Climate-KIC

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Building Market Brief

United Kingdom

Climate Innovation Experience
Edition

Building Market Brief
United Kingdom

Prelude

In light of the necessary global transformation towards a low-carbon economy, the building sector is facing dramatic changes and dire need for disruptive innovations in the years to come. These changes come with risks as well as opportunities. A solid and regional specific understanding is needed to minimize the first and maximize the second when designing, investing in or implementing low-carbon solutions.

Global greenhouse gas emissions from the building sector have globally more than doubled since 1970. In Europe buildings are responsible for 40% of the energy consumption and 36% of the emissions. As such, a low-carbon transformation of the building sector, (deep) refurbishment of the existing building stock and a revitalization of the sector are key components of the EU Roadmap 2050.

With this European perspective in mind, one of the major barriers curtailing large scale investments into low-carbon technologies in the building sector is the lack of cross-country comparable market data. Such an overview would enable inventors, low-carbon technology suppliers and other key stakeholder to exchange know-how and transfer solutions across borders. As the building sector is commonly described as one of the most fractured and regionally colored industries - with very specific habits, traditions and stakeholder setups - this is often impossible.

It is exactly this gap of understanding and data availability that the Building Market Brief series addresses. On a limited number of pages, the condensed essence of a countries' building sector and its spirit is summed up and quantified with indicators aligned across countries. The series of reports provides a reliable basis for low-carbon innovation, investments and adoption, by offering a pan-European market understanding and providing comparable insights of the sector. It aims at documenting a holistic understanding, taken from multiple perspectives, market experts, models and statistical data. This information contributes to enable optimization, integration and scaling. We endeavor a sustained, collective effort to channel investments and behavior in a manner necessary to realize this low-carbon future of the building sector.

Therefore, we would like to address low-carbon innovation suppliers and entrepreneurs that look for suiting markets for their ideas or inspiration for their developments, but also investors and policy makers who would benefit from a better pan-EU overview, allowing for benchmarking and cross-country experience exchange.

I am confident that the information and insights provided by the Building Market Brief series contribute to the transformation into a low-carbon economy as one of the key challenges of this century.

York Ostermeyer
Editor in chief

Acronyms list:

2DS:	2-Degrees Scenario
BSM:	Building Stock Model
CCS:	Carbon Capture and Storage
CERT:	Carbon Emissions Reduction Target
CESP:	Community Energy Saving Programme
DH:	District Heating
ECA :	Enhanced Capital Allowance
ECO:	Energy Company Obligation
EMF:	European Mortgage Federation
EPBD:	Energy Performance Building Directive
EPC:	Energy Performance Certificate
EU(28):	European Union
EUROSTAT:	European Statistical Office
GBP:	Great Britain Poung
GDP:	Gross Domestic Product
GHG:	Greenhouse Gases
HDD:	Heating Degree Days
INDC:	Intended Nationally Defined Contribution(s)
KWh:	Kilo Watt Hours
LCA:	Life Cycle Assessment
MDB:	Multi-Dwelling Building(s)
MEPS:	Minimum Energy Performance Standard
NEEAP:	National Energy Efficiency Action Plan
nZEB:	nearly Zero Energy Building(s)
ONS:	Office for National Statistics
R&D:	Research & Development
RES:	Renewable Energy Sources
RS:	Reference Scenario
SDB:	Single-Dwelling Building(s) also called Single-Family Houses
SME:	Small and medium-sized enterprises
t CO_2eq.:	Tonne CO_2 equivalent
TJ:	Terajoule
UK CCC:	UK Committee on Climate Change
UN:	United Nations

How to use this report
How to read it and meta structure

This report is meant to provide an intuitive and reliable entry point for assessing the character of the construction sector in the addressed country. It is not necessarily meant to be read from the beginning to the end but rather to be used as an encyclopedia of facts and figures with links to complementary data sources if one wants to get more detailed information on a certain aspect. The structure of the report in independent subchapters enables the readers to start reading at any point depending on their needs and interests. Condensed information is provided from as many perspectives and sources as possible. This might lead to conflicting statements from different sources hopefully helping to communicate the complexity of the market rather than provide streamlined insights. This report is part of a series, one for each country. All reports follow a similar methodology, making all indicators listed comparable between countries. Even if not familiar with a certain indicator the knowledge on one market can therefore be used by the reader to put other markets into perspective. The structure of the reports also allows direct comparison. The readers will find the same indicator on the same page at roughly the same position in every report if it was available for the respective country.

This report is divided into three main chapters according to the methodology followed: **Chapter A**, a literature-based approach; **Chapter B**, a survey-based approach; and **Chapter C** a model-based approach. This structure is complemented by an executive summary and indicator factsheets in the beginning of each report.

Each of the chapters is divided into subsequent subchapters or sections addressing specific topic condensed in a 2-pager format. The main body of the text aims to highlight the most relevant information from the graphs and contextualize the data by explaining relevant frame conditions. For this purpose, the graphs and figure trends are listed side by side with absolute numbers in most cases. This aims to allow an easy perception of the development of a sector as well as to put trends into an absolute perspective, comparing relevance between countries. Specially highlighted numbers are also listed in the factsheet at the beginning of the report where they are sided with numbers form different fields to provide market characterization indicators.

The graphs in the report follow a color code. The color therefore indicates what kind of data is visualized in the graph, making the reading of the report as intuitive as possible.

The chapter's content is complemented by market expert comments and additional sources of information such as reports and data bases in the side bar of each page. The comments refer to opinions voiced by experts as a direct reaction to the report as well as in complementary workshops and interviews and are listed to provide a holistic view of the market as possible. Great care was taken to quote a wide array of opinions.

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Content

Executive summary

Economic framework conditions

The United Kingdom of Great Britain and Northern Ireland, e.g. the United Kingdom (UK), is an island nation that lies off the north-western coast of the European mainland. The UK has a population of 64.8 million (2015), or roughly 12.6% of the EU population. The nominal GDP of the country in 2015 was 2,580 billion EUR, and it grew at an average annual growth rate of 2.88% from 2005-15. In the same period its GDP per capita increased from €33,520 per capita (2005) to €39,769 per capita (2015) and the disposable income per capita grew at an average annual growth rate of +2.27% (Section A). The UK have a services-oriented economy (79.94% of the Gross Value Added in 2015 is contributed by the tertiary sector, followed by industry & manufacturing (16.7%) and agriculture (0.65%).

The monthly consumption expenditure per household grew by +17.95% in from 2005-15, while that spent on housing and energy grew by +23.78% in the same period, representing almost a quarter of the total household expenditure (24%) in 2015. There is a significant difference between income decile with the bottom 10% spending 9.7% on energy alone or being flagged as “energy poor” and not being able to heat their homes to comfort standards.

The construction sector of the UK accounts for over 6.1% of the British GDP. In 2015 totalling €160 billion, was spent on building construction expenditure. Since 2005 the total investments in building construction increased at an average annual rate of +2.1% per year (Section A5).

Household sizes have been relatively stable in the UK in the past 10 years, one-person households making up 28.7% and two-person households 36.2%. (Section A1)

The UK are considered as an innovative country which is ranked 7th in the EU 28 countries (European Innovation Scoreboard 2017). A rough 4.1% of total private equity investments (€343.2 million) in the year 2016 were made in energy & environment companies. (Section A1).

The structure of the building sector in the UK

The majority of UK building stock is in the residential sector (2,670 million m²), which constitutes about 77% of the total floor area which was about 3,467 million m² in 2015. The share of non-residential buildings is 23% of the total area which is a normal share compared to other countries. Roughly 16% of the total non-residential floor area is occupied by offices.

About 87% of the residential floor area consists of Single-Family Houses (detached, semi-detached or terraced houses). The residential floor area is also predominately privately owned (with a share of 83%) and 73% of the dwellings are owner-occupied. The social housing sector accounts for about 18%. (Sections A2 and A6).

The age distribution of the residential building stock shows a large share of old buildings, with about 67% being constructed before the 1970’s with a steady decline ever since. The construction faced a major drop from 2007, increasing this trend. Residential market has still not achieved the pace of transactions it had pre-2007, while non-residential transactions are back on track

The first set of prescriptive national building standards were introduced in the Building Regulations 1965. Later, The Building Act of 1984 introduced functional performance standards based on statutory guidance. The standards were revised and strengthened in 2010 with a scope for subsequent revisions in 2013 and 2016. The previous ambition of achieving zero-carbon standard has since been abandoned and currently there is no definitive strategy to align with the EU’s nearly zero-energy buildings requirement by 2020. (Sections A2 and A4).

In recent years, especially after 2000, the percentage of buildings that are low-carbon intensive has increased significantly. However, Buildings with less than 10 $kgCO_2$-eq per m² still only represent about 5% of the total floor area built after 2000. Moreover, there remains a significant number of buildings with high GHG emissions that needs to be addressed, as well as a share of buildings built in recent decades that do not meet the targets of a nearly Zero Energy Building (Section C1)

Policy framework and other demand side drivers

The UK's 2008 Climate Change Act puts into force the requirement to reduce GHG emissions to 80% of 1990 levels across all sectors within the UK by 2050 and that carbon budgets would be established for every 5 years to that date. As part of the act, the independent UK Committee on Climate Change (UK CCC) was established to set the budgets and design strategies that would achieve the budgets. The UK CCC also evaluates UK Government policies as to whether they are aligned with the 5-year budgets and where shortfalls in policy need to be addressed.

The current budget for the UK is the 'Fifth Carbon Budget', which set a 26% reduction in the UK's net carbon emissions from 2016 to 2030. When accounting for the potential of the UK being a net seller of allowances in the EU ETS, these reductions are estimated as 36% reduction in net carbon emissions from 2016 to 2030. For the building sector, over this period, the budget reduction to 2030 is 89 $MtCO_2$-eq, or a 20% reduction in 2016-2030. The UK CCC have outlined a possible package of measures to deliver these reductions, which include: insulating all lofts by 2022, all cavity walls by 2030, and 2 million solid walls by 2030; improving new building codes with improved performance requirements for fabric (aligned with former Code for Sustainable homes: roof/walls: 0.13 $W/m^2/K$ and windows 1.0 $W/m^2/K$); installing 2.5 million heat pumps in homes by 2030; and installing 40 TWh of low carbon heat networks (~3 million homes). The UK's Clean Growth Strategy has set the focus for energy and carbon emission reduction policies for the current government. Within the Strategy, energy efficiency and low carbon heating is a priority for new and existing buildings. This includes retrofitting as many homes as possible across the UK to be EPC band C by 2035 (where 'practical, cost-effective and affordable'); that all fuel-poor homes as possible to reach EPC band C by 2030; that as many privately rented homes as possible to reach EPC band C by 2030; and that as much social housing as possible to reach EPC band C by 2030.

Further, the gradual warming up of temperatures has resulted in the reduction of Heating Degree Days (HDD) in the UK. They have reduced by 9.7% since 1980 (by2009). In the future increased heating in summers will result in more demand for cooling. These have decreased by 15.5% (2009) since 1980. Therefore, there is a potential of substantial reduction in heating energy demands in the country, giving way to increase in cooling energy needs. (Section A2).

Growth in energy demand and related carbon emissions are not so much driven by change of household sizes but rather creation of new residential space. (Section A1). Considering the current trends, a net addition of 27% to the floor area by 2050 is expected (according to the modelled results). This increase is also driven by an increase in the demand for floor area per person. Refurbishment of the existing stock is projected to be an on-going process up to 2050 (Section C4). This increase is mainly driven by a growing population (+15% in 2050) and, to some extent, by an increase in the demand for floor area per person. Refurbishment of the existing stock is projected to be an on-going process up to 2050 when most buildings will be partially or comprehensively refurbished (Section C4).

Demand side energy, carbon and market trends

Although population and floor area are expected to grow, final energy demand for heating, hot water, and ventilation (including ambient heat) is expected to be 17% lower than present values in in 2050 under current and decided policies (what is called in this report the Reference Scenario1). With more stringent policies and regulations (the 2-Degrees Scenario2), the reduction would reach more than 34% by 2050 (Section C3)

The main driver responsible for this reduction are government efforts to upgrade existing buildings, aiming at as many homes as possible to achieve at least EPC C by 2035. For new construction, the trend towards improving energy performance is being driven through incremental improvements to building regulations. Although no concrete strategy exists for implementing the nearly-zero energy buildings requirements set by the European Commission, the devolved administrations of Scotland and Wales have indicated they will likely pursue these policies through adoption of more stringent energy performance standards. England and Northern Ireland have not yet indicated actions towards this policy (Section A4 & C3).

The implementation of these plans will also demand a shift towards more efficient building technologies and low emission heating system. Heat pumps and other renewable energy sources such as district heating, are expected to compensate the demand for fossil fuels that will no longer be attractive (also due to carbon pricing) when retrofitting or building new.

From the market perspective, this transformation of the building stock will translate into an increasing demand for more efficient buildings but also for energy with a lower carbon intensity. A relationship between house values and their Energy Performance Certificate (EPC) rating can already be observed. Prices can vary by 5% or even 10% from the lowest to the highest rating bands (Section A6). Decarbonized energy will also remain an important area of market transition, with more low carbon heat being seen as an attractive investment for supplying existing housing energy demand.

According to BSM calculations, the total market volume of the energy- and GHG-related building market amounts to €57.6 billion per year in 2018 (Section C5). The largest share of this market volume comes from energy sales (€23.7 billion per year), even though electricity sales for household appliances are not included. This volume is expected to be more or less stable in the medium and long term despite growth in population and floor area as the increase in energy prices compensate the stagnation or reduction in energy demand (due to more efficient buildings). The remaining percentages are split between the building envelope (€22.3 billion per year) and building technology (€11.6 billion per year). Both volumes are expected to increase in the short term only in the 2DS driven by an increase in the refurbishment rate and a shift to renewable heating (e.g. heat pumps) and RES (Section C6 &C7).

In the long term, all volumes level out again compared with present values. For energy sales, a higher rate of refurbishment in the 2DS results in a lower energy demand that is only compensated for by the shift from cheaper gas to more expensive electricity through the increased share of heat pumps. The reduction on the envelope market volumes is partially explained by the decrease on partial refurbishments (usually linked to replacement of old elements) but also by the reduction in new construction driven by the expected stabilization and even slowdown of the growth of the floor area per person after 2030. Decreased construction activities, also impact the market for building technologies, which suffer from further reductions due to decrease in installed capacities for heating systems and cost reductions, especially for heat pumps.

The growth in dual and single person homes remains one of the most important drivers in the demand for housing going forward. The number of persons per household have dropped, with currently more than 28% of households being of a single person. The rate of owner-occupied households has not from 63% over the past 10 years, there has been a growth in more outright owners while the proportion of those buying with a mortgage is down, which follows the trend in wealth accumulation among baby boomers. There has also been a drop in the number of owner-occupied households for those aged 25-44 years old.

Continued support for first time buyers remains with the UK's buying schemes that provide access to reduced interest rates (e.g. Help to Buy) and sales tax (e.g. stamp duty) exemptions. The housing market continues to be strong in London and the South East, though has experienced recent downward pressure in pricing due to the political climate and the negatiations with the European Union.

The supply side: construction sector and technology providers

The supply side in the UK, particularly architects, engineers, planners and other stakeholders, consider that upgrading the envelope fields the biggest opportunities for improving the energy performance of existing buildings and educating the user in case of new buildings. In both case building automation and smart metering is seen as a complementary technology with huge potential (Section B2 & B3).

In the UK the interaction between the architect and the client on key decisions is in the centre of construction and planning processes. In larger projects this is overtaken in significance by the communication between the architect and specialized consultants, with the client and the architect deciding more on the general strategy. There is a good agreement that the need to deliver lower carbon projects in the future is a driving the architects and engineers to evolving their roles to meet this need. Social media a seen to play a key role to inform especially decisions on smaller buildings when involvement of specialized consultants is rare. (Section B4).

There is an increasing interest in low carbon innovation in the UK market, driven by the interest in saving energy and costs as well as technical reasons resulting from an outdated stock that needs to be upgraded to current standards. In larger projects there is a complementary desire to promote the project with ambitious sustainability goals. On the downside there is a mayor deficiency in funding mechanisms for this trend perceived across all stakeholder groups. This is complemented by a shortage of integrated design strategies for delivering high performance dwellings, with many of the sectors lacking the skills to meet passive design standards or install high performance technologies (Section B5)

To respond to this situation the UK government has focused its efforts on improving the minimum energy performance standards for private rental sector from 2018 to achieve a minimum of EPC band E, increasing the band C by 2030. It will also increase the performance requirements for the non-rental sector for 2034/35, though no plans have been announced as to how these targets will be achieved.

From the perspective of supply-side stakeholders, the most effective drivers for low-carbon technologies are tailored policies and mandatory standards for new buildings and refurbishment, flanked with extensive professional education and simplification/ standardization of solutions to match the UK's history of building codes based on implementing modular solutions, added up in a point code to reflect a buildings energy performance rather than being based on a energy demand model. (Section B7).

Conclusion and outlook

The climate policies adopted by the UK government remain among the most ambitious in the EU and will be a driving force in changes to improve the energy performance component of future building codes and setting of requirements to retrofit the existing building stock. These policies focused on existing and new buildings, accompanied by necessary financial instruments, will drive the low carbon transformation of the UK's housing stock.

As of yet, there remains only limited concrete proposals as to how the UK government will meet the ambitions of the Clean Growth Strategy of moving as many houses as possible to EPC band C by 2035 and the GHG emission reductions set out in the Fifth Carbon Budget. Further, meeting these ambitions will necessitate significant investment in existing building performance and low carbon heat and power. Doing so will also require a focus on improving the existing skills of delivering high quality retrofits and new building construction, along with greater awareness and uptake of low carbon heating and power technologies.

A

Market overview

A

Aim

Chapter A intends to provide an overview of the country's building market, its frame conditions, trends and market mechanisms for the demand of low carbon products and solutions. It does this by providing a brief introduction of the country´s economy and society as well as a characterization of the building stock and influencing climate factors. Energy and climate goals of the country are also synthesized, which include grid mix, emission factors and implication of climate goals. This is followed by an overview of the current framework of standards and support measures. Investments and employment in the construction sector are finally depicted.

This chapter is based on an extensive literature study. The sources cover a wide rage including European statistical data, the respective countries own statistical office, national and international public reports, scientific publications and market information such as prices and sales volumes. The main contribution is, therefore, collecting and summarizing this information, though readily available present in a fragmented manner. All data sources are clearly marked to allow the reader accessing more detailed information as needed. The complete list of sources can be found in the annex of the report.

A1 Introduction
United Kingdom's economy and society

USEFUL READING:

PWC 2017. UK Economic Outlook. PWC.
www.pwc.co.uk

NOTE

The GDP figures and growth rate calculations are in current EUR.

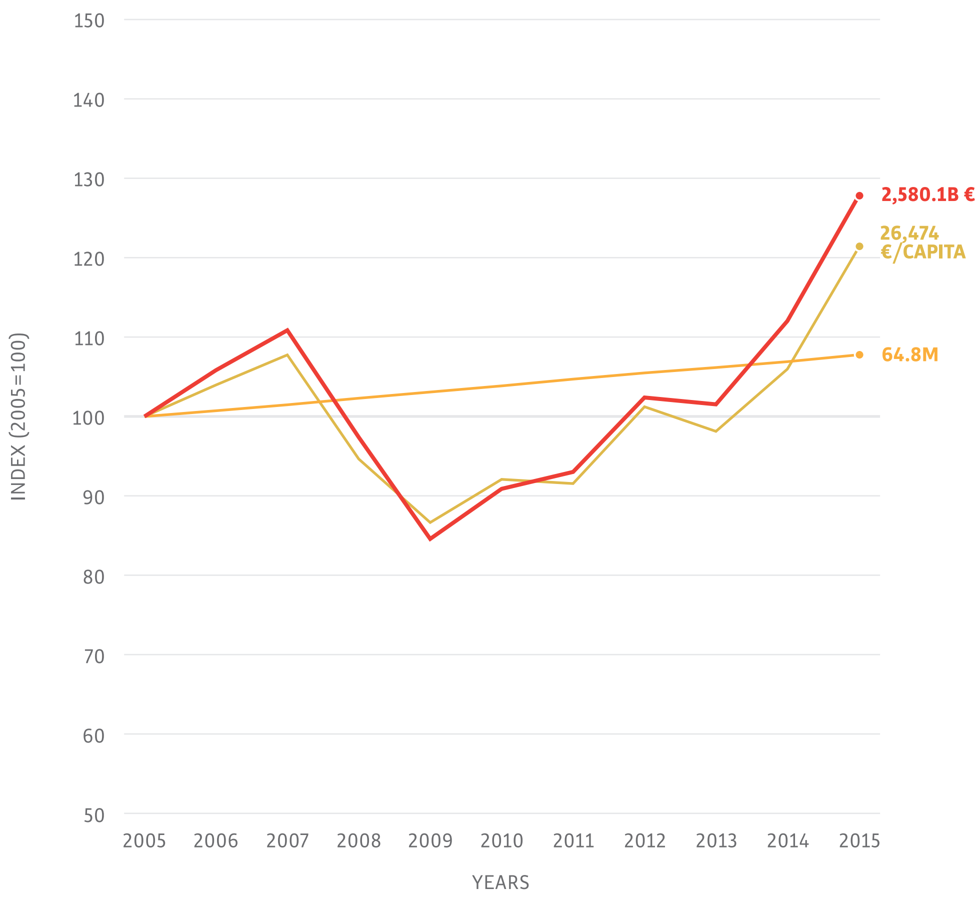
The GDP of the United Kingdom (UK) grew at an average annual rate 2.88% from 2005 to 2015, standing at € 2,580 billion in 2015. During the same period, gross disposable income per capita grew at an average annual rate of 2.27% and stood at € 26,474 (in current €) in 2015, whilst GDP per capita increased from 33,520 €/capita in 2005 to 39,769 €/capita by 2015. The population grew at a rate of 0.75% annually to stand at 64.8 million in 2015[1 2].

A1.1 – *Trends in UK's GDP, disposable incomes and population.*

Due to recent political and economic events (Brexit), UK's GDP is expected to slow down, along with slow growth in consumer spending and damp investments. Although with a weak pound, exports may be boosted.

Sources:
EUROSTAT

Notes:
GDP index depicted in the graph is in current €.



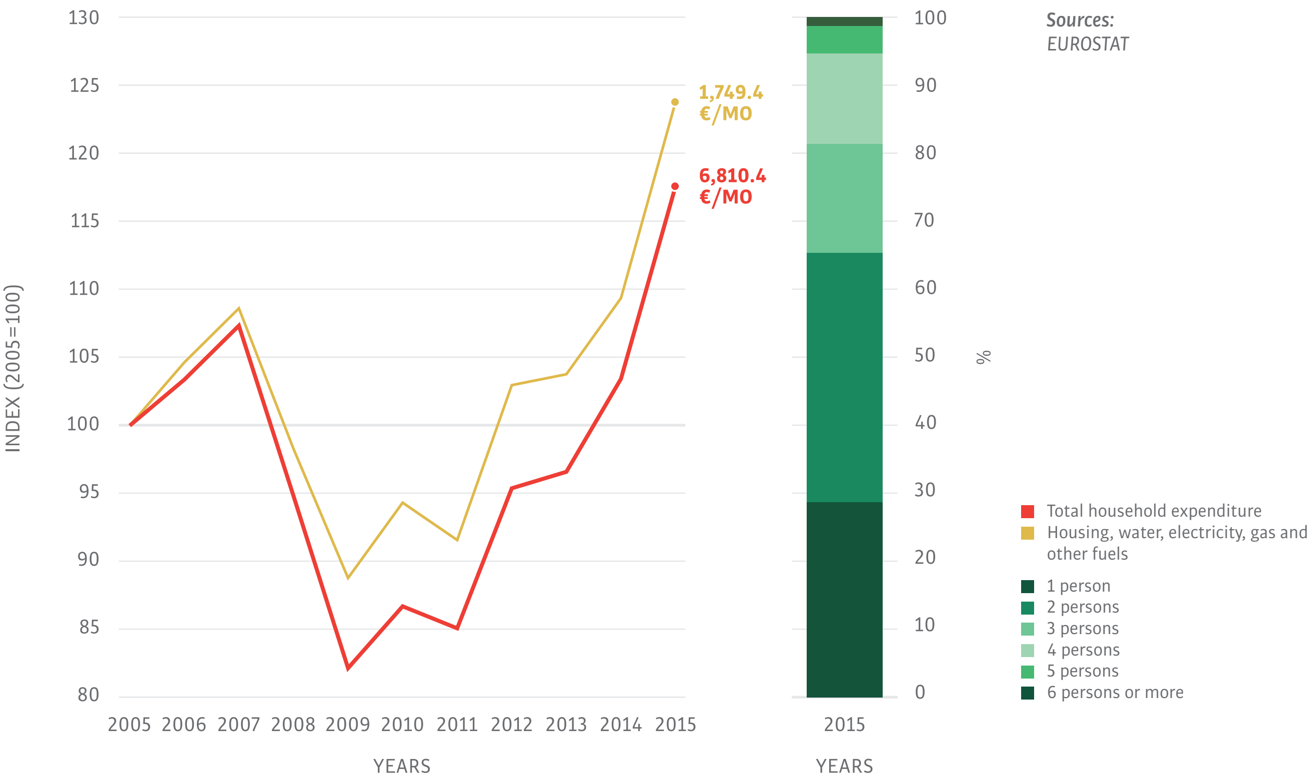
In export and trade, the UK's services sector has seen its trade surplus improve substantially, rising from an average of 1% of GDP in the 1990s to over 4% in the past decade. By contrast, the trade deficit in the UK's trade in goods has increased from an average of 2% of GDP in the 1990s to over 6% in the past decade[3]. The services sector contributed 79.3% of the value added in 2015, industry 14%, manufacturing 10% and agriculture 0.6%[4]. Overall, SMEs had a share of 52.1% in terms of value added, constituting 99.7% of total UK enterprises and accounting for some 53.6% of employment[5]. In 2015, about 1.67% of GDP was spent on R&D in the UK, compared to the EU28 average of 2.03% in the same year[6]. UK is grouped amongst the 'Innovation Leaders' in the European Innovation Scoreboard 2017, with relative strengths in the areas of human resources, attractive research systems, and employment impacts[7].

The Global Cleantech Innovation Index 2017 ranked the UK 7th in cleantech performance amongst a group of forty companies[8]. In 2014, and in 2014, the UK was ranked 6th in the same index. The country fields impressive scores in the both early-stage and later-stage financing activity and therefore also performs well in demonstrating emerging cleantech. Roughly 4.1% of total private equity investments (€ 343.2 million) in 2016 were made in energy and environment companies, whilst in 2015, the figure was an impressive 8.6% (€ 1093.2 million)[9].

Monthly household consumption expenditure grew by 17.59% from 2005 to 2015, whilst that spent on housing and energy grew by 23.78%, representing an annual average increase of 2% and 2.44%, respectively. Within these overall figures, the budget spent on energy varied considerably between different income deciles. In 2015, the top 10% of the households spent 2.9% of the household budget on housing energy, whilst the bottom 10% spent 9.7%, the average coming to 4.4%[10]. As a proportion of total consumption, housing and energy expenditure showed a marginal increase from 24.4% in 2005 to 25.68 in 2015[11].

***A1.2** – United Kingdom households witnessed a dip in single-person households between 2005 and 15. In 2015, 64.9% of households were one- and two-person households.*

The total household expenditure is roughly 61.22% of the GDP, while that on housing and fuel a 15.72% of the GDP.



Sources:
EUROSTAT

From 2005 to 2015, the UK witnessed a drop in the proportion of one-person households, for whilst 31% of households were one-person in 2005, only 28.7% were in 2015. Two-person households, by contrast, increased in proportion from 34.7% to 36.2%. Combined, one- and two-person households comprised 64.9% of total households. In 2016, married or civil-partner couple families remained the most common family type in the UK, although cohabiting couple families have been the fastest growing family type over the past 20 years[12].

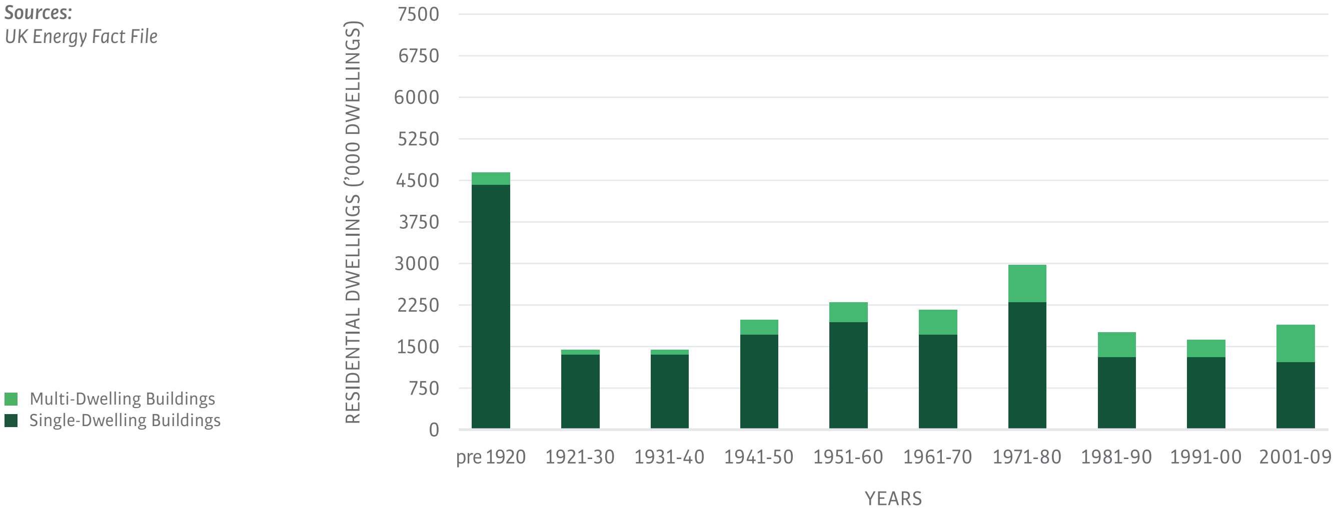
A2

Building stock
Building characteristics and influencing climate factors

The UK contains 27.8 million dwellings[13]. Over 65% of residential dwellings were constructed before the 1970s, with a steady decline in new construction ever since. Housing sales transactions in the UK nosedived in 2007 (from 1.6 million in 2007 to 0.9 million in 2008), and whilst they have been gradually recovering since, the residential market has still not achieved its pre-2007 pace of transactions. Non-residential transactions, however, are back on track[14]. Similarly, the housing supply peaked in 2007–08 and has declined since, with a gradual recovery[15]. An increasing number of one-person households has added to the demand for housing, which the supply is still unable to meet[16]. The average useable floor area per dwelling in 2016 was 94 m², with homes in the private rented sector being slightly larger (77m²) compared to those in the social rented sector (66m²), with owner-occupied homes being the largest (107m²). Housing in the UK can be divided into terraced (28%), detached (26%), and semi-detached (25%), with flats comprising the remaining (21%).

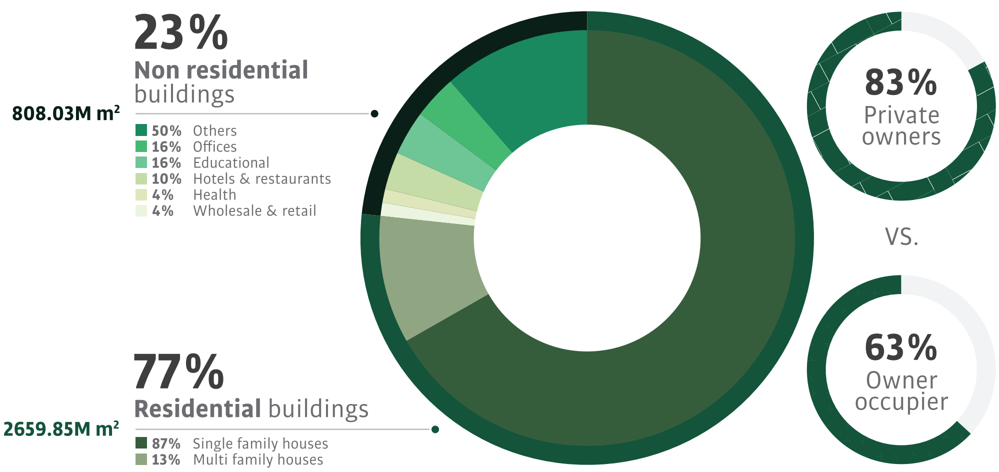
A2.1 – *Trends in residential building space.*
Single family dwellings are still the preferred type of residences in the UK.

Sources:
UK Energy Fact File



A2.2 – *Breakdown of the building stock.*

Sources:
Source: EU Building Observatory, Entranze, CUES Analysis



In the UK, the residential stock accounts for 77% of the total floor area of 3,467 million m², whilst non-residential stock comprises 23% of the total. Around 87% of residential dwellings are single-dwelling building, whilst the remaining 13% are multi-dwelling. In the non-residential sector, 16% of the space is occupied by offices, followed by educational institutions (16%) and hotels and restaurants (10%). The UK has a high number of owner-occupied residences at some 73%, whilst social dwellings comprise 18% and private tenants 9%. Home ownership is, however, witnessing a gradual decline due to the increasing gap in between earnings and housing prices giving way to private rentals[17].

Along with changes in the socio-economic situation, the evolution of the UK's building stock will be influenced by climate change. Events such as flooding, heat waves, extreme temperatures, and so on will create significant room for improvement and opportunities to design buildings that are resilient to climate-related vulnerabilities. The gradual increase in temperatures has resulted in the reduction of the number of HDD's in the UK by 9.7% from 1980 to 2009[18]. In the future, increased heating during summers will result in a corresponding demand for cooling. Therefore, a potentially substantial reduction in heating energy demands will give way to an increase in cooling energy needs.

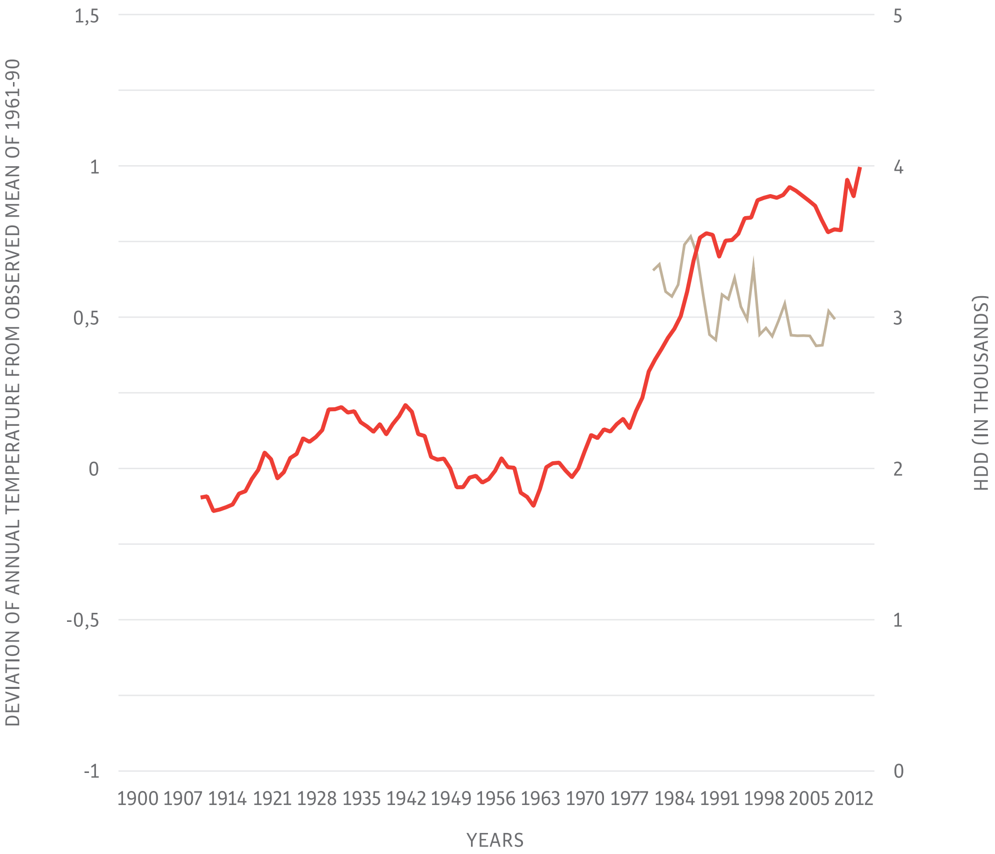
NOTE

(HDD) is an indicators to quantify the heat energy demand for a building. It is the number of degrees that a day's average temperature is below a base temperature, below which buildings need to be heated.

USEFUL READING:

London Climate Change Partnership 2002. The Impacts of Climate Change on London.
www.ukcip.org.uk

A2.3– *A period of constant warming.*
Substantially reduced heating demand due to increasingly warmer mean temperatures.



Sources:
UK Met Office, EUROSTAT

Climate change is expected to alter the state of the construction industry and therefore the building stock in the UK, and all potential climate change impacts should therefore be considered when designing new buildings, and appropriate contingency measures should be put in place to manage environmental risks.

USEFUL READING:

BPIE 2014. Renovation strategies of selected EU countries. Buildings Performance Institute Europe, Brussels.
www.bpie.eu

BPIE 2011. Europe's buildings under the microscope. Buildings Performance Institute Europe, Brussels.
www.bpie.eu

A3 Energy, emissions, and climate goals

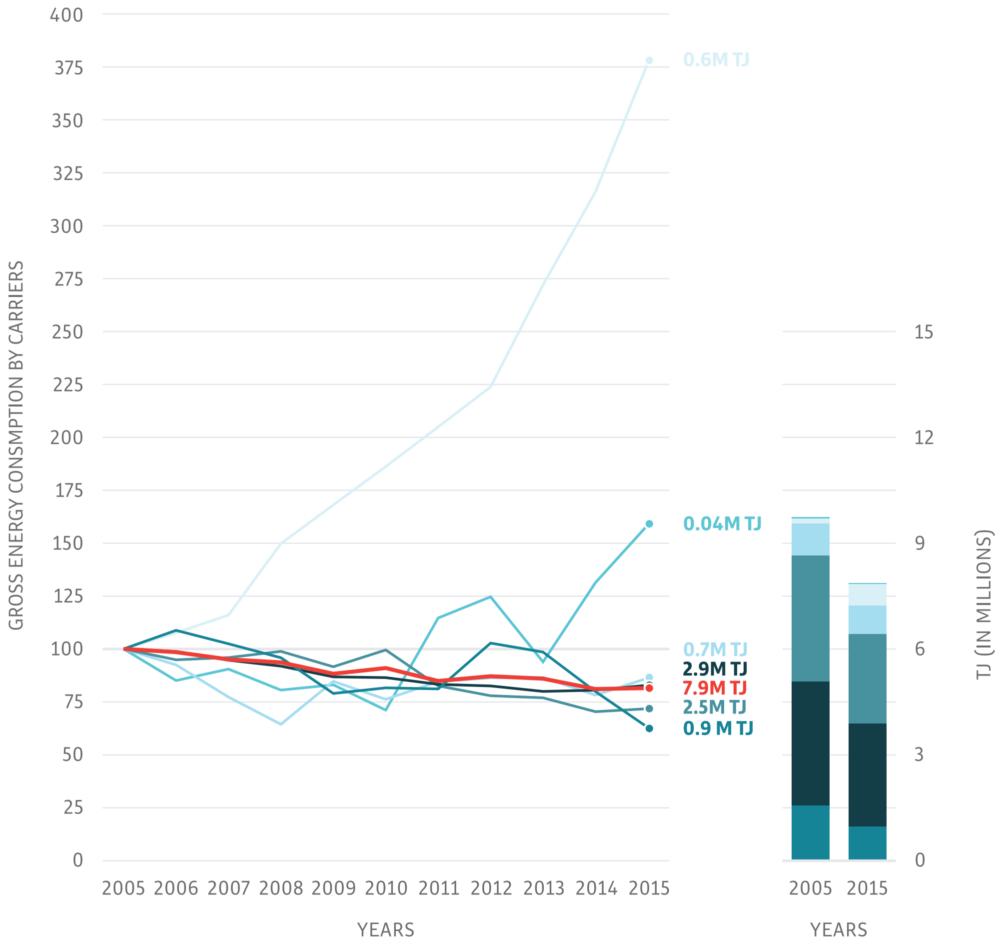
Introduction to the energy mix, emissions profiles, and the implications of climate goals

The UK's energy mix is heavily fossil-fuel dependent, with 36.7% of energy coming from fossil fuels, followed by gas at 32.1% and solid fuels at 12.5%, then nuclear and renewable energy[19]. Gross inland energy consumption has declined at an average annual rate of 1.98% from 2005 to 2015. During the same period, the percentage of renewable energy in gross energy consumption rose from 1.3% in 2005 to 8.2% in 2015[20]. The UK's low-carbon transition plan of 2009 envisages generating 40% of electricity from low-carbon sources by 2020, including 30% from renewables[21].

A3.1 – *A decade since 2005, UK's total gross inland energy consumption decreased by -18.54%.*

The government has intends to deploy three low-carbon technology pathways: renewables, nuclear and carbon capture and storage (CCS). As part of its EU obligations, the United Kingdom must obtain 15% of its final gross energy consumption from renewable energy sources by 2020.

Sources:
EUROSTAT



Total Petroleum Products
Solid Fuels
Gas
Waste (non-renewable)
Nuclear Heat
Renewable Energies
All Products

MARKET EXPERT COMMENT

In 2017 the electricity grid emissions were 0.35 kg CO_2eq/kWhelec, down 15% from 2014 due to a significant reduction in coal generation and an increase in renewable generation in 2015.
- Ian Hamilton

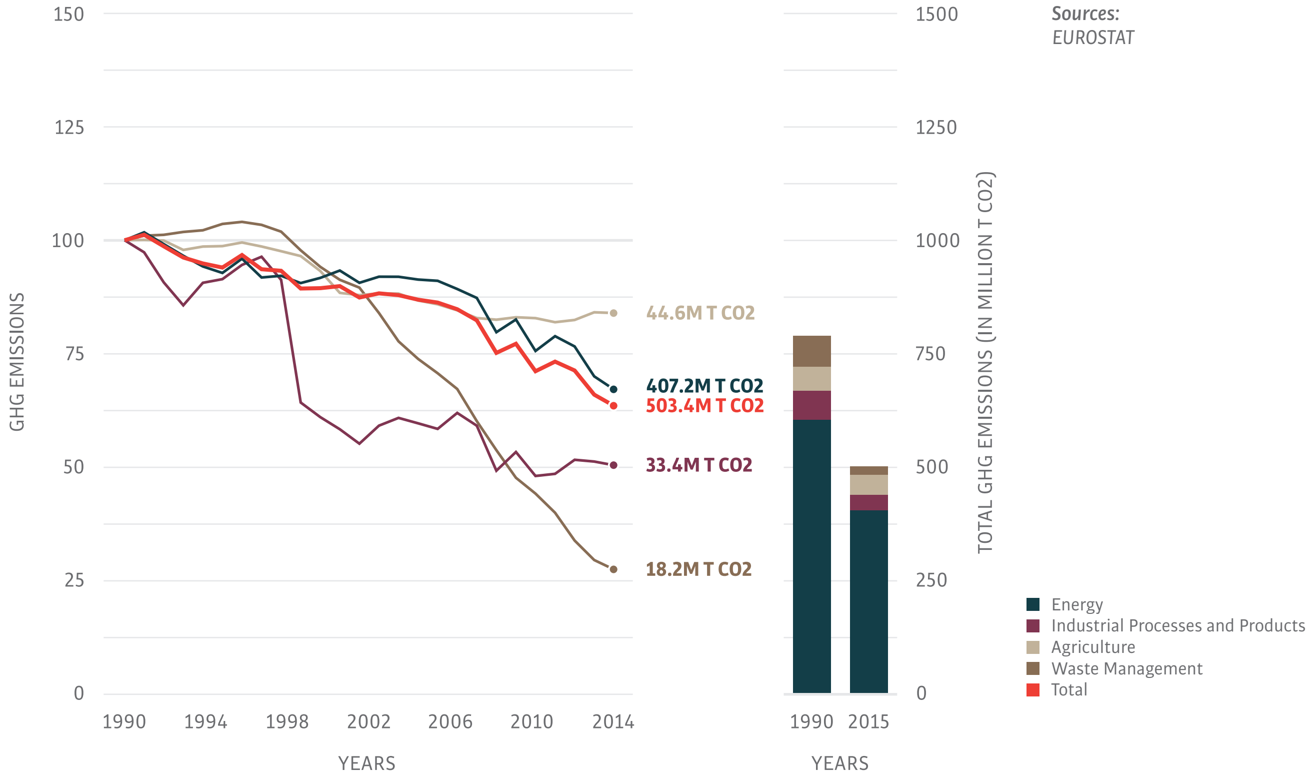
The UK consumed 302,850 GWh of electricity in 2015 (compared to 348,878 GWh in 2005) with residential electricity consumption constituting 108,157 GWh in 2015 (31% of the total). United Kingdom household energy consumption is dominated by gas (62% in 2015) followed by electricity (25.5%),[22] the latter of which is powered by a high proportion of gas (30%) and coal (22%), followed by nuclear power (21%)[23]. The resultant emission factor is 0.412 kg CO_2eq/kWh[24]. The average electricity price for medium size households in the UK was around 0.2125 €/kWh_{electr} and that for mid-size industry was 0.1184 €/kWh_{electr}[25].

In 2015, the UK's residential energy consumption was around 1.52 million TJ, or 27.6% of total energy consumption.[26]. Space heating was the dominant use (68.5%), followed by lighting and appliances (17.2%) and water heating (12.1%). The fuel used for space heating is pre-dominantly gas (75.7%), followed by electricity (8.7%), and in water heating, too, gas was the pre-dominantly fuel (74.4%)[27]. The renewable energy share in heating and cooling was 5.5% (2015), up from 0.8% in 2005,[28] which results in an average emissions factor of 0.20 kg CO_2eq/kWh$_{heat}$. Heat energy prices for gas range between 0.34 GBP/kWh$_{heat}$ - 0.40 GBP/kWh$_{heat}$[29].

The energy consumed by households and commercial institutions together constitutes the emissions attributable to buildings (84.88 Mt CO_2 eq. in 2015), which is over 16.85% of total emissions. Since 1990, building sector emissions have fallen by 19.64% at an average annual rate of -0.55%.[30].

***A3.2** – Since 1990, UK's total direct CO_2 emissions decreased by 36.55% while building sector emissions reduced by 19.64%.*

UK's total emissions decreased considerably due to the slump in coal usage and increase in renewable power. It was 503.5 Mt in 2015, down from 793.55 Mt in 1990. The emissions per capita in 2015 was 8.28 t CO_2eq/capita.



Sources:
EUROSTAT

SSince 1990, the amount of residential building space to be heated has increased along with the population (from 57.15 to 66.87 million); despite this, however, overall emissions have declined. The slump in coal usage and the simultaneous increase in the proportion of gas and renewables in use are a few influencing factors.

By 2012, the UK reduced GHG emissions by 26.8% compared to 1990 levels, exceeding its Kyoto Protocol Phase I target of 12.5%. As per the Climate Change Act of 2008, the UK has laid out unilaterally binding targets of cutting GHG emissions by at least 34% by 2020 and 80% by 2050, compared to 1990 levels. As per the act, it sets carbon budgets, of which the fifth (2016) sets a target of 57% emissions reduction by 2030[31 32 33]. In July 2009, the government published the strategic Low Carbon Transition Plan, which established policies and proposals to meet carbon budgets, to which end the government set out sector-specific targets and benchmarks[34]. Recently, the UK Government submitted its INDC (along with that of the EU) to the UN in accordance with the Paris conference[35].

A4

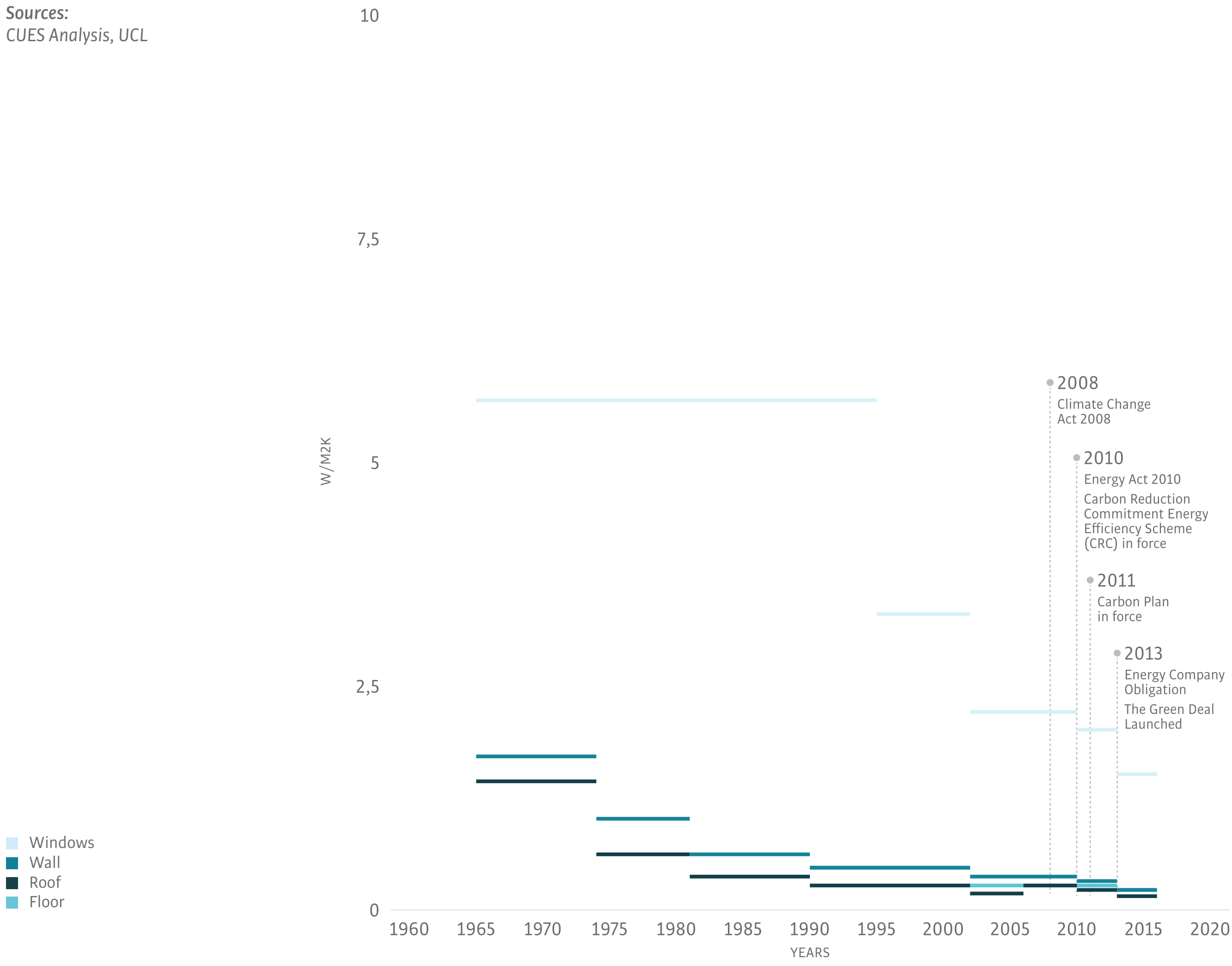
Policy framework
Building sector norms and a legal framework

The United Kingdom's Climate Change Act (2008) targets a GHG emissions reduction of at least 34% by 2020 and 80% by 2050 (compared to 1990 levels), as well as the meeting of five-yearly carbon budgets. The UK's EU obligations require 15% of gross energy consumption to be from renewable sources, which aligns with the country's decarbonisation efforts, for which it has outlined three broad pathways: renewables, nuclear power, and carbon capture and storage (CCS). The government has ambitiously committed 1 billion GBP in funding to the development and commercialisation of CCS so that it can be deployed by 2020,[36] though this later revised to scale in 2030.[37]

In the UK, buildings are the second largest end-use sector in terms of energy, after transport, and its building stock is some of the oldest in Europe, though an average new home built in England requires about half as much energy per square metre as the average existing home.[38 39 40] In 2012, the UK Government launched its Energy Efficiency Strategy, which was subsequently updated in 2013. Its Energy Company Obligation (ECO) scheme is still ongoing, and a series of other measures have delivered energy efficiency gains in buildings.

A4.1 – *Trends in building standard evolution.*
Building standards have over the period of time become stringen.

Sources:
CUES Analysis, UCL



Building Standards

The first set of prescriptive national building standards was introduced in the Building Regulations of 1965. Later, The Building Act of 1984 introduced functional performance standards based on statutory guidance.[41] The standards were revised and strengthened in 2010, with subsequent revisions occurring in 2013 and 2016.[42] The previous ambition of achieving a zero-carbon standard has since been abandoned, and currently, no strategy exists to align the UK with the EU's nearly zero-energy buildings by 2020 requirement. Due to new building and insulation retrofitting, the number of homes with cavity wall insulation increased from 47% in 2007 to 69% by 2016, the number with loft insulation of at least a 125-mm thickness increased from 44% in 2007 to 66% by 2017, and the number with whole-house double glazing increased slightly from 80% in 2007 to 81% in 2017.[43] Energy Performance Certificates are required for the sale, rent, or construction of a building.

Financial Support Measures

In 2013, the UK Government introduced the Green Deal, its flagship programme for building refurbishment alongside the ECO. The ECO requires energy suppliers to improve household energy efficiency by investing in energy efficiency measures and passing the costs on to the bill payers. In the Green Deal, loans were used to implement energy efficiency measures in properties and were paid on the basis of money saved on energy bills. Due to its complexity, slow uptake, and high interest rates, funding for the Green Deal Loan Programme was discontinued in 2015.[44] The ECO was preceded by the Community Energy Saving Programme (CESP, 2009), which established quantified targets for reducing carbon and fuel poverty in the most deprived areas of the UK. Prior, in 2008, the Carbon Emissions Reduction Target (CERT) Program obliged large energy suppliers to help households reduce their emissions.

The Energy Act of 2011 also required private landlords to make reasonable energy efficiency improvements requested by tenants by 2016 and, by 2018, to improve the least efficient properties to a minimum of energy efficiency rating of E before rental. The most recent Clean Growth Strategy establishes an ambition for all fuel-poor households to be living in at least EPC-C residences by 2030 and for as many homes as possible to achieve at least EPC-C by 2035.[45] The Carbon Trust grants zero-interest loans for energy efficiency investments to industries, as well as managing the Enhanced Capital Allowance (ECA) scheme. This scheme encourages businesses to claim 100% of their first-year capital allowance on the purchase of qualifying energy efficiency plants and machinery.[46]

A5

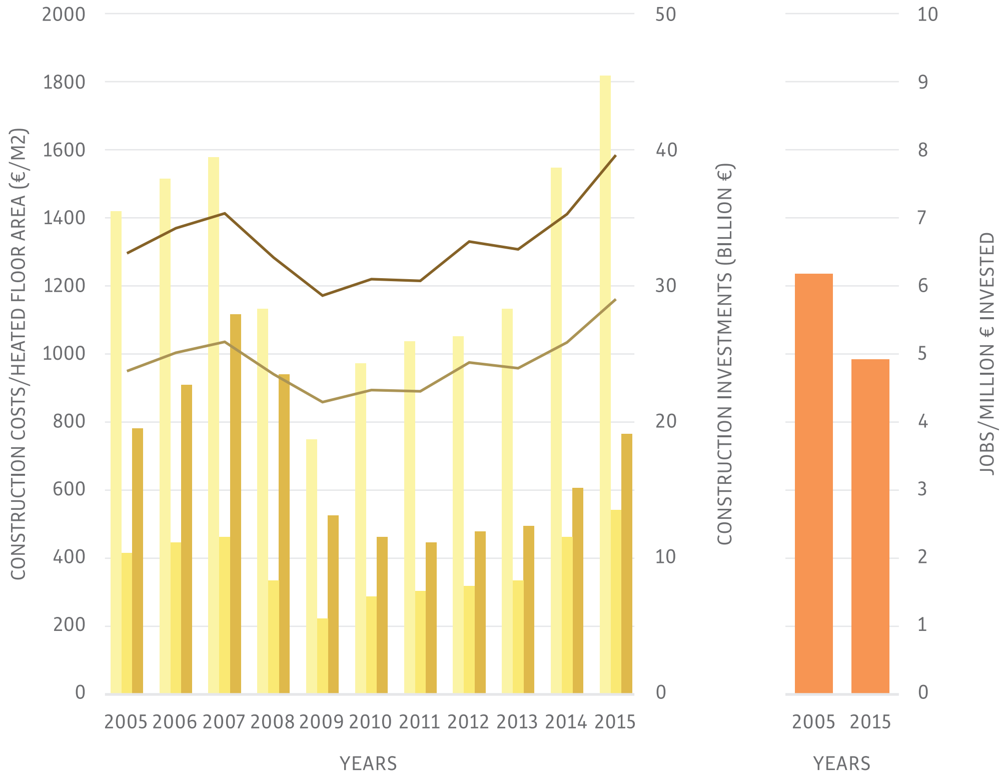
Investment and employment
Construction costs and jobs in the building sector

Notes:
Measured in current€.

The construction sector accounts for over 6% of the UK's GDP, and in 2015, roughly € 160 billion was spent on building construction expenditure. Of this, some 46% was spent on constructing new buildings whilst the remaining went into repair and maintenance related work. Since 2005, total investment in building construction increased at an average annual rate of 2.1%. Aside from its apparent economic significance, the building construction sector of the economy impacts employment as well. In 2015, for every million € thus invested, around 5 jobs were created that could be directly linked to building construction.[47 48]

***A5.1** – Total construction investments by type of development (€ billion), along with jobs attributed to construction related investment.*
The total employment contribution by construction and ancillary sectors linked to it was 7.5% in 2015.

Sources:
EUROSTAT, ONS, CUES Analysis

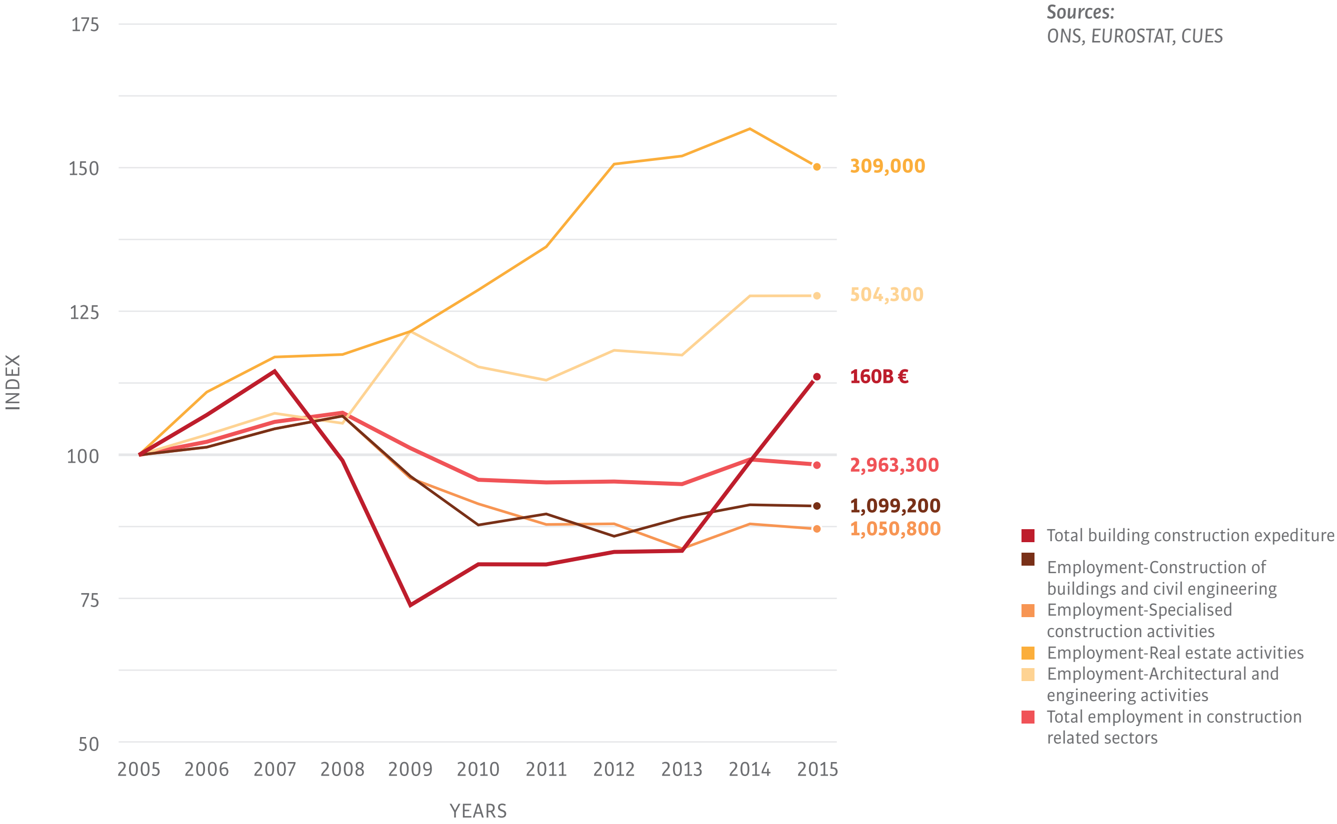


The investment in building construction is driven by an increase in population and the average net floor area per person. Since 2005, the proportion of building investment in single- and multi-dwelling building has varied. In 2015, over 76% of total housing construction costs could be attributed to single-dwelling development and the remaining to multi-dwelling.

The UK has 27.8 million residential dwellings, many of which require refurbishment if the country wishes to meet its energy efficiency targets, but the current rates of deep renovation are too low for the UK to meet its goals. The UK Committee on Climate Change (UK CCC) outlines the need to insulate all practicable lofts by 2022 (8.4 million) and cavity walls by 2030 (6.2 million), as well as 2 million solid walls also by 2030. In addition, 2.5 million heat pumps must be installed in homes by 2030, and approximately 3 million homes must be connected to low-carbon heat networks.[49]

Of the 30 million total employment in the UK in 2015, roughly 9.8% was attributed directly to the construction sector (including building construction) or sectors which are linked to main construction activity, including professional services such as architecture or building engineering and specialised construction activities such as refurbishment. In 2015, for all enterprise sizes, hourly labour costs were € 30 in construction, € 28 in real estate activities, and € 38 in professional, scientific, and technical activities (which includes architecture and engineering services).[50]

A5.2 – *Index of employment and investment (2005=100).*
Increase in total construction investments, is paralleled by a similar trend in total employment related to construction.



Sources:
ONS, EUROSTAT, CUES

In 2015, 64% of the UK's population was of a working age (15–64),[51] and sectors such as manufacturing, education, human health and social work and wholesale, retail, and repair of motor vehicles employed roughly 45% of the employed population.[52] Gradual growth was witnessed in employment in the construction sector and the ancillary sectors which depend directly or indirectly on the construction activity, such as architectural and engineering services and real estate activities. Between 2005 and 2015, whilst total construction expenditure jumped by 13.9%, total employment in construction and its ancillary sectors decreased by 1.7%. Of this, employment in real estate activities increased by 50% and architectural and engineering activities by 27.8% (2005–2015).

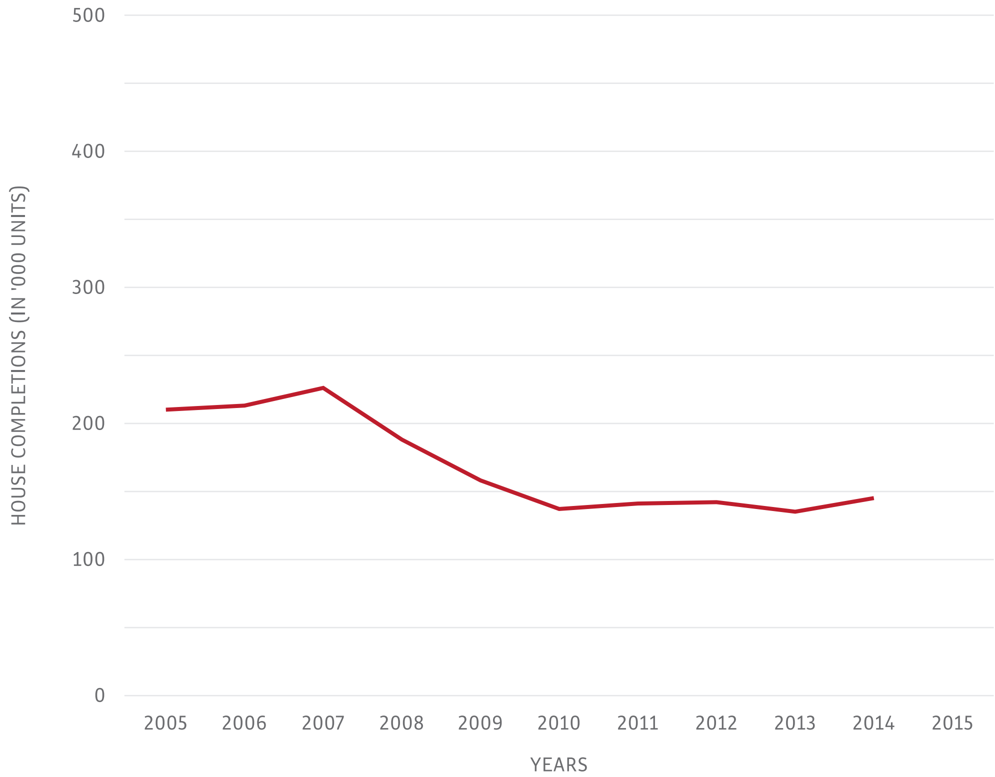
The building construction sector is thus an important economic sector of the UK, and the changing trends in business, lifestyle and demographics, along with the development of the building stock, should therefore be closely monitored. To transition the existing stock toward a low-carbon path would require not only specialised skills but also targeted investments.

A6 Demand, supply, and affordability
Housing market conditions

Residential property dominates the building environment, with £ 5,475 (€ 6,680) billion of assets, over six times the value of commercial property. More than £ 1,000 (€ 1,220) billion of the UK's housing stock is privately rented, representing 20% of residential property (2016), with 17% being rented from local authorities or social landlords.[53] Based upon the latest Office for National Statistics (ONS) house-building report for June 2017, over 178,000 new homes had been completed in the UK in the previous 12 months.[54] Measuring pure demand (200,000–250,000 additional households in England every year) against the supply of new homes (net housing supply in England averaging 160,000 over the last 15 years) indicates that more homes are needed, and this demand-supply imbalance has placed housebuilding high on the political agenda in recent years.[55]

A6.1 – *Housing completions in the UK*

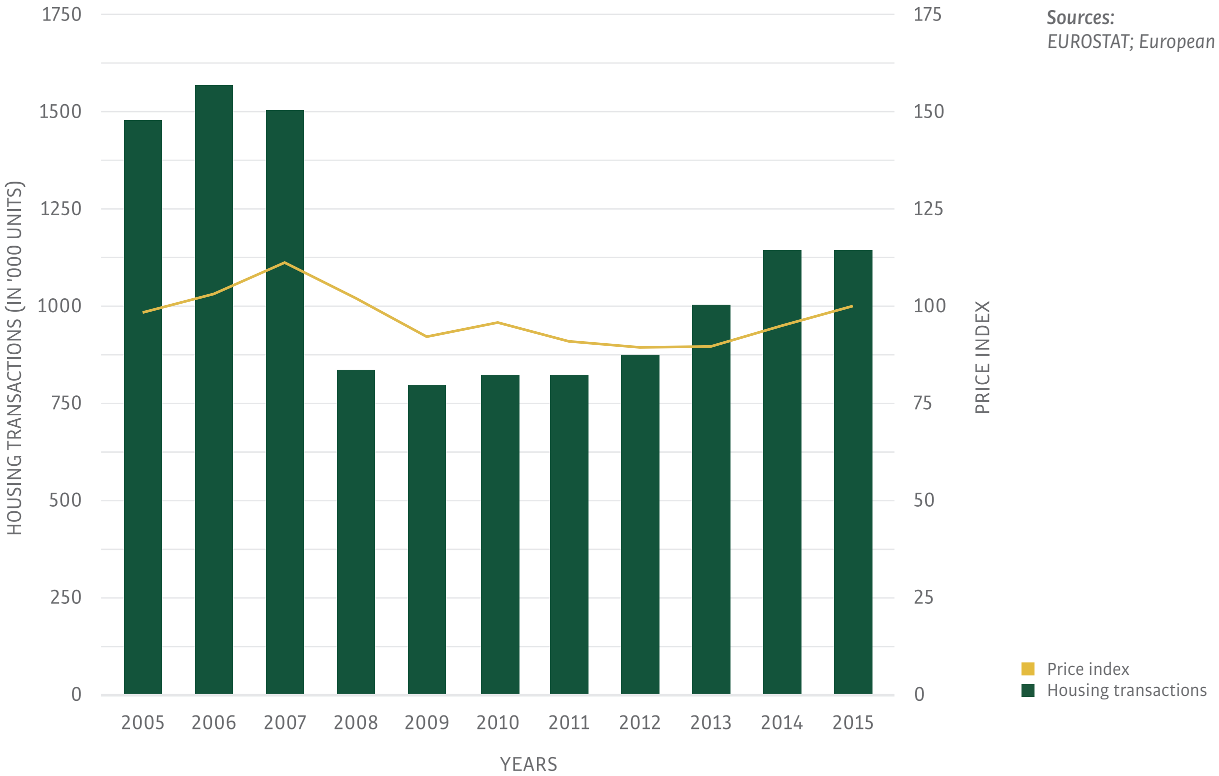
Sources:
European Central Bank



For decades, the UK has failed to build enough houses on a regular annual basis. The tenure of housing built has also changed since the 1970s, with the government drastically reducing the building or funding of council housing. The loosening of mortgage credit witnessed throughout most of the 2000's, as well as in the introduction of the buy-to-let mortgage in the mid-1990s, increased competition for housing, helping push average prices up by 260% (1995–2007). Yet, the affordability constraints resulting from rising prices were masked somewhat by the generous mortgage offers available prior to the financial crisis, with some lenders offering to lend up to 125% of the value of a home. In the wake of the financial crisis, the clampdown on lending, with many lenders requiring a 25% deposit, marked a sharp reversal in the previous trend and highlighted the affordability challenge, even as mortgage rates fell to record lows. The forbearance shown in the mortgage market immediately after the crisis, coupled with a continued demand for housing, underpinned pricing.

As such, affordability is still an issue, exacerbated by transaction costs. In 1997, a stamp duty land tax of 1% was charged on all residential property transactions. Today, all transactions valued at more than £ 125,000 (€ 152,500) are charged at a minimum of 2%, rising to 12% in some circumstances. The rise in transaction costs is a factor for why activity in the re-sales market is lower than long-term norms, as evident in the decrease in the number of homes being listed for sales by agents in the last 20 years.

A6.2 – *UK housing price, property transactions and stock for sale*



Sources:
EUROSTAT; European Central Bank

Whilst overall supply in England is set to breach 180,000 this year, two thirds of respondents to the Housebuilder Survey thought that this level of delivery was not sustainable owing to factors such as labour costs and availability, build costs, and the planning system.[56]

The impact of sustainability on real estate value is a highly contested topic. The Department of Business, Energy and Industrial Strategy (BEIS) 2013 report, which analysed 300,000 property sales data from 1995 to 2011, estimated that conducting energy efficiency improvements to one's home could increase its value by, on average, 14%. This equates to a value uplift of around £ 16,000 (€ 19,520) for an averagely valued property in the UK. Perhaps more importantly still, the minimum energy efficiency legislation (which comes into force in April 2018) will prevent landlords from renting out properties with low EPC ratings (i.e., F and G ratings), which includes circa 25% of UK residential property stock according to Knight Frank research. Being unable to rent out a property will significantly impair saleability, and the discounting of such properties in line with the costs of bringing them up to the minimum E level is expected.

A Knight Frank Green Homes report in 2010 surveyed UK housebuilders focussed upon achieving a near-zero carbon build standard and found that householders felt that a near-zero carbon home would cost on average 22% more than building to current 'typical' standards. Of the respondents, 62% felt that no sale or rental premium would be achievable for reaching this level, and the majority of respondents thus believed that the increased cost would lead to a lower land value payable by housebuilders.

A7

The retrofit challenge
Status of building refurbishment

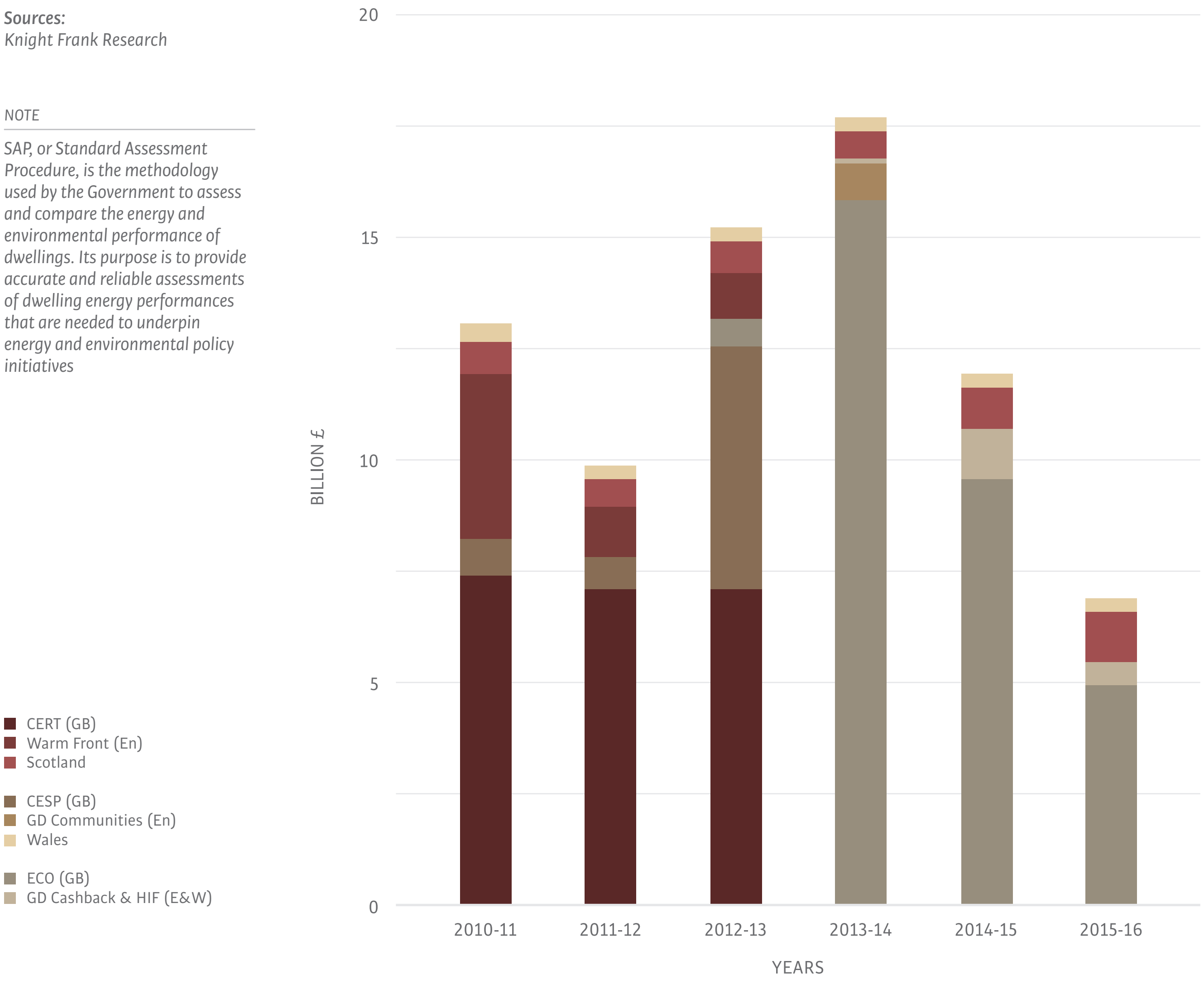
The UK's 27.8 million homes are amongst the least energy efficient in Europe,[58] accounting for 29% of energy use in 2015.[59] In 2010, the government suggested that retrofitting homes and small businesses could catalyse some £ 7 (€ 8.4) billion of investment annually and create up to 250,000 jobs by 2030.[60] However, average of one home retrofit per minute is estimated to be needed from 2013 to 2050 for the UK to meet its 80% carbon reduction target,[61] rates which have not been seen. Government programmes, particularly the series of supplier obligation schemes in effect since 1994, generate a majority of the demand for energy efficiency measures in the UK,[62] and over time, they have generally increased in complexity as well as ambition.

A7.1 – *Total annual level of investment since April 2010, including public expenditure and supplier obligation expenditure[63].*

Sources:
Knight Frank Research

NOTE

SAP, or Standard Assessment Procedure, is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings. Its purpose is to provide accurate and reliable assessments of dwelling energy performances that are needed to underpin energy and environmental policy initiatives



Whilst some of these schemes have been successful, much of the energy efficiency industry is hugely reliant on subsidy-based schemes. Additionally, inconsistent government policies have severely undermined the industry's confidence and ability to plan,[63] whilst the withdrawal of funding has caused significant job losses and led firms to go out of business. Despite the challenges, significant improvements have been made. In 2014, the average Standard Assessment Procedure (SAP) rating of English dwellings was 61 points, rising from 45 points in 1996.[64]

The dramatic fall between 2012–13 and 2013–14 in the measures installed under governmental programs was due to the switch from CERT and CESP to the Green Deal and ECO. The Green Deal was designed as a market-based approach that provided a loan to households to undertake retrofits so long as the retrofit payback did not exceed the energy savings (a requirement known as the 'golden rule'). The subsequent drop between 2014–15 and 2015–16 was in large part due to the cuts to ECO targets, announced in late 2013, taking hold.

Government policies have been particularly successful at encouraging both cavity wall and loft insulation due to the cheap and easy installation of both.[65] By the end of 2016, 16 million lofts are estimated to have been insulated; however, 8.4 million remain uninsulated, of which 1.7 million are considered to be difficult, costly, or impossible to insulate.[66] By 2016, 13.5 million homes had cavity wall insulation (68% of properties with a cavity wall), leaving 6.2 million properties with cavity walls which could also benefit. Of these 6.2 million properties, 1.4 million are considered to have limited potential or be hard-to-treat.[67]

Homes with solid walls must be insulated by means of fixing internal or external insulation to the wall,[68] which is relatively more labour-intensive and expensive.[69] By 2016, 715,000 homes are estimated to have had solid wall insulation (8.4% of all properties with solid walls), leaving around 7.8 million uninsulated solid walls, and it is not yet known exactly how many solid walls will be too costly or difficult to treat. Therefore, the remaining potential to insulate the housing stock is overwhelmingly concentrated in solid wall properties.[70]

NOTE

Insulated is defined as lofts with 125mm or more of insulation

B

Market mechanisms, barriers and drivers

Aim

The chapter 'Market Mechanisms, Barriers and Drivers' provides stakeholders' perspective on residential building projects in the United Kingdom (UK). The aim of this chapter is to support the conception of business strategies and policy measures to foster energy efficiency and low carbon solutions.

Based on a survey covering the whole value chain and a series of experts' interviews, this chapter aims to capture the stakeholders' perspective on low carbon building concepts and solutions, covering both the construction of new buildings and the retrofit of existing ones. Special attention is put on those aspects considered as most critical for in the uptake of respective technologies, particularly the decision-making process.

B

Methodology

The data gathered in this chapter was obtained via an online survey and in-depth market expert interviews.

The data from the online survey were collected from June 2018 to September 2018 and covered stakeholders along the complete value chain of the building. Stakeholders from a stratified sample of a total of 21 groups were approached, providing a differentiated view of the market. The study is centred around concrete past projects of the respondents. The survey results are used to quantify findings when a statistically relevant response rate is available.

The content and topic of the survey is based on exploratory interviews and findings from a literature review study. Sources used are listed in the reference section of this report. Questions and answer options were tested in a pilot phase. Every survey question offered a pre-selection of choices as well as 'other' and 'I don't know / can't judge' options.

The in-depth experts' interviews to market experts were conducted between August and September 2018. The experts were selected to cover the complete value chain of the construction sector in the respective country (i.e. planning, technology and material suppliers, construction and installation, use, end of life and overarching), as well as projects types (new built and refurbishment) and project scales (small and large typologies of buildings), where applicable. The results from these interviews are presented and clearly marked after the survey results, to complement this information. These statements may, in rare occasions, conflict the results from the survey.

The level of agreement among the interviewees on the statements in the main text is ranked in the following stages:

- **Very high**: virtually all experts that feel confident to comment on the statement agree.
- **High**: nearly all experts agree at least to a certain degree.
- **Medium**: there is a trend among the experts to back up the statement, but a notable number are not convinced, though they don't disagree.
- **Low**: some experts emphasize the statement but there is no consensus among the experts, some experts might even disagree

B1 *Value chain & life cycle of the building*
Defining the scope and rationale

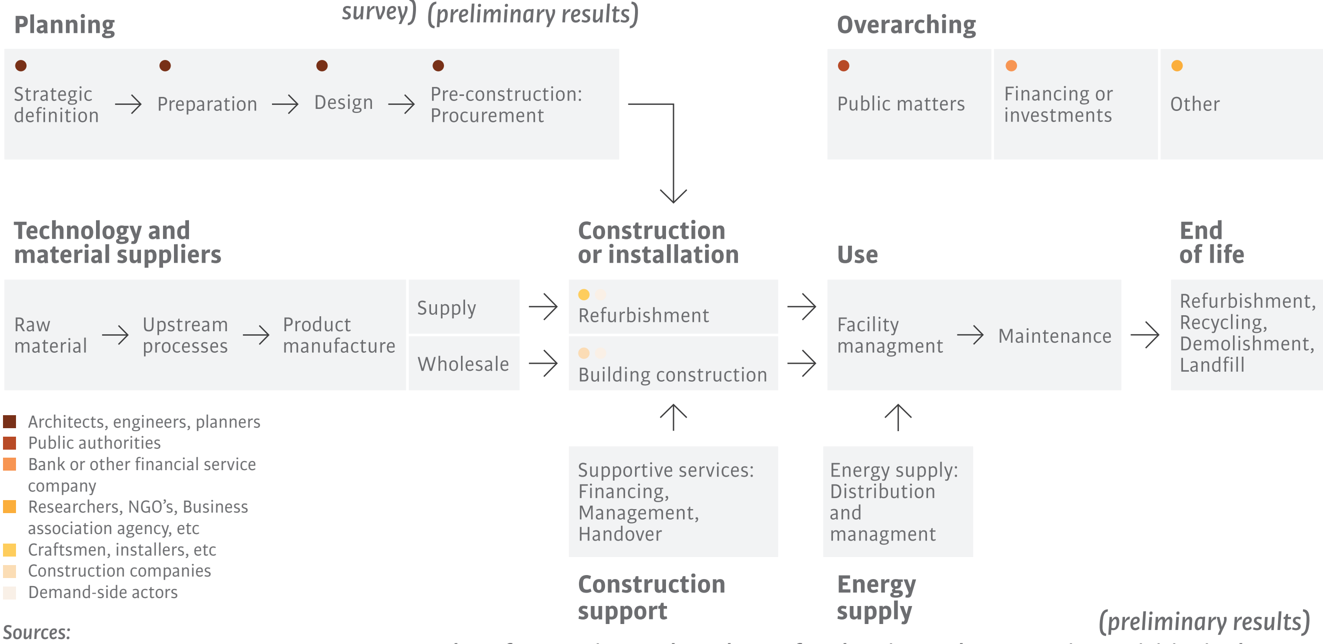
USEFUL LINKS:

www.ec.europa.eu

The value chain refers to all stakeholders from the raw material, material and technology production, installation usage and deconstruction professions. To provide a comprehensive understanding of stakeholders' view, this study covers groups along the whole building value chain in the United Kingdom (UK), entailing more than 20 stakeholder groups. To properly contextualize the market structure the exact number and size of enterprises is listed below for the main stakeholder groups.

Figure B1.1.1 visualizes the structure and main phases in the building value chain that were used as basis for the survey and structure of the following subchapters. From the table B1.1.2 below it becomes apparent the majority of companies and also of the professionals of the main sectors of the building value chain in The United Kingdom (UK) are small and medium sized companies up to 50 employees. Only in the main sector of (new) building construction larger companies prevail.

*B1.1.1 – Characterization of the residential building value chain in the **UK** (the "universe" of the survey) (preliminary results)*



Sources: NACE Rev. 2, Eurostat

(preliminary results)

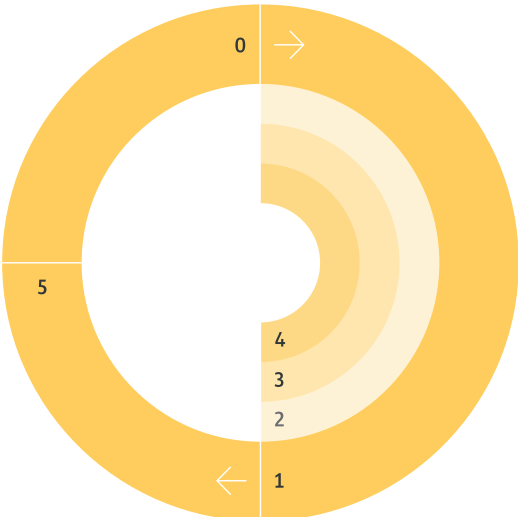
***B1.1.2** – Number of enterprises and employees for planning and construction activities in the **UK**.*

		Total	0 to 9	10 to 19	20 to 49	50 to 249	250 or +
Number of enterprises	**Construction of buildings**	**82,342**	**77,959**	**2,664**	**1,111**	**500**	**108**
	Development of building projects	33,363	32,270	877	164	45	7
	Construction of residential and non-residential buildings	48,979	45,689	1,787	947	455	101
	Specialised construction activities	-	-	-	-	-	-
	Demolition and site preparation	4,284	3,871	214	133	-	-
	Electrical, plumbing and other construction installation activities	82,400	76,620	3,619	1,548	-	-
	Building completion and finishing	69,716	66,543	2,236	741	177	19
	Other specialised construction activities	29,774	27,288	1,484	711	266	25
Number of employees	**Construction of buildings**	**368,436**	**131,256**	**42,687**	**53,134**	**95,258**	**46,101**
	Development of building projects	59,652	38,653	7,926	6,060	4,541	2,471
	Construction of residential and non-residential buildings	308,784	92,603	34,760	47,074	90,171	43,630
	Specialised construction activities	-	-	-	-	-	-
	Demolition and site preparation	19,827	5,294	2,512	4,466	-	-
	Electrical, plumbing and other construction installation activities	346,282	139,782	51,586	61,435	-	-
	Building completion and finishing	192,681	106,514	31,913	27,011	22,712	4,530
	Other specialised construction activities	153,030	50,223	23,214	31,337	36,613	11,643

The building life cycle refers to the prospect of a building over the course of its entire life - encompassing the design, construction, operation, maintenance, modification and eventual demolition and waste treatment. To characterize what measures have taken place during the complete building's cycle in the United Kingdom, the building typologies are differentiated between small (one family home, row houses, small multi-dwelling building, etc.) and large projects (large multi-dwelling buildings) and types of projects are differentiated between new building activities, light modification of an existing building (overhaul, partial retrofit, refurbishment) and in-depth modifications of an existing building (deep comprehensive retrofit).

Figure B1.2 depicts the buildings life cycle, starting with planning/ construction phase (0), followed by a usage/ maintenance phase (1), continued by repair (2), interrupted by different intensities of light (3) and deep refurbishment (4), and eventually ending with deconstruction (5).

B1.2 – *Type of projects over the life cycle of the building.* ***(UK)*** *(preliminary results)*



Phase 0
Construction

Phase 1
Usage and maintenance

Phase 2
Repairs

Phase 3
Light/partial refurbishment

Phase 4
Deep/comprenhensive refurbishment

Phase 5
Deconstruction

The statements and findings of this chapter are accordingly aggregated into the following project types a) to f):

	SMALL BUILDING	LARGE BUILDING
Construction of a new building	a)	b)
Overhaul or partial retrofit or refurbishment project	c)	d)
Comprehensive retrofit project	e)	f)

All questions in the survey are related to a concrete project that the respondent or interviewee worked on. This is to ensure receive concrete and specific answers.

There is a **good** agreement among the interviewees that the residential construction sector is highly focused on delivering single family dwellings, with the majority of activity in these areas happening in the south and southeast of England. London, and city centres such as Birmingham, Manchester and Newcastle continue to see a stronger focus on delivering multi-unit residential building. There is concern that there lacks available land to achieve the targets needed to address the housing shortage in growth areas. Building refurbishments remains an important area for the sector, though energy performance improvements are not the main motivation of those investing.

B2 Technology competences
Familiarity with technology groups

MARKET EXPERT COMMENT

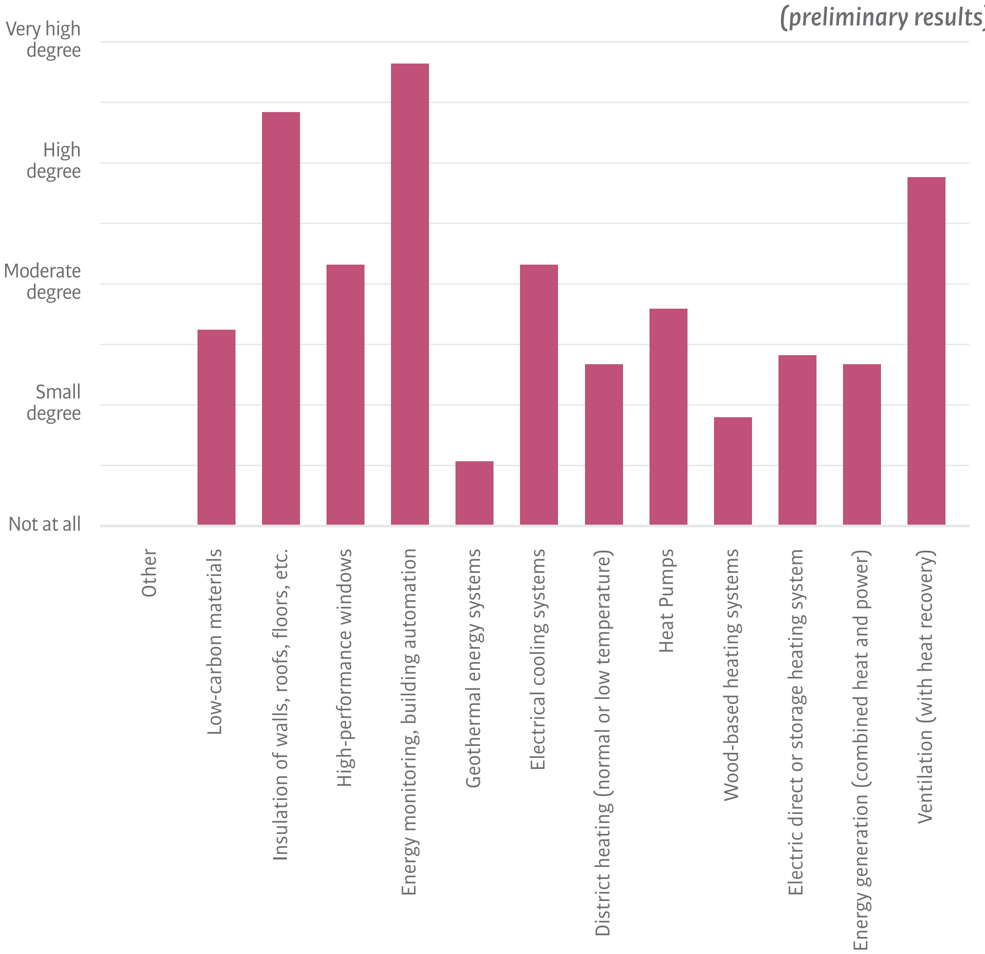
'There is not so much a skills problem as there is a coordination problem. Trades coming on to construction sites need better oversight and management to achieve the performance levels needed.'
- Peter
Consulting Engineer, London.

Competences related to implementation of technologies differ significantly in different markets. It is important to identify the level of knowledge towards different solutions a market has in order to design education programs when necessary. Hence, the following section assesses the level of competence and familiarity of stakeholders involved in planning and construction projects to different energy efficiency and low carbon technology groups in the UK.

Survey respondents from the groups of planners, constructors and facility managers/maintenance in the United Kingdom were asked ***'How familiar are you with the following technologies?'*** They were then provided with a pre-selected list of technologies and the options ***'worked with it once; worked with it several times, part of day to day business, no experience'*** on all technologies. Answering was not mandatory. The respondents could also add technologies they felt highly relevant in a free entry field. The final responses are listed in table B2.1, indicating the average familiarity of respondents with the listed technologies. Interviewees were asked the same question and given the opportunity to contextualize and comment.

'Energy monitoring, building automation, regulation and control, smart metering' has the highest level of familiarity among the respondents in the United Kingdom (UK) (Figure B2.1). The technology with the least level of familiarity among the respondents is 'Geothermal energy systems'. Respondents are similarly low familiarized with 'Geothermal energy systems', and 'Wood-based systems''.

B2.1 *– Familiarity level with low carbon and energy efficiency technologies in the **UK**.*
(preliminary results)



There is a **high** agreement among interviewees that the general level of craftsmanship competence in the UK is moderate in comparison with many other countries. The reliance on overseas trained construction workers has been seen as critical to delivering large scale construction projects, though there remains a strong skill level among trades. The interviewees see a main problem being that most skilled trades are not typically involved in small scale building projects or retrofits. This leads to these activities being carried out by workers with only limited experience.

There is a **very high** agreement among interviewees that the time invested in professional training has been dropping in the past years.

There is a **high** agreement among interviewees that the competences related to technologies are increasingly influenced by installer led experience, using technologies that have a high degree of installer support and training, such as with large manufacturers. The use of highly specialised or advanced systems is limited to high value projects.

There is a **high** agreement among interviewees that there is a general lack of knowledge around integrated design methods of designs and technology combinations that can delivered high energy performance standards among builders.

There is a **medium** agreement among interviewees that the design competences for low carbon technologies is higher than the installation competences. This is mostly the case among volume production where onsite installers are separated from the design team. For small scale building, the general contractor or architect will draw on their experience as compared to seeking out leading methods of design or building.

There is a **strong** agreement that the general competence in designing low carbon buildings is improving, though there is a gap between design and installation that needs to be closed. The main reason being fielded is the focus on increasing building regulations and the growing awareness of advanced low carbon systems available in the UK market. There is a **high** agreement among interviewees that there is low competence in the market regarding the life cycle performance of technologies.

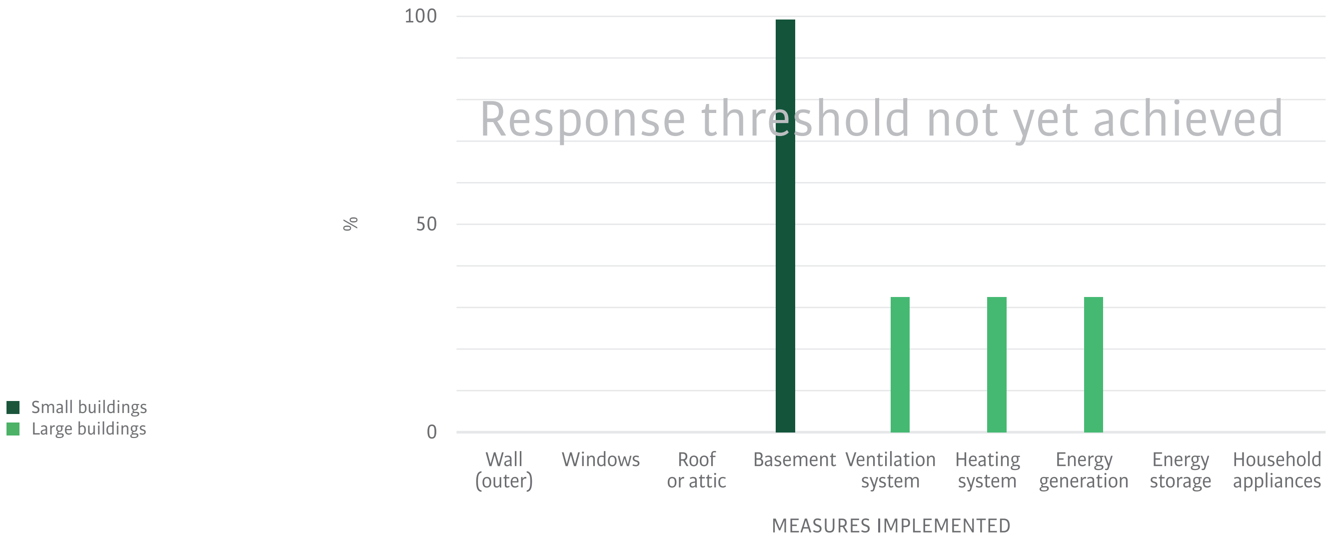
B3

State of play
Measures implemented in the building stock

In most European countries, the state of the building stock is mostly unknown due to limited monitoring of past and present retrofit measures. This section characterizes the measures that have been implemented in the residential buildings in the United Kingdom (UK) for the different project types. The results in B3.1 and B3.2 are based on the survey results. These have been complimented by insights from in-depth stakeholder interviews.

To gather this information, survey respondents were asked ***'What measures were implemented in your latest project?'*** The respondent was provided with a table with 9 different elements covering all building components which they had to choose from. Then had to indicate what was the type of measure. The answer options were: 'Maintenance (including repair)', 'Upgrade of existing elements or systems (incl. insulation and control)' and 'New element or systems'. Additionally, to these answer options, they were provided the option of ***'I don't know'*** and ***'Other'***. Interviewees were asked the same question and given the opportunity to contextualize and comment.

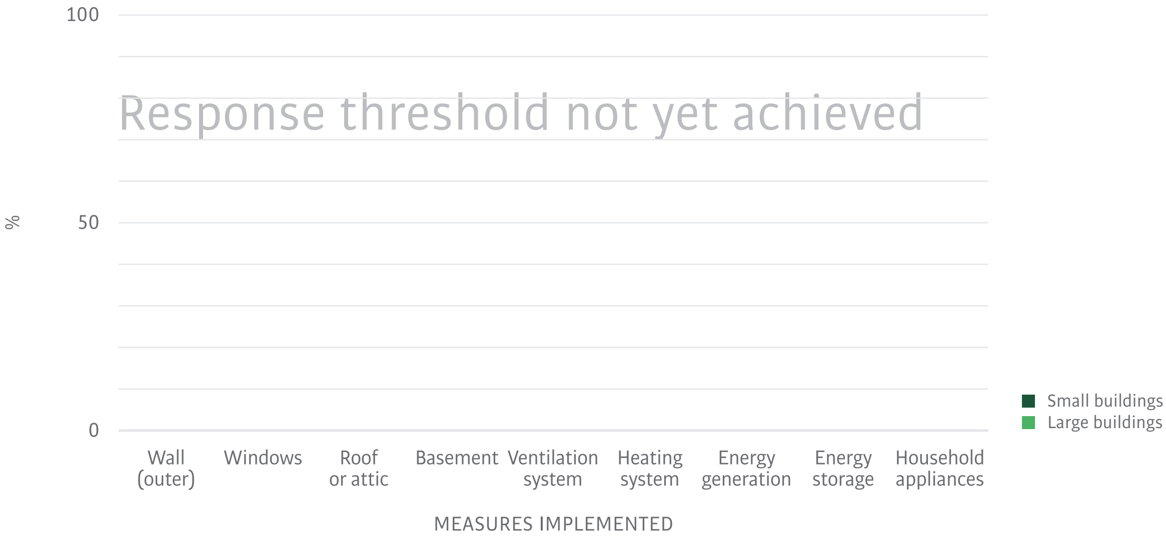
B3.1 *– Measures implemented in (c) overhaul or partial retrofit or refurbishment project in small building and (d) overhaul or partial retrofit or refurbishment project in large buildings in the* ***UK****.* *(preliminary results)*



There is a **high** level of agreement among the interviewees that insulating cavity walls and lofts are the most common activity to improve the energy performance of UK housing. Glazing was also seen as a highly active area of installation that most undertook due to user comfort to reduce noise and cold drafts. There was also a good agreement that installing of PV panels was the most popular low carbon technology installed, mostly among middle/high income owner-occupied housing.

There is a **very high** agreement among the interviewees that heating system exchange is almost exclusively conducted as the result of the original system reaching the end of its life or failing and that there is very few changes towards a different energy carrier in these incidents.

B3.2 – *Measures implemented in (e) comprehensive retrofit project in small building, (f) comprehensive retrofit projects of large building in the* ***UK****.* *(preliminary results)*



There is a **high** agreement among the interviewees that deep refurbishment/ comprehensive retrofit are centred around upgrading or exchanging the envelope of the building to current standard as well as to increase the available floorspace by adding rooms in the rear garden or in the loft space. There was agreement that most heating system upgrades continued on the same energy carrier source.

There is a **very high** agreement among the interviewees that, while decentralised energy generation, especially PV, have scaled among private homes in the past 10 years.

There is a **very high** agreement among the interviewees that deep refurbishment/ comprehensive retrofit is very rare compared to more shallow interventions among private homes. In social landlord or local council housing there has been a big push to invest in improving the building stock to a standard nearer to existing building regulations. This push has been driven by grants or low interest loans being made available to building owners. Recently, the implementation of the Minimum Energy Efficiency Standards will begin to push low grade private rental sector properties to invest in energy performance or out of the rental market altogether. More complicated ownership structures remain a barrier in multi-unit building refurbishment.

There is a **high** agreement among the interviewees that the current rate of deep refurbishment/ comprehensive retrofit in the current economy remains a small number over the overall refurbishment activity.

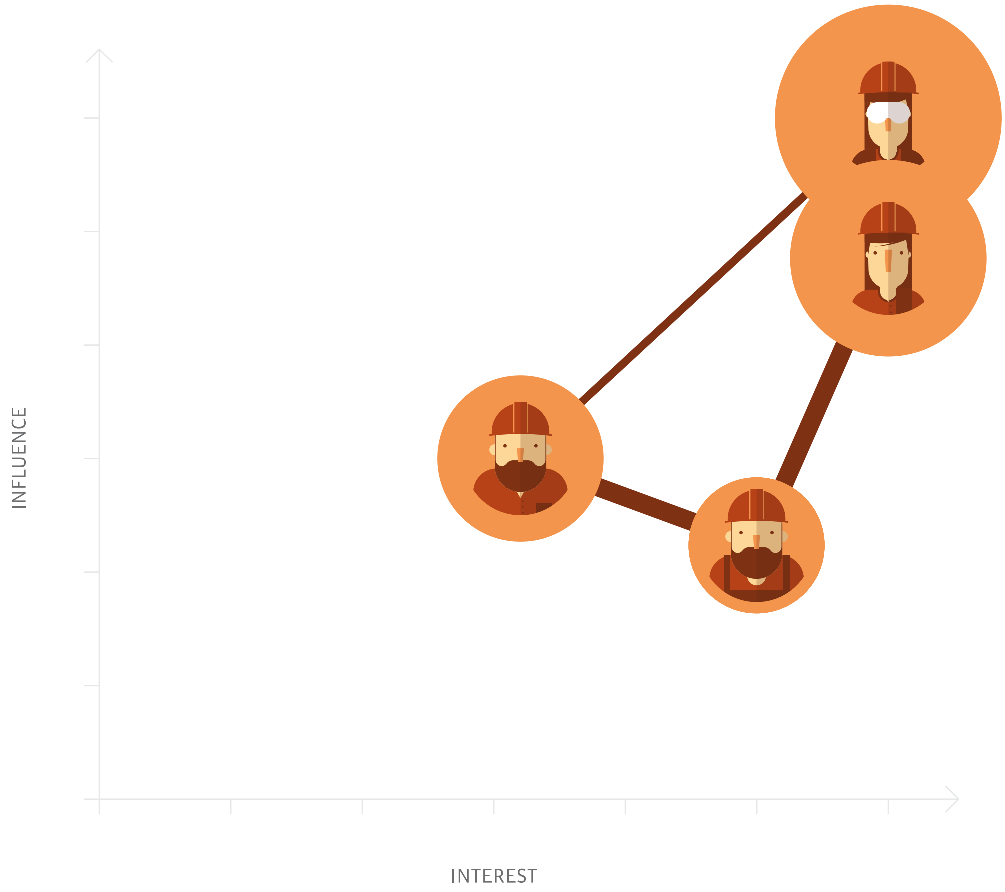
B4 Deep-dive into stakeholder's interaction
The technology selection

The stakeholder setup in the building sector is considered to be complex and fragmented. Furthermore, it varies across project types, phases or even decisions. This section assesses the level of power and interaction of the stakeholders involved in the technology selection for residential building projects in the United Kingdom.

Referred to their latest project, survey respondents were asked ***'What was your level of interest in the energy-efficiency and low-carbon strategy in your project?'***. And ***'How much did you communicate with the stakeholders about the energy-efficiency or low-carbon strategy in your project?'*** Followed by ***'What was the level of influence of the following stakeholders in the energy-efficiency and low-carbon strategy in your project?'*** This was complimented by ***'What was your level of interest in the technology selection in your project?'*** And, ***'How much did you communicate with the following stakeholders about the technology selection in your project?'***. Finally, ***'What was the level of influence of the following stakeholders on the technology selection in your last project?'***. In doing so, respondents were provided with a scale 0-5. Results are illustrated in figure B4.1 below. Interviewees were asked the same question and given the opportunity to contextualize and comment.

For the decision on what technology will be implemented in the project, 'engineers' in the UK are perceived to have the highest level of influence as well as interest. In close communication with 'architect', who are perceived as also having a high level of interest, though not so much influence. Architects, in turn, communicate closely with the 'constructor' – perceived to have low influence and medium interest in this decision. Likewise, the constructor is identified to communicate on a daily basis with the installer.

***B4.1** – Stakeholder interaction regarding the technology selection in the **UK**. (preliminary results)*



There is an agreement among the interviewees that the Architect has the strongest roll for leading the decision of selecting and investing in new building construction. Most interviewees agree that the Architect and Client are the leaders for making key decisions. However, for large construction projects, as the design process progresses, the role of the architect and the engineering consultant begins to interact more, with the engineer taking a leading role on meeting energy performance requirements of the building regulations and the technologies selection.

There is **good** agreement that the Architect has the main role for communication between the project consultants and once a project goes to the construction site. For large building projects, this role may be changed to work with onsite project managers, often employed by the construction company, who work with the architect to make decisions during the deli-very of the building. Among small home construction and refurbishment projects, a general contractor would take this role, where employed. Otherwise, this would be the role of the client to coordinate between the architect and trades.

There is a **high** level of agreement that the roles of the architect and engineer are evolving to cover the advanced knowledge needed to deliver high energy performance buildings, particularly for architects learning to design with passive standards and meeting more onerous building regulations. However, high performance building remains a niche market and there remains a considerable knowledge gap among the sector.

There is a **high** agreement among the interviewees that the role of the contractor or technology supplier is stronger for single component interventions, while the Architect and Engineer play a more important role in systemic interventions. The Client is in many cases communicating directly with the design team of architects and engineers or directly with others, suppliers or planners, which significantly increases their influence on the technology selection.

There is a **very high** agreement that the influence of online media, social networks, marketing and peer networks is high in this type of projects with private clients.

There is a **high** level of agreement among the interviewees that there lacks a strong framework for delivering deep refurbishments in the UK, which many of those involved in the design and construction view as a barrier to delivery. Major refurbishments or additions will trigger building controls that require the latest building regulations to be complied with, but design techniques and compliance may be lacking.

There is a **high** level of agreement that the role of the architect is strongest for new constructure of bespoke housing, where designs and technology choices are being driven by the relationship between them and the client. Among large volume construction, the design team and the contractor shape the delivery of housing through standardized designs and technology purchase that match compliance requirements.

B5 **Motivations and barriers behind projects** *The demand-side's perspective*

MARKET EXPERT COMMENT

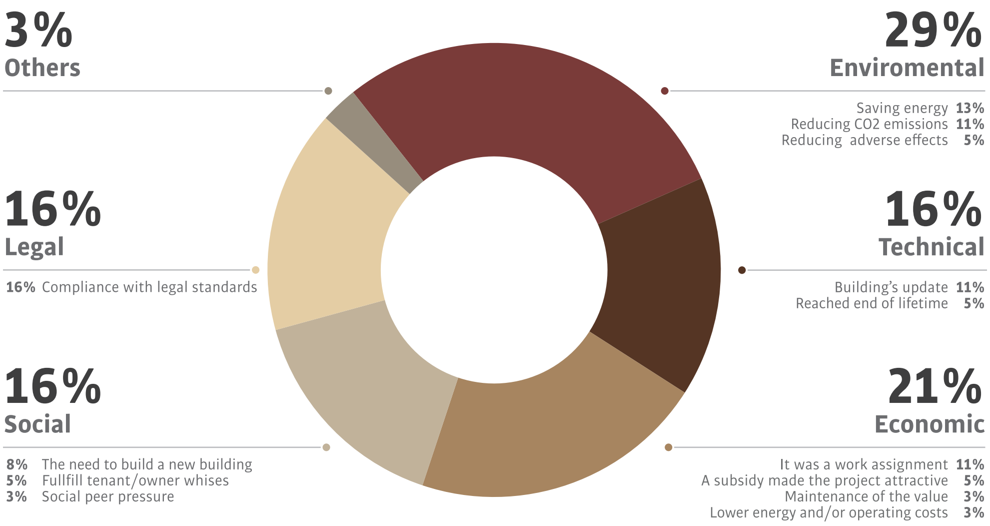
'More and more buyers want low energy housing. They recognize the value for money that an EPC Band A property has in terms of operating costs and the benefit of greater thermal comfort.'
- Richard
Energy Efficiency Expert, London.

Motivations behind projects differ significantly depending on the project type, the building typology and the demand-side's perspective. The following section describes UK's stakeholders' motivations behind projects as well as hindering factors in pursuing 'higher' performing buildings, meaning, even more performance energy-efficient or low-carbon technologies or solutions.

Survey respondents were asked ***'What were the main motivations for your project?'*** They were then provided with a pre-selected list of arguments structured into ***environmental, technical, economic, social and legal*** clusters as well as the option to select ***'Other'***, and ***'I don't know'***. This question allowed participants to choose more than one answer option. Thus, the percentage of answers is calculated on the basis of the total number of options selected. The final responses have been classified according to the professional organizations (POs) perspectives. Main motivations have been listed in table B5.1, indicating in each case the % of responses that were selected for that answer. Interviewees were asked the same question and given the opportunity to contextualize and comment.

For professional organizations, main motivations for professional organizations' are environmental and legal arguments, such as 'saving energy' and 'compliance with legal standards' (10% to 15% of the responses). One of the least identified motivations is 'marketing reasons (e.g. prestige project)' or 'social peer pressure' (both, 0%).

B5.1 *– Main motivations behind projects in the **UK**. The Professional organisation's perspective. (preliminary results)*



There is a **high** level of agreement that social and technical factors are among the main factors driving investment in energy performance among small scale building, while social and other (such as prestige) are the main drivers for delivering large scale high performance buildings.

There is a **high** degree of agreement that there is a lack of available funding among small scale projects for owners to invest in deep refurbishment as they balance prioritizing competing demands on those funds. Most owner occupiers invest in meeting the building regulation requirements and extending a convenience service (such as central heating or double glazing) throughout a dwelling.

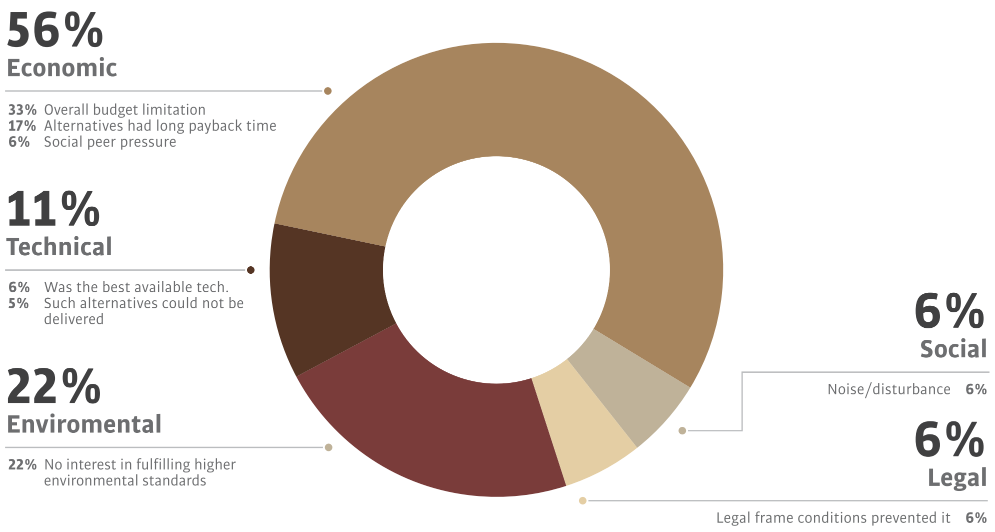
There is a **high** level of agreement that key trigger points typically facilitate investment in energy performance, either due to replacement of broken system or upon occupancy of a new property and an interest in 'modernizing'. The remaining barriers to capitalizing on these trigger points that could increase the marginal investment in energy performance, such as interest and education, and uncertainty on the future value.

There is a **high** degree of agreement among interviewees that modernizing and improving comfort in the building is seen as a key mechanism for improving energy performance alongside design improvements. Focusing on education among home owners at this stage would facilitate higher performance.

There is a **high** degree of agreement that volume housing builders are not necessarily interested in pushing towards higher performance standards unless it is perceived as being in demand by house purchasers, with most new dwellings already amounting to a significant investment of purchasers, despite the marginal costs overall.

To identify what were the main barriers to not pursue higher performing technologies, Survey respondents were asked ***'What were the hindering factors for not implementing (even) more energy-efficient or low-carbon technologies in your project?*** They were then provided with a pre-selected list of arguments structured into environmental, technical, economic, social and legal clusters as well as the option to select ***'Other'***, and ***'I don't know'*** The final responses have been classified according to the professional organizations (POs) perspective. Main barriers for not pursuing (even) more energy-efficient and/or low carbon technologies have been listed in table B5.2. In each case it is indicated the % of responses that were selected for that answer. Interviewees were asked the same question and given the opportunity to contextualize and comment.

***B5.2** – Main barrier for not implementing (even) more energy-efficient or low-carbon technologies in residential building projects in the **UK**. The PO's perspective (preliminary results)*



Economic aspects are perceived to be the main barriers for not implementing 'higher' performing solutions for professional organizations. 'Overall budget limitation and focus on other measures' (33%) was the most common answer along with 'No interest in fulfilling higher environmental standards' (22%). This followed by social aspects, such as 'noise / disturbance that the implementation would have caused' has the lowest impact (5%).

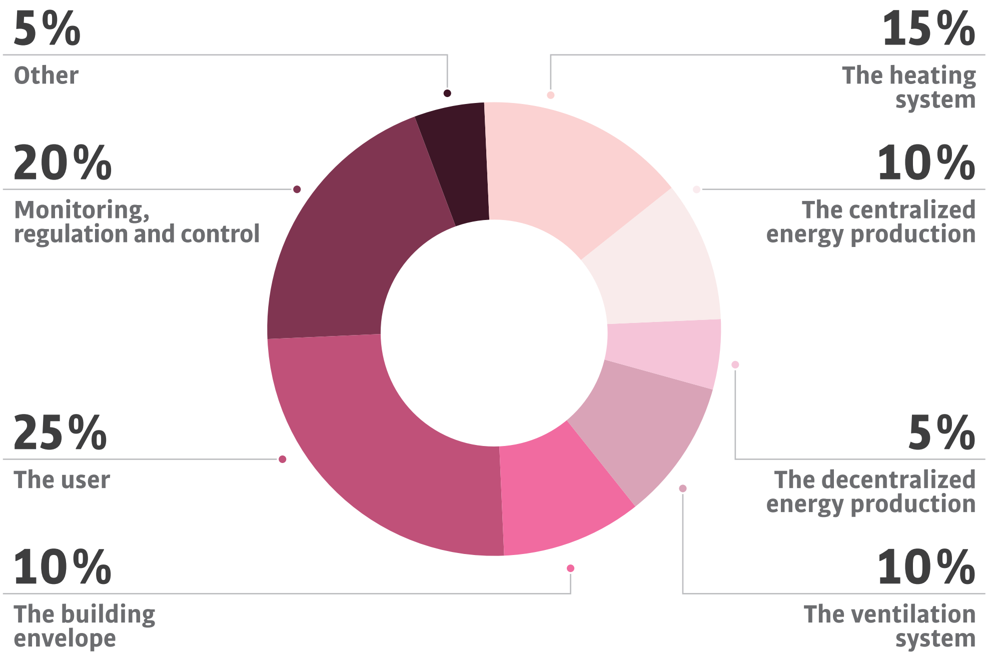
B6 Promising approaches to reach carbon ambitions

General potential in new and existing buildings

Buildings are complex systems formed by an extensive range of elements and components. The carbon performance of a building is highly dependent on the nature and conception of these components. This section identifies what building concepts do market actors see as most favourable to reduce carbon emissions and achieve climate-protection goals in the United Kingdom. Results are presented for new built and refurbishment projects.

Survey respondents were asked ***'What technology or approach has the highest potential to contribute to reach ambitious climate-protection goals in the United Kingdom.'*** They were then provided with a preselection of 8 aspects as well as ***'Other', 'I don't know' and 'none' for both new buildings and refurbishment***. This question allowed participants to choose more than one answer option. Thus, percentage of answers was calculated on the basis of the total number of options selected. Interviewees were asked the same question and given the opportunity to contextualize and comment.

B6.1 *– Technologies perceived to have the highest potential to contribute to reach to climate-protection goals in the **UK** for new buildings.* (preliminary results)



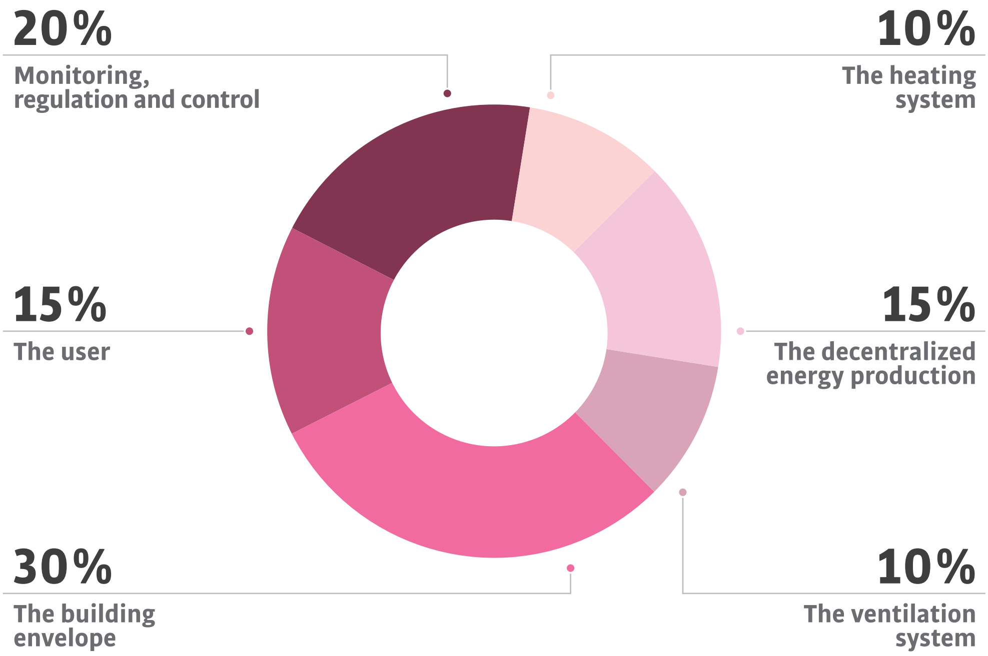
There is a **high** level of agreement among those interviewed that improvements in building fabric are among the most important areas to reduce energy costs for new dwellings. Many of the interviewees felt low carbon heating systems had promise (e.g. heat pumps), but worried that the UK housing market were not yet skilled to deliver the products and homeowners were not familiar with them.

There is a **high** level of agreement that the skills gap for new construction among those working on building sites has stifled innovations in new dwelling construction that undermine high levels of building energy performance being achieved. There is also high level of agreement that there is a need to scale up both the skills to deliver energy performance for new and existing housing, but also skills for assessment of houses, engagement with households.

'The user' (25%) and 'monitoring, regulation and control' (20%) are perceived to have the highest potential in new buildings to contribute to reach ambitious climate-protection goals (Table B6.1). This is followed by 'the heating system' (15%). On the other hand, 'efficient household appliances' (0%) is perceived as not having any potential in achieving climate goals.

There is a general agreement among those interviewed that increasing the standards for building fabric would be challenging with the current approach to volume building, with not enough time spent on making sure the envelop is well joined and sealed. Though all agreed that it played an important role in reducing energy use and carbon emissions. Interviewees agreed that improvements to the installation of existing available technologies through inspection could result in better performance, though they worried about the compliance costs.

B6.2 – *Technologies perceived to have the highest potential to contribute to reach to climate-protection goals in the* **UK** *in refurbishment projects.* *(preliminary results)*



When it comes to refurbishment projects, 'the building envelope' is the considered to be the measure with the highest potential (about one third of the statements), followed by the 'monitoring, regulation and controls' (20%) (Graph B6.2). 'Centralized energy production' and 'efficient household appliances', on the other hand, are not identified to have a high potential to achieve climate-protection goals in refurbishment (both, 0%).

There is a **high** level of agreement among interviewees that decentralized energy technologies and heating technologies would deliver the greatest energy and CO_2 savings among existing dwellings. There was agreement that insulation of building fabric was important, though most felt that as the majority of cavity walls are filled that solid wall insulation would be the greatest challenge to deliver cost effectively. There was a high level of agreement that building users could be better informed about how to heat and ventilate their home to reduce damp and mould.

MARKET EXPERT COMMENT

'The key technology will be heat pumps. Most people with gardens have space for these systems. The problem is that people are not familiar with them and the market needs to change that.'
- Bill
Architect, West England.

'As more cavity and lofts are insulated, the next big challenge is to address solid walled properties and insulating them with systems that maintain their character. There are lots of products on the market that will deliver this if used properly.'
- Sophie
Architect, Nottingham.

B7 Drivers & barriers to reach carbon ambitions
Towards promising approaches

Many barriers hinder the uptake of energy efficient and low carbon solutions. These barriers are context specific and therefore vary considerably depending on the country, building type, stakeholder group and even on the specific technology. The following section describes stakeholders' perceived drivers and barriers to the technology that had been identified in previous section B6 as hosting the highest potential for new buildings. Being 'the user' in the case of the United Kingdom.

Survey respondents were asked to state for which specific technologies they are experts in. For one of those they were questioned on ***'What is the biggest barrier for the upscaling of this technology in the United Kingdom.'*** Figure B7.1 visualizes the results for 'building automation and smart metering' as a potential technology to enable or support the user in reducing energy or carbon consumption. Interviewees were asked the same question and given the opportunity to contextualize and comment.

B7.1 – *Perceived barriers to insulation in* **UK.**
(preliminary results)

There is a **high** agreement among interviewees that the greatest barrier for envelope related technologies is the cost of installing high performance materials in retrofit activities and an expectation of already achieved high performance for new buildings. Most purchasers of new buildings assume that building regulations are already of a high standard and therefore further investment is unnecessary, while refurbishment is subject to uncertainty of the cost and concern over affecting the aesthetic character.

There is a **high** agreement among interviewees that the greatest barrier for heating systems is the lack of familiarity with high performance systems and the uncertainty of installing and using the systems. They effect is that home owners are risk averse in selecting these systems unless there is a high level of support and knowledge and experience with the builder on delivering the system.

There is a high agreement among interviewees that the greatest barrier to decentralized energy generation is the lack of lack of familiarity and changes in the regulatory system for supporting incentives in the longer term (e.g. FIT and RHI).

Identifying stakeholders' market specific drivers and motivations is crucial in order to trace effective marketing campaigns and policy instruments to foster the uptake of low carbon energy solutions. The following section describes stakeholder perceived drivers to 'building automation and smart metering', as a key element to 'the user', identified in section B2 as hosting the highest potential in new buildings in the United Kingdom.

Survey respondents were asked what were ***'the most promising approach to support the market uptake of low carbon technologies.'*** Figure B7.2 visualizes the results for 'building automation and smart metering'. Interviewees were asked the same question and given the opportunity to contextualize and comment.

B7.2 *– Perceived drivers in the* ***United Kingdom*** *to 'building automation and smart metering'. (preliminary results)*

There is a **high** agreement among interviewees that the greatest potential for supporting the uptake of envelope related is policy that connects regulations with incentives.

There is a **high** agreement among interviewees that the greatest potential for supporting the upscaling of low carbon heating systems and active building components is through improvements in standards for refurbishment and new building construction by strengthening the minimal energy performance standards.

There is a **medium** agreement among the interviewees that a simplification of components and increased prefabrication and standardisation would support the general uptake of low carbon solutions. Particularly by focusing on having new advanced systems be of a similar size of the systems they are replacing.

C

Market volumes and policy scenarios

Aim

This chapter presents data on the current state of UK building stock greenhouse gas (GHG) emissions as well as annual market volumes in the short, medium, and long term for two scenarios.

The first section of this chapter presents structural and GHG-related data on the building stock (section C.1). The data was collected from statistical sources, standards and norms. Market experts via interviews complement this information. A synthetic building inventory of 10,000 representative buildings has been generated based on the data collected. To set up this inventory, the building stock model (BSM) integrates a parametric variation approach.

At its core, this chapter describes the market volumes for a Reference Scenario (RS) and a 2-Degree Scenario (2DS). The RS reflects current and published energy and climate policy instruments and some incremental reinforcements that could be expected (similarly to the EU Reference Scenario). Both European and national policies are taken into account. The 2DS is designed to achieve ambitious climate-change-mitigation goals. The < 2º C goal of the Paris Agreement of 2015 serves as a guideline. National peculiarities and implementation approaches that may typically be expected are reflected in the scenario definition (section C.2).

In both scenarios, the effect of an increase in energy efficiency and in the share of renewable energy sources (RESs) have been considered. The resulting market volumes for the various technology groups are listed. The aim is to provide realistic market volumes estimates for different market segments. We limit our analysis in this chapter to English residential building stock.

All data sources are clearly marked to allow the reader to access more detailed information as needed. The complete list of sources can be found in the annex to this report. Key sources are listed as links in the side bar.

C

C1 **Status quo of the building stock** Structure and greenhouse gas emission intensity

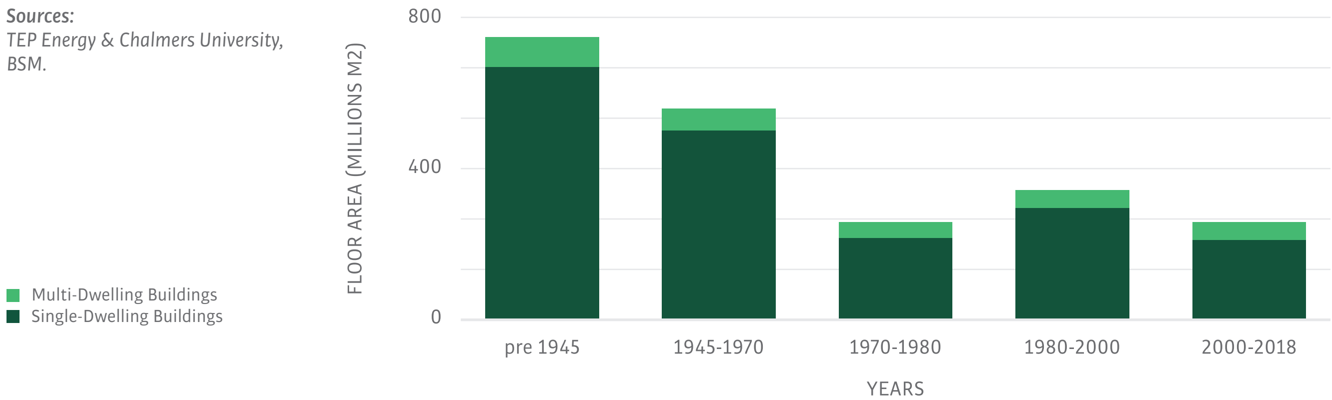
The residential building stock of England currently encompasses around 19.7 million buildings (and 23.4 million dwellings), totalling about 2,195 million m² of heated floor area. English housing stock is largely characterized by single-dwelling buildings (SDBs), which make up 94% of the stock. This includes row houses and attached houses. Only about 6% of buildings are multi-dwelling buildings (MDBs). However, MDBs make up a larger share of the stock in terms of heated floor area, with about 13% of the total floor area.

Notes:
We limit our analysis in this chapter to English residential building stock as a representation of the UK.

The age distribution of the stock (Figure C.1.1) demonstrates a large percentage of old buildings, with almost 34% of the heated floor area built before 1945, and another 25% built between 1945 and 1970. The rest of the stock was constructed after 1970, especially during the construction boom in the 1970s and 1980s; however, a decreasing amount of floor area has been added since then. The percentage of the floor area covered by MDBs has increased over the years, with MDBs taking up relatively low percentages of the constructed floor area before the 1970s, and larger percentages afterwards. The percentage of the floor area covered by MDBs peaked in the 1970s and 1980s and then decreased; however, the percentage began to increase again after 2000.

C1.1 – *Age distribution of English building stock, differentiating between single-dwelling buildings (SDB), includding row houses, and multi-dwelling buildings (MDB).*

Sources:
TEP Energy & Chalmers University, BSM.



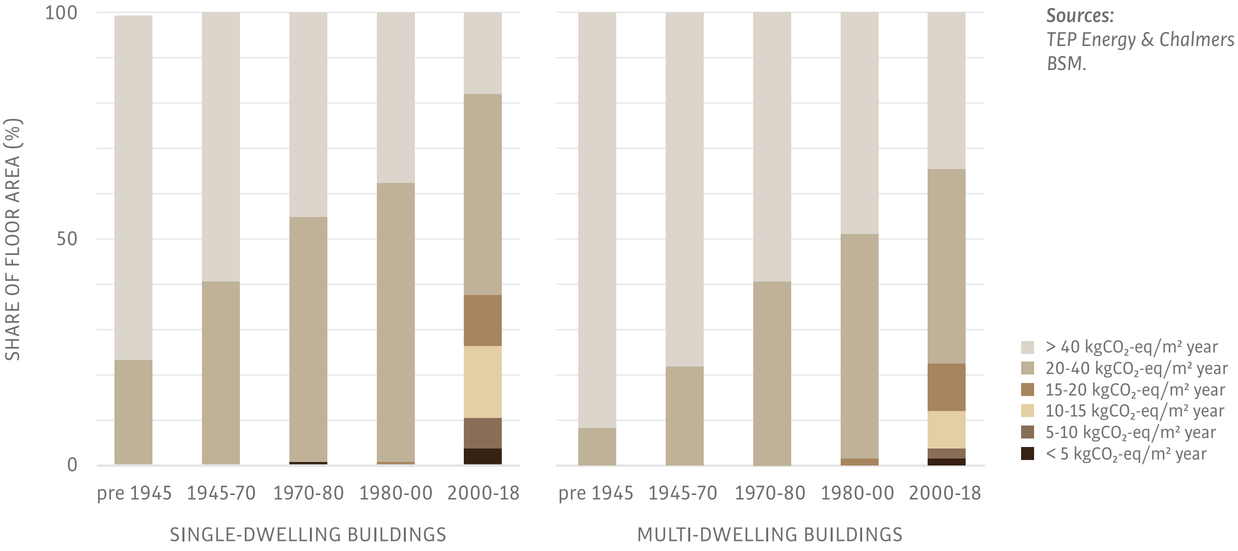
Notes:
GHG intensity: GHG emissions from final energy consumption for heating, hot water, ventilation and cooling from a life-cycle perspective. For example, 10 kg CO_2-eq per m² is equivalent to 45 kWh per m² in a gas-supplied building. GHG emissions embodied in the construction of the building are not included.

Figure C.1.2 illustrates the carbon efficiency of the stock in terms of its GHG intensity. The effect of the building code on the construction of new, more energy-efficient buildings is that the percentage of buildings with a high GHG intensity decreases. Moreover, after 2000, the percentages of low-carbon buildings have clearly increased. While this trend towards low-carbon buildings does exist, the majority of English housing stock (about 95% of the floor area) still has a GHG intensity of more than 20 kgCO_2-eq per m².

Figure C.1.3 illustrates the distribution of final energy demand of the English housing stock, which, like Figure C.1.2, reveals a clear trend towards new, more energy-efficient buildings. Some effects of the renovation efforts are, however, visible in the percentage of buildings built before 2000 with an energy demand of less than 100 kWh/m² year.

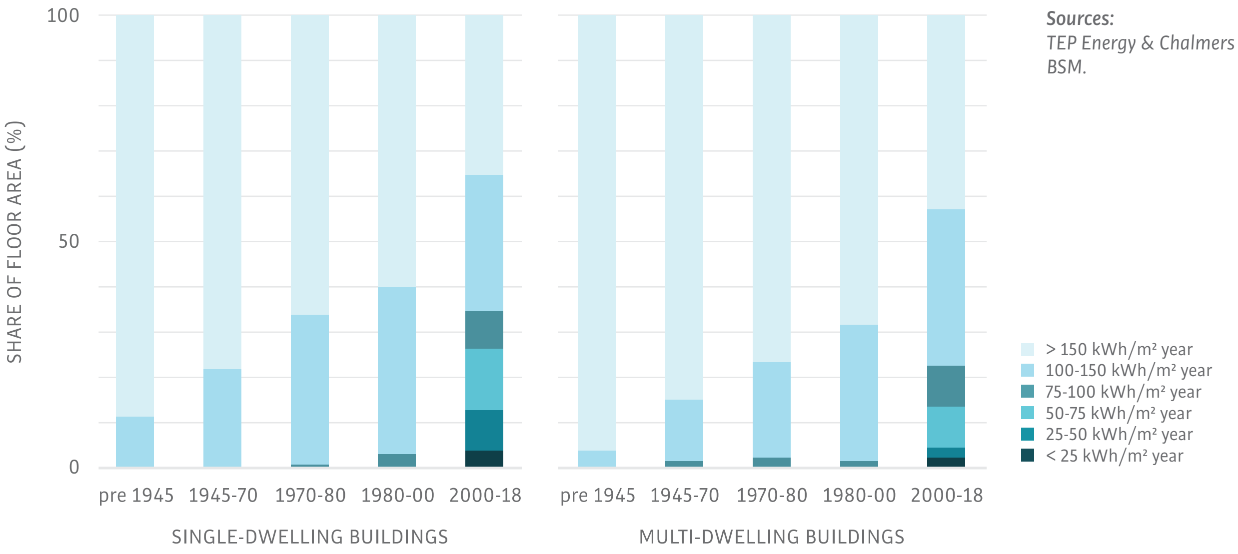
The effects of renovation efforts on English housing stock have so far been minimal and low-carbon buildings have so far not gained a significant share in buildings built before 2000. This is primarily because the majority of houses are still heated by natural gas, which is a fossil fuel. Moreover, so far the applied refurbishment measures have only targeted single components (e.g., loft insulation, window replacement) instead of a comprehensive retrofit, leading to only marginal improvements in the efficiency of the building.

C1.2 – *GHG-intensity of English building stock in 2018 according to building age and building type.*



Sources:
TEP Energy & Chalmers University, BSM.

C1.3 – *Specific final energy demand distribution of the English building stock in 2018 according to building age and building type.*



Sources:
TEP Energy & Chalmers University, BSM.

The effects of renovation efforts on English housing stock have so far been minimal and low-carbon buildings have so far not gained a significant share in buildings built before 2000. This is primarily because the majority of houses are still heated by natural gas, which is a fossil fuel. Moreover, so far the applied refurbishment measures have only targeted single components (e.g., loft insulation, window replacement) instead of a comprehensive retrofit, leading to only marginal improvements in the efficiency of the building. The problem of the large percentage of buildings with high GHG intensities remains to be addressed in the upcoming decades.

C2 Policy scenarios
To shape carbon emissions

Notes:
The Reference Scenario (RS) represents an upper bound of future carbon emissions. It comprehends current and decided energy and climate policy goals and instruments and some moderate re-enforcements.

The 2-Degree Scenario (2DS) is designed to achieve ambitious climate-change mitigation goals. The < 2°C goal of the Paris Agreement of 2015 serves as a guideline. National peculiarities and implementation approaches that typically could be expected for England are part of this scenario.

At present, England has already implemented some policy instruments to foster energy efficiency and the use of RESs, and to curb CO_2 emissions (see section A.3). The basis of these policies is the Climate Change Act of 2008[1], in which the UK commits to reducing overall CO_2 emissions by 80% by 2050 (compared to 1990), and the need to reinforce action on climate mitigation and adaptation. As part of the Climate Change Act, the independent UK Committee on Climate Change (UK CCC)[2] was established to set carbon budgets for every 5 years and design strategies that achieve these budgets.[3]

The development of market volumes very much depends on these economic and policy framework conditions and how they will develop. In order to reflect the uncertainties in these framework conditions that arise, for instance, from decisions about policy instruments that are yet to be taken, two scenarios have been defined. Market volumes are then calculated for these two scenarios to constrain the uncertainties. For the sake of comparison between the two scenarios, other drivers such as population growth and the energy price are kept the same in both scenarios (see section C.3).

- Part of the Reference Scenario (RS) is based on current and decided energy and climate policy goals and instruments. At the European scale, these are the Renewable Energy Directive[4], the Energy Efficiency Directive[5], the Directive on Energy Performance of Buildings[6], and the Ecodesign Directive[7]. At the national scale, there is the Climate Change Act of 2008.

- The 2-Degrees Scenario (2DS) is designed to achieve ambitious climate change mitigation goals. To achieve the < 2°C goal of the Paris Agreement of 2015, further-reaching measures are needed to cut direct CO_2 emissions (almost) completely from the buildings sector. According to the UK CCC strategy, key actions will be aimed at increasing the number of building refurbishments in order to insulate all lofts by 2020, all cavity walls by 2030, and two million solid walls by 2030. The building code for new construction is likely to be strengthened in terms of its energy-efficiency requirements and those for low-carbon heat supply through heat pumps and low-carbon heat networks. For existing buildings, tangible instruments are part of the 2DS, for example, a further upscaling of the large-scale renovation programmes and the low-carbon requirements for the replacement of existing heating systems.

To achieve these ambitious climate-change mitigation goals, tangible policy instruments need to be implemented. Specific, concrete assumptions are made to substantiate input for the BSM calculation and to underpin results for the short-, mid-, and long-term (2021, 2030, and 2050 respectively) development of various market segments.

- Building codes that are already strict in the RS are tightened in the 2DS. Nearly Zero Energy Buildings (nZEB)/Zero Carbon Buildings and a ban on the use of fossil energy in new buildings are part of this scenario.

- As heat pumps will play a major role due to the phasing out of gas supply in the housing sector, mandatory energy-efficiency standards will be introduced in the 2DS in order to ensure the efficient use of electricity from RESs, including own-produced solar energy (which is incentivised by feed-in tariffs).

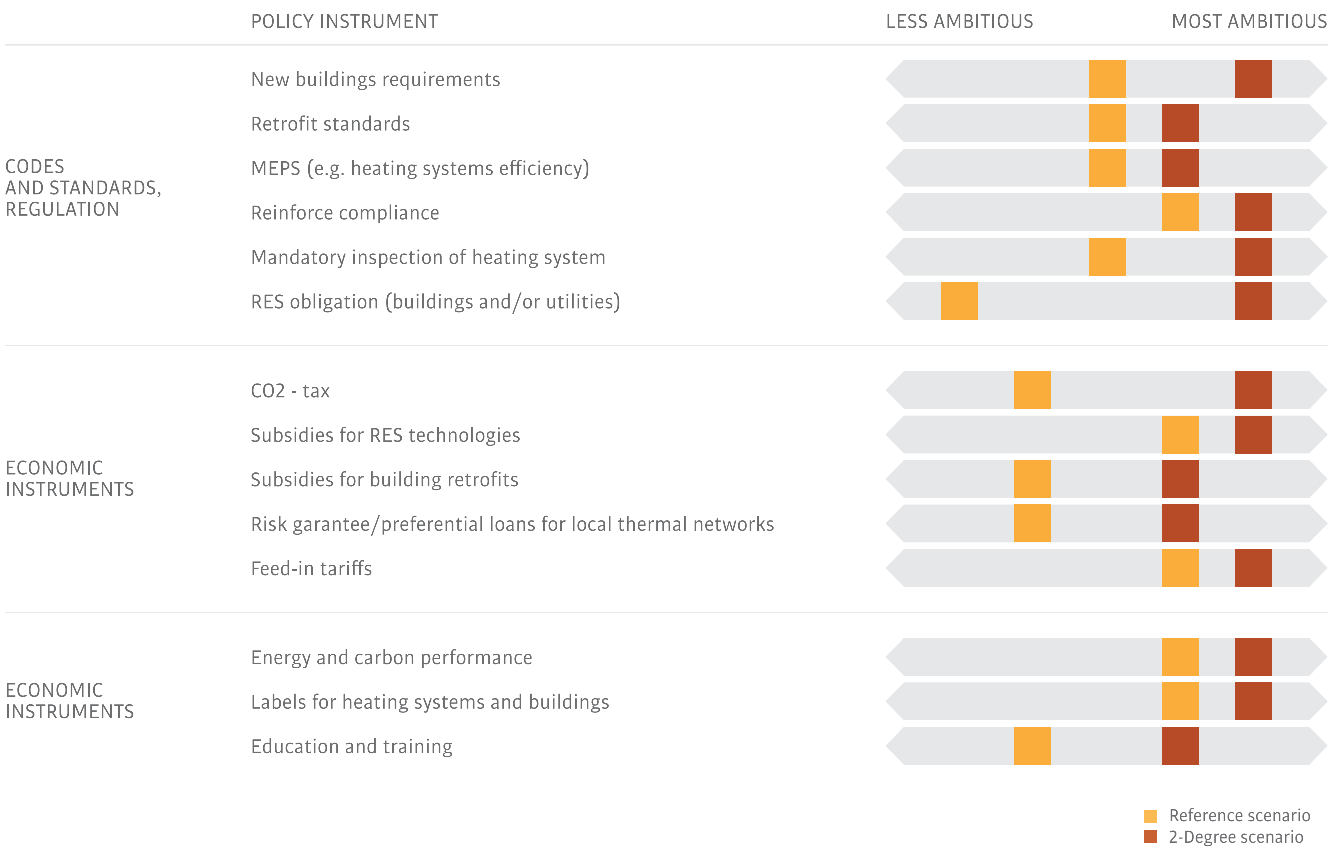
- In the 2DS, extra effort will be undertaken to reinforce compliance with codes and standards, and to secure the efficient operation of building technologies, particularly heating and hot water systems.

- In order to foster the diffusion of efficient low-carbon technologies and retrofitting measures, the existing energy levy will be increased and converted into a CO_2 tax in the case of the 2DS. Tax revenues will be used to scale up the existing retrofit subsidy programme and/or tax incentives.
- Based on urban energy planning, the gas grid is to be partly replaced by up-to-date district heating networks in order to supply high-density areas and districts with energy from RESs and residual heat.
- These policy instruments would need to be complemented and underpinned by coherent information measures (e.g. energy and performance labels and certificates) and an education programme that includes builders, installers, and planners.

The ***building stock model*** *(BMS) simulates the dynamics of the building stock and the energy- and climate-related decisions of building owners and tenants. Decisions, e.g. regarding choice of heating system or whether to retrofit depend on:*

- *Technology prices and their energy performance,*
- *Energy prices (including taxes),*
- *Subsidies, tax exemptions and other financial incentives,*
- *Codes and standards, and*
- *Availability (e.g. of RESs and of energy infrastructure)*

C2.1 – *Scenario definition.*



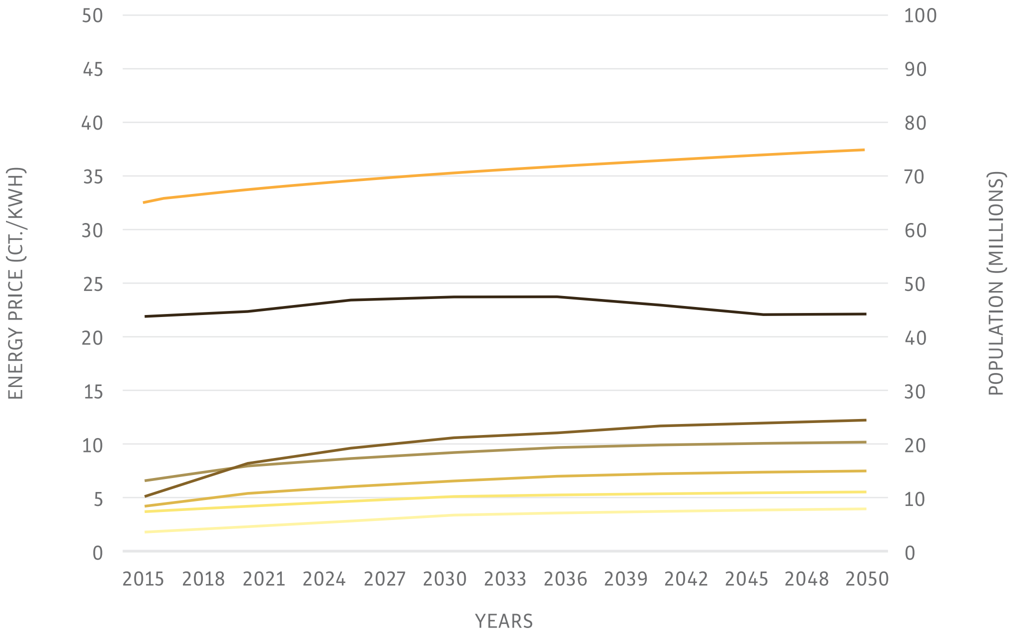
C3 Development scenario
Drivers and general implications

Notes:
The impact of these drivers is highlighted in sensitivity analyses available from the CUES Foundation.

Drivers such as population growth and energy price developments are held the same in both scenarios in order to increase comparability. Population growth is based on the EU Reference Scenario and is shown in Figure C.3.1, together with the assumed energy price development. These drivers target different aspects. Population development principally drives new construction activity in the market, while energy price development is a key driver for the diffusion of low-carbon technologies and retrofitting activities.

C3.1 – *Poulation growth and energy price development.*

Sources:
EU Reference Scenario, EUROSTAT, ENERGIFORSK, TEP and Chalmers.



Notes:
Ambient Heat is the heat extracted by the heat pump from the air, ground, or groundwater to heat the building.

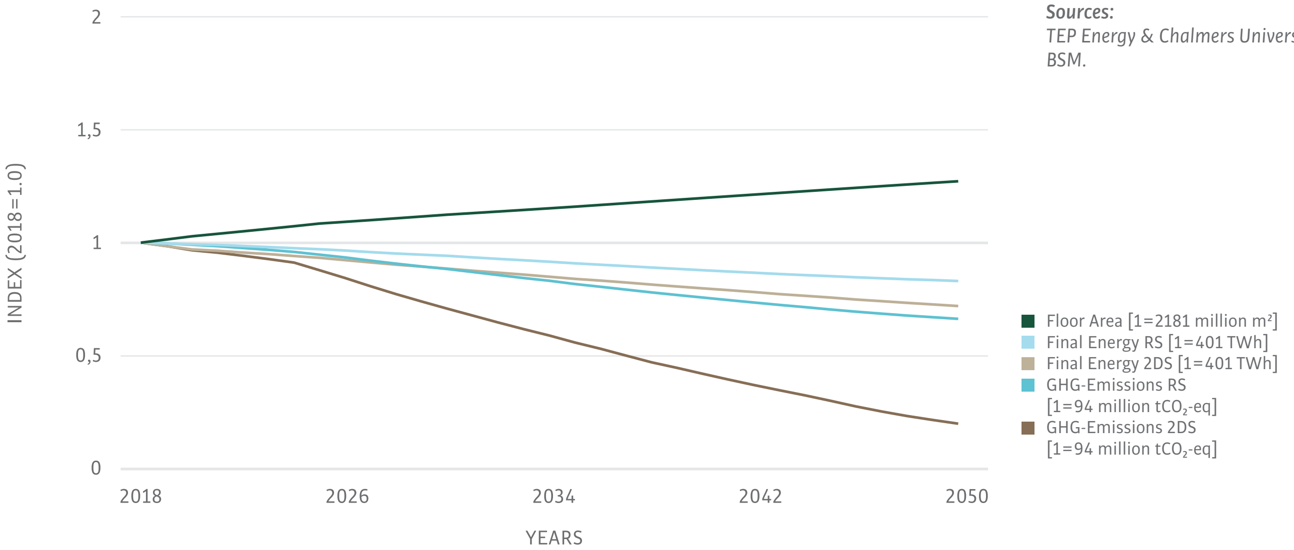
On the basis of the framework conditions outlined above, the main findings on final energy demand and GHG emissions are illustrated in Figure C.3.2 and can be summarized as follows:

— Although the population is set to grow significantly by 15% by 2050, and consequently the total floor area by 27%, final energy demand for heating, hot water, and ventilation decreases by 17% in the RS and by 34% in the 2DS. This is due to building code requirements for new buildings and to retrofitting activities that take place in both scenarios. In the 2DS, final energy demand, which includes RESs, decreases more than in the RS. This is due to the effect of greater retrofitting activity and the more stringent standards of the 2DS. In this scenario, retrofitting activity is fostered as a consequence of subsidies and an increasing CO_2 tax.

— Currently, gas is the dominant energy carrier in the English housing sector (see Figure C.3.3). It remains the dominant fuel in the RS, even if demand for it were to decrease by 20% by 2050. However, fossil gas is phased out almost completely in the 2DS. Consumer gas suppliers should be prepared to diversity their activities and to carefully manage their infrastructure assets. Renewable gas, district heating, or developing heat pump-related energy services might be elements of new business strategies.

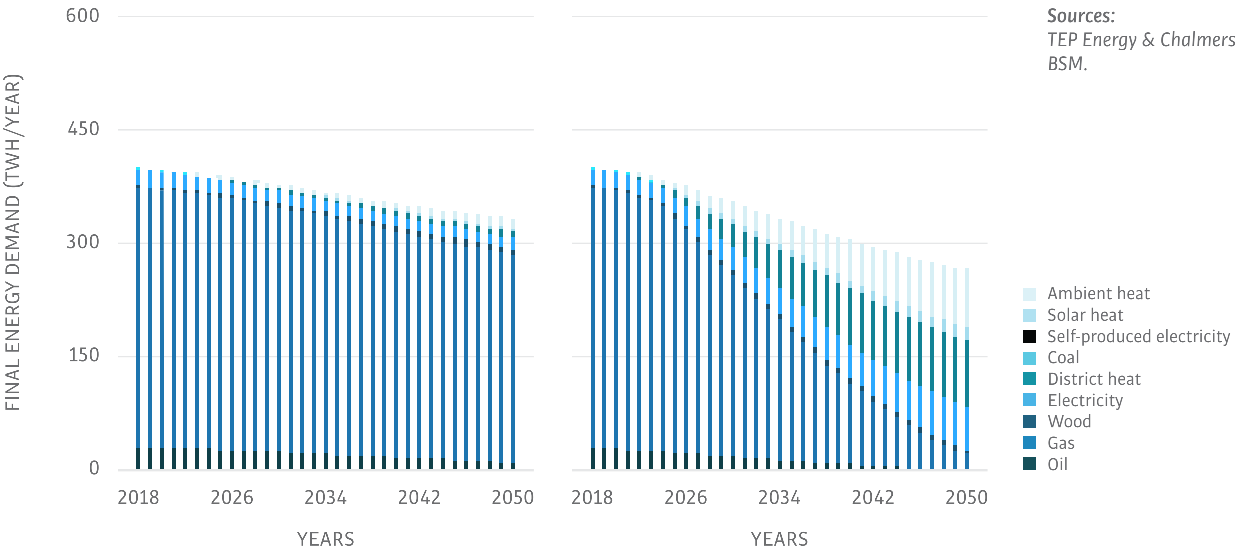
— Gas grids are partly compensated for by the large-scale expansion of district heating in the 2DS. The UK CCC's goal of 60 TWh of heat supplied from district heating are met and exceeded, with heat supplied from this source reaching a total of 86 TWh in 2050 in the 2DS.

C3.2 – Development of floor area, energy, and GHG emissions according to the modelled Reference Scenario (RS) and 2-Degrees Scenario (2DS).



Sources:
TEP Energy & Chalmers University, BSM.

C3.3 – Development of final energy demand for heating, hot water, and ventilation according to energy carriers in the Reference Scenario (left) and 2-Degrees Scenario (right).



Sources:
TEP Energy & Chalmers University, BSM.

C4

Structural change of the building stock
Short-, mid-, and long-term development

Notes:
Partially refurbished means that a building has 1–2 building components that have been refurbished in an energy efficient manner since 2015.

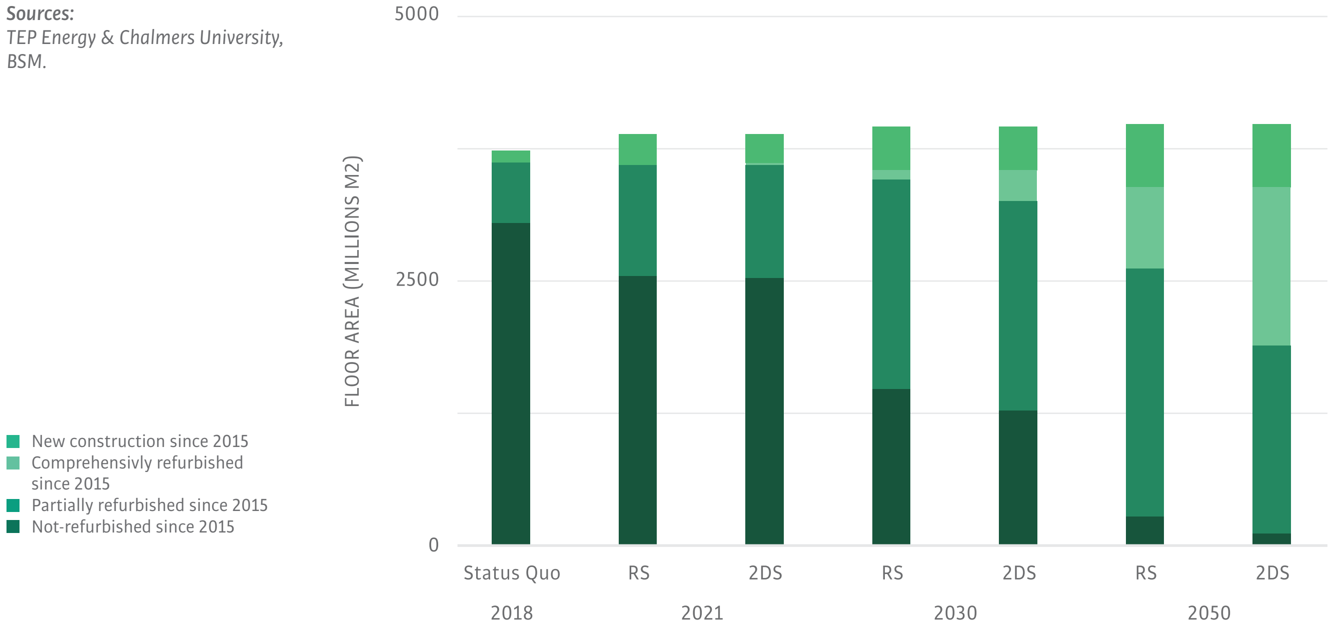
Comprehensively refurbished means that a building has 3 or more building components that have been refurbished in an energy efficient manner since 2015.

English residential building stock is projected to grow by about 597 million m² of floor area to almost 2.8 billion m² in 2050 in both scenarios (see Figure C.4.1). The stock existing in 2018, however, is projected to decrease over this time period by almost 15% down to only 1.9 billion m² in 2050 as a result of demolition. This still means a 27% net addition in floor area by 2050, with newly constructed buildings making up 31% of the stock in 2050. This increase is primarily driven by a 15% growth in population and by an increase in the demanded floor area per person. The latter is mainly explained by the decrease in the average number of persons per dwelling due to a trend towards smaller household sizes.

The refurbishment of the existing stock is an on-going process up to 2050 (see Figure C.4.1), at which point both scenarios expect that most buildings will be at least partially refurbished. In the short term, the refurbishment rate is projected to remain almost the same under both scenarios. Refurbishments are carried out mainly as component-based retrofits resulting in similar percentages of partially refurbished buildings. In the medium term, the refurbishment activity should increase in the 2DS compared with the RS. This will occur as a consequence of subsidies, tax incentives, and increases in CO_2 taxes. The increased refurbishment activity in the 2DS will, among other things, be reflected in the larger percentage of comprehensively refurbished buildings (5% of the stock) compared to the RS (1% of the stock). This trend will continue in the long term until 2050, when a total of 23% of the stock is comprehensively refurbished in the 2DS, while only 6% is completely refurbished in the

C4.1 – *Refurbishment and new construction activities relating to building stock according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*

Sources:
TEP Energy & Chalmers University, BSM.



RS.

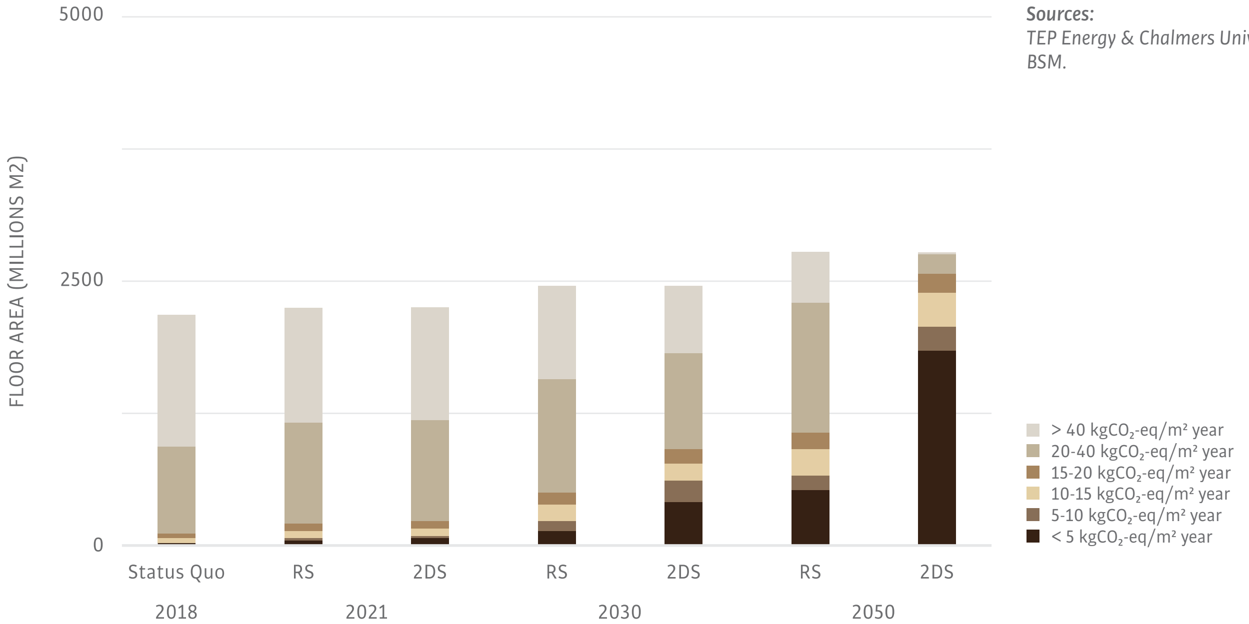
CCurrently, most residential buildings in England emit more than 20 kg CO_2-eq per m², with only 5% of the floor area covered by buildings emitting less than that (see Figure C.4.2). In the short term (until 2021), both scenarios anticipate only minimal changes in the GHG intensity of the building stock. Nevertheless, the percentage of buildings emitting less than 20 kg CO_2-eq per m² doubles in both scenarios. This increase stems mainly from new buildings added to the stock after 2018, which have a carbon intensity of less than 10 kg CO_2 per m².

Both scenarios project that the majority of buildings will still emit more than 20kg CO_2 per m² in 2030; however, there are significant differences between the two scenarios. In the RS, buildings emitting less than 20kg CO_2 per m² still only make up 20% of the stock, because only a small percentage of the stock is refurbished comprehensively, and the majority of the stock is still heated by fossil fuels. In the 2DS, the percentage of low-carbon buildings is significantly higher, because the percentage of buildings with a GHG intensity of less than 20kg CO_2 per m² is almost double that in the RS. This is due to more refurbishments and a faster change to RESs in the 2DS compared to the RS.

After 2030, there is a clear shift to low-carbon buildings in the 2DS, resulting in the majority of the stock emitting less than 5kg CO_2 per m². This is triggered by policies dedicated to phasing out fossil energy in the heating sector, which is primarily driven by a shift to district heating and electrically driven heat pumps, as well as the continued efforts in building retrofitting. An important prerequisite of this development is the decarbonization of the English electricity mix according to the EU Reference Scenario. In the RS, the shift towards low carbon buildings is less pronounced even if the percentage of low-carbon buildings increases further. This is due to the fact that in this scenario fossil fuels, especially gas, are still dominant technologies in the existing stock, and RES such as heat pumps are mainly applied in new construction.

Notes:
GHG intensity: GHG emissions from final energy consumption include those from electricity for heating, hot water, ventilation, and cooling from a life-cycle perspective. For example, 10 kg CO_2-eq per m² is equivalent to 45 kWh per m² in a gas-supplied building. GHG emissions embodied in the construction of the building are not included.

***C4.2** – Structural changes in the GHG intensity of building stock according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*



Sources:
TEP Energy & Chalmers University, BSM.

C5

Structural change of the building market
Short-, mid-, and long-term development

Notes:
Construction activities not directly related to energy and GHG emissions (e.g. structural or interior work, kitchens and bathrooms) are not included.

-

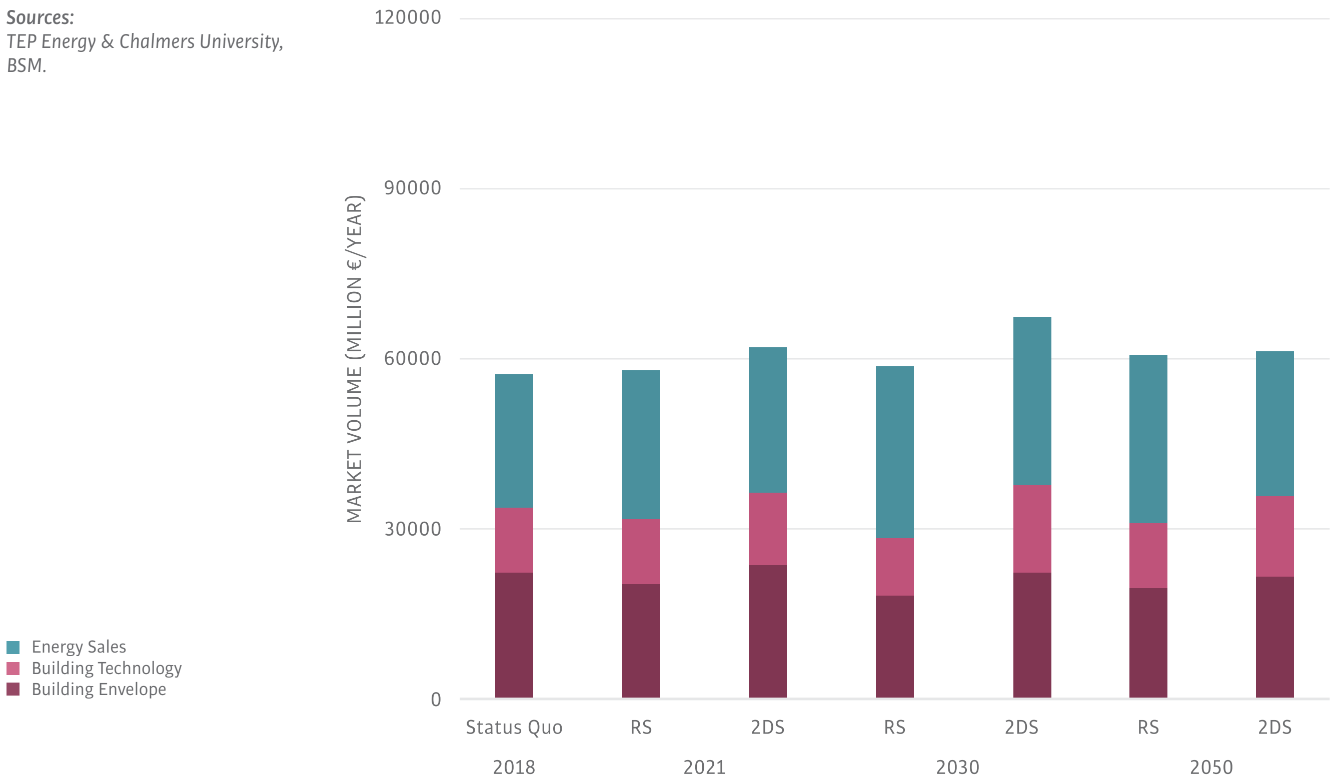
The market volumes presented in this and the next sections reflect the demand side. Possible shortages in capacity of the by the supply side to deliver (both in labour and material) are not explicitly taken into account.

In this and the following sections, energy- and GHG-related building market demand is assessed. This includes the building envelope market, the building technology market, and related energy sales. Within this scope, the building envelope market encompasses all construction, retrofitting, refurbishment, and maintenance activities on building envelope components (walls, roof, floor, and windows). The building technology market includes heating, hot water, and ventilation technologies. In the category of energy sales, all energy related to the building envelope and building technologies is included, while electricity sales from household appliances and CO_2 taxes are not. Hence, the whole value chain related to energy consumption and greenhouse gas emissions, including planning, installation, material and product sales, operation and maintenance, and the like is covered, both for existing buildings through refurbishment and the construction of new buildings.

According to BSM calculations, the total market volume of the energy- and GHG-related building market, including energy sales, amounts to €57.6 billion per year for 2018 (see Figure C.5.1). The largest share of the market volume comes from energy sales (€23.7 billion per year), even though electricity sales for household appliances are not balanced. The rest is split between the building envelope (€22.3 billion per year) and building technology (€11.6 billion per year).

***C5.1** – Development of energy-relevant market volume in the residential building market according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*

Sources:
TEP Energy & Chalmers University, BSM.

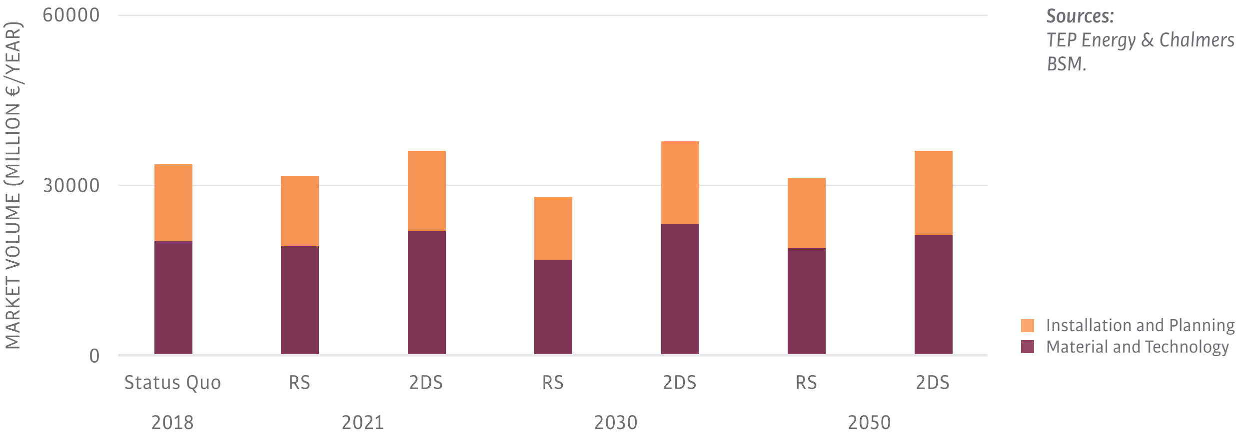


In the short term, the market volume stays constant in the RS. There is a slight increase in energy sales, mainly from an increase in energy prices, rather than an increase in sales. This increase is dampened by decreasing volumes in building envelope (-9%). In the 2DS, there is, however, already a slight increase in market volume from building envelope measures

(+6%) and building technologies (+10%). This is principally triggered by policies targeting an increase in refurbishment taking effect in 2020, and the acceleration of the phasing out of fossil-energy heating systems.

Until 2030, the total market volumes increase in both scenarios. In the RS, only the market volume for energy sales increases, compensating for decreasing market volumes in the other sectors. This is due to an increase in energy prices as well as to a growth of the building stock as a result of new construction, which counterbalance the energy-efficiency gains through retrofitting. In the 2DS, the partial electrification of the heat supply counterbalances the higher rate of refurbishment and, consequently, lower energy demand to some degree and results in a net increase in energy sales volume as price and quantity effects level out. The market volume for building technologies increases significantly (+30%) as the shift from gas to heat pumps and district heating accelerates.

C5.2 – *Development of energy-relevant market volumes (excluding energy sales) for material and technology, and installation and planning according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*



Sources:
TEP Energy & Chalmers University, BSM.

In the long term, until 2050, the overall market volumes level out in the two scenarios. The reduction of energy demand in the building sector in both scenarios leads to a decreased market volume of energy sales, which can no longer be offset by the shift to higher-priced energy carriers. This effect is stronger in the 2DS where energy sales almost revert to 2018 levels. Compared to 2030, the market volumes for building technologies and building envelope increase slightly in the RS and but decrease in the 2DS.

The market volume (excluding energy sales) is split about 40%–60% between installation, engineering, and technical planning (€13.3 billion per year) and material and technology (€20.5 billion per year). The increase in the market volume in the medium term in the 2DS mainly results from the material and technology category, for which the market volume increases to €23.3 billion per year in 2030 (+14%).

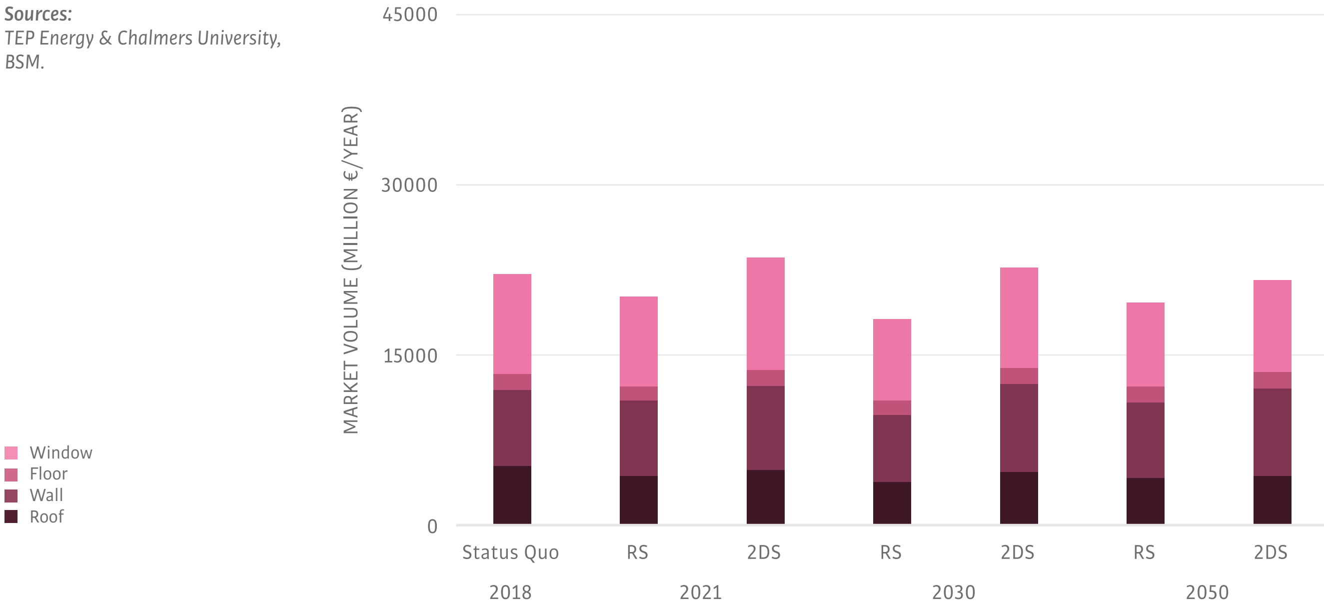
C6 Building envelope
Market volumes and development

The current annual market volume in the building envelope market amounts to €22.3 billion per year. This market volume is split between the various key building components (see Figure C.6.1). Window installation, replacement and refurbishment measures make up the largest share (€8.8 billion per year), closely followed by wall (€6.7 billion per year) and roof (€5.2billion per year). Significantly lower are the shares of floor/basement ceiling insulations (€1.5 billion per year).

In 2018, about half of the building envelope market stems from the construction of new buildings (about 1.4% of floor area is added per year), and the other half from retrofitting existing buildings (an equivalent of about 1% of the building envelope is retrofitted energy efficiently, and an additional 1% is overhauled each year).

***C6.1** – Development of energy-relevant market volumes for a variety of building components for both new construction and refurbishment according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*

Sources:
TEP Energy & Chalmers University, BSM.

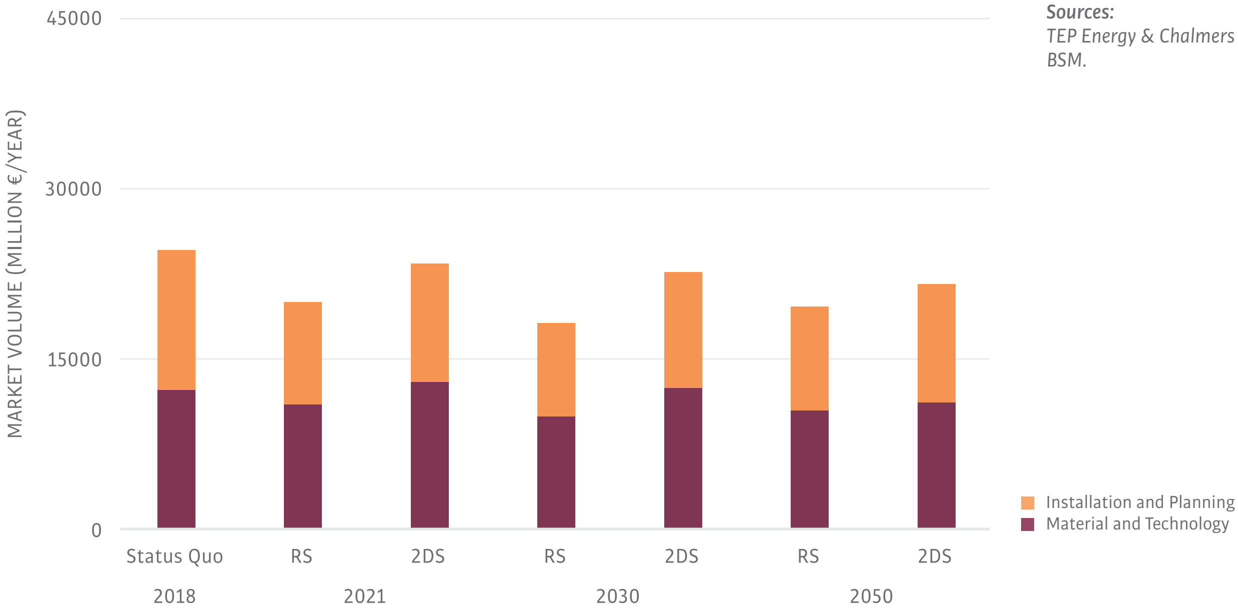


In the short term, the envelope market volume increases only in the 2DS as policies to increase the rate and extent of refurbishment take hold. The market volume grows especially for windows, which increases to €9.8 billion per year (+12%), and walls, which increases to €7.5 billion per year (+11%). In contrast, there is even a slight decrease in the RS. This is mainly due to a decrease in new construction compared to 2018 as population growth slows down. This decrease in new construction activity is compensated for in the 2DS by an increase in the refurbishment market.

In the medium term, the envelope market decreases further to €18.3 billion per year in the RS, because the number of new construction projects remains low. In the 2DS, refurbishment activity remains high, nevertheless the market volume decreases slightly to total of €22.8 billion per year. The higher refurbishment activity in the 2DS cannot compensate for the decrease in new construction projects.

In the long run (i.e., up to 2050), the market volumes decrease down to €21.7 billion per year in the 2DS. In the RS, the market increases slightly to €19.7 billion per year because

***C6.2** – Development of energy-relevant market volumes for material and technology, and installation and planning for building envelope components according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*



Sources:
TEP Energy & Chalmers University, BSM.

refurbishment activities also pick up in the RS between 2030 and 2050. The increase in the market in the RS in 2030 is primarily a result of increasing market shares for wall insulation.

The envelope market volume is split about 45%–65% between installation, engineering, and technical planning (€10.0 billion per year) and material and technology (€12.3 billion per year) (see Figure C.6.2). The decreasing market in the RS in the short term results in an almost equal reduction in installation and planning (-8%) and material and technology (-10%). Similarly, the increase in market volume in the in the 2DS results is distributed equally between the two. The market volume for material and technology increases to €13.1 billion per year (+7%), while the market for installation and planning increases to €10.5 billion per year (+5%). This results from an increase in the extent of refurbishment (e.g., through the application of thicker insulation and more efficient windows) rather than a significant increase in the rate of refurbishment.

In the medium term, the market decreases in both scenarios compared to 2030 as new construction activity decreases further. In the 2DS, however, the market still remains above 2018 levels as there is a significant increase in the refurbishment rate, not just in the extent of refurbishment. As a result the market share for installation and planning almost stays constant at €10.3 billion per year, while material and technology decreases to €12.4 billion per year again.

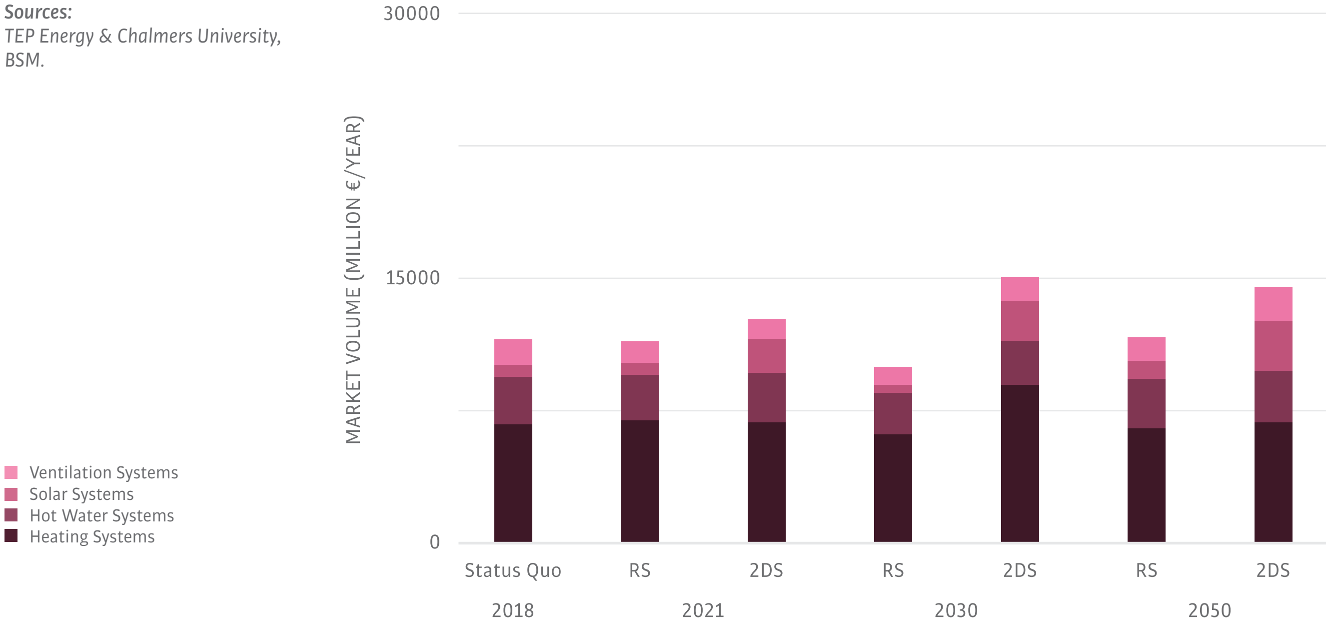
In the long term, the market share of material and technology almost levels out between the two scenarios. However, the 2DS projects higher market volumes for installation and planning than in the RS.

C7 Building technologies
Market volumes and development

The current English building technologies market amounts to €11.6 billion per year. The majority of the market comprises heating and hot water systems, at €6.8 and €2.7 billion per year, respectively (see Figure C.7.1). The remainder is split between solar systems (both thermal solar collectors and photovoltaic systems) and ventilation systems, at about €0.7 and €1.4 billion per year each.

***C7.1** – Development of energy-relevant market volumes of various building technologies in both new construction and refurbishment according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*

Sources:
TEP Energy & Chalmers University, BSM.



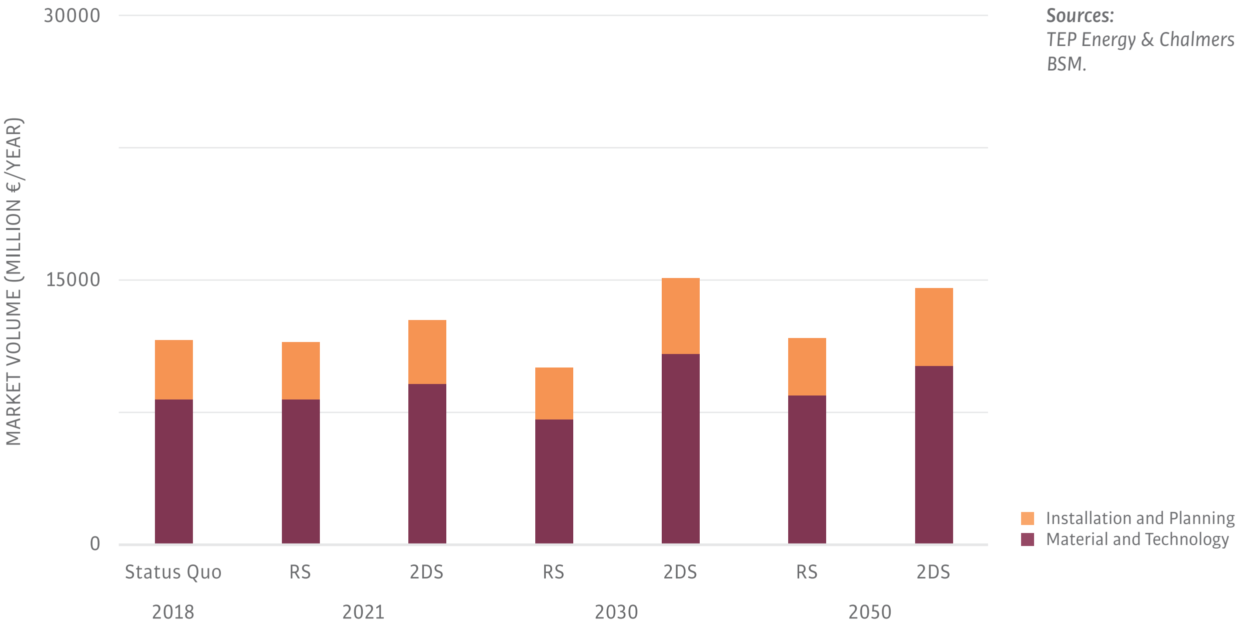
In the short term, the market volume for building technologies remains more or less constant in the RS. However, it increases significantly in the 2DS (to €12.7 billion per year, i.e. by 10%). Policies for decarbonizing the building sector, such as RES obligations, take effect here. As a result, the market volume for solar systems almost triples to 1.9 billion. In addition, restrictions on fossil-energy heating and the CO_2 tax, which lowers the economic viability of gas systems, as well as subsidies and tax incentives for renewable heating systems, help finance the shift towards more expensive heating solutions such as heat pumps.

In the medium term, until 2030, market volume in the RS decreases as the rate of new construction further decreases. In contrast, market volume in the 2DS increases further to €15.1 billion per year as the decrease in new construction is counterbalanced by the increased market volumes of solar and heating systems (+229% and +34%, respectively).

In the long run, towards 2050, the market volumes in the RS recover as reduced new construction activity is offset by increased replacement sales. Moreover, the decarbonisation of the building sector also takes effect in this scenario, resulting in more sales of solar systems (+49%). The market volume in the 2DS decreases again slightly compared to 2030 to €14.6 billion per year.

The building technologies market volume (see Figure C.7.2) is comprised of about 30% installation and planning (€3.3 billion per year) and 70% material and technology (€8.3 billion

***C7.2** – Development of energy-relevant market volumes for material and technology, and installation and planning for building technologies according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS).*



Sources:
TEP Energy & Chalmers University, BSM.

per year). The increase in the short term in the market volume in the 2DS yields an increased market volume in 2021 for the material and technology category, amounting to €9.2 billion per year (+10%), and €3.6 billion per year (+9%) for installation and planning.

In the medium term, the market decreases significantly in the RS, affecting both installation and planning and material and technology due to the decrease in new construction activity. The market for the former decreases to €2.9 billion per year (-15%), and the latter to €7.2 billion per year (-24%). In the 2DS, the decrease in new construction activity is offset, resulting in a further increase of the market volume in both sectors up to €10.9 billion per year (+31%) for material and technology and €4.3 billion per year (+28%) for installation and planning. The larger increase in material and technology is primarily a result of the higher material costs of the growing percentage of heat pumps installed as opposed to other systems.

In the long term, the market in the RS recovers because the decrease in new construction activity is also offset by the growing percentage of heat pumps installed in this scenario. This is reflected in the decreasing percentage of installation and planning (28%) in favor of material and technology (72%). In the 2DS the market remains decreases slightly. Moreover, there is a shift towards more installation and planning compared to material and technology as key renewable technologies such as heat pumps, PV, and solar collectors decrease in cost.

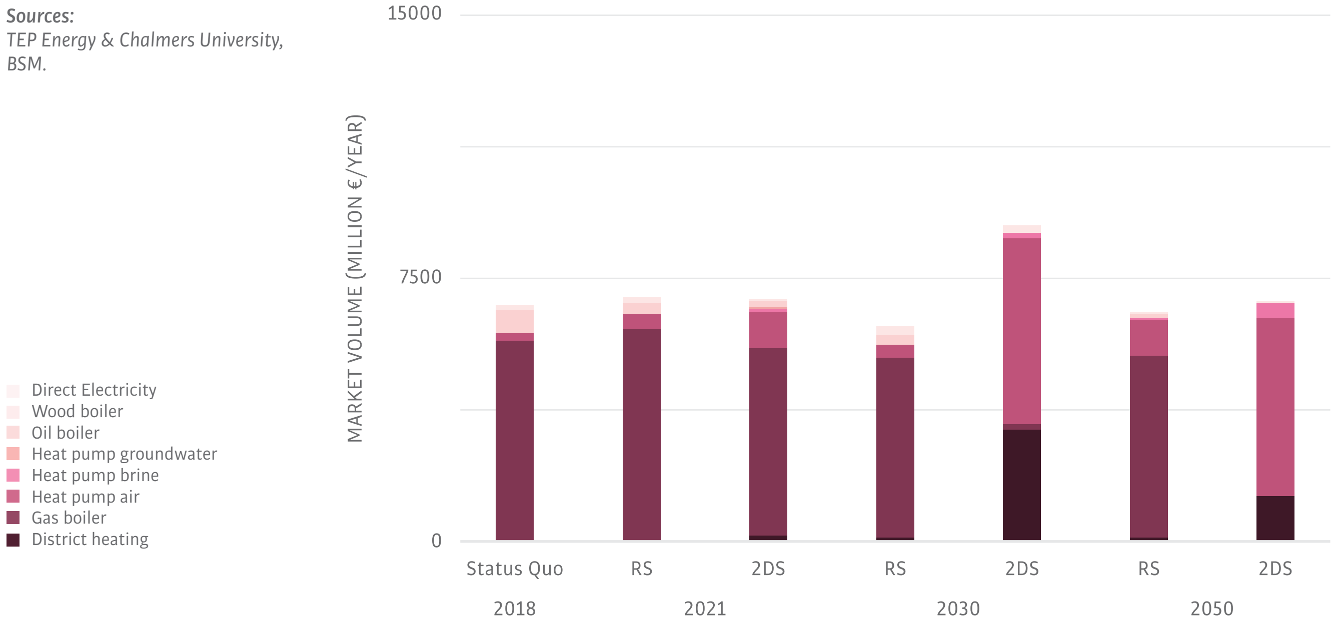
C8 A deep dive into heating systems
Market volumes and development

The current annual market size for heating systems amounts to €6.8 billion per year. The majority of this comes from sales and installation of gas boilers, which have a market size of about €5.8 billion per year. The second and third largest shares come from the sale and installation of oil boilers and air-source heat pumps, with €0.6 and €0.2 billion per year each. The rest of the market is made up by heating systems with lower market shares, such as other types of heat pumps and district heating (see Figure C.8.1).

In the short term, market volumes increase slightly in both scenarios. However, in the 2DS, the policy to phase out fossil fuels takes effect and reduces the market volume for gas boilers to €5.4 billion per year (-6%). It is replaced by an increase mainly in the market volume of air-source heat pumps (€1.0 billion per year).

***C8.1** – Development of the market volumes of various heating system technologies (construction of new buildings and refurbishment of existing ones) according to the Refernce Scenario (RS) and the 2-Degrees Scenario (2DS).*

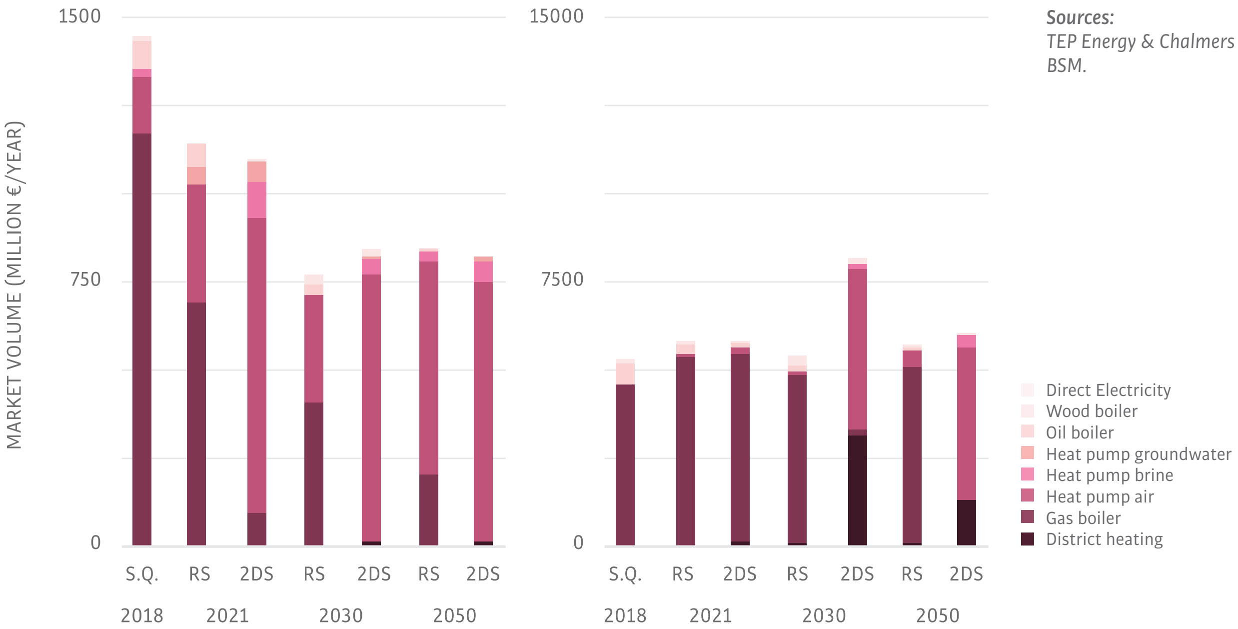
Sources:
TEP Energy & Chalmers University, BSM.



Until 2030, the market volumes in the RS decrease primarily because the rate of new construction declines. In the 2DS, they increase to a total of €9.1 billion per year (+34%) as policies to phase out fossil fuels take full effect. The 2DS shows an almost complete phasing out of gas boilers by 2030. These are replaced by an increase of air-source heat pumps (€5.3 billion per year) and a large expansion in district heating (€3.2 billion per year).

The long-term development up to 2050 shows the market volumes of the two scenarios converging again. The heating system market in the RS is still dominated by gas boilers. However, heat pumps have gained a significant market share by then, with €1.1 billion per year. In the 2DS, gas boilers are phased out completely and the market comprises mainly heat pumps and district heating. The market size of the latter drops again, compared to 2030, to €1.3 billion per year as the expansion of district heating is completed and the market is dominated by replacement sales for existing infrastructure.

C8.2 – Development of energy-relevant market volumes of various heating system technologies according to the Reference Scenario (RS) and the 2-Degrees Scenario (2DS) for the market segments new construction (left) and refurbishment (right).



Sources:
TEP Energy & Chalmers University, BSM.

In 2018, the heating system market (see Figure C.8.2) is made up of about 20% new construction (€1.4 billion per year) and 80% refurbishment (€5.3 billion per year). Both market segments are still dominated by gas boilers, which make up more than 80% of the market in both cases. In the case of existing stock, the remaining market is primarily made up of oil boilers and a small number of heat pumps. Heat pumps are mainly installed in new buildings (€0.16 billion per year), where they make up the largest percentage after gas boilers (€1.2 billion per year).

In the short term, the percentage of heat pumps used in new construction increases in both scenarios: replacing gas boilers with air-source heat pumps makes up a market volume of €0.34 billion per year (+109%) in the RS and €8.4 billion per year (+416%) in the 2DS. The replacement of gas as the dominant technology in new construction is a slow process in the RS, with the market volumes still at €0.4 billion per year (-65%) in 2030 and at €0.2 billion (-82%) in 2050. This transition is accelerated in the 2DS, where gas is already completely phased out in new construction in 2030, having been replaced by air-source heat pumps as the dominant technology, as well as small percentages of other heat pumps and district heating.

For existing stock, gas-fueled heating is still dominant in the short term for both scenarios, with only small increases in the percentages of heat pumps (€0.2 billion per year) primarily replacing oil boilers in the 2DS. In the RS, gas also remains the dominant technology in the existing stock in the medium term and long term, with only a slow diffusion of heat pumps up to a market volume of €0.5 billion per year for air-source heat pumps in 2050. In the 2DS, however, gas boilers are replaced by heat pumps and the extension of district heating in English cities, resulting in market volumes of €4.3 billion per year for air-source heat pumps and €1.3 billion per year for district heating in 2050.

F2 Building inventory factsheet

Single-dwelling
BUILDING

Construction period	1920	1945	1960	1980	1990	2000	2010	
Details								
Cumulative floor area (million m²)	380.7	304.4	293.4	434.7	168.5	135.9	80.2	35.1
Heated floor area (m²)	117	99	95	94	95	107	107	116
Average number of floors (#)	2	2	2	2	2	2	2	2
Envelope surface area (m²)	247	227	225	224	227	246	241	244
Window wall ratio (%)	20%	22%	21%	21%	17%	17%	15%	17%
U-Value (W/m² a)								
Wall	2.02	1.56	1.15	0.92	0.58	0.54	0.57	0.28
Roof	0.58	0.46	0.41	0.39	0.33	0.29	0.25	0.25
Floor	0.69	0.7	0.69	0.69	0.7	0.7	0.69	0.21
Window	3.21	2.97	2.88	2.85	2.85	2.79	2.76	1.85
Heating Systems								
Oil boiler	19%	2%	5%	7%	5%	5%	3%	7%
Gas boiler	75%	96%	92%	90%	90%	92%	93%	90%
District heating	0%	0%	0%	0%	0%	0%	0%	0%
Heat pumps	0%	0%	0%	0%	0%	0%	1%	2%
Wood stove	1%	1%	0%	0%	0%	0%	0%	0%
Direct electricity	4%	1%	2%	3%	4%	3%	3%	1%
Coal boiler	1%	0%	1%	0%	0%	0%	0%	0%

Multi-dwelling
BUILDING

Construction period	1920	1945	1960	1980	1990	2000	2010	
Details								
Cumulative floor area (million m²)	58.4	21.7	28.3	73	30.6	17.3	21	14.7
Heated floor area (m²)	189	174	221	261	222	297	486	478
Average number of floors (#)	3	2	2	2	2	3	3	3
Envelope surface area (m²)	402	376	430	472	433	520	733	720
Window wall ratio (%)	21%	19%	20%	18%	19%	17%	18%	18%
U-Value (W/m² a)								
Wall	2.04	1.82	1.33	1.18	0.62	0.56	0.58	0.28
Roof	1.65	1.38	1.42	1.5	1.33	1.44	1.49	0.21
Floor	0.87	0.9	0.95	0.98	1.02	0.98	1.01	0.21
Window	3.4	3.16	2.91	2.89	2.93	2.82	2.79	1.85
Heating Systems								
Oil boiler	1%	0%	1%	0%	0%	0%	0%	0%
Gas boiler	85%	91%	86%	80%	69%	59%	60%	72%
District heating	0%	0%	0%	0%	0%	0%	0%	0%
Heat pumps	0%	0%	0%	0%	0%	0%	0%	1%
Wood stove	0%	0%	0%	0%	0%	0%	0%	0%
Direct electricity	13%	9%	13%	20%	31%	41%	40%	27%
Coal boiler	0%	0%	0%	0%	0%	0%	0%	0%

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