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LSBU BSRIA

NET ZERO BUILDING CENTRE

TOPIC GUIDE

Net Zero Carbon Buildings

By Aaron Gillich

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ACKNOWLEDGEMENTS

The Net Zero Building Centre is a joint venture between BSRIA and London South Bank University (LSBU). Its aim is to accelerate decarbonisation in the built environment. It is an innovation hub and centre of excellence that builds on the shared strengths of BSRIA and LSBU in field of low carbon buildings.

BSRIA is a non-profit distributing, member-based association promoting knowledge and providing specialist services for construction and building services stakeholders.

LSBU has world leading expertise in the built environment, drawing on decades of academic and applied research experience in energy, civil and building services engineering, and a long-standing professional reputation in the construction and property industry.

BSRIA and LSBU have sought to ensure that the contents of this guide were relevant and up to date at the time of publication. However, readers should be aware that legislation, standards and codes of practice change regularly.

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NET ZERO BUILDING CENTRE

TOPIC GUIDE

Net Zero Carbon Buildings

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INTRODUCTION

The UK is committed to creating a net zero carbon economy by 2050. This guide defines the terminology of net zero and its implications for the built environment. It outlines the key issues in the design and performance of buildings and how they affect your role.

Who is this guide for?

- Facilities managers, building owners, building occupiers, building services professionals, product manufacturers

WHAT IS NET ZERO?

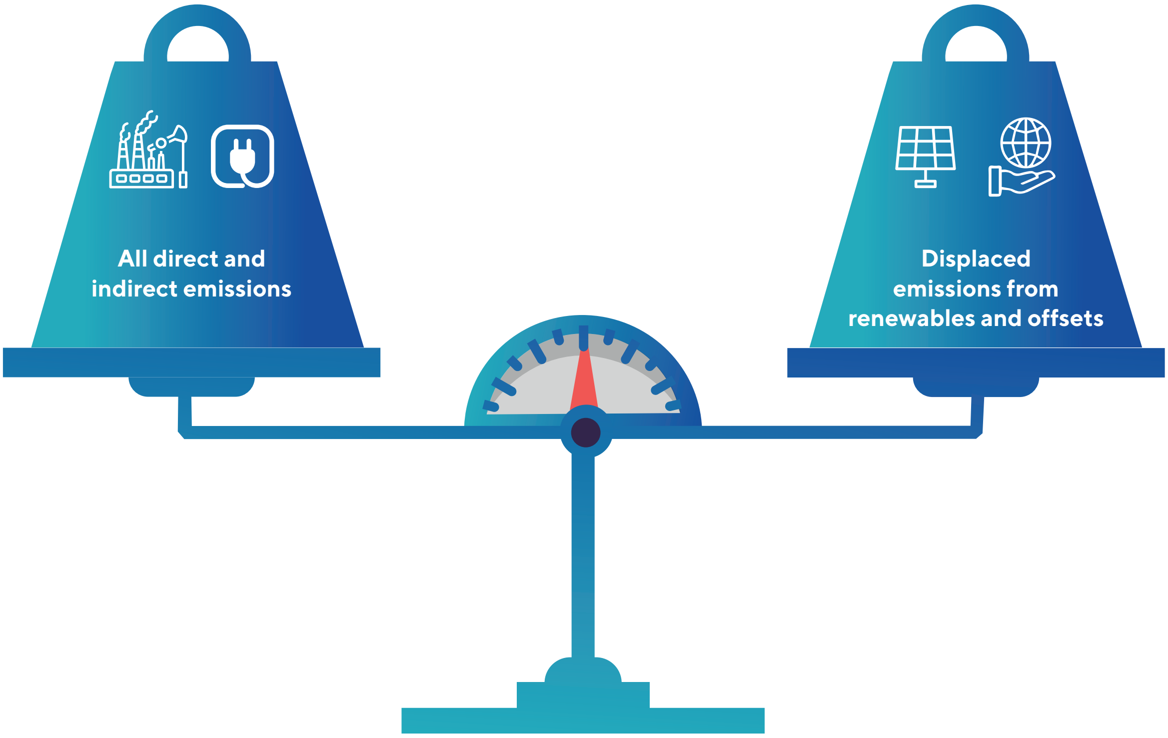
The United Nations defines net zero as cutting all greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere.

The term net zero was first popularised by the Paris Climate Agreement in 2015. There is a scientific consensus that in order to limit the world to only 1.5°C of climate change, global greenhouse gas emissions must be reduced by 45% by 2030, and to net zero by 2050. This means that by 2050, any greenhouse gases emitted must be balanced with an equivalent removal of greenhouse gases from the atmosphere.

If we fail to do this, then the Earth will warm by more than 1.5°C, leading to devastating consequences including the significant risk of feedback loops creating runaway climate change that threatens the viability of most life on earth. We are currently at around 1°C of climate warming, and we are already witnessing the catastrophic effects this is having, with record-breaking temperatures and widespread disruption to global food, water, and natural systems.

Nearly all countries worldwide have signed on to the Paris Climate Agreement and created their own net zero plans. For the UK, this included updating the 2008 Climate Change Act to require the UK to be a net zero carbon economy by 2050.

Net zero by 2050 is therefore an extremely important target to mitigate the worst impacts of climate change.



Net zero requires balancing all emissions with equivalent removals from the atmosphere.

NET ZERO BUILT ENVIRONMENT

The term net zero refers to all greenhouse gas emissions, from all sectors, and in all forms. The term zero carbon is often used as shorthand since carbon is the dominant greenhouse gas in the built environment, but net zero must include all emissions including methane and a number of other greenhouse gases.

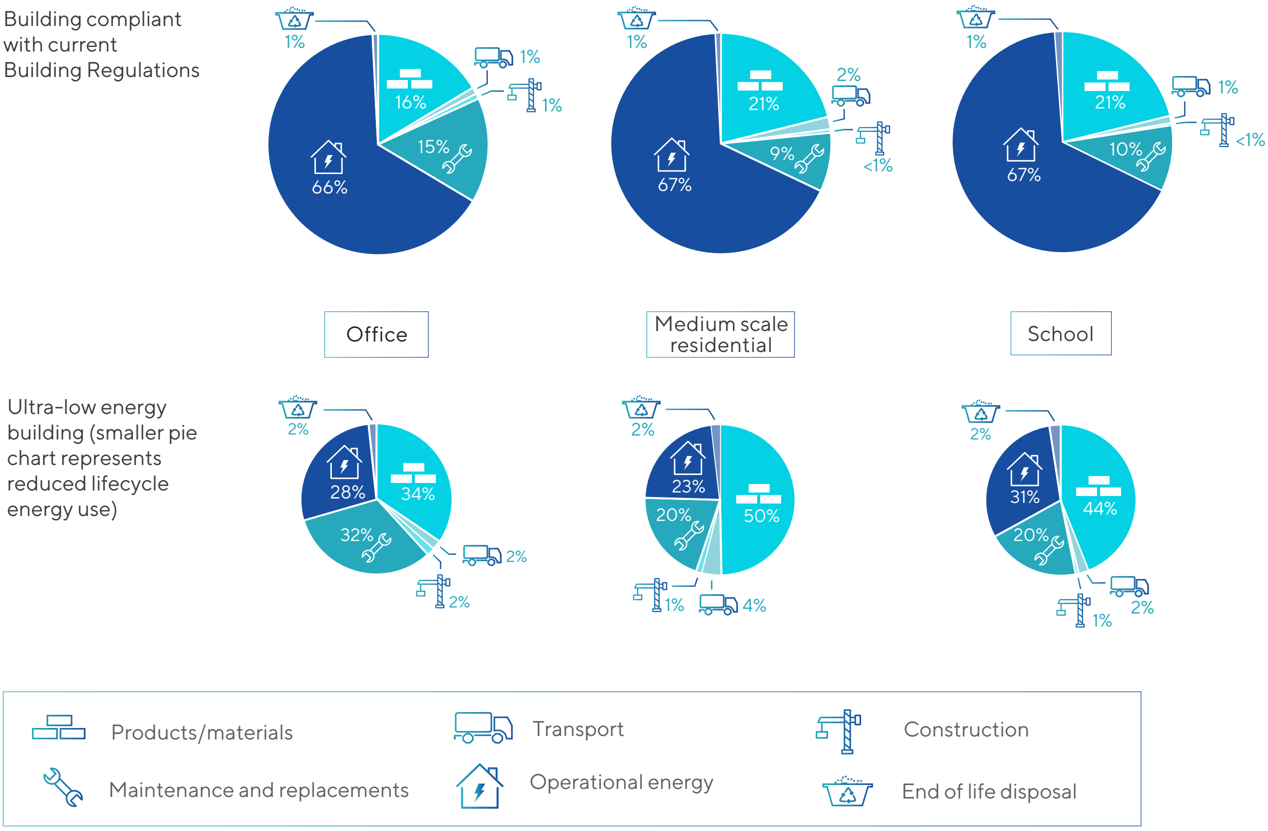
Most pathways to net zero accept that we will not be able to completely decarbonise all sectors of the economy, and that some form of greenhouse gas removal will be needed to offset emissions from hard-to-treat sectors.

According to the UK's net zero strategy[1], the built environment must become truly zero emissions. The net part of the term net zero is reserved for harder to treat sectors like shipping, industry, and food production. This context is important, as it means that we must face a number of difficult decisions and design challenges to create truly zero carbon buildings, and shouldn't expect to rely on clever carbon accounting or offsets from a silver bullet carbon removal technology.

EMBODIED CARBON AND WHOLE-LIFE VALUE

Buildings produce emissions from both the energy used in operation and the embodied emissions from the materials and processes in their construction. Together, operational and embodied emissions are called whole-life carbon emissions. Net zero targets refer to whole life carbon, and so it is very important that we understand the impacts of embodied carbon in our buildings.

Until very recently, our decarbonisation efforts have focused almost exclusively on operational emissions, but embodied emissions can account for up to half or even two thirds of a building's lifetime carbon emissions. As we make progress in reducing operational emissions, embodied carbon will play an even greater role in a building's carbon footprint as shown in the figure below.

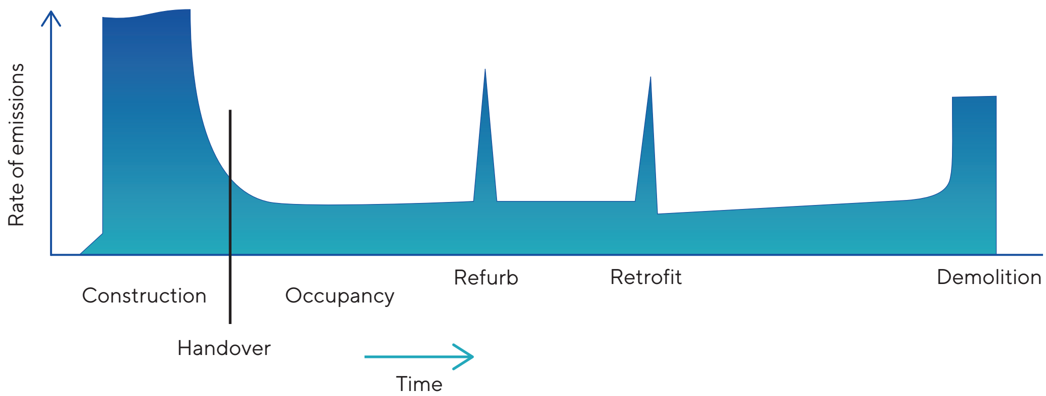


Breakdown of whole life carbon for typical office, medium scale residential and school developments over 60 years (adapted from the LETI Embodied Carbon Primer[4])

There are a number of sources published by UKGBC[2], RICS[3], LETI[4] and others with detailed guidance on embodied carbon and how to approach both new build and retrofit projects with a whole life value approach. As shown in the figure below, embodied emissions largely occur at the beginning of a building's lifecycle. A whole life carbon approach is therefore essential for meeting the interim target of halving carbon emissions this decade.

These are currently voluntary approaches, and it is incumbent upon building professionals to include embodied carbon in their project plans. Industry has proposed an amendment to the Building Regulations to account for embodied carbon. There is much interest in this from the sector but so far no formal adoption into policy.

Many elements of net zero such as embodied carbon can represent additional upfront cost. However, the co-benefits of net zero in terms of improved building performance, health outcomes, and reduced operating costs are widely documented. The upfront costs of net zero should always be framed in the context of the whole life value and co-benefits that are achieved.

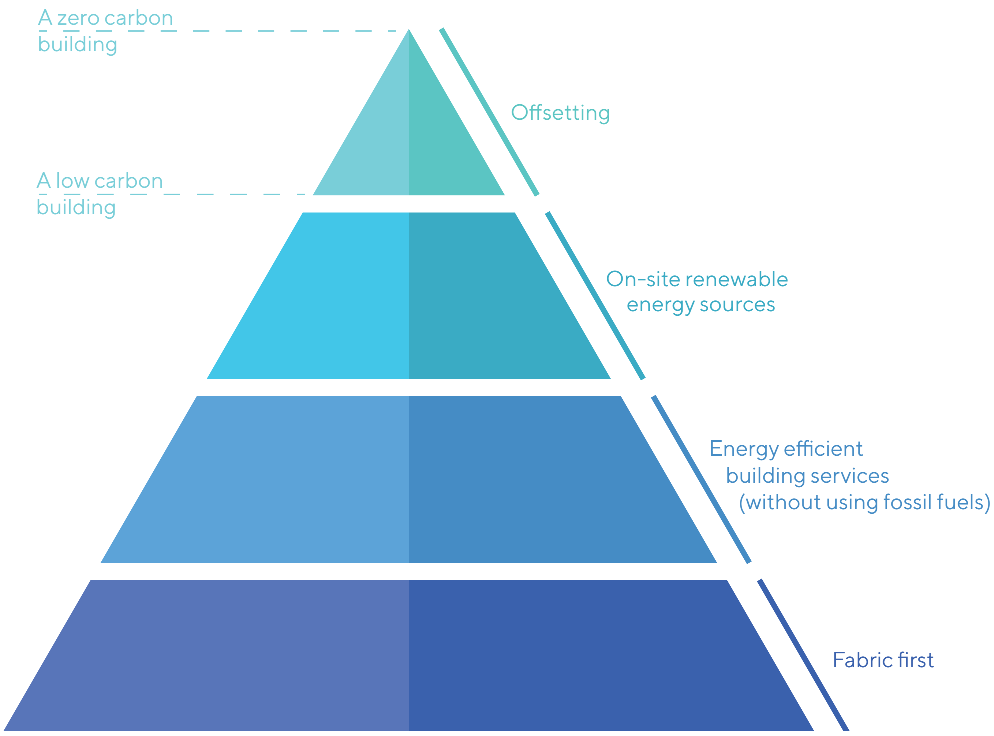


Timeline of CO_2 emissions throughout a building's lifecycle

NET ZERO BUILDING DESIGN

Current regulations do not require net zero building designs, nor is there any immediate timeline for this requirement. Any building that only meets the regulatory minimum will require retrofitting to be part of a net zero built environment. Retrofitting is more complex and costly than getting it right the first time, not to mention that the building will continue to create emissions and contribute to climate change until it has been retrofitted to a net zero standard.

Building professionals have a responsibility to avoid design solutions today that create problems tomorrow. All new buildings should target net zero designs from the outset. A net zero design should aim to minimise energy use using a fabric first approach and avoid the need for fossil fuel use on site.



The hierarchy for designing a zero carbon building

Fabric first uses the principles of building physics to deliver comfort by maximising the performance of the components and materials that make up the building fabric. This then minimises the need for mechanical and electrical building systems and more complex solutions as shown in the hierarchy figure above. A fabric first approach should be non-controversial, but the UK stock (even new builds) still fails to meet best practice for energy use. The average existing home has a space heating demand of approximately 130 kWh/m².year, and a typical new build consumes 85 kWh/m².year. On the other hand, a home built with fabric first principles such as Passivhaus or LETI exemplar consumes only 15 kWh/m².year.

A fabric first approach not only minimises the amount of operational energy needed to run the building, but may also create a host of knock-on benefits including:

- reduced system size and cost
- greater comfort and building performance
- improved health outcomes
- reducing operating costs and fuel poverty
- reducing the need for new energy infrastructure

It is also the most future-proof way to improve energy security and mitigate against future energy price shocks.

Designing buildings that do not rely on fossil fuels is a challenge. Since the creation of the gas grid in the 1970s, the UK's infrastructure has evolved around the availability of cheap gas, and now over 85% of UK buildings rely on gas boilers for heating and hot water. There are also nearly 2 million homes and buildings in the UK that still rely on oil boilers. To create a net zero built environment, every single one of these fossil fuel boilers will need to be replaced by a low carbon alternative. There is a range of solutions available including heat pumps, heat networks, or direct electric heating.

There is a misconception among many building professionals that heat pumps always require extensive retrofits to the building fabric and other systems in order to be technically viable. Reducing demand through energy efficiency measures is always a good idea in its own right, but a costly deep retrofit should not be viewed as a prerequisite to heat pumps in all cases. Most buildings were designed with fossil fuel heating in mind, so some changes to the fabric and systems might be required in order to deliver comfort from a low carbon heating system. This could be relatively straightforward measures such as weatherproofing or resizing some heat emitters. In some cases, it will be preferable to carry out a deep retrofit that significantly reduces heat loss and minimises energy costs prior to switching heat sources. The most suitable combination of low carbon heat and energy efficiency measures is a design question that must be addressed on a building-by-building basis. No single low carbon heating technology will dominate the low carbon heating market the way that gas boilers have dominated the fossil fuel heating era.

NET ZERO BUILDING OPERATION

It is not enough to simply design buildings that are net zero in principle. They must also be operated in a manner that delivers a zero carbon performance throughout their lifetimes. This needs to include both effective design for operation, smooth handover from one building stage to the next, and an effective and proactive approach to building management and maintenance.

Efficient performance is important not only to ensure comfort and carbon objectives are met, but to do so in a way that minimises operational costs, particularly as utility costs continue to rise.

For a long time, the availability of cheap gas has allowed us to ignore a significant number of building performance issues. There is substantial case study evidence of buildings that have retrofitted low carbon heating to replace gas boilers and discovered a number of maintenance issues not directly linked to the gas boiler such as circulation pumps that also required replacing in order to facilitate the low carbon heat transition.

Switching from gas to low carbon heating is going to require a far more nuanced understanding of how buildings operate. A number of tools are available to support this, including BREEAM and LEED. While these can be useful, they must be carefully implemented to avoid giving undue credence to green design features that then go underutilised in operation. Schemes such as the Well Building Standard and NABERS are increasingly including performance related metrics, but can be costly and time consuming. Frameworks such as BSRIA's Soft Landings (BG 54/2018[5]) have been a vital tool in the past and will be extremely important in creating a chain of information that can be utilised by a range of stakeholders to maintain buildings' zero carbon performance over time.

All building professionals should ensure that they are aware of the tools and analysis methods that can be used to verify building performance such as suitable benchmarks, degree days, or CUSUM analysis. Building managers and maintenance personnel should ensure that they have access to the information they need to make informed decisions about their buildings.

NET ZERO SYSTEMS

The transition to net zero is going to force building professionals to increasingly think of buildings not simply as standalone items, but rather as components within an energy system.

Heating and transportation account for two thirds of the UK's energy use. At present, these are both largely served by separate fossil fuel energy vectors – gas and petroleum that will need to be completely phased out over the coming decades. The electricity grid will need to expand to meet a significant portion of these loads. The Future Energy Scenarios report[6] predicts both annual and peak electricity demand will approximately double by 2050. This means that there will be increasing competition for every single kWh on the electricity grid.

How and where this capacity is added will be a subtle and expensive infrastructure decision. There is the cost of adding the capacity to the grid mostly through renewables and interconnectors, and then there is the cost of local reinforcement to constrained assets such as substations and electrical cables. Many building professionals already cite a lack of local electrical capacity as a prohibitive barrier in creating buildings that don't rely on gas. Every project that defaults to gas due to constraints on the local electricity network is one more project that must be retrofitted away from gas later, likely at even greater expense.

There are a number of options for decarbonising heat and the most suitable and cost-effective solutions will vary by building. The solutions favoured in most scenarios are combinations of heat pumps, heat networks, and direct electric heating, complemented by ideas like hybrid combination systems or biofuels in some areas. In most cases, regardless of the end use technology, much of UK heat demand will likely rely on low carbon electricity as a fuel source.

This has important implications for building designers. The price of gas does not vary throughout the day. However, the intermittency of wind and solar causes the supply (and hence the price) of electricity to vary throughout the day and across seasons. This is both a challenge and an opportunity for building design. We are already seeing buildings use assets such as supermarket chillers to create a flexible demand and generate revenue through flexibility services to the grid.

At the system level, flexibility and storage helps avoid the need for costly and more carbon intensive solutions to address peaks in demand. With buildings, heat, and transport all competing for the same electrons, the capacity for a building to offer flexibility in its demand will have a significant impact on its ability to operate cost effectively. The figure overleaf illustrates how we will shift from the centralised distribution of energy resources, towards buildings as flexible assets in a distributed energy system.

The role of heat networks in the UK is also set to increase. The UK has struggled to scale up the use of heat networks, largely because cheap gas boilers always presented a challenging counterfactual. Now as gas is being phased out, the option of linking to a heat network might be more suitable than a local heating solution for many buildings. Where suitable, an ambient temperature fifth generation network can offer a way to increase performance and flexibility, decreasing the burden on the grid.

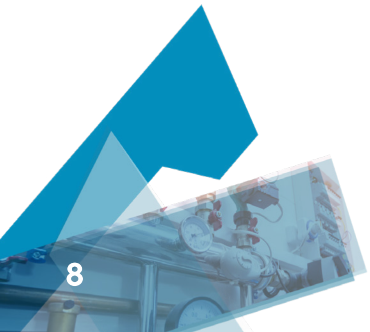
In summary, designs will consider how buildings can compete or collaborate with heating and transportation demands on the grid, design options for storage and grid flexibility, and the availability of heat networks including fifth generation systems. For these reasons, the net zero transition will increasingly make us think about buildings not as standalone designs, but rather as components in a net zero infrastructure system.

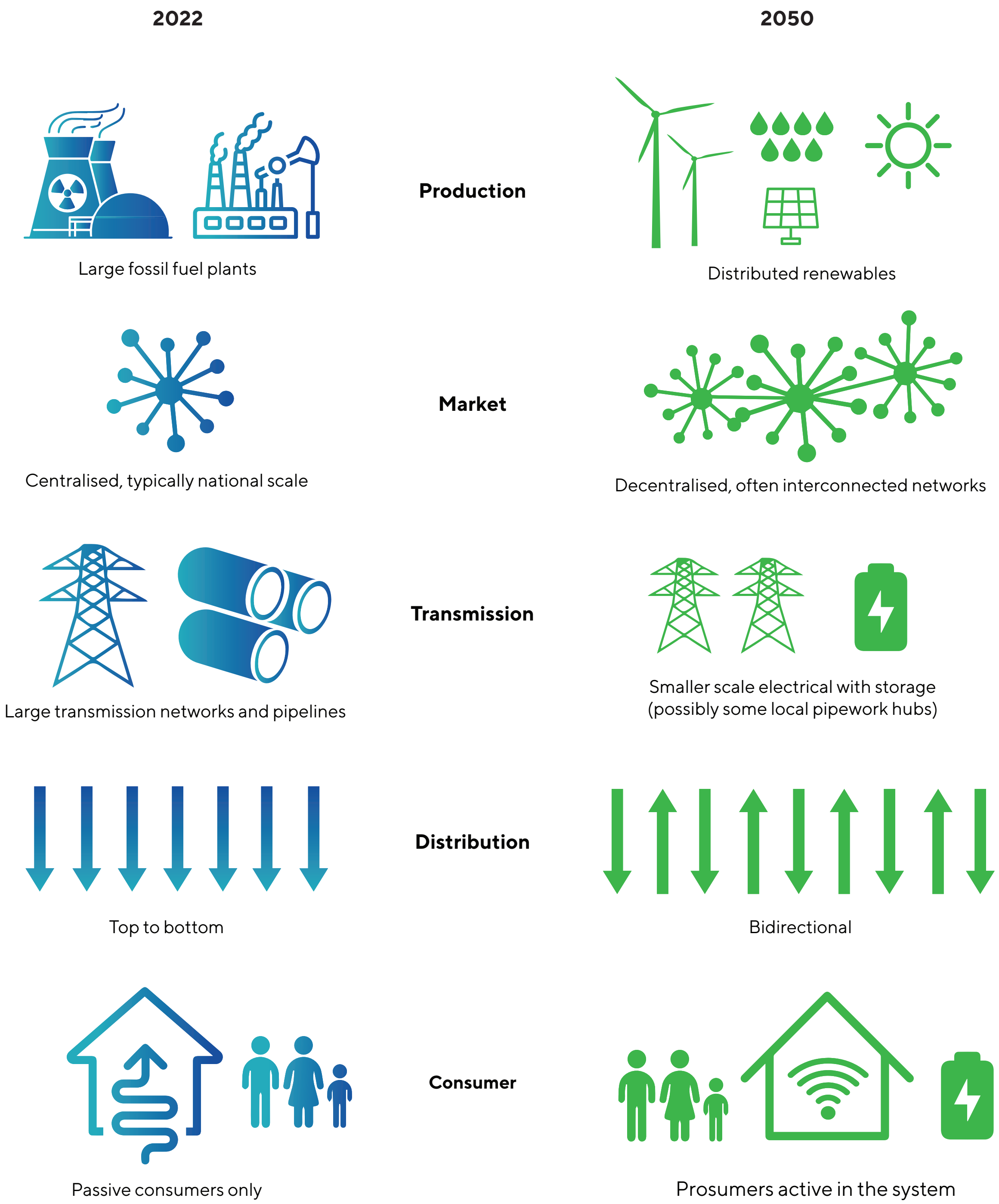
FUTURE OF THE GAS GRID AND HYDROGEN

One of the most critical questions facing the UK's net zero transition is the phase out of the gas grid.

The discovery of cheap and plentiful North Sea gas was the catalyst for the establishment of a national gas grid, which has now benefited from a half century of investment to become the backbone of the UK's current energy system. The gas grid is currently five times the size of the entire electricity grid. It delivers an astounding 100 GW of flexible capacity each morning as the UK wakes up and turns on their heating and hot water. To deliver a net zero future, the gas grid in its current form must end as soon as possible, but there are no viable, scalable alternatives to replace it.

A combination of reductions in energy demand, improvements in efficiency and added electrical capacity will all play a role, but will not cover the hole left by the end of gas. For these reasons, the UK has so far been reluctant to announce a definite timetable for the phase out of the gas grid.





Future changes to electricity networks

Some measures have been announced such as the Committee on Climate Change's recommendation that no new homes should be connected to the gas grid from 2025[7]. However, only around 150,000 new homes are built in the UK per year, so this will have a small impact next to the 1.6 million gas boilers that are still retrofitted into existing homes each year. It is likely that the UK government will make a formal decision about the future of the gas grid in the next five years, and that this will call for a phase out of the gas grid in the mid-2030s.

In the meantime, it is incumbent upon building professionals to expedite the phase out of gas by avoiding specifying gas boilers wherever possible. Many organisations in the UK are now signing pledges not to accept any design jobs that require specifying gas boilers.

One of the options to replace gas that receives a lot of attention in the media is hydrogen. It is very likely that hydrogen will play a role in the UK's net zero future, but the nature and scale of that role is highly uncertain.

Hydrogen can be burned in much the same way as gas, but without producing carbon emissions at the point of combustion. It is in principle a zero carbon fuel source, but that significantly depends on the source of the hydrogen to begin with. There are two primary methods of creating hydrogen: electrolysis and steam methane reformation.

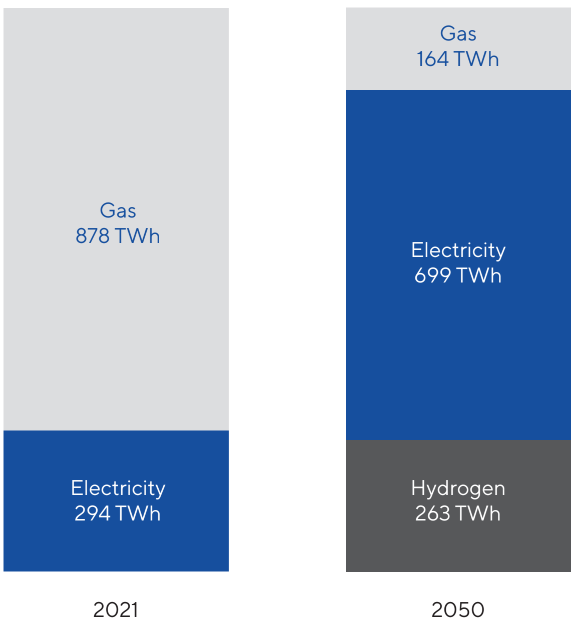
The electrolysis method of producing hydrogen uses electricity to separate hydrogen molecules from water and store them as a usable fuel. This can be zero carbon if it uses a renewable electricity source. However, the cost for this is typically high, and has approximately half the round-trip efficiency of other storage options such as batteries and pumped hydro. It could be a viable storage medium for excess electricity at off-peak times if there are no other suitable storage options.

Steam methane reformation uses a chemical process to remove the hydrogen from a natural gas molecule. This can only be considered zero carbon if the remaining CO_2 from the natural gas is sequestered at the source. Steam methane reformation is significantly lower in cost than electrolysis, and makes up around 95% of the current global market for hydrogen. Companies typically vent the CO_2 to the atmosphere, as there are no requirements to sequester it.

The fossil fuel industry are clear advocates of maximising the use of hydrogen in future energy systems for obvious reasons. They support replacing natural gas with hydrogen in the existing gas pipework. In principle, hydrogen could serve any end use currently met by gas including domestic heating and hot water, electricity production, and industrial use.

A significant number of studies have now shown that hydrogen is likely among the least cost-effective options for decarbonising building heating. It is also subject to considerable cost and safety concerns that will take well over a decade to resolve. Hydrogen will likely serve an important role for isolated industrial uses or local hubs, but will not replace gas at scale. The National Grid Future Energy Scenarios report[6] estimates that the hydrogen economy in 2050 will be comparable in scale to the electricity used today, which is a fraction of the size of the current gas grid. This is illustrated in the figure below.

Discussions about the future of UK heating often invoke the false dichotomy of heat pumps versus hydrogen. Many argue that decisions on low carbon heating should be delayed until the future of the gas grid is decided. It is important that as building professionals we encourage more urgent action on decarbonising heat in a technology neutral way. The question we should advance is not about heat pumps versus hydrogen, but rather which low carbon heating solution for a given building is the best alternative to gas that we can implement right now.

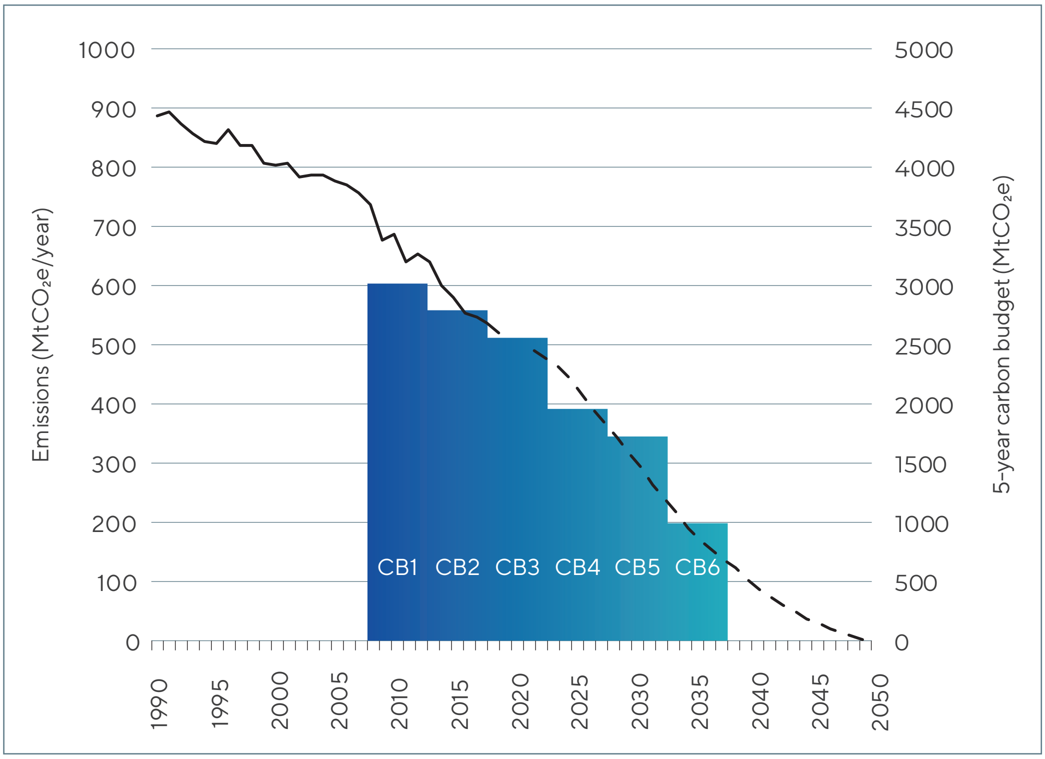


UK energy use by fuel type in 2021 and 2050 prediction (average of net zero compliant scenarios in Future Energy Scenarios[6])

NET ZERO LEGISLATION AND DRIVERS FOR CHANGE

The drivers for change in the net zero transition are complex. In short, the UK government has laudable goals but a lack of actionable policies to back them up. The legislative frameworks in place are effective, but slow moving, and in many areas of the built environment the commercial demand for net zero now exceeds the regulatory requirements. This dynamic is important to understand as it sets a clear opportunity for industry leadership and the potential for building services professionals to be drivers for change in their own right.

The core legislation behind the UK's net zero strategy is the 2008 Climate Change Act. This created the Committee on Climate Change, whose role is to set carbon budgets in five-year intervals, and carry out analyses and recommendations on the options for meeting these budgets. The Government decides whether to adopt these carbon budgets into law, and then sets out its own policies to meet them, sometimes differing significantly from the CCC recommendations.



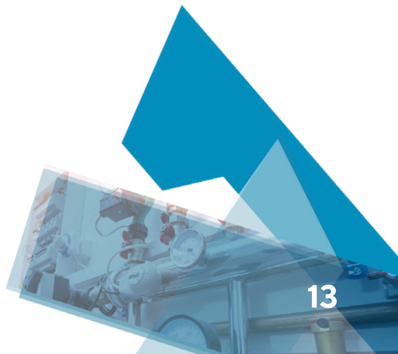
UK Committee on Climate Change carbon budgets with historic (solid line) and future emissions (dashed line).

The Government recently adopted the sixth carbon budget[8]. The first four budgets were met relatively easily, mostly by phasing out coal. However, these quick wins are mostly behind us, and meeting the fifth and sixth budgets will require much more dedicated efforts across a range of sectors. Some of these efforts are on track but in others, notably buildings, there are critical policy gaps that threaten to undermine the UK's net zero goals (see figure on previous page).

The UK has a slow but credible timeline towards decarbonising new builds; however, new builds represent only 10% of the problem. The remaining 90% of the net zero built environment must come from retrofitting existing buildings. The UK must retrofit one million homes per year and the retrofit industry will need to grow by at least a factor of 10 to achieve this. Here there is no credible strategy nor any announced policies that will come close to addressing the gap.

There is more action at the local level, with 75% of local authorities now declaring climate emergencies. Most have set goals to be carbon neutral by 2030 for large portions of their economies, a full 20 years ahead of the national target. Many private sector organisations have set similar targets. Major firms in the property sector have announced timelines to have net zero portfolios by 2030.

Companies do this where they see a market opportunity, so this fact should be a signal that stronger policy action is needed. There is a tremendous potential for building professionals to answer this call and fill this leadership vacuum. If demand for net zero buildings exceeds supply it is incumbent on us to drive net zero solutions at every opportunity and meet this demand.



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