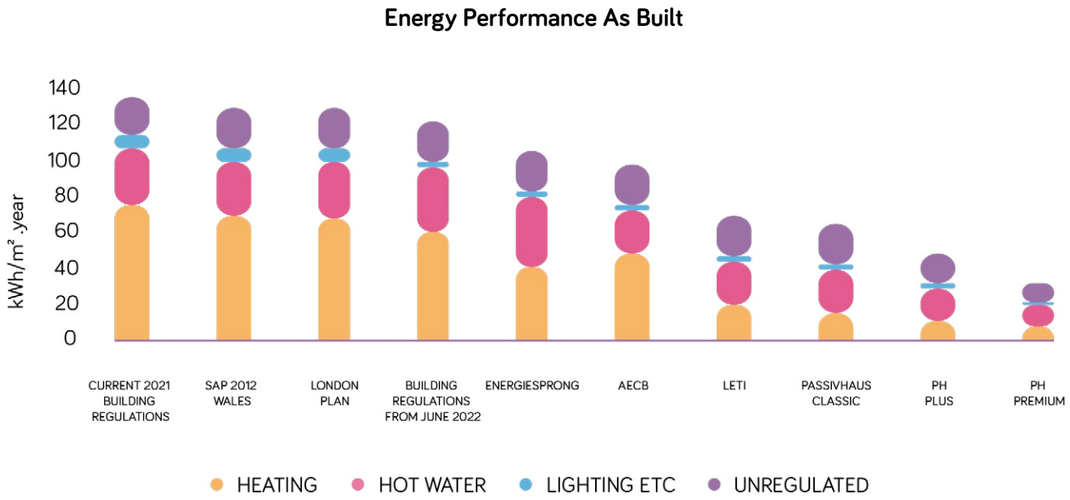

FIGURE 3
Energy Performance, as built, all figures have been adjusted to allow for the typical heating demand performance gap of buildings to that particular standard, as revealed in monitoring studies. Assumed performance gaps: Current Building Regulations 2021, London Plan, Proposed Building Regulations 2022 – 60%, AECB – 20%, LETI – 30%, Passivhaus and Energiesprong – 0%. (performance gap included within the orange bars)[8]

Ventilation Performance Gap

In a Passivhaus, the ventilation system is quality assured and certified –the design must be checked by a certifier. The system is commissioned and performance tested (ie, the air flow into/out of each room is measured), and the commissioning report is also checked by the certifier before certification can be granted.

Unfortunately, in most non-Passivhaus homes, ventilation systems fail to comply with the building regulations, and fail to deliver the required air flows - as evidenced in studies by AECOM for MHCLG and the Zero Carbon Hub. [9] [10]


Carrowbreck Meadow: Hamson Barron Smith © Jefferson Smith

1.4 Quality and Robustness

Whilst the quality assurance inherent to Passivhaus effectively eliminates the performance gap (as set out above), there are several other benefits of this process:

Attention to detail

High-profile stories in the press have highlighted serious defects in new build properties due to errors and failings in the construction process, resulting in structural damage and major leaks. Beyond these high-profile cases, defects are extremely common in mainstream housebuilding. In Passivhaus, close attention is paid to the requirements for properly constructed details, in particular airtightness. This requires a close focus on site, and a robust mechanism to ensure the appropriate steps are followed and the right material is used in the right location. The net effect is that the final building will be of a better construction quality than one that did not require this level of supervision and attention to detail.

Durability

Careful workmanship often means that building components are more carefully installed and operate in optimal conditions – thus extending their durability. For example, sealed glazing units should last longer protected in deep reveals with no hidden areas of condensation. To achieve the required levels of thermal performance and airtightness, the individual components tend to be of a high quality. Whilst there is some cost as a result, these components usually last longer and will require fewer call-backs during use. This not only improves the occupant experience, but is also a significant benefit for developers and landlords.

Airtightness and the building fabric

Having a robust airtight layer significantly protects against the risk of interstitial condensation where the warm internal air meets a cold surface within the building fabric. In turn, this reduces the risk of unseen mould and rot.

Resilience - Dealing with the future

We live in a changing climate. The thermal stability of a Passivhaus building provides resilience in the face of temperature extremes. Should changes to the UK climate reach a point where active cooling is required, the amount of energy a Passivhaus requires will be significantly lower than for a typical building. The summer overheating criteria, high levels of insulation and high airtightness will already have greatly mitigated the impact, slowing the rate by which the outside temperature can affect the interior.

1.5 The Joy of Passivhaus

Individual reports of comfort and satisfaction are borne out by more systematic research. A building user survey into a Passivhaus co-housing development for the then Technology Strategy Board described the comfort and satisfaction scores as “quite remarkable”.[11]

Occupants were asked to rate their homes on metrics such as overall comfort, temperature quality of air in winter, design, and on these parameters the development scored “exceptionally well”.

“Having just come home from a long dog walk in the pouring rain I felt I just had to tell you what a lovely home you have created here. My mac is dry in no time and the house is cosy all day long.” [12]
- Message to the architect from the owner of a Passivhaus self-build

“Cycling back home in winter after a hard day’s work - although there’s usually no heating on - the warmth hits you as you go in through the door and it still feels quite magical.” [13]
- Owner describing the results of his Passivhaus retrofit

> “The air quality in the house is amazing... we all now have amazingly wonderful sleeps at night which we believe is due to the air quality. The consistent temperature in this house is perfect.”
>
> *Resident, Carrowbreck* Meadow

> “Now that I live in a Passivhaus, I never want to move, because I look at a typical home and think 'that looks really cold and uncomfortable.”
>
> *Australian Engineer*

Goldsmith Street: Mikhail Riches © Tim Crocker

> “It’s great in the cold weather - my new home is cosy and warm and I don’t have to worry about heating costs any more as I rarely use it. I really like living here, the bungalows are brilliant!”
>
> *Resident, Racecourse Estate*

CLIMATE EMERGENCY

KEY BENEFITS

- Lower carbon emissions
- Lowers peak demand
- Lowers the overall requirement for renewable energy
- More economical to save energy than to generate it
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- Enables decarbonisation without increasing fuel bills
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2. CLIMATE EMERGENCY

The 2021 IPCC report brought - once again - into sharp focus that we now only have a few years left to reduce emissions enough to avoid a catastrophic rise in global temperatures.

The energy we use in our buildings is responsible for 23% of the UK's carbon emissions.[14] The majority of that energy is used for heating. By improving the building fabric, there is significant scope to reduce the demand for heating and, in turn, impactfully cut carbon emissions.

The UK has now set targets to reduce total emissions by 78% of 1990 levels by 2035 and to net-zero by 2050. This is unattainable without decarbonising our buildings. Passivhaus offers the most robust & cost-effective route to net zero for the building sector.

> "Today's IPCC report is a code red for humanity. The alarm bells are deafening, and the evidence is irrefutable: greenhouse-gas emissions from fossil-fuel burning and deforestation are choking our planet and putting billions of people at immediate risk."
>
> *António Guterres,*
> *UN Secretary-General*

2.1 Carbon Emissions

A new Passivhaus home built in 2022 will result in 86% fewer lifetime emissions than an equivalent Building Regulations[15] new-build fitted with a gas boiler and 37% fewer lifetime emissions than an equivalent Building Regulations new-build fitted with an Air Source Heat Pump.[16]

FIGURE 4
Cumulative CO_2e emissions in tonnes from 2021 to 2050

2.2 Energy Capacity

Whilst renewable, low-and-zero carbon energy - sun, wind and tides – is abundant in the UK, our ability to harvest this energy is limited. Every solar panel and wind turbine must be manufactured, deployed, maintained, and then disposed of. All of this takes money, raw materials, space for installation – and of course, energy. There is therefore a limit on the amount of renewable energy we can produce.

Renewable energy has another constraint, which is its seasonal disparity. Whilst we may have enough renewable energy over a year to match our demand, we may not have enough at certain times. Much of our renewable energy is solar, which peaks in the summer, whilst our buildings' biggest demand for energy, heating, peaks in the winter. This means that energy storage is critical as we transition away from fossil fuels. Alongside the expense and energy required to create it, the problem with storage is that there are always losses. So, the more storage required, the more additional renewable energy must be generated to cover the storage losses.

The National Grid publish forward-looking scenarios every year looking at the future trajectories for our energy infrastructure. Their 2020 projections showed that, for every one of their possible scenarios, there would have to be a significant reduction in the amount of thermal energy (heating and hot water) demanded by our homes. The diagram below shows the level of thermal demand required to meet their Consumer Transformation scenario and how a Passivhaus compares. It demonstrates that all our homes (not just the new-build ones) will need to be close to Passivhaus levels of performance by 2050 for the generation vs demand equation to balance.

Thermal Demand of UK Homes (MWh/year)

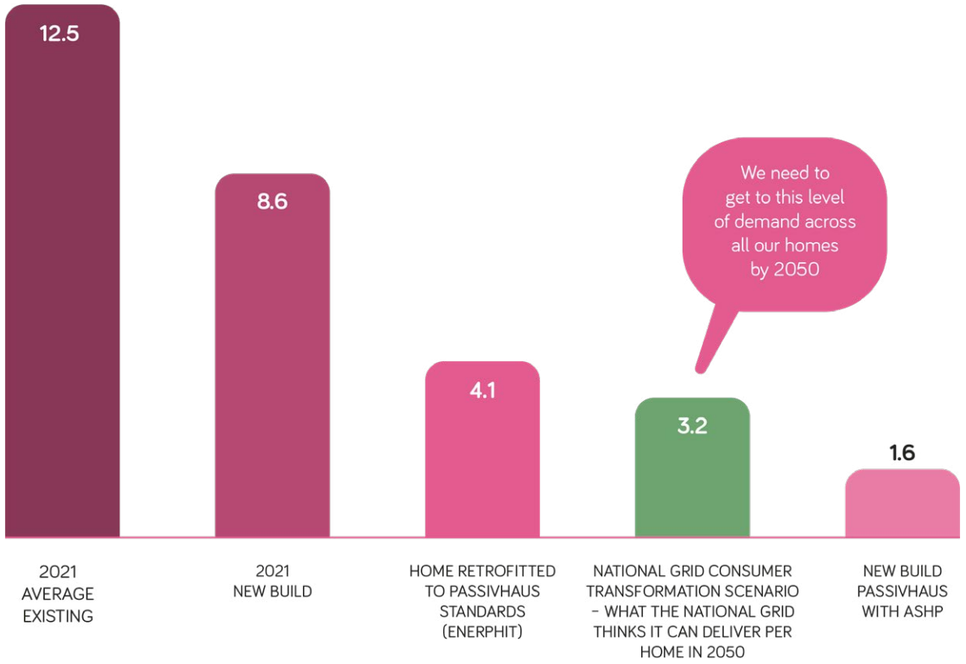


FIGURE 5
Heating and Hot Water demand in UK homes in MWh/year

2.3 Peak Load

It is estimated that the peak thermal load currently demanded by our homes and delivered by gas is 170GW. The current electric grid capacity is around 100GW. If all existing homes switched from gas to electricity without demand reduction, an additional average 6.5kW peak load per home would be required. Assuming ASHPs are installed this would increase the peak demand to a total of 81 GW - or 81% of current grid delivery capacity for all electricity uses for all sectors.

The National Grid's 2021 Steady Progression scenario projects a requirement to increase this to 240GW by 2050 to meet the needs of all sectors - and this won't even get us to zero carbon. To reach net zero, the more ambitious Consumer Transformation scenario increase is even more dramatic, requiring an increase in peak capacity to 374GW by 2050, almost 4 times the current level!

If our homes undergo deep energy retrofit works, to the EnerPHit Standard, this would reduce the average increase in heating demand to 1.3kW peak load per home, resulting in 80% less additional demand on the grid. This clearly demonstrates that demand reduction will support the grid in achieving a net zero balance, whilst still allowing electrification of transport and industry as required.

As well as reducing loads, a well-insulated building like a Passivhaus makes things easier for the grid because it can "load shift". In a Passivhaus you can move the timing of heating energy use away from peak demand times, with minimal or no loss of comfort. Thus, when non-shiftable loads (eg for lighting and cooking) are at their highest, the heating in a Passivhaus can be turned off for several hours. Heating can even be 'pre-charged' when total demand, and therefore energy cost, is lower (eg during the afternoon).

> "Energy needs to be used efficiently... Reducing the initial demand for energy makes decarbonisation easier."
>
> *Future Energy Scenarios 2021, National Grid ESO*

Energy demand that can be shifted backwards and forwards in time like this is described in government literature as a "flexible asset" as it enables more value to be derived from a given amount of installed generation.[17]

Calculations suggest that in a Passivhaus it is possible to advance or delay heating for up to 24 hours, without loss of comfort – several times longer than in a standard dwelling.[18] This also opens the possibility of 'pre-heating' a full day in advance when renewable supply is high, but forecast to fall, eg towards the end of a spell of high winds.

There will always be a finite amount of renewable energy. Our grid cannot deliver – or store - the renewable power needed to heat our homes and hot water without significant reductions in demand, and the ability to adjust demand to match supply. Passivhaus helps with all of these.

The graphs below show the impact of this 'load shifting', i.e shifting the time of the day the heating is turned on. In the typical home, this results in the home not being warm at the required times, in the Passivhaus home, there is minimal or no impact on comfort.

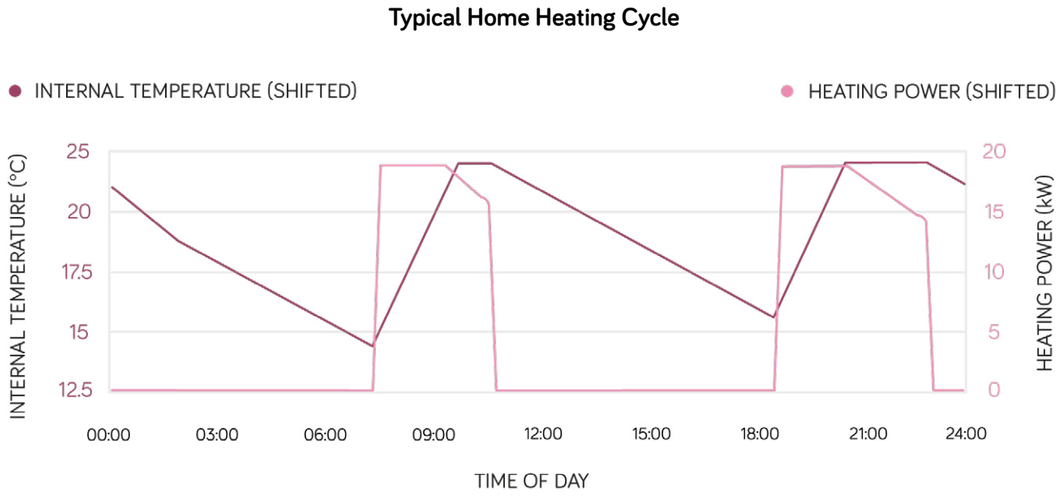


FIGURE 6
Heating cycle in a typical home – cannot be delayed without incurring occupant discomfort

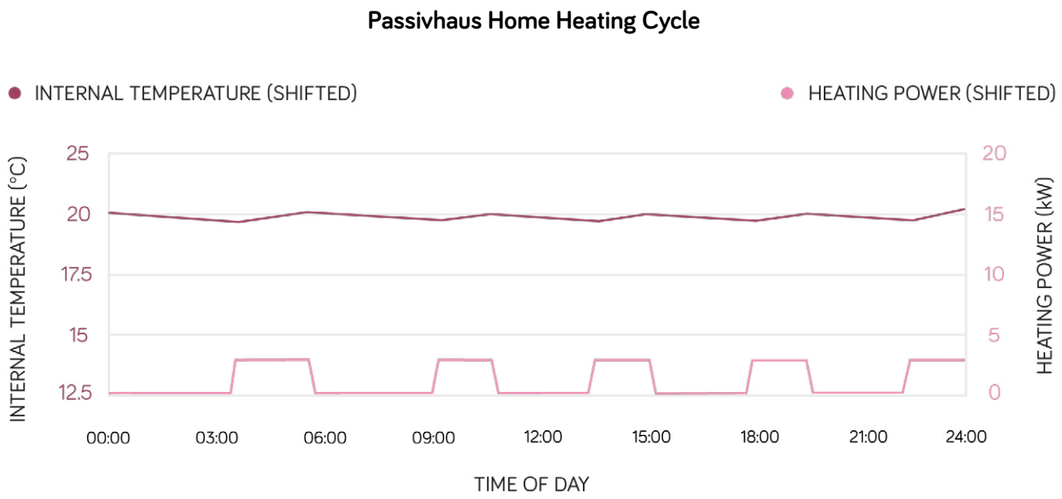


FIGURE 7
Passivhaus heating cycle. Note significantly smaller heating load and the ability to advance/delay heating without undue impact on internal temperature

2.4 Lifetime Generation Costs

For every additional MWh of energy that we need to generate because we have decided not to reduce the demand, there is a cost. This cost can be calculated per MWh generated over the lifetime of the source and is known as the Levelised Cost of Energy (LCOE). A BEIS analysis published in 2020[19] estimated the Levelised Cost of Energy for different renewable generation technologies in 2025 would be between £44 and £57 per MWh.

Assuming a 4% uplift in Passivhaus construction costs[20] on a baseline build cost per m² of £1800 and a building lifetime of 80 years, the Levelised Cost of Energy Saved is just £30 per MWh.

This demonstrates that the most affordable form of energy is the energy that is saved rather than generated.

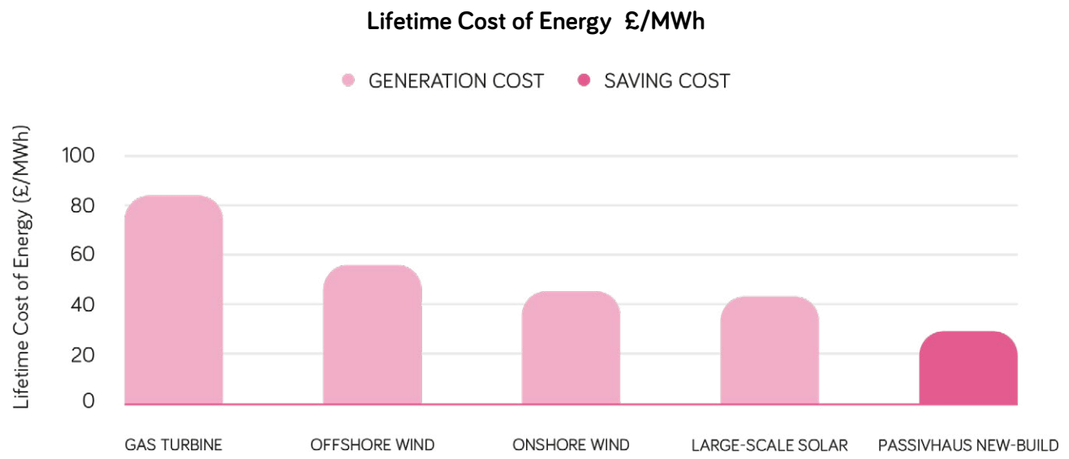


FIGURE 8
Levelised Cost of Energy – Generation vs saving

2.5 Passivhaus, our Route to Net Zero

In summary, as we face a climate emergency there are several ways in which Passivhaus can contribute to the solutions:

- A new Passivhaus home built in England in 2022 will result in 86% fewer lifetime emissions than an equivalent Building Regulations[21] new-build fitted with a gas boiler
- A new Passivhaus home built in 2022 will result in 37% fewer lifetime emissions than an equivalent Building Regulations new-build fitted with an Air Source Heat Pump
- Achieving net zero on site is difficult – reducing demand to Passivhaus levels gives us the best chance of achieving it
- Achieving net zero as a nation is also difficult. There will always be a finite amount of renewable energy. Our grid cannot deliver the peak power needed to heat our homes and hot water without slashing demand, and without demand flexibility. Passivhaus helps with both limitations
- It is more economical to save energy than it is to generate it.

HEALTH AND WELLBEING

KEY BENEFITS

- Eliminates cold homes – and associated health impacts
- Guarantees good levels of ventilation – essential for health
- Reduces internal pollutants such as VOCs
- Deals with internal humidity – eliminates condensation and mould
- Improves quality of life for people with chronic illness or disabilities
- Protects against external air pollutants
- Reduces risk of airborne infection
- Reduces the impact of external noise
- Reduces risk of buildings becoming too hot in summer
- Improves health of people in schools and offices

3. HEALTH AND WELLBEING

In this section, we compare differences between the performance of Passivhaus and non-Passivhaus buildings from the perspective of how those differences might affect the health and wellbeing of the occupants.

The evidence tells us that a healthy building is a building that its occupants can easily manage to keep warm and well-ventilated, and that they can easily afford to run.

Warmth and ventilation are the top building performance issues affecting health, but other indoor environmental factors can also make a big impact on health and wellbeing – for example, overheating, air pollution and noise. For a detailed examination of the evidence linking building performance to human health and wellbeing, and further discussion of what this means to people's lives, see forthcoming Passivhaus Trust Health & Wellbeing Research Paper.

As we saw above, compared with a standard new-build home, Passivhaus requires a better-constructed building envelope with a much lower heating demand than a home built only to the regulations. Passivhaus also sets strict limits on the predicted hours of overheating.

Ventilation in a Passivhaus building is similarly tightly specified and, as with the thermal envelope, its as-built performance is subject to rigorous checks to ensure that in reality it performs as designed. Passivhaus delivers much better-performing ventilation systems than in most buildings designed to the building regulations.

Medical research has established that the kind of improvements in building performance that are achieved in Passivhaus result in significant improvements in health and wellbeing, as described below.

Larch Corner: Mark Siddall

3.1 Cold Homes

When people are cold in their homes, their health is at risk. Even just a couple of degrees cooling can result in measurable physiological changes and have impacts on health. Colder conditions may also lead to poorer ventilation, and poorer indoor air quality.

Passivhaus homes are easy to keep warm – and warm throughout:

> "We had lots of snow this winter, but it was lovely inside, it only dropped once below 20, to 19.5. Even when we were snowed in, it stayed the same as it always is."
>
> *Passivhaus occupants in Wales* [22]

> "Day or night you can wander around and feel comfortable."
>
> *EnerPHit occupants* [23]

Old Holloway © Juraj Mikurcik

People living in Passivhaus homes repeatedly comment on the warmth and comfort. Temperatures of around 20 or 21ºC are the norm, with people also remarking on how stable and steady the warmth is. Research by the University of Bath into the performance of Passivhaus homes echoes these observations.[24] Similarly, numerous studies of Passivhaus thermal comfort suggests winter temperatures are stable, and occupants are very satisfied.[25]

There is a strong link between cold homes and poor health

It is estimated that cold homes, in England alone, cost the NHS £857million each year.

National Energy Action suggest that up to 10,000 people a year die as a result of cold homes in the UK.

Passivhaus homes are warm and comfortable all year round

People who live in energy efficient homes have been found to be in better health, with improved mental wellbeing, reduced contact with the health service and reduced absence from school or work.

For people on the tightest incomes, every shortfall in energy efficiency is likely to represent more days when the house doesn't feel warm enough. The performance gap may mean that non-Passivhaus homes cannot be kept warm at all – with all the health consequences that brings.

This reality was set out clearly by the Centre for Sustainable Energy. They interviewed people living in fuel poverty about how they coped, finding: "Any winter heat demand, however low, presents a cost that may have to be sacrificed by those in the most constrained financial circumstances." [26] In other words, when the money runs out, some households have no choice but to turn off the heating, whatever the weather.

The amount of time a home stays warm and comfortable without heating is very important to people on precarious incomes. A Passivhaus offers far more 'hours of comfort' than a typical regulations compliant home. But low temperatures are not just uncomfortable, they can also be dangerous. Our thinking should shift to 'hours of safety' - a concept developed by the Rocky Mountain Institute. A Passivhaus will maintain a safe temperature, without heating, for longer. This is useful when considering fuel poverty and housing, both at the individual and a community level.

The Deerings: Gresford Architects © Quintin Lake

3.2 Summer Comfort

Passivhaus delivers homes that are comfortable in summer.

The health implications of summer overheating in our homes are significant. It is estimated that there are currently around 2000 heat-related deaths in the UK every year and that this could rise to more than 7000 by 2050.[27]

The Passivhaus standard includes an overheating criterion which requires that the building, as a whole, spends less than 10% of the year at temperatures of 25ºC or above. Whilst this is the maximum requirement, the best practice in the UK is to design to 5% or, ideally, 0% above 25°C, and to take account of potential complicating factors (such as noise or security) in the summer comfort strategy, through an additional stress test. It should also be noted that the Passivhaus modelling system uses local climate data rather than the generic mid-UK location used by SAP in support of Building Regulation compliance.

A detailed study[28] of in-use Passivhaus dwellings showed 89% of these homes met the CIBSE TM59 Overheating Criterion 1. The recent Independent Assessment of UK Climate Risk by the Climate Change Committee (CCC)[29] put the national percentage of homes overheating at around 20%. In another study, this time for MCHLG,[30] 8 new-build dwelling typologies[31] were modelled in 5 different locations in the UK. The analysis found that all the dwellings exceeded the CIBSE TM59 overheating Criterion 1, in all locations. Whilst these studies cannot be directly compared, the contrast is striking. The Passivhaus buildings appear to greatly outperform both our existing stock and the modelled new build regulation-compliant archetypes, in terms of summer comfort.

Three of the main issues contributing to overheating in new homes are inadequate ventilation, excess unshaded glazing, and excess heat loss from building services such as hot water systems. The Passivhaus design software, PHPP, includes checks to limit all three of these factors to help reduce overheating risk. Recent guidance issued by the Passivhaus Trust[32] quantifies and clarifies some of these contributing factors as well as suggesting several stress tests. Following this guidance offers the opportunity to make Passivhaus buildings in the UK even more robust in the face of a warming climate.

Dundon Passivhaus: Prewett Bizley Architects
© Prewett Bizley Architects

3.3 Indoor Air Quality

Good ventilation is as important to health as the right temperature.

Since the Covid-19 epidemic, the dangers posed by under-ventilated buildings have gained fresh urgency. The problem is long-standing, and the implications reach further than the transmission of airborne viruses. All areas of human health and wellbeing are impacted: physical, mental, social, and even economic.

> "It is highly likely that through excess indoor pollution, poor housing conditions are in part responsible for the stark social gradient of childhood disease observed in the UK."
>
> *The Royal College of Paediatricians* [35]

Research has repeatedly demonstrated a link between higher ventilation rates and better health.[33] The Royal College of Physicians has warned that indoor air pollution causes thousands of deaths per year and costs the health service tens of millions of pounds.[34]

In a follow-up review of indoor pollution and child health, the Royal College of Paediatricians author team wrote: "It is highly likely that through excess indoor pollution, poor housing conditions are in part responsible for the stark social gradient of childhood disease observed in the UK." [35]

There is a severe ventilation performance gap in UK construction. Studies have revealed that when mechanical ventilation systems are installed in new non-Passivhaus homes they often fail to comply with the regulations, fail to deliver enough air movement, are noisy, and get switched off by irritated occupants.[36] Occupants also close vents and disable fans when they are cold and cannot afford to increase their heating.

People with low incomes are trebly vulnerable to harm from under-ventilation. As well as being more likely to shut off ventilation, they are:

- More likely to live in overcrowded conditions and/or dry laundry passively indoors and/or live with a smoker[37]
- More likely to have chronic health conditions (eg heart or lung conditions) that may be exacerbated by poor indoor air quality[38]

A study of ventilation systems in a number of low energy homes found that it was "...apparent, from the interviews, that the Passivhaus projects investigated had fewer performance issues than the non-Passivhaus dwellings, particularly with draughts or other discomfort and high temperatures. This difference in performance between the Passivhaus and non-Passivhaus dwellings may be in part due to the level of detail and planning required for a Passivhaus as a whole building system." [39]

The careful design and installation of ventilation systems in Passivhaus buildings results in more effective ventilation, as indicated on a range of air quality measurements such as carbon dioxide, relative humidity, and levels of indoor pollutants such as VOCs (volatile organic compounds).[40]

Thanks to the careful design and quality assurance processes involved in Passivhaus, the ventilation system itself but, equally importantly, the ease and affordability of heating make it a lot easier and more congenial to have a well-ventilated home.

Passivhaus provides good indoor air quality for all occupants. It is a particularly good choice for people who are vulnerable owing to low incomes or poor health.

Indoor air quality in many homes is poor

- Poor indoor air quality has a significant effect on our health
- Contaminants include: particulates, volatile organic compounds (VOCs), nitrous oxide, carbon monoxide, CO_2 and mould spores
- Children are particularly at risk as they are more affected by lower concentrations
- The primary way to deal with these pollutants is to provide good levels of ventilation
- Studies have shown that our new and existing homes are chronically under- ventilated - especially in winter

Passivhaus homes are well ventilated at all times

- This system filters all air that comes into the building
- Data shows that the levels of ventilation achieved in Passivhaus buildings is consistent and in-line with, or above, recommended minimums for optimum air quality
- Studies have shown that concentrations of pollutants in Passivhaus homes are nearly always well within recommended limits

> "My baby daughter had patches on her lung ... You could hear the raspiness in her cough, and a constantly runny nose. She doesn't suffer from that anymore — since we've been here, she doesn't cough in the night."
>
> *Occupant of Passivhaus retrofit* [41]

> "Where I was to where I am now it's an upgrade. It's much, much better because I'm asthmatic as well so it's a lot better for me."
>
> *Occupant of Passivhaus retrofit* [42]

Akerman Road: Passivhaus Homes

3.4 Quiet

Passivhaus enables people to ventilate securely and comfortably. As with noisy fans, noise entering homes through open windows and trickle vents leads people in conventional buildings to restrict ventilation. Windows may also be closed because of pollution, security fears, or even insects.

In Passivhaus, the provision of plentiful fresh air without the need for ventilation openings, combined with the highly-insulated, airtight construction and triple-glazing, permits a dramatic reduction in noise penetration compared to standard construction. Noise disturbance, especially at night when it disrupts sleep, is very damaging to mental and physical health.

At the same time, the airtight envelope, and filters in the ventilation intake, provide occupants with a level of protection from outdoor pollutants.

> "It's really, really quiet. You don't hear anything outside."
>
> *Tenant, Passivhaus social home* [43]

> "It's many people's first comment on entering - how quiet it is."
>
> *Passivhaus owner* [44]

Churwell Avenue: Hesketh Hayden Architects © Taran Wilkhu, The Modern House

3.5 Schools and Offices

Passivhaus homes offer their residents guaranteed quality and performance, and low carbon emissions. As we saw above, this means residents are at lower risk from health issues relating to environmental factors, and they will enjoy lower bills. These benefits apply to non-domestic Passivhaus buildings as well.

Advice from the UK Science Advisory Group on Emergencies (SAGE) is that buildings, where CO_2 levels are above 1500ppm, should urgently seek ventilation improvement to cut the risk of Covid transmission. This advice stresses the importance of meeting current recommendations, as most standards, including CIBSE, BE, ISO etc generally recommend 900-1200ppm is not exceeded. As with homes, Passivhaus schools and offices appear to deliver carbon dioxide levels reliably within this guidance.

Passivhaus construction is the most appropriate to meet the current guidance and proposed regulations, and indeed, is already likely to be helping protect occupants from Covid infection.

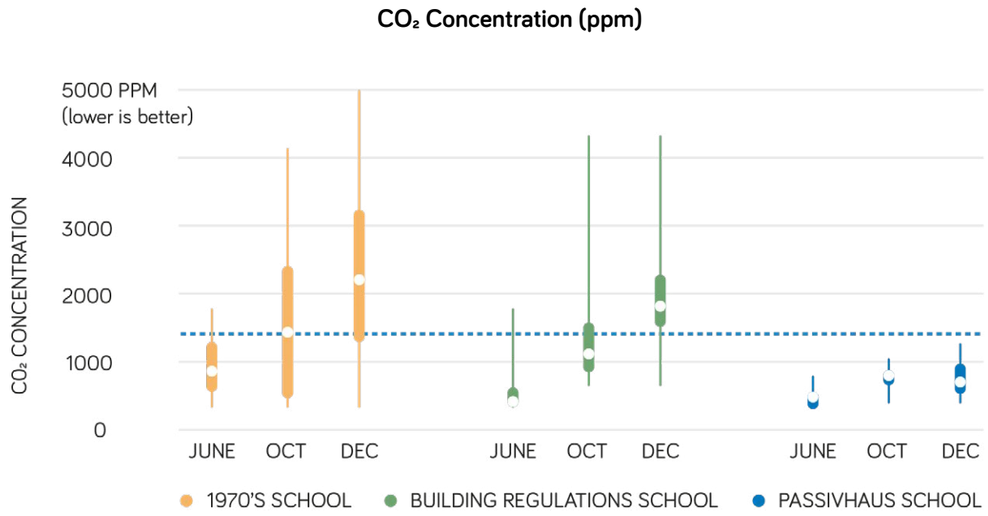


FIGURE 9
Comparative study of indoor air quality in schools through measurement of CO_2 Concentration
by Architype architects/ Chryssa Thoua, UCL

- The continuous mechanical ventilation in all Passivhaus buildings provides high levels of fresh air - and is constantly removing stale air
- This is extremely effective in controlling CO_2 levels - as well as the levels of other pollutants
- The graph above shows the seasonal CO_2 levels in 3 different types of schools -Passivhaus peaks below 1500ppm and is nearly always below 1000ppm

Switch chapters via the icons

River Studio: Sjolander da Cruz Architects

PEOPLE PERFORMANCE

KEY BENEFITS

- Reduced absenteeism
- Improved productivity
- Improved learning outcomes
- Attract and retain staff

4. PEOPLE PERFORMANCE

Not only physical health is affected by the indoor environment. A lot of evidence points to the need for good air quality, thermal comfort, and a quiet environment for optimal learning, and optimal performance at work.

A better school or work environment will not only benefit individual students and employees, but it will also benefit their schools and their employers. Income may well depend at least to some extent on how well the people in the building are able to achieve what they are meant to.

4.1 Ventilation and Cognition

There have been several studies assessing whether CO_2 directly affects our performance at cognitive work. The studies have looked at different groups of people (e.g. office workers, school children). There is an overall pattern in the results: where CO_2 levels are high, in particular above around 2000ppm, performance does appear to be affected.

This study showed a clear degradation in decision making at just 1000ppm with a significant impact at 2500ppm.[45]

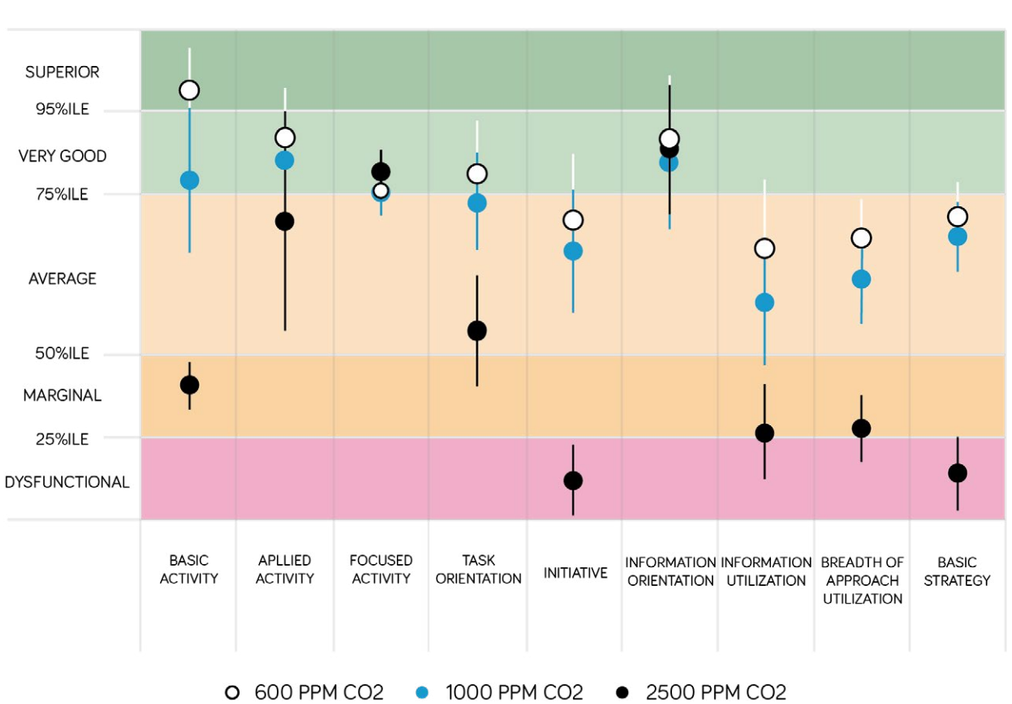


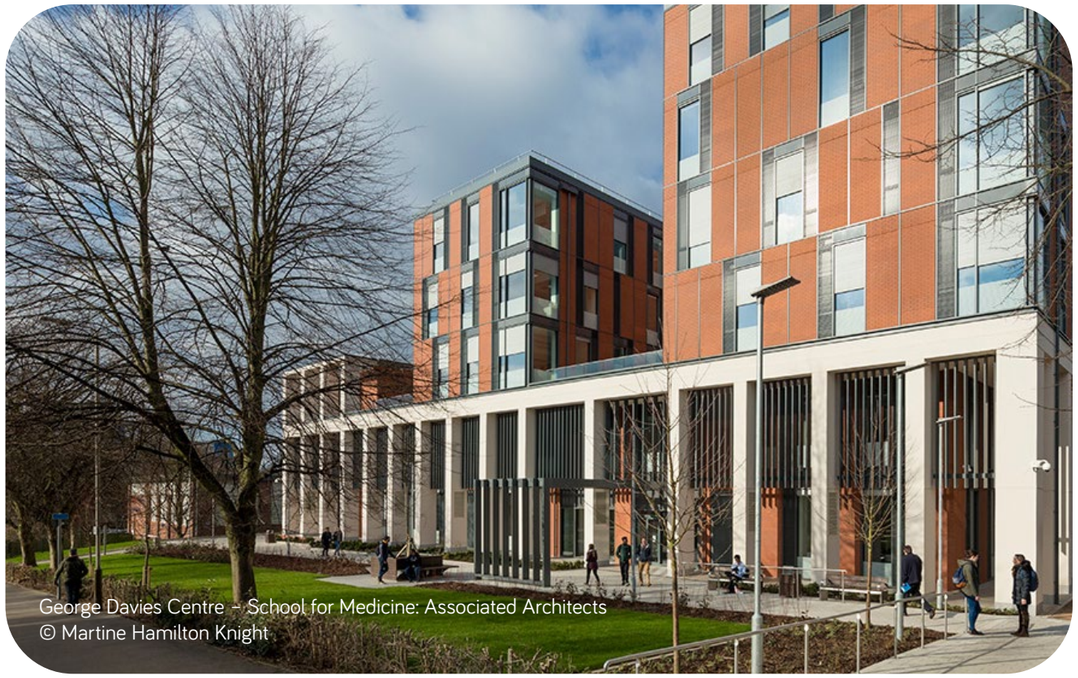
FIGURE 10
Impact of CO_2 Concentration on People Performance

These results suggest that the human brain is sensitive to changes in CO_2 levels even when these levels are not high enough to cause known physical problems otherwise. Reviews of similar studies have reached similar conclusions – CO_2 does seem to have an effect on cognitive performance.[46]

Systematic research in British schools has found CO_2 concentrations that are well above the guideline value of 1000 ppm and peaking above 3750 ppm.[47] By contrast, research shows that new Passivhaus schools remained below 1000ppm[48] almost all the time which put them comfortably inside the BB101 recommended levels (average CO_2 concentration of 1,000ppm or below).

Research has also suggested an impact of pollutants other than CO_2 on cognitive performance. Studies have attempted to look more specifically at the cognitive effects of individual pollutants by adding them in to a space and altering nothing else. Results showing higher levels of volatile organic compounds (VOCs) were associated with lowered cognitive scores.[49]

Harris Academy Sutton: Architype © Jack Hobhouse



George Davies Centre - School for Medicine: Associated Architects
© Martine Hamilton Knight

4.2 Noise and Cognition

In schools, excessive noise has been shown directly to interfere with children's learning.[50] CIBSE TM40 explains that the evidence of detrimental effects on children's cognitive performance is very strong, particularly in relation to schools exposed to noise from air traffic.

Effects include deficits in attention, poorer speech development and poorer memory. This results in effects on overall capabilities. For example, in a school study, the mean reading age of the children in classrooms exposed to high noise levels was found to be 3–4 months behind that of the control children. The effects are sustained over time if exposure to environmental noise continues (e.g. in schools near airports).

4.3 Thermal Comfort and Cognition

The WELL standard cites research that saw employees perform 6% worse in tests when the office is overheated, and 4% worse when the office is cold.[51]

Two studies in the US concluded that for each degree warmer or cooler than 22°C (the temperature that on average US office workers find most comfortable), the average speed at performing a test task dropped by around 1%.

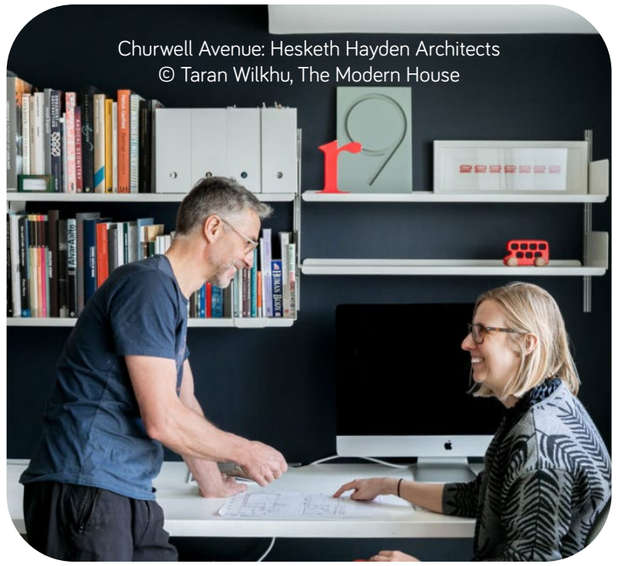
This evidence shows that there could be a significant benefit in cognitive performance and learning outcomes for people living and working in Passivhaus buildings, from both the warmth and consistency of temperature.

We have seen improvements in attendance and productivity when people study or work in a healthy, comfortable, well-ventilated building. The environmental qualities required for optimum performance closely match the internal conditions in Passivhaus: comfortable, well-ventilated, and quiet.

In a commercial organisation – or any organisation subject to performance targets – improved productivity is likely to translate to increased income. It is worth considering whether the potential benefits from the enhanced studying or working environment offered by Passivhaus might repay the initial investment.

> "Higher levels of VOCs were associated with lowered cognitive scores."
>
> *Joseph Allen et al. in Environmental Health Perspectives, 2016*

> "The mean reading age of the children in classrooms exposed to high noise levels was found to be 3-4 months behind that of the children in the control group."
>
> *CIBSE TM40*



Churwell Avenue: Hesketh Hayden Architects
© Taran Wilkhu, The Modern House

Rocking Horse Nursery: BMJ Architects

> "In one of the offices, people managed a test in an average of 8 minutes when CO_2 was low, compared with 13 minutes when CO_2 levels were high."
>
> *Oxford Brookes*

> "The research team estimated that a 500 ppm difference could roughly correspond to each student missing on average two-and-a-half extra days of school each year."
>
> *'Healthy Buildings', Joseph Allen and John Macomber*

Switch chapters via the icons

> "Buildings with higher ventilation rates are associated with 1.6 fewer days sickness per year."
>
> *'Healthy Buildings', Joseph Allen and John Macomber*

> "For each degree warmer or cooler than 22°C, average speed at performing a test task dropped by around 1%."
>
> *Seppanen et al 'Effect of temperature on task performance in an office environment' Berkeley National Laboratory 2006*

> "Employees perform 6% worse in tests when the office was overheated, and 4 % worse when the office was cold."
>
> *Well Standard*

George Davies Centre - School of Medicine:
Associated Architects © Martine Hamilton Knight

FINANCIAL BENEFITS

KEY BENEFITS

- Lower energy bills
- Rental - fewer and shorter void periods
- Reduces the extent and depth of fuel poverty
- Higher capital value 5-7%
- Lower maintenance costs
- Lower management costs
- Ability to access cheaper time of day tariffs
- Lower whole life costs
- Lower borrowing costs / Green mortgages
- Ability to access cheaper green finance
- Holds value in the event of future carbon or efficiency legislation
- Lower risk of defects litigation
- Lower risk of repetitive damage due to quality issues

5. FINANCIAL BENEFITS

Analysis by the Passivhaus Trust in 2019 demonstrated that, compared with standard construction, building to the Passivhaus standard incurred an extra cost of approximately 8%, forecast to reduce to 4% at scale and over time.[52] However, these additional costs result in a far superior quality product, with a higher capital value, lower running costs, and lower maintenance costs.

> "Investing in value instead of energy consumption requires little financial efforts but rather creativity and intelligent solutions."
>
> *Wolfgang Feist, Founder, Passivhaus Institut*

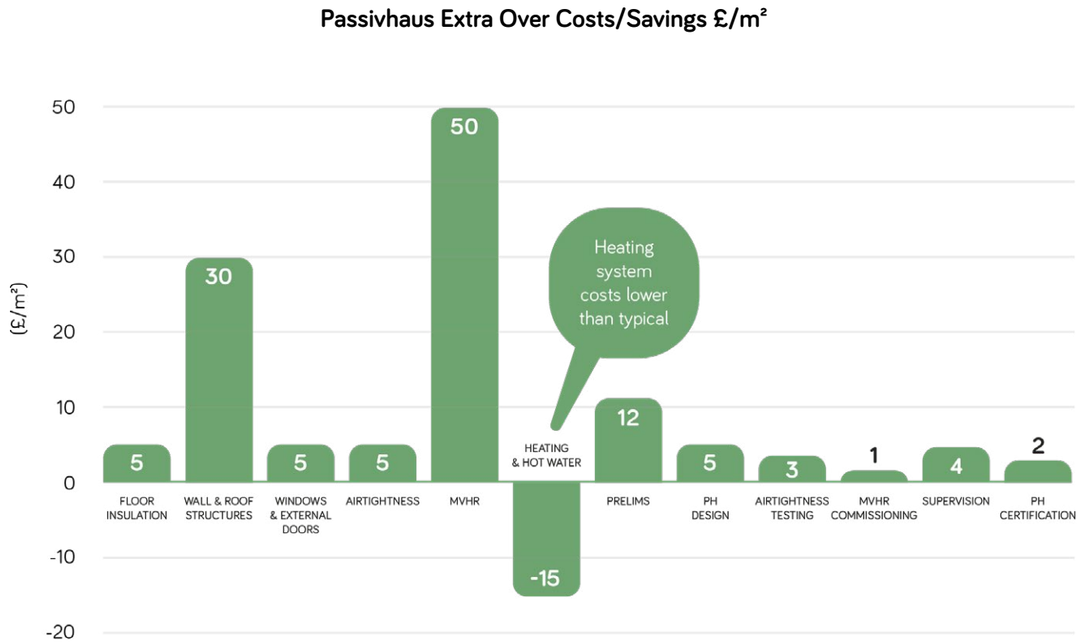


FIGURE 11
Passivhaus extra over costs/ savings by category (Passivhaus Construction Costs, Passivhaus Trust, October 2019)

Simple yet impactful early design decisions including building form, orientation & window design can drive efficiency. By offsetting these design savings against the extra costs for the higher quality fabric, it is possible to deliver higher quality Passivhaus buildings at no extra cost. Experience in countries like Germany where the Passivhaus standard has been popular for longer and has become more familiar suggests that Passivhaus can have zero extra-over costs, and even cost less than building to other standards such as the local building regulations.[53]

5.1 Running Costs

The diagram below shows the annual energy costs (including standing charges) for a 90m² dwelling.[54] It demonstrates that Passivhaus delivers a 30% saving on energy bills compared to a typical new build using either a gas boiler or an Air Source Heat Pump.

FIGURE 12
Annual energy costs for a 90m² dwelling.

> "Rent arrears have been almost eliminated and void rates are substantially lower, with tenants less inclined to move out." [55]

In rental properties, even though the landlord may not be paying the fuel bills, lower running costs have a commercial benefit. Hastoe Housing experiences lower void rates in their Passivhaus properties as people are less inclined to move out, and lower rent arrears as people are not living in fuel poverty.

Another advantage for a Passivhaus is the ability to access flexible tariffs. In a typical building, there is a periodic heating cycle during the winter, with the house being warmed up when the occupants are awake and using the building, then cooling down at other times. It would be impossible to shift the timing of the heating system without the occupants noticing the cold. In contrast, even in winter, Passivhaus maintains a constant internal temperature night and day. The rate of cooling in a Passivhaus is so low that heating can be advanced or delayed by several hours without a significant impact on the internal temperature. This means that a Passivhaus can time its use of heating to coincide with cheaper electricity tariffs, which can offer significant savings.

A Passivhaus can therefore act as a thermal store, which means that it can support dynamic demand response without the need for additional technologies such as batteries or thermal stores. Demand response is likely to be needed in the future to help reduce peak loads on the national grid.

5.2 Fuel Poverty

Whilst exact definitions of fuel poverty vary between nations, in general, a household is considered to be in fuel poverty when they need to spend more than 10% of their income on heating their home. The currently available evidence base, alongside expert discussion, suggests indoor temperatures of at least 18°C should be maintained to minimise risk to health.[56]

Over 14% of households in the UK are considered to be in fuel poverty.[57] The problem is most severe in Scotland where nearly 25% of all households are affected. Overall, this encompasses more than four million UK households.

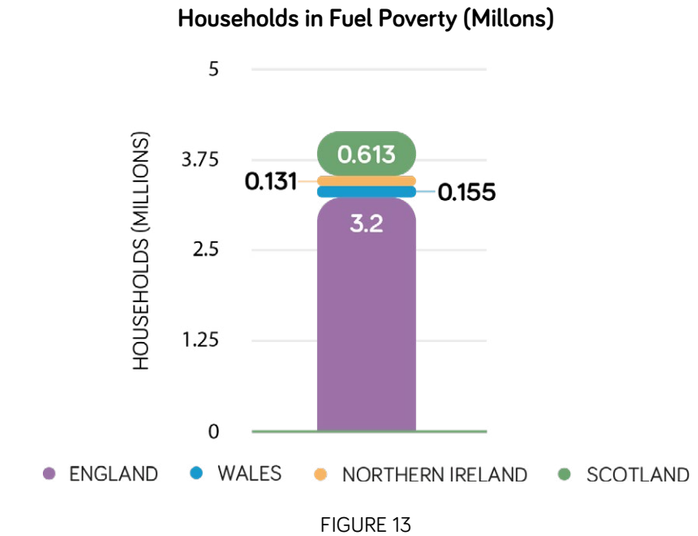


FIGURE 13
Fuel Poverty by Millions of Households

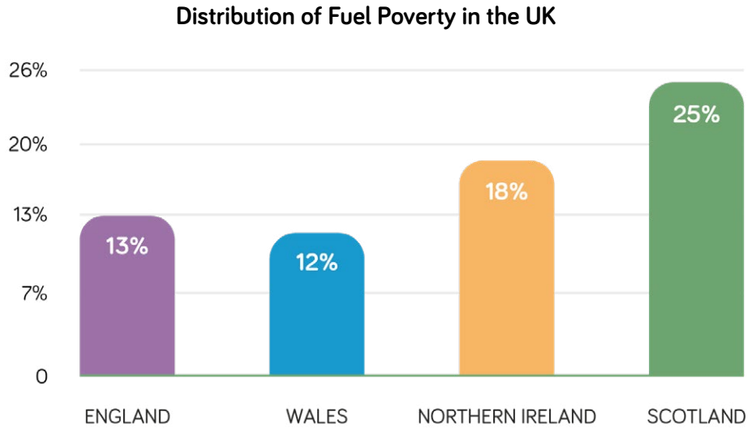


FIGURE 14
Fuel Poverty by Percentage of Households

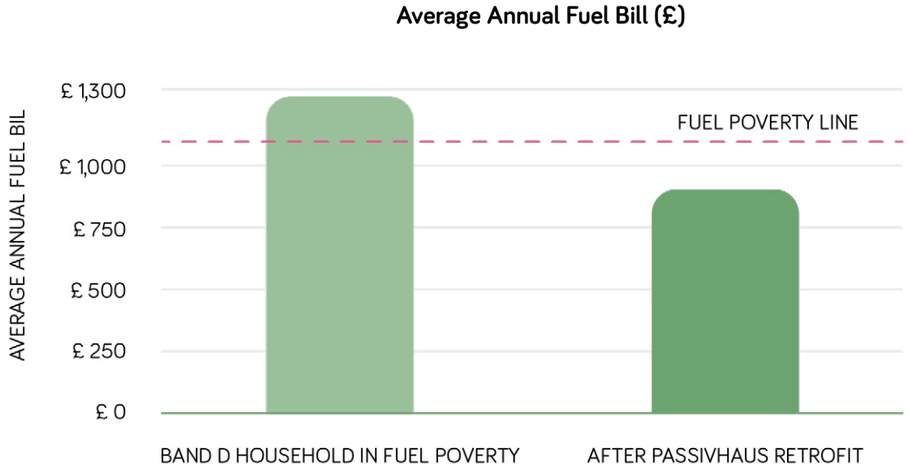


FIGURE 15
Passivhaus and Fuel Poverty

There is a strong link between fuel poverty and energy efficiency with the majority of all fuel poor households living in properties with a Band D EPC or below.

The average reduction in the annual fuel bill that would be needed by these households to come out of fuel poverty is £216.

A Passivhaus retrofit of one of these homes would reduce fuel bills by £380.[58]

5.3 Maintenance Costs

> Our oldest Passivhaus dwellings are almost 10 years old and, so far, we haven't had to replace a single component ....
>
> *Emma Osmundsen,*
> *Managing Director of Exeter City Living Ltd*

Building to the Passivhaus standard results in, quite simply, a better quality building. This is first because the standard requires a robust, evidence-based quality assurance process, and second because better quality components, in particular windows, are required to meet the standard. Whilst both these factors contribute to higher initial construction costs, they also result in reduced maintenance costs, fewer repairs and replacements and, in general, fewer call-backs to deal with issues. All of this results in reduced costs - both for the contractor in the period after practical completion and for the occupier over the lifetime of the building.

Whilst there is little formal research to quantify this, anecdotal evidence suggests it is significant.

5.4 Management Costs

Maintenance of tenanted properties involves considerable back-office management costs, as well as the obvious cost of repair teams. Every complaint of mould or heating problems sets off a chain of phone calls and paperwork, to establish the nature of the problem, and arrange a time and the personnel to rectify it. Reduced maintenance removes a whole burden from landlord staff teams, freeing them to do more pro-active work.

As Passivhaus landlord Hastoe notes, affordable heating reduces the risk of condensation and damp, which in turn, cuts landlord workloads and protects the condition of the buildings.

Quantity surveyors and project managers Baker Ruff Hannon see landlords building to Passivhaus when they are retaining ownership, because of this long-term value. They told the Passivhaus Trust: "Capital cost, whilst important, is also balanced by longer-term lifecycle, ownership and occupancy cost. Higher up-front investment in Passivhaus is made in return for long term benefits." [59]

The quality of the build with Passivhaus may also contribute to an easier life for tenants and their landlords thanks to better soundproofing. Emma Osmundsen, Managing Director of Exeter City Living Ltd told the Passivhaus Trust: "We have seen our housing management costs slashed as the level of anti-social behaviour is noticeably lower on our Passivhaus developments. Qualitative research findings suggest that this is due to better acoustic attenuation due to the Passivhaus detailing."

Knights Place: Gale & Snowden Architects and Engineers

5.5 Whole life cost savings

Lower running and maintenance costs and potentially more affordable borrowing mean that Passivhaus homes offer significant whole life cost savings.

Setting the initial extra construction costs against the savings in running costs over time allows us to compare the whole life cost-benefit of Passivhaus compared to a typical dwelling. This comparison shows that the initial additional costs are recovered after 8 years if heating and hot water is provided by direct electric heating, 15 years using an air source heat pump and 21 years with a gas boiler.[60] If gas prices suffer repeated price spikes such as those seen in late 2021, costs in a gas-heated dwelling would be recovered more rapidly, too.

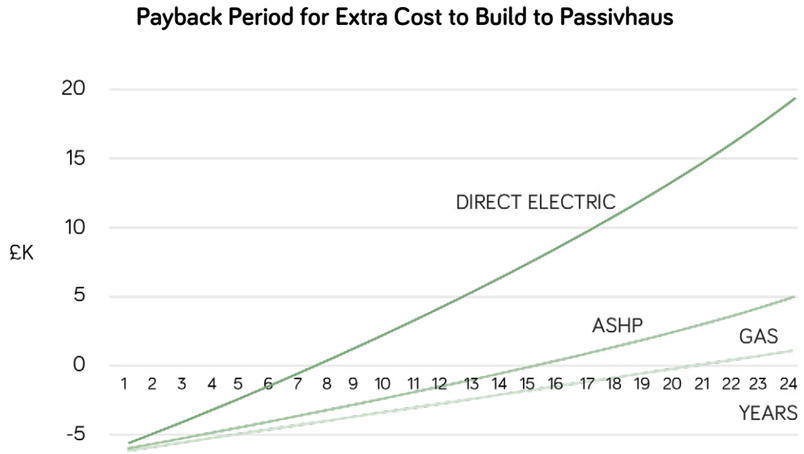


FIGURE 16
Initial Passivhaus build uplift costs vs 2021 Building Regulations new build for a 90m² dwelling payback period by heat source (years 1-25 only)

If the lifetime of the building is assumed to be 60 years, then the whole life cost-benefit of Passivhaus vs non-Passivhaus is as shown below.

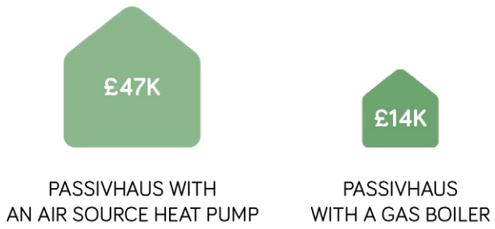


FIGURE 17
Net Whole Life Cost Benefit of Passivhaus vs 2021 Building Regulations over 60 years

Note that this calculation only considers the initial build cost and the whole-life energy cost savings. Additional financial benefits such as better mortgage rates and lower maintenance costs have not been included but would result in even quicker payback periods and larger whole life benefits.

5.6 Green Finance

An increasing focus on climate change is resulting in ethical and commercial pressure on companies and investors to disinvest from traditional fossil fuel markets. The result is that many investment funds are looking to invest in 'green' markets where the investments have a less damaging impact on climate change. These kinds of financial products are in high demand.

The Green Finance Institute has launched an initiative called the 'Coalition for the Energy Efficiency of Buildings' (CEEB) to try to find ways of putting investors and green construction together. It aims to develop the market for financing net-zero carbon and climate-resilient buildings in the UK by accelerating the pace of financial innovation and scaling up.

CEEB is actively looking at how financial products that enable investment in green construction can be brought forward.[61] Most of the models rely on some element of the repayment flowing from the reduction in energy bills, which relies on a genuine improvement in energy efficiency.

As set out earlier, the Passivhaus standard has a proven track record of delivering buildings whose performance matches the design intent. Therefore, they offer investors assurance that the reduction in energy bills will be realised, and the occupants will be able to afford the finance repayments. An at-scale project which requires certification to the Passivhaus standard is therefore likely to be more able to leverage green finance opportunities.

There is now considerable evidence suggesting that more energy-efficient homes benefit from a lower risk of loan default as well as higher resale values.[62] [63] Research by the Energy Saving Trust, BRE, Nationwide, and others is starting to demonstrate that discounted green mortgages make sound financial sense. Energy efficiency measures have a positive impact on mortgage affordability by driving down householder bills.[64]

Some discounted mortgages for energy-efficient properties are already available, with the Ecology Building Society and several others offering targeted mortgage products in this area. The Ecology Building Society offer a 1.25% mortgage discount on Passivhaus buildings compared to 0.75% discount for an EPC Band A property.


Castle Crescent:
John Gilbert Architects
© Tom Manley Photography

> "As contractors the Passivhaus approach is a quality standard helping us to deliver projects profitably by avoiding costly defects and call backs. At Makar we prioritise getting things right first time, and to a high standard of quality. This is why we follow Passivhaus principles."
>
> *Neil Sutherland, Architect & Director, MAKAR Limited*

> "The Passivhaus requirements to front load & complete the design in the pre-construction phase results in many added benefits, including early procurement of sub-contractors and full co-ordination of the digital model. This should, in practice, enable a more efficient build process resulting in less site modification and waste, and ultimately a smoother commissioning and handover process."
>
> *Allan Smith, Low Carbon Manager, Morrison Construction*

> "The City of Edinburgh Council have adopted Certified Passivhaus as a proven approach. It provides clarity around design and construction expectations thereby ensuring building performance and user comfort expectations are delivered."
>
> *Patrick Brown, Head of Capital Programme Team, City of Edinburgh Council*

Geanaisean: Makar

5.7 Passivhaus Adds Value

RICS highlight that higher build quality, potentially lower finance costs, lower running costs and general comfort improvements should also be considered as part of the valuation. These considerations apply to energy-efficient homes generally but are likely to be even more pronounced for a home certified to Passivhaus - because it's the highest standard of energy efficiency, and because the rigorous certification process guarantees performance.

Research done for the European Commission[65] has found that there is some evidence to suggest that "better energy performing buildings show shorter vacancy periods, have a lower loss of rental income due to changing tenants and… show a more positive operating impact for the owner".

By contrast cheap, low-quality buildings have significant additional costs associated with:

- Higher defects
- Legal action from clients/ buyers/ residents
- Health and safety issues
- Overheating complaints
- Complaints of draughts and cold homes[66]

With good ventilation and thermal comfort, Passivhaus premises certainly offer conditions for better staff health and productivity. Additionally, low running costs mean the net benefit is even greater: a win-win for commercial tenants and owner-occupiers. In their book, 'Healthy Buildings' Joseph Allen and John Macomber argue that "healthy buildings represent one of the greatest businesses opportunities ever." [67]

In their TM40 standard for healthy indoor environments, CIBSE points out that alongside immediate productivity, employee perceptions and satisfaction with the workplace matter. "These can influence motivation…and retention [which] can translate into large benefits for organisations."

Hope View House: Warren Benbow Architects © Lisa Lodwig

SOCIAL

KEY BENEFITS

- Improved health & wellbeing of communities
- Reduced demand on health and social services
- Improved learning outcomes for children
- Economic stimulus of construction
- Upskilling of the construction workforce
- Clear statement of intent for transition to a net zero economy
- Demonstrates compliance with social value policies and targets
- Aligns with several UN Sustainable Development Goals

6. SOCIAL

The enhanced value provided by building to the Passivhaus standard may be evidenced through occupant health, capital value increase and wider social value. Social value relates to "overall social welfare efficiency, not simply economic market efficiency".[68] RIBA's 2021 Built for the Environment report[69] highlighted the importance of moving away from decisions dominated by capital cost. Instead, it called for understanding and adopting holistic, whole-life costing models.

6.1 Social value

A good building will create social value, i.e., benefits to society. There are many interconnected social benefits from Passivhaus construction. These include better comfort and wellbeing, improved mental and physical health, education and skills attainments – which in turn may benefit the economy and society. There are also climate and other wider environmental benefits.

Mildmay Community Centre. bere:architects © Tim Crocker

Social value can be described in words. But increasingly, particularly in the light of more official requirements for social value reporting, there is also a demand for it to be quantified. Formal evaluation systems for social returns (SROI – social return on investment) are therefore being developed. Their purpose is to give insights into the relative impact of different measures in different areas of life, and to draw attention to valuable opportunities that might not be immediately obvious to the project client and designers. There are increasing signs that an assessment of social value is becoming a key part of the decision-making process for several organisations. Some examples of enhanced social value associated with Passivhaus buildings are described below.

- The New Economics Foundation has suggested alternative indicators of national success should be wellbeing, good jobs, environment, fairness and health.
- The 2012 Social Value act means that public sector bodies are required to demonstrate social value for their spending.

- The Treasury Green Book states "Evaluation of 'wider social and environmental costs and benefits for which there is no market price' is required as a part of value for money assessments."
- Social returns are increasingly important to private sector investors. They want to demonstrate to their shareholders and upstream investors that the money they are investing is doing good.

6.2 Fuel Poverty is not just about money

> "Positive health outcomes [from better quality housing] are consistently strongest among vulnerable groups, including children, the elderly and those with pre-existing illnesses."
>
> *OECD/IEA 2014*

Fuel poverty can lead to multiple health issues as well as affecting wellbeing and impacting relationships. There are impacts on health, social connections, learning, earning potential, and ultimately in life expectancy. In particular, cold and damp homes impair children's ability to learn and also result in greater vulnerability to colds and infections. High quality housing such as Passivhaus is beneficial to people on very low incomes, or in other groups particularly badly harmed by poor housing.

Retrofit Action For Tomorrow

6.3 Health and Social Care costs of poor housing

In their 2021 report "The cost of poor housing" [70] the BRE made a comprehensive attempt to estimate the overall societal costs of sub-standard housing in England. They estimated the annual NHS costs of leaving England's poor housing unimproved was £1.4 billion. Much of that cost relates to excess cold. However, the overall costs to society may be 13 times as much.

The BRE confined the assessment to societal 'hard costs' - impacts that have a fairly clear monetary cost. They considered costs like higher energy bills (which impinge on spending elsewhere), costs of missing education and employment opportunities; costs to employers and other services such as education from absenteeism, in terms of lost productivity, 'catch-up' sessions etc; higher building maintenance costs, loss of asset value (or rental value), and higher insurance premiums; and higher emergency service costs and higher enforcement and re-housing costs for local authorities.

The wellbeing improvement from raising a home EPC one band was valued through the HACT Social Value Bank[71] at around £220 annually per adult benefiting. Freeing a household from severe condensation and mould problems equated to a social benefit of up to £1,200 annually, per adult benefiting – depending on the vulnerability of the people affected.

Agar Grove 1b: mae and Max Fordham © Jim Stephenson

6.4 Building back better

As UK CCC chief executive Chris Stark, and Julie Hirigoyen, chief executive at UKGBC, point out, construction and retrofit are one of the best ways to create jobs per £1 invested. Retrofit has the potential to create new and higher-skilled jobs in every region and community and boost existing firms (especially SMEs and their supply chains).

A report to BEIS backs up the value to the domestic economy of investment in construction. Investing in the construction sector as a part of the decarbonisation drive is highly likely to retain the benefit from the investment (supply chain and jobs) locally; the business is "less susceptible to offshoring than traditional stimulus measures".[72]

The Construction Leadership Council recently published a national retrofit strategy suggesting that a retrofit programme could result in 500,000 new jobs by 2030, alongside a £308.7bn boost to the economy.[73]

Constructing and retrofitting to Passivhaus standards would thus facilitate a green recovery with a robust return on investment in terms of environmental, social and economic benefits – all three pillars of building back better.

A combination of constructing Passivhaus buildings and mandating workforce training as a part of the contract could enable trainees to consolidate learning with on-site experience, improving employability and earning potential, and increasing local construction skills levels.

6.5 Climate Justice

In a UK poll, 70% favoured accelerating climate action by meeting the government zero-carbon target much sooner - from 2050 to 2030. A poll for The Independent found overwhelming support for radical change to end the UK's net carbon emissions by the end of the decade. Support was high across all age ranges, social groups, and parts of the country.[74]

We have already seen that full decarbonisation of the energy system requires a significant demand reduction, alongside a lot more renewable energy generation. But there is another imperative. Decarbonised heat is likely to cost more per kWh than the fossil fuel equivalent. It means that lowered energy consumption in homes is going to be essential to avoid higher fuel bills. The alternative: decarbonisation may make existing fuel poverty worse - unfair and politically very unpalatable.

Passivhaus enables a cost-effective, and fair, transition to electric-based heating – which is what we need to support our national transition to net zero.

Li-An Lim on Unsplash

BENEFIT MAPPING – Tailoring your business case

The benefits of Passivhaus are mapped below. We hope that this matrix may be valuable in helping various stakeholders build tailored business cases relevant to their interests.

BENEFIT MAPPING	HOME-OWNERS & SELF-BUILDERS	DEVELOPERS	RESIDENTIAL TENANTS	DOMESTIC LANDLORDS	SCHOOLS, HOSPITALS & SOCIAL CARE	EMPLOERS & COMMERCIAL LANDLORDS	LOCAL & NATIONAL GOVERNMENT
BUILDING PERFORMANCE							
Low energy demand	●		●	◐	●		●
Reduces performance gap	●		◐	◐	●		●
High levels of comfort	●	◐	●	●	●	●	●
Effective and healthy ventilation	●	◐	●	◐	●	●	●
Higher performance building components	●	●	●	●	●	●	●
Better site QA procedures resulting in better construction quality	●	●		◐	●	●	●
Lower risk of building fabric damage	●	●		◐	●	●	●
Resilient and future-proofed buildings	●		●	◐	●	●	●
CLIMATE EMERGENCY							
Lower carbon emissions	●	◐	●	●	●		●
Lowers peak demand							●
Lowers the overall requirement for renewable energy							●
More economical to save energy than to generate it							●
Gives us the best chance of achieving net zero in buildings	◐	◐			◐		●
Enables decarbonisation without increasing fuel bills	●	◐	●	●	●	●	●
Robust in the face of short-term extremes and longer-term climate changes	●	◐	●	●	●		●
Ability to support demand response							●
Lower cooling requirement in a future warmer climate	●	◐	●	●	●		●
HEALTH & WELLBEING							
Eliminates cold homes - and associated health impacts	●		●	●	●	●	●
Guarantees good levels of ventilation – essential for health	●	◐	●	●	●	●	●
Reduces internal pollutants such as VOCs	●		●	●	●	●	●
Deals with internal humidity – eliminates condensation and mould	●	◐	●	●	●	●	●
Improves quality of life for people with chronic illness or disabilities	●	◐	●	●	●	●	●
Protects against external air pollutants	●		●	●	●	●	●
Reduces risk of airborne infection	●		●	●	●	●	●
Reduces the impact of external noise	●	◐	●	●	●	●	●
Reduces risk of buildings becoming too hot in summer	●	◐	●	●	●	●	●
Improves health of people in schools and offices		◐			●	●	●
PEOPLE PERFORMANCE							
Reduced absenteeism		◐			●	●	◐
Improved Productivity	◐	◐			●	●	◐
Improved learning outcomes		◐			●	●	◐
Improved learning outcomes		◐			●	●	◐
FINANCIAL							
Lower energy bills	●		●	●	●	●	●
Rental - fewer and shorter void periods				●		●	◐
Reduces the extent and depth of fuel poverty	●		●	◐	◐	●	●
Higher capital value 5-7%	●	●		●		●	◐
Lower maintenance cost	●	●		●	●	●	◐
Lower management costs		●		●	●	●	◐
Ability to access cheaper time of day tariffs	●		●	●	●	●	◐
Lower whole life costs	◐			◐	●	●	●
Lower borrowing costs / Green mortgages	●	●		●		●	◐
Ability to access cheaper green finance	●	◐		◐	●		●
Holds value in the event of future carbon or efficiency legislation	●	●		●	●	●	●
Lower risk of defects litigation	◐	●		●	●	●	●
Lower risk of reputional damage due to quality issues	◐	●		●	●	●	●
SOCIAL RETURN ON INVESTMENT							
Improved health and wellbeing of communities	◐		◐	◐	◐	◐	●
Reduced demand on health and social services					●		●
Improved learning outcomes for children	●	◐	●	◐	●	◐	●
Economic stimulus of construction		◐					●
Upskilling of the construction workforce		●					●
Clear statement of intent for transition to a net zero economy		●		●	●	●	●
Demonstrates compliance with social value policies and targets		◐			●	●	●
Aligns with several UN Sustainable Development Goals					●	●	●

KEY: ● Highly relevant to this group ◐ Moderately relevant to this group

SUMMARY AND CONCLUSIONS

This research has shown that there are wide ranging benefits associated with building or retrofitting to the rigorous, quality-assured Passivhaus standard.

Passivhaus buildings:

- Deliver outstanding levels of building performance
- Offer exceptional levels of comfort
- Support our transition to net zero
- Support positive health outcomes
- Provide optimum conditions for productivity and learning
- Offer significant whole life cost savings
- Deliver a robust return on investment in terms of environmental, social and economic benefits
- Protect vulnerable members of society from fuel poverty

When this research is read alongside our costs paper,[75] the case for Passivhaus in the UK is robustly made. Our approach to both our new buildings and the retrofit of our existing stock in the UK must be ambitious and inclusive. The Passivhaus standard gives us a range of approaches for our journey to Net Zero, making it widely applicable across all building typologies.

Overall, this study has shown that building to the Passivhaus standard in the UK is not only the most appropriate choice for delivering high quality buildings but also is the best choice for the environment and population at large. With rapidly rising climate anxiety among our children,[76] it is our moral responsibility not just to the planet but to our children to act today. And what better way to show our society that we are acting on climate change than to radically transform the spaces where they live, work and play.

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The Passivhaus Trust is an independent, non-profit organisation that provides leadership in the UK for the adoption of the Passivhaus standard and methodology. Passivhaus is the leading international low energy design standard, backed with over 30 years of building performance evidence. It is a tried & tested solution that enables a meaningful transition to net-zero now. Over 65,000 buildings have been certified to this standard worldwide. The Trust promotes Passivhaus as a robust way of providing high standards of occupant comfort and health AND slashing energy use and carbon emissions from buildings in the UK.

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