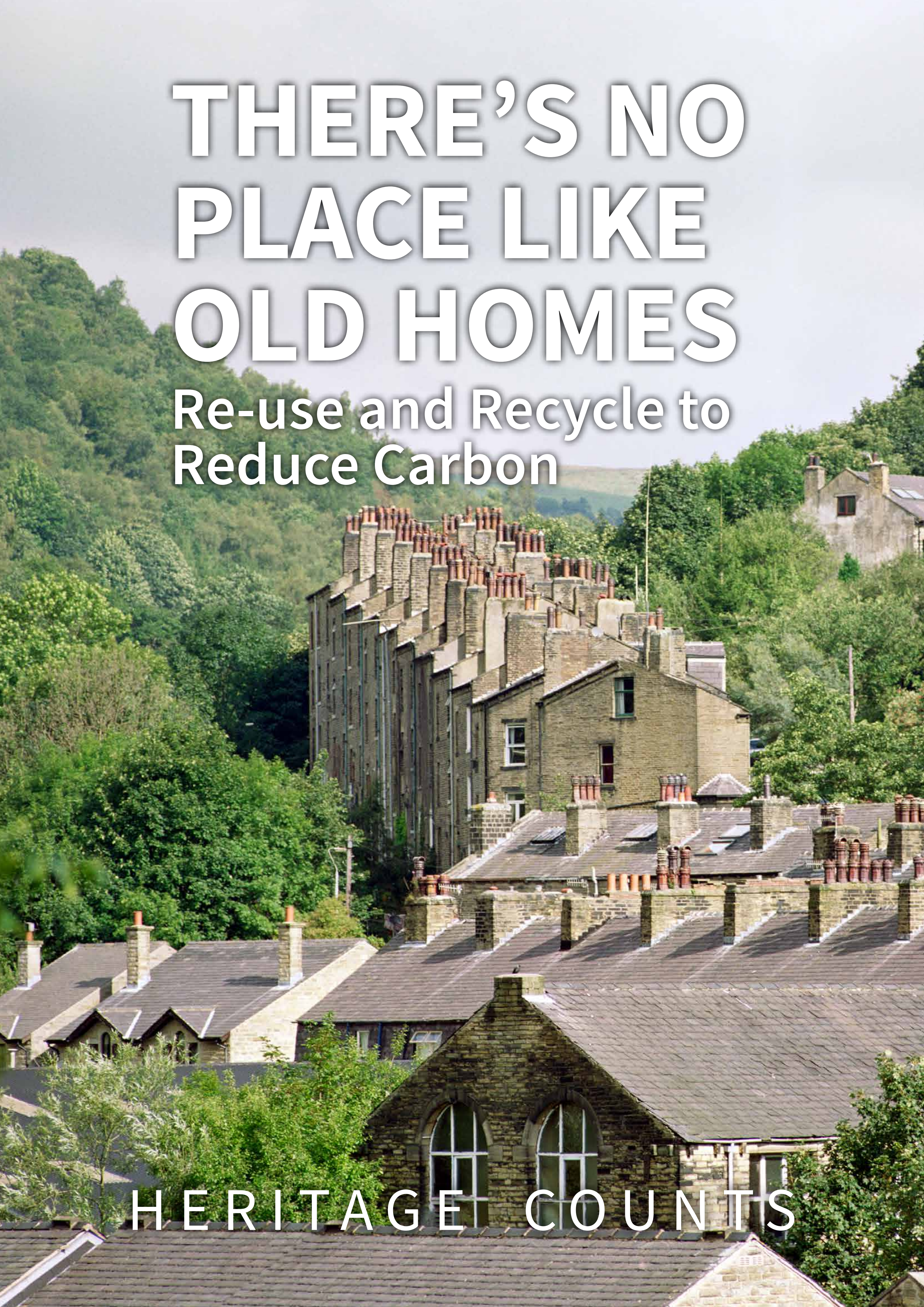
THERE'S NO PLACE LIKE OLD HOMES

Re-use and Recycle to Reduce Carbon



HERITAGE COUNTS

Early morning view from Mam Tor looking down onto Castleton, Peak District, Derbyshire.

Foreword from Sir Laurie Magnus, Chairman of Historic England

I am delighted to introduce this important research that Historic England has commissioned on behalf of the Historic Environment Forum as part of its Heritage Counts series.

Our sector has, for many years, been banging the drum for the historic environment to be recognised - not as a fossil of past times - but as a vital resource for the future. The research reported here demonstrates this more starkly than ever, particularly with climate change being recognised as the biggest challenge facing us today. While the threat it poses to our cherished historic environment is substantial, there are multiple ways in which historic structures can create opportunities for a more sustainable way of living. Huge amounts of carbon are locked up in existing historic buildings. Continuing to use and re-use these assets can reduce the need for new carbon-generating construction activities, thereby reducing the need for new material extraction and reducing waste production.

Our built environment is a major source of greenhouse gas emissions – the third biggest in most assessments. It is therefore exciting to see that this year's Heritage Counts research shows that we can dramatically reduce carbon in existing buildings through retrofit, refurbishment and, very importantly, through regular repair and maintenance. By extending the life of our cherished historic assets, we can materially reduce the need for high carbon consuming activities and materials.

The Heritage Counts research also demonstrates that up to one third of the total carbon emitted from a new home is released during the construction and demolition process. This locked up, or 'embodied', carbon is a very important source of emissions that is often overlooked. Failing to account for the full carbon cost of demolition and construction of a building, as well as the energy used during its life, is false accounting. The construction sector needs to address this accounting gap and we in the historic environment sector can and must help them to do so.

Our historic environment offers practical and effective solutions to the real and present danger posed by climate change. Our historic assets are not only a great tangible legacy of our past: they also have a vital role to play in our lives today by making a crucial contribution to a more sustainable future. It is no understatement to say that, in general, the greenest buildings are the ones that are already built.

Foreword from Ben Cowell, Chairman of Historic Environment Forum

Heritage Counts is an annual publication produced by Historic England on behalf of the Historic Environment Forum (HEF). The HEF brings together all of the leading organisations with varied responsibilities for the nation's heritage. This year, Heritage Counts addresses the most important issue of our day: decarbonising our economy in order to combat the warming of our climate.

Too often, the historic environment is cast as a problem rather than a solution. The complex range of regulations that comprise the heritage protection system are sometimes viewed as a barrier to change, rather than an enabler of the sorts of progressive adjustments that will need to be made if we are to avoid overheating the planet.

This characterisation is unfair. The HEF continues to pursue an important programme of investigation looking into improvements that might be made to the heritage protection regime. And as this year's Heritage Counts shows, historic assets are an intrinsic part of a more carbon-friendly future.

Most of us live in the past. Nearly two thirds of our housing stock is at least half a century old. It is relatively unusual to be living in a recently constructed home: dwellings constructed since 2000 amount to a mere 12 per cent of the total. As this year's Heritage Counts shows, the number of historic houses in fact increases annually, as older buildings are repurposed as modern homes. Astonishingly, the number of pre-1919 houses has grown by more than 60,000 in the last eight years alone.

Previous Heritage Counts research has demonstrated the popular preference for living in houses with period quality and character. This year's research suggests that the appeal of the past can extend far beyond aesthetics. Simply put, re-using old buildings is an everyday form of carbon capture and storage that each of us promotes every time we choose to enhance or adapt an existing house rather than buy off-plan from a new development.

New developments matter of course, given our changing demography. But new development needs to work within the grain of the existing landscape. Reduce, reuse and recycle are imperatives that apply as much to housing as to any other aspect of our busy 21st century lives.

The member organisations of the Historic Environment Forum represent the diverse constituent parts of the heritage sector, from archaeologists to building conservation experts, from the secular to the religious, and from the urban to the rural. All have different remits and priorities, yet all are united with one clear message: that looking after the past is essential to our future. The critically important findings in this year's Heritage Counts make that assertion all the more compelling.

My final task is to thank John Sell, who chaired the HEF for 20 years before stepping down in 2019. We dedicate this volume to him, in gratitude for all he has done for the historic environment in England.


Aerial view of earthworks in the landscape. © Historic England Archive

Executive Summary

Research Context

Climate change is the biggest challenge facing our planet today

The world is 0.8°C warmer today than it was a century ago with the 10 warmest years in the UK's history occurring in since 1990 (BEIS, 2019). In May 2019, the UK became the first Country to declare a climate emergency (Parliament, 2019). The UK government went on to make a legally binding commitment to becoming carbon[1] neutral by 2050 (BEIS, 2019). To achieve this, extensive changes across society and the economy are urgently required.

Buildings are the third largest carbon emitting sector in the UK today (CCC, 2019)

Buildings in England have a larger carbon footprint than the carbon emissions from the whole of Scotland and Northern Ireland combined (Historic England, CCC, 2019). According to the UK Green Construction Board, when construction, transportation and buildings' electricity use are taken into account, the built environment sector is responsible for up to 42% of total greenhouse gas (GHG) emissions in the UK (UKGBC). However, little effective action has been taken to reduce carbon in the built environment to date – **buildings are not on track to meet the UK's 2050 net zero targets** (CCC, 2019). The UK government's independent advisory body, the Committee on Climate Change, conclude that there is an acute need to substantially step up action to cut emissions from buildings (CCC, 2019).

The built historic environment is a vital part of our built environment and a continuous source of new homes

In 2018, 5.1m homes, or 21% of all homes in England, were over 100 years old (VOA, 2019). These historic properties, traditionally constructed before 1919, generally of solid wall (i.e. not cavity wall) or solid timber frame construction, are primarily made up of terraced homes.

In 2018, there were 60,400 more pre-1919 homes than there were 8 years prior, as a result of the conversion of existing historic homes into multiple dwellings and through the conversion of non-domestic historic buildings into homes. In the same 8 years however, we have lost over 70,000 homes in England through demolition (MHCLG, 2019) – most of these were modern buildings that did not survived the test of time.

The Heritage Counts Research

In 2019, Historic England commissioned a scoping study, on behalf of the Historic Environment Forum, from Carrig Conservation International to assess the "whole life" carbon of historic buildings (Carrig, 2019). Buildings contribute to global warming over their whole lives: when we build, maintain, use and demolish or re-purpose them. However, the focus of carbon reduction strategies to date, has largely concentrated on emissions that occur when buildings are used – known as operational emissions. Meanwhile the carbon emitted during construction, maintenance and demolition or re-use – known as the embodied carbon emissions of buildings – remain largely neglected. A whole building approach measures carbon emitted at all stage of a building's lifespan and demonstrates the importance of embodied carbon emissions.

The Carrig study uses a whole life approach to estimate carbon emissions associated with two completed historic building refurbishment and retrofit projects – one in the East Midlands and one in London. Using standard models and software applied to actual data (emissions before and after refurbishment), the life cycle carbon emissions were estimated for a 60-year period and also compared to equivalent new buildings.

[1] Global warming is caused by greenhouse gases (GHGs) – the most common of which is carbon dioxide (CO_2) also referred to simply as "carbon". Although GHGs occur naturally, scientific evidence shows that human activity (industrialisation, deforestation, large scale agriculture) has generated record levels of GHG emission which are leading to global warming.

The findings

We can dramatically reduce carbon in the built historic environment

> *"We cannot meet our climate objectives without a major improvement in the existing built stock"*
>
> The Committee on Climate Change

New evidence for Heritage Counts shows that we can reduce the carbon emissions of historic buildings by over 60% by 2050 through refurbishment and retrofit. The UK's Committee on Climate Change has identified retrofitting existing homes as one of five priorities for government action (CCC, 2019). The Heritage Counts research also demonstrates that the speed at which carbon is reduced in buildings has a greater impact than the scale of retrofit showing that the sooner actions are taken the more effectively we can address carbon in buildings.

Embodied carbon is a significant source of carbon emissions that is largely overlooked

> *"Every tonne of carbon counts, wherever it is emitted."*
>
> The Committee on Climate Change

Buildings contribute to global warming over their whole lives and the Heritage Counts research confirms that if we do not count embodied carbon we underestimate the emissions of a new building by up to a third. If we are to meet the UK Parliament's legally binding commitment to become carbon neutral by 2050, then addressing the embodied carbon of the built environment must become a priority.

Recycle first to meet 2050 carbon targets

> *"The greenest building is the one that already exists"*
>
> Carl Elefante,
> former president of the American Institute of Architects

When a typical historic building – the Victorian Terrace- is sympathetically refurbished and retrofitted, it will emit less carbon by 2050 than a new building. But only if the whole life carbon of the building is considered.

Retrofit, refurbishment and conversion also generate embodied carbon emissions so the amount of materials used, the carbon content of materials and how retrofit is carried out need to be key considerations of any retrofit project.

Meeting 2050 net zero carbon targets

Use and re-use first

The Heritage Counts research shows that demolishing a historic building and replacing it with a new building can result in greater carbon emissions by 2050. If we reuse what is already here we can avoid carbon emissions. More research is needed to identify and quantify the opportunities for reuse of heritage assets.

Promote sympathetic retrofit

To achieve the level of benefit reported in the Heritage Counts research findings, retrofit measures must be sympathetically and responsibly implemented. Inappropriate retrofit measures can lead to unintended consequences and actually damage buildings. The heritage sector must continue to signpost and share the rigorous research, evidence and guidance that the sector has developed and contributed to over many years.

Empower members of the public to reduce carbon in their buildings

A whole building solution must focus on the users of buildings. How we use buildings impacts the amount of carbon emitted from buildings. While the Heritage Counts research focusses on standardised, expert led, refurbishment and retrofit, there are alternative, lower impact, everyday activities occupiers can undertake to reduce carbon emissions from buildings. The sector must invest in disseminating existing research and develop clear messages, easy to access and digest guides, expert advice and case studies to support the custodians of the built historic environment with their everyday decisions to reduce carbon in buildings.

Demand and enable longer lifespans for buildings

The longer a building and its component parts last, the less embodied carbon is expended over the life of the building. Repair and maintenance can reduce building obsolescence and increase the life spans of buildings. However, there are currently few incentives that encourage building repair and maintenance in the UK. The UK's VAT system imposes a 20% tax rate on repair, maintenance and refurbishing existing buildings, whilst new-build developments are VAT-free. Regulations state that for a development to qualify for zero rating *"any pre-existing building must have been demolished completely, all the way down to ground level"* (HMRC, 2019). Redressing the inequality between new and existing development in must become a priority. The taxation system must encourage retention, repair, maintenance and retrofit, if we are to meet our 2050 carbon targets.

More research and innovation to develop robust carbon accounting methods, data and solutions

The Carrig research has identified large data constraints that limit the predictive capacity of life cycle assessment models for historic buildings. The current methods used for carbon accounting hide the vast majority of carbon costs for construction and retrofit. The evidence on building lifespans, on the durability and energy intensity of building components and materials needs to be strengthened. For example, the assumptions used in the Heritage Counts study are in part based on modern buildings due to a lack of information on traditional building materials; yet we know that traditional building techniques and materials differ significantly in terms of durability and resilience.

More research is needed to improve underlying data and assumptions for life cycle assessment models, particularly for historic buildings, to more accurately understand the carbon cost of construction and retrofit decisions. There is currently a genuine need for a platform that brings together professional and industry bodies, policy makers, regulators and academics to research what works and what doesn't work for reducing carbon in buildings and to develop new innovative approaches for tackling carbon over the whole life of buildings.

The UK has declared a climate emergency which demands a new approach to managing change to the built environment. **We must prioritise our existing buildings** by making refurbishment and reuse of existing buildings worthwhile. **We must move towards a whole life carbon approach for buildings** otherwise we may meet carbon targets without actually reducing carbon emissions and in the process lose the war against climate change. A whole building approach will enable a more holistic and sustainable approach towards a low carbon future.

A sustainable approach also requires us to look beyond the buildings themselves and consider the wider context of our built environment. The reuse and recycling of historic buildings can reduce other negative environmental impacts such as waste production, resource depletion, water pollution, land-take, erosion and health impacts. There are also important social and economic impacts – historic buildings form a vital part of our nation's infrastructure providing homes, amenities, utilities and premises for businesses. They add to the unique character of places and play an important part in society, enhancing our wellbeing and quality of life. A truly sustainable future for our precious historic environment must take a balanced approach that considers their value of our historic environment society, the economy and to the environment.

1. Research Context

There is an urgent need to tackle carbon emissions

1.1

"Humanity has just 10 years to achieve a paradigm shift on greenhouse gas emissions"

John Gummer, chair of the Committee on Climate Change

- On 12 December 2015, the international community reached a landmark agreement, known as The Paris Agreement, within the United Nations Framework Convention on Climate Change (UNFCCC, 2015). The agreement aims to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris agreement was seen as a historic turning point for humankind (Guardian, 2015) providing a new course in the global climate effort (UNFCCC, 2015).
- The Committee on Climate Change (CCC) is an independent non-departmental, public body, advising the United Kingdom and devolved Governments and Parliaments on tackling and preparing for climate change. In June 2019, the CCC recommended that the UK Parliament sign into law an amendment to the Climate Change Act 2008, committing to achieving a zero carbon emission target by 2050 (CCC, 2019a). **The UK is the first of the G7 nations to make a legally binding commitment to becoming carbon neutral by 2050**. This means that the UK will deliver towards the Paris Agreement by reducing carbon emissions by at least 100% below 1990 levels by 2050 (CCC, 2019a).
- According to the Committee on Climate Change, reaching net-zero Greenhouse gas emissions **requires extensive changes across society and the economy**, with complete switchovers of several parts of the UK capital stock to low-carbon technologies (CCC, 2019a). Major infrastructure decisions need to be made in the near future and quickly implemented (CCC, 2019a). The public will need to be engaged in making the required changes.

1.2

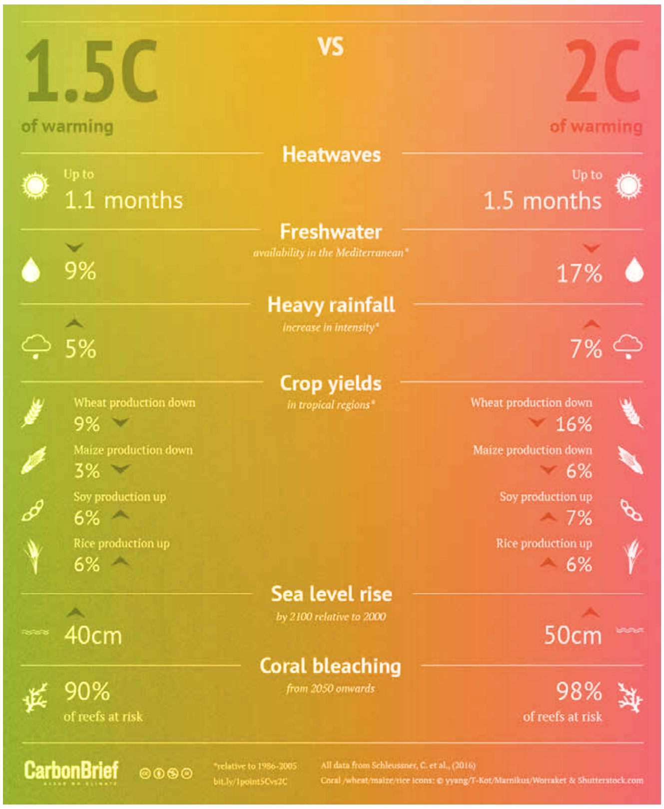
"Rapid, far-reaching and unprecedented changes in all aspects of society are required to respond to the global threat of climate change"

(IPCC, 2018)

- In 2018, the United Nations Intergovernmental Panel on Climate Change (IPCC) published a landmark report in which the science community called for urgent action to prevent further global warming (IPCC, 2018). In the report, experts warn that global warming **must be kept at a maximum of 1.5°C** beyond which the risks of drought, flood and extreme heat are significantly greater (IPCC, 2018).
- At the current rates of warming, global average temperatures will rise by 4 to 5°C above preindustrial levels by 2100 and **the world will reach the 1.5°C threshold between 2030 and 2052** (CCC, 2019a). This would lead to severe and widespread climate impacts.

Displayed outside Hull City Hall, this 75m long wind turbine blade is one of the largest single cast, hand-made objects in the world. © Historic England Archive

The comparative impact of exceeding the 1.5°C threshold



Source: Carbon Brief (2016), How do the impacts of 1.5°C of warming compare to 2C of warming?

A NOTE ON GREENHOUSE GASES AND CARBON

Global warming is caused by the emission of greenhouse gases (GHGs). The most common of these is carbon dioxide (CO_2 , typically abbreviated as simply 'carbon'), but there are many other gases that contribute to global warming, two of which include methane (CH_4) and nitrous oxide (N_2O). Each GHG has a different warming effect on the earth's atmosphere. In order to sum the total effect of all gases, each is converted into its equivalent CO_2 warming effect and all CO_2- equivalents (CO_2e) are then summed. (EPA) This report generally refers to carbon based on estimates of CO_2e.

GLOBAL WARMING – KEY FACTS

The average temperature in the most recent decade (2008 to 2017) was 0.8°C warmer than in the period from 1961 to 1990 (BEIS, 2019).

The ten warmest years in the UK have all occurred since 1990 (BEIS, 2019).

If global average temperatures rise by above 4°C, summer daily maximum temperatures in the UK could rise by 10°C by 2080 (Environment Agency, 2018).

England has recently experienced several extreme weather events. Heavy, prolonged rainfall, leading to significant floods in winter 2013 to 2014 and again in 2015 to 2016 (Environment Agency, 2018).

England experienced heatwave conditions in the summer of 2018, which was the joint hottest summer ever recorded in England, along with 2006, 2003 and 1976. By the 2040s, heatwaves like that of 2003 could be experienced every other year (Environment Agency, 2018).

New research suggests that if action is not taken to reduce emissions, UK sea levels could rise by up to 4 metres by 2300 (Environment Agency, 2018).

Approximately 1,200 hectares (ha) of internationally protected intertidal habitat and a further 500 ha of freshwater habitat will be lost due to coastal squeeze[2] over the next 5 to 10 years (Environment Agency, 2018).

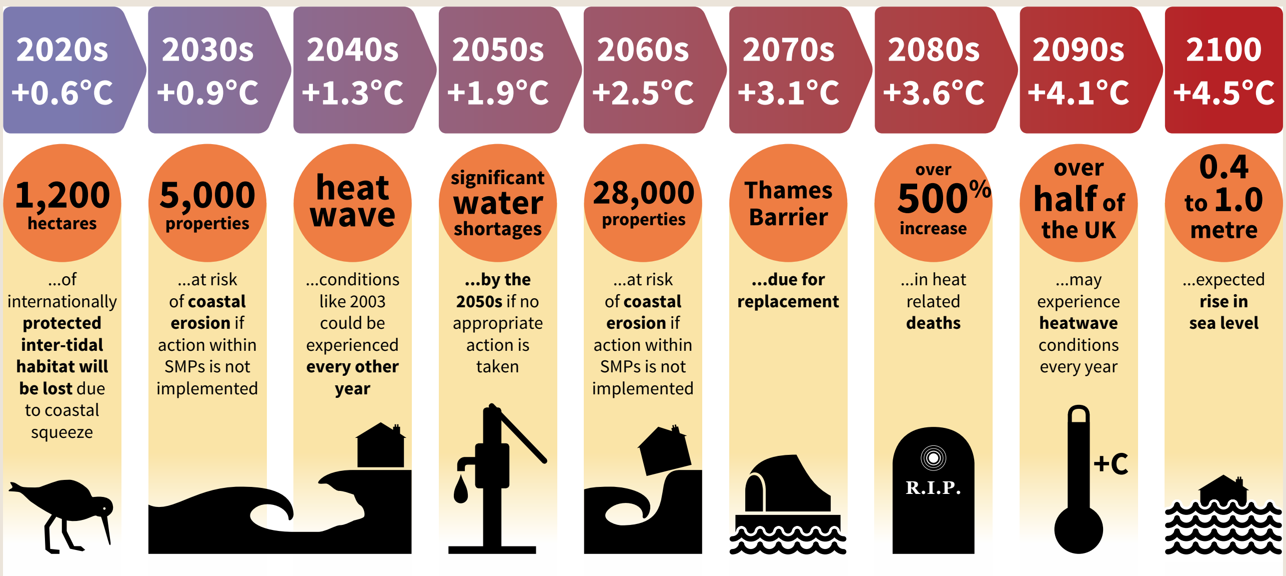
There are 240,000 homes and existing properties currently in high flood risk areas. Maintenance and repair costs are expected to rise by approximately 20% to 50% (Environment Agency, 2018).

The total area of agricultural land at risk of flooding in England is around 1.3 million ha, or 12% of the total (Environment Agency, 2018).

The electricity transmission and distribution network could experience an increase in the numbers of faults due to lightning, of up to 36%, by the 2080s (Environment Agency, 2018).

The UK greenhouse gas emissions statistics, estimate that the UK's net carbon dioxide emissions were 364.1 million tonnes (Mt) in 2018, 2.4% lower than in 2017. Greenhouse gas emissions have fallen by 40% since 1990 (BEIS, 2019).

Future impacts



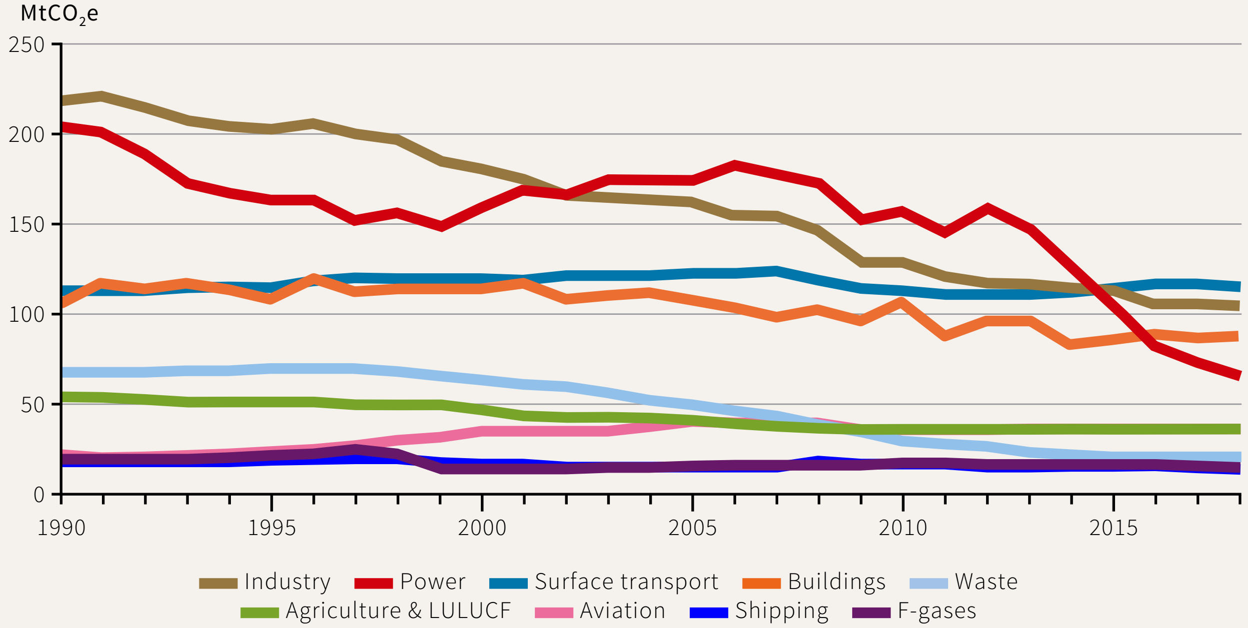
Global temperature increases from A1F1 scenario (high emissions). IPCC. (2013). Annex II. Climate System Scenario Tables available at: http://www.ipcc.ch/report/ar5/wg1/

[2] Defined as intertidal habitat loss which arises due to the high water mark being fixed by a defence and the low water mark migrating landwards in response to sea level rise.

1.3 The built environment is one of the largest carbon polluters

- Buildings are today the third largest greenhouse gas (GHG) emitting sector in the UK after surface transport (largest polluting sector in the UK today) and industry (CCC, 2019b).

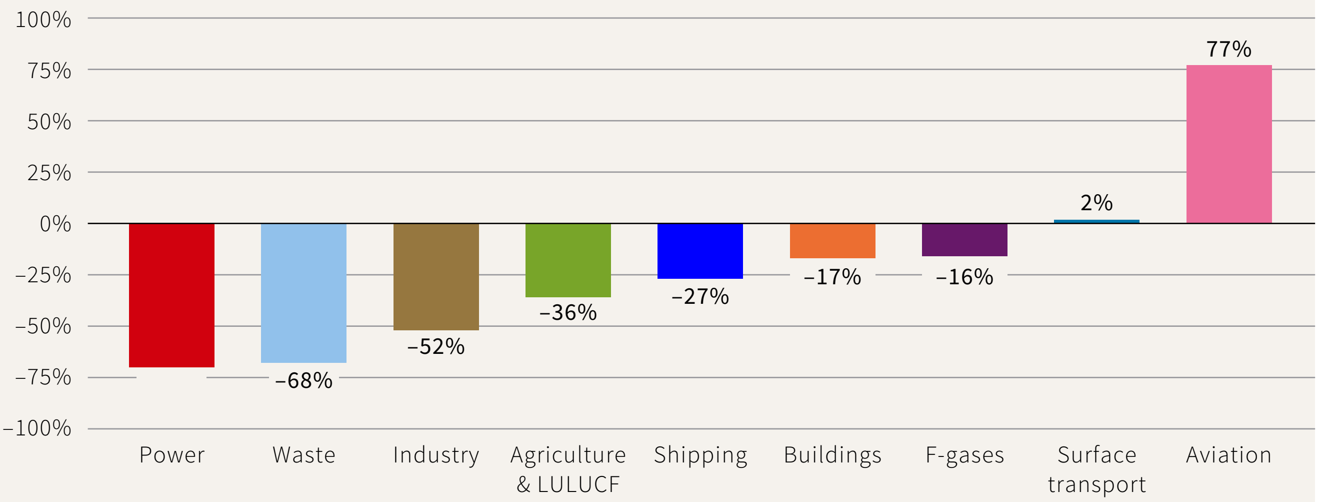
Trends in greenhouse gas emissions, UK, by sector (1990-2018)



Source: CCC, 2019b

- Direct GHG emissions from buildings have reduced by 17% since 1990 (CCC, 2019b). However, the pace of emission reduction in buildings is significantly below that of other sectors. Progress to date has almost entirely been driven by reductions in the power sector. In fact, buildings had higher emission levels in 2018 than in 2015 and emissions actually increased by 3% in between 2013 and 2018 (CCC, 2019b). But when building emissions are adjusted to consider lower winter temperatures, in particular the extreme cold weather in February 2018, the result is a 1% fall in emissions between 2013 and 2018 (CCC, 2019b).

Change in UK greenhouse gas emissions, UK, by sector (1990-2018)



Source: CCC, 2019b

A NOTE ON HOW EMISSIONS FROM BUILDINGS ARE MEASURED

Direct greenhouse gas (GHG) emissions from buildings accounted for 18% of the UK's total emissions in 2018 and 17% in 2014 (**CCC, 2019**b, **CCC, 2014**). Estimates based on 2014 data show that when electricity emissions for buildings are included, GHG emissions from buildings accounted for 34% of all UK emissions in 2014 (**CCC, 2014**). This does not however include emissions relating to construction, which are reported separately as part of industry sector's emissions in the CCC estimates.

According to the UK Green Building Council **the built environment contributes 42% of the UK's total carbon footprint**. (**UKGBC**). This estimate of emissions includes the direct emissions from buildings (17%), plus the embodied emissions from buildings through new construction (6%), plus electricity grid emissions (5%) and finally it also includes the emissions generated from transport (14%).

Overall the UKGBC estimates of emissions are a more comprehensive cover of the emissions from the built environment, which includes the direct, indirect and embodied emissions.

- The Committee on Climate Change concludes **"There is an acute need for a substantial step up action to cut emissions in buildings" (CCC, 2019b).**

Ferry Bridge power station, West Yorkshire. Houses in the foreground have been retrofitted with solar panels.

CARBON AND THE BUILT ENVIRONMENT – KEY FACTS

The construction of new buildings emits 48 mega-tonnes of carbon dioxide (CO_2) in the UK each year – that's equal to the total emissions for the whole of Scotland (UKGBC, CCC, 2019b).

The construction industry is a voracious guzzler of resources – grabbing 55% of all the materials that are used to produce goods in the economy each year (BREEAM, 2014). Most of these materials are finite and cannot be renewed.

Aside from oil and gas used for energy, more than 90% of minerals extracted in the UK are used to supply the construction industry (BGS, 2017).

Construction, demolition and excavation (CD&E; including dredging) generated around three fifths (61%) of total UK waste in 2016 (Defra, 2019).

London's existing domestic buildings contribute 36 per cent of the region's carbon dioxide emissions alone (GLA).

Evidence from the insurance sector for example, demonstrates that insurance pay-outs (generally referred to as 'losses') arising from natural catastrophes are increasing:

- The extreme freeze that hit the UK early in 2018 resulted in insurers paying a record amount for burst pipes - £194million in a three month period.

Craftspeople attending a two-day Repair and Maintenance course. © Historic England Archive

- 2018's extreme heat wave led to more than 10,000 households needing to claim for damage caused by subsidence, at a cost of more than £64million (ABI).

Flooding can have a significant impact on mental health. One study found that one fifth of people who have experienced a flood were suffering from depression one year after the flood, over a quarter from anxiety and over a third were affected by post-traumatic stress disorder (PTSD) (Mason, 2009).

The scale of retrofit in the short to medium term is enormous: according to Chris Stark, Chief Executive of the Committee on Climate Change, with 30 million homes and 30 years to decarbonise, "simple arithmetic" suggests we need to "decarbonise" one million homes every year, starting now (BBC, 2019).

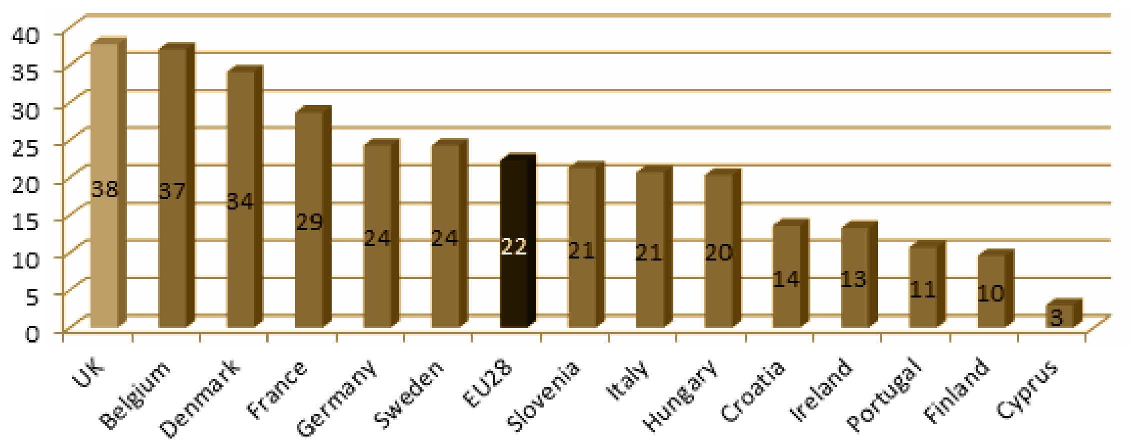
1.4 Historic properties form a vital and unique part of our built environment

- The UK has the oldest housing stock in Europe (EU 28), with 38% of the UKs homes dating from before 1946, compared to 29% in France, 20% in Italy, 13% in Ireland and just 3% in Cyprus (BRE, 2016). In fact, 21% of England's residential stock is now over 100 years old – there were over 5.1m pre-1919 dwellings in the UK in 2018 (VOA, 2018).
- Research by Whitman et. al. (2016) found that terraced housing is the dominant pre-1919 domestic typology accounting for over 50% of pre-1919 dwellings. These houses are also the largest group in a state of disrepair (Whitman et. al., 2016).
- **It is always assumed that new homes are only provided by new buildings. This is in fact not the case. There are more pre-1919 homes today than there were eight years ago.** The number of pre-1919 dwellings in England has grown and continues to grow – there were 60,400 more pre-1919 dwellings in 2018 compared to 2012 (VOA, 2018). On first glance this evidence appears counterintuitive, however it is through the conversion of existing historic homes into multiple dwellings and through the conversion of non-domestic historic assets into homes that our historic buildings continue to give.
- The location of new pre-1919 dwellings corresponds with historic towns and cities such as Brighton, Norwich and Bristol where larger homes are being subdivided into flats and smaller dwellings. Other locations include former industrial cities such as Birmingham, Liverpool and Manchester where ex-industrial warehouses, factories and mills are being converted into multiple dwellings.

WHAT IS THE SIGNIFICANCE OF PRE-1919?

Traditional construction differs significantly from modern construction. Traditional buildings built before 1919 are generally of solid wall (i.e. not cavity wall) or solid timber frame construction. Most modern buildings depend on impermeable barriers to control the movement of moisture and air through the building fabric. In contrast, traditional forms of building construction take up moisture from their surroundings and release it according to environmental conditions. Traditional construction tends to 'buffer' moisture and heat which can help even out fluctuations in humidity and temperature.

Pre 1946 homes, EU 28 (% of total residential stock)



Source: BRE, 2016

The historic environment is adaptable and is a continuous source of new homes

No. of pre 1919 dwellings	2012	2018	Net change
	5.05m (22%)	5.1m (21%)	+60,390

Source: VOA, 2018

Historic buildings are an important source of new homes, meeting society's ever changing and evolving needs.

A traditionally built cottage in Gloucestershire. Traditional buildings are often constructed from locally sourced materials, suited to local environmental conditions, and constructed using local labour. © Historic England Archive

DYNAMIC TISSUE TYPES AND PLOT SPRAWL

Unpublished PhD notes, Polly Hudson, UCL. October 2019

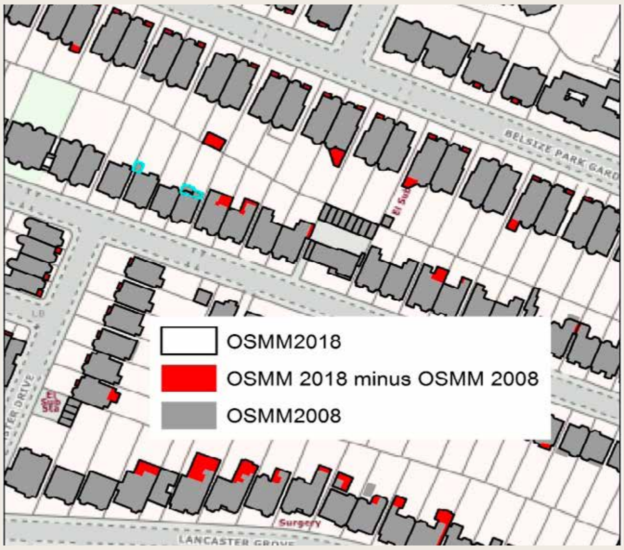
"My research looks to identify rules of dynamic behaviour in the building stock, able to be used in advanced computational models, to predict vulnerability, adaptability or resilience to demolition. Information on building age and building lifespans is critical to this process. Dynamic rules are particularly important in urban metabolism models to predict energy and waste flows, and in What if? Planning scenario models designed to identify risk and optimise systems at local and city scale.

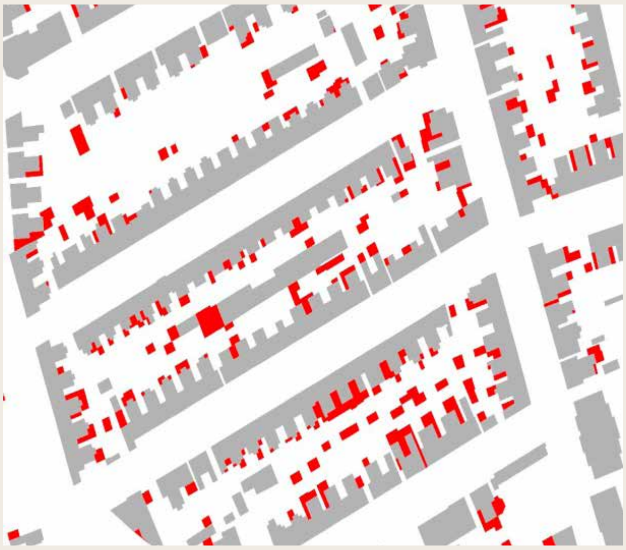
An element of my research assesses percentage increase in footprint area between 2008 and 2018, within residential plots, using four randomly selected samples in Greater London.

Findings show how rapidly and efficiently terraced areas accommodate new extension, and how incremental development is a key factor in its longevity and resilience.

The findings also illustrate the speed of plot sprawl occurring, with entire street patterns discernible through new extensions from the last decade alone. More detailed analysis of the capacity to adapt within plots/parcels (externally, internally or splitting from house to flats and back), is now needed as the case for building reuse grows.

Incremental development is also studied, within land parcels, using **building age diversity**. The hypothesis that age diversity indicates potential adaptability and thus resilience to demolition is tested for a range of ownership and land use types. The results indicate that sites of current social housing parcels, characterised by homogeneity of age, were particularly vulnerable to repeat demolitions when analysed over 130 years. Sample parcels representing public institutions such as museums, universities and law courts were found to be often characterised by age diversity, having developed incrementally to optimise existing systems."





Capturing new extension (in red) between 2008-2018. (Close up and expanded view). © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900.

KEY

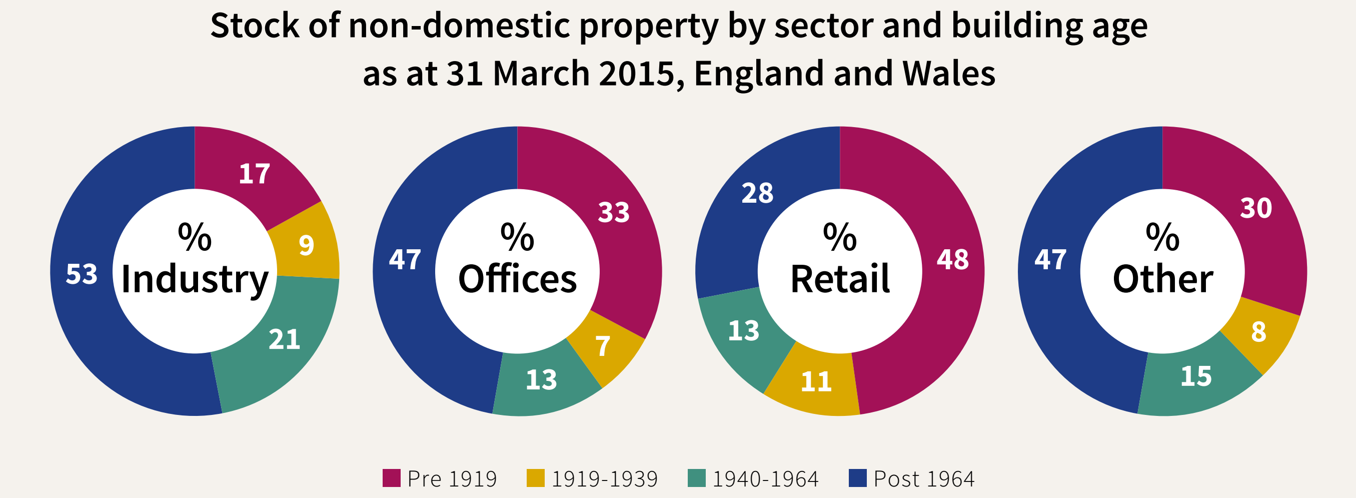
– The area coloured grey defines the footprint of a building in 2008.

– The red polygons represent the extension to the building's footprint between 2008 and 2018.

– Polygons highlighted in turquoise represent examples of full/partial footprints demolished between 2008 and 2018.

Evidence is largely limited to domestic historic property

- While data on the historic residential stock is readily available in the UK, the data on non-domestic stock held by the Valuation Office Agency (VOA) remains elusive. In 2016, the VOA provided a Historic England funded research project (Whitman et al, 2016) with data on non-domestic units for England and Wales. This data shows that 33% of all offices in England and Wales were built pre-1919, as were 48% of all retail buildings and 17% of industrial buildings. These statistics demonstrate the importance of historic properties for the economy, providing much needed workspaces for business up and down the country.

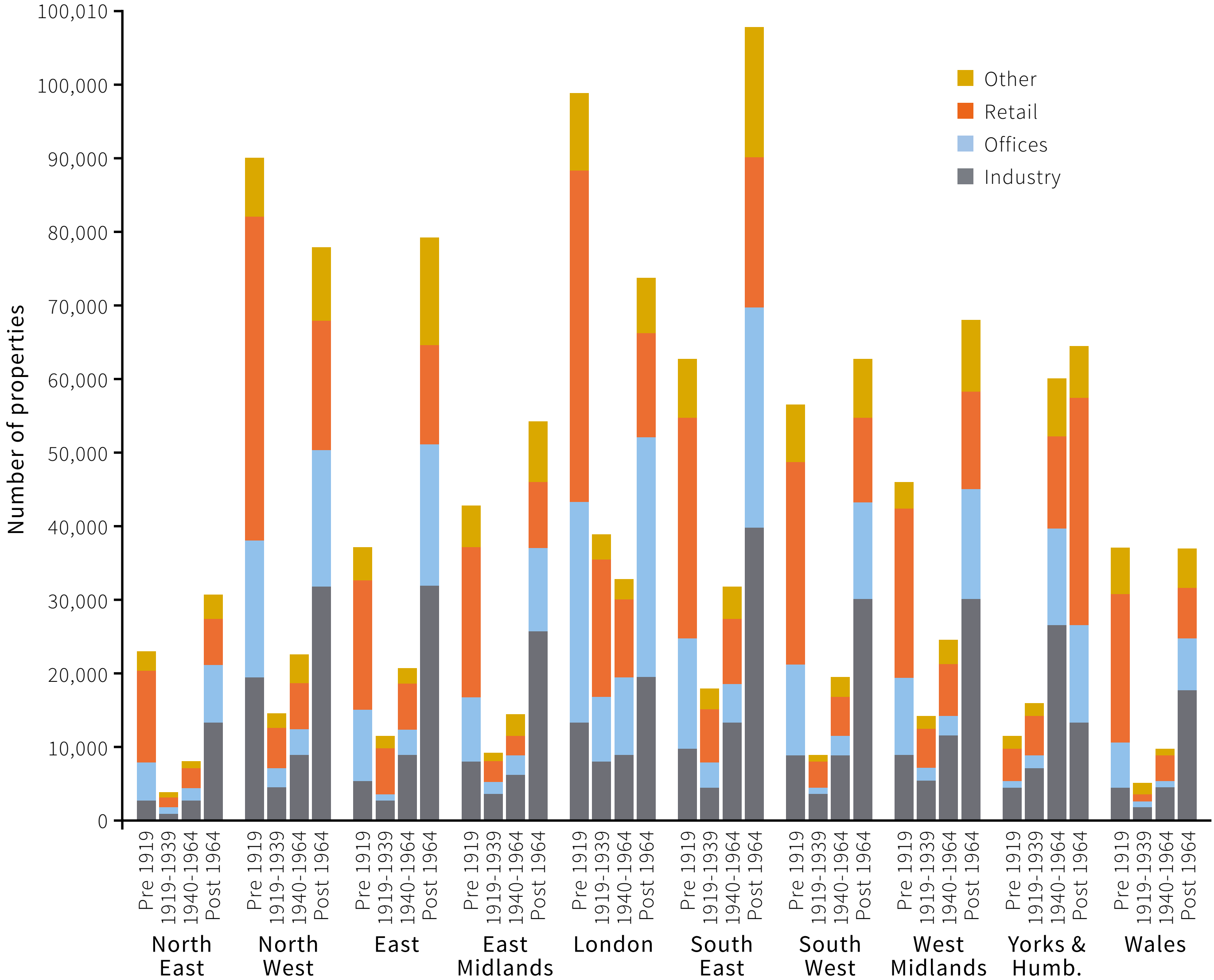


Source: Whitman et al, 2016

A row of terraced houses in the Old Kent Road area of Southwark, Greater London. © Historic England Archive

- The non-domestic pre-1919 building stock is unevenly distributed across the country, varying from region to region. In the North West and London the pre-1919 building stock outweigh their post-1964 counterparts, whereas in Yorkshire and Humberside there remain very few pre-1919 non-domestic buildings (Whitman et al, 2016).
- **Many non-domestic assets continue to be converted into residential units.** According to the latest housing supply statistics, over 12% of all new housing in England in 2018/19 resulted from change of use from a non-domestic use to residential (MHCLG, 2019). And this is a growing trend - in 2007/08 only 8% of new homes were from a change of use, however since 2014/15 change of use accounts for between 12% and 17% of all new homes in England (MHCLG, 2019).
- **Non residential historic assets are an important part of our built historic environment which we cannot analyse in full due to data limitations. The Heritage Counts research therefore focuses on residential stock but we acknowledge the importance of this group of assets.**

Non-domestic, pre-1919 stock (% of total stock) by region and sector, as at 31 March 2015



Source: Whitman et. al., 2016

New dwellings were created at the pre-1919 Green Lane works by converting the historic industrial buildings into flats.
© Historic England Archive

CASE STUDY: FORMER GAS RETORT HOUSE, BIRMINGHAM

Birmingham's Grade II* listed 'Former Gas Retort House' was constructed in 1822 for the Birmingham Gas Light and Coke Company to contain the risky, high-temperature process of producing town gas by heating coal. When the gas works closed in 1850, the building became functionally obsolete – it was no longer required for its original purpose.

Historic mapping indicates that Retort House was used as a warehouse following the closure of the gas works; the building has been occupied by several interim uses including as a film set and performance art venue, and more recently the building was refurbished and used for commercial office, leisure and workshops. In 1998 site was added to Historic England's 'Heritage at Risk' register as it was at risk of falling into disrepair if a long-term occupant could not be found. In 2014, the site was purchased by the Church of England and it has now found a permanent function as St Luke's Gas Street church.

APEC Architects completed work to sensitively retrofit the structure and make it fit for its new purpose. Several measures were considered to improve the building's thermal performance: insulated roof panels had been previously installed and the option of adding further insulation was investigated but dismissed as detrimental to the historically significant roof trusses. Steel secondary windows were installed behind the surviving glazing, and new aluminium double glazing units were fitted in the previously boarded-up ventilation arches to allow light back into the space. Insulation of the walls was considered, but dismissed due to the building's listed status. Instead, insulated raised timber floors were installed throughout, and air source heat pumps now heat and cool the space. To accommodate the features required of a modern church (toilets, a kitchen and a plant area), freestanding insulated pods were constructed in elm, a renewable product with negative embodied emissions.

In this way, an irreplaceable component in Birmingham's industrial heritage has been preserved through retrofitting and occupation, and the building's fabric has been effectively recycled without incurring the carbon cost of demolition and new building.

Below: Inside of Gas Retort House, which now functions as a church. © APEC

Above: Gas Retort House. © Phillip King & Church of England Birmingham

Right top & bottom: Views of the worship space at Gas Retort House, before renovations took place. © APEC

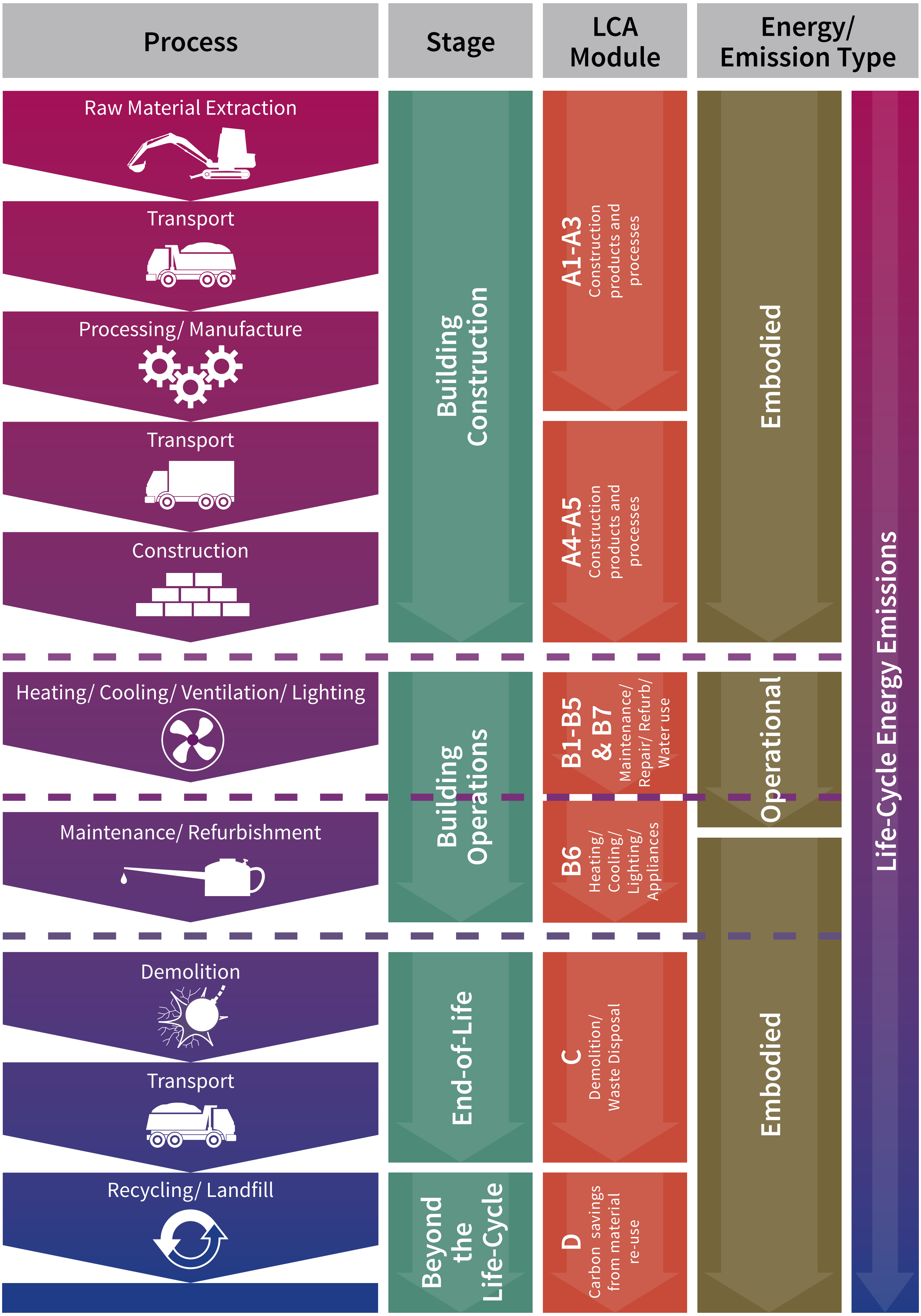
2. The Research

Towards a whole-life approach to carbon emissions

Very few studies have considered the whole life carbon of historic buildings. A new scoping study by Carrig Conservation International (2019) commissioned for Heritage Counts uses real data from two historic buildings, to estimate carbon emissions before and after refubishment and retrofit using a life cycle assessment method. The research also estimates carbon in a scenario, where the historic buildings are demolished and replaced with a typical new building.

2.1 The Model: assessing carbon in buildings using life cycle assessment

- Life Cycle Assessment examines carbon over a building's life cycle to estimate the whole carbon footprint of a building over a set number of years. The life cycle of a building is divided into stages that share common characteristics: construction; operation; maintenance/refurbishment; and demolition and/or reuse (or decommissioning) (see right).
  - Construction (A1-A5) necessitates the use of a variety of resources including design and construction teams, building materials, transport, plant and equipment. All of these require the use of fossil fuels and the emission of greenhouse gases: materials must be extracted, processed, transported and assembled, often being moved between multiple manufacturing locations; products must be moved to site; designers and construction teams require offices and transport; and construction requires on-site fuel consumption and produces waste.
  - Operation (B) involves the use of energy to provide services such as hot water, cooling, ventilation, lighting and powering equipment. Fuels such as electricity, natural gas, heating oil and solid fuels are traditionally used for these purposes and all result in GHG emissions either directly on-site (natural gas, heating oil and heating oil) or indirectly due to the combustion of fossil fuels off-site (electricity). The energy used in buildings is affected by many factors such as climate; exposure; orientation; form of construction; efficiency of building services and controls; occupant behaviour.
  - Maintenance (B) relates to the on-going upkeep and repair of a building to maintain its current level of performance, but typically excludes large projects such as extensions. Maintenance activities consume materials and require the use of energy and therefore create greenhouse gas emissions in the same way as for the construction stage. Refurbishment requires more materials and intervention than general maintenance and therefore higher emissions would be associated with this.
  - Demolition and reuse (C&D) occur at the end of a building's life. It involves the use of energy for on-site demolition and transport of materials off-site. Demolition typically involves energy use and emissions, whereas the recycling and reuse of materials results in avoided emissions associated with the production of new materials. Where materials can be reused, the related avoided emissions can be credited to the building's life cycle. However, the emissions benefits of such materials can be accounted for either at the beginning or end of a building's life, but not both, since this would constitute the double counting of emissions benefits.



Source: Carrig (2019)

The stages of a whole life cycle of a building and the respective processes included in Life Cycle Assessment. Different energy and emissions types (embodied or operational) are associated with the processes.

Victoria Square, Ancoats, Greater Manchester, viewed from the roof of the George Leigh Street School. Basement ruins are nearby. © Historic England Archive

- The sum of the emissions from the construction, maintenance/refurbishment, and demolition and reuse phases is termed 'embodied' emissions. 'Operational' emissions refer to the energy-related emissions associated with the day-to-day use of a building as a result of its services such as space heating and cooling, lighting and powering. Embodied and operational emissions together comprise the life cycle emissions of a building.
- Life cycle assessment offers a more complete measurement method of all carbon emissions from a building, and also involves the estimation of the environmental impacts of products and services. The assessment process is well established and is formalised in the ISO 14040 (Environmental management — Life cycle assessment — Principles and framework) and ISO 4044 (Environmental management — Life cycle assessment — Requirements and guidelines) standards, which describe the main steps that should be undertaken in any life cycle study.

2.2 The case studies: applied life cycle assessment

- For the Heritage Counts research, Carrig obtained data for two completed energy refurbishment projects:

  – The Victorian Terrace: this case study involved the retrofit of a Victorian-era red brick end-of-terrace dwelling in the East Midlands, which was retained as a single-family dwelling. This is likely to be representative of a great number of English terraced dwellings, and involved energy-efficiency interventions only.

  – The Chapel Conversion: this case study involved conversion, conservation and retrofit of a small, a two-room, derelict Gothic Revival chapel in London to create a single-family home. This unusual example of a conversion required a higher than average amount of materials relative to its size in order to bring this once unused ecclesiastical building back to life, while obtaining a very high-end finish.


Victorian Terrace after retrofit.


Chapel interior before and after conversion.


Chapel exterior before...


...and after conversion.

- The life cycle carbon emissions of these case studies were assessed according to three scenarios:
  - **Base-case (before):** assumes that the building continues to operate as normal, and the cumulative operational carbon emissions increase steadily over time.
  - **Refurbishment (after):** the reuse and upgrading of the existing building to improve energy efficiency. In carbon terms, this results in an initial increase in embodied emissions, but an immediate decrease in operational emissions compared to the Base-case.

Victorian Terrace Refurbishment			
Building option	**Base-case**	**Refurbished**	**New build**
Assumed climate	Finnigley	Finnigley	Finnigley
Year built	1891	1891, refurbished 2019	2019
Building height	2-storey	2-storey	2-storey
Floor area (m^2)	83.1	83.1	83.1
Summary of works	None	Energy efficient retrofit of the existing dwelling including: insulation (wall, attic, floor); secondary glazing, draught proofing	Complete demolition of the existing dwelling and its replacement with typical new domestic building using cavity blockwork, PIR insulation, timber floors, triple glazing, pitched roof
Structure	Load-bearing masonry	Load-bearing masonry	Load-bearing masonry
Envelope	Solid brick; single glazed sash windows	Internallyiinsulated solid brick; single glazed sash windows with secondary glazing	Insulated cavity wall, ; triple glazing
Glazing (%)	18	18	18
Heating system (efficiency)	Gas-fired (80%)	Gas-fired (80%)	Gas-fired (90%)
Wall R-value (m^2-K/W)	0.6	3.23	6.25
Roof R-value (m^2-K/W)	2.94	6.25	9.09
Air Change Rate (l/s. person)	7.5	5	5

Source: Carrig (2019)

– **New-build:** demolition and replacement of the existing building. This requires a significant initial embodied energy investment, but is followed by low cumulative carbon emissions due to low operational energy requirements. The New-build scenario is based on an actual residential building that is currently under construction and has been designed to meet current building regulations and standards. The dwelling is representative of new residential construction in the UK, with concrete block cavity walls and high levels of insulation in the walls, roof and ground floor slab.

Chapel Conversion			
Building option	**Base-case**	**Conversion**	**New build**
Assumed climate	Gatwick	Gatwick	Gatwick
Year built	Mid-19thC	Mid-19thC, refurbished 2015	2019
Building height	1-storey	1-storey	1-storey
Floor area (m^2)	56	56	56
Summary of works	None	Energy efficient retrofit of the existing chapel to a dwelling including: improved glazing; wall, roof and floor insulation; internal remodelling; conservation of internal and external materials	Complete demolition of the existing dwelling and its replacement with typical new domestic building using cavity blockwork, PIR insulation, timber floors, triple glazing, pitched roof
Structure	Load-bearing masonry	Load-bearing masonry	Load-bearing masonry
Envelope	Solid masonry, uninsulated solid floor, timber single glazed windows	Insulated masonry, insulated solid floor, insulated roof, timber single glazed windows with secondary glazing.	Insulated cavity wall, ; triple glazing
Glazing (%)	15	15	15
Heating system (efficiency)	Gas-fired (80%)	Gas-fired (80%)	Gas-fired (90%)
Wall R-value (m^2-K/W)	0.43	0.91	6.25
Roof R-value (m^2-K/W)	0.40	5.56	9.09
Air Change Rate (l/s. person)	7.5	5	5

Source: Carrig (2019)

2.3 The calculations: carbon over the life cycle

- **To estimate embodied carbon emissions** relating to demolition, refurbishment, construction and maintenance, estimates for approximately 40 material emissions factors were used. The model considered the amount of materials needed, the carbon intensity[3] of each material, the waste emissions of each material and the number of materials in each of the case study scenarios. Scheduled replacement of windows was assumed every 30 years, roofing every 100 years and boilers every 20 years. The refurbishment of smaller items was ignored in the model.

- **Demolition emissions relating to the construction of a new build** on the site of a demolished historic building are estimated assuming a construction and demolition (C&D) recovery rate of 92% (DEFRA, 2019) and a C&D waste emissions factor of 1 $kgCO_2e$/tonne[4] for recovered waste and 285 $kgCO_2e$/tonne for landfilled waste (WRAP, 2019).

- **The operational emissions for the case study scenarios were estimated** by considering the annual quantity of fuel used by each building case, the number of fuels used, and the carbon (CO_2e) emissions intensity of each fuel over the reference study period.

- **Reference study period (RSP)**. To compare life cycle carbon emissions across all types and ages of buildings, a 60-year reference study period (RSP) is used. This is the industry standard, as recommended by the Royal Institute of Chartered Surveyors (Sturgis and Papakosta, 2017). Sixty years is not chosen to represent the actual lifespan of a building, but to represent the time before which a major intervention such as refurbishment may be required.

- **The life cycle carbon emissions for each building case** were taken as the sum of the embodied emissions (demolition, construction and maintenance) and the operational emissions.

A NOTE ON THE REFERENCE STUDY PERIOD (RSP) AND LIFE SPAN

“Choosing the right RSP is important in a Life Cycle Assessment study. While buildings may last longer than the commonly used RSP of 60 years, using longer RSPs would make calculations of future energy, carbon and costs harder and less accurate since more predictions would have to be made. Using a standard RSP also allows for comparison with other building projects which may have different life spans. An RSP of 60 years is merely a time in which you can anaylse carbon emissions, not the expected life span of a building.”

Aneta Nerguti, Research Assistant, Carrig Conservation International

Grade I listed Jews House, Lincoln, is one of the earliest extant town houses in England. Built between 1150 and 1180, this Norman stone house is over 900 years old and still in active use. The building is an exceptionally important example of C12 domestic architecture. The building has been adapted and changed over time however key structures such as the ornate carved doorway and arched windows remain. The building continues to be in active use, currently housing a restaurant.

[3] Carbon intensity measures the CO2e per unit (kg, m3, m2, number) for each construction material.
[4] Carbon dioxide equivalent or “CO2e” is a term for describing different greenhouse gases in a common unit.
For any quantity and type of greenhouse gas, CO2e signifies the amount of CO2 which would have the equivalent global warming impact

Advertising posters, by a partial ruin on George Leigh Street, Ancoats, Greater Manchester. © Historic England Archive

2.4 Limitations of the research

- **Buildings have a wide variety of significant environmental impacts that are not considered** in the Heritage Counts research. This includes resource depletion, water pollution, land-take, erosion, health impacts and impacts due to land filling of construction and demolition waste.
- **It should be borne in mind that the emissions performance of historic buildings is only one criterion to be considered** when making design decisions about whether and how to refurbish and conserve them. This must be complimented by other relevant criteria such as heritage and cultural value, historic importance, material compatibility, moisture-related issues, accessibility, functional use, etc.
- **This research has demonstrated that there is a lack of national and international data for life cycle analysis of historic building refurbishment** and that it is difficult to find secondary sources of data which are suitable for this purpose. The design and development of an on-going data collection programme would be needed to address the data gaps. Due to these data constraints the choice of case studies for this research was very limited.
- While several separate components exist, **there is not a complete lifecycle assessment (LCA) methodology which can be applied to analyse the life cycle emissions impacts of refurbishment projects for historic and existing buildings**. The methodology presented here is a start, however it will be necessary to formally establish and operationalise such methodologies which can be used to analyse the data for a variety of strategic needs including: knowledge for policymaking; identifying and monitoring energy efficient refurbishment technologies; establishing research needs; producing and updating guidance for practitioners; and developing support tools.

- **The LCA model makes some generic assumptions about the longevity and lifespans of buildings** and building components. However, while it is evidenced that the materials of historic buildings can survive for centuries, there is little evidence as yet regarding the durability of some of the materials and building components of newer buildings. An argument for the retention of old timber sash windows is the quality of the timber used in their construction. During the 18th and 19th centuries, the timbers and were extremely slow grown *pinus sylvestris* or Scots pine sourced from Scandinavia and the Baltic. A quality that is very difficult to source today.
- **The LCA models are based on some standardised assumptions about building management.** The highest demands for carbon in the operation of buildings are from space heating and cooling. Sensitivity tests show that the overall carbon footprint of a building is significantly impacted by the space heating and cooling assumptions. For historic buildings in particular, the space conditioning paradigm has arguably locked building management into a narrow band of thought, where the aim is to stop the conditioned air from escaping the building. Alternative approaches and methods to space conditioning are not considered in these models.

REDUCING CARBON: DESIGNING FOR A LOWER CARBON FUTURE

"Life cycle assessment at the concept-design stage of any energy retrofit project enables the design team to review the embodied carbon of any material and system upgrades before they are specified. This extra review process will allow designers to make better, lower-carbon choices and will reduce the overall carbon impact of the building over its whole life cycle. This, however, is difficult to do at the moment as there is no single LCA tool which helps building practitioners, with minimal LCA software experience, to evaluate the embodied and operational carbon emissions of their design choices at this early stage in the design process. Such a tool would also allow users to look at other environmental impacts such as resource depletion and ecosystem quality, making projects more holistic and sustainable across different environmental indicators."

Caroline Engel Purcell,
Head of Research,
Carrig Conservation International

- Life cycle analysis identifies the overall best combined opportunities for reducing lifetime emissions, and also helps to avoid any unintended consequences that could arise from a focus on operational emissions alone.

> *"For many of our challenges, we don't need new technologies or new ideas; we need the will, foresight and courage to use the best of the old ideas"*
>
> Dr Shoshanna Saxe

Before the invention of thermometers and register grates in the 18th century, people recognised from experience that they lost most of their body heat into the cooler materials around them. Radiating heat from the body accounts for about 60-65% of total heat loss. An easy way to deal with this was simply by adding a radiant break in front materials like stone, brick and plaster. Organic materials such as cloth and leather and timber were used, so fabric was hung on walls and under ceilings, and floors were covered with timber or mats. These could also all be used to cut that other major source of discomfort, draughtiness. Panelling and shutters also served multiple purposes in the quest for comfort.

The blinding of Tobit / British Library, London, UK / BL 3264022 © British Library Board. All Rights Reserved / Bridgeman Images

3. The Research Findings

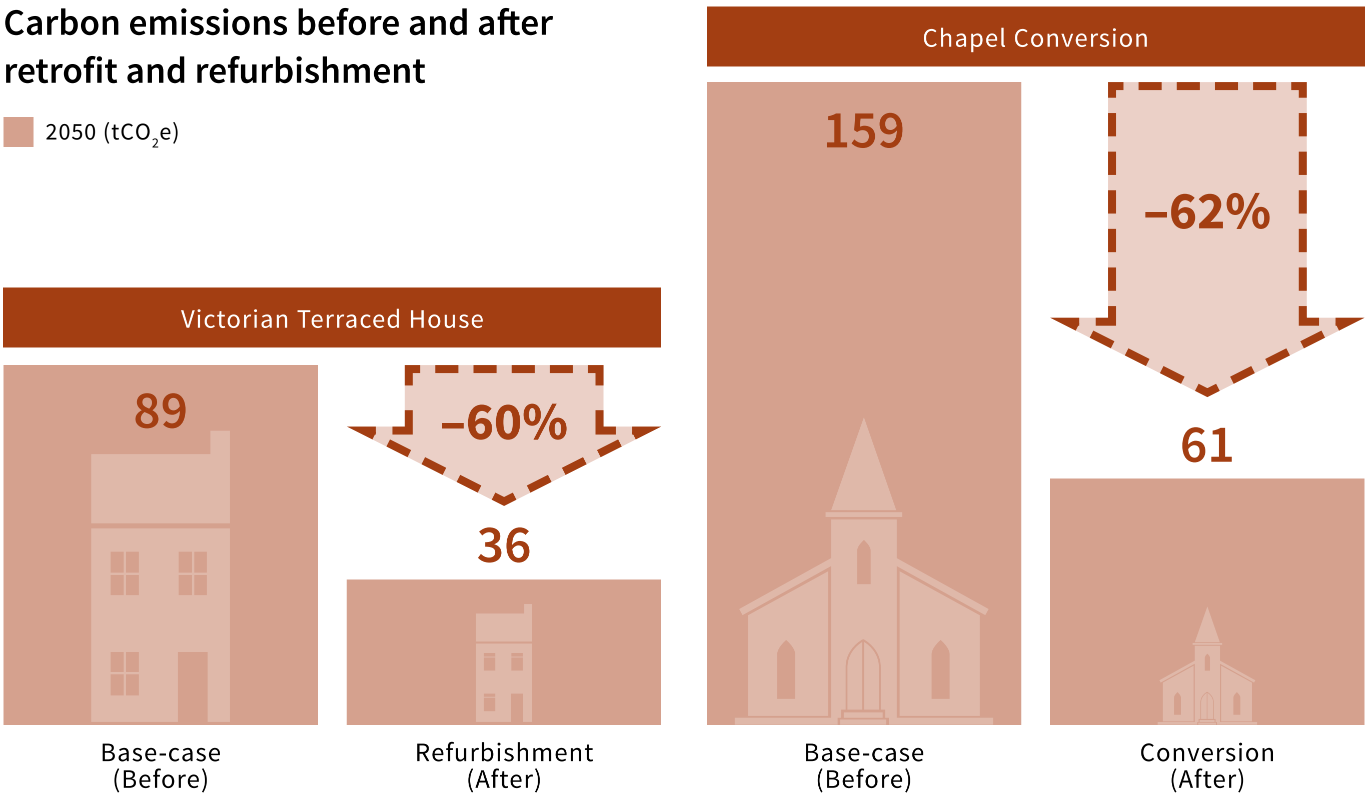
Carbon in the built historic environment

3.1 We can dramatically reduce carbon in the built historic environment through retrofit and refurbishment.

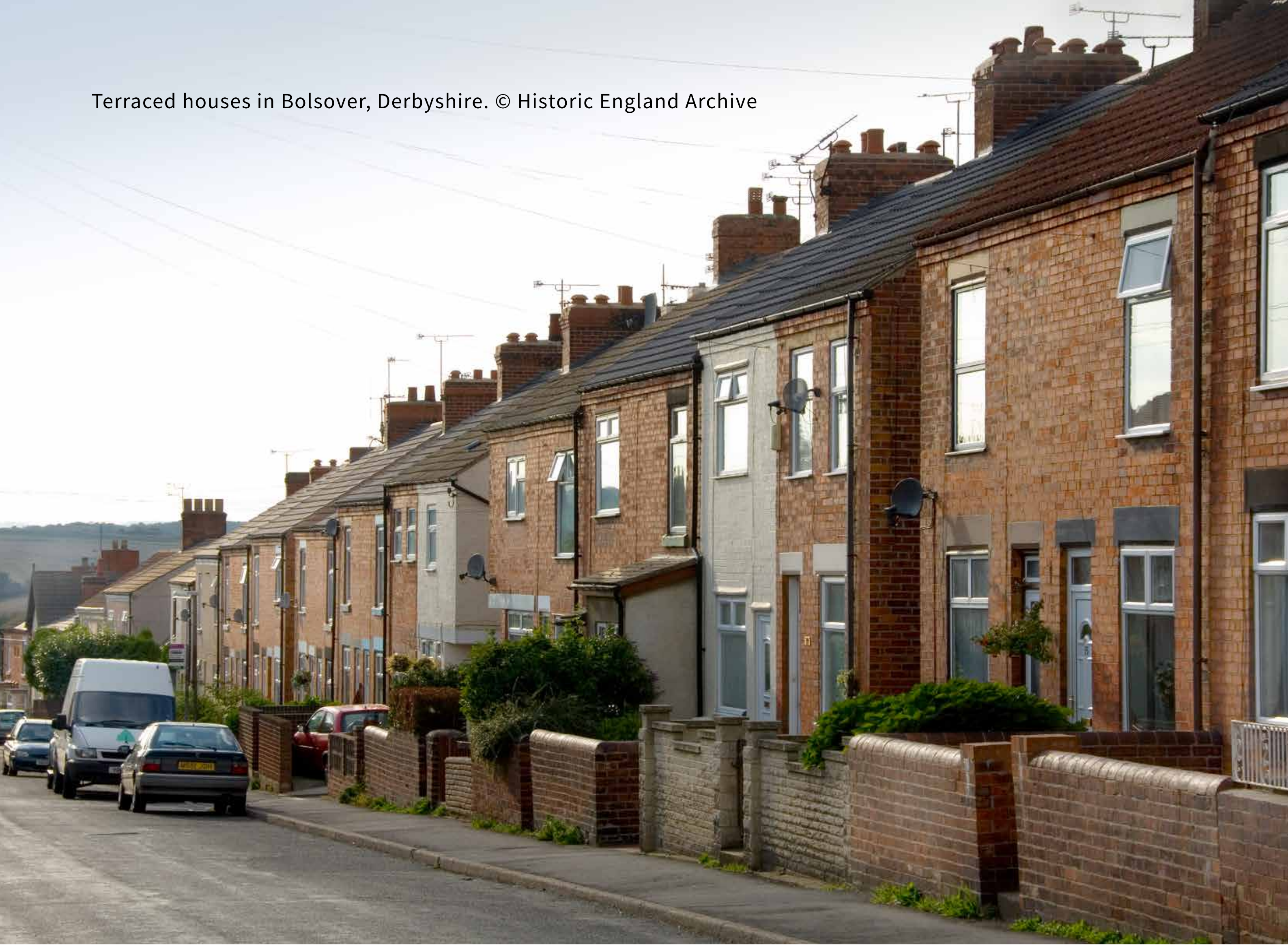
> *We cannot meet our climate objectives without a major improvement in the existing built stock*
>
> (CCC, 2019c)

- This year's Heritage Counts research shows that the refurbishment and retrofit of two case study historic buildings resulted in a dramatic reductions in carbon emissions. **Carbon emissions are reduced by 60% in the Victorian Terrace case study as a result of energy efficiency interventions and by 62% in the Chapel Conversion case study by 2050.** In the Victorian retrofit, carbon emissions are reduced by 53tCO_2e by 2050 – it would take 10 years for a forest of 12,594 conifer trees to offset this carbon, this represents an area of approximately 5 ha or 7 football pitches. In the case of the Chapel Conversion, 98tCO_2e of carbon emissions are saved by 2050 – it would take ten years for a forest of 23,288 conifer trees to offset this carbon, this represents an area of approximately 9.3 ha or 13 football pitches.

Carbon emissions before and after retrofit and refurbishment



Source: Carrig (2019)



Terraced houses in Bolsover, Derbyshire. © Historic England Archive

Evidence from other national examples confirm the Heritage Counts findings:

- In late 2013/early 2014, Reading Borough Council and English Heritage (*now Historic England*) jointly funded research into energy-saving measures in four solid-walled properties in Reading. The aim was to investigate the relative merits of different wall insulation options, and how they compare with other measures in terms of effectiveness and pay-back periods. The research found that **significant carbon savings ranging from 57% to 66% was achieved** in all four case studies following a full package of energy efficiency measures including wall insulation (Newman, 2017).
- In 2016, a deep retrofit project undertaken by Arboreal Architecture to 170-year old grade II listed Victorian townhouse, won IBSE Building Performance Award - Residential Building of the Year - in recognition of achieving such a high energy performance whilst protecting the historic character of a listed building. Using Passivhaus methodology, the estimated Space **Heat Demand of the 170sqm building has been reduced by over 75%** from 180kWh/m2/yr (5,631 $kgCO_2e$) to 40kWh/m2/yr (1,251 $kgCO_2e$). (Arboreal, 2014)

> *"It is estimated that twenty-five million existing homes will need to be energy-retrofitted over the next 30 years in order to meet our 2050 carbon targets"*
>
> (RIBA, 2019)

RETROFIT MUST BE SEEN WITHIN A WIDER SUSTAINABILITY PERSPECTIVE


Homes
of today
for tomorrow
Decarbonising Welsh Housing between 2020 and 2050
Housing Information Group
Simon Lannon and Ed Green, Thursday 26th September 2019

"Whilst the reductions quoted in this year's Heritage Counts research are technically feasible, we must also consider the very real challenges associated with achieving these targets without potential widespread damage to the historic environment and people's health. These targets are not achievable at scale without significant change. The Welsh Government study Homes of today for tomorrow: decarbonising Welsh Housing between 2020 and 2050 takes a realistic and pragmatic line in seeing retrofit of the existing housing stock alongside a process of grid decarbonisation."

David Pickles, Senior Architect, Historic England

- Retrofit undertaken in a responsible and considered manner will significantly reduce carbon in buildings.

CASE STUDY: ZETLAND ROAD PASSIVE HOUSE

The aim of the Zetland Road Passive project was to take a pair of typical 'hard to treat' Victorian townhouses in Manchester and prove that it was possible for them to meet the world's highest performance standards set by the PassivHaus Institute, and that this could be accomplished without compromising the buildings heritage. The townhouses have now been retrofitted to become Europe's first Passivehaus Enerphit Plus standard homes.

From the street the buildings retain their Victorian appearance with the original brickwork incorporated into the design to provide thermal mass. The technologies used enable the house to achieve the Enerphit Plus standard of generating 60 kwh of renewable energy each year for every square metre of floor area. This is produced by 60m$_2$ of photovoltaic cells on the roof. The insulation and ventilation allow the house to maintain comfortable temperatures and air quality year round without a central heating system. Windows are angled towards the sun to maximise passive solar gain. Each layer of the walls, roof and floors is highly breathable to allow drying both inside and out should moisture get in.

The approach adopted by the developer was to use natural materials as far as possible and minimise the use of petrochemicals. Internal insulation of

Above: A Victorian semi-detached house, after its PassivHaus refurbishment. © Rick McCullagh

the brickwork is achieved using timber 'I' joists with blown cellulose and wood fibre board. The original building footprints were retained, avoiding the need to increase the embodied energy by adding extensions. Lime has been a critical material in the project, providing the breathability that is central to the project's design philosophy.

The Zetland Road PassivHaus project was always intended as a valuable case study that would not only inspire others to follow suit, but also to share information on how it can be achieved. The push to meet the world's highest standards has led to the creation of techniques, details and products that can be shared with the construction community.

Rear of a Victorian semi-detached townhouse with a new timber-clad extension. © Rick McCullagh

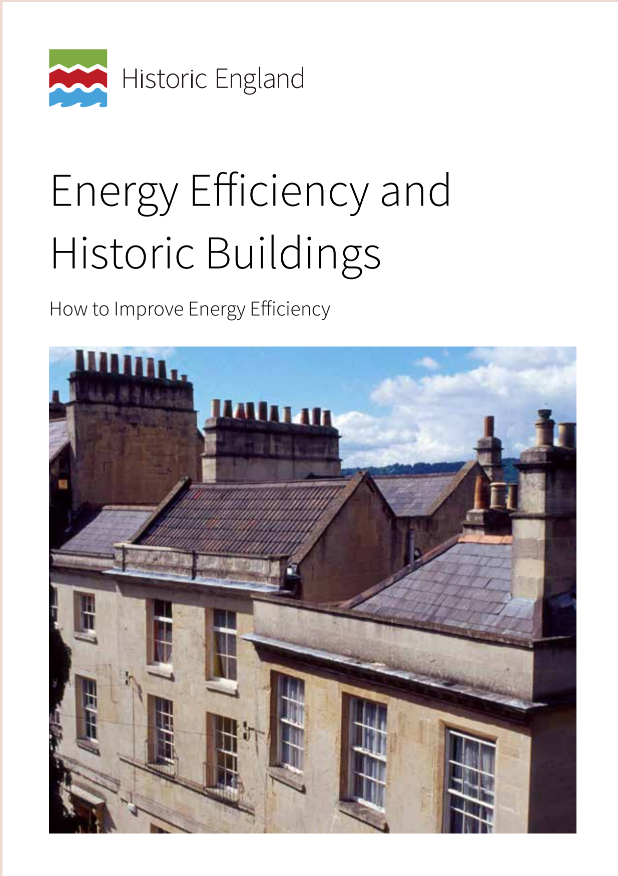
REDUCING CARBON IN BUILDINGS – IF YOU GET IT RIGHT, ITS RIGHT ALL ROUND

Many current approaches to "deep retrofit" aim to cut energy and carbon mainly by stopping air that has been conditioned – heated or cooled – from escaping the building. This is technically very difficult and risky, and can easily cause problems that shorten the lifespan of buildings. Elements of the sealing system like house wrap and insulation are carbon-intensive to make and install, but as yet we have very little evidence how they will work over the longer term, and how often they will need to be replaced. Sealing the buildings also compromises usability, because it creates problems of indoor air quality. What's more, we know that the 'rebound effect' is all too common: a building gets sealed up, but the energy used doesn't go down, and indeed may increase.

The good news is there is absolutely no conflict between good carbon reduction, good care for buildings, and good comfort and usability. If you get it right, its right all round. The safe and effective approach to retrofit is to recognise that each building is unique: not just in its materials and design, but also in the way it is being used. That immediately unlocks many no-carbon or low-carbon things that building owners can do to dramatically cut their use of energy and carbon.

Historic England has lots of practical advice on this; https://historicengland.org.uk/images-books/publications/eehb-how-to-improve-energy-efficiency/ our free guidance note is a good place to start as are Historic England's "webinars."

Dr Robyn Pender,
Senior Building Conservation Advisor,
Historic England



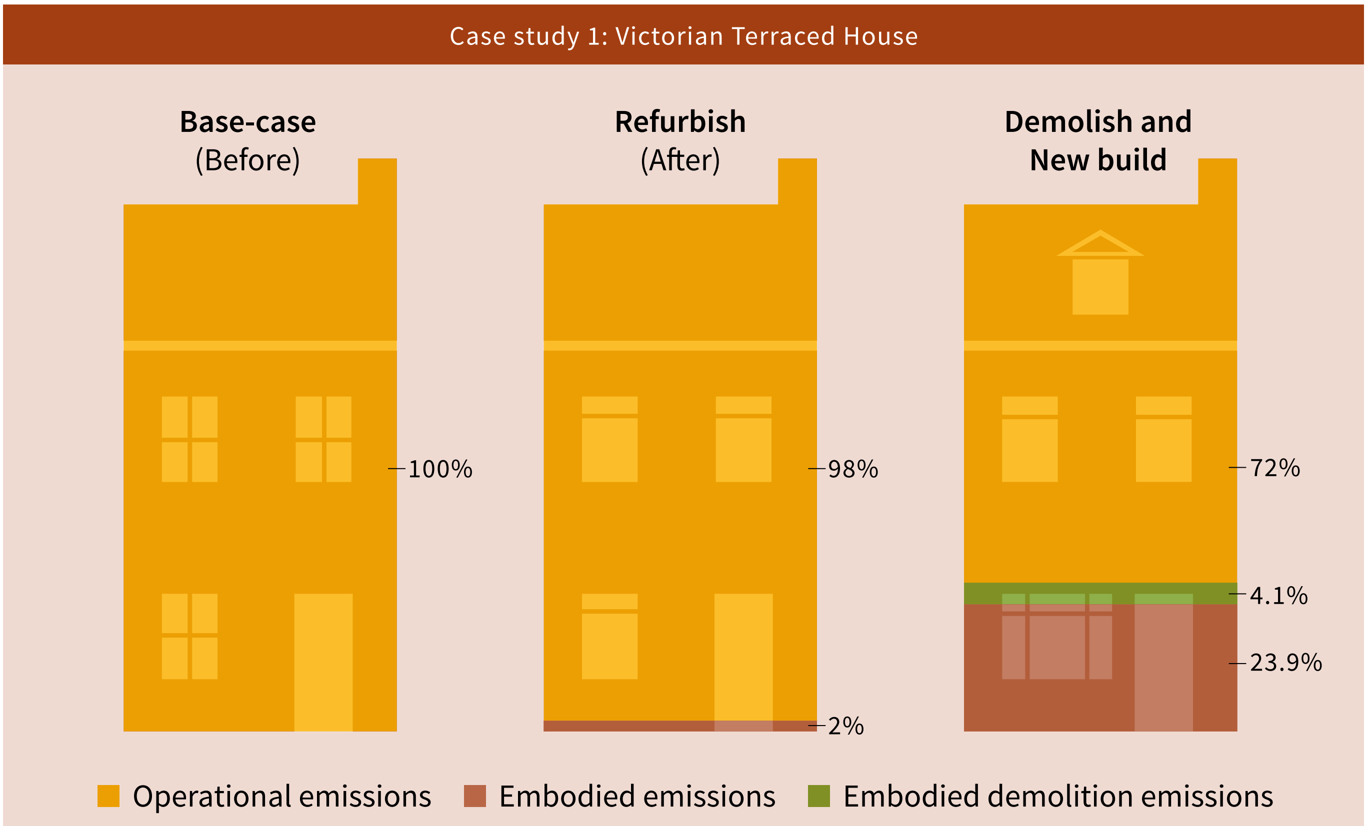
The guidance document *"Energy Efficiency and Historic Buildings: How to Improve Energy Efficiency"* available online from the Historic England website.

3.2 Embodied carbon is a significant source of carbon emissions that is largely overlooked

> *A large part of the whole-life carbon footprint of buildings is not associated with their use, but is embodied in the materials used for construction.*
>
> (Dunant, 2018)

- New evidence gathered for Heritage Counts demonstrates that if we do not count embodied carbon emissions we underestimate the carbon emissions of a new building by up to 31% over 60 years.
- In the example of the Victorian Terrace refurbishment, the construction-related embodied carbon emissions from the refurbishment works were estimated to be 1.2 tCO_2e (2% of the building's total emissions over 60 years). On the other hand, the **construction of a new home of the same size produces up to 13 times more embodied carbon than refurbishment**. For the New Build, 16.35 tCO_2e or 28% of building's total emissions were embodied emissions. Demolition emissions alone account for 4% of carbon emissions from the New Build over the 60 year reference study period. It would take ten years for a forest of 3,885 newly planted trees to offset the 16.35 tCO_2e of embodied carbon emissions.

Embodied and operational carbon as a share of the whole life carbon: the case of the Victorian Terrace

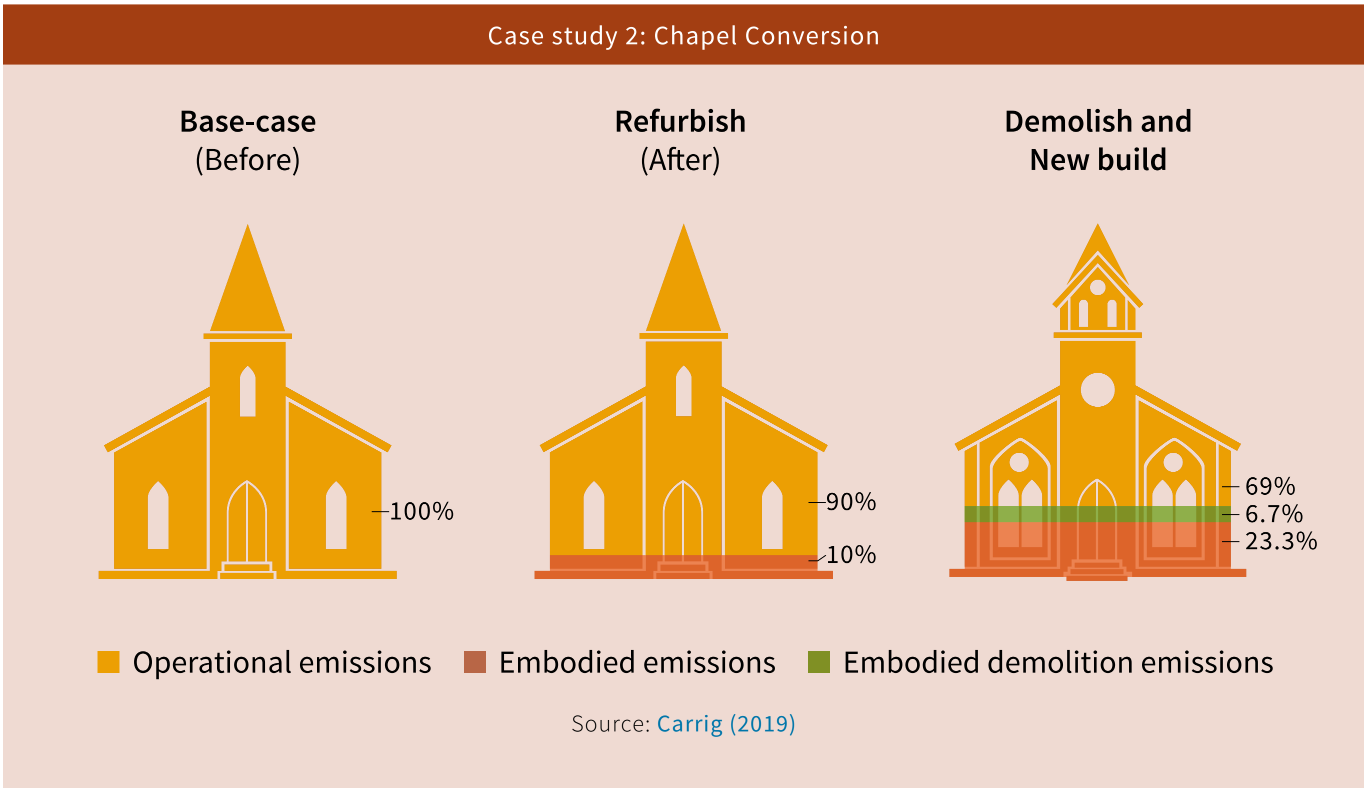


Source: Carrig (2019)

- The Chapel Conversion case study, which involved the relatively unusual reuse of a derelict ecclesiastical building and significant conservation and repair works in addition to energy efficient upgrades, resulted in significant embodied emissions compared to the Victorian Terrace case. The embodied emissions are estimated to be 9.9 tCO_2e (10% of the building's total emissions over 60 years). The New Build scenario on the other hand would result in 18.8 tCO_2e (31.13% of building's total emissions over 60 years). In this case, demolition is estimated to contribute 7% of a new buildings emission over the 60 years.
- There are no embodied emissions for the Base-case as the carbon embedded in the existing fabric has already been spent and has no consequence on current and future emissions.
- **Embodied emissions account for a very significant proportion of the lifecycle emissions of a building.**


New build by FAT Architecture in Ancoats, Greater Manchester. © Historic England Archive

Embodied and operational carbon as a share of the whole life carbon: the case of the Chapel Conversion



Source: Carrig (2019)

3.3 Retrofit to reduce the social costs of carbon

> *"80% of buildings in 2050 have already been built, so a major priority is decarbonising our existing stock."*
>
> UKGBC

- Changes to our climate are already producing severe, damaging impacts on infrastructure and property; on human health and wellbeing; on agricultural productivity and on ecosystem services. There is growing evidence that society at large is paying a heavy price for climate change. For example, 2018's extreme heat wave led to more than 10,000 households needing to claim for damages caused by subsidence, at a cost of more than £64million (ABI). A study found that one fifth of people who have experienced a flood were suffering from depression one year after the flood, over a quarter from anxiety and over a third were affected by post-traumatic stress disorder (PTSD) (Mason, 2009).
- To understand the potential scale and impact of retrofit in England, a model based on the findings from this year's Heritage Counts case studies was developed and applied to the existing stock of pre-1919 dwellings in England (Historic England, 2020). Three hypothetical scenarios are developed based on a very limited sample; however the objective of the analysis is to contextualise the case for retrofitting existing buildings.
- Three hypothetical scenarios are developed using shadow prices to value emissions (HMT, Green Book, 2018). The Shadow price of carbon is based on estimates of the lifetime damage costs associated with greenhouse gas emissions, known as the social cost of carbon (BEIS, 2019).

Scenario I: There is no refurbishment or demolition of 5.1m pre-1919 residential building.

Scenario II: 50%, 2.6m, pre-1919 homes are refurbished in a 10 year plan, starting in 2021.

Scenario III: 15%, 765k, pre 1919 homes are refurbished in a 10 year plan, starting in 2021.

Scenario IV: 25%, 1.3m, pre 1919 homes are refurbished in a 25 year plan, starting in 2021.

Carbon savings in three hypothetical scenarios

Scenarios	Carbon reduced relative to Scenario I ($MtCO_2$)		Carbon Cost reduced relative to Scenario I (2019 prices)	
	Mt CO_2	Carbon offsetting equivalent: 10 year-old trees (million)	£bn	% In UK's GDP (2019)
I (Do nothing)	0	0	£0	0%
II (50% over 10 years)	–39.6 (-27%)	9.4	£3.40	0.11%
II (15% over 10 years)	–11.9 (-8%)	2.8	£2.40	0.08%
III (25% over 25 years)	–15.5 (-10%)	3.7	£2.50	0.08%

Source: Historic England, 2020

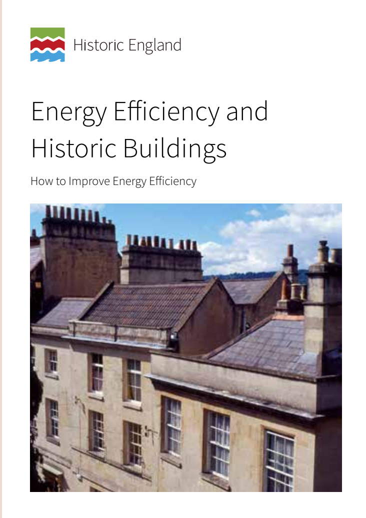
- The results of the model of these hypothetical scenarios shows that compared to a do nothing outlook:
  - Refurbishing 50% of all pre-1919 residential buildings over ten years would lead to a reduction in carbon emissions of 27% or 39.6 million (tCO_2e) by 2050 compared to the baseline do nothing scenario. In monetary terms, this implies that £3.4 billion is saved in terms of the costs of reducing GHG emissions to meet UK's target. This represents almost 0.11% of UK's GDP in 2019.
  - Retrofitting 15% of pre-1919 buildings over 10 years, as per scenario II, carbon emission are 8% or 11.9 million (tCO_2e) lower by 2050 (compared to the baseline). It would It would take ten years for a forest of 2.8 million newly planted trees to offset this carbon – this is approximately 1,120 ha which is the equivalent of 1,569 football pitches. In monetary terms, £2.4 million would be saved in the costs of decreasing carbon emissions to achieve UK's target.
  - Refurbishment of 25% of all pre 1919 homes over 25 years (as in scenario IV); carbon emissions are reduced by 10% or 15.5 million tCO_2e in relation to the baseline. It would take 10 years for a forest of 3.7 million newly planted trees to offset this carbon; this is approximately 1,480 ha which is the equivalent of 2,073 football pitches. In monetary terms, this would save £2.5 million in the cost of decreasing carbon emissions to achieve UK's target, which is equivalent to 0.08% of UK's GDP in 2019.
- **This hypothetical analysis demonstrates that the speed at which carbon is reduced in the built environment has a significant impact.** Comparing Scenario III (15% of stock over ten years) with Scenario IV(25% of stock over 25 years), shows that a slower paced retrofit programme over a longer period of time, would impact many more buildings (510k or 10% more pre-1919 buildings), however would only result in 2% less carbon by 2050 compared to the quicker retrofit programme. In addition the carbon cost savings of the larger but slower paced retrofit programme are relatively small compared to a smaller scale but quicker retrofit programme (Scenario III).

> *"30 million homes and 30 years to decarbonise, simple arithmetic suggests we need to "decarbonise" one million homes every year, starting now"*
>
> Chris Stark,
> Chief Executive of the Committee on Climate Change
>
> (BBC, 2019)

The **sooner we reduce carbon in the built environment, the greater the impact will be. We must act now to achieve the best outcomes for society** and to meet our 2050 targets.

ENERGY EFFICIENCY AND HISTORIC BUILDINGS

Historic England, 2018



The Energy Efficiency and Historic Buildings guidance document, available online.

Although there are no 'one-size-fits-all' solutions for making energy and carbon savings in older houses, there are some general principles that apply across the board:

Understand your home and its context: Account for the historic significance of your house and the potential harm from changes

- Its location, orientation and exposure to sun, wind and rain
- Its design, construction and condition
- The performance and behaviour of the building materials
- The design, condition and operation of services such as heating and hot water
- How you use your home
- Your own requirements, aspirations and aims
- Your budget and other resources, opportunities and constraints
- Success cannot be achieved by technical means alone; everyone in the home needs to be fully involved in your energy saving plans.

Reduce energy use: Review and question your current habits and comfort standards to find out what's really necessary. You might be able to make energy savings through a more flexible approach to comfort in different parts of the home, so for instance by heating bedrooms to a lower temperature than living rooms.

Avoid waste: Lights and equipment in homes are often left on unnecessarily. It's important to use energy-using systems efficiently, and to turn all energy-using equipment off or down when not needed.

Increase efficiency: Building services such as heating, hot water supply and lighting and other energy-using equipment like computers and appliances should be designed, selected and run to use as little energy as possible.

The comfort of your building will be enhanced by regular maintenance: a wet home is a cold home.

Improve control: The control systems on building services should be efficient as possible and easy to understand and use, but many are not as manageable and responsive as they could be. This can lead to increased energy use and carbon emissions.

Use lower-carbon energy supplies: Switch to energy sources with lower emissions such as on- or off-site renewable energy (solar, wind or water power), or select lower-carbon supplies such as gas or wood instead of coal.

Avoid complication: Solutions should be kept as simple as possible and done well.

Review outcomes: When you review how the measures you've taken are performing, check their performance as part of the overall system. Watch out for unintended consequences such as overheating, moisture problems and poor indoor air quality.

Measures used in combination can have a powerful multiplier effect. For example, combining a 50% reduction in the demand for energy and the amount of carbon in the energy supply with a 100% increase in equipment-efficiency can cut carbon emissions by almost 90%.

CASE STUDY: GIBSON MILL / HARDCASTLE CRAGS

Gibson Mill in West Yorkshire is a Grade II listed mill that dates from around 1800. Situated in Hardcastle Crags, it was one of the first mills of the Industrial Revolution, driven by a water wheel and producing cotton cloth until 1890.

At the turn of the century, it started a new life as an Entertainment Emporium with roller skating and tea dances until 1940 when it slipped into disuse. It was acquired by the National Trust in 1950, but remained largely unused until the 1990s, when an ambitious project to restore the site was developed.

Delivered by architects EcoArc and supported by a grant from the National Lottery Heritage Fund, Gibson Mill is today self-sufficient in energy, water and waste materials and its only mains connection with the outside world is the phone/broadband line. Solar panels provide hot water and electricity and have a negligible impact on its historic structure. Elements of the mill's existing hydro system are used to provide electricity.

The project was completed in2005 and Gibson Mill and Hardcastle Crags now attract around 150,000 visitors per year, and staff estimate that since 2009 the mill has generated approximately 12,000 kWh of electricity each year thanks to their hydro scheme and photovoltaic panels. However, the site has also faced difficulties such as a general decrease in water flow from the river, and the larger of its hydro turbines is not currently in operation. The degree of the project's success has also produced its own challenges, as significantly increased visitor numbers have placed increasing strain on its facilities.

Gibson Mill.
© National Trust Images_Paul Harris

Gibson Mill was the first heritage building in England to be used as a visitor centre operable all year round in a solely sustainable way and has become a source of inspiration for individuals and organisations considering similar developments, winning numerous awards.

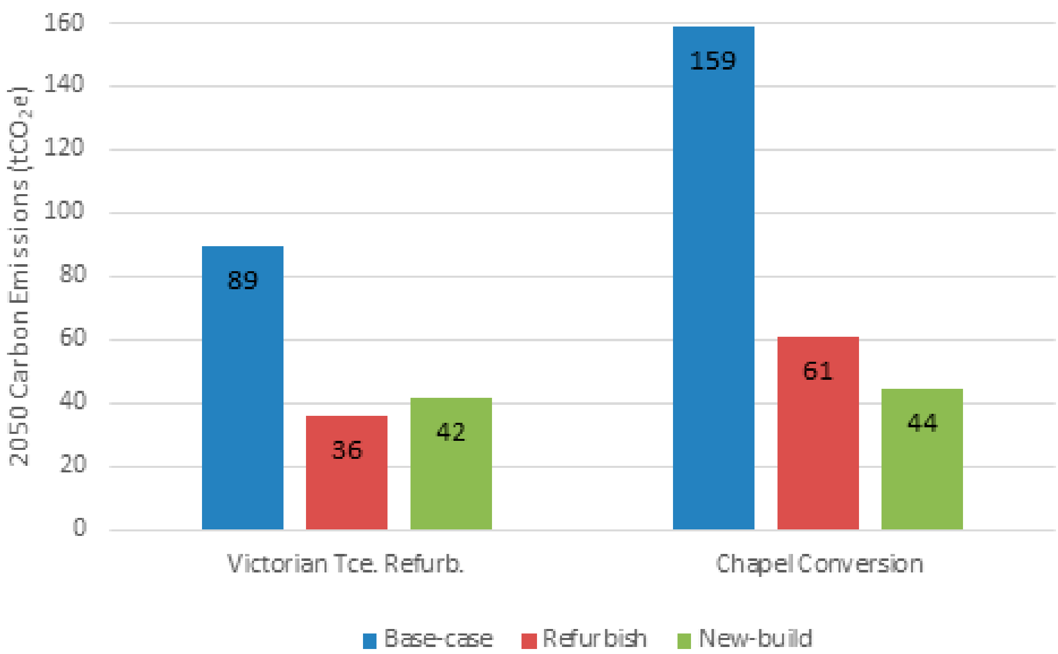
More information on this project can be found on the Trust's website at https://www.nationaltrust.org.uk/hardcastle-crags/projects/making-gibson-mill-self-sufficient

3.4 Recycle first to meet 2050 carbon targets

> *In order to achieve a net zero carbon economy, the UK must account for and offset all carbon impacts from the built environment. This will require moving towards a net zero whole life carbon approach for all buildings*
>
> (UKGBC, 2019)

- Traditional buildings are inherently sustainable. The Heritage Counts research shows that when a typical historic building – the Victorian Terrace – is responsibly refurbished and retrofitted, it will emit less carbon by 2050 than a new building. But only if the whole life carbon of the building is considered.
- On the other hand, the Converted Chapel case study emits more carbon than a new build by 2050. In this one off conversion of a derelict ecclesiastical building, the unusually high demand for new materials generated significant amounts of embodied carbon. The amount and carbon content of materials needs to be a key consideration of any retrofit project. Generally more materials lead to higher embodied emissions, albeit the embodied carbon of materials varies from product to product. Life Cycle Assessment tools that can be applied to refurbishment projects for historic buildings are needed to enable building practitioners to evaluate the embodied and operational carbon emissions of their design choices.

Carbon emissions by 2050, tCO_2e



Source: Carrig (2019)

HOW WE RETROFIT MATTERS

"When we retrofit buildings the first thing that happens to carbon emissions - and other environmental impacts from buildings - is that they increase. ***How*** *we carry out retrofit - the measures selected, the materials used and how they are fitted - is thus at least as important as the reductions in emissions which may (or may not) be achieved in the medium term. Worse, if we make mistakes, and work has to be undone, then the embodied energy of the work is permanently lost."*

Nigel Griffiths, Director,
Sustainable Traditional Buildings Alliance

- The Marginal Abatement Cost (MAC) is the cost of reducing carbon emissions by one unit using an alternative technology, design or system. For example, where a building's energy refurbishment costs money to implement but results in GHG emissions savings, then the cost per unit saving is the emissions savings divided by the cost of implementation. MAC can be used by policymakers to rank the most cost-effective emissions reduction interventions.
- For the Victorian Terrace refurbishment, MAC results indicate that Refurbishment is more cost-effective than new build in reducing life cycle emissions. Any reductions in retrofit or refurbishment capital costs, for example through lower VAT rates, would further improve MAC results. In the case of the Chapel Conversion, the new-build has significantly lower MACs due to the high cost of the work undertaken, rather than very low carbon savings of the Conversion.

THE REUSE AND ENERGY UPGRADE OF OUR EXISTING BUILDINGS IS ESSENTIAL

"The misconception that to conserve or energy renovate existing buildings is too expensive is all too prevalent. The heritage sector must fight this and encourage all sectors of society to appreciate the value of our built heritage for their contribution to reducing our carbon footprint, minimising resource depletion, and to sustaining continuity within our communities. The reuse and energy upgrade of our existing buildings is essential to the health and wellbeing of our people and our planet."

Peter Cox, Managing Director,
Carrig Conservation International

Looking ahead to the 2050 carbon targets, the energy refurbishment of historic and traditional buildings can be a quicker and more effective solution to reduce embodied and operational carbon emissions from the built environment.

PLANNING RESPONSIBLE RETROFIT OF TRADITIONAL BUILDINGS

Sustainable Traditional Buildings Alliance (STBA), 2015

A guide for anyone involved in a project aiming to reduce the energy use of a traditional building through technical interventions.

Retrofit is the process of improving the energy and environmental performance of buildings through technical interventions. A prime focus of retrofit is on reducing heat losses through building fabric (i.e. walls, doors, windows, floors and roof) – thereby cutting heating costs, energy use and CO_2 emissions.

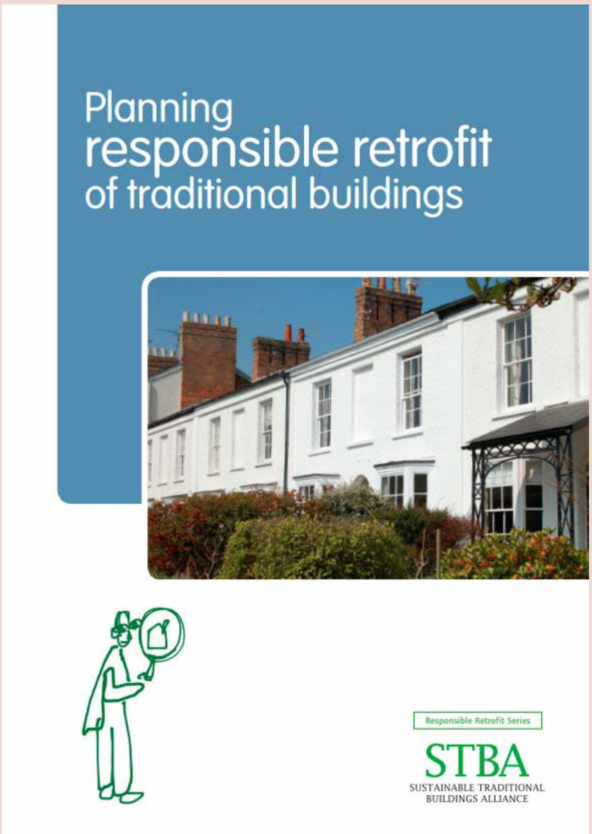
Responsible retrofit also requires a Whole Building Approach whereby there is integration of the fabric measures (such as insulation, windows, draught proofing), and services (particularly ventilation, heating, controls and renewables) along with proper consideration of how people live and use the building. All of these must be adapted to the context of the building (its exposure, status, condition, form etc.). When these are integrated well, a building is in balance. All these factors influence energy use and the effectiveness of energy saving measures.

Achieving responsible retrofit often requires compromises between different values. Every building is different due to its location, orientation, design, construction, engineering services, and the way it is used, managed and maintained. Buildings and occupants benefit from different approaches. There are also many different ways of reducing heat loss, energy use and carbon emission.

Not all buildings can be retrofitted, and for some buildings and people there are more appropriate ways of reducing environmental impact than technical interventions.

To achieve the benefits of retrofit it is important that retrofit processes consider occupants' lifestyle changes and an on-going programme of repairs and maintenance.

Responsible retrofit should deliver sustained net reductions in energy use, at minimal environmental impact, while maintaining or improving the traditional built environment and making a positive contribution to human health.



4. The Recommendations

Meeting net zero carbon targets

4.1 Use and re-use first

> *The greenest building is the one that already exists*
>
> Carl Elefante,
> former president of the American Institute of Architects

- The Heritage Counts research shows that demolishing a historic building and replacing it with a new building can result in greater carbon emissions by 2050.
- Around the country there are so many examples of historic assets currently neglected, underused and even at risk of demolition. According to official estimates from the Historic England Heritage at Risk dataset there were over 4,612 designated heritage assets 'at risk' in 2019 (Historic England, 2019). These are sites that are most at risk of being lost as a result of neglect, decay or inappropriate development.
- On the other hand, there are also inspiring examples of 'at risk' historic buildings being brought into use, now providing much needed homes, working spaces, leisure and community spaces.
- **There are so many untapped opportunities within the built historic environment**. Research limited to specific areas and historic building types quantifies some of that opportunity:
  - **Underused historic mills in Greater Manchester and Lancashire have the capacity to generate thousands of new jobs and new homes.** Research in 2017 found there were approximately **542** surviving mills in Greater Manchester and **540** in Lancashire. **The vacant or underused floorspace within these mills has the potential to generate 133,000 new jobs (equivalent to £6bn of Gross Value Added per annum) or 25,000 new homes within these local economies** (Historic England, 2017).
  - **New research has revealed that there are great opportunities for new homes above shops within historic high streets**. In October 2019, Poyntons Consultancy was instructed by Nottingham City Council to produce a report looking at the residential capacity of a specific historic area around the Old Market Square in the centre of the City. The findings show that there is potential for over 300 new residential units above shops in existing buildings (Poyntons, *forthcoming*). More productive use of these assets will not only reduce the carbon footprint of new home provision but will also provide much needed opportunities for our struggling high streets.
- **Underused or unused historic assets are opportunity sites** which can be a source of sustainable homes, community spaces and work places of the future. But the future of many historic assets remains uncertain. More research and evidence to identify and quantify the scale of opportunities for re-use are required.

Tower Mill, Dukinfield, Greater Manchester, has been restored and returned to use as a site for textile manufacture.
© Historic England Archive

THERE IS MUCH THAT IS SUSTAINABLE ABOUT OLDER BUILDINGS

“Old buildings are widely regarded as high energy consumers by definition, and that to reduce their energy use and emissions substantially requires radical action, particularly insulation to their fabric. The true situation is more complicated. It raises more questions, but also offers opportunities. There is much that is sustainable about older buildings, not least that they have lasted. During the lives of these older buildings, some newer ones have come and gone, while others have disappointed in their performance and running costs.”

Dr William Bordass, William Bordass Associates

The **RetroFirst campaign** led by the Architects' Journal champions the reuse and refurbishment of existing buildings as a means to reduce carbon emissions and waste from the building sector (Hurst, 2019). The campaign targets three means of reform: **tax** (reverse VAT rates so that renovation works are charged at 5% and new build is charged at 20%), **policy** (promote the reuse of buildings and materials through changes to planning and building regulations) and **procurement** (start by requiring all publicly-funded commissions to consider refurbishment before demolition and rebuild).

We must prioritise what is already here through the productive use and reuse of the historic environment – this will address our social and economic and also secure our sustainable low carbon future.

4.2 Developing robust carbon accounting methods and data

> *What you measure affects what you do. If you don't measure the right thing, you don't do the right thing.*
>
> (Nobel economist Joseph E. Stiglitz)

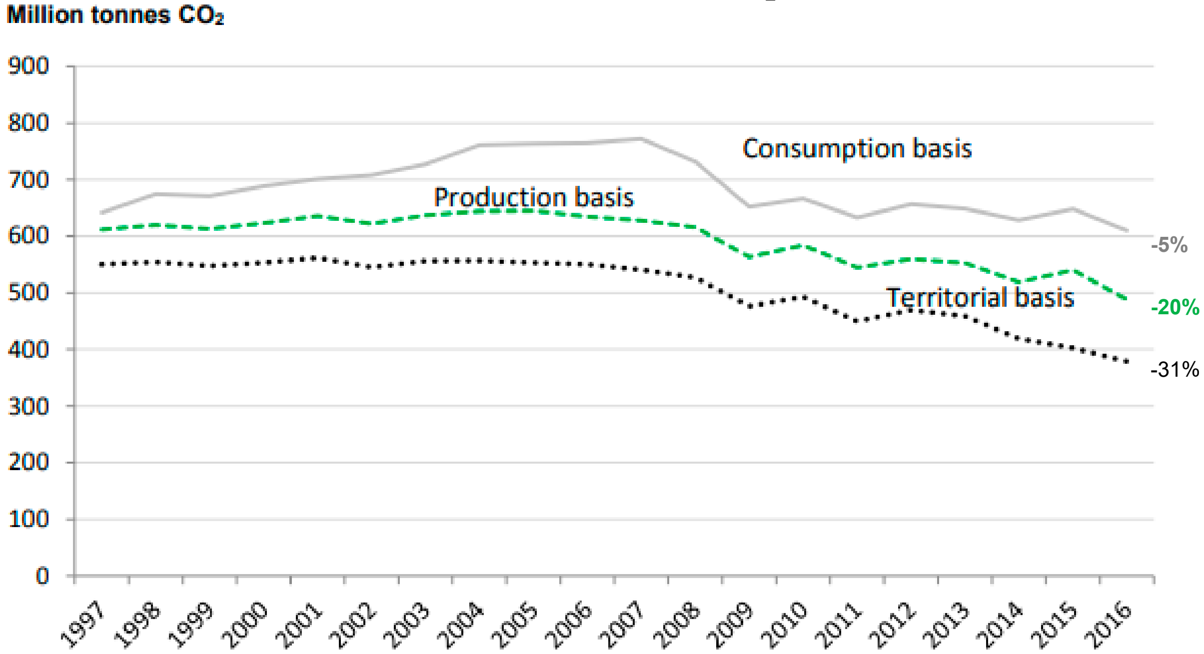
- A whole life carbon approach relies on data capture. One of the greatest challenges of the Heritage Counts research has been the acquisition of case study data. The research has exposed an enormous gap in relevant verifiable hard data on historic buildings, and indeed limitations in the data available for construction and demolition waste management.
- The data, the models and the quality of the data have an enormous impact on the actions we take, so it is imperative that we get the right measures and methods. For example, the embodied carbon burden of installing triple glazing rather than double glazing can be greater than the operational carbon emissions.

Right: Brierfield Mill, Lancashire. Work will return the building to use as a mixture of enterprise, leisure, residential and public realm spaces.

COUNTING EMBODIED CARBON: CARBON TRENDS IN THE UK

- To meet the UK's zero carbon emission target by 2050 the UK will need to reduce carbon emissions by at least 100% below 1990 levels (CCC, 2019a). In the UK, three different approaches are used to measure and report greenhouse gas (GHG) emissions (Defra, 2019).

Relationship of different measure of the UK's CO_2 emissions 1997 to 2016, Mt CO_2



Source: Defra, 2019

1. **Territorial carbon:** Only includes emissions that occur within the UK's borders. Emissions in international territory, i.e. from international manufacture and transport are reported as "memorandum items". *Territorial emissions form the basis for reporting on progress towards our domestic and international emissions reduction targets*.

   Current trend: 31% reduction in CO_2 1997-2016

2. **Production based carbon:** Emissions are measured on a "residents" basis representing emissions caused by UK residents and industry, whether in the UK or abroad. However they exclude emissions within the UK which can be attributed to overseas residents and businesses. International aviation and shipping emissions are allocated to countries based on the operator of the vessel.

   Current trend: 20% reduction in CO_2 1997-2016

3. **Consumption-based carbon:** Emissions are measured on a "consumption" basis, taking account of emissions embedded within the manufactured goods and services which the UK imports and exports. Measured this way, our CO_2 footprint is notably larger because of the embedded emissions in imports.

   Current trend: 5% reduction in CO_2 1997-2016

The UK's carbon emissions vary significantly according to each of the three approaches. The current measure used to officially report UK carbon emissions to the EU and UN demonstrates a 31% reduction in carbon (1997-2016).The consumption measure of carbon on the other hand only measures a 5% reduction in carbon in the same time period (Defra, 2019).

Many of the materials used in new buildings and standard retrofit are imported. Although the UK has extensive mineral and stone resources, it has increasingly focused on global imports of building materials. In 2018, the UK imported approximately 130,000 tonnes of 'worked stone' annually, with the majority (68%) of this sourced from China and India (Historic England, HMRC).

As the UK economy continues to move from a manufacturing base towards a service economy, we can expect to see significant declines in territorial emissions. Consumption emissions on the other hand, that capture the growing demand for imports and products produced overseas, are unlikely to demonstrate similar reductions.

In the context of the Heritage Counts research, territorial measures of carbon do not support a whole life carbon assessment of buildings, as the embodied carbon is not fully accounted for.

> *UK emissions now constitute only a small proportion of the global total, but those who say the UK's actions no longer matter are wrong. Every tonne of carbon counts, wherever it is emitted.*
>
> Net Zero – The UK's contribution to stopping global warming, Committee on Climate Change (2019a)

- The built environment industry, regulators and policy makers have to date focused mainly operational emissions of the built environment while the embodied aspect of carbon emissions has not been fully addressed or captured. This focus is evident in the carbon targets including in building regulations (Part L), planning requirements by local authorities and sustainability assessment rating schemes (BREEAM, LEED, etc.) which largely focus on operational aspects.
- If the carbon inputs of all aspects of constructing, maintaining, operating, retrofitting, and demolishing buildings are not measured and not included in emission calculations, there is a significant danger that although we might meet targets, we would not be truly reducing carbon emissions and will therefore lose the war against climate change.

Right: Installation of secondary glazing at The Engine House, Swindon, Wiltshire. © Historic England Archive

4.3 Promoting sympathetic retrofit: advice and guidance

> *Successful energy retrofits are about striking the right balance. Understanding the opportunities and benefits in terms of energy savings, comfort, wellbeing and related costs for each individual measure is key to allowing designers and clients to make informed decisions.*
>
> (RIBA, 2019)

- This year's Heritage Counts research shows that we urgently need to tackle carbon in the built environment and that retrofit can significantly reduce carbon.
- As we embark on the much-needed journey towards a low carbon future, we must be aware of the significant and growing risk to our historic environment that comes from **inappropriate retrofit and maladaptation**. Poor retrofit and poorly considered solutions will not only threaten the building and the wellbeing of its occupants, but will also fail to deliver the expected carbon benefits.

> *Not all buildings can be retrofitted, and for some buildings and people there are more appropriate ways of reducing environmental impact than technical interventions*
>
> (STBA 2015)

POOR RETROFIT AND MALADAPTATION- INSULATION

Solid wall heat losses and the potential for energy saving Consequences for consideration to maximise SWI benefits: A route-map for change. Dr Elizabeth Milsom, BRE, 2016

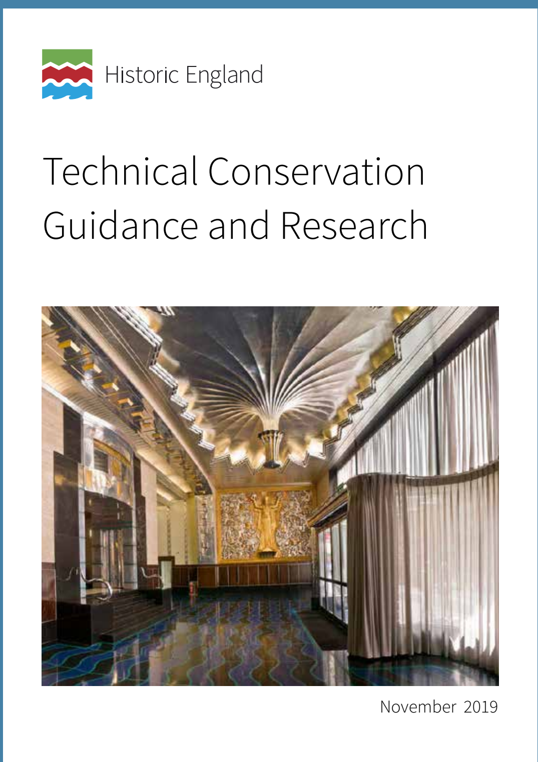
We are seeing an alarming increase in problems with old buildings which people are being persuaded to insulate. In theory, insulating a building sounds good. In practise, the moment you put something onto a wall, you prevent it breathing. You shift the Dew Point within the wall. You create condensation. You create a damp wall. For years they have been tanking and re-plastering in impervious materials to trap moisture. This then transmits heat very quickly, cooling the wall. Damp walls are cold walls. Damp houses are cold houses. It thus follows that internally insulating a house is fraught with danger. You need to really know what you are doing if it is to succeed – and there is very little research available to support internal insulation. **If in doubt, don't do it.**

External insulation is a different kettle of fish. The wall of your house is kept warm – so the dewpoint shifts to the outside. This means that moist warm air diffuses through the fabric, and can condense near the outside of the wall, between it, and the insulation. We've seen this a great deal now. The problem then is that water builds up into the wall, and eventually the base of your wall just gets wet and cold. You then start seeing 'damp' symptoms internally – mould, plaster coming off – and of course the house loses heat quickly through the wet wall. The end result is a colder and damper house than you started with. If there is a ventilated cavity between the insulation and wall, you may avoid the problem.

Source: BRE 2016

- The heritage sector must continue to signpost and share the rigorous research, evidence and guidance that the sector has developed and contributed to over many years. In addition, further research and evidence to supplement existing guidance on the embodied carbon of building materials suitable for different types of historic buildings is also needed. For instance, the guidance could review and compare the environmental impacts of different types of hygroscopic insulations, such as wood fibreboard, mineral wool, lime plasters with cork and hemp, etc.
- There is no consolidated guidance documentation available to practitioners for assessing the life cycle emission impacts of refurbishment options for historic buildings, either at the concept or detailed design stage. Although a number of different standards and guidance documents have been identified in this study for the different life cycle stages or for new buildings. Given that the greatest impact on emissions can be made early in the design process, the necessary guidance should focus on the concept-design stage. This should be based on current relevant guidance and research.
- The sector must ensure advice and guidance is freely available, easily accessible and appropriately targeted at key audiences.
- Partnership and collaboration are a vital part of disseminating and developing targeted advice and guidance. **There is currently a genuine need for a platform that brings together professional and industry bodies, policy makers, regulators and academics to share and provide guidance, research and information on what works and what doesn't work for buildings.**

> *"Achieving net zero carbon by 2050 is a difficult but critical target that we must all work together to address and as an industry we stand ready to respond."*
>
> Stephen Jones, Chief Executive of UK Finance



This brochure lists Historic England's technical conservation guidance and research reports on all aspects of the repair and maintenance of the historic built environment.

All advice and reports are free to download from the relevant sections of our website www.HistoricEngland.org.uk

Each publication can be opened by clicking on the thumbnail image, or the weblink at the foot of the page will take you to the relevant web site section.

The lateest technical conservation guidance and research reports are added throughout the year. To find out about the latest guidance go to Historic England's new Advice Finder www.HistoricEngland.org.uk/advice/find/

For more information about technical advice and research contact conservation@HistoricEngland.org.uk

4.4 Promoting sympathetic retrofit: skills and industry

> *"...the way new homes are built and existing homes retrofitted often falls short of design standards. This is unacceptable. In the long run, consumers pay a heavy price for poor-quality build and retrofit."*
>
> (CCC, 2019a)

- The Committee on Climate Change (CCC) has recommended that existing homes in the UK need to be retrofitted and that *"29 million existing homes across the UK must be made low carbon, low-energy and resilient to a changing climate"*. The scale of need is enormous and the demand for retrofit is likely to soar in the near future. This will bring great opportunities to reduce carbon in the historic environment, but it also poses risks.
- A key challenge is ensuring that the professionals who will be carrying out retrofit have the necessary skills and knowledge to work with building occupants and achieve a successful retrofit, avoiding maladaptation. The Committee on Climate Change concluded that the UK Government should use initiatives under the Construction Sector Deal to tackle the low-carbon skills gap (CCC, 2019d). New support to train designers, builders and installers is needed for low-carbon heating, energy and water efficiency, ventilation and thermal comfort, and property-level flood resilience (CCC, 2019d).
- The heritage sector will need to work closely with professional bodies, to address the availability of skills and disseminate the sector's knowledge base within industry.

The Roundhouse, Birmingham. The once-vacant building will be returned to use as a mixed-use leisure activity base and enterprise hub. © Historic England Archive

> *"There are significant problems with skills both in surveying, designing and installing retrofit measures as well as with supply chain issues. The STBA's Melin project in Wales funded through the BEIS Thermal Innovation Fund is highlighting just how difficult these issues are. Financial return on retrofit investment is a big problem for homeowners without any incentives. The Green Deal failed miserably to address this."*
>
> David Pickles,
> Senior Architect , Historic England

melin
together we can

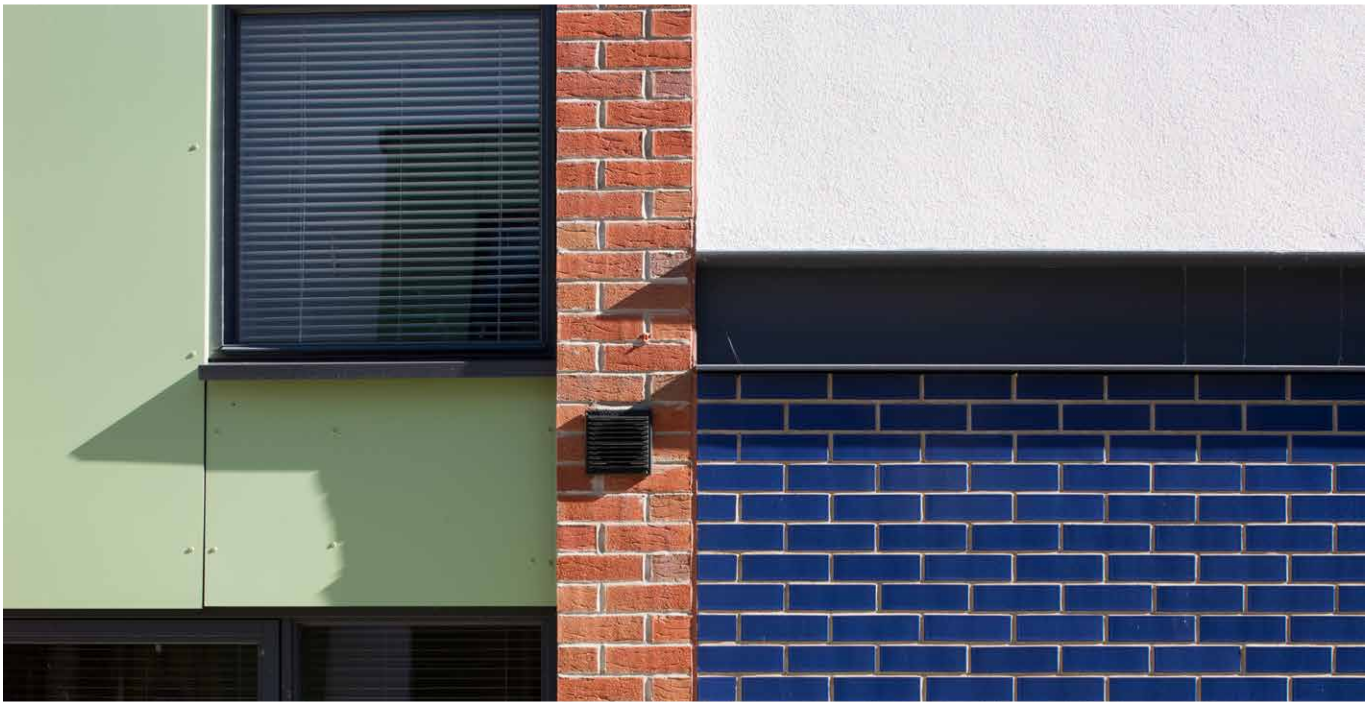
4.5 Empowering members of the public to become sophisticated low carbon consumers

> *People represent the least understood aspect of retrofit, and introduce the most uncertainty around effectiveness, making future work around lifestyle and behaviour change particularly important*
>
> (Lannon and Green, 2019)

- How we use buildings has a huge impact on the carbon emitted by buildings. The energy use of two similar dwellings, built side by side, occupied by different households, can vary widely.· A vital part of reducing carbon in buildings must therefore focus on enabling custodians of historic buildings to reduce their own carbon footprints by undertaking small and large changes.

- While evidence and guidance on reducing carbon in the historic built environment does exist, it is extremely difficult for non-technical consumers to navigate. The heritage sector needs to work closely with industry, policy, regulators and professional bodies to empower non-technical occupiers and custodians of historic assets to make the right decisions for themselves and their buildings. The sector must invest in people by developing easy access guides, action plans and user friendly tools to guide members of the public and custodians of the built historic environment in their low carbon decisions.

> *Solving the global climate change crisis is going to rely on, in one way or another, changing human behaviour*
>
> (Williamson et al., 2018)



Mixed materials used at the Paintworks, Bath Road, Bristol. © Historic England Archive

4.6 Demand and support longer lifespans for buildings

> *Retrofitting existing new homes is a UK infrastructure priority and should be supported by HM Treasury*
>
> (CCC, 2019d)

- The longer a building and its component parts last, the less embodied carbon is expended over the life of the building. To get the best use out of existing buildings we need to make sure they have the longest possible effective lives. This means that their materials and construction must also be long-lived and easy to maintain.

DURABILITY MATTERS: ARE TRADITIONAL MATERIALS THE NEW 'GREEN'?

Durability plays an important part of preserving our old buildings and living sustainable lives. The term means 'to endure' and symbolises longevity. The symbiotic relationship between conservation and sustainability mean maximising the use of existing materials and minimising waste.

Traditional building materials, if properly looked after, are inherently sustainable as they are durable and have the ability to resist wear and decay. Old oak beams used for structural support in medieval timber framed buildings are denser than new wood which makes them stronger, dimensionally more stable and have better resistance to wood rot. Plaster performs better to a modern drywall as it can sustain exposure to moisture which makes them naturally resilient and helps recovery after a flood.

Traditional building materials were often locally sourced making them less energy intensive in their supply. Cob buildings (made from locally sourced clay, straw and sand), common to Devon and Cornwall, are thermally efficient and have good compressive strength. However the lifespan of traditional materials is based on good care and maintenance.

The embodied energy of traditional building materials and their durability characteristics need more research

Soki Rhee-Duverne, Building Conservation Advisor, Historic England

- Regular repair and maintenance can reduce building obsolescence and increase the life spans of buildings and the individual components of buildings. Without regular maintenance small problems can soon escalate and risk permanently damaging homes if they're not tackled when they're first spotted. However, there are currently few incentives that encourage building repair and maintenance in the UK. In fact, some of our existing regulations and policies can be seen to actively discourage repair and maintenance. This is particularly true of the UK's current VAT system.

- VAT was first introduced in the UK in 1973. While all new construction and alteration work was zero-rated (0% VAT paid on works), repair work was standard rated VAT (20% VAT). In 2012, VAT on alteration work was changed from a zero rating to standard rating. VAT rules **arguably** penalise **owners** carrying out maintenance work that **extends the lifespans** of their buildings, **meanwhile VAT** supports demolition and new build, at great environmental cost.

- For a development to be counted as "new" and qualify for zero rating it has to be built from scratch and, before construction starts, *"any pre-existing building must have been demolished completely, all the way down to ground level"* (HMRC, 2019). The tax rules **generate inequality**. In the current VAT system if a property owner or developer plans to refurbish or convert an original building into much needed new homes, they find themselves having to pay VAT of 20%, making the houses more expensive compared to demolishing and building new. This is problematic in the context of the Heritage Counts research – demolition creates carbon. Carbon emissions from demolition account for as much as 7% of the total carbon emitted from a new building over 60 years.

- The VAT rules on construction are out of date and **do not support** the government's **aim** to hit its target to bring UK carbon emissions down to net zero by 2050. Changing VAT rules to encourage the re-use of buildings, and curtail the excesses of new construction, is the best way to start making a change and avoid future carbon emissions from buildings.

Terraced houses, Rochdale, Greater Manchester. © Historic England Archive

Friends' Meeting House, Pardshaw, Cumbria. A listed building constructed with traditional materials (wood).
© Historic England Archive

5. Conclusions

- Our built historic environment is part of our past, our present and our future. The decision to invest in historic assets and to protect, conserve and encourage their repair and maintenance has traditionally focused on their cultural and heritage values. In more recent years, the heritage sector has also highlighted the social and economic value of the built historic environment. This year, Heritage Counts examines the environmental values of heritage, particularly focusing on carbon in the built historic environment.
- **We cannot meet our 2050 carbon emission targets if we do not tackle carbon emissions in our existing building stock**. Buildings are the third largest carbon polluting sector in the UK. In England, the direct carbon footprint of buildings is larger than the combined emissions of the whole of Scotland and the whole of Northern Ireland. If we are to meet carbon targets, we urgently need to reduce emissions from buildings.
- This year's Heritage Counts research has demonstrated that **we can dramatically reduce carbon in historic buildings through retrofit**. Using two cases studies – a typical Victorian retrofit, and a bespoke ecclesiastical conversion with retrofit – the research shows that carbon emissions are reduced by more than 60% by 2050 as a result of the energy efficiency interventions. In the Victorian retrofit, carbon emissions are reduced by 53tCO_2e by 2050 – it would take ten years for a forest of 12,594 conifer trees to offset this carbon, this represents an area of approximately 5 ha or seven football pitches. In the case of the Chapel Conversion, 98tCO_2e of carbon emissions are saved by 2050 – it would take ten years for a forest of 23,288 conifer trees to offset this carbon, this represents an area of approximately 9.3 ha or 13 football pitches.

MODELLING THE WHOLE LIFE CARBON EMISSIONS OF BUILDINGS

> "*Buildings contribute to global warming over their whole lives: when we build, maintain, use and demolish them. The use phase gives rise to 'operational' emissions which, over the lifecycle of a building, have historically had a proportionately greater impact than the other phases, collectively referred to as 'embodied' emissions. However, government is increasingly regulating operational emissions through building standards, often by increasing the amount of materials in a building and, therefore, its embodied emissions. As a result, embodied emissions can now account for a very significant proportion of the lifecycle emissions of a building.* ***Failure to model the whole life of the building ignores these impacts and so we simply shift the problem from one part of the building lifecycle to another.***"

Prof Aidan Duffy,
Lecturer & Centre Manager: Dublin Energy Lab, TU Dublin

Traditional timber windows can have long service lives if well-maintained.. © Historic England Archive

- **Embodied carbon is a significant source of carbon that is largely overlooked, but can account for as much as a third of a new building's carbon emissions over a 60 year period.** If we are to design and implement the best overall opportunities for reducing the emissions of buildings, then the carbon emissions of all aspects of constructing, maintaining, operating, retrofitting, and demolishing buildings – that is the embodied *and* operational carbon emissions of buildings – must be addressed.
- Retrofit also generates embodied emissions, a typical retrofit such as the Victorian Terrace case study results in embodied carbon emissions equivalent to 2% of the total carbon emitted by the building over 60 years. The more bespoke Converted Chapel case study results in embodied emissions of nearly 10% - due to the large amount of materials used for this project.
- **The Heritage Counts research shows that when a typical historic building- the Victorian Terrace- is refurbished and retrofitted, it will emit less carbon by 2050 than a new building** – but only if the whole life carbon emissions of buildings, including demolition, are considered. For the Chapel Conversion, on the other hand, the new-build outperforms the Conversion in terms of carbon emissions. The derelict state of the building, the reconfiguration of the internal layout and the high specification resulted in a greater investment in products to bring the Chapel back into use and in high embodied carbon emissions. How we carry out retrofit - the measures selected, the materials used and how they are fitted – has a large impact on the whole life emissions of buildings.
- **We urgently need to tackle carbon in the built historic environment but we must get it right.** While our goals and needs are clear, the means and the pathways to success are complex. Every building is unique, every occupier has different demands from their buildings, every retrofit project is different, different materials contain different quantities of carbon. **Our approach to reducing carbon in the built historic environment must therefore be thoughtful, nuanced and evidence led.**

Metal window frames being installed at Shrewsbury Flaxmill Maltings, Shropshire. © Historic England Archive

RECOMMENDATIONS: MEETING NET ZERO

1. Climate change is the single most important issue of our time and buildings are a key source of greenhouse gas emissions driving climate change. The government, research councils, professional bodies and industry should **create a joint platform/ a centre for scientific research and excellence that aims to understand and share information, guidance and evidence on what works and what doesn't work for reducing carbon in buildings; in particular in existing buildings, which constitute 80% of all buildings that will exist in 2050.**
2. We must focus on using and re-using our historic assets to fully exploit the opportunities that already exist. If we re-use what is already here we can avoid emitting carbon - embodied carbon accounts for up to a third of the carbon emissions of a new building. Historic buildings are a constant source of new homes through conversion and change of use, but there are many assets that are under-used, vacant and at risk of demolition. **The heritage sector needs to identify and quantify the opportunities for re-use available in the built historic environment.**
3. We must count and measure carbon in buildings more accurately, only then will we take the right actions to reduce carbon in the built environment. **The design and development of an on-going data collection programme is needed to address the data gaps uncovered in this year's research.**
4. **The development of a Life Cycle Assessment methodology that can be applied to refurbishment projects for historic buildings** without the need for bespoke, technical research such as that of the Heritage Counts 2019 research is necessary if we are to make informed decisions on how to reduce carbon in the built historic environment
5. A whole building solution must centre on the users of buildings. To reduce carbon in buildings we must change behaviours of occupiers. This year's Heritage Counts research has highlighted how difficult it is for non –technical users to access the existing evidence base and information. The heritage sector will need to work closely with industry, policy, regulators and professional bodies to empower non-technical occupiers and custodians of historic assets to make the right decisions for themselves and their buildings. **Ready access to bespoke, non-technical information, advice and guidance is needed, as well as access to skilled professionals.**
6. We must encourage retrofit through guidance, advice, new research and innovative practices. The **heritage sector must continue to disseminate advice and guidance but must also work with partners to develop new dissemination channels and audiences for its best practice advice and guidance.**
7. We must encourage longer lifespans in buildings through refurbishment and repair and maintenance. However, the UKs VAT system disincentives refurbishment and repair and maintenance while incentivising new development. Current VAT rules on construction are out of date and stand in the way of reducing UK carbon emissions. **Changing VAT rules to encourage the re-use of buildings is the best way to start making that change to meet our 2050 targets.**

The climate change crisis demands a new approach to managing change to the built environment. **We must prioritise our existing buildings** by making refurbishment and re-use of existing buildings worthwhile, compared to knockingthem down. **We must move towards a whole life carbon approach for buildings to** ensure we make more holistic and sustainable decisions. If we do not count the whole life carbon of buildings we may meet carbon targets without actually reducing carbon emissions and thereby lose the war against climate change.

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Redhill Street Mill, Ancoats, Greater Manchester. New dwellings have been created by converting historic industrial buildings. © Historic England Archive

ACKNOWLEDGEMENTS

Heritage Counts is produced on behalf of the Historic Environment Forum by Historic England. This year we would like to particularly acknowledge and thank the following for their support:

Dr Meredith Wiggins, Historic England

Dr Robyn Pender, Historic England

Peter Cox, Carrig Conservation International

Caroline Engel Purcell, Carrig Conservation International

Aneta Nerguti, Carrig Conservation International

Prof Aidan Duffy, Dublin Energy Lab

Craig Ross, Royal Institution of Chartered Surveyors (RICS)

Carys Rowlands, Royal Institute of British Architects (RIBA)

Nigel Griffiths, Sustainable Traditional Buildings Alliance (STBA)

Emma Robinson, Historic Houses

Karl Creaser, previously Historic England

Desi Gradinarova, previously Heritage Alliance

Rachael McMillan, Historic England

Sally Embree, Historic England

Iain McCaig, Historic England

David Pickles, Historic England

Soki Rhee-Duverne, Historic England

Sarah Khan, Roger Mears *Architects*

And all those who provided case studies, sector updates, and indicator data.

Prepared and edited by Adala Leeson and Anna Kirkham, Historic England.

Product design by Vince Griffin, Historic England.

This document has been prepared as part of Heritage Counts 2019 by Historic England on behalf of the Historic Environment Forum.

February 2020 – Project Code: HE0031

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Front cover: View of terraced housing, Hebden Royd, Calderdale, West Yorkshire.

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