UK housing: Fit for the future?

Committee on Climate Change
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Executive summary

Key messages

UK homes are not fit for the future. Greenhouse gas emission reductions from UK housing have stalled, and efforts to adapt the housing stock for higher temperatures, flooding and water scarcity are falling far behind the increase in risk from the changing climate. The quality, design and use of homes across the UK must be improved now to address the challenges of climate change. Doing so will also improve health, wellbeing and comfort, including for vulnerable groups such as the elderly and those living with chronic illnesses. This report identifies five priorities for government action:

1. Performance and compliance. The way new homes are built and existing homes retrofitted often falls short of design standards. This is unacceptable. In the long run, consumers pay a heavy price for poor-quality build and retrofit. Greater levels of inspection and stricter enforcement of building standards are required, alongside stiffer penalties for non-compliance. The 'as-built' performance of homes, for example how thermally efficient they are, must also be better monitored. Closing the energy use performance gap in new homes (the difference between how they are designed and how they actually perform) could save between £70 and £260 in energy bills per household per year.

2. Skills gap. The chopping and changing of UK Government policy has inhibited skills development in housing design, construction and in the installation of new measures. Key steps for the UK in reducing emissions, like the wider deployment of heat pumps, require new skills. The UK Government should use initiatives under the Construction Sector Deal to tackle this low-carbon skills gap. New support to train designers, builders and installers is needed for low-carbon heating, energy and water efficiency, ventilation and thermal comfort, and property-level flood resilience.

3. Retrofitting existing homes. The 29 million existing homes across the UK must be made low-carbon, low-energy and resilient to a changing climate. This is a UK infrastructure priority and should be supported as such by HM Treasury. Homes should use low-carbon sources of heating such as heat pumps and heat networks. The uptake of energy efficiency measures such as loft and wall insulation must be increased. At the same time, upgrades or repairs to homes should include increasing the uptake of: passive cooling measures (shading and ventilation); measures to reduce indoor moisture; improved air quality and water efficiency; and, in homes at risk of flooding, the installation of property-level flood protection.

4. Building new homes. There are plans for 1.5 million new UK homes by 2022. These new homes must be built to be low-carbon, energy and water efficient and climate resilient. The costs of building to a specification that achieves the aims set out in this report are not prohibitive, and getting design right from the outset is vastly cheaper than forcing retrofit later. From 2025 at the latest, no new homes should be connected to the gas grid. They should instead be heated through low carbon sources, have ultra-high levels of energy efficiency alongside appropriate ventilation and, where possible, be timber-framed. A statutory requirement for reducing overheating risks in new builds is needed, alongside more ambitious water efficiency standards, property-level flood protection in flood risk areas, and increasing requirements for greenspace and sustainable transport in planning and guidance.

5. Finance and funding. There are urgent funding needs which must be addressed now with the support of HM Treasury: low-carbon heating (currently only funded up to 2021), and resources for local authorities, in particular building control. The UK Government must implement the Green Finance Taskforce recommendations around green mortgages, green loans and fiscal incentives to help finance upfront costs, as well as improving consumer access to data and advice. It should widen the scope of these measures to include resilience.

Householders can also make a big difference with small changes. Even before these actions can be delivered by Government, many householders can make changes immediately to lower their utility bills and improve their homes, for example setting boilers to the correct temperature, installing shading, and increasing insulation.

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Homes of the future are needed today

Decarbonising and adapting the UK's housing stock is critical for meeting legally-binding emissions targets by 2050 and preparing for the impacts of climate change. The UK Government, householders and developers need to implement policies and measures now that ensure new and existing homes are fit for the future.

What does a low-carbon, sustainable home look like?

Current technology, and measures aimed at preparing for the impacts of climate change, can help new and existing homes to become low-carbon and ultra-efficient as well as adapted to flooding, heat and water scarcity.

Existing homes

Improving existing homes can help existing house-holders meet the challenges of climate change

1. **Insulation** in lofts and walls (cavity and solid)
2. **Double or triple glazing with shading** (e.g. tinted window film, blinds, curtains and trees outside)
3. **Low-carbon heating** with heat pumps or connections to district heat networks
4. **Draught proofing** of floors, windows and doors
5. **Highly energy-efficient appliances** (e.g. A^{++} and A^{+++} rating)
6. **Highly water-efficient devices** with low-flow showers and taps, insulated tanks and hot water thermostats
7. **Green space (e.g. gardens and trees)** to help reduce the risks and impacts of flooding and overheating
8. **Flood resilience and resistance** with removable air brick covers, relocated appliances (e.g. installing washing machines upstairs), treated wooden floors

24% REDUCTION NEEDED IN DIRECT CO_2 FROM HOMES BY 2030, FROM 1990 LEVELS

15% REDUCTION REQUIRED IN ENERGY USED FOR HEATING EXISTING BUILDINGS BY 2030 THROUGH EFFICIENCY IMPROVEMENTS[1]

New build homes

New build homes can and should meet even more ambitious standards in some areas

- **A** **High levels of airtightness**
- **B** **More fresh air** with mechanical ventilation and heat recovery, and passive cooling measures such as openable windows
- **C** **Triple glazed windows and external shading** especially on south and west faces
- **D** **Low-carbon heating** and no new homes on the gas grid by 2025 at the latest
- **E** **Water management and cooling** more ambitious water efficiency standards, green roofs and reflective walls
- **F** **Flood resilience and resistance** e.g. raised electricals, concrete floors and greening your garden
- **G** **Construction and site planning** timber frames, sustainable transport options (such as cycling)

What householders can do today

There are number of practical, easy and cheap steps that householders can take now to adapt their homes, and reduce their bills and carbon emissions:

1 Improve home energy, heating and water usage and efficiency

- Install low-energy lighting, hot water tank insulation, low-flow shower heads and draught-proofing
- Turn off the lights/other electricals when not being used
- Turn taps off when brushing teeth, have shorter showers, check pipes for leaks and water gardens only as needed
- Install water and smart energy meters to manage water and energy use and help identify water leaks

2 Is the heating system working correctly?

- Check your boiler annually and ensure your heating system is operating at no more than 55˚C
- Install heating controls like timers and room thermostats
- Turn your thermostat temperature down to 19˚C

3 Reduce the risk of overheating in summer

- Opt for thick curtains or blinds (close them during the day), plant trees to provide shade and open windows at night
- Use fans for bedrooms and living spaces (as long as temperatures are below 36˚C)

4 Flooding

- If you're in a flood risk area sign up to flood warnings and devise your own household plan to prepare for possible floods

Our recommendations to Government

The Government needs to take action in five areas NOW to improve the UK's housing stock and help achieve long-term emissions reduction targets. This includes:

1. Enforcing standards, ensuring compliance with those standards and closing the 'performance gap'
2. Delivering a step-change in construction skills
3. Retrofitting existing homes so they are low-carbon, energy efficient and resilient to a changing climate
4. Ensuring new homes are low-carbon, ultra energy efficient and climate resilient, with sustainable transport options
5. Addressing urgent funding needs

Notes

[1] A 15% reduction relative to 2015

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We cannot meet our climate objectives without a major improvement in UK housing. There are 29 million homes in the UK. The UK Government is committed to building around 1.5 million new homes by 2022 - and there are major plans for new housing in every part of the UK. The quality of these existing and new homes has an important role in safeguarding people's health and wellbeing, and in addressing climate change. In this report, we assess progress in improving housing to meet our climate objectives, and make recommendations for further action.

We will not meet our targets for emissions reduction without near complete decarbonisation of the housing stock. Energy use in homes accounts for about 14% of UK greenhouse gas emissions.[1] These emissions need to fall by at least 24% by 2030 from 1990 levels, but are currently off track. In 2017, annual temperature-adjusted emissions from buildings *rose* by around 1% relative to the previous year.

The housing stock is not well-adapted for the current or future climate. Around 20% of homes (4.5 million[2]) currently overheat even in cool summers; 1.8 million people live in areas which are at significant risk of flooding; and the average daily water consumption per person across the UK is around 140 litres, above the sustainable level in a changing climate and higher than many other European countries. Cost-effective adaptation measures are not being taken up at anywhere near the levels they can or should be.

Current policies are not driving the required changes:

- *Policies to support low-carbon measures have been weakened or withdrawn,* including Zero Carbon Homes and the Code for Sustainable Homes. This has led to many new homes being built only to minimum standards for water and energy efficiency; for example, just 1% of new homes in 2018 were Energy Performance Certificate band A.[3] Low-carbon heat and energy efficiency uptake in existing homes has stalled, including uptake of highly cost-effective measures such as loft insulation. Only around 1 million homes have low-carbon heat, and the majority of this is wood stoves or biomass boilers rather than heat pumps. The low uptake of heat pumps is symptomatic of low awareness, financing constraints, concerns around disruption and difficulty in finding trusted installers with the right skills.
- *There are policy gaps in supporting the uptake of cost-effective measures to reduce climate-related risks; such as property-level flood resilience, water efficiency devices and appropriate ventilation and shading.* Often, these measures are not considered or installed by home owners or housing developers, because of a lack of appropriate regulation, guidance and communication with householders. Requirements to minimise overheating risk are inadequate, and there are no targets for the uptake of property-level flood resilience. While efforts are being made to improve water efficiency, further ambition to reduce per capita consumption levels is needed to reduce the risks of water deficits in a changing climate.
- *Building standards are not sufficiently ambitious; they are overly complex and compliance is poor.* The 2018 Hackitt Review of Building Regulations and Fire Safety identified worrying deficiencies in the current system of Building Regulations. Compliance is weak, and there is indifference around build quality and confusion over roles and responsibilities.[4] This is leading to safeguarding risks, needlessly high utility bills and poorer levels of health, wellbeing and comfort for householders. As a result many new homes lose more heat than

[1] Not including electricity consumption in homes - currently 6% of UK emissions.
[2] England only as data not available for the devolved administrations
[3] Data to the end of September 2018 for England and Wales. MHCLG (2018) Live tables on Energy Performance of Buildings Certificates
[4] MHCLG (2018) *Independent Review of Building Regulations and Fire Safety: final report.*

they should, some as much as twice the amount they are designed to. Loopholes that have allowed poor quality housing to be built also need to be closed. The provisions in the Town and Country Planning Act 1990 currently mean that in some circumstances homes can be built now, subject only to the standards in place at the date planning permission was granted - which may be a number of years earlier. Changes to permitted development rights in England mean that it is permissible to convert light industrial and commercial units to residential dwellings, without the need to ensure those properties meet the building standards set out in Approved Documents L and F for new dwellings. These loopholes mean new homes are still being built which do not meet the current minimum standards. The latest Government data show that 12% of the homes built in 2018 were rated EPC C, whilst 7% were rated D or below.[5]

- *Local authorities do not have sufficient resources to address these concerns and there is not enough use of local and urban planning to make progress on climate change mitigation or adaptation*. There have been some positive clarifications to the National Planning Policy Framework in England to address overheating and flooding, but the revisions have removed the requirement for local authorities to give active support to energy efficiency improvements to existing buildings, and have failed to clarify how far local and regional authorities are permitted to go in setting their own tighter standards for new-build homes. The proportion of urban greenspace in England has dropped since 2001 from 63% to 55%, adding to the problem of increased temperatures in cities (the Urban Heat Island Effect). This subsequently increases the risk of homes overheating. Current standards and planning guidance in England do not encourage high quality sustainable drainage systems in all developments. The planning process often leads to green measures put in at the initial design of the project being removed to bring down costs, or areas of greenspace in existing developments being built on. Many new developments are designed for travel by car, with limited or no access to public transport and a lack of high quality pedestrian or cycling routes.

Urgent changes are needed in five areas.

1. Performance and compliance

Closing the 'performance gap' between how homes are designed and how they actually perform when built or retrofitted is a vital first step to ensure improvements to Building Regulations are effective. Depending on the type of house, closing the performance gap could deliver £70-£260 in annual bill savings. An immediate improvement would be to enforce current standards, and to revise monitoring metrics and certification to focus on ‘as-built’ performance. Further tightening of building standards will have little impact if these issues are left unresolved.

2. Skills gap

Regular changes to key policies have led to uncertainty and poor focus on new housing design and construction skills in the UK. The UK Government should use the initiatives announced under the Construction Sector Deal to tackle the low-carbon skills gap. Developing a better-skilled construction sector will deliver better homes, high-quality jobs and ensure we realise the domestic and international industrial opportunities related to low-carbon building.

Professional standards and skills across the building, heat and ventilation supply trades need to be reviewed, with a nationwide training programme to upskill the existing workforce, along with an increased focus on incentivising high 'as-built' performance. There is an urgent need for

[5] MHCLG (2018) *Live tables on Energy Performance of Buildings Certificates.*

further work to ensure that low-carbon heat and mechanical ventilation systems are designed, commissioned and installed properly, and that householders are supported to use them effectively. Similar efforts are needed to develop appropriate skills and training for passive cooling measures, water efficiency, property-level flood resilience and Sustainable Drainage Systems (SuDS).

3. Retrofitting existing homes

The UK Government must take action to support developers and home owners to retrofit existing homes. Given the scale of the challenge, retrofit must be viewed and supported by HM Treasury and the devolved administrations as a national infrastructure priority.

- *Strengthen policies to drive retrofit energy efficiency measures in homes.* Our scenarios include around a 15% reduction in energy used for heating existing homes by 2030. Polices are needed for households deemed able-to-pay, and a delivery mechanism is needed for social housing minimum standards. Major delivery risks around Private Rented Sector regulations remain. Backstop mandatory targets, as in Scotland, could help create policy certainty and drive innovation and growth. The Green Finance Taskforce's proposals on Green Building Passports should be implemented to provide householders with a holistic and long-term view of renovation needs.
- *Measures to address poor thermal efficiency, overheating, indoor air quality and moisture must be considered together when retrofitting existing homes, and building new homes*. The technology exists to deliver homes with high thermal efficiency (warm in winter and cool in summer), safe moisture levels and excellent indoor air quality, but an integrated approach to design, build and retrofit is needed. Regulations around ventilation must evolve to keep pace with improvements in the energy efficiency of buildings, and there is a need for a more coordinated approach to the requirements for energy and ventilation in buildings. Rather than piecemeal incremental change, long-term investments that treat homes as a system are needed, focussing on improvements at key trigger points such as moving home and renovating.
- *Develop a strategy for low-carbon heat uptake beyond 2021*. Aligning infrastructure investment in low-carbon heat with the UK's climate change targets requires the UK Government to develop a strategy for decarbonised heat. In the 2020s this should include roll-out of heat pumps in homes that are off the gas grid, with a focus on the 1 million homes using high-carbon fossil fuels; a major programme to build and extend low-carbon heat networks in heat-dense areas (e.g. cities), aiming for around 1.5 million homes connected by 2030; support to develop an option to deploy hydrogen for heating homes; continued support for biomethane injected in to the gas grid (with potential to supply up to around 6%of buildings gas demand by 2030); and tackling the current balance of tax and regulatory costs across fuels, which currently weaken the private economic case for electrification. Deployment at scale of 'hybrid' heat pumps[6] in buildings on the gas grid should start soon (up to 10 million by 2035). No new homes should be connected to the gas grid from 2025.
- *Improve awareness of climate-related risks and take-up of resilience measures.* Further action is needed to assess and reduce risks of overheating in existing homes, prioritising passive cooling and behavioural changes. Defra should set an ambitious per capita water consumption target which addresses future supply-demand deficits resulting from both 2 and 4 degree climate change scenarios. This should be met through water efficiency

[6] A hybrid system is capable of switching from electricity to gas, depending on cost and heating requirement.

measures, increased metering, compulsory water efficiency labelling and more ambitious Building Regulations. The UK Government and devolved administrations should increase the number of properties fitted with property level flood resilience. The reinsurance programme Flood Re can help target the most at-risk households, while the insurance and mortgage industries should incentivise uptake of measures in at-risk properties. Householders must have sufficient information on the benefits of adaptation and the incentives to take action so that when Flood Re is withdrawn in 2039, properties remain insurable.

- *A green infrastructure retrofit strategy is needed.* Local authorities should include retrofit programmes when creating local plans. Green infrastructure retrofit can be included as part of regeneration or urban improvement schemes. Funding schemes tailored to multi-benefit green infrastructure are needed, including funding pots that multiple partners can bid into together.

4. Building new homes

Immediate Government action is needed to ensure the new homes planned across the UK are fit for purpose, integrating the highest possible levels of emissions reduction with a package of design improvements to adapt to the changing climate. This will require an ambitious trajectory of standards, regulations and targets for new homes throughout the UK:

- *By 2025 at the latest, no new homes should connect to the gas grid.* Instead they should have low-carbon heating systems such as heat pumps and low-carbon heat networks.
- *Make all new homes suitable for low-carbon heating at the earliest opportunity*, through use of appropriately sized radiators and low-temperature compatible thermal stores. This can save £1,500 - £5,500 per home compared to later having to retrofit low-carbon heat from scratch.
- *New homes should deliver ultra-high levels of energy efficiency as soon as possible and by 2025 at the latest,* consistent with a space heat demand of 15-20 kWh/m^2/yr. Designing in these features from the start is around one-fifth of the cost of retrofitting to the same quality and standard. When installed alongside heat pumps in a typical home,[7] ultra-high levels of fabric efficiency can deliver average bill savings of around £85 per household per year, contribute to reducing annual and peak electricity demand alongside other measures, provide comfort and health benefits for occupants, and create an industrial opportunity for the UK to export innovation and expertise.
- *Statutory requirements should be in place to reduce overheating risk in new-build homes.* Evidence suggests that all new-build homes are at risk of overheating.[8] Passive cooling measures should be adopted to reduce overheating risks before considering active measures such as air conditioning.
- *Improve focus on reducing the whole-life carbon impact of new homes, including embodied and sequestered carbon*. Using wood in construction to displace high-carbon materials such as cement and steel is one of the most effective ways to use limited biomass resources to mitigate climate change. New policies will be needed to support this. Increasing the number of new homes built in the UK each year using timber frame construction systems from around 27,000-50,000 in recent years to 270,000 annually could triple the amount of carbon stored in UK homes to 3 Mt every year. Low-regrets action should also be pursued to support the assessment and benchmarking of whole-life carbon in buildings.

[7] Taken to be a three bedroom semi-detached home.
[8] MHCLG (2018) *Government response to EAC Inquiry on Heatwaves*.

- *Improve water efficiency performance in homes.* Defra should set an ambitious per capita consumption target for water to be met through water efficiency measures, increased metering, compulsory water efficiency labelling, improved behaviours and more ambitious Building Regulation standards. Water efficiency should be included in energy retrofit programmes as standard. There is a need for further research to understand how the design water efficiency level compares to the actual water efficiency of homes once built and occupied.
- *Alongside continued funding for flood defences, strengthen flood resilience measures at property and community level.* Planning Guidance in England and Defra's non-statutory standards must be updated to encourage multi-functional SuDS with clear policy on who should maintain and adopt SuDS by default. The automatic right to connect new developments to the existing sewage network should be made conditional either on national SuDS standards being met or by water company agreement. Local authorities and MHCLG should also incorporate national green infrastructure standards from the 25 Year Environment Plan into local planning. Targets for urban greenspace are needed to drive change. The UK Government should consider the introduction of Flood Protection Certificates and the potential for building standards or regulations to promote property-level flood resilience, as the current uptake is significantly lower than it should be.
- *New developments should enable sustainable travel, which should be a primary consideration from the beginning of the planning process.* This includes planning neighbourhoods around infrastructure to encourage walking, cycling, the use of public transport and electric vehicles. Walking and cycling routes should be well lit, feel safe and be segregated from busy traffic. Integrating consideration of sustainable transport into plans for new houses should ensure developments are easy to serve by public transport. Local authorities must consider where best to locate new homes to minimise the need to travel to work and amenities such as shops and schools. New developments should ensure easy access to electric vehicle charging points for residents in both private and public parking spaces.

5. Finance and funding

In the 2019 Spending Review, HM Treasury must address the multi-billion pound funding gap to deliver low-carbon heating (currently only funded up to 2021). Building control enforcement should also be adequately funded as a matter of urgency.

Green finance can facilitate access to capital, enabling and incentivising householders to take action and realise the benefits of low-carbon and resilient homes. The UK Government should implement the Green Finance Taskforce recommendations around green mortgages and green loans to encourage uptake and support financing of upfront costs. Lenders should incorporate fully energy costs in mortgage affordability calculations. The Government should widen the scope of Green Finance measures, for example including water efficiency, flood and heat resilience and introducing resilience surveys. It should work with the National Infrastructure Commission and others to promote research and development and develop standards for new homes. The insurance industry, and the finance industry more broadly, has a key role in incentivising uptake of property level flood resilience.

Policy frameworks and support need to create an attractive package for householders, aligned to 'trigger points' when important decisions are being made, such as when a home is purchased, a boiler breaks down, or when other renovations are taking place.

Many of the measures analysed in this report have clear, multiple benefits alongside reducing emissions and increasing resilience to climate change: reducing utility bills, and improving comfort, health and the natural environment.

Where properly planned and used, our homes can be low-carbon, more comfortable to live in, better for our health, and more affordable to run. The health cost to the NHS of conditions exacerbated by poor housing is currently estimated to be £1.4 – 2.0 billion per year in England alone.

Thermally comfortable housing could reduce the risk of heat and cold-related deaths. Improved energy efficiency has the potential to reduce energy bills and tackle fuel poverty. Greater water efficiency savings have a positive impact on energy use and bills as well as water bills. Green spaces and SuDS can help to sequester carbon, increase biomass and biodiversity, improve water quality and help control surface water flooding. Green spaces can also bring multiple health benefits. Encouraging walking, cycling and the use of public transport and electric vehicles will improve outdoor air quality. Ensuring local bus services go to places people want, at times they need to travel can help people feel more connected to their community.

The need to decarbonise and improve the climate resilience of our homes has the potential to create big opportunities for businesses and high-quality skilled jobs.

Government support and frameworks for the measures outlined in this report will drive demand for improvements and cut the costs per property as measures are implemented at scale. A stable policy framework and direction of travel will help to provide the long-term policy certainty that is needed to raise awareness and help skills and supply chains develop. Developing expertise in low-carbon, resilient homes represents an industrial opportunity for the UK to export innovation and skills.

Recommendations

To take forward our key messages, we make 36 recommendations for action. These feed into a wide array of current work the UK Government and devolved administrations are planning for 2019, including: the reviews of Part L and Part F of the Building Regulations, an update of the planning practice guidance in England, development of a roadmap for policy on heat decarbonisation, review of a per capita water consumption target in England and the Government's commitment to halve the energy use of new homes by 2030.

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Compliance and the performance gap	1. Overhaul the compliance and enforcement framework so that it is outcomes-based (focussing on performance of homes once built), places risk with those able to control it, and provides transparent information and a clear audit trail, with effective oversight and sanctions. Fund local authorities to enforce standards properly across the country.	*MHCLG, devolved administrations, HMT* *by 2019*
Compliance and the performance gap	2. Reform monitoring metrics and certification to reflect real-world performance, rather than modelled data (e.g. SAP). Accurate performance testing and reporting must be made widespread, committing developers to the standards they advertise.	*BEIS, MHCLG, devolved administrations, industry* *2020-2025*
Compliance and the performance gap	3. Review professional standards and skills across the building, heat and ventilation supply trades with a nationwide training programme to upskill the existing workforce, along with an increased focus on incentivising high 'as-built' performance. Ensure appropriate accreditation schemes are in place.	*BEIS, industry* *2019*
Compliance and the performance gap	4. Undertake a large-scale study to provide robust quantification and benchmarking of the performance gap for energy, water and ventilation.	*BEIS, industry* *2019*
Building regulations	5. Implement tighter standards for new buildings to ensure they are designed for a changing climate, properly ventilated, moisture-safe, are future-proofed for low-carbon heating and deliver ultra-high levels of energy efficiency. The whole-life carbon and peak demand impacts of new homes should be minimised.	*MHCLG, devolved administrations,* *in force and forward trajectory set out by 2020*
Building regulations	6. Government should develop a targeted package of new measures to incentivise and support those developers and individuals who wish to take early action in building low-carbon and resilient homes.	*MHCLG, BEIS, HMT, devolved administrations* *by 2020*
Building regulations	7. All new homes should be made low-carbon heat ready. By 2025 at the latest, no new homes should connect to the gas grid, and should instead rely on low-carbon heating systems such as heat pumps.	*MHCLG, BEIS, devolved administrations* *trajectory set out by 2020*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Building regulations	8. The Standard Assessment Procedure should be reviewed and revised to drive high real-world performance and value properly the benefits of low-carbon technologies. It should formally integrate a forward trajectory for declining grid carbon intensity, in line with Government projections.	*MHCLG, BEIS* *by 2020*
Building regulations	9. New-build homes should deliver ultra-high levels of energy efficiency as soon as possible, and by 2025 at the latest. This should be consistent with a space heat demand of 15-20 kWh/m^2/yr.	*MHCLG, devolved administrations* *trajectory set out by 2020*
Building regulations	10. Regulations around ventilation and indoor air quality must evolve to keep pace with improvements in the energy efficiency of buildings. Part F of the Building Regulations should be reviewed alongside Part L, with a view to tightening standards and coordinating requirements to fully reflect interdependencies. Where updates affect Part B and vice versa, Government should review the standards as a whole. Steps must be taken to improve the design, commissioning, and installation of mechanical ventilation systems, with further research into how challenges in maintaining and operating them can be overcome.	*MHCLG, Defra, devolved administrations* *2019*
Building regulations	11. It is critical that the 2019 reviews of Building Standards by MHCLG, Scottish Government and Welsh Government: • Introduces a new standard or other requirement to ensure that overheating risk is assessed for current and future climates at design stage of new-build homes or renovations. • Ensures that passive cooling measures are installed at build stage where there is a risk of overheating identified. Where active cooling measures are also needed, consideration should be given to potential synergies in the choice and installation approach for heating and cooling systems, for example through the use of air source heat pumps combined with mechanical ventilation.	*MHCLG, Scottish Government, Welsh Government* *2019*
Building regulations	12. Examine the potential role for new-build standards in encouraging deployment of technologies to support peak management and demand reduction.	*MHCLG, BEIS, devolved administrations* *by 2020*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Building regulations	13. Close loopholes allowing homes to be built which do not meet the current minimum standards for new dwellings. This includes provisions around the expiry of planning permission, and permitted development rights relating to change of use.	*MHCLG* *2019*
Low-carbon homes	14. In our report on *hydrogen* in November 2018, we recommended that the Government should develop a fully-fledged UK strategy for decarbonised heat within the next 3 years. Subsequently, BEIS has committed to publication of a new heat roadmap within 18 months. It is essential that Treasury should commit now to working with BEIS on development of the roadmap/strategy. This must include clear signals on the future use of the gas grid in the UK and commitments to funding and, as a minimum: • A clear trajectory of standards covering owner-occupied, social- and private-rented homes, announced well in advance (including detailed plans on phasing out the installation of high-carbon fossil fuel heating and improvements in the efficiency of existing heating systems). • A support framework for low-carbon heating (heat pumps, biomethane, and networked low-carbon heat). • A review of the balance of tax and regulatory costs across fuels in order to improve alignment with implicit carbon prices and reflect the progressive decarbonisation of electricity. • An attractive package for householders aligned to trigger points (such as when a home is sold or renovated). • A nationwide training programme to upskill the existing workforce. • A governance framework to drive decisions on heat infrastructure through the 2020s.	*HMT, BEIS* *within the next 18 months - 3 years*
Low-carbon homes	15. Following UK exit from the EU, product standards should remain in place or be replaced with equivalent or more ambitious regulation.	*BEIS* *ongoing*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Low-carbon homes	16. Develop new policies to support a substantial increase in the use of wood in construction. This will need to focus on overcoming a range of cultural, skills and financial barriers in the construction sector. Undertake low-regrets action to support the assessment and benchmarking of whole-life carbon in buildings with a view to informing the future policy framework.	*MHCLG, BEIS, devolved administrations* *new policies for wood in construction in 2019, with groundwork on whole-life carbon by 2024*
Low-carbon homes	17. BEIS, Ofgem and National Grid should implement the remaining actions set out in the Smart Systems and Flexibility Plan, alongside the continuation of wider improvements that are already underway. Actions include encouraging suppliers to offer smart tariffs and capitalising on EV potential to provide demand-side response and storage services.	*BEIS, Ofgem, National Grid* *actions implemented by 2022*
Low-carbon and resilient homes	18. Improve consumer access to data and advice by implementing the Green Task Force proposal on Green Building Passports, improving EPCs and access to data underpinning EPCs and SAP, and identifying options to go further in particular to include resilience measures. Water efficiency, flood resilience and other resilience measures should be considered in digital 'green passports', and resilience surveys or Flood Protection Certificates developed alongside EPCs.	*BEIS, HMT, devolved administrations* *2019-2020*
Low-carbon and resilient homes	19. Implement GFT recommendations around green mortgages and fiscal incentives to encourage uptake and support financing of upfront costs. To help drive the market for resilient products and services the Government should also look to widen the scope of green finance to include resilience.	*BEIS, HMT* *2019*
Overheating	20. Further action should be taken to better understand when overheating occurs in existing homes in order for passive cooling measures and behaviour change programmes to be targeted effectively.	*Department of Health and Social Care, MHCLG, Scottish Government, Welsh Government,* *by 2020*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Overheating	21. In England the Government must ensure that Planning Guidance is updated to clearly require local authorities to include overheating risk in Local Plans, as set out in the updated National Planning Policy Framework. Guidance should contain a requirement for local authorities to include an assessment of overheating risk as part of the planning process. This should require developers to carry out an initial assessment of the strategic features that increase risk, such as site location, building layout, façade, green space availability, and introduce appropriate mitigation measures at the early planning stages.	*MHCLG* *by 2020*
Water efficiency	22. Local authorities should include water efficiency measures in energy efficient retrofit programmes. Water efficiency should be included in social housing standards (such as the Decent Homes and Welsh Housing Quality Standard).	*Local authorities* *Ongoing*
Water efficiency	23. Defra should set a per capita consumption target which can address future supply-demand deficits resulting from both 2 and 4 degree climate change scenarios. Further research should be undertaken to understand the costs and benefits of targets between 50 and 100 litres per day by 2050. The devolved administrations should consider whether it is necessary to introduce similar targets. As a first step to meeting a target and improving water efficiency in homes, the UK Government and devolved administrations should: • Enable water companies to implement compulsory metering beyond water stressed areas by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters. • Review new-build regulation standards to allow local authorities to set more ambitious standards, especially in current and future water-stressed areas. • Introduce compulsory water efficiency labelling of household water products. • Work with water companies and local authorities to run partnership retrofit and behaviour change programmes in existing homes.	*Defra* *by 2021*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Property level flood protection	24. Defra should develop a long-term strategy to manage flood risks in each part of the country (as first recommended in 2015), so that as Flood Re is withdrawn properties can remain insurable at reasonable costs. This should include: • Continuing to support the industry round table in communicating risk and possible adaptation actions to households and communities that are expected to remain or become at high flood risk by the 2030s. The Flood Re database should be used to initially target those at risk. • Pilot schemes to test and increase understanding of potential PFR options and their benefits to homeowners and landlords. • The introduction of resilience surveys and Flood Protection Certificates which can be used by homeowners, insurance companies and lenders. The UK Government should work with BRE to further develop and widen the use of the Property Flood Resilience database tool. • Detail of how the new Code of Practice will ensure skills are improved and better compliance and enforcement of installing measures. • Plans to work with the insurance industry to ensure they have the evidence needed in order to confidently make informed judgements about which resilience and resistance measures installed in properties lead to reduced risk. Insurers should insist that resilience and resistance measures be implemented during post-flood repairs as a condition of continuing insurance cover.	*Defra, Environment Agency, Insurance companies* *by 2020*
Property level flood protection	25. MHCLG and the devolved governments should examine the potential for regulations on flood protection approaches for both refurbishment and new-build homes.	*Defra, MHCLG, devolved administrations* *by 2021*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Green infrastructure	26. Policy is needed in England to address the outstanding barriers to deliver high-quality, effective green SuDS in new development and retrofit: • The Planning Guidance for England must be updated urgently to encourage multi-benefit SuDS in all developments, to bring together other aspects of planning related to green infrastructure and to help address skills and knowledge gaps. • Defra should update the non-statutory standards using latest evidence on the full costs and benefits of SuDS. To promote water company adoption of SuDs Defra should consult with Water UK to ensure that standards are aligned to the most up to date 'Sewers for Adoption'. • The automatic right to connect new development to the existing sewerage network should be made conditional on national SuDS standards being met or by water company agreement. • A clear policy is required on who should maintain and adopt SuDS by default, unless agreed otherwise. • Improved information on the implementation of green SuDS across the UK.	*Defra, MHCLG and local authorities* *by 2020*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Green infrastructure	27. The UK Government and devolved administrations should take steps to monitor and reverse the decline in urban greenspace through clearer policy and more support for schemes that deliver multiple benefits: • The UK Government should set a national target for increasing the area of urban greenspace, as part of the 25 Year Environment Plan metrics. New standards for green infrastructure should be set in England (as actioned in the 25 YEP) and embedded within planning policy. • The UK Government should assess the need for a national green infrastructure retrofit strategy to help guide local authorities and water companies in creating and including green infrastructure in drainage and local plans. • Options for funding schemes tailored to multi-benefit green infrastructure schemes. This could include providing funding pots that multiple partners can bid into together. • The devolved administrations should monitor changes in urban greenspace over time, and if declining should also take steps aligned with those suggested for England to reverse the decline.	*Defra, devolved administrations* *by 2021*
Transport	28. Sub-national transport bodies should play a role in coordinating regional housing plans and sharing good practice across local authorities.	*Sub-national Transport Bodies* *by 2021*
Transport	29. The Government should review the powers of planners and develop mechanisms to fund costs of building high-quality walking, cycling and public transport infrastructure, even when outside the immediate housing site boundary.	*MHCLG, DfT, devolved administrations* *by 2020*
Transport	30. MHCLG and DfT should explore the potential for new rail stations, and light rail, tram and bus (including bus rapid transit) routes to unlock areas for housing development whilst mitigating transport impacts.	*MHCLG, DfT* *by 2020*
Transport	31. Local authorities must consult the bus industry at the Local Plan stage to ensure new housing areas can be serviced by commercially viable routes.	*Local authorities* *by 2020*

Table 1. Recommendations		
Topic	Recommendation	Owner and timing
Transport	32. For areas within walking distance of high-quality public transport (such as local rail, trams and bus rapid transit), MHCLG and DfT should set minimum density guidelines to ensure local authorities concentrate housing in these areas wherever possible.	*MHCLG, DfT* *by 2020*
Transport	33. Government must strengthen the importance of sustainable transport plans that are integrated into the development throughout the design process, including the development of walking and cycling routes and early consultation with public transport providers.	*MHCLG, DfT, devolved administrations* *by 2020*
Transport	34. To encourage uptake of electric vehicles, the government should immediately consult on regulations to include appropriate cabling ready for installation of electric vehicle chargers or electric vehicle chargers themselves in all new parking spaces for housing developments with off-street parking.	*OLEV* *by 2020*
Local action and planning	35. MHCLG must clarify the rights and obligations of local and regional authorities in relation to climate change mitigation and adaptation. This includes clear statutory duties, and clarification of how far local and regional authorities are permitted to go in setting tighter new-build standards.	*MHCLG* *2019*
Local action and planning	36. Fund local and regional authorities adequately to drive and influence emissions reductions and adapt their localities to a changing climate, and to discharge their responsibilities in relation to the enforcement of building regulations and wider Government policy.	*HMT* *2019 spending review*

Chapter 1: Introduction and context

1.1 Purpose and aim

This is a joint report by the Committee on Climate Change's Mitigation and Adaptation Committees. This report aims to assess the measures that need to be adopted in the housing sector to both manage climate change impacts and reduce greenhouse gas emissions.

There are currently 27.2 million households in the UK.[9] The Government is committed to build around 1.5 million new homes by 2022.[10] The quality of these existing and new homes not only has a critical role in safeguarding people's health and wellbeing, but in addressing climate change.

In previous reports the Committee has assessed adaptation and mitigation requirements of homes separately. However, this report takes a more detailed holistic approach. The way homes are designed and lived in affects both the level of greenhouse gas emissions from the buildings sector, and how exposed people are to the impacts of a changing climate such as hot weather and flooding. Mitigation and adaptation measures are best designed and implemented together, to make the most of potential synergies and avoid negative trade-offs.

This report includes an assessment of policies and actions for both existing homes and new builds across the UK. The report considers the current state of play and what is needed for low-carbon heat, energy efficiency, cooling and ventilation, broader life-cycle carbon associated with homes,[11] peak electricity demand management, water efficiency, property level flood resilience, surface water flood alleviation, green spaces and infrastructure, and sustainable transport.

The report is intended for Government, developers, builders, householders and financial institutions in order to help focus priorities for climate change mitigation and adaptation when building new homes and improving our existing housing stock. It will help inform the UK Government and devolved administrations, and provide a focus for actions now, over the coming decade and beyond.

1.2 Why housing is important for addressing climate change

1.2.1 Reducing greenhouse gas emissions from homes

Heating and hot water for UK homes make up 25% of total energy use[12] and 15% of our greenhouse gas emissions.[13]

A further 4% of greenhouse gas emissions are the result of electricity used in the home for appliances and lighting.[14] Nearly all homes are naturally ventilated, although cooling energy demand is increasing and projected to increase further with rising temperatures.[15]

[9] ONS 2017: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families
[10] BEIS (2018) *Industrial Strategy - Construction Sector Deal.*
[11] Such as carbon embodied in construction.
[12] BEIS (2018) *Energy Consumption in the UK*, Table 1.04: Overall energy consumption for heat and other end uses by fuel 2010 to 2017.
[13] CCC (2018) *Reducing UK emissions – 2018 Progress Report to Parliament*. This includes emissions from electricity demand for heating and hot water in homes, which accounts for 1% of UK GHGs.
[14] CCC (2018) *Reducing UK emissions – 2018 Progress Report to Parliament.*
[15] BEIS (2018), *Energy consumption in the UK*; DECC (2013), *The future of heating: Meeting the challenge.*

Progress in reducing emissions from homes is set out in our annual Progress Report to Parliament. A near complete decarbonisation of how we heat our homes is required to meet the UK's legally binding targets to reduce emissions by at least 80% on 1990 levels, and prepare the stock for future net-zero ambitions.[16]

Emissions are not falling at the rate needed to meet the UK's carbon targets:

- Direct emissions from homes were 64 million tonnes (Mt) CO_2 in 2017.
- When adjusting for annual temperature variation, emissions rose by 1% in 2017. [17] Emissions were just 9% below 1990 levels. This compares to a 13% reduction in residential emissions in our cost-effective pathway for meeting carbon budgets, on track to a 24% reduction by 2030.
- Whilst energy use per household and per person have fallen since 1990 – by 21% and 14% respectively – this does not include any progress since 2014.[18]

The reasons for this are clear.

Current policy is failing to drive uptake of energy efficiency in existing homes – installation of loft and wall insulation is at just 5% of peak market delivery in 2012 (Figure 1.1), despite significant remaining cost-effective potential.[19] The overall efficiency of the housing stock remains low (Box 1.1), and UK homes lag behind other comparable countries.[20]

The UK Government is currently working towards low-carbon heat in every home by 2050. However, fewer than 500,000 homes currently have some form of low-carbon heating when not counting closed stoves or wood used on open fires:

- Around 24 TWh of woody biomass was used for heating UK homes in 2017.[21] A 2014 survey suggests that around half of this is used on open fires, which are not an efficient use of fuel and which we do not count as low-carbon heat uptake.[22] A further 45% was used in closed stoves, leaving an estimated 90,000 with pellet stoves, boilers or range cookers. Biomass for heat is in general not consistent with the long-term best use of limited bioenergy resources except in niche uses.[23]
- Deployment of heat pumps remains very low at around 160,000 heat pumps, with only around 18,000 units sold in 2016.
- Whilst delivery of heat through heat networks appears to be broadly on track with our assessment of what is required to meet future targets, only 7% of heat in these networks currently comes from low-carbon primary fuel sources.

[16] The Government has now sought advice on the date by which the UK should achieve a net zero greenhouse gas or carbon target following the Paris agreement. See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/748489/CCC_commission_for_Paris_Advice_-_Scot__UK.pdf

[17] Temperature adjustments are made to account for the varying length of the heating season year-to-year, with heating demand adjusted in line with the long-term average.

[18] BEIS (2018) *Energy Consumption in the UK*, Table 3.04 Domestic energy intensity 1990 to 2017.

[19] Including insulating a total of 5 million cavity walls and lofts, and one million solid walls. A further million solid walls are included in our fifth carbon budget scenario because of the fuel poverty and related health benefits.

[20] Association for the Conservation of Energy (2015) *The cold man of Europe - 2015.*

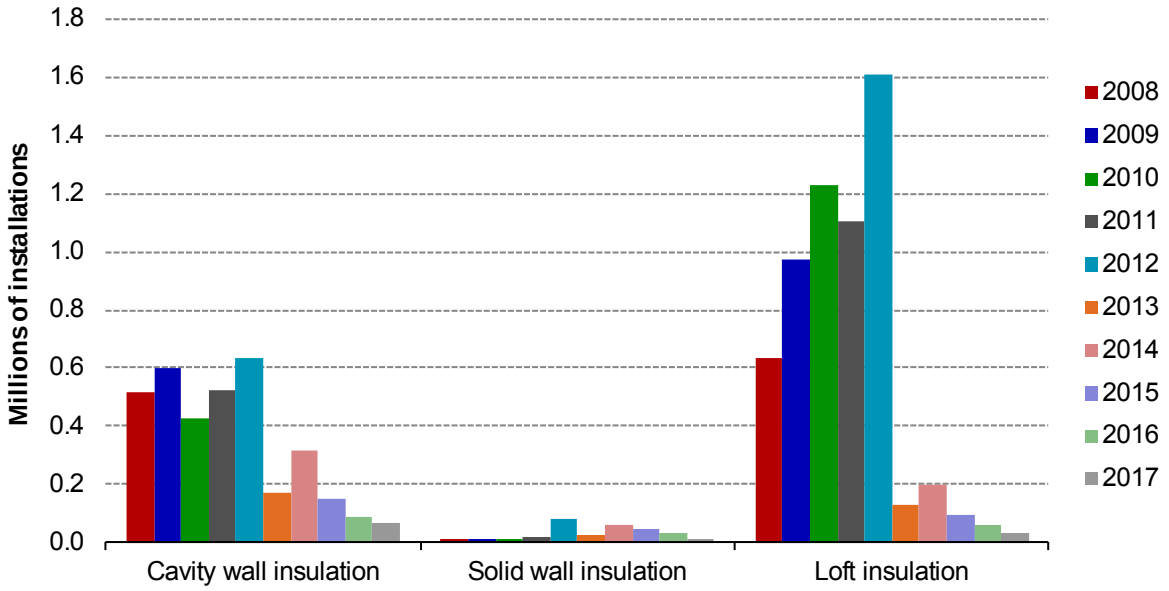
[21] BEIS (2018) *Digest of UK Energy Statistics.*

[22] BEIS (2016) *Summary results of the domestic wood use survey*, available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/517572/Summary_results_of_the_domestic_wood_use_survey_.pdf

[23] CCC (2018) *Biomass in a low-carbon economy*.

The numbers of homes connected up to natural gas heating has risen from 14 million in 1990 to 23.9 million currently.[24]

Figure 1.1. Annual installation rates of loft insulation, cavity wall insulation and solid wall insulation (2008-2017)



Source: BEIS (2018) *Household Energy Efficiency National Statistics;* previous DECC publications.
Notes: Installations under Government schemes.

Box 1.1. Energy efficiency of the UK housing stock - SAP scores and EPC ratings

The Standard Assessment Procedure (SAP), is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings. It is the basis for establishing compliance with Building Regulations, and for Energy Performance Certificates (EPCs). EPCs have two metrics, a fuel cost-based energy efficiency rating (commonly called the 'EPC' rating, in £/kWh/m^2) and a rating relating to emissions of CO_2 (the Environmental Impact (EI) rating, in CO_2/m^2). Ratings are banded A-G, with A being the highest performing.

The EPC rating is based on a 'SAP' score. A higher 'SAP' score indicates lower running costs, with an EPC rating of A being equivalent to a SAP score of 92 to 100 points. A score of 100 indicates that no heating or hot water costs are required for that building.

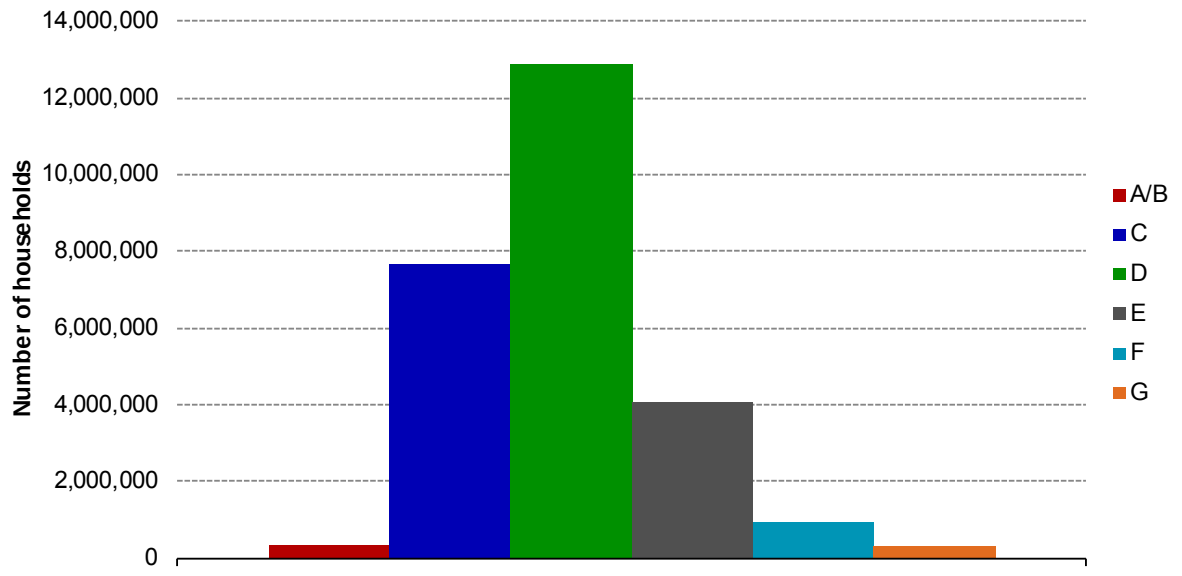
In 2016, the average SAP score of English dwellings was 62 points, up from 45 points in 1996. This increase was evident in all tenures. However, the increase appears to be slowing and there was no change in the average SAP score of homes between 2015 and 2016 (in any tenure).

Energy Performance Certificate (EPC) data indicates that D is the most common EPC rating across Great Britain. Few properties have A or B ratings (estimated to only make up 1.4% of all properties in England and Scotland in 2016) (Figure B1.1).

[24] BEIS (2018) *Energy Consumption in the UK*; Table 3.18: Installed central heating by type in UK 1970-2016. Latest data available is for 2014.

Box 1.1. Energy efficiency of the UK housing stock - SAP scores and EPC ratings

Figure B1.1 Distribution of the English and Scottish Housing Stock by SAP band (2016)



Source: MHCLG (2018) *2016-17 English Housing Survey Headline Report, Annex Table 2.6*; Scottish Government (2017) *Scottish house condition survey 2016: key findings*.

Source: MHCLG (2018) *2016-17 English Housing Survey Headline Report.*

1.2.2 Climate risks and progress in adapting to climate change

The major risks related to the UK's housing stock are set out in the second UK Climate Change Risk Assessment (CCRA2).

The quality of the design and construction of homes determines how vulnerable people are to flooding, heat, cold and other forms of extreme weather. Indoor air quality, relating to a wide variety of pollutants (including moisture), is also a key concern. Of the six urgent areas of climate change risk to be tackled as a priority,[25] three identified in the CCRA were particularly relevant to residential buildings:

- Flooding and coastal change:
  - Across the UK, approximately 1.8 million people are living in homes which are in areas of significant river, surface water or coastal flooding (defined in the UK Climate Change Risk Assessment as a 1 in 75 (1.3%) or greater annual chance). This could rise to 3.5 million under a 4°C climate change scenario by the 2080s.[26,27] People living in properties located within the UK's most deprived communities face even higher increases in risk. At present

[25] CCC (2016) *UK Climate Change Risk Assessment 2017: Evidence Report.*
[26] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.*
[27] Assuming current levels of adaptation are continued and no population growth.

there is a low uptake of low-regret actions to reduce impacts, such as property level flood resilience.[28]

  - The impacts of flooding and coastal change in the UK are already significant and expected to increase as a result of climate change.[29] Improving protection for some communities will be possible through community scale defences, but others will face significantly increased risks. If unmanaged, these risks will affect property values, business revenues and in extreme cases the viability of communities.
  - Warming of 4°C or more implies inevitable increases in flood risk across all UK regions, even in the most ambitious adaptation scenarios considered in producing CCRA2.[30]

- Heat-related health impacts:
  - The average number of hot days in the UK has been increasing since the 1960s. The chance of a summer as hot as 2018 is around 50% by 2050.[31] Projections show that maximum summer temperatures could rise by 6 - 9°C by the end of the century compared to the 1981-2000 average.[32]
  - Studies based on sample buildings in England show around 20% of homes overheat in the current climate.[33] The south of the UK is more severely affected by indoor overheating problems, but there are few studies of overheating in buildings in northern England and in Scotland, Wales and Northern Ireland. Dwelling types that have been found to be more prone to overheating include 1960s – 1970s and post-1990s mid- and top-floor purpose-built flats that lack sufficient ventilation and protection from heating by the sun.[34]
  - In the absence of action, annual UK heat-related mortality is projected to increase from a current baseline of 2,000 heat-related deaths per year to 5,000 per year by 2050 (7,000 per year by 2050 taking account of population growth).[35] High temperatures are also associated with heat-related illnesses. The elderly, very young and people with pre-existing heart and respiratory diseases are particularly at risk. In otherwise healthy people overheating can cause discomfort leading to lack of sleep, productivity and alertness.
  - The Urban Heat Island effect may be considered beneficial in winter, since it reduces somewhat both the impacts on health from cold weather and heating demand. However, in summer, and especially during heatwaves which are expected to become more common, it can exacerbate overheating since it prevents buildings cooling down, particularly at night.
  - Cold-related deaths are still projected to remain high in the future. Current estimates suggest there could be around 41,000 cold-related deaths per year, projected to decline

[28] CCC (2017) *Progress on preparing for climate change.*
[29] CCC (2018) *Managing the coast in a changing climate.*
[30] CCC (2016) *UK Climate Change Risk Assessment 2017: Evidence Report.*
[31] Met Office (2018) *UKCP18*. Under a high climate change and population scenario.
[32] *Ibid.*
[33] Kovats, R.S., Osborn, D., et al. (2016) *UK Climate Change Risk Assessment Evidence Report: Chapter 5, People and the Built Environment*.
[34] CCC (2016) *UK Climate Change Risk Assessment 2017: Evidence Report.*
[35] CCC (2016) *UK Climate Change Risk Assessment 2017: Evidence Report.*

by 1,000 per year by the 2050s. Reducing exposure to cold in winter through better insulation of homes could reduce this much further.[36]

- Water scarcity:
  - Population growth will increase the demand for water, whilst climate change is projected to make summers drier. The potential for water deficits is most acute in London and the south east, but routine deficits between available water and demand may emerge in northern and western UK areas by mid-century.
  - There remains an urgent need for more co-ordinated action to ensure resilient supplies especially in times of drought, and further steps to achieve the ambitious reductions in water demand and leakage that are likely to be required.

The CCRA2 Evidence Report also found that by making homes more air tight, the ingress of externally sourced pollution may reduce, however it can also increase the concentrations of indoor sources of pollution unless properly ventilated. Conversely, when overheating increases, more windows are opened and households could increase their exposure to outdoor pollutants – this is especially an issue in cities with high pollution levels.

The Committee's latest adaptation progress report to Parliament identified a number of housing-related adaptation priorities in England where the level of action at the national level is currently insufficient to manage the risk:[37]

- Surface water flood alleviation. The scale of the investment to tackle surface water flooding has yet to be assessed and the ownership of the problem is fragmented between different bodies.
- New development and surface water flood risk. Survey data from CIWEM suggests there is little confidence among relevant practitioners that high quality SuDS are being built in the majority of major new developments.[38] In many cases the SuDS being built are below-ground retention systems, rather than surface level 'green' SuDS (e.g. grassed areas, swales and ponds) that deliver a range of benefits and can be more readily adapted to cope with future change.
- Property level flood resilience (PFR). It would be cost-effective to protect at least 153,000 properties using PLR measures. This is expected to increase to more than 217,000 by the time Flood Re (the re-insurance scheme set up for flood risk properties) is withdrawn (in 2039).
- Health impacts from heat. There are no legal safeguards to avoid new homes overheating, and no policies in place to begin the process of adapting the existing housing stock to higher temperatures.

Progress is being made in managing river flooding, and improving water efficiency in homes, though more remains to be done:

- Investment in flood alleviation schemes has increased since 2015, and for the period between now and 2021 is consistent with the most recent assessment of long-term funding needs. Between April 2015 and April 2017, 97,000 homes in England benefited from new or replacement flood defences.

[36] CCC (2016) *UK Climate Change Risk Assessment 2017: Evidence Report.*
[37] CCC (2017) *Progress in preparing for climate change.*
[38] CIWEM (2016) *A place for SuDS?*

- Household water consumption per person in England and Wales has continued to decline, from 155 litres per person per day (l/p/d) in 2003/04 to 141 l/p/d in 2017/18. Water companies have implemented a range of actions to reduce household water demand, including encouraging the uptake of water metering (one of the most effective ways to encourage reduced water use), although this has been slower to occur in devolved administrations.[39,40] However, the CCRA highlighted that current planned action is not sufficient in the longer term to meet projected supply-demand deficits.

The Adaptation Committee also assessed the Scottish Climate Change Adaptation Programme in 2016:[41]

- Action is being taken to reduce the vulnerability of communities to flooding. However, there are limited data at a national scale to determine how much progress is being made. The report highlighted that development in the floodplain, along with ongoing increases in impermeable surfacing, were likely to be adding to long-term costs and risks. There was also a lack of data on the uptake of property-level flood protection and sustainable drainage, and trends in urban greenspace.
- Further action was deemed to be needed to adapt the housing stock to extreme wind and rain, cold and hot temperatures, to better protect health and wellbeing. While risks from cold, wind and rain are well-acknowledged, the risks from overheating in homes are less well known. Heat currently contributes to fewer deaths than cold in Scotland but the number of heat-related deaths is expected to increase. There may be between 70 – 280 heat-related deaths per year in Scotland by the 2050s in the absence of adaptation (compared to around 40 deaths per year at present). The future effects of heat on health and wellbeing more generally have not been estimated. There are currently no plans in place that aim to prevent heat-related risks to people during periods of hot weather.
- Little progress was being made in reducing the demand for water, despite the potential risk of water scarcity in some parts of Scotland in the future. Building Regulations have included water efficiency standards in new developments since 2014, and Scottish Water has a water efficiency plan. However the overall consumption of water per person is still high even though it has decreased over recent years.

An updated assessment of the SCCAP by the CCC is due in early 2019.

1.3 Socio-economic factors

1.3.1 Housing Condition and health

Housing plays a key role in protecting the health and wellbeing of occupants, as well as addressing climate change.

Due to differences in how housing condition is calculated it is not possible to directly compare figures across nations, but the figures below summarise condition data for each of the four UK countries:

[39] For example we reported in our assessment of the Scottish Climate Change Adaptation Programme in 2015 that only 400 properties out of 2.4 million are metered in Scotland. CCC (2016) *Scottish Climate Change Adaption. Programme: An independent assessment for the Scottish Parliament.*
[40] More than 45% of households in England now have water meters installed, compared to 43% in 2013.
[41] CCC (2016) *Scottish Climate Change Adaptation Programme - An Independent Assessment.*

England:

- 4.7 million dwellings in England (20%) failed to meet the Decent Home Standard in 2016, although this had fallen from 7.7 million homes in 2006.[42,43]
- The private rented sector in England continues to have the highest proportion of poor quality housing, as defined by the Decent Homes standard, at 27%.[44]
- It has been estimated that spending £10 billion to improve all of the 'poor' housing in England would save the NHS £1.4 billion per annum in health costs. Such investment has been estimated to pay for itself in just over seven years – and then accrue further benefits.[45,46]
- There were an estimated 2.55 million (11%) fuel poor households in England in 2016,[47] using the low income, high cost definition.[48]

Scotland:

- Around 1% (or 24,000) of all dwellings fell below the Scottish Government's Tolerable Standard in 2017.[49] The Scottish Housing Quality Standard (SHQS), applicable only to social housing, has a 37% failure rate in the social sector (not allowing for abeyances and exemptions), an improvement on the 60% failure rate in 2010. In social housing, 80% of homes are compliant with the Energy Efficiency Standard for Social Housing (EESSH).[50]
- There were estimated to be 613,000 fuel-poor households[51] in 2017, equivalent to 24.9% of all households.

Wales:

- In Wales, 23% of households are currently classed as fuel poor. The most recent housing condition survey found that condition has improved across all tenures. The private rented sector generally has the oldest housing stock and a higher proportion of poor quality housing (for example, homes showing problems with damp, mould or other hazards).[52]

[42] MHCLG (2018) *2016-2017 English Housing Headline Report.*
[43] The Decent Homes Standard is a minimum standard that council and housing association homes should meet according to the UK Government. Under the standard, council or housing association homes must: be free from any hazard that poses a serious threat to health or safety; be in a reasonable state of repair; have reasonably modern facilities; have efficient heating and insulation.
[44] MHCLG (2018) *English Housing Survey Private Rented Sector, 2016-2017*.
[45] Nicol S. et al. (2015), *The cost of poor housing to the NHS.*
[46] The Academic – Practitioner Partnership (2016) *Good Housing Better Health*.
[47] BEIS (2018) *Annual Fuel Poverty Statistics Report, 2018* (2016 Data).
[48] Low Income, High Costs definition is the new definition of fuel poverty. A household is in fuel poverty if their income is below the poverty line and their energy costs are higher than is typical for their household type. The devolved administrations have retained the previous ten percent definition, which means a household is deemed to be in fuel poverty if it needs to spend more than 10% of household income on fuel.
[49] The tolerable standard is a condemnatory standard; a house that falls below it is not acceptable as living accommodation.
[50] For more information on EESSH, see: https://www.gov.scot/policies/home-energy-and-fuel-poverty/energy-efficiency-in-social-housing/
[51] A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (including Housing Benefit or Income Support for Mortgage Interest) on all household fuel use.
[52] Welsh Government (2018) *Welsh Housing Condition Survey 2017-18: Headline Report.*

Northern Ireland:

- In Northern Ireland, 21.5% of properties are classed as fuel poor. Approximately 2% of properties have been classified as being unfit under the Northern Ireland Standard of Fitness for Habitation.[53]

It is likely the number of vulnerable people receiving community care in their own homes will increase in the future.

The NHS 2019 Long Term Plan highlighted the likely shift from hospital-focused systems in the future to community-based care.[54] GP care is likely to continue to be important as well as community-based speciality care facilities. The NHS may rely increasingly on the voluntary sector and on a public and private network of providers to deliver health care within patients' homes. This will be coupled with increasing pressure on NHS, public and community transport services, as patients who are no longer able to drive will rely on these to attend medical appointments. The housing stock needs to be improved so that patients can be increasingly cared for at home.

Health inequalities will also be an important future factor to consider in improving housing condition.

Healthy life expectancy in the UK has not risen as fast as life expectancy.[55] There are also important regional differences in longevity and other measures of population health. Poor quality housing particularly impacts the health of people with lower incomes, and can exacerbate health inequality.

Impacts of future hazards such as heatwaves and flooding on vulnerable people may be exacerbated by changes in social protection measures and the level of social care that elderly or vulnerable individuals receive at home. Making homes adaptable for each stage of life and to the climate could help to manage increasing ill health. For example, improving thermal comfort in homes is a win-win-win situation – improving the health and well-being of occupants, in turn taking pressure off the NHS, and reducing greenhouse gas emissions.

1.3.2 Tenure

Tenure is important for considering barriers and incentives to climate change mitigation and adaptation measures.

Demand for housing in the UK has increased, partly as a result of increasing population together with decreasing average household size. A number of local authorities have transferred much of their housing stock to housing associations and registered social landlords. The number of private rentals has more than doubled between 1996 and 2016 (Figure 1.2). In the UK, Wales has the greatest percentage of owner-occupied dwellings (73%) and Scotland had the least (63%). Scotland has the largest share of social rented dwellings (28%).[56] Different types of tenure need different approaches:

- A person in rented accommodation is more likely to be in fuel poverty, which may mean they have limited resources for measures such as energy efficiency and property-level

[53] Northern Ireland Housing Executive (2017) *House condition survey revised preliminary report 2016.*
[54] NHS England (2019) *NHS Long Term Plan.*
[55] House of Commons (2010) *The ageing population.*
[56] BRE (2018) *The cost of poor housing in the European Union.*

adaptation.[57] Many landlords have little incentive to invest in improvements to their property given that for most measures, the tenant would receive the reward for this through reduced energy bills and better comfort. Regulations have been introduced to protect tenant rights, for example over safety features of the property and in relation to energy efficiency. However, initial evidence suggests that many landlords are refusing tenant requests for energy efficiency improvements.[58]

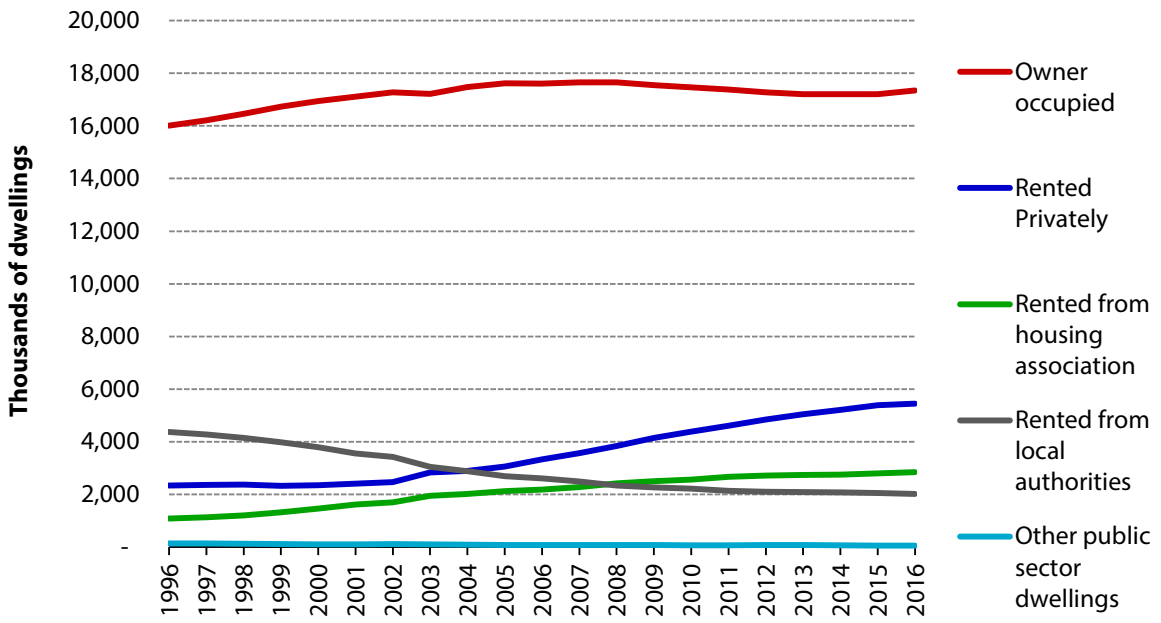
- Social landlords can also be well-placed to oversee mitigation and adaptation action. They are driven by the social and charitable objectives of providing decent and affordable housing that complies with regulation, have control over whole estates and have better access to capital. These objectives determine their asset-management strategies, including the pursuit of affordable heating. They tend to approach investment in terms of coordinated stock upgrades (and planned maintenance cycles in the case of heating systems, for example).
- However, an upcoming report by Sustainable Homes has found that UK social housing is not fit for 2050.[59] Long-term strategies do not exist to make homes ready for 2050, despite it being within reach of most landlord financial planning cycles.
- Owner occupiers are often able to make changes most easily, and see the direct benefit of investments. However, there is a lack of advice on improvements needed to bring homes up to appropriate standards. Home owners of newly built homes are not thought to have any legal basis to demand that their homes be brought up to Building Regulations standards or to correct any issues that would come up in any house quality assessments in the UK, unless their home is still under warranty. During the first two years after a new home is built a warranty will cover issues with build works. After this, typically up to year 10, a builder is only responsible for major problems with the structure of the house.[60]

Tenure can also affect the type of adaptations that can be made. For example:

- Changes to building fabric are easier if the building is owned by a single household or entity, for example a detached house or a housing association block of flats.
- Leasehold properties may require the agreement of the freeholder to undertake modifications, and properties which are listed may have further restrictions to what can done without gaining approval from local authorities.
- Multi-tenement flats[61] can also be hard to alter given that the agreement of all households is needed to make changes. There is also the difficulty in attributing costs and benefits of measures to each flat.[62] This may be a particular issue in Scotland where flats make up a larger proportion of the housing stock (37%).[63] The Scottish Government's area-based energy efficiency scheme tries to address these issues by allowing occupied and private rental flats to access funding if they meet certain criteria and are covering social tenant contributions through the Energy Company Obligation.

[57] BEIS (2018) *Fuel Poverty statistics 2016.*
[58] Cornwall Energy Daily Bulletin 3rd August 2016 reports a survey by online letting agent PropertyLetByUs that shows 58% of tenants surveyed have had requests for energy efficiency improvements refused.
[59] Sustainable Homes (2019) *Housing 2050 – How UK social housing can meet the challenge of climate change.*
[60] Homes Owners Alliance, https://hoa.org.uk/advice/guides-for-homeowners/i-am-buying/new-home-warranties-cover/
[61] For example blocks of flats which include owner occupiers, private rentals and social housing.
[58] Citizens Advice (2013) *Communal Improvements Energy efficiency in tenements in Scotland.*
[63] Scottish Government (2018) *Scottish condition survey 2017: key findings.*

Figure 1.2. Trends in property numbers by tenure, Great Britain (1996-2016)



Source: MHCLG Live Tables (2018). See: https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants

1.3.3 Demographic change

The UK population is growing and growing older, increasing the demand for housing. There are more elderly people living on their own due to better health and a desire for people to stay in their own homes longer.

The UK population is expected to increase from 65.6 million in mid-2016 to 73 million by 2035 and 86 million by 2085, with England projected to grow more quickly than the other UK nations.[64]

The building of new homes is set to increase, with a Government commitment to build 1.5 million new homes by 2022.[65] The number of households is also projected to increase due to population growth and more people living alone – from 23.0 million in 2018 to 31.5 million by 2040 in England alone.[66]

The biggest population increases will be in those aged 85 and over, which will increase the vulnerable population to climate-related risks, such as overheating.

A significant trend over the last 20 years has seen a larger proportion of homes containing one person:

[64] ONS central population projections.
[65] BEIS (2018) *Industrial strategy - Construction sector deal.*
[66] ONS (2018) *Household projections for England.*

- According to the General Lifestyle Survey (2013) 17% of households contained one person in 1971.[67] This has risen to around 28% in 2017.[68] Although the total number has not changed much in the last decade, those living alone aged 65 to 74 years have increased by 15% between 1996 and 2017, and those aged over 75 years increased 24% over the same period.[69]
- This could be attributed to the improvement in the health of the population and the increase in unpaid carers (e.g. care provided by a spouse or family member)[70] as well as a desire for people to stay in their own homes longer.
- Reports by Scottish Widows[71] and Country Wide lettings in 2017[72] found that the number of people renting in retirement is on the rise. Retired people in 2017 accounted for 8.0% of all tenants, compared with 5.2% in 2007. The largest proportion is in Wales, where nearly 1 in 5 of tenants are retired. By the early 2030s one in eight retirees in Great Britain are projected to live in rented accommodation.[73]

In addition to population growth and ageing, the distribution within the UK is likely to change.

A large proportion of homes in the UK are located in towns and cities, for example in England and Scotland around 80% of dwellings are in urban areas.[74] There is limited information regarding future trends in urbanisation in the UK (either development of new towns or expansion of current cities):

- The expansion of urban areas is restricted by the policy to avoid building on greenbelt sites, however populations within cities in the UK continue to rise.[75]
- In recent years there has been an increase in planned and constructed high-rise blocks of flats in cities across the UK. The majority of these are being used for residential flats.[76]
- Locating new homes within towns and cities can reduce the demand for travel, as employment opportunities, retail and leisure activities, and public services are already located nearby.

Coastal communities tend to have higher than average populations of over-75s, higher unemployment, and poorer infrastructure compared to communities inland.[77]

[67] ONS (2013) *General Lifestyle Survey 2011*.
[68] ONS (2017) *Families and Households: 2017*.
[69] *Ibid*.
[70] ONS (2014) *Changes in the Older Resident Care Home Population between 2001 and 2011*.
[71] Scottish Widows (2017) *Retirement report 2017: Renters in retirement*.
[72] See https://www.countrywide.co.uk/news/2017/retirees-spend-a-record-37bn-paying-rent/
[73] Scottish Widows (2017) *Retirement report 2017: Renters in retirement*.
[74] ONS (2018) *Rural population 2014/15*. Scottish Government (2018) *Scottish condition survey 2017: key findings*.
[75] Centre for cities data (2001-2016).
[76] AMA research (2017) *Construction in the high-rise buildings market report UK 2016 – 2020 analysis*.
[77] England and Knox (2016) *Targeting flood investment and policy to minimise flood disadvantage*, Joseph Rowntree Foundation.

1.3.4 Technological changes

A number of technological changes are affecting how much time people spend indoors, and what is important to occupants in their homes and their behaviour.

An increasing number of people in the UK are installing 'smart' measures in their homes, such as smart meters, smart appliances, and smart heating and lighting systems and controls.

These new technologies can be used to help improve energy efficiency, save money on bills and potentially reduce vulnerability to climate change by monitoring risks such as indoor temperature. However they also mean more households are reliant on digital and ICT infrastructure – networks which can be at risk from severe weather.[78] It is important that the sector is resilient to future climates by taking steps now to protect ICT infrastructure from flooding and overheating.

An increasing number of people are also working from home, meaning that more time is being spent in homes during the day:

- Between January and March 2017 nearly 14% of the UK workforce were home workers.
- The number of home workers has grown by 1.3 million since 1998 to 4.3 million.
- Home workers tend to work in higher skilled roles compared to the rest of the population, with almost two thirds of them being self-employed in 2014.
- Working from home is more prevalent among older individuals.
- The South of England has the highest levels of home working rates, the highest being in the South West at a rate of 17%. The lowest rate was in Northern Ireland at just 2%.[79, 80]

Smart meters have an important role to play within a wider package of support to enable more informed energy choices and to facilitate behaviour change. They can give occupants more control over energy use, and support improved understanding of energy costs and bills. They can also be used to track progress in, and performance of, energy efficiency and heating measures.

The Government wants energy suppliers to install smart electricity and gas meters in every home in England, Wales and Scotland, with every home being offered a meter by the end of 2020. Approximately 9.5 million smart meters were installed by December 2017, with 4.5 million of these added in 2017. This is behind the original expected deployment trajectory, and a recent NAO report concluded that there are serious issues that need to be addressed if smart meters rollout is to progress successfully and deliver value for money.[81]

Water meters can help incentivise conservation of water and provide a much more precise picture of water use to customers, including identifying leakage. Smart metering can also help companies identify households with the highest water consumption, who might struggle to pay

[78] CCC (2017) *Progress in preparing for climate change – 2017 report to Parliament.*
[79] See: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/adhocs/008283homeworkersratesandlevelsjanuarytomarch2016and2017
[80] Home workers include those who worked within their home or its grounds, and those who use their home as a base but worked in different places.
[81] National Audit Office (2018) *Rolling out smart meters.*

their bills. Smart meters could better enable variable tariffs and more regular and transparent billing (which helps households to budget).[82]

Energy providers are increasingly providing specialised charging tariffs and equipment to facilitate the smart charging of electric vehicles. The potential to charge vehicles when most beneficial for the electricity system as a whole could reduce the need to upgrade local electricity grids, reduce costs for the electric vehicle owner and enable greater deployment of intermittent renewable electricity generation. For these reasons, the Government has taken primary powers to ensure that charging points have smart capability in the 2018 Automated and Electric Vehicles Act.

Going beyond smart meters, the growing trend for 'smart' systems could play a bigger role in helping to reduce energy demand and vulnerability to climate risk. Smart systems can be used to control services such as heating, ventilation and lighting, as well as other appliances such as showers, washing machines and kettles. They can provide for more comfortable homes, and create opportunities to save bills and emissions through better managing or reducing use.

As well as enabling all households to better manage energy use, the availability of affordable real-time monitoring data on energy, temperature and humidity can deliver information that could help vulnerable households in particular. For example, data could be used to trigger warnings for care givers or health professionals when a home is consistently under heated, or overheating.[83, 84] On a neighbourhood scale, collecting data such as travel use could be used to target and encourage smarter travel choices.

However, concerns around reliability, perceived need, cost, security and ease of use must be addressed to ensure that smart technology can be easily usable by all individuals.

1.4 What low-carbon, sustainable homes look like

The homes we live in should be low-carbon, resilient to weather-related impacts, affordable to run, comfortable to live in and good for our health.

The technology already exists to create homes that are low-carbon, climate resilient, better for health and the natural environment. Taking action will lead to multiple benefits:

- Energy efficiency measures, if implemented correctly, can reduce emissions and energy bills, improve health and wellbeing, and help tackle fuel poverty.
- Water efficiency savings reduce demand, but also have an impact on energy, carbon and bills (Chapter 2). Studies in Scotland and Wales have shown the multi benefits of linking up water and energy efficiency policy and retrofits.[85,86]
- Green spaces (also known as green infrastructure when present in urban areas) and sustainable drainage systems (SuDS) can help to mitigate surface water flooding, but also

[82] National Infrastructure Commission (2018), *Preparing for a drier future: England's water infrastructure needs*.
[83] CSE (2017) *Smarter homes workshop findings*, https://www.cse.org.uk/downloads/file/smarter-warmer-homes-workshop-oct-2017.pdf
[84] There are a number of examples of projects developing platforms using smart monitoring for safeguarding purposes. The SPHERE project at Bristol University is analysing the relationships between the health of building occupants, the conditions of their home and their activities as revealed by their energy consumption patterns. Other platforms, such as Switchee and Howz monitor housing conditions using sensors that can alert social housing landlords, carers or others if people are living in dangerously cold or damp homes.
[85] Waterwise (2018) https://www.waterwise.org.uk/delivering-changes-in-scotland/
[86] Burton (2013) *Integrating water efficiency into energy programmes – a case study from policy to implementation*.

help to sequester carbon, increase biomass and biodiversity and improve air and water quality. Green spaces and designing neighbourhoods to facilitate active transport (cycling and walking) can also bring health benefits through improving air quality and encouraging exercise.[87]

A wide range of design features influence the sustainability and resilience of a home.

The infographic presented in the Executive Summary of this report sets out the types of measures that can help to improve sustainability and resilience, including those measures that can be installed easily by householders. Table 1.1 illustrates the cost savings that can be achieved by installing measures in new homes at the outset.

[87] Bozovic, Ranko & Maksimovic, Čedo & Mijic, Ana & Smith, K.M. & Suter, Ivo & Van Reeuwijk, Maarten. (2017). *Blue Green Solutions. A Systems Approach to Sustainable, Resilient and Cost-Efficient Urban Development*.

Table 1.1. Costs of designing in measures for a new home at the outset, relative to trying to achieve the same outcomes later

Measure	Cost (£) – new build	Cost (£) - retrofit (equivalent outcome)
Building a home with an air source heat pump and ultra-high levels of fabric efficiency (equivalent to a space heat demand of 15 kWh/m^2/yr)[1]	4,800	26,300
Passive cooling measures package[1,2]	2,300	9,200
Water efficiency package of measures[2]	300	3,300
Flood resilience and resistance package of measures[2]	1,500	3,100

Source: [1] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*. [2] Wood PLC (2018) for the CCC.
Notes: All values are rounded to the nearest £hundred. The retrofit costs provided are illustrative of the costs that would be incurred where retrofitting the same measures as we recommend in a new build, and are not representative of the costs of recommended retrofit measures more widely. For a number of these measures, the prohibitively high retrofit costs mean that they would not be cost-effective and would be unlikely to be retrofitted in practice. This illustrates the importance of setting the right standards at the outset.
Mitigation measures (air source heat pump and energy efficiency) - new build costs are based on a semi-detached home built in 2020. Costs represent the incremental costs of incorporating an air source heat pump and ultra-high levels of energy efficiency (equivalent to a space heat demand of 15 kWh/m^2/yr), relative to building a home to current standards with a gas boiler. Retrofit costs represent the costs of retrofitting an air source heat pump and ultra-high levels of energy efficiency in 2030, to a home built in 2020. Retrofit costs have not been discounted back to 2020 prices.
Passive cooling measures - are for a small semi-detached house. Measures include high thermal mass floors, walls and natural ventilation (numbers from Wood PLC), and shading through inward opening windows fitted with external shutters (Numbers from Currie & Brown).
Water efficiency measures - are for a small semi-detached house. Measures include dual flush WC, low flow shower and taps (all zero cost for new builds), low water-use dishwasher and washing machine, and a water butt. Retrofit costs are for a discretionary retrofit and are therefore higher than if replacing or upgrading a product at its end of life.
Flood resilience and resistance measures - are for a three-bed semi-detached house at high risk of flooding (greater than 1% Annual Exceedance Probability). These compare the costs of installing in a new build compared to repairs following a flood. Resilience measures include floors (dense screed and new floor with treated timber joists), wall-mounted boiler, moving a washing machine to first floor, raised ovens and electrics, raised service meters. Resistance measures are a 'fit and forget' package'.

Homes are already being built to deliver a range of these outcomes, with a number of standards in existence internationally to improve quality of homes.

Examples of good practice internationally include:

- The 'Energiesprong' standard. Energiesprong is a new-build and whole house refurbishment approach including guaranteed actual whole-home measured energy consumption, as opposed to modelled performance. It originated in the Netherlands as a Government-funded

innovation programme and has since been adopted in a number of other countries. Nottingham Council has been the first to adopt this housing approach in the UK (Box 1.3).

- The 'Passivhaus' standard. Passivhaus buildings are designed to use very little energy for heating and cooling, with the design characterised by high levels of fabric efficiency and airtightness as well as measures to address overheating risk. According to the Passivhaus Trust, there were around 1,000 Passivhaus units in the UK at the end of last year.[88]

Box 1.3. Nottingham City Homes - 2050 'Energiesprong' homes

Nottingham City Homes are retrofitting 200 social homes with a view to minimising total social housing spend over a 30 year period. The homes are being retrofitted to the Energiesprong standard, through substantial fabric improvements, ground-source heat pumps with a shared borehole and solar panels on roofs. The costs of the retrofit are covered by bringing forward planned maintenance spend, a 'comfort plan' fee levied on tenants, and subsidies/income from installed renewables, with innovation funding bridging the funding gap in advance of cost reductions through industrialised delivery.

Source: For further information see: https://www.energiesprong.uk/projects/nottingham. Photo courtesy of Melius Homes.

[88] Including both new buildings and buildings retrofitted to the EnerPHit standard, based on similar design and testing criteria. For further information see: http://www.passivhaustrust.org.uk/news/detail/?nId=787#.XFHlQ5XKBQs

Lessons are being learnt from pilot projects and innovative schemes.

The UK Government recently launched a Grand Challenge Mission to halve energy use of new buildings by 2030, and to make sure that every new building is safe, high quality, much more efficient and uses 'clean' heating.[89] The mission is backed by £170 million of public money, over the 4 years to 2021-22, through the Transforming Construction Industrial Strategy Challenge Fund. This is expected to be matched by £250 million of private sector investment. As part of the Mission, a design competition for the 'Home of the Future' is due to be launched in 2019.[90]

The Welsh Government launched the 'Innovative housing programme' in 2017 – a demonstrator scheme which seeks to stimulate the design and delivery of new high quality and affordable homes.[91] The programme has been allocated £90m of funding over three years. These homes aim to significantly reduce or eliminate fuel bills and will help inform the Welsh Government about the type of homes it supports in the future. Entering its third year, the programme is now focusing on mainstreaming some of the innovative schemes tested in year 1 and 2. The approaches planned to be tested at scale are those which have potential to be cost-competitive with traditional homes whilst significantly reducing fuel bills (to less than £100 per year), or eliminating fuel poverty completely (in the case of the 'Homes As Power Stations' initiative).

Now is the time to get our approach right to retrofitting existing houses and building new homes.

The next few years will present significant opportunities to change the way homes are designed, built and retrofitted in the UK. The time to get the approach right is now:

- The UK Government is committed to building around 1.5 million new homes by 2022.[92] Getting standards right now is a fraction of the cost of retrofitting to the same quality and standard later (Table B1.2).
- A review of Part L (which covers conservation of fuel and power) and Part F (ventilation) of Building Regulations is expected in England and Wales in 2019 and 2020, which will have impacts on both existing and new homes. A review of the energy standards of the building regulations in Scotland has also commenced which is programmed for implementation in 2021.
- Substantial progress in reducing greenhouse gas emissions from homes will need to be made in the next few years in order to have a good chance of meeting the UK's existing 2050 target. The Committee's review of long-term targets will be completed early in 2019, to inform Government decisions and plans for any further strengthening of policies. The UK Government's aspirational target to halve emissions in new homes by 2030 is out of step with the urgent timeline the UK has signed up to under the 2015 Paris Agreement.
- The need for homes to be adapted to rising temperatures and flooding is becoming more acute. Around 90,000 homes are projected to be built in high flood risk areas over the next

[89] See https://www.gov.uk/government/publications/industrial-strategy-the-grand-challenges/missions
[90] BEIS (2018) *Clean Growth - Transforming Heating, Overview of Current Evidence*.
[91] See: https://gov.wales/topics/housing-and-regeneration/housing-supply/innovative-housing-programme/?lang=en
[92] BEIS (2018) *Industrial Strategy, Construction Sector Deal*. New homes will include around 120,000 social and affordable housing.

five years.[93] Summers like that of 2018 have already become 30 times more likely due to climate change.[94]

The Government should act now to set an ambitious trajectory of standards, regulations and targets for new homes, ensuring they are fit for 2050 and beyond. Many of those changes are needed urgently, to start over the next two years.

The rest of this report looks at the current state of UK housing from a low-carbon and climate-resilience perspective, identifies what needs to be done, the barriers and gaps to effective action, and recommends where improvements need to be made to ensure that housing quality is brought up to where it needs to be, both to support meeting climate objectives, as well as health and wellbeing.

1.5 Structure of this report

The remainder of the report is structure as follows, considering mitigation and adaptation together where possible:

Chapter 2 sets out our analysis of the fabric measures that are needed to ensure that current and future homes will be fit for the future, focussed on measures inside the home: measures to support heating decarbonisation; energy efficiency, overheating, indoor air-quality and moisture; whole-life carbon; flexibility measures in homes, and water efficiency.

Chapter 3 considers measures around the home and communities, including property level flood resilience and resistance; green infrastructure, and sustainable transport.

Chapter 4 considers four cross-cutting areas where progress is needed, building on the advice of previous chapters: addressing compliance issues and closing the 'performance gap', building regulations, wider principles to guide the retrofit of existing homes and local authority action to deliver low-carbon, resilient homes.

[93] CCC (2017) *Progress in preparing for climate change*. 'High' flood risk in this context means areas at greater than 1% annual flood risk.
[94] See: https://www.metoffice.gov.uk/news/releases/2018/2018-uk-summer-heatwave

Chapter 2: Low-carbon, low-energy and water efficient homes

Key messages

UK homes have a critical role to play in meeting the twin climate goals of reducing emissions and adapting to the current and future climate. It will not be possible to meet the legally-binding 2050 emissions reduction target (or future ambitions for net-zero emissions) without a near complete decarbonisation of how we heat our homes. Retrofitting of measures offers substantial opportunities for addressing climate risks and improving people's health and wellbeing. Upcoming reviews of building regulations provide an opportunity to make sure new homes are built for the future. Our homes must be low-carbon, energy efficient, have safe moisture levels, excellent indoor environmental quality, and be climate resilient.

This is not happening at present. Greenhouse gas emissions from existing homes are not falling, policy is failing to drive sufficient uptake of energy efficiency and low-carbon heat, the Government's own research has concluded that all new build homes are at risk of overheating[95], and household water consumption needs to come down from around 140l/p/d to well below 100l/p/d by 2050 to address risks of future lower water availability:

- **Low-carbon, energy efficient homes.** Decarbonising how we heat our homes requires a strategic approach which a) deploys low-regret options now (energy efficiency, heat pumps in homes off the gas grid and in new builds, hybrid heat pumps in homes on the gas grid, low-carbon heat networks, biomethane injected in to the gas grid) and b) builds towards strategic decisions on the future of the gas grid (and role of hydrogen for heat) in the mid- to late-2020s. Switching to low-carbon heating must be done alongside energy efficiency, so as to size the new heating system properly and guarantee high-performing, low-energy systems. HMT and BEIS must commit to a fully-fledged heat strategy which includes a clear trajectory of standards set well in advance, funding for low-carbon heat from 2021, incentives for able-to-pay householders and a governance framework to drive decisions on heat infrastructure.
- **Thermal comfort, ventilation and indoor air quality.** The technology exists to deliver homes which have high levels of thermal efficiency (staying warm in winter while cool in summer), while being moisture-safe and with excellent indoor air quality. Achieving this requires a holistic approach in design, build and retrofit, which is currently not being driven effectively by existing policy. Standards for overheating must be put in place. Passive cooling measures should be adopted in existing and new homes to reduce overheating risks before considering active measures such as air conditioning. Regulations around ventilation must evolve to keep pace with improvements in the energy efficiency of buildings and there is a need for better coordination across energy and ventilation requirements. Further work is needed to ensure mechanical ventilation systems perform as they should.
- **Electrical energy efficiency, flexibility and peak management**. Fabric efficiency (walls, lofts) and other measures such as glazing will reduce space heating demand, but more is needed to reduce energy requirements for hot water and appliances. This means insulating hot water tanks and pipes, putting in hot water thermostats, low-energy lighting and highly efficient appliances. Measures such as batteries and smart appliances also allow householders to use energy more flexibly, helping to shift consumption away from peak and towards periods when renewable energy is available.
- **Whole-life carbon impacts and wood in construction**. We need more focus on the whole-life carbon impact of new homes, including embodied and sequestered carbon. As part of this, using wood in construction to displace high-carbon materials such as cement and steel is one of the most effective ways to use limited biomass resources to mitigate climate change, because it both displaces industrial carbon emissions and stores carbon long-term in buildings.[96] In the 2017 *Clean*

[95] MHCLG (2018) *Government response to EAC Inquiry on Heatwaves*.
[96] CCC (2018) *Biomass in a low-carbon economy*.

Key messages

Growth Strategy, the Government committed to developing new policies to support a substantial increase in the use of wood in construction - these are needed to overcome a range of cultural, skills and financial barriers in the construction sector. Low-regret action should also be taken to support the assessment and benchmarking of whole-life carbon in buildings, with a view to informing the future policy framework.

- **Water efficiency**. Reducing water use in homes is one of the most important ways of enhancing the resilience of water supplies across the UK. Defra should set an ambitious per capita consumption target for water to be met through water efficiency measures, increased metering, compulsory water efficiency labelling, improved behaviours and more ambitious building regulations. Reducing water consumption also reduces energy use and household bills. There is a need for water and energy retrofit programmes to be better aligned, and for research to better understand how the designed water efficiency level compares to the actual water efficiency of homes once built and occupied.

2.1 Purpose of this chapter

This chapter sets out how UK homes can contribute to long-term emission reductions and be well-adapted to the current and future climate.

Where possible we consider the costs and benefits of measures and identify those which are low-regret. The chapter is structured into sections on: heating decarbonisation; energy efficiency, overheating, indoor air quality and moisture; whole-life carbon; flexibility measures in homes; and water efficiency.

2.2 Decarbonising heating – a strategic approach

This section summarises our strategic advice on decarbonising heating in the 2016 Heat report and 2018 Hydrogen review.

Energy efficiency must be pursued alongside heat decarbonisation. We cover energy efficiency in more detail in the next section, as well as how this can be implemented without adverse impacts on indoor air quality or exacerbating overheating risks**.**

Deployment of low-carbon heat cannot wait until the 2030s. In the next decade, there is a set of measures that are sensible regardless of the longer-term path to decarbonising heating in buildings. In our 2016 Heat report we identified low-regret opportunities for heat pumps to be installed in homes that are off the gas grid and in new build, for low-carbon heat networks in heat-dense areas (e.g. cities) and to increase volumes of biomethane injection into the gas grid (Box 2.1).

Low-carbon heating must be installed alongside the continued rollout of energy efficiency measures (walls, cavities, lofts, glazing and draught proofing) and passive cooling (e.g. shading), so as to enable new heating systems to be sized properly and to guarantee high performing, low-energy systems. Risks from overheating, inadequate ventilation and moisture must be considered and mitigated (Section 2.3).

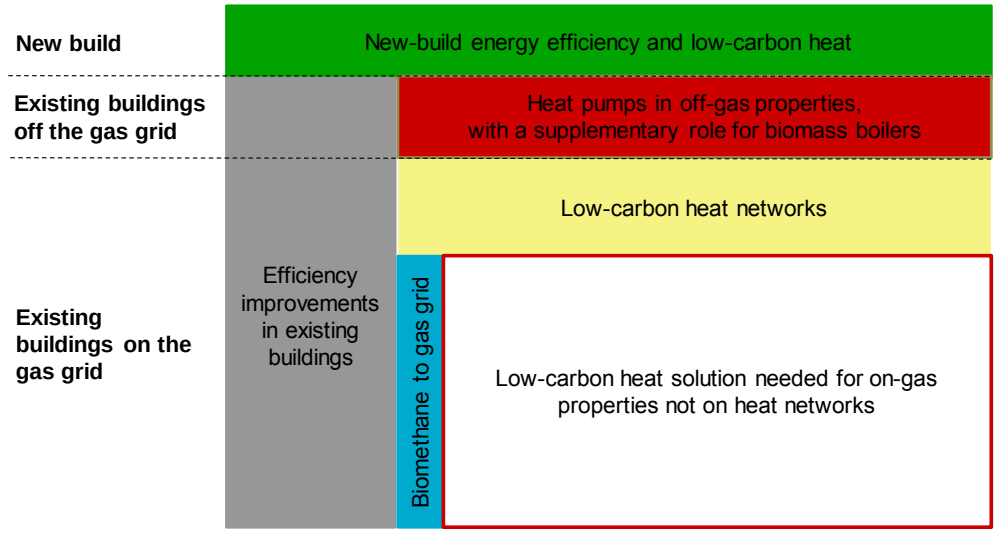
Box 2.1. Low-regret actions for buildings decarbonisation

In our 2016 report, *Next steps for UK Heat Policy*, the Committee identified low-regret routes to reducing emissions from heating buildings that the Government should pursue immediately: energy efficiency improvements to existing buildings; ensuring that new buildings are efficient and low-carbon from the outset; installation of heat pumps in buildings off the gas grid; roll-out of low-carbon heat networks in population-dense urban areas; and injection of biomethane into the gas grid:

- **Heat pumps in buildings not on the gas grid.** Heat pumps are the leading low-carbon option for buildings not connected to the gas grid. Together with new build properties, installation of heat pumps in buildings off the gas grid can help create the scale needed for supply chains to develop, potentially in advance of accelerated heat pump roll-out in on-gas grid properties after 2030.
- **Low-carbon new build.** Installing low-carbon heating from the outset in new homes means that costs of connecting to the gas grid can be avoided and the system designed optimally for the property. This makes heat pumps cheaper to install and run in new homes than in existing gas-heated homes.
- **Low-carbon heat networks.** District heating schemes require a certain density of heat demand in order to be economic, which means that they are suited to urban areas, new build developments and some rural areas. Low-carbon heat sources can include waste heat, large-scale (e.g. water-source) heat pumps, geothermal heat and potentially hydrogen.
- **Biomethane.** Injecting biomethane into the gas grid is a means of decarbonising supply without requiring changes from consumers, and provides a route for capture and use of methane emissions from biodegradable wastes. However, its potential is limited to around 5% of gas consumption.

We consider energy efficiency improvements and new build in greater detail in subsequent sections of this report.

Figure B2.1. Low-regret measures and remaining challenges for existing buildings on the gas grid



Source: CCC (2016) *Next steps for UK Heat Policy*.
Notes: The sizes of the blocks broadly reflect the scale of emissions reduction, but not precisely. Some potential for heat networks will be in new build and off the gas grid, rather than all on-grid as presented.

Source: CCC (2016) *Next steps for UK Heat Policy*.

Whilst the low-regrets measures set out above can make a significant contribution to reducing emissions from buildings, they still leave a substantial challenge over what to do about existing buildings on the gas grid, especially those in less heat-dense areas.

We have recently updated our advice in this area, identifying potential for near-term deployment of 'hybrid' heat pumps at scale on the gas grid (e.g. 10 million hybrid heat pumps by 2035).[97] This approach would have a number of benefits including enabling greater reductions in near-term emissions from buildings and providing a potential route, with hydrogen, to reach very low emissions by 2050 (Box 2.2). This is effectively a further 'low-regret' action which Government can pursue now – compatible with a range of future pathways, developing options and delivering near-term emission reductions.

Box 2.2. Low-carbon heat in existing homes on the gas grid

Our 2018 report, *Hydrogen in a Low-Carbon Economy*, examined the merits of a range of scenarios for decarbonising on-gas buildings using different combinations of electrification and hydrogen for heating. Our assessment is that:

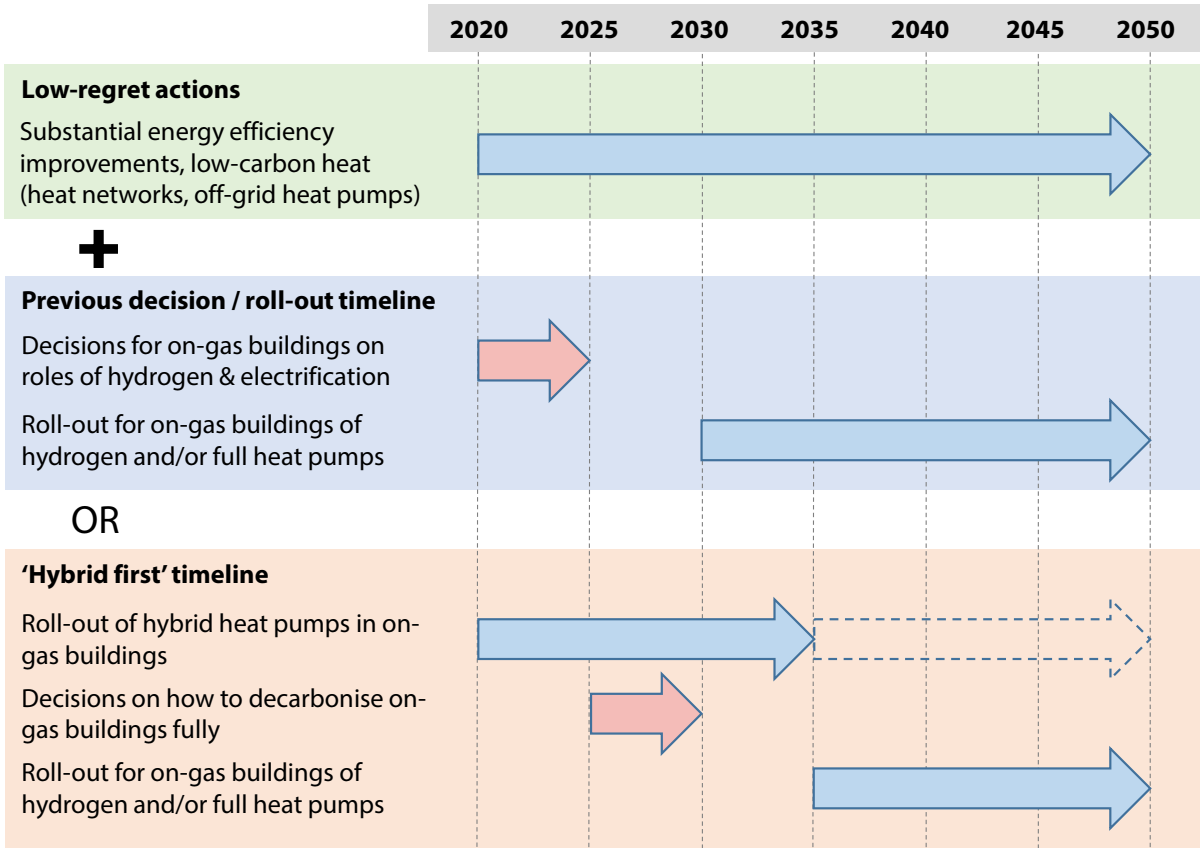
- Hydrogen could play a valuable role as part of a heating solution for UK buildings, primarily in combination with heat pumps as part of 'hybrid heat pump' systems. Heat pumps, powered by increasingly low-carbon electricity, offer the potential to provide heat efficiently for most of the time, with hydrogen boilers contributing mainly as back-up to meet peak demands on the coldest winter days.
- Whilst early deployment of hybrid heat pumps would predominantly be expected to be in combination with natural gas boilers, in the longer-term hydrogen could displace this fossil fuel use. While not without challenges, this would enable the energy system to reach very low emissions. Feasibility and public acceptance issues look likely to be easier than strategies for the full electrification of heat, or the full use of hydrogen as a like-for-like replacement for natural gas as we use it today.

We have previously identified the need for key strategic decisions in the early 2020s on low-carbon heat for properties on the gas grid. The new evidence suggests there is now a case to deploy hybrid heat pumps at scale from 2020. This will allow the decision over how to decarbonise heat fully for on-gas properties to follow slightly later than we had previously set out (Figure 2.2).

[97] CCC (2018) *Hydrogen in a low-carbon economy*. 'Hybrid' heat pumps use a heat pump to meet the bulk of heat demand, while retaining boilers to provide heat on colder winter days. A hybrid heat pump can be retrofitted around the existing boiler, making it part of an upgraded, smart heating system.

Box 2.2. Low-carbon heat in existing homes on the gas grid

Figure B2.2. Pursuing a 'hybrid first' approach alongside other low-regret actions



Source: CCC (2018) *Hydrogen in a low-carbon economy.*
Notes: 'Low-regret' actions are those that the Committee recommended in 2016 should be pursued immediately, with subsequent decisions to be made by the mid-2020s on the respective roles of hydrogen and electrification in on-gas buildings outside heat network areas, for roll-out between 2030 and 2050 (shown the middle section of the diagram). The 'hybrid first' timeline would entail pursuing the low-regret actions now alongside deployment of hybrid heat pumps in on-gas properties, with decisions on achieving full decarbonisation able to come slightly later.

Source: CCC (2018) *Hydrogen in a low-carbon economy.*

Further policy progress will be needed to deploy the low-regret options.

A UK strategy is needed for decarbonising heating and hot water demand, with HM Treasury taking a lead role. This should build on the Heat Roadmap the Government have committed to publishing within the next 18 months.[98] Alongside greater action on energy efficiency (considered further in section 2.3), early clarity is needed on the support framework for low-carbon heating, including a long-term policy framework for heat networks and financial support for heat pumps and biomethane post-2021. Detailed plans are needed on phasing out the installation of high-carbon fossil fuel heating (including the proposed regulatory approach). Standards should drive continued efficiency improvements in boilers and heating systems,

[98] BEIS (2018) *Clean Growth - Transforming Heating, Overview of Current Evidence*

including through upcoming reviews of Building Regulations where needed. Hydraulic balancing can boost overall system efficiency but has been overlooked in Boiler plus (which focuses on the boiler rather than the system). [99] Appropriate training for installers and heating engineers will be needed to underpin the transition.

Important questions remain to be resolved around the current balance of tax and regulatory costs across fuels: costs are significantly larger for electricity than gas or oil heating, and the full carbon costs are not reflected in the pricing of heating fuels. These factors currently weaken the private economic case for electrification.

Recommendation: In our report on hydrogen in November 2018, we recommended that the Government should develop a fully-fledged UK strategy for decarbonised heat within the next 3 years. Subsequently, BEIS has committed to publication of a new heat roadmap within 18 months. It is essential that Treasury should commit now to working with BEIS on development of the roadmap/strategy. This must include clear signals on the future use of the gas grid in the UK and commitments to funding and, as a minimum:

- A clear trajectory of standards covering owner-occupied, social- and private-rented homes, announced well in advance (including detailed plans on phasing out the installation of high-carbon fossil fuel heating and improvements in the efficiency of existing heating systems).
- A support framework for low-carbon heating (heat pumps, biomethane, and networked low-carbon heat).
- A review of the balance of tax and regulatory costs across fuels in order to improve alignment with implicit carbon prices and reflect the progressive decarbonisation of electricity.
- An attractive package for householders aligned to trigger points (such as when a home is sold or renovated).
- A nationwide training programme to upskill the existing workforce.
- A governance framework to drive decisions on heat infrastructure through the 2020s.

(*Owner: HMT, BEIS. Timing: within the next 18 months - 3 years).*

All new homes should be future-proofed for low-carbon heating, and by 2025 at the latest, no new homes should be connecting to the gas grid.

We have previously recommended that Government strengthen new build standards to future-proof for low-carbon heating, with a further tightening of standards in 2025 to support deployment of low-carbon heat.

We recently commissioned Currie & Brown and Aecom to undertake research on the cost-effectiveness of new lower-carbon and lower-energy buildings.[100] This research has yielded new insights on the cost savings that can be delivered through future-proofing measures and the

[99] For further discussion see: https://uk.grundfos.com/content/dam/UK/Brochure/E3915%20Hydronic%20Balancing%20report%203.pdf and https://www.sustainableenergyassociation.com/resources/next-steps-for-boiler-plus/. Lime scale build up is also an issue.

[100] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*

timescale on which low-carbon heat can be expected to offer cost-effective carbon savings in new build homes.

Future-proofing new homes for low-carbon heating, through the use of appropriately-sized heat emitters and low-temperature compatible thermal stores, has been estimated to save £1,500-£5,500 of costs compared to later having to retrofit low-carbon heat from scratch.[101] All new homes should therefore be future-proofed for low-carbon heating at the earliest opportunity:

- A range of low-carbon heating systems rely on low flow and return temperatures to operate efficiently. This includes heat pumps and low-temperature district heat networks.
- Two future-proofing measures reduce the costs of retrofitting low-carbon heat at a future date: heat emitters suitable for low temperature heating (radiators approximately 2.5 times the output capacity of standard radiators, achieved through double emitter panels and increased length or height, or underfloor heating); and low-temperature compatible hot water stores in homes where thermal stores are necessary (incorporating larger heat exchangers such as double coil heating elements).[102]
- Low-temperature radiators add around £150-£500 to the upfront cost of building a home.[103] Where a hot water store is to be added to a new build home (e.g. for the purposes of meeting hot water demand in larger properties), the incremental costs of making it low-temperature ready are expected to be negligible where deployed at scale.[104]
- If these features were to be retrofitted at a later date, additional costs of £1,500-£5,500 would be incurred reflecting the need for radiator replacement, adjustments to plumbing, removal and disposal and making good. This is expected to be an underestimate on the basis that 'hassle' costs would be additional. Installing larger radiators from the outset has the additional benefit of enabling gas boilers to operate more efficiently.

The evidence indicates that low-carbon heat is now cost-effective in all new build homes by 2025 or earlier. On this basis, no new homes should connect to the gas grid from 2025 at the latest. Instead, new homes should make use of low-carbon heating systems such as heat pumps and low-carbon heat networks. Early deployment of low-carbon heat in new homes will help reduce the retrofit challenge by increasing familiarity amongst installers and the general public, better prepare the stock for net-zero ambitions, and help develop supply chains for broader uptake:

- As part of our 2015 analysis for the fifth carbon budget we identified the potential for cost-effective deployment of heat pumps in 1.1 million new homes to 2030, based on assumed

[101] Cost range reflects £1,500 for a small flat, extending up to £5,500 for a detached house.
[102] The analysis did not highlight a significant efficiency benefit from underfloor heating in comparison to appropriately sized radiators running at the same temperature. It therefore focused on modelling radiators as the lower cost option. However, underfloor heating may be preferable for other reasons in some new build homes, e.g. for convenience, and to minimise use of wall space.
[103] Cost range reflects £150 for a small flat, extending up to £500 for a detached house. These costs are based on the assumption that radiators in homes built to current standards are sized to match heat demand. To the extent radiators are typically oversized in new build homes, this will reduce the incremental costs further.
[104] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*. For homes which do not have hot water stores at the point of build, this will need to be added as part of any heat pump installation. The assumed sizing is 200-210l for flats and semi-detached homes. There must be adequate space provision in properties to allow for this. National space standards set out minimum areas for different types of property. The required storage space includes an allowance of 0.5m^2 for services (e.g. hot water storage and boilers). This is expected to be adequate.

uptake in 50% of new build homes from 2025, alongside heat networks for 1.5m new and existing homes.[105]

- The evidence now indicates that low-carbon heat, and heat pumps specifically, are expected to deliver cost-effective carbon savings in all new build homes by 2025 or earlier:[106]
  - The modelling undertaken by Currie & Brown and Aecom finds that heat pumps become cost-effective across new build homes by 2021.
  - New evidence since our fifth carbon budget analysis - including updated electricity costs and costs of gas grid connections - also points to cost-effectiveness earlier in the 2020s.
    - Relative to our previous analysis, estimates of the long-run variable cost of electricity in 2050 have been revised down.[107]
    - We have also revised our assessment of projected electricity grid carbon intensity to reflect recent progress in closing coal generation and installing renewable electricity generation capacity.
    - Updated modelling now accounts for the gas network costs that can be avoided where low-carbon heat is installed from the outset (assumed to be c. £350-£1100 per home).[108]
- Of all of the measures examined as part of Currie & Brown and Aecom's analysis of tighter standards in new build homes, heat pumps were found to offer the most potential for carbon savings, delivering around 25-85 tCO_2 savings per home over a 60 year lifetime, relative to a new home built to current standards with a gas boiler.[109] This represents a reduction in lifetime regulated carbon emissions of over 90%.[110]
- Alongside carbon savings, there is scope for heat pumps to deliver average annual bill savings. For a semi-detached home these are expected to be in the region of £55 per year on average, relative to a home built to current standards with gas heating.[111]
- Heat pumps are expected to add £800-£2500 to the costs of building a home in 2020 depending on the type of house. This represents a 0.6-2.0% increment on total build costs.[112]

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[105] CCC (2015) *Sectoral scenarios for the Fifth Carbon Budget*.
[106] Recent modelling by the CCC, and Currie & Brown and Aecom, has focused predominantly on heat pumps as one of the leading low-carbon heating options in new homes. See Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*. Findings remain applicable to low-carbon heating more broadly.
[107] This is to reflect changes in wholesale electricity costs and to be consistent with the cost reductions implied by recent modelling undertaken by Imperial College London for the Committee on the decarbonisation of the UK's energy system, and a reduction in subsidy payments to low-carbon generators beyond 2030.
[108] Aqua Consultants for the CCC, as part of Frontier Economics and Aqua Consultants (2016) *Future Regulation of the UK Gas Grid, Impacts and Institutional implications of UK gas grid future scenarios*.
[109] Costs reflect homes built in 2020. Carbon savings vary by building archetype, ranging from around 25 tCO_2 of lifetime savings in a small flat (50m^2) to 85 tCO_2 savings in a 4 bedroom detached house (117 m^2).
[110] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.
[111] Figure denotes average annual bill savings for a home built in 2020. The scale and nature of the bill impact is in part a function of the standing charges associated with gas and electricity bills, and will vary with the scale of standing charges assumed. For more detail on the assumptions underpinning the modelling see Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.
[112] Range reflects costs for a small flat (£800) relative to a semi-detached home (£2500). The uplift cost is higher for a semi-detached property than for a detached home, due to the need to install a hot water store which would not otherwise be necessary.

Costs are expected to come down by c. 4-5% by 2025, reflecting learning around installation practice.[113]

A pathway for delivering on uptake for 2025 could imply roll-out of low-carbon heat in up to 50% of homes from 2020.

Recommendation: All new homes should be made low-carbon heat ready. By 2025 at the latest, no new homes should connect to the gas grid, and should instead rely on low-carbon heating systems such as heat pumps.

(*Owner: MHCLG, BEIS, devolved administrations. Timing: trajectory set out by 2020).*

There are a range of regulatory routes which could be used to drive low-carbon heat in new build homes. Last year the Dutch Government introduced regulations which by default prevent new homes connecting to the gas grid.[114] Alternative approaches might include a heat supply standard ($kgCO_2e/kWh$ of heat) or carbon standard ($kgCO_2/m^2/yr$) as used in the building standards framework currently. However, a reliance on heat or carbon standards can be associated with sub-optimal outcomes where there are deficiencies in the mode of application (e.g. where standards are set on an average basis across groups of dwellings), or in the calculation methodology (e.g. inaccurate valuation of grid carbon intensity).

The latter is already a significant issue in the Standard Assessment Procedure (SAP). SAP undervalues the carbon savings that can be delivered by heat pumps and other electricity-based heating systems because it does not account for the declining carbon intensity of the grid (Box 2.3). The grid carbon intensity in the current version of SAP (SAP 2012) is 4 times higher than the projected 15-year grid average, with the planned grid carbon intensity in the forthcoming version of SAP (SAP 10) remaining around twice as high.

Box 2.3. The influence of SAP assumptions on the uptake of low-carbon technologies

The Standard Assessment Procedure (SAP), is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings. It is the basis for establishing compliance with Building Regulations, and for Energy Performance Certificates. SAP makes assessments based on a range of assumptions around things like the efficiency of heating systems and the emissions intensity of fuels. These assumptions can have a profound influence on the extent to which low-carbon measures are deployed in homes. There are a number of areas where SAP currently fails to properly value the benefits of low-carbon technologies.

The first is in relation to emission factors for electricity. SAP calculates the energy and carbon implications of a building component by using a single emissions factor for each fuel. These emission factors reflect the average carbon intensity forecast over a 3-5 year period following the SAP update - for SAP 2012 the electricity carbon intensity was set at 0.519 $kgCO_2$ per kWh and this carbon intensity remains the basis of SAP calculations today.

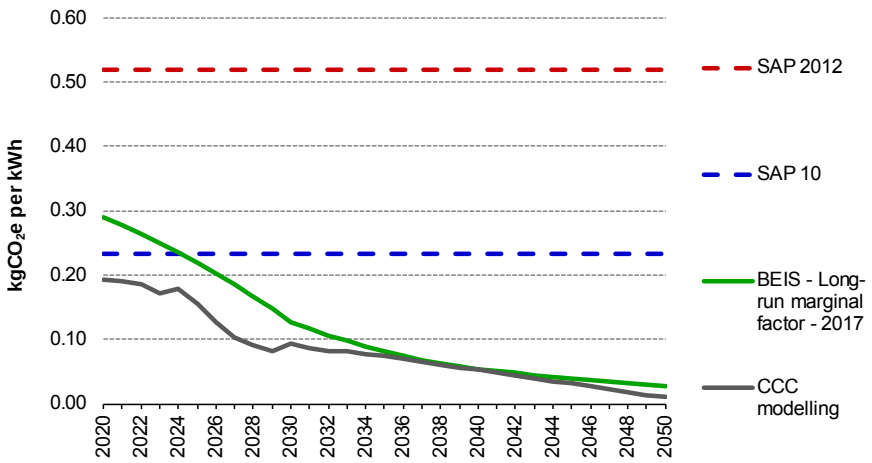
[113] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.
[114] As of 1st July 2018, the default situation for all new building permit applications in the Netherlands is that the building will not be allowed to connect to the gas grid. Local authorities have the power to grant exemptions, although the exemptions regime is planned to become stricter with time. Vivid Economics and Imperial College (2017) *International Comparisons of Heating, Cooling and Heat Decarbonisation Policies, Annex*; Delta EE (2018) *Do gas boilers still have a role to play in Dutch new build homes?* Delta-EE Research Blog.

Box 2.3. The influence of SAP assumptions on the uptake of low-carbon technologies

In reality, building components have much longer lifetimes (15 years in the case of heat pumps) and electricity emission factors are not static, but decreasing. The carbon intensity of electricity has more than halved since 2012 and is projected to fall by over 50% again by 2030.

Figure B2.3 illustrates the difference between the current SAP assumptions on average electricity carbon intensity, and Government and Committee projections for electricity carbon intensity out to 2050.

Figure B2.3 Comparing assumptions on the trajectory of electricity carbon intensity



Source: Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*
Notes: Based on SAP 2012: The Government's Standard Assessment Procedure for Energy Rating of Dwellings; SAP 10: The Government's Standard Assessment Procedure for Energy Rating of Dwellings; BEIS (2018) Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal, Data tables 1 to 19; CCC assumptions.

In order to properly value the benefits of low-carbon technologies, it is critical that the methodologies underpinning standards accurately reflect the Government expectations on declining grid carbon intensity over the lifetime of the measures being installed.

Secondly, SAP can materially influence the uptake of low-carbon technologies through the technologies it includes and the assumptions it makes around the efficiency of low-carbon heating systems. Committee assessments of achievable Seasonal Performance Factors (SPFs) for air source heat pumps indicate space heating efficiencies significantly higher than those assumed under the SAP default values.[115] In our fifth carbon budget scenarios, we assume a current SPF of 2.5 for air source heat pumps in retrofit, with potential to increase to 3.0 with learning. For new build, we assume an SPF of 2.75. Recent evidence suggests CCC assumptions may remain pessimistic for new homes.

Source: Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings* BRE (2011) *Technical papers supporting SAP12,* available at: https://www.bre.co.uk/filelibrary/SAP/2012/STP11-HP-01_Heat_Pumps.pdf

[115] CCC assumptions are based on results from two sets of field trials conducted by the Energy Savings Trust and DECC, along with results from monitoring of heat pumps installed under the Renewable Heat Premium Payment (RHPP) scheme and stakeholder views of the scope for improvement over time.

Recommendation: The Standard Assessment Procedure should be reviewed and revised to drive high real-world performance and value properly the benefits of low-carbon technologies. It should formally integrate a forward trajectory for declining grid carbon intensity, in line with Government projections.

(*Owner: MHCLG, BEIS. Timing: by 2020).*

2.3 Energy efficiency, overheating, indoor air quality and moisture

2.3.1 A holistic approach

Measures to address thermal efficiency, overheating, indoor air quality and moisture must be considered together when retrofitting or building new homes.

The technology exists to deliver homes which have high levels of thermal efficiency, are better adapted to a changing climate, with safe moisture levels and with excellent indoor air quality. However, the lack of a holistic approach in current design and build practices can lead to build quality issues. Close interlinkages between these various objectives drive the need to consider them alongside one another:

- Loft and wall insulation can help to prevent heat penetration through roofs and walls. However, once heat has entered a home, insulation also can reduce heat loss through the building fabric at night.[116] Access to purge ventilation has been found to be a key determinant of whether insulation exacerbates or mitigates overheating risk.[117,118] Studies show that overheating risks can, in principle, be largely mitigated with adequate ventilation and other measures such as external shading.[119]
- Achieving very high levels of thermal efficiency requires increased airtightness and the use of Mechanical Ventilation and Heat Recovery (MVHR) systems.[120] MVHR technology has significant potential to improve air quality in homes, where properly designed, commissioned, installed, maintained and operated. However, there is also evidence that this is not always the case in current installations:
  - The use of MVHR, if implemented correctly, can result in better levels of ventilation compared to naturally ventilated houses and can also have benefits for health and wellbeing where wider issues prevent natural ventilation strategies (e.g. external

[116] Mavrogianni, A; et al. (2012) *Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings.* Building and Environment, 55 117-130.
[117] Purge ventilation is manually controlled ventilation of rooms or spaces at a relatively high rate to rapidly dilute pollutants and/or water vapour. Purge ventilation may be provided by natural means (e.g. an openable window) or by mechanical means (e.g. a fan).
[118] Fosas, D. et al. (2018) *Mitigation versus adaptation: does insulating dwellings increase overheating risk?* Building and Environment, 143, 740-759.
[119] *Ibid*.; Tink, V. Porritt, S. Allinson, D. and Loveday, D. (2018). *Measuring and mitigating overheating risk in solid wall dwellings retrofitted with internal wall insulation.* Building and Environment, 141, 247-261; Schnieders, J. (2003) CEPHEUS - measurement results from more than 100 dwelling units in passive houses. *ECEEE 2003 summer study - time to turn down energy demand.*
[120] Based on modelling in SAP undertaken by Currie & Brown and Aecom, the tightest standards (25kWh/m^2/yr and below) cannot be achieved without improved airtightness and the use of MVHR systems in at least some archetypes. 15kWh/m^2/yr would require MVHR in all. See Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*

pollution, security concerns or noise).[121] This benefit is particularly relevant in cities with high outdoor pollution levels, which are often the site of low-income housing.

  - As well as enabling heat recovery in the winter, MVHR can support comfortable internal temperatures during the summer, providing systems have effective summer bypasses. There is also potential for MVHR systems to support cooling functionality where designed appropriately (e.g. alongside a cooling unit).
  - Nevertheless, a range of studies have also found cases of poor environmental conditions in houses with MVHR due to issues such as poor design and commissioning, and lack of education around use.[122] As a result, inadequate ventilation can then exacerbate health risks relating to a range of pollutants e.g. volatile organic compounds. The effectiveness of summer bypasses can also vary across products, as a result of limited guidance and standards in this area.

- Unless properly addressed, creating low-energy buildings with increasing amounts of insulation and airtightness can lead to an increased risk of moisture-related damage to the structure and internal environment, as well as adding to the risk of mould growth, with implications for occupant health. These risks can be addressed through testing of materials and appropriate design and installation, including taking a 'whole building' approach.[123]

The current regulations relating to thermal efficiency, overheating, air quality and moisture penetration are set out in Building Regulations across the UK. There are also a range of wider regulations, standards and guidance documents that are relevant (Table 2.1). The technical guidance documents are periodically updated, with different components generally being reviewed at different times. Upcoming reviews are expected of Approved Document L and Approved Document F in England, with a review of the Scottish energy standards already underway.

The regulatory and policy framework should require holistic approaches to delivering energy efficient, better ventilated, moisture-safe and thermally-comfortable homes. This should include an update to building regulations, requiring appropriate assessment and mitigation of overheating, indoor air quality and moisture risks during the design and build process for new homes and retrofits.

[121] Sharpe, T. Mawditt, I. Gupta, R. McGill, G. and Gregg, M. (2016) *Characteristics and performance of MVHR systems - A meta study of MVHR systems used in the Innovate UK Building Performance Evaluation Programme*. Technical Report. Innovate UK.
[122] *Ibid.*
[123] BSI (2017) *Moisture in buildings: an integrated approach to risk assessment and guidance;* BRE (2016) *Solid wall heat losses and the potential for energy saving*.

Table 2.1. Relevant legislative frameworks				
	England	**Wales**	**Scotland**	**Northern Ireland**
Regulations	The Building Regulations 2010 and (Amendment) Regulations 2013	The Building regulations 2010 and (Amendment) (Wales) Regulations 2014	The Building (Scotland) Regulations 2004	The Building Regulations (Northern Ireland) 2012
Technical guidance	Approved Document L, F, C	Approved Document L, F, C	Domestic Technical Handbook	Technical Booklet F1, K and C
Supporting guidance	Domestic Building Services Compliance Guide, Domestic Ventilation Compliance Guide	Domestic Building Services Compliance Guide, Domestic Ventilation Compliance Guide	Domestic Building Services Compliance Guide, Domestic Ventilation Guide, Accredited Construction Details (Scotland) 2015	
Calculation procedure	SAP 2012			

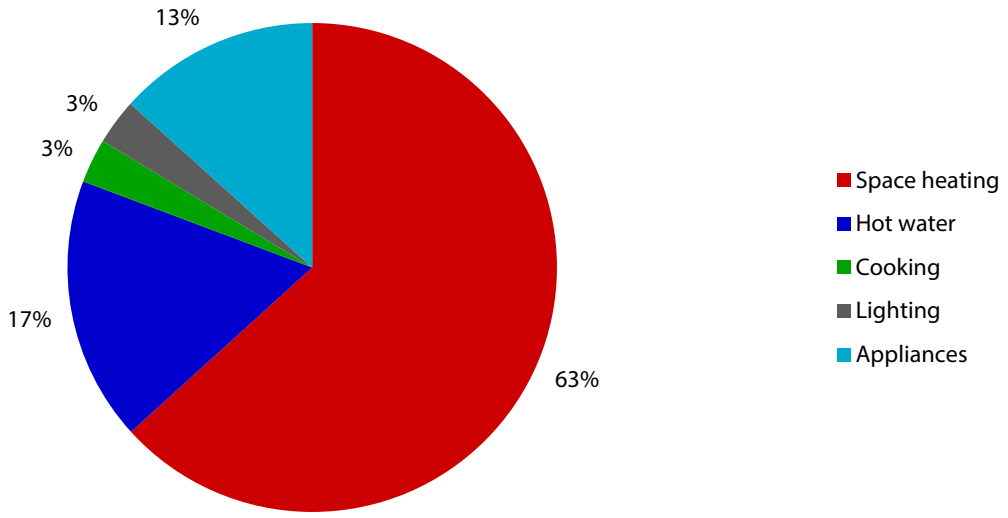
2.3.2 Energy efficiency retrofit

There is an urgent need to retrofit energy efficiency measures in existing homes as part of a broader programme of heat decarbonisation.

Energy efficiency is critical to reducing emissions and energy bills, improving health and wellbeing, helping tackle fuel poverty and making buildings better suited to low-carbon heating. Expertise in highly energy efficient buildings also represents an industrial opportunity for the UK.

Space heating is the dominant driver of energy consumption in existing homes (making up 63% of annual energy consumption), followed by hot water demand (17%) and appliance demand (13%) (Figure 2.1).

Figure 2.1. Breakdown of energy consumption in existing homes, TWh (2017)



Source: BEIS (2018) *Energy Consumption in the UK.*

There is considerable potential to improve the energy efficiency of existing buildings at reasonable cost. Our scenarios include around a 15% reduction in energy used for heating existing buildings by 2030 through efficiency improvements, requiring insulation of about 7.5 million walls and lofts in homes,[124] glazing improvements, draught proofing, hot water efficiency, and heating controls (Box 2.4).

Box 2.4. Summary of carbon savings from energy efficiency measures (Central Scenario for the fifth carbon budget)

Solid wall insulation: we assume cost-effective uptake in around one million homes, focused on properties not connected to the gas grid, alongside uptake in a further one million homes for wider fuel poverty benefits.

Cavity wall and loft insulation: we assume that almost all of the potential for low-cost cavity wall and loft top-up insulation is delivered in the 2020s. For cavity walls, this includes four million easy-to-treat walls and two million hard-to-treat walls where the cavity can be treated cost-effectively. Cavity walls that would require more expensive solid wall treatment are excluded.

Other fabric measures: measures are focused on reducing heat loss from flooring, doors and windows through the installation of floor insulation, insulated doors and draught strips.

Glazing: this covers two types of glazing improvements – switching from single to double glazing, where energy savings would be higher, and from pre-2002 double to new double glazing.

Heating controls: these comprise three controls: thermostatic radiator valves (TRVs), timers and thermostats. The largest savings potential comes from installing TRVs.

[124] In both cases, relative to 2015.

Box 2.4. Summary of carbon savings from energy efficiency measures (Central Scenario for the fifth carbon budget)

Hot water efficiency measures: insulating hot water tanks, the installation of hot water cylinder thermostats, and the use of reduced flow showers all save hot water use.

Behavioural change: turning down the thermostat by one degree centigrade and switching lights off are low-cost changes households can make.

Lighting: Savings from switching from incandescent lamps to compact fluorescents and from halogens to LEDs are focused on indirect emissions. There is however, a corresponding increase in direct emissions of 1 $MtCO_2$ by 2030 due to the heat replacement effect. This occurs because as lighting and other electricity products become more efficient, they produce less waste heat. Our assessment allows for a small amount of additional heating requirement.

Appliances: Driven by end of lifetime replacements and tightening EU energy efficiency standards, we expect a high uptake of the most efficient cold and wet energy efficient appliances (e.g. fridges and dishwashers). This will provide a significant electricity saving but would increase direct emissions by 0.8 $MtCO_2$ by 2030.

Annual direct emissions savings from all the residential energy efficiency measures considered could save 6 $MtCO_2$ by 2030.

In addition, we estimate that take-up of energy efficiency measures can reduce electricity use by around 30 TWh by 2030. Electricity demand reduction is driven by the large uptake of the most efficient white appliances, electric ovens and televisions which deliver over 60% of the savings by 2030. A further 6.8 TWh is due to householders switching to more efficient lighting.

Source: CCC (2015) *Sectoral scenarios for the Fifth carbon budget*. Supporting research is set out in Element Energy and Energy Savings Trust (2013) *Review of potential for carbon savings from residential energy efficiency*, and considered in CCC (2013) *Fourth Carbon Budget review*, both available online at: https://www.theccc.org.uk/publication/fourth-carbon-budget-review/

Current policy is failing to drive uptake.

In many areas current policy is failing to drive uptake, including for highly cost-effective measures such as loft insulation. Policies have yet to be set out to deliver the stated ambition on home retrofits (EPC band C by 2035), including for those households deemed 'able-to-pay', and a delivery mechanism for social housing minimum standards. Policy needs to incentivise efficient long-term investments, rather than piecemeal incremental change. Backstop mandatory requirements can support this, as in Scotland, creating policy certainty and driving innovation and growth (Box 2.5).

Box 2.5. Energy Efficient Scotland Route Map and Consultation

In March 2018 the Scottish Government published their route map and consultation on delivering an 'Energy Efficient Scotland'.

Ambition

The route map sets out an ambition to ensure all Scottish homes achieve an EPC band C rating by 2040, where technically feasible and cost-effective. Since publication of the route map, the Scottish Parliament has given majority backing for proposals to bring forward these energy efficiency targets by a decade to 2030. This sits alongside commitments to maximise the number of social-rented homes achieving EPC band B by 2032 (becoming carbon neutral by 2040 as far as reasonably practical), and a detailed trajectory for private-rented homes to reach EPC band C by 2030 where technically feasible and cost-effective. Finally, a target is set to bring all homes with households in fuel poverty to EPC band C by 2030 and EPC band B by 2040, where technically feasible and cost-effective.

As well as improving the energy efficiency of all Scottish buildings the Route Map is focussed on decarbonising heat – with an initial focus on off-gas grid areas. To support the work on energy efficiency and low-carbon heat, the Scottish Government has consulted twice on Local Heat and Energy Efficiency Strategies (LHEES) which aim to link long-term targets and national policies with delivery in local authorities. The Scottish Government is currently funding 22 local authorities to support the development of LHEES and proposes to fund the remaining local authorities over the next 2 years.

Framework for achieving the ambition

The proposed delivery framework includes a mix of existing and new measures. These include continuing the existing programme of grants and loans, funding support for fuel poverty programmes, local authorities and LHEES, and for nationally delivered support to cover those households and businesses not covered by area-based schemes. Alongside this there is a broader framework for consumer protection, skills and training, the supply chain and quality assurance as well as assessment. The roadmap recognises the need to make sure EPCs more accurately record the energy efficiency of buildings.

The Scottish Government will be undertaking further consultation in early 2019 on the intended approach to legislating for Energy Efficient Scotland, as well as seeking views on the impacts of accelerating the Programme.

Source: Scottish Government (2018) *Energy Efficient Scotland: route map.*

Standards and labelling for appliance efficiency also provide a positive example of where regulation has been used effectively to drive energy efficiency improvements.[125] The latest government estimates suggest that these policies have saved around 30 $MtCO_2e$ since 2008.[126]

Recommendation: Following UK exit from the EU, product standards should remain in place or be replaced with equivalent or more ambitious regulation.

(*Owner: BEIS. Timing: ongoing).*

[125] The EU Ecodesign Directive and the Energy Labelling Framework Regulation respectively operate by setting minimum performance and information requirements for energy using products, taking the least efficient products off the market and giving consumers clear information to make informed purchasing decisions. This is implemented through product specific EU regulations.

[126] BEIS (2018) *Updated energy and emissions projections 2017, based on traded and non-traded savings.*

2.3.3 Ultra low-energy new homes

We have consistently recommended that Government strengthen new build standards to ensure that all new homes are highly energy efficient.

Ambitious standards were set under the Zero Carbon Homes policy which would have come in to force in 2016, had they not been cancelled. The UK is also signed up to delivering nearly-zero energy homes by 2021 under the Energy Performance in Buildings directive, although the status of this is now unclear. Meanwhile, the aspirational target to halve emissions in new homes by 2030 under the Government's Building Mission is out of step with the urgent timeline the UK has signed up to under the 2015 Paris Agreement.

Over the past year we have undertaken research to assess what level of energy efficiency can best support long-term decarbonisation needs. This has included the research we commissioned from Currie & Brown and Aecom on the cost-effectiveness of new lower-carbon and lower-energy buildings, alongside a broader programme of stakeholder engagement.[127] Below we set out our recommendations based on the findings of this work.

New homes should deliver ultra-high levels of energy efficiency as soon as possible, and by 2025 at the latest.

Ultra-high energy efficiency standards have potential to represent a more cost-effective option than some more moderate levels of tightening, due to the cost savings associated with the reduced need for radiators and associated heating distribution pipes (Box 2.6). Implementing ultra-high levels of energy efficiency (consistent with space heating standards of 15-20 kWh/m^2/yr) can save consumers money on bills, provide comfort and health benefits, deliver some reduction in annual and peak electricity demand, and provide an industrial opportunity for the UK to export innovation and expertise. It could also support the delivery of European requirements around nearly-zero energy buildings:

- Ultra-high energy efficiency standards, installed alongside an air source heat pump, represent a 1.1-4.3% uplift on **build costs** relative to current standards, depending on the type of building.[128] This cost would affect housebuilder profits, be reflected in land values and/or be passed through to the house buyer (see section 4.3). A significant (up to c.£3,300) saving in the capital cost of the heating distribution system helps to offset the additional costs associated with the most energy efficient fabric specifications.[129]
- For a semi-detached home built with a gas boiler in 2020, the modelling indicates that ultra-high energy efficiency standards can deliver annual average bill savings of around £55 over the lifetime of the build.[130] When installed alongside heat pumps, ultra-high energy efficiency standards are expected to deliver average annual bill savings of around £85

[127] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*
[128] Equivalent to incremental costs of between £1,300 for a small flat and £6,900 for a detached house. Costs based on buildings constructed in 2020 with an air source heat pump and a space heat demand of 15 kWh/m^2/yr when modelled in SAP 2012 software.
[129] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.* Based on a detached house. This is contingent on the closure of the performance gap, which may be associated with additional costs (not included in the modelling).
[130] Relative to a home built to England and Wales Part L, 2013.

relative to a home built to current standards with gas heating, and around £30-40 relative to installing a heat pump alone.[131]

- As well as bill savings, ultra-high energy efficiency standards can deliver **carbon savings** in gas-heated homes.[132] In a semi-detached home built with a gas boiler in 2020, ultra-high efficiency standards can deliver carbon savings of around 27 tCO_2 over the lifetime of the build.[133]
- Ultra-high energy efficiency standards, as part of a wider set of measures, can make some contribution to minimising the impact of new homes on **annual electricity demand and on peak demand.** This can reduce system costs and drive additional carbon savings to the extent further reliance on high-carbon peaking-plants can be avoided. Total annual energy consumption in existing homes is currently 467 TWh.[134] Where all new homes are built to current standards with an air source heat pump, they are estimated to add up to 43 TWh to annual demand by 2050.[135] Ultra-high energy efficiency standards could help reduce this by around 4 TWh. Ultra-high energy efficiency standards could also help reduce the peak demand associated with heat pumps in new homes (estimated to be up to 15-16 GW).[136] This would need to be further supplemented with action to reduce the demand associated with appliance and hot water use (considered further below).
- Highly energy efficient homes can provide **comfort and health benefits,** offering warmer homes in the winter and, if implemented correctly, enhanced protection from overheating in the summer alongside improved indoor air quality. Insulation and airtightness can also reduce noise disturbance, with associated physical and mental health benefits.
- Finally, developing expertise in highly energy efficient buildings represents **an industrial opportunity** for the UK, in retrofit as well as new build. The construction sector, encompassing contracting, product manufacturing and professional services, exported over £8bn of products and services in 2016.[137] European requirements on net-zero energy buildings, and growing interest in markets such as Canada and China could represent export opportunities for UK innovation and expertise.[138]

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[131] The scale and nature of the bill impact is in part a function of the standing charges associated with gas and electricity bills, and will vary with the scale of standing charges assumed. Where moving to and from a tariff which does not include standing charges (i.e. where these costs are incorporated in the unit rate), the saving associated with ultra-high energy efficiency standards and a heat pump relative to installing a heat pump alone could be up to £40. For more detail on the assumptions underpinning the modelling see Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.

[132] Standards which deliver a space heat demand of 15 kWh/m^2/yr in gas heated homes become cost-effective in most homes against a high carbon price in the mid-2020s.

[133] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.

[134] BEIS (2018) *Energy Consumption in the UK*.

[135] This reflects energy demand associated with space heating, hot water demand, pumps and fans, lighting, appliances and cooking, based on Currie & Brown estimates and CCC modelling.

[136] Figures represent a broad estimate based on National Grid data on current residential peak demand drawn from National Grid's Future Energy Scenarios for 2017 and recent modelling undertaken by Robert Sansom.

[137] Published in HM Government (2018) *Industrial Strategy: Construction Sector Deal*, based on Office for National Statistics - UK Balance of Payments Pink Book (2017). Table 9.11 and Table 3.8 for data construction contracting and services exports. BEIS, Monthly Statistics of Building Materials and Components, 2017 for data on construction products exports.

[138] British Columbia has a goal for all new buildings to be net-zero energy ready by 2030. In 2017 it introduced the British Columbia Energy Step Code, which is a voluntary provincial standard that paves the way for this progress; British Columbia (2017) *BC Energy Step Code: A Best Practice Guide for Local Governments*. China aims to increase the share of new green buildings in urban areas to 50% by 2020, and China Green Building Council has recently

Designing in appropriate standards from the start is a fraction of the cost of trying to retrofit later (with retrofits being in the order of five times more expensive).[139] In the case of ultra-energy efficient fabric measures, the prohibitively high retrofit costs (£20,000+) mean that this is unlikely to be done in practice.[140]

Box 2.6. Research on the costs and benefits of tighter standards for new buildings

In 2018 we commissioned research to look at the cost-effectiveness of new lower-carbon and lower-energy buildings. This included examining how costs vary across different combinations of measures - by building type and size - and how these costs are expected to change over time. The work has also examined approaches to standard-setting more broadly, identifying those which have potential to represent 'best practice' in the UK context.

The research has generated a wide range of important insights, which underpin the recommendations in this report:

- **Low-carbon heat supply is a priority and the penalty of delayed action is significant.** Air source heat pumps are found to be cost-effective in homes by 2021, against central carbon prices. Air source heat pumps are found to offer cost-effective reductions in regulated carbon emissions of more than 90% over the lifetime of a building relative to a gas-heated home built to current standards. Where a home is built with gas heating in 2020, and has an air source heat pump retrofitted in 2030, the lifetime emissions are found to be more than three times higher than a home built with an air source heat pump at the outset.
- **There is potential to cost-effectively tighten efficiency standards for new buildings.** In 2025 ultra-high energy efficiency standards (with a space heat demand of 15 kWh/m^2/yr) are cost-effective alongside heat pumps across almost all archetypes at central carbon prices.[141] Ultra-high levels of energy efficiency are generally found to be more cost-effective than tightening to 20-30 kWh/m^2/yr of space heat demand, due to a significant (up to c. £3,300) saving in the capital cost of the heating distribution system which helps offset some of the additional costs associated with the most energy efficient fabric specifications.
- **Achieving higher standards via retrofit is very expensive compared to doing so in new buildings.** To improve fabric standards and install low-carbon heat via retrofit costs up to five times more than achieving the same standards when first constructing the home. Targeted preparatory measures (low-temperature compatible heat emitters and thermal stores) in new buildings can reduce retrofit costs by up to £5500.

A range of wider recommendations are also made around the performance gap and compliance tools which are reflected elsewhere in this report.

Source: Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*

partnered with the World Green Building Council (World GBC) and committed to introducing a 'nearly net zero' standard for its Three Star rating system in 2018 as part of World GBC's Advancing Net Zero project. See: https://www.worldgbc.org/news-media/world-green-building-council-and-china-green-building-council-announce-partnership-0

[139] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.* Multiple reflects the costs of retrofitting a home with an air source heat pump to a space heat demand standard of 15 kWh/m^2/yr, relative to installing these measures in a new build home.

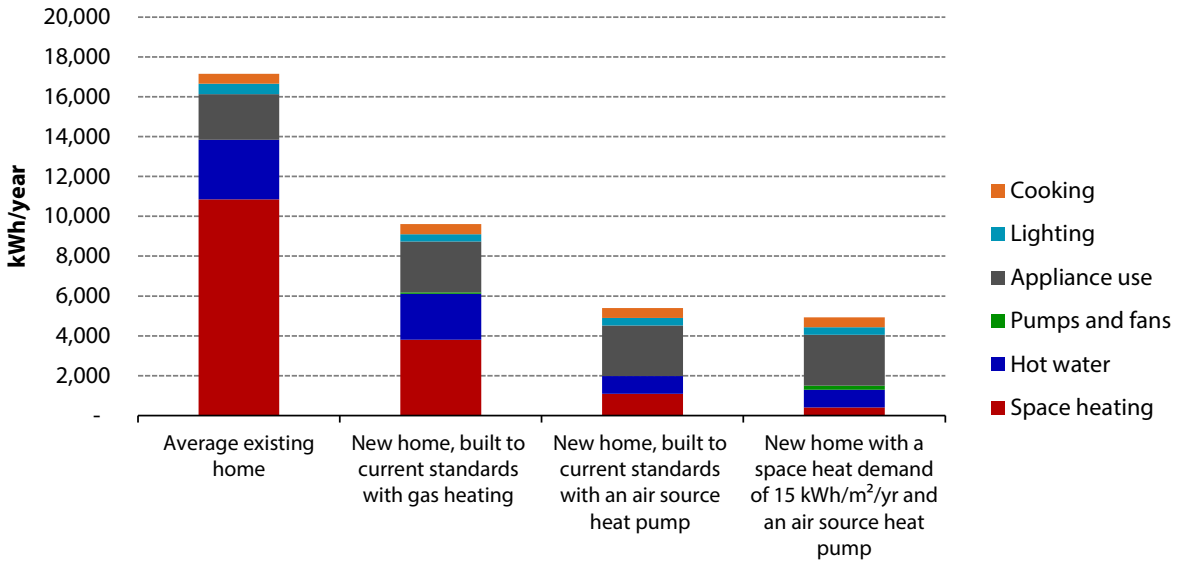
[140] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.* Based on a new semi-detached home built to current standards in 2020 and retrofitted in 2030 to a space heat demand standard of 15 kWh/m^2/yr.

[141] The exception is the semi-detached house, where ultra-high energy efficiency standards alongside a heat pump become cost-effective shortly after.

We consider the implications of the costs associated with delivering these tighter standards in greater detail in Chapter 4.

In addition to the important role for fabric energy efficiency in new build homes, the energy required for hot water and appliance use represents an increasingly significant contribution to total demand (Figure 2.2).

Figure 2.2. Breakdown of energy consumption in existing and new homes



Source: BEIS (2018) *Energy Consumption in the UK*; Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*
Notes: Average existing home drawn from ECUK data, pump and fan use is not separated out. Cooking demand for all homes based on current average consumption implied by ECUK. Appliance use for new homes drawn from SAP. Other new home consumption based on modelling undertaken by Currie & Brown and Aecom in SAP. 'New home' represents a three bed semi-detached home, with 'current standards' denoting England and Wales Part L, 2013 and assumed to be performing as designed.

This reinforces the importance of driving uptake of a wider range of energy efficiency measures in new build homes, including tightening appliance standards, hot water efficiency measures (such as reduced flow showers, considered further in section 2.6), and low-energy lighting.

Recommendation: New build homes should deliver ultra-high levels of energy efficiency as soon as possible, and by 2025 at the latest. This should be consistent with a space heat demand of 15-20 kWh/m^2/yr.

(*Owner: MHCLG, devolved administrations. Timing: trajectory set out by 2020).*

2.3.4 Indoor air quality

Regulations around ventilation must evolve to keep pace with improvements in energy efficiency and to deliver excellent levels of indoor air quality in homes.

All buildings need adequate levels of ventilation to maintain indoor air quality and reduce the risk of overheating in the summer.

Current ventilation requirements are set out in Approved Document F. This examines three aspects of ventilation in buildings: whole building ventilation, local extract ventilation and purge ventilation:

- The regulations relating to background ventilation are based around a two tier system, where default guidance is intended to cover all levels of design air permeability and alternative guidance is provided for dwellings designed to an air permeability leakier than 5m^3/(h.m^2) at 50 Pa.[142] Under these lower levels of air tightness, lower levels of ventilation provision are deemed necessary.[143]

The regulations covering required air permeability are set out in Approved Document L. Compliance is assessed by measuring the airtightness of dwellings through pressure testing. Testing is mandatory for a required sample for each dwelling type on a development.

Buildings with ultra-high levels of energy efficiency require high levels of air tightness[144] and in turn active ventilation strategies. There is a need for regulations around ventilation to evolve to keep pace with improvements in the energy efficiency of buildings. Coordination should be improved to fully reflect the interactions and interdependencies (for instance, through combining into a single Approved Document and/or integrated approaches to testing compliance). Ventilation and energy requirements should be reviewed together to ensure they are fit for purpose as our buildings become more energy efficient. We welcome the Government's recent commitment to do so. Considerations should include:

- How Part L and Part F of Building Regulations can be better coordinated to reflect interdependencies. An approach which supports the holistic consideration of energy efficiency, overheating and ventilation strategies is likely to support the best outcomes for occupants. Combining energy efficiency and ventilation requirements could drive this.
- Whether building regulations should restrict the use of single aspect dwellings in favour of dual aspect dwellings, building on the requirements set out in the London Plan.[145]
- Whether the current 'two tier' system (based around a boundary air permeability level of 5m^3/(h.m^2) at 50 Pa) remains appropriate. A recent paper by Crawley et al. has recommended ranges of air permeability be matched with categories of ventilation at each design stage.[146]
- Whether the current approach to compliance testing is fit for purpose. The current approach focuses on measuring air tightness rather than air quality. Furthermore, evidence suggests that the current approach is not leading to an accurate assessment of 'as-built' air permeability performance, and may drive an overreliance on secondary sealing rather than

[142] MHCLG (2013) *Approved Document F: ventilation (2010 edition incorporating 2010 and 2013 amendments).*
[143] The regulations in Scotland recommend trickle ventilation based on infiltration rates of 5 to 10m^3/h/m^2 @50 Pa as a matter of course in a modern house. However, where lower infiltration air rates of less than 5m^3/h/m^2 @ 50Pa are proposed, alternative mechanical ventilation systems should be adopted.
[144] Recent modelling by Currie and Brown has indicated that a semi-detached home with a space heat demand standard of 15 kWh/m^2/yr can most cost-effectively be achieved with an air-tightness of 1m^3/h.m^2 at 50 Pa. See Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*.
[145] In the London Plan a single aspect dwelling should only be provided where it is considered a more appropriate design solution than a dual aspect dwelling and it can be demonstrated that it will have adequate passive ventilation, daylight and privacy, and avoid overheating. See Mayor of London (2018) *Draft New London Plan showing Minor Suggested Changes*.
[146] Crawley, J. Wingfield, J. & Elwell, C. (2018) The relationship between airtightness and ventilation in new UK dwellings. *Building Services Engineering Research and Technology*.

focusing on the quality of the primary air barrier. [147] This is problematic due to the potential lack of durability of remedial measures (e.g. draught excluder tape).

- Whether the current air flow rate metric is fit for purpose or whether an alternative volumetric approach could better support high indoor air quality across a range of building forms (e.g. based on air change rates per hour).There is also a question about whether regulations need to evolve to reflect different needs across existing buildings and new build homes.
- Whether the current regulatory framework relating to pollutants is sufficient, particularly as homes become more airtight.[148] There is scope to better address risks through source control and labelling requirements, alongside considering whether the list of pollutants addressed in Appendix A of Part F is appropriate.[149]

Regulatory changes should be accompanied by wider policy initiatives to deliver learning and skills development for key technologies. Given the central role of mechanical ventilation systems in ultra-energy efficient homes, there is an urgent need for further work to ensure these systems are designed, commissioned and installed properly, and that householders are supported to use and maintain them effectively:

- Steps must be taken to improve the design, commissioning and installation of systems. This includes addressing the skills gap through appropriate training, providing practical installation guidance, and improving quality control onsite to avoid installation defects.
- Further research is needed into how challenges in operating and maintaining mechanical ventilation systems can be overcome. There is a need for further consideration of design approaches to ensure that systems are designed around the needs and preferences of those using them. This includes making sure that systems are designed to facilitate easy access, whilst minimising noise disturbance in the home. Innovative approaches to design and maintenance can also play a role. This includes incorporation of MVHR systems in heating system maintenance contracts, and alarm systems to alert users to when filters need changing. There is also a need for improved handover processes and occupant guidance.

Effective operation of these systems is a critical precursor to ultra-high energy efficiency standards and must be addressed as a priority in advance of any uplifts to mandatory standards.

Recommendation: Regulations around ventilation and indoor air quality must evolve to keep pace with improvements in the energy efficiency of buildings. Part F of the Building Regulations should be reviewed alongside Part L, with a view to tightening standards and coordinating requirements to fully reflect interdependencies. Where updates affect Part B and vice versa, Government should review the standards as a whole. Steps must be taken to improve the design, commissioning, and installation of mechanical ventilation systems, with further research into how challenges in maintaining and operating them can be overcome.

(*Owner: MHCLG, Defra, devolved administrations. Timing: 2019).*

[147] Love, J. Wingfield, J. Smith, AZP. Biddulph, P. Oreszczyn, T. Lowe, R. and Elwell, C.A. (2017) *Hitting the target and missing the point: Analysis of air permeability data for new UK dwellings and what it reveals about the testing procedure.* Energy and Buildings, 155, 88-97.

[148] Including the Control of Substances Hazardous to Health Regulations 2002 and the Volatile Organic Compounds in Paints, Varnishes and Refinishing Products Regulations 2012.

[149] The European Union EU-LCI working group is developing a harmonisation framework for health-based evaluation of indoor emissions from construction products, which has potential to form the basis for a source control and labelling framework in the UK.

2.3.5 Overheating

There are a number of adaptation measures available to builders and home owners to reduce the risk of overheating in homes, improve comfort levels for occupants and avoid the need to invest in alternative cooling measures, such as air-conditioning.

The determinants of overheating risk in homes include location, orientation, house type, ventilation strategy, and occupant behaviour. A combination or package of adaptation options is likely to be needed to reduce the risk:

- Passive cooling measures (as opposed to mechanical) consist of reducing internal heat gains, enhancing natural ventilation and reducing solar gain through the windows and fabric of the building. When installed and operated correctly they have been found to be effective at reducing the number of hours during which overheating occurs.[150] A 2018 study has found that external shutters provided the largest reduction in heat mortality risk, while closed windows caused a large increase in risk. Ensuring adequate ventilation, targeted installation of shutters, and openable windows in dwellings with heat-vulnerable occupants may save energy and significantly reduce heat-related mortality.[151]
- Additional green measures such as trees, green roofs and green walls can also help to provide shading and absorb heat plus bring a range of multi-benefits (Chapter 3). The uptake of green roofs in London is supported by the London Plan.[152]

Research for the Committee found that a number of passive cooling measures are cost-effective[153] for householders as part of retrofit and new build in south west England: [154,155]

- The most cost-effective measures are those that improve ventilation (for example opening of windows and night ventilation) and provide shading (for example blinds, curtains, tinted window films and external shading). Other measure such as using energy efficiency appliances to reduce waste heat are also cost-effective.
- In addition, installing external shutters and improving roof albedo (white roofs) are cost-effective in new builds. These measures should be installed at new build stage to avoid the need for costly retrofit later.[156] For example the costs of installing opening inward windows and shutters at build stage in a flat would be around £650 compared to £3,600 to retrofit.[157]
- Some measures are more effective in certain types of properties. Internal blinds are more cost-effective in flats compared to other types of dwelling.

[150] Mavrogianni et al. (2014) *The impact of occupancy patterns, occupant-controlled ventilation and shading on indoor overheating risk in domestic environments*.
[151] Taylor et al. (2018) *Estimating the influence of housing energy efficiency and overheating adaptations on heat-related mortality in the West Midlands, UK*. Atmosphere 2018, 9 (190).
[152] The London Plan requires all major development proposals to include roof, wall and site planting, especially green roofs and walls where possible, to deliver cooling benefits as an adaptation measure to climate change.
[153] Cost-benefit analysis (CBA), which compares costs with benefits, is preferred for ranking of options. However, cost-effectiveness analysis (CEA) provides an alternative approach in cases where benefits cannot be monetised and compared directly with costs.
[154] Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*
[155] David Langdon for the CCC (2011) *An assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*
[156] *Ibid*.
[157] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.*

The package of low-regret adaptation options we have identified for reducing the impact of overheating in the south-west may also deliver savings to other parts of the country, particularly in areas of heat stress. Other factors will influence the cost-effectiveness of measures, for example:

- Additional benefits to some of these measures that have not been included in analysis, such as energy efficient appliances, will reduce electricity consumption and carbon emissions.
- A major source of uncertainty in building performance relates to occupancy and behavioural assumptions. The way inhabitants occupy and operate a building has a measurable impact on thermal discomfort and health risks to occupants associated with their exposure to high indoor temperatures. [158] Appropriate occupant behaviour (such as opening windows when outside temperatures are lower than inside, and closing curtains during the day to limit solar gains) are an additional effective, no-cost adaptation option to address overheating.

For some properties, particularly in cities, it may not be possible to achieve temperatures which are comfortable for occupants in the future using only passive cooling and behaviour measures. Generally in urban areas householders may be less able to open windows for ventilation, particularly at night, due to issues with security, noise and pollution. In London and the south-east other active cooling measures may be required due to high external temperatures and the undesired ingress of outdoor pollutants (Box 2.7).

Box 2.7. Use of air conditioning and active cooling measures

Passive cooling measures are a preferable adaptation to air conditioning, which is energy-intensive and expels waste heat into the environment. Air conditioning can increase carbon emissions (if powered from non-renewable energy), contribute to the Urban Heat Island Effect and increase occupant bills (potentially increasing the risk of summer-time fuel poverty). For example, our research has found that air conditioning could cost households up to £266 per year in a flat and £140 per year for a detached house in energy bills in order to mitigate overheating risk.

For those dwellings where it is not possible to improve overheating completely with passive cooling and behaviour change, additional active cooling solutions could be considered. For example air to air heat pumps when combined with ventilation systems such as Mechanical Ventilation and Heat Recovery could be used for both heating and cooling.

Source: Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector;* IEA (2018) *The Future of Cooling.*

[158] Mavrogianni et al. (2014) *The impact of occupancy patters, occupant-controlled ventilation and shading on overheating risk in domestic environments.* Building and Environment, 78 (2014), 183-198.

There remain limitations in assessing the extent of overheating risk in existing homes across the whole of the UK.

A methodology for identifying both dwellings and affected populations which are at risk of overheating is needed. There is a general lack of information around how occupants currently use and operate their homes which makes it difficult to understand the overall scale of the risk across the UK, and how to target packages of mitigating measures.

Recommendation: Further action should be taken to better understand when overheating occurs in existing homes in order for passive cooling measures and behaviour change programmes to be targeted effectively.
(*Owner: Department of Health and Social Care, MHCLG, Scottish Government, Welsh Government. Timing: by 2020).*

Overheating risk is not adequately addressed in the current policy and regulatory framework, including Building Regulations. The current approach is not sufficient for identifying current or future levels of overheating.

An investigation by the Ministry of Housing, Communities and Local Government (MHCLG) carried out in 2015 found that 'all new homes exceed the overheating threshold to some extent'.[159] There remain no legal safeguards to avoid new homes overheating, despite the Committee's previous recommendations. Policies to address overheating are not generally included in Local Plans that are used to assess planning applications.[160]

The Building Regulations Part L Approved Documents include limiting effects of heat gains in summer, however the main purpose is for conservation of fuel and power (to limit solar gain to either eliminate or reduce the need for air conditioning). There are no requirements in Building Regulations to consider the risk of overheating in terms of minimising the risks to health and safety. This urgently needs to be revised as part of the MHCLGs, Welsh Government and Scottish Government's reviews of Building Regulations in 2019. Alongside the review of Part L and Part F of Building Regulations MHCLG plan to consult on a method for reducing overheating risk in new homes.

The calculations of solar gains in current regulations have also been widely criticised.[161] BEIS have produced draft changes to these calculations which could be a positive step towards reducing overheating risk alongside better regulation (Box 2.8).

[159] Environmental Audit Committee (2018) *Heatwaves: Adapting to Climate Change inquiry.*
[160] Adaptation Sub-Committee (2017) *2017 Report to Parliament – Progress in preparing for climate change.*
[161] Zero Carbon Hub (2015) *Overheating in Homes - The Big Picture.*

Box 2.8. Overheating assessment methodology - SAP 2012 vs SAP 10

The Approved Document accompanying Part L of Building Regulations for dwellings provides a test for solar gains (SAP Appendix P). It is currently simplistic in its approach and assumptions, and is seen as not sufficient to identify either current or future levels of overheating risk in dwellings. The recently published draft SAP10 changes the methodology for the assessment of the risk of summer-time overheating under Criterion 3 in Approved Documents and makes it more robust.

If taken forward to the final document, this may result in more properties failing this Criterion within SAP, and therefore failing to meet building regulations without mitigation measures.

The previous methodology was said to be very difficult to fail due to a number of unrealistic assumptions such as that windows are constantly open, so this could be a positive step towards overheating risk mitigation in UK housing.

However, BRE highlight that Appendix P should not be relied upon to assess thermal comfort, and without better regulation there is a risk that this could encourage developers to opt for active cooling measures, instead of prioritising the implementation of passive cooling strategies. Active cooling may be seen as an easy fix in locations with significant air pollution, noise, and security and safety issues.

Source: CIBSE (2018) Building Regulations Part L & F Briefing; AES (2018) *Potential Impact Assessment, Changes in wording and methodology between SAP 2012 (SAP 09) and Draft SAP 2016 (SAP 10) with regards to the assessment of summertime overheating;* Zero Carbon Hub (2015) *Overheating in Homes - The Big Picture*.

Recommendation: It is critical that the 2019 reviews of Building Standards by MHCLG, Scottish Government and Welsh Government:

- Introduces a new standard or other requirement to ensure that overheating risk is assessed for current and future climates at design stage of new build homes or renovations.
- Ensures that passive cooling measures are installed at build stage where there is a risk of overheating identified. Where active cooling measures are also needed, consideration should be given to potential synergies in the choice and installation approach for heating and cooling systems, for example through the use of air source heat pumps combined with mechanical ventilation.

(Owner: MHCLG, Scottish Government, Welsh Government. Timing: 2019).

Recommendation: In England the Government must ensure that Planning Guidance is updated to clearly require local authorities to include overheating risk in Local Plans, as set out in the updated National Planning Policy Framework. Guidance should contain a requirement for local authorities to include an assessment of overheating risk as part of the planning process. This should require developers to carry out an initial assessment of the strategic features that increase risk, such as site location, building layout, façade, green space availability, and introduce appropriate mitigation measures at the early planning stages.

(Owner: MHCLG. Timing: by 2020).

2.4 Addressing the broader whole-life carbon impacts of homes

In the previous sections, we have considered a range of measures to decarbonise heating in homes, alongside energy efficiency measures to reduce wider energy use. These measures abate the emissions associated with the 'operational' life of homes (those associated with energy use during a building's lifetime). Alongside this it is necessary to consider how the construction of

our homes, and the disposal of construction materials at the end of life, can contribute to minimising atmospheric carbon. Our 2018 report, *Biomass in a low-carbon economy*, finds that the use of wood in construction is one of the most effective ways to use limited biomass resources to reduce atmospheric CO_2 (Box 2.9).

Box 2.9. Embodied emissions and sequestration potential

Embodied emissions (those caused by the extraction, manufacture and assembly of materials plus maintenance and end-of-life disposal) account for 25% to 50% of the overall carbon footprint of new buildings.[162] There will also be embodied emissions associated with the renovation of existing homes. Addressing the embodied carbon associated with homes will be a necessary part of any ambition to drive towards future 'net zero' greenhouse gas or carbon targets.

In addition to the potential for savings in the embodied carbon associated with buildings, there is also potential for sequestered carbon to be stored in buildings through the use of materials such as wood in construction. Wood in construction does not currently provide permanent sequestration of carbon. However it provides storage on timescales of decades to centuries and there is significant potential to grow the overall store of carbon in the built environment provided inflows of timber (through new build) exceed outflows (from disposal).

Between 27,000 – 50,000 new homes (15%-28%) built in the UK each year already use timber frame construction systems and wood is also widely used in traditional masonry systems.

Modelling undertaken for our recent report, *Biomass in a low-carbon economy*, found that currently, timber frame construction can reduce embodied emissions by up to around 3 tCO_2e per home[163] through the displacement of high-carbon materials such as cement and steel, although there are uncertainties related to end-of-life processes.[164]

Increasing this to 270,000 each year could would result in annual net carbon storage of around 3 Mt CO_2e by 2050, accounting for losses due to demolition and disposals. This level of timber construction could further reduce embodied emissions in the residential sector by 0.5-1 Mt CO_2e per annum in 2050.

There is a risk that the Government's intended ban on combustible materials will affect the uptake of wood in construction (both engineered wood and timber frame homes), with some anecdotal evidence that this is taking place. Clarity from Government on the role and fire safety of wood in construction is needed.

Source: CCC (2018) *Biomass in a low-carbon economy;* MHCLG (2018) *Final Impact Assessment: Ban on combustible materials in external wall systems.*

[162] NHBC (2012) *Operational and embodied carbon in new build housing*; UKGBC (2017) *Embodied carbon: developing a client brief*.

[163] Bangor University calculates that the structural elements of a new detached 3-bed timber frame house has 'cradle-to-gate' emissions around3.2 tCO_2e lower than a masonry alternative. A 2012 NHBC study (which takes into account refurbishment and disposal) finds this saving to be around 7 tCO_2e over a 60 year period. See NHBC (2012) *Operational and embodied carbon in new build housing*.

[164] An example is the impact of carbonation on concrete. Concrete can absorb CO_2 throughout its life although this generally occurs at very low levels during the operational phase of a building's life. However during disposal this may increase due to crushing and increased exposure to air. Some estimates conclude that carbonation could reduce the embodied CO_2 of concrete by 7.5% over the full lifecycle - See: MPA (2016) *Whole-life carbon & buildings*. Other sources estimate a smaller reduction of 3-4% - See: NIBIO (2018) *The environmental impacts of wood compared to other building materials*. It may be possible to further reduce the embodied emissions by reusing old concrete or processing outputs from waste incinerators as recycled aggregates.

There are a wide range of potential policy levers that could, and in some cases already do, seek to address the whole-life carbon associated with homes. Regulation can be used to control the carbon intensity of new build, through measures such as carbon pricing and standards such as whole-life carbon intensity targets in Building Regulations. Minimising the need for new build (e.g. through measures to reduce under occupation in existing buildings) could also play a role in delivering carbon savings where those buildings can be decarbonised cost-effectively.

Whilst further work is needed to determine the best overall package of measures to address the whole-life carbon impacts of homes, low-regret measures include:

- Policies which support a substantial increase in the use of wood in construction.
- Action to support the assessment and benchmarking of whole-life carbon over the next 3-5 years, with a view to informing a decision on a future mandatory framework.

Recommendation: Develop new policies to support a substantial increase in the use of wood in construction. This will need to focus on overcoming a range of cultural, skills and financial barriers in the construction sector. Undertake low-regrets action to support the assessment and benchmarking of whole-life carbon in buildings with a view to informing the future policy framework.

(Owner: MHCLG, BEIS, devolved administrations. Timing: new policies for wood in construction in 2019, with groundwork on whole-life carbon by 2024).

2.5 Flexibility measures in homes

As we decarbonise heating and transport and increase our reliance on renewable forms of generation, meeting electricity demand will face new challenges:

- By 2050 we can expect substantial electrification of surface transport and electric heating loads, such that electricity demand could be around double today's level. Our central estimate for electricity generation required to meet the demand in our 2030 scenarios is 365 TWh, including electricity demand from 2m heat pumps and 20 TWh of demand from EVs. With accelerated uptake of EVs or heat pumps, electricity demand could increase to 390 TWh.[165]
- Increasing penetration of variable renewable energy into the UK's electricity system provides a need for more electricity grid services - such as balancing and frequency response - to ensure that variable supply can match electricity demand at all times, and power quality can be maintained. Several options are available to provide this 'system flexibility',[166] including flexible generators, battery storage, interconnection and demand-side response.[167] Flexibility measures have potential to bring electricity system costs down by £3-8bn/yr[168] by 2030 or up to £16bn/year by 2050.[169]

Energy systems are designed to meet energy demand at all times. This can be particularly challenging during 'peak demand' periods, which often occur on cold winter evenings, and may

[165] CCC (2018) *Reducing UK emissions - 2018 Progress report to Parliament.*
[166] Defined as the modification of generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system.
[167] Demand-side response is where consumers (the 'demand-side') can sign up to special tariffs and schemes which reward them for changing how and when they use electricity.
[168] Imperial College for the CCC (2015) *Value of flexibility in a decarbonised grid and system externalities of low-carbon generation technologies*
[169] Imperial College for the CCC (2018) *Analysis of alternative heat decarbonisation pathways*

coincide with periods of low electricity supply from variable renewables such as wind and solar. New electricity demands could add to this challenge.

We have considered in previous sections the steps that could be taken to minimise electricity demand in existing and new homes. Our homes, and the way we use them, can also help by shifting consumption away from peak, and towards periods when renewable energy is available. The demand profile and characteristics of each household will determine how flexible their energy demands can be. Some key enablers include:

- **Fabric efficiency and thermal storage.** Homes which are better insulated and have high levels of fabric efficiency retain more heat in the building itself. This can be used to smooth out demand from heating systems or allow heating demand to follow variations in generation, known as 'pre-heating'. Hot water tanks and phase change-based materials can also provide thermal storage.[170] Analysis by Imperial College London suggests that current new build standards, alongside deployment of household level energy efficiency measures in existing homes consistent with the Committee's scenarios for 2050, provide significant pre-heating potential. Imperial's analysis assumes 100% of the heating demand for new houses to be flexible and available for pre-heating, and 50% of post-1952 buildings to be capable of shifting their heating demands via preheating or thermal storage for up to 4 hours away from peak periods. The scale of pre-heating which actually takes place will also be a function of other factors such as price signals and the installation of smart control systems.
- **Batteries.** Whilst fabric efficiency and thermal storage can enable shifting of heat demands, batteries can enable peak management for all demands associated with electricity use. Currie & Brown and Aecom's modelling of tighter new build standards found the current costs of a 2kW battery to be in the region of £2,000 per home, reducing to £1,600 by 2020.[171]
- **Smart meters and smart appliances.** The Government has a manifesto commitment to ensure that every home and business in the country is offered a smart meter (Chapter 1). Smart meters create a platform for more cost-reflective energy pricing, and a medium through which smart appliances can communicate. In October 2018 Government also announced the steps it will be taking to set regulatory requirements for smart appliances. These measures will act as enablers for smart control of heating and appliances.
- **Smart charging of electric vehicles.** 'Smart charging' functionality in EV charging points (e.g. where charging is timed to take advantage of off-peak periods, or where the power of a charge is altered to help balance the frequency of the electricity grid), is important to help manage the system impacts of EV electricity demand. There is also potential for EVs to facilitate wider demand flexibility in homes, for instance by storing excess household power in the EV battery for use during high electricity grid demand. Regulatory changes are underway to facilitate smart charging for electric vehicles.

Recent modelling by Imperial College London finds that more cost-effective methods for balancing the grid, such as demand-side response (e.g. shifting demand for electric heating via thermal storage in domestic premises or electric vehicle charging) are likely to play a greater role

[170] In their 2019 research *The costs and benefits of tighter standard for new buildings*, Currie & Brown and Aecom found the costs of a hot water cylinder, suitable for shifting >90% of heating load to off-peak ranged from £2,000 for a small flat up to £4,500 for a detached house.
[171] Assumes a Lithium Ion battery at c. 10-15kg per kWh.

in providing electricity system flexibility than methods such as battery storage or electrolysis. This illustrates the central role homes can play in providing flexibility.

In 2017 BEIS and Ofgem jointly launched the Smart Systems and Flexibility Plan, which committed to a series of actions necessary to remove barriers to smart technologies, enable smart homes and businesses, and facilitate markets for flexibility. A progress update was published in October 2018. Regulatory changes are underway that involve smart meter data sharing, half-hourly settlement and smart charging standards for electric vehicles. These should promote opportunities for consumers to provide electricity system flexibility services, whilst providing adequate protection for consumers on levels of service and participation, cost and data privacy.

The Government has also committed to giving consumers more control over how they use energy through smart technologies, as part of its Grand Challenge Mission to halve the energy use of new buildings by 2030.

If all new homes between now and 2050 are built to current standards with air source heat pumps, the associated energy demand is estimated to add up to 16 GW to peak demand,[172] with an increase in total annual demand of 43 TWh.[173] On this basis there is value in minimising the impact of new buildings on peak and annual demand, and of maximising the role these new homes could play in providing flexibility to the system. There are a range of measures that are available to developers to design into new homes (including hot water efficiency measures, thermal stores and batteries), which the new build standards framework could play a role in incentivising.

Recommendation: BEIS, Ofgem and National Grid should implement the remaining actions set out in the Smart Systems and Flexibility Plan, alongside the continuation of wider improvements that are already underway. Actions include encouraging suppliers to offer smart tariffs and capitalising on EV potential to provide demand-side response and storage services.

(Owner: BEIS, Ofgem, National Grid. Timing: actions implemented by 2022).

Recommendation: Examine the potential role for new build standards in encouraging deployment of technologies to support peak management and demand reduction.

(Owner: MHCLG, BEIS, devolved administrations. Timing: by 2020).

2.6 Water efficiency

One of the major risks identified for the UK from climate change is reduced water availability.

The UK Climate Change Risk Assessment sets out the risks to people from changes in water availability. Higher temperatures are likely to drive up the demand for water (alongside population growth). Water shortages are projected to become an increasing problem in London and the South East of England, as well as the Yorkshire, Humber and East Anglia regions.

[172] Figures represent a broad estimate based on National Grid data on current residential peak demand drawn from National Grid's Future Energy Scenarios for 2017 and on recent modelling undertaken by Robert Sansom.
[173] This reflects energy demand associated with space heating, hot water demand, pumps and fans, lighting, appliances and cooking, based on Currie & Brown estimates and CCC modelling, assuming no improvements in heat pump efficiency over time.

However, the CCRA found that deficits are also projected in other parts of the UK as well including areas of south Wales and the central belt of Scotland.[174]

As well as substantial impacts on the natural environment, the impacts from increased supply-demand deficits could include higher water bills, and more frequent use of measures to restrict consumption (Temporary Use Bans, Non-Essential Use Bans and potentially more extreme measures such as standpipes or rota cuts). The National Infrastructure Commission (NIC) assessed that in the event of a drought it is more likely that emergency action, including tankering water across the country and removing more water from the environment than would otherwise be allowed, would be taken rather than cutting off supplies to homes and businesses. The NIC have estimated that the cost of maintaining current levels of resilience and relying on emergency action for more severe droughts to 2050 was between £25 and £40 billion, not including further impacts on the environment and public health.[175]

Whilst the water industry and its regulators are rigorously planning for resilient water supplies, additional action is needed to manage the risk and impact of future water supply-demand deficits.

Projected supply-demand deficits could be substantially reduced if leakage and household consumption were reduced as set out in current Water Resource Management Plans. However the CCRA found that this is still not sufficient in the longer term. Substantial additional action will be required to mitigate supply deficits in all water resource zones, in particular under a high climate change and population growth scenario by the 2080s.

Household water consumption per person in England and Wales has declined from 155 litres per person per day (l/p/d) in 2003/04 to 141 l/p/d in 2017/18.[176] The latest figures for Northern Ireland and Scotland are 152 and 153 l/p/d respectively. These are estimated to be higher than in many other European countries.[177] A study for the Environment Agency concluded that a strong national focus on water efficiency combined with metering and economic instruments, was responsible for the differences in per capita consumption of the countries reviewed. [178]

The CCRA found that a package of adaptation measures, including per capita consumption of 92/l/p/d by 2050 could significantly, but not fully alleviate projected future supply-demand deficits under a high climate change scenario.

Updated research for the Committee has identified a number of low-regret adaptation options to improve the water efficiency of both existing and new homes.[179] Measures not only reduce household water consumption but also save energy and carbon emissions and reduce water and energy bills.

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[174] CCC (2016) *Climate change risk assessment evidence report.*
[175] NIC (2018) *Preparing for a drier future.*
[176] Defra (2018) *Water conservation report.*
[177] These comparisons are not straightforward as the ways in which other countries collect and analyse data on household water use varies and therefore estimates must be treated with a large degree of caution. Some of the more consistent estimates across different evidence sources are for current per capita consumption in Germany, which tend to be around 120 l/p/d, while estimates for Belgium over the last 15 years fall between 85 and 110 l/p/d. A recent cross-country analysis using data for 2009 to 2011 placed England and Wales 16th of the 24 European countries in the analysis. While not included in the study, the estimates we have for per capita consumption in Northern Ireland and Scotland would place them roughly just below England and Wales in this ranking.
[178] Aquaterra for the Environment Agency (2008) *International comparisons of domestic per capita consumption.*
[179] Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*

These improvements can be achieved at a much lower cost at the time when products need replacing or at the new build stage than what is incurred when retrofitting buildings.

For existing homes:

- Analysis for south east England shows that there are a number of upgrade measures including low-flow taps, click lock kitchen taps, dual-flush WCs and low-flow showers that could be installed at zero additional cost to homes over the lifetime of the equipment.
- In the case of discretionary retrofits, installation of a low flow shower was shown to be the only low-regret measure and only when considered from a householder perspective. When including energy and carbon savings installation of low-flow taps also becomes a low-regret adaptation measure.
- For these measures, and others such as water efficient dishwasher and washing machines, savings to householders through lower water bills, outweigh any additional costs associated with fitting the water-efficient measures (Figure 2.3).
- The research did not include fixing leaks found in private pipes running from public pipes to people's homes, and this is an area that requires further investigation.

There are strong links between water and energy efficiency which could be maximised through upgrades and retrofit, especially by local authorities and housing associations as there is an opportunity to procure water efficient devices to help reduce water and fuel poverty (Box 2.10).

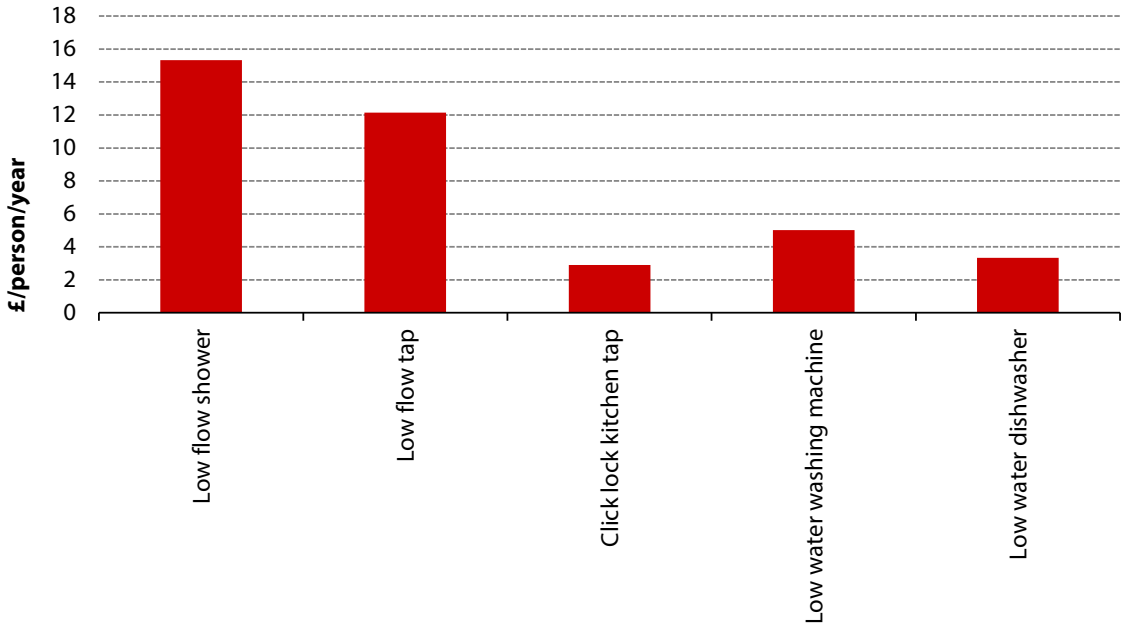
Recommendation: Local authorities should include water efficiency measures in energy efficient retrofit programmes. Water efficiency should be included in social housing standards (such as the Decent Homes and Welsh Housing Quality Standard).

(Owner: Local authorities. Timing: Ongoing.)

For new builds, research for the south east shows that a water efficiency standard of 105 litres per person per day by the 2030s is cost-effective and could be achieved at a small additional build cost.[180,181] This assessment of cost benefit analysis for water stress measures represents a conservative view on anticipated benefits due to the use of current Long Run Marginal Costs, which could be higher in future. As the identified replacement measures and new build package can be installed at zero or low additional costs in the south east, it suggests that these same adaptation measures will be low-regret across all other water stressed regions.

[180] Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*
[181] Under a best case scenario (assuming low costs and high benefits). One-off cost estimated to be £281. A new build package of 110 l/p/d would be zero additional cost.

Figure 2.3. Estimated energy bill savings from reduced water use



Source: Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*

Box 2.10. Water and energy efficiency

Local authorities and housing associations regularly run retrofit programmes (fixing and amending water-using fittings in homes) and there is an opportunity to procure water efficient devices to help reduce water and fuel poverty.

- Waterwise research (for the Greater London Authority) revealed that 80% of social housing in London has baths but not showers – this is in part because much of the stock was constructed before showers were considered a standard fitting, and in part because social housing standards such as Decent Homes do not require consideration of water efficiency. This is significant as an average bath uses 80 litres of hot water compared with 32 litres for a 4-minute shower with a water efficient shower head.
- Hot water demand accounts for 40% of energy used for a 'Part L' semi-detached house. Research to support changes to the devolved administration's Building Regulations showed that bill savings of up to £48 per year, increasing to £180 with behaviour change, are possible if water and efficiency standards are tightened.

Research to support the Welsh Housing Quality Standard estimated that if every social housing property in Wales had water-efficient taps and a retrofitted toilet and shower, combined energy and water bills could be reduced by £3.5 million a year. Similar guidance could be developed for the Scottish Housing Quality Standard or the Decent Homes Standard in Northern Ireland.

Source: Waterwise (2017) *Waterwise efficiency strategy for the UK*; BEIS (2018) *2017 domestic energy use UK*; Burton (2013) *Integrating water efficiency into energy programmes – a case study from policy to implementation*; Waterwise (2017) *Waterwise efficiency strategy for the UK.*

Ambitious reductions in per capita consumption are possible and beneficial.

Defra is committed to putting out a call for evidence on a per capita consumption target in 2019 to support the commitment for a target in the 25 Year Environment Plan. The target will be a national, non-binding target that can be used to judge the effectiveness of Government actions and those of the water industry in reducing water use.

The research results presented above are consistent with other studies. Box 2.12 summarises some of the recent reports that have considered consumption targets for existing and new homes.

Box 2.11. Water efficiency studies

There have been a number of studies to assess what level of consumption per person is possible technologically and cost-effectively:

- NIC sets out an aim for water efficiency to provide 34% of the recommended level of resilience. The NIC found that it is possible to reduce consumption to 118 l/p/d by 2050 through metering alone – assuming meters are rolled out everywhere by 2030. This level is in line with work also done by Water UK.
- Waterwise recommend a more ambitious target of 100 l/p/d or less for all England and Wales water companies by 2045. Southern Water has already set a target of 100 l/p/d across its region by 2040.
- A recent study by Ofwat shows that average household consumption of 50-70 l/p/d in 50 years is possible technologically, although the study did not consider costs.
- The Code for Sustainable Homes found that it would be possible for new build homes to get down to 80 l/p/d through efficiency measures only (including using just over 28 l/p/d of recycled water). Applying this to existing homes and excluding water recycling due to costs of retrofit (as it would require a separate plumbing system), it could be possible to retrofit homes to around 110 l/p/d by replacing appliances at their natural end of life:
    - Most appliances would reach the end of their useful life before 2050 so would be replaced anyway, providing an opportunity for home owners and landlords to purchase new water efficient products.

A per capita consumption target and compulsory product labelling could help to drive demand and reduce costs for water efficient appliances.

Source: National Infrastructure Commission (2018) *Preparing for a drier future: England's water infrastructure needs*; See: https://www.waterwise.org.uk/southern-water-target-100/; Ofwat (2018) *Deep reductions on household water demand*; Defra (2008) *Future Water*.

In order to meet a per capita consumption target there is a need for reduction in household usage. This should be driven in part by improving building standards and an increase in water metering. Behaviour change also plays a role in reducing consumption with a need for better incentives and information, such as compulsory water labelling of products to drive change.

Reducing per capita consumption will require improvements in the way households use water and further action by water companies, beyond current levels of ambition:[182]

- Changes in lifestyles, occupancy and technology will create opportunities to improve the way households use water and are important contextual factors for long-term demand management. Examples include changing per person demand (e.g. as individuals use showers instead of baths, or purchase more water-efficient washing machines) and changing living practices (e.g. water use is lower in multiple occupancy homes because of economies of scale in use of washing machines, cooking and dish-washing).
- The water industry has a critical role to play. Water companies will need to be more ambitious and take action to go further in managing demand and in improving water efficiency. They will need to work with households to help improve water efficiency and waste less water.

Defra should consider the following as part of its 2019 per capita consumption target consultation:

- New build homes provide the opportunity to be ambitious at much lower cost. Current **new build regulation standards** (Part G) should be strengthened to allow local authorities, especially those in current or future water stressed areas, to be more ambitious in order to drive reductions and help meet a per capita consumption target.
  - The current water efficiency standard in Building Regulations in England is 125 litres per person per day (l/p/d), or an optional 110 l/p/d for water companies in current water stressed areas.
  - Existing homes built to a Part G Building Regulations standard of 125 l/p/d could be using more than this in practice. There is evidence that homes in London built to 105 l/p/d under the Code for Sustainable Homes shows a range of between 110 l/p/d and 140 l/p/d depending on occupancy.[183] More work is needed to understand and address the reasons for this (see Section 4.2 on the performance gap of homes).
  - In Wales regulations are somewhat tighter and require that the estimated consumption water in all new homes should not be more than 110 l/p/d (calculated in accordance with the 'water efficiency calculator for new dwellings').
  - Requiring all homes in England to be built to 110 l/p/d is possible under Part G of regulations and would be no additional cost. However, in order to help alleviate future supply-demand deficits much tighter standards are required.
  - Further savings could be achieved in England with a 'fittings based approach' as modelled for Wales and Scotland where potential water, energy and bill savings of greater water efficiency are modelled in building regulations.[184] Measures required for much tighter standards, such as rainwater harvesting and water re-use are available, more work is needed to understand the current costs and benefits of these measures.
- **Reducing leakage** in household pipes and appliances. For example, one study has identified leakage (such as drips from pipes or cisterns) occurs in approximately 4% of WCs in the UK.

[182] As recommended by the NIC it will also be necessary, alongside reductions in per capita consumption, for water companies to reduce leakage from pipes and increase supply-side measures such as building new infrastructure and developing ways of transferring water from areas of surplus to areas of deficit
[183] Waterwise (2018) *Advice on water efficiency new homes for England.*
[184] Waterwise (2018) *Advice on water efficiency new homes for England.*

Average leakage rates of 72 litres per WC per day were derived, with new properties (post-2000) most likely to have leaks. The overall contribution of WC leakage to average per capita consumption is between 1.7% and 4.6%.[185]

- Standard **waters meters** can reduce average consumption by 15% and smart meters by 17%, whilst helping customers and water companies to **identify leakage**.
  - At present, water companies in England can only impose mandatory metering in water stressed areas. The Committee agree with the recommendation made by the NIC in 2018 that compulsory metering should be allowed by all water companies, not just those currently in water stressed areas.
  - Defra should enable companies to implement compulsory metering beyond water stressed areas, by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters as a first step in a concerted campaign to improve water efficiency.
- Innovative water products are being developed all the time, but customers are not always aware of them.[186] An **effective water labelling scheme** is essential for transforming the market so customers can be aware of and buy water-efficient products. Manufacturers in the UK make voluntary use of the European Water Label, but uptake is still relatively low:
  - Labelling can help to reduce water via building regulations for new builds, encourage behaviour change and increase use of water-efficient products in water company incentive and retrofit programmes.
  - Waterwise reported that many UK water companies are keen to see a mandatory label, as has been the case with the energy label now widely recognised at point of sale.[187]
  - Research by the Energy Saving Trust for the Waterwise Water Efficiency Strategy for the UK has identified that mandatory water efficiency labelling could save around 30 litres per person per day by 2050.[188]
  - A more efficient appliance may initially be marginally more expensive to purchase. However as the technology for these is well-tested marginal costs may drop quickly as appliance market increases.
- **Household behaviour** can have a significant impact on water demand. For example, if every household in the UK took one minute off a shower every day, it would save £215 million on collective energy bills a year. If everyone in a four-person metered household with a power shower did this, it could save the household £60 on energy bills and a further £60 on water bills every year.[189] Water companies can also run awareness and educational campaigns:
  - Examples include water companies informing people of the water saving efforts of their neighbours to nudge further water saving behaviour and use of experimental trials of information provision.
  - Partnership retrofitting (for example between local authorities and water companies) and behaviour change programmes tend to show greater uptake, greater engagement and

[185] Ricardo Energy & Environment (2015) *Leaky Loos Phase II.*
[186] Examples include smart point of use water management devices, smart rainwater butts, air flush toilets, ultra-low-flow products and improved customer engagement displays and devices.
[187] Waterwise (2017) *Water Efficiency Strategy for the UK.*
[188] https://www.waterwise.org.uk/resource/water-efficiency-strategy-for-the-uk-year-1-full-report/
[189] http://www.energysavingtrust.org.uk/sites/default/files/reports/AtHomewithWater%287%29.pdf

greater water, carbon and financial savings, and to be more innovative than solo approaches.

- There is a role for social enterprises, cooperatives and community organisations to work together with governments and the water sector to deliver water efficiency.
- The establishment of partnerships and trusts for resource efficiency could also deliver social and economic benefit to local communities.
- As delivery is scaled up there may be a skills and capacity gap – a partnership approach between the water companies, plumbers and builders to identify gaps could help with long-term delivery. Waterwise have been delivering water efficiency training to water company staff, plumbers and energy retrofit staff across the UK to help improve skills.[190]

Recommendation: Defra should set a per capita consumption target which can address future supply-demand deficits resulting from both 2 and 4 degree climate change scenarios. Further research should be undertaken to understand the costs and benefits of targets between 50 and 100 litres per day by 2050. The devolved administrations should consider whether it is necessary to introduce similar targets. As a first step to meeting a target and improving water efficiency in homes, the UK Government and devolved administrations should:

- Enable water companies to implement compulsory metering beyond water stressed areas by amending regulations before the end of 2019 and requiring all companies to consider systematic roll out of smart meters.
- Review new build regulation standards to allow local authorities to set more ambitious standards, especially in current and future water-stressed areas.
- Introduce compulsory water efficiency labelling of household water products.
- Work with water companies and local authorities to run partnership retrofit and behaviour change programmes in existing homes.

(Owner: Defra. Timing: by 2021).

[190] Discussion with Waterwise (2019).

Chapter 3: Climate-resilient neighbourhoods and sustainable transport

Key messages

How homes are used and how the areas around them are utilised is key to addressing climate change. There are 1.8 million people living in areas of significant flood risk, and this could grow to 3.5 million by the 2080s. Cost-effective measures to reduce the impacts of flooding through property-level protection are not being taken up. Greenspace can act to help mitigate flood risk as well as provide cooling and a host of other benefits, but the proportion of urban greenspace in England is declining rather than increasing, and trends in the devolved administrations are not known. Many new developments are also designed only for travel by car, with limited or no access to public transport.

The following measures are required:

- **Property-level flood protection**. The planned rate of uptake in England, at 500 properties per year, is currently five times lower than it should be to ensure homes that are not cost-effective to protect through community flood defences are protected at the property-level. There is a need for a long-term strategy to increase the uptake of property resilience and resistance measures. Householders must have the incentive to take action so that when Flood Re is withdrawn in 2039, properties can remain insurable. Government, industry and the insurance companies all play a key role in achieving this. A new Code of Practice should help to improve skills, compliance and enforcement of installing measures. The UK Government should consider the introduction of Flood Protection Certificates and examine the potential for building standards or other regulations.
- **Green infrastructure and sustainable drainage.** Sustainable Drainage Systems (SuDS) are starting to be more widely installed, but there is evidence to suggest it is not yet common place for these to be 'green' systems that have a host of benefits. To help with this the Planning Guidance and Defra's non-statutory standards for SuDS should be updated to encourage multi-functional SuDS with clear policy on who should maintain and adopt SuDS by default. The automatic right to connect new development to the existing sewage network should be made conditional on national SuDS standards being met or by water company agreement. The Government should also consider the need of a national retrofit strategy and approach to help guide local authorities when creating local plans, and introduce targets for increasing the amount of greenspace in urban areas.
- **Sustainable transport.** Given new evidence that many recently constructed housing developments are encouraging car-dependent lifestyles, the planning process must change to increase the importance of sustainable travel, including walking, cycling, and the use of public transport and electric vehicles. The need to encourage a shift to lower emission, healthier and more inclusive modes of travel should be a primary consideration from the beginning of the process, including the choice of location, housing layout, housing densities and accompanying infrastructure, such as public transport hubs and cycle paths. Local authorities must consider where best to locate new homes to minimise the need to travel to work and amenities such as shops and schools.

3.1 Purpose of this chapter

This chapter sets out how UK homes and neighbourhoods can be well-adapted to flood risk, and how the spaces around our homes can help contribute to long-term emission reductions and resilience to climate change.

Where possible the chapter considers the costs and benefits of these measures and identifies those which are low-regret. Our analysis looks at property level flood resilience and resistance, green infrastructure, and sustainable transport.

3.2 Property level flood resilience and resistance

There are an increasing number of homes expected to be at high flood risk in the coming decades, not all of which will be possible to protect with community defences.

The CCRA found that an estimated 1.8 million people are living in areas of the UK at significant (1% annual chance) risk of river, surface water or coastal flooding. The population living in such areas is projected to rise to 2.5 million by the 2080s under a 2C scenario and 3.5 million under a 4C scenario.[191]

The Environment Agency's Long Term Investment Scenarios show that it will not be cost-effective to build community flood alleviation schemes to protect all of these properties. Making properties more resilient and resistant to flooding can be a cost-effective way to manage flood risk when community-scale defences are not affordable, and can also help to reduce residual risk if defences fail.

In general, it is recognised that the most effective measure to speed up property reinstatement after a flood is to reduce the likelihood of water entering a property and to use property-level resilience measures, such as water-resilient fittings and materials wherever feasible. Property level flood resilience and resistance (PFR) can be defined as:[192,193,194]

- Flood resilience measures - which aim to minimise impact of flooding and facilitate repair, drying & cleaning and subsequent reoccupation. They can be implemented incrementally;
- Flood resistance measures - which aim to prevent water entering the building and damaging it in the first place. For a shallow flooding event, smaller properties can be protected for as little as £800,[195] while recovering from a flood without resistance measures could cost on average as much as £45,000.[196]

The greatest benefit of resistance and resilience measures will be felt by households that are at highest risk of flooding.

However, particularly for low-cost measures many other households could benefit (for example properties which are not currently at risk but projected to be in the future).

Updated research for the Committee has identified a number of low-regret adaptation options to protect both existing and new homes from flood damage in the Aire catchment in Yorkshire and Humber.[197] The assessment evaluated the costs of measures against the benefit of avoiding flooding or minimising impacts. It was then expanded to also include avoided costs of evacuation and mental health benefits as a dedicated sensitivity scenario (Box 3.1).It is difficult to generalise the results and to say with certainty if these measures are cost-effective beyond the Aire catchment. Climate risks are context-specific, especially flooding where the risk and severity of the impact depend upon where a property is located.

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[191] Sayers et al. (2015) *Climate Change Risk Assessment 2017: Projections of future flood risk in the UK.* Assuming no population growth and continuing current levels of adaptation.
[192] See: http://www.aviva.co.uk/home/home-advice/extreme-weather-advice/article/getting-back-normal-after-flood/
[193] ABI. *A guide to resistant and resilient repair after a flood.*
[194] NFF (2014) *Ready for flooding –Before, during and after.*
[195] Wood PLC et al. (2019) Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.
[196] See: https://www.building.co.uk/news/average-cost-of-repairing-flood-hit-home-as-high-as-30k/5067762.article
[197] Wood PLC et al. (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector*.

However, the assessment provides an indication of potential low-regret measures. Other projects, such as a flood demonstration project in Carlisle, have been used to showcase how resilience products can be installed.[198]

Box 3.1. Cost-effective adaptation measures for property-level flood protection

Updated research for the CCC presented the costs and benefits of a range of adaptation measures:

- The installation of a **flood resistance package** was found to be 'low-regret' (cost-effective and easily installed) in all types of residential dwellings and all stages, including new build, repair and discretionary retrofit, when potential flooding is greater than 1% Annual Exceedance Probability (AEP). These measures include airbrick covers, door-guards, repointing external walls up to a height of one metre, main sewer non-return vales, drainage bungs and toilet pan seals:
  - While it is less costly for households to install measures as part of a repair following a flood, the benefits are less as they would have failed to avoid the damages of the flood. If these options are fitted as a discretionary retrofit measure before flooding occurs, rather than as part of the repair work (e.g. after a flood), they save more damages from flooding.
  - There are some properties, where although it is cost-effective to implement resistance measures, they may be unsuitable (for example in older houses where measures will never be fully effective).
- In new builds the research found a number of zero cost **flood resilience measures** that can be incorporated at the new build stage for properties at greater than 1% AEP flood risk. These include installing a chemical damp-proof course, moving the washing machine to the first floor, raising the service meters, wall-mounting the boiler and raising the oven. Installation of a new floor with treated timber joists during discretionary retrofits is the only measure which is cost-effective for existing homes.

Overall, the inclusion of wider benefits associated with reduced evacuation costs and intangible human health impacts has produced an expanded list of low-regret adaptation measures compared with previous analysis done for the CCC in 2011. Additional measures include:

- Installation of dense screed in new build properties and on repair.
- Moving washing machine and oven above flood level on repair in the case of deep floods.

The period of evacuation time is strongly associated with health impacts. A Flood Re and UWE report suggests that stress and mental health issues are related to length of evacuation. Therefore, implementation of flood resilience and resistance measures can help in reducing time for repair and recovery after flooding and positively affect mental health.[199]

- Flood resistance measures in general are assumed to result in zero displacement.
- There are no studies of resilience measures which quantify the increased speed of reoccupation, however anecdotal evidence suggest that successful full-scale resilience adoption allows reoccupation of an affected property within 24 hours.

Source: Wood PLC et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*

[198] See: http://edition.pagesuite-professional.co.uk/html5/reader/production/default.aspx?pubname=&edid=a56b3613-b7cb-4bc7-9141-48e0b04d3712

[199] Flood Re (2018) *Evidence review for property flood resilience phase 2 report.*

Property level measures are being installed in some homes post-flood, however the amount of homes projected to be cost effective for property level measures is increasing faster than the projected uptake.

In England, the Flood Defence Grant in Aid scheme has installed measures in around 4,000 properties up to 2018.[200] Around 6,000 home and business owners also benefitted from a scheme following storms in 2013/14 to help protect their property against future flooding, and a further 17,600 properties were eligible to receive recovery grants in areas impacted by 2015/16 storms. According to Defra, two thirds of those eligible applied for grants, 95% of which were approved.

In Scotland it is estimated that 40,000 properties at risk could potentially benefit from property level protection measures. However, while some of the local authorities offer funded or subsidised scheme and some residents installed products independently with help from the Scottish Flood Forum, the uptake is low.[201]

In our 2017 progress report we found that the commitment in the current six-year investment plan in England would result in around 500 properties being fitted with PFR measures per year between 2015 and 2021. At this rate, PFR would be fitted to around 12,000 properties by 2039, when Flood Re will be withdrawn. More than 217,000 properties would be cost-effective to protect by this time.

Flood Re is developing a strategy to incentivise PFR, however, there are no targets for PFR in properties, nor are there any plans in place for how PFR will be incentivised once Flood Re has been withdrawn.

Flood Re was set up to aid the transition towards risk-reflective pricing by 2039. It is an industry funded re-insurance scheme that aims to make flood insurance available to those who face significant flood risk. Flood Re has been operating for less than 2.5 years and currently subsidises around 150,000 insurance policies:

- In 2018 Flood Re published a report to assess how the scheme might play a more direct role in incentivising households and insurers to implement property-level resilience measures. This concluded that incentivising and rewarding homeowner action will be more effective than penalising a lack of action. Flood Re have committed to undertake further work to understand specifically how communicating messages about PFR could be most effective, including through the fire service, insurers, Government and local flood groups.[202]
- Flood Re's transition plan also stated 'We will use our database of high flood risk properties and work with others to identify where we believe that spending would be the most effective in cutting the cost of flooding to households and insurers.' The plan committed to work with the Government, the devolved administrations, the Environment Agency, local authorities, and the Committee.

[200] Discussion with Defra (2019).
[201] See: https://www.webarchive.org.uk/wayback/archive/20180516031016/http://www.gov.scot/Topics/Environment/Water/Flooding/resources/research/PLP-Evidence
[202] Flood Re (2018) *Incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures*.

- Flood Re now holds data on more than 100,000 households in the UK considered by insurance companies to be at the greatest flood risk. The process of releasing data to inform and help target new policies in high risk areas has not yet begun.

Neither the transition to risk-reflective pricing nor the steps towards removing Flood Re were mentioned in the second National Adaptation Programme (NAP), which outlines the UK Government's adaptation actions for the period 2018 - 2023. The removal of Flood Re in 2039 will be a significant event and the NAP has no targets or actions for managing the transition between now and 2023. Despite this, Defra are leading a number of initiatives to improve the evidence base of PFR and an industry led roundtable is aiming to develop action and policy for property flood level solutions.

In Scotland a Property Flood Resilience Delivery Group (PFRDG) is due to be set up in 2019. The aim of the group will be to mainstream PFR and help property owners take action to make their properties more resilient against the impacts of flooding.[203] The new Scottish Climate Change Adaptation Plan is also due for publication later in 2019. It is expected that this will make reference to actions to incentivise greater uptake of PFR measures.

Many insurers do not allow improvements to be made when flooded properties are reinstated, even if paid for by policy holders.

As part of the support information for a recovery scheme following the 2015/6 floods in 2016, the Government published a handbook to help practitioners both select and give better advice to households on low cost flood resilient measures.[204]

Insurance brokers who were interviewed in a Biba study included within the Property Flood Resilience Action Plan (Bonfield Plan) found that: [205]

- Internal resilience measures were seen in a positive light by just under half. However, installing them was not a common occurrence.
- Insurers do not recognise any standards for resilience measures.
- One-third of the brokers said they would not pay insurance claims if spent on flood resilient or resistant repairs, even if they were cost-neutral.
- Over half of the brokers said that they would not allow for improvements to be made to a flooded property if they required additional cost, even if this cost were met by the policy holder.
- The same survey also suggested that fitting resilience and resistance measures does not generally lead to lower insurance premiums.

Other barriers to wider uptake of PFR include lack of specialist installers and compliance and verification of installed measures. Property owners also lack motivation and information in order to implement risk reducing measures.

Evidence from a Social Market Foundation report (commissioned by Flood Re) and existing schemes suggest that important barriers to growth in uptake include a number of factors:[206,207]

[203] Flood Resilience Properties Advisory Group (2018) *Framework for delivery property flood resilience in Scotland*.
[204] Defra (2016) *Practitioners' Handbook for low cost repairable or resilient reinstatement for surveyors and local authorities*.
[205] Defra (2016) *The property flood resilience action plan.*
[206] Social Market Foundation (2018) *Incentivising household action on flooding.*
[207] BRE, *A Future Flood Resilient Built Environment.*

- **Lack of motivation:** Subsidised insurance schemes like Flood Re have largely removed the financial incentives for high risk households to take action to prevent flooding. Households need to be motivated to act. This means householders recognising that they are at risk of flooding (either now or in the future) and taking responsibility for protecting their property.
- **Lack of familiarity and access to information**: Households need to access information about various products on the market, and then be able to assess cost and benefits.
- **Costs and behavioural biases to taking action:** Some measures, in particular resilience or (recoverable) measures can be expensive. There are also some behavioural biases that could restrict the likelihood of action. For example owners could be reluctant to implement risk reducing measures which they perceive to demonstrate to the wider public (and potential home-buyers) that their properties are at risk, and equally buyers may be put off by resilience measures which make a property appear to be flood prone.
- **Lack of professional skills and knowledge:** There is a lack of specialist capacity amongst installers and surveyors, alongside a lack of independent verification of this capacity to build consumer confidence. Surveyors also have an important part to play in assurance to insurers that measures have been property installed.

Planning rules for new homes do not include provisions for PFR.

New homes built after 1st January 2009 are excluded from Flood Re. This ought to incentivise the location of new development away from flood risk areas and/or the installation of PFR, so that homes are insurable at reasonable cost.

The Building Research Establishment (BRE) conducted a survey for the Adaptation Committee of building professionals including architects, developers and consultants.[208] They found that the application of flood resilience measures in building design and construction was limited.

A report by the Royal Institute of British Architects (RIBA) found that statutory guidance, building standards and approved construction techniques for new flood resilience properties are lacking.[209]

Uptake of property level flood protection measures needs to be significantly increased. This can be achieved by providing homeowners with better information on costs and benefits of measures. The insurance industry must be fully engaged in property level protection. Resilience surveys and Flood Protection Certificates should be introduced.

The Committee's 2017 progress report and a report by the Social Market Foundation highlighted a number of ways to incentivise uptake from householders and insurance:[210]

- **Increasing understanding of risk and help available:** For example through pilot studies of how flood risk can be best communicated. A survey among 531 people living in areas at flood risk found that most were not aware of Government schemes (such as £5,000 grants for homes and businesses flooded in 2013 floods) to protect their properties, and few had taken up any scheme.[211]
- **Increasing ownership of the issue:** It is important that the approach to managing flood risk at a property level becomes normal practice so that homeowners and landlords can take a

[208] BRE (2017) for the CCC. *Resilience of new developments to high temperatures and flooding.*
[209] RIBA (2018) *The value of flood resilient architectural design*.
[210] Social Market Foundation (2018) *Incentivising household action on flooding.*
[211] Ipsos Mori (2015) for Defra. *Affordability and Availability of Flood Insurance.*

more precautionary approach, especially when refreshing or upgrading their property. Flood Re have suggested that at risk households could have a resilience survey that results in the issue of a Flood Performance Certificate. Working with surveyors and estate agents, this could then be available when properties are sold, rented or built.[212] BRE have developed a Property Flood Resilience database (PFR-d) tool for surveyors of PFR.[213] Surveyors must be independent of product manufacturers or suppliers. To gain access to the tool surveyors' must complete a certification scheme to test competence and independence. Once installers have installed PFR into a property surveyors can calculates a 'PFR-score', similar to an Energy Performance Certificate. If measures are certified and/or tested, the property will achieve a higher 'PFR-score'. The tool could then be used by other bodies (e.g. insurers to make decisions about insurance premiums). There is also potential to expand to wider resilience measures.

- **Increasing understanding of potential options and their benefits** by continuing the sharing of knowledge and best practices locally. For example, the Environment Agency's research and development team have recently started work to assess behaviours and map gaps and issues to PFR uptake. This includes proposing pilots to test methods of increasing uptake.[214] Resilience surveys and improved communication on available finance (e.g. government grants) can support homeowners and landlords in decision making.
- **Finance and reducing costs:** Introducing rigorous independent standards and certification of products should help to drive up skills and increase consumer confidence. This will widen uptake and reduce costs of measures. Alongside this there is a role for government grant schemes to be extended or reformed to include properties at high risk of flooding, for example like the Homeowner Flood Protection Grant Scheme in Northern Ireland. Property Flood Resilience schemes can be advanced by Flood Risk Management Authorities (such as county councils or the Environment Agency) for support through Flood Defence Grant in Aid or the Local Levy. Local Councils also have discretionary powers to fund grants, loans or other payments for home improvements, this can include funding for PFR.[215]
- **Insurance and finance industry playing a key role**: with Flood Re being used to initially target at risk households:
  - Flood Re have found that "building back better" when renovating (either after a flood or at another stage of renovations) would potentially have broad benefits and help to change social attitudes towards the acceptability of flood resilience measures in homes. For example, this could stimulate demand for products, develop trade skills, and encourage innovation in industry.[216]
  - The insurance industry has a role to play in achieving this. Insurance companies should insist on PFR after a flood claim, especially when measures are cost effective and cheaper than other alternatives. In order for them to do this PFR measures should be independently certified and tested.

[212] Flood Re (2018) *Incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures.*
[213] See: https://bregroup.com/expertise/resilience/flood-resilience/resilience-projects-and-publications/
[214] Discussion with Environment Agency (2019).
[215] Discussion with Defra (2019).
[216] Flood Re (2018) *Incentivising household action on flooding and options for using incentives to increase the take up of flood resilience and resistance measures.*

– Lenders should take a stronger role in encouraging PFR, for example through green finance mechanisms such as loans to complete work or linking installation of measures to overall property value.

These measures should increase the number of households voluntarily taking up relevant measures.

Better installation, enforcement and compliance in relation to PFR measures is essential. This can partly be achieved by a Certification Scheme and a new Code of practice due to be introduced in 2019.

Defra have committed in the National Adaption Programme to support the industry-led Property Flood Resilience Roundtable, including supporting an industry-owned voluntary Code of Practice to promote consumer and business confidence in measures to reduce the impact of flooding on buildings, and on those who live and work in them.[217]

There is a need for an independent Certification Scheme for surveyors, supported by training and an open standard for installers. The Code of Practice suggest a single surveyor has overall responsibility for the delivery of PFR measures within a property.

Building regulations and standards must be introduced for PFR in new and existing homes that are at high risk of flooding.

As a first step towards regulating property level protection it is important that the skills and knowledge required to install measures are improved, alongside a better understanding of the effectiveness of measures. Given the scale of the financial, emotional and behavioural/psychological barriers involved in homeowners or landlords installing PFR, it is likely that stronger incentives, including mandatory approaches, may be needed. This is particularly true if the adoption of resilience and resistance measures is to play a significant part in ensuring that, by 2039, a market for household flood insurance exists that is both risk reflective and affordable.[218]

Building regulations (or other standards) can ensure that measures are undertaken on a mandatory basis whilst properties are being reinstated post-flooding and during renovation, and also that (at a minimum) low and negligible cost resistance and resilience measures are rolled out to all new properties. Regulations should be linked to planning policy and guidance.

This would help to support a change in social norms, for example if all new properties were required to have raised electrical points, then it would no longer be seen as a signal of flood risk, rather the 'new norm'.

Recommendation: Defra should develop a long-term strategy to manage flood risks in each part of the country (as first recommended in 2015), so that as Flood Re is withdrawn properties can remain insurable at reasonable costs. This should include:

- Continuing to support the industry round table in communicating risk and possible adaptation actions to households and communities that are expected to remain or become at high flood risk by the 2030s. The Flood Re database should be used to initially target those at risk.
- Pilot schemes to test and increase understanding of potential PFR options and their benefits to homeowners and landlords.

[217] See: https://www.cila.co.uk/cila/download-link/sig-downloads/property/331-2017-pfr-end-of-year-report/file
[218] Social Market Foundation (2018) *Incentivising household action on flooding.*

- The introduction of resilience surveys and Flood Protection Certificates which can be used by homeowners, insurance companies and lenders. The UK Government should work with BRE to further develop and widen the use of the Property Flood Resilience database tool.
- Detail of how the new Code of Practice will ensure skills are improved and better compliance and enforcement of installing measures.
- Plans to work with the insurance industry to ensure they have the evidence needed in order to confidently make informed judgements about which resilience and resistance measures installed in properties lead to reduced risk. Insurers should insist that resilience and resistance measures be implemented during post-flood repairs as a condition of continuing insurance cover.

(Owner: Defra, Environment Agency, Insurance companies. Timing: by 2020).

Recommendation: MHCLG and the devolved governments, should examine the potential for regulations on flood protection approaches for both refurbishment and new builds of homes.

(Owner: Defra, MHCLG, Scottish Government, Welsh Government, Northern Ireland Executive. Timing: by 2021).

3.3 Greenspace and sustainable drainage

Greenspace in residential areas has a significant role to play in climate adaptation, and also provides a host of wider benefits.

Ensuring that housing developments have adequate areas of greenspace is an important adaptation measure for two reasons; reducing flood risk through improving drainage and reducing surface water flood risk, and reducing heat risks by providing shading and reducing the Urban Heat Island effect.

Greenspace is often also referred to as a 'green infrastructure', when it is considered in an urban setting. Examples of green infrastructure include trees, hedges, green roofs, walls, grassed areas, permeable paving, rain gardens, and swales. The latter examples can be used as sustainable drainage systems, as they help to reduce the speed and total flow of rainwater into sewers and thereby reduce the risk of surface water flooding.

Alongside acting as an adaptation measure, green infrastructure can bring a host of wider benefits to people and wildlife:[219]

- Maintaining and improving freshwater quality and supply
- Supporting biodiversity
- Providing amenity value to people
- Health benefits
- Providing spaces for walking and cycling.[220]

[219] Maksimovic, C; Mijic, A; Suter, I; Van Reeuwijk, M (2017) *Blue-green solutions. A systems approach to sustainable, resilient and cost-effective urban development.*

[220] Birmingham is one city that has made extensive use of the ecosystem approach and a range of practical tools to help gain full benefit from a strategic approach to green infrastructure. See: neat.ecosystemsknowledge.net/birmingham2.html

There are examples where full benefits have been calculated at local and city levels across the UK:[221]

- The Natural Capital Account for London's Public Green Space highlight the significant benefit of protecting and investing in London's Green Infrastructure. The account shows London's green spaces provide services valued at £5 billion per year including £950 million per year in avoided health costs.[222]
- A study of 11 UK cities valued the cooling effects of green space over 100 years as around £11 billion, with the total value associated with living green space estimated to be just over £130 billion in the UK.[223]

The proportion of urban area that is made up of greenspace is declining in England.

The total proportion of urban greenspace in England declined between 2001 and 2018 from 63% to 55% of urban area. Though there had been no change between 2011 and 2016, the area declined by a further 1% between 2016 and 2018.[224] Statistics are not available for the devolved administrations; monitoring of urban greenspace would be a useful action to include in their future national adaptation programmes.

As well as concerns over the decline in amount of urban greenspace, access to green space is not equal across the population. People living in the most deprived areas are less likely to live in the greenest areas, and will therefore have less opportunities to gain the health benefits of greenspace compared with people living in less deprived areas.[225]

Sustainable Drainage Systems are starting to be more widely installed in new developments in England, but it is unclear how far 'green' SuDS with multiple benefits are being favoured over 'grey' SuDS.

SuDs can be classified as 'grey' (for example underground pipes or tanks), or 'green' (for example green space, swales, green roofs). Grey SuDS do not have the same multiple benefits as green SuDS and are not adaptable to a changing climate, and so priority to green SuDS should be given wherever possible. This does not appear to be happening at present, at least in England, and new developments are adding pressure to existing drainage networks:

- A survey by CIWEM found little confidence among practitioners that green SuDS are being built in the majority of major new developments. For example, around 30% of the 500 respondents said that SuDS (of any type) are not used in all major developments, as current guidance requires, and a further 28% did not know whether this was the case.[226] In many cases the SuDS being built were below-ground retention systems.
- MHCLG's review of planning policy and its application of SuDS in 2018 found that 87% of a sample of approved planning applications in England explicitly featured SuDS. The review also found that most local plans contained policies, in line with national requirements that

[221] Elements of landscaping, including green infrastructure, can be costed through reference to Spon's. Spon's (2018) *External Works and Landscape Price Book, 2018.*
[222] Greater London Authority (2017) *Natural capital accounts for public green space in London.*
[223] Eftec for ONS (2018) *UK natural capital: ecosystem accounts for urban areas.* The 11 city regions included in the analysis are: Cardiff, Edinburgh, Glasgow, Greater Manchester, Liverpool, London, Sheffield and the city regions of the North East, West Midlands, West of England and West Yorkshire.
[224] ADAS (2019) for the CCC. *Research to provide updated indicators of climate change risk and adaptation action in England.*
[225] PHE (2014) *Local action on health inequalities: Improving access to green spaces.*
[226] CIWEM (2016) *A place for SuDS?*

SuDS should be prioritised in areas at risk of flooding, with about 83% of plans stating that they should be provided in all major new developments.[227] However, it made no distinction whether the SuDS being installed were green or grey.

The barriers to uptake of SuDS in England, including green SuDS, are well known:

- **There is a lack of compulsory, enforceable national standards for SuDS required in new or existing developments:**
  - Different national and local organisational structures is a challenge to the delivery of successful SuDS.[228]
  - Non-statutory Technical Standards for SuDS only apply to developments of 10 or more houses, do not promote the benefits of green SuDS, and fail to provide clear guidance on responsibilities for adoption and maintenance of SuDS.
  - The Landscape Institute surveyed Lead Local Flood Authorities and found that those responsible for SuDS feel it is difficult to challenge 'grey' SuDS as they can't refuse them if they store a sufficient quantity of water. Refusal of permission for a grey SuDS scheme is unlikely to be supported by an inspector at appeal or inquiry due to the Non-Statutory Technical Standards only requiring water quantity to be addressed, which is easier to measure for a grey than a green SuDS scheme.[229]
- **There is confusion over adoption and maintenance:**
  - CIWEM's survey found that the greatest barrier to SuDS delivery was the lack of a single adopting body or clear route for adoption of SuDS in new developments and responsibilities around maintenance. Of the responders, 60% identified responsibilities for maintenance and adoption not being clearly defined as a significant barrier to the delivery of SuDS in new development.
  - A third of local planning authority respondents to the SuDS review were unsure of the extent to which SuDS were adopted as agreed. A reactive approach was taken by most, checking only following complaints or issues raised by third parties.
- **Knowledge and awareness gaps exist:**
  - The design standards of SuDS can vary locally, thus their overall impact in managing flood risk and making new developments adaptable to climate change is not known.
  - There is a lack of general knowledge on how to adequately manage and maintain SuDS with only 8% of responders to CIWEM's survey considering current guidance effective at driving installation of high quality and effective SuDS.[230,231] These factors are likely to result in green SuDS not being proposed due to the perceived impact on the viability of a development.[232]
  - The SuDS review found that 40% of Lead Local Flood Authorities (LLFAs) in England suggested that their time, expertise and resources were under pressure with regards to

[227] MHCLG (2018) *A review of the application and effectiveness of planning policy for Sustainable Drainage Systems (SuDS*).
[228] E.g. in CIWEM's report*, A Place for SuDS,* 2017.
[229] Landscape Institute (2018) *Achieving sustainable drainage.*
[230] Peter Melville-Shreeve, Ana Arahuetes, Sarah Cotterill, Raziyeh Farmani, Virginia Stovin, Laura Grant and David Butler (in press) *State of SuDS Delivery in the UK*. Water and Environment Journal.
[231] Defra (2018) *A review of the application and effectiveness of planning policy for sustainable drainage systems.*
[232] CIWEM (2016) *A place for SuDS?*

assessing planning applications. Once completed Local Planning Authorities (LPAs) had no specific checking regimes in place to ensure that SuDS had been constructed as agreed due to a lack of resources.

  - Whether and how SuDS are retrofitted into existing developments is not widely monitored. If the risk of surface water flooding is being managed through building and upsizing of traditional systems such as sewers and underground storage, unsustainable solutions are perpetuated as they are not adaptable to a changing climate.

- **Difficult to quantify benefits:**
  - The full benefits of green infrastructure are often not accounted for in housing developments. Those that are put in at the beginning of a design project are often 'value engineered' out to bring down costs, use the space to deliver a larger number of new homes or areas of green space in existing developments being built on. [233,234]
  - There is currently no easily accessible source of 'whole-life' cost information that allows simple comparison between the costs of green infrastructure solutions and traditional grey infrastructure solutions at a specific site level.[235] However, recent research by the Welsh Government has found that SuDS were more cost-effective to fit and maintain than traditional 'grey' drainage in a range of recent developments.[236] The report also found that the operational costs of landscape SuDS were always cheaper than conventional grey solutions. Landscape SuDS can reduce the costs of energy and maintenance - savings of which can be passed on to water bill payers.[237]

The devolved administrations have stronger policies than in England to encourage or enforce sustainable drainage in new developments, though it is likely that still more could be done to encourage green SuDS.

In Wales, from 7 January 2019 all new developments of more than one dwelling or where the construction area is 100m^2 or more will require SuDS. SuDS on new developments must be designed and built in accordance with the Statutory SuDS Standards published by the Welsh Ministers and SuDS Schemes must be approved by SuDS Approving Bodies (SABs) in every local authority before construction work begins.

In Scotland, the Water Environment (Controlled Activities) Regulations have required SuDS for new developments since 2006 (for those where surface water drains into the water environment in order to protect water quality), and SuDS are routinely installed in new developments. The Flood Risk Management (Scotland) Act 2009 places a duty on local authorities to map SuDS in their area, although there is no statutory timescale for delivery. National promotion of SuDS by the SuDS Working Party is on-going with contributions being made to good practice publications and guidance such as 'Sewers for Scotland'. The SUDS Working Party, as well as authorities with responsibilities for surface water, highlighted to the Scottish Government that there were issues with the effectiveness of SuDS implementation in Scotland. To address these

[233] BRE (2017) for the CCC. *Resilience of new developments to high temperatures and flooding.*
[234] Building with Nature (2018), https://www.theplanner.co.uk/opinion/setting-a-new-standard-for-green-infrastructure
[235] McLintock, M. (2018) *Maximising the benefits of green infrastructure in social housing. Scottish Natural Heritage Research Report No.1046.*
[236]Environmental Policy Consulting (2017) for the Welsh Government. *Final report: Analysis of evidence including costs and benefits of SuDS construction and adoption*.
[237] Environmental Policy Consulting for Welsh Government (2017) *Sustainable Drainage Systems on new developments.*

issues the Scottish Government set up a new working group with Scottish Government, Scottish Water and local authorities, looking at SuDS implementation. The working group is on-going and is concerned with the adequacy of the installation and subsequent on-going maintenance of SuDS installations.

In Northern Ireland, Planning Policy Statement 15 (PPS15) 'Planning and Flood Risk' sets out the Department of Environment's planning policies to minimise flood risk to people, property and the environment. The Water and Sewerage Services Act (2016) extends the powers of Northern Ireland Water to adopt sustainable drainage systems (as they define them) and to require construction of SuDS. Section 5 supports this by introducing restrictions on the right to connect new surface water sewers to the public network.

There have been a number of policy developments since the Committee's last adaptation report to Parliament in 2017 that could place more attention on green SuDS and green infrastructure in England, if translated into action.

As part of the 25 Year Environment Plan commitments:

- The Government changed the National Planning Policy Framework (NPPF) to further encourage SuDS in major new developments and helped to clarify maintenance arrangements by requiring a maintenance plan is in place. While this improvement has been welcomed by the Committee, it was disappointing not to see this clause extended to all developments, with use of smaller scale SuDS schemes for minor developments. The revised NPPF also specified that 'where possible' SuDS should provide multifunctional benefits. This should be the default.
- Recommendations are included for green infrastructure including increased tree planting and new standards for green infrastructure.
- The new National Adaptation Programme includes actions relating to SuDS from the 25 Year Environment Plan, however the focus is solely on SuDS in new build, and there is no mention of retrofit.

Defra and Environment Agency also published a Surface Water Management Action Plan in July 2018 which considers issues related to surface water to ensure that those responsible for managing risks are taking the appropriate actions.

Immediate action can be taken to improve uptake of green infrastructure in England, including green SuDS in existing and new developments.

1. The importance of **shaded spaces** in urban areas should be included in the National Planning Policy Framework's (NPPF) section on 'promoting healthy and safe communities', so that all local planning authorities have to demonstrate their provision of shaded spaces in the clearance process of their local plans. Natural England are leading the establishment of a national framework of green infrastructure standards due to be published in 2019. Once published, local authorities should assess green infrastructure provision against new standards. MHCLG should also incorporate them in national planning policy and guidance for new builds.

2. **Improving Planning Guidance and knowledge** in England to ensure that designs for SuDS and other greenspaces are included in the housing delivery process from the start:

- Planning Guidance should be updated to bring the parts of the NPPF dealing with green infrastructure together. This should include using the latest evidence to support SuDS including the full costs and benefits of green SuDS and practicality of installations.

- The Construction Industry Research and Information Association (CIRIA) SuDS Manual[238] aims to assist planning, design, construction, management and maintenance of good SuDS. It provides the evidence and technical guidance needed to deliver surface water attenuation in all types of development, as well as benefits to biodiversity, water quality and amenity.
- Other guidance and standards, such as Building with Nature Benchmark can help industry bodies address skills and knowledge gaps.

3. Government should consider systems approaches to value more effectively **the full benefits of green infrastructure** as well exploring any unintended consequences from poorly designed schemes.[239] This could include demonstrating the value of green infrastructure in terms of 'preventative spend' (e.g. health outcomes / flood prevention) to secure funding from a wider range of sources (e.g. NHS, local authorities, health & social care partnerships, water companies). Funding schemes that deliver a range of benefits, with funding pots that multiple partners can bid into together, and innovation in the green finance sector could help in this area.

4. Following updates to planning guidance there is an **urgent need for clear standards** for the quality of SuDS:

- The Non-Statutory Technical Standards should to be expanded to include water quality, biodiversity and amenity.
- 'Sewers for Adoption 8' (2019) includes (for the first time) guidance on SuDS components. Water companies are responsible for producing Drainage and Wastewater Management Plans and can set guidelines, along with Lead Local Flood Authorities detailing the specifications that SuDS should meet in order to be adopted. Water Companies use Sewers for Adoption to identify what they can, or can't, adopt as a sewer under the Water Act, developers should be building SuDS at least to these standards.

5. To avoid adding further pressure to existing drainage networks the Government should **remove the automatic right to connect** to sewers in new developments (as recommended previously by the CCC), and allow water companies to consult on all planning applications.

6. The Government should consider the need for **water company drainage and wastewater action plans** to be statutory, as suggested by the Surface Water Flooding Action Plan.[240] This would have implications for how water companies work with other drainage bodies. Points to consider include:

- Ofwat's guidance to water companies is clear that building and adopting SuDS will meet their duty of drainage requirements. There are a number of examples where local authorities and water companies have successfully worked together to retrofit SuDS (for example Hammersmith and Fulham Council and Thames Water's retrofitting social housing scheme, Box 3.2).
- Drainage on a wider, integrated scale requires more collaborative working. CIRIA have produced a wide range of guidance and frameworks for SUDS alongside the SuDS manual and are due to produce guidance on Integrated Water Management in 2018/19.[241]

[238] CIRIA (2016) *The SuDS Manual (C753)*.
[239] Mare Lohmus et al. (2015) *Making green infrastructure healthier infrastructure.* Infection Ecology & Epidemiology Journal.
[240] Defra and Environment Agency (2018) *Surface water management action plan.*
[241] See: https://www.susdrain.org/resources/ciria-guidance.html

- A report by Business in the Community (BITC) looked at how SuDs could be rolled out across Greater Manchester. United Utilities charge a surface water flooding charge to businesses to encourage them to install SuDS to reduce water run-off.[242]

Box 3.2. Climate-proofing Social Housing Landscapes

A project led by Groundwork in partnership with Hammersmith and Fulham Council sought to demonstrate how retrofitting open spaces on housing estates can be a cost effective solution to improving London's resilience to climate change. It involved design and implementation of open space adaptation schemes on three housing estates, incorporating green roofs and integrated SDS. The project was funded in part by the borough, EU Life funding and the Greater London Authority.

Outcomes achieved included:

- 100% of rainfall on estates being diverted from drains – found to represent 1,286,815L diverted annually.
- Retrofits provided reported to have GHG savings of 6.2 tonnes/ year.
- Small contribution to local employment; development of new skills.
- Raised awareness of potential benefits of SuDS.
- Modelling by New Economics Foundation found benefit for every £1 invested in a range between £2.31 and £5.15, when taking into account broader social benefits.
- Monitoring and evaluation of data highly valued by third parties, e.g. Thames Water. Programme has led to funding of further green infrastructure work with boroughs.
- High confidence of a risk reduction at the local scale

Monitoring and evaluation was treated as a key aspect of the project. This has helped to communicate the benefits and influence the work of others. The project prioritised working with communities where past work had been done and existing relationships were established. Groundwork operating as lead agency may also have helped to circumvent potential reluctance among residents to engage with a Council.

Source: AECOM for the CCC (2018) *Adaptation actions in cities: what works?*

Recommendation: Policy is needed in England to address the outstanding barriers to deliver high quality, effective green SuDS in new development and retrofit:

- The Planning Guidance for England must be updated urgently to encourage multi-benefit SuDS in all developments, to bring together other aspects of planning related to green infrastructure and to help address skills and knowledge gaps.
- Defra should update the non-statutory standards using latest evidence on the full costs and benefits of SuDS. To promote water company adoption of SuDs Defra should consult with Water UK to ensure that standards are aligned to most up to date 'Sewers for Adoption'.
- The automatic right to connect new development to the existing sewerage network to be made conditional on national SuDS standards being met or by water company agreement.

[242] BITC (2018) *Water resilient cities.*

- A clear policy is required on who should maintain and adopt SuDS by default, unless agreed otherwise.
- Improved information on the implementation of green SuDS across the UK.

(Owner: Defra, MHCLG and local authorities. Timing: by 2020).

In the long-term the UK Government and devolved administrations should aim to increase urban greenspace as much as possible.

The Committee agree with the Environmental Audit Committee's findings in their 2018 heatwaves report. The Government's commitments to green towns and cities are not measurable or target driven and do not link green space to urban heat island reduction. Towns and cities must begin to include a percentage of green space to limit increase in the urban heat island. This is already being done in some major cities:

- The London Plan proposes a policy called the urban greening factors, which enables developers to quantify how much green space they should incorporate into their building plans. The London Environment Strategy proposes increase green coverage from to 50% in 2050.
- Bristol City council are planning to increase tree canopy from 15% to 30%, primarily for cooling shade.
- The Green Infrastructure Partnership exists to help disseminate good practice in the provision of green infrastructure in the UK.[243]

Recommendation: The UK Government and devolved administrations should take steps to monitor and reverse the decline in urban greenspace through clearer policy and more support for schemes that deliver multiple benefits:

- The UK Government should set a national target for increasing the area of urban greenspace, as part of the 25 Year Environment Plan (YEP) metrics. New standards for green infrastructure should be set in England (as actioned in the 25 YEP) and embedded within planning policy.
- The UK Government should assess the need for a national green infrastructure retrofit strategy to help guide local authorities and water companies in creating and including green infrastructure in drainage and local plans.
- Options for funding schemes tailored to multi-benefit green infrastructure schemes. This could include providing funding pots that multiple partners can bid into together.
- The devolved administrations should monitor changes in urban greenspace over time, and if declining should also take steps aligned with those suggested for England to reverse the decline.

(Owner: Defra, Devolved Governments. Timing: by 2021).

[243] www.gip-uk.org/#about

3.4 Sustainable Transport

3.4.1 Walking, cycling and public transport

New housing developments should be designed to facilitate sustainable travel. To reduce emissions from cars, it must be easy and enjoyable for people to switch to walking, cycling and using public transport. Electric vehicles should be used when car travel is essential. Transport is now the largest emitting sector of the UK economy, with emissions from car travel representing 15% of UK greenhouse gas emissions in 2017.[244]

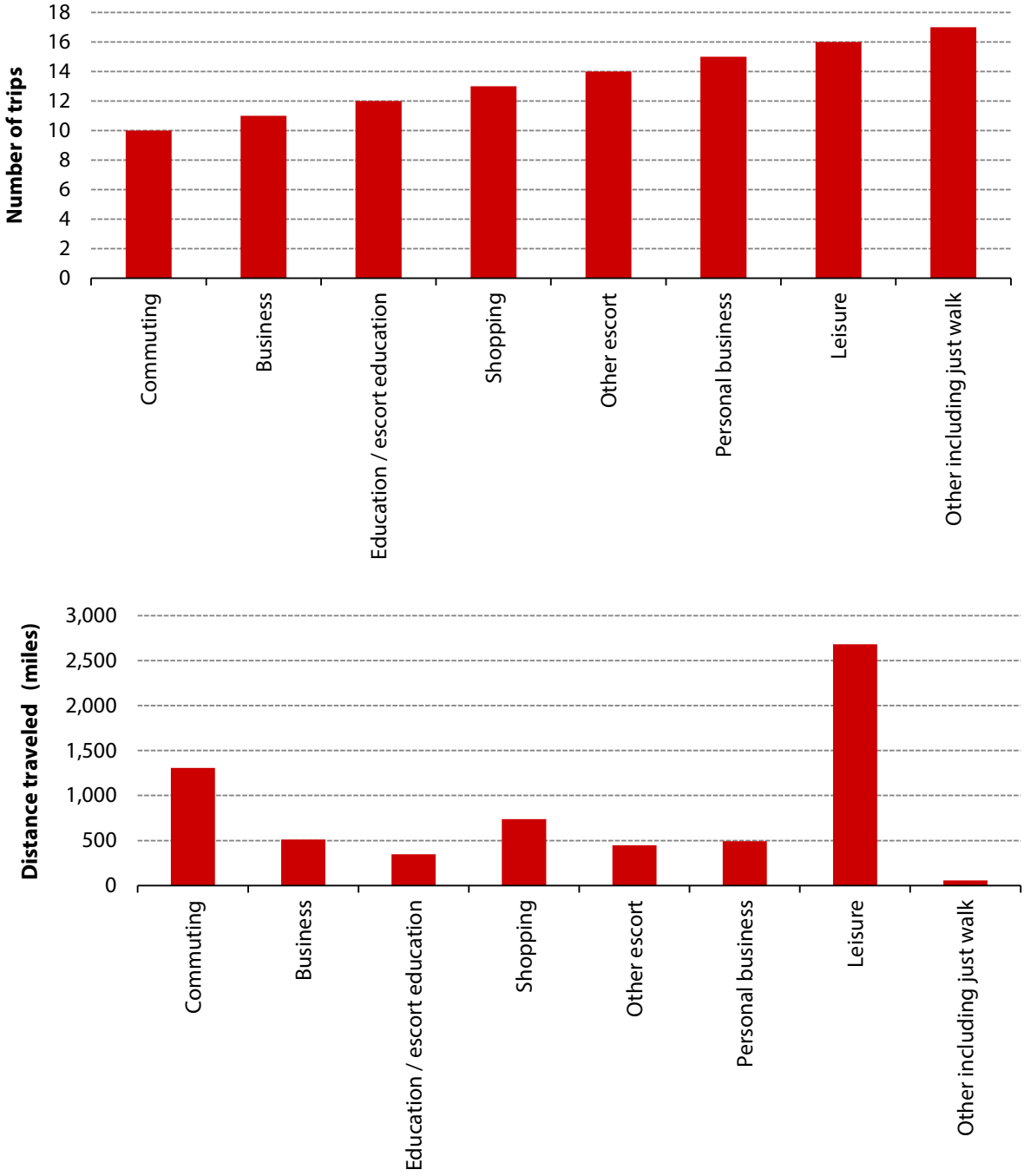
In order to reduce transport emissions, it is important to ensure that the location, layout, facilities and accompanying travel infrastructure for homes enable people to travel sustainably, whether by walking, cycling, public transport or driving in an electric vehicle.

From 2002 to 2017, on average across England, more trips were for shopping compared to any other trip purpose, although more miles were travelled for commuting purposes and to visit friends (Figure 3.1).[245] This emphasises the importance of locating shops and jobs near people's homes as far as possible accompanied by sustainable travel infrastructure, to reduce the need for car travel for these purposes.

In the current planning process, access to sustainable transport is not sufficiently prioritised, resulting in transport being considered in isolation to other key aspects of the development. This can lead to many new housing projects being designed around car use, located away from social hubs and lacking safe walking and cycling infrastructure.[246]

[244] Committee on Climate Change (2018) *Reducing UK emissions: 2018 Progress Report to Parliament.*
[245] Department for Transport (2018) *National Travel Survey: England 2017.* The National Travel Survey no longer covers the devolved administrations, and each devolved administration has different methods of collecting similar data which do not precisely align.
[246] Transport for New Homes (2018) *Project summary and recommendations July 2018.*

Figure 3.1. Average number of trips per person per year and average miles travelled per person per year in England (2017)



Source: DfT (2018*) National Travel Survey*.
Notes: Leisure includes visits to friends at home and elsewhere, entertainment, sport, holidays and day trips. Escort trips are used when the traveller has no purpose of his or her own to travel, other than to escort or accompany another person. Escort education includes trips taking a child to school.

Where possible, housing should be developed within existing urban areas. This provides easy access to amenities, reducing the need to travel.

Local authorities can use a series of spatial principles to assess the levels of traffic that a new housing development will create. New houses within and adjacent to urban areas tend to generate the least traffic:

- Creating new developments in large towns or redeveloping existing urban sites (brownfield land) make it easy for new residents to travel sustainably, as the homes are already sited in close proximity to education, shops, businesses and entertainment. These sites work best when not cut off from the town by major roads and roundabouts.
- Where this isn't possible, adding housing to smaller towns with good access to public transport or creating new villages where residents can easily access public transport is preferable.

Local authorities should prioritise locating housing in areas which minimise extra traffic.

However, many new areas of housing are being developed in locations which are remote from rail stations or located with good access to motorways only. This will generate large amounts of traffic:

- It is possible that the current planning system directs development preferentially to fields and meadows outside the town as this is often viewed as easier to develop.[247] In Trowbridge, Wiltshire, for example, houses are being built outside the town on a major road, whilst a large site in the town centre goes undeveloped.
- Whilst achieving sustainable development is a goal of the National Planning Policy Framework, pressures to deliver affordable housing have led to policies that require local authorities to maintain a five-year supply of potential land to build houses on and an emphasis on economic viability of these houses, both of which can lead to a focus on quantity of housing rather than quality.[248]
- Analysis by KPMG for Greener Journeys found that property developments in a regional centre, accompanied by public transport investment, had the largest positive economic impact on the area, when compared to those on the urban fringe, even if these were accompanied by public transport investment.[249]
- As well as increasing the need to travel for those living there, public services to low density urban developments are often higher cost due to the need to cover a wider area. These services include waste collection, school transport, police and emergency response.[250]

Recommendation: Sub-national transport bodies should play a role in coordinating regional housing plans and sharing good practice across local authorities.

(*Owner: Sub-national Transport Bodies. Timing: by 2021).*

[247] Transport for New Homes (2018) *Project summary and recommendations July 2018.*
[248] RTPI (2018) *Settlement patterns, urban form and sustainability: An evidence review.*
[249] KPMG for Greener Journeys (2018) *Sustainable transport: The key to unlocking the benefits of new housing.*
[250] RTPI (2018) *Settlement patterns, urban form and sustainability: An evidence review.*

Many new developments, particularly those built on large greenfield sites on the edges of towns, are designed for travel by car.

Car travel is likely to increase transport emissions in these areas in the near term. In 2017, the Department for Communities and Local Government (now the Ministry of Housing, Communities and Local Government) launched a new Housing Infrastructure Fund, consisting of up to £2.3 bn of government funding to fund infrastructure required to deliver 100,000 new homes. This was extended to £5.5 bn to unlock up to 650,000 new homes in total by Autumn Budget 2018. Whilst this funding can be used for a variety of new infrastructure projects, including new transport links, the guidance for applying for the funding does not mention the importance of ensuring that this transport is low emission and sustainable.[251]

A recent project by Transport for New Homes included visits to over 20 housing developments to assess how easy it was to access public transport or walk or cycle to local amenities.[252] Most of the new housing developments had plentiful car parking, but limited or no access to public transport, limited facilities and services, and a lack of safe pedestrian or cycling routes to town centres or the surrounding area. New developments across a variety of areas were advertised on the basis of easy access to major roads, in some cases, with the Government co-funding new roads with the developer.

Action must be taken to ensure that new developments encourage people to travel sustainably. To facilitate walking and cycling, new houses should be linked to towns where possible by suburban streets, rather than busy link roads.

The Department for Transport has set a target to double cycling trips by 2025 (from 2013 levels) in the Cycling and Walking Investment Strategy, and new developments should be planned with the necessary infrastructure to support this aim.[253] Public Health England has assessed that investment in active travel, including cycling infrastructure, can lead to numerous health gains, including improved cardiovascular outcomes.[254] Segregated cycle paths and bicycle parking can also help people feel safe when planning a journey by bicycle:

- New developments should include high-quality cycling infrastructure, including cycle parking near shops, facilities and connections to other transport modes. Segregated cycle paths can help people feel safe even when travelling on busy roads.
- Some roads connecting local centres to new estates do not have pavements, discouraging walking. Walking routes along dual carriageways, across large roundabouts, through underpasses or by streams or hedge-lines often connect new housing to towns, but are unattractive to use in the dark and can feel unsafe for those walking alone.
- Reducing motor traffic on roads appropriate for walking and cycling increases the likelihood people will choose to walk or cycle, due to improved perceptions of safety and ease of crossing.[255] New developments can benefit from a grid-like layout, ensuring that walkers and cyclists can travel easily from street to street but reducing the routes cars can use by the careful placement of plants, gates and bollards. When connecting new developments to

[251] Department for Communities and Local Government (2017) *An Introduction to the Housing Infrastructure Fund.*
[252] Transport for New Homes (2018) *Project summary and recommendations July 2018.*
[253] Department for Transport (2017) *Cycling and walking investment strategy.*
[254] Public Health England (2017) *Planning for Health: An evidence resource for planning and designing healthier places.*
[255] Aldred, R. and Croft, J. (2019) Evaluating active travel and health economic impacts of small streetscape schemes: An exploratory study in London. *Journal of Transport and Health,* 12, 86-96.

existing towns by cycle routes, it is important to ensure the route feels safe, by limiting through motor traffic and parked cars (which can limit visibility) using the same road.[256]

Recommendation: The Government should review the powers of planners and develop mechanisms to fund costs of building high quality walking, cycling and public transport infrastructure, even when outside the immediate housing site boundary.

(*Owner: MHCLG, DfT, devolved administrations. Timing: by 2020).*

Developments must be serviced by public transport from the day people begin to move in.

Many new homes are not well connected to public transport and are located in places that may be difficult to service with buses:

- Transport for New Homes found from their research covering over a hundred urban extensions and green field estates that bus infrastructure was rarely given significant funding and only 1 new train station was delivered after many years of lobbying by a local authority.[257] Once travelling by car is established as a preferred mode of travel, it can be difficult to encourage people to change even with the provision of improved public transport infrastructure. When homes aren't connected to public transport and there are few local amenities, older people and teenagers struggle to access activities if they aren't able to drive or be given lifts.
- Public transport services are most cost effective when they can serve a number of residential areas along their routes. The placing of new housing in 'urban extensions' or 'garden villages' away from urban centres makes it harder to ensure adequate bus provision. Developing new housing in this way avoids large upfront infrastructure costs, so can initially seem less expensive. However, these residents will still require transport and other services and these costs should be factored in to the decision to develop. Small low density remote settlements can be prohibitively expensive to service with public transport.
- When there is insufficient certainty that new stations, bus infrastructure or cycle routes would be built, planners are prevented from relying on these modes of transport, resulting in increased road building to service the new development. In the case of local rail, this is often despite great enthusiasm from planners, Local Enterprise Partnerships and MPs.[258]

Transport planning must be integrated with local housing plans and be accompanied by clear coordination at a regional level. Discussions between local authorities, bus companies and developers should take place early to ensure sustainable travel is prioritised throughout the design process:

- Local plans must incorporate funded public transport networks and cycle networks to link new homes to sustainable transport possibilities. If new roads are built, the inclusion of bus priority lanes should be considered, as well as provision for cyclists and pedestrians. Some Councils have had success in using payments arising as part of legal agreements between the planning permission applicant and the local planning authority to ensure bus services are available at new developments from the day people move in. Across Devon, for example,

[256] Aldred, R. (2015) Adults' attitudes towards child cycling: a study on the impact of infrastructure. *European Journal of Transport and Infrastucture research,* 15, 92-115.
[257] Transport for New Homes (2018) *Project summary and recommendations July 2018.*
[258] Transport for New Homes (2018) *Project summary and recommendations July 2018.*

passenger numbers have increased by 40% since 2002 as a result, although have begun to level off in recent years.[259]

- The bus industry should be consulted as plans are being drawn up. Bus routes should be planned as new estates are being designed, ensuring that the roads are wide enough and buses can serve all areas of the estate.
- In areas where the demand for housing exceeds the amount of available land within or adjacent to existing urban areas, a series of linked small settlements could be located between two existing urban areas or between an urban area and another destination such as a university or science park. Linking small settlements in this way increases the likelihood that buses can service several different residential areas along a route, making them more commercially viable.
- Bus and other public transport routes should cohesively link housing to existing stations by public transport routes, enabling easy interchange. This should include integrated timetabling, information provision and smart ticketing.

Recommendation: MHCLG and DfT should explore the potential for new rail stations, and light rail, tram and bus (including bus rapid transit) routes to unlock areas for housing development whilst mitigating transport impacts.

(*Owner: MHCLG, DfT. Timing: by 2020).*

Recommendation: Local authorities must consult the bus industry at the Local Plan stage to ensure new housing areas can be serviced by commercially viable routes.

(*Owner: Local authorities. Timing: by 2020).*

When located near high capacity, frequent public transport, such as rail, light rail, trams or bus rapid transit, housing should be higher density, in order to make the best use of the infrastructure.

The National Planning Policy Framework suggests that minimum densities should be in place for areas well served by public transport but does not define what density should be used. Local authorities would benefit from the addition of density guidelines, to indicate what number of dwellings per hectare are appropriate for different types of transport infrastructure:

- The Royal Town Planning Institute (RTPI) recommends average levels of 50-100 dwellings per hectare (dph) for areas with good local bus services, rising to 100-200 dph for housing located around important public transport nodes.[260] In contrast, in England in 2016/17 the average density of new residential addresses was 32 addresses per hectare, although many of these are likely to be located away from public transport connections.[261]
- High density housing plans must still incorporate sustainable drainage and green space, ensuring where possible that the community design has wider benefits for water quality and diversity. The East Village development in Stratford, London has combined these considerations to ensure a large number of people can benefit from the excellent transport links to London Underground and National Rail lines. Green spaces are interlinked with

[259] Transport Committee (2018) *Oral Evidence: Health of the Bus Market. 12th November 2018.*
[260] RTPI (2018) *Settlement patterns, urban form and sustainability: An evidence review.*
[261] MHCLG (2018) *Land Use Change Statistics in England: 2016-17.*

medium rise but high density housing (147 dph).[262] Interspersing dense housing with green space also has positive impacts by making walking attractive.[263]

- Evidence suggests that existing changes to planning policy, encouraging higher densities in urban areas, may have already contributed to a modest fall in national driving (compared to the counterfactual), especially amongst young adults.[264]

Recommendation: For areas within walking distance of high quality public transport (such as local rail, trams and bus rapid transit), MHCLG and DfT should set minimum density guidelines to ensure local authorities concentrate housing in these areas wherever possible.

(*Owner: MHCLG, DfT. Timing: by 2020).*

Councils and local authorities around the UK must introduce innovative policies to deter people from driving into busy city centres, where there are more sustainable alternatives. Otherwise, extensive development on the periphery of towns is likely to exacerbate congestion, noise and air quality issues. Successful initiatives include workplace parking levies, congestion charges and pedestrianisation of urban centres (Box 3.3).

Box 3.3. Examples of measures to deter driving in busy city centres

Within the UK, cities have had success in charging car drivers to park or to travel within city centres. Nottingham has introduced a work place parking levy to generate funds for public transport improvements. This levy also explicitly encourages employers to consider the development potential of land currently used for parking in central areas, which could free up further land for housing. London has introduced a congestion charge to discourage driving in the city centre, whereas emissions based parking charges have been introduced in the City of London.

Internationally, the Norwegian Government has asked cities in Norway to estimate what kind of investment they require to enable them to thrive without growing traffic levels. Madrid plans to ban cars from 500 acres in the city centre, redesigning some of its busiest streets to encourage people to walk. Mexico City and Bogota have already implemented schemes which restrict the number of cars in the city on certain days of the week. Pontevedra in Spain introduced a ban on cars crossing the city and removed parking, resulting in reduced traffic fatalities. 75% of car journeys are now made on foot or by bike. Pontevedra has grown in size and supports a thriving small business sector.

Source: Marsden, G. et al. (2018*) All Change? The future of travel demand and the implications for policy and planning.*

If it is not possible to locate new housing developments near existing amenities, providing new schools, doctor's surgeries, shops and businesses within new developments can minimise the need for new residents to travel.

Whilst it might not be possible or practical for all journeys, a significant proportion of trips can either be eliminated or be short enough that walking or cycling is a practical choice. What is good for emissions is good for most other aspects of urban policy, by improving the economic and social well-being of cities:

[262] LSE London/LSE Cities report for the GLA (2018) *Residents' experience of high-density housing in London.*
[263] Brookfield, K. (2016) Residents' preferences for walkable neighbourhoods. *Journal of Urban Design,* 22, 44-58.
[264] Melia, S. et al. (2018) Is the urbanisation of young adults reducing their driving? *Transportation Research Part A: Policy and Practice*, 118, 444-456.

- Places of work, retail and community provision should all be integrated within walking distances in the residential area, without interruption by busy high-speed roads, large car parks or roundabouts. Even people who would not previously choose to walk have been found to change their behaviour and increase their number of walking trips when moving to homes with a wide variety of destinations within walking distance.[265]
- Local shops, schools and restaurants can generate a community feel and often feature on advertising literature for new houses. The inclusion of small scale, affordable and flexible premises for businesses in plans can encourage people to enter the area for leisure, ensuring new developments can support a good range of shops and community facilities, as well as providing employment near homes.
- Improving walkable access to recreational and non-recreational destinations can also lead to improved social outcomes among older adults.[266]

Recommendation: Government must strengthen the importance of sustainable transport plans that are integrated into the development throughout the design process, including the development of walking and cycling routes and early consultation with public transport providers.

(*Owner: MHCLG, DfT, devolved administrations. Timing: by 2020).*

3.4.2 Electric vehicle charging infrastructure for off-street parking

New homes should either have charge points installed or have accessible cabling to ensure easy installation at a later date.

In order to meet the Fifth Carbon Budget, the Committee has recommended that 60% of new car and van sales in 2030 are electric vehicles (EVs). Charging points must be installed in homes with off street parking or nearby for those without off street parking to enable vehicles to be charged overnight:

- The Government has indicated in its Road to Zero Strategy their intention that all new homes, where appropriate, should have a charge point available.[267] They plan to consult on introducing this as a requirement to new homes being built.
- In London, 20% of new homes with parking spaces must come with charging infrastructure already installed, with cabling for chargers installed in the remaining 80%.[268] Many other cities around the world have similar requirements, including Oslo, San Francisco and several cities in China.

Recent analysis for the Committee by Systra suggests that 27,000 new public charging points across the UK are needed to facilitate adoption of electric vehicles in urban areas.[269]

These could be installed on streets (including on new lamp posts) or outside shops or businesses developed in new residential areas to enable drivers to top up whilst they are doing other

[265] Giles-Corti, B. et al. (2013) The influence of urban design on neighbourhood walking following residential relocation: Longitudinal results from the RESIDE study. *Social Science and Medicine,* 77, 20-30.
[266] Public Health England (2018) *Planning for Health: An evidence resource for planning and designing healthier places.*
[267] Office for Low Emission Vehicles (2018) *Reducing emissions from road transport: Road to Zero Strategy.*
[268] ICCT (2018) *Electric vehicle capitals: Accelerating the global transition to electric drive.*
[269] SYSTRA for the Committee on Climate Change (2018) *Plugging the gap: An assessment of future demand for the UK's electric vehicle charging network.*

activities. In the Road to Zero strategy, the Government indicated that all new street lighting columns should include charging points in areas where there is significant on street parking.[270]

Recommendation: To encourage uptake of electric vehicles, the Government should immediately consult on regulations to include appropriate cabling ready for installation of electric vehicle chargers or electric vehicle chargers themselves in all new parking spaces for housing developments with off-street parking.

(*Owner: OLEV. Timing: by 2020).*

[270] Office for Low Emission Vehicles (2018) *Reducing emissions from road transport: Road to Zero Strategy.*

Chapter 4: Areas for progress in delivering better homes

Key messages

Addressing the multiple gaps and barriers to delivering high quality, sustainable housing set out in the previous chapters can be achieved through strategic forward planning, robust policies and effective implementation of those policies. Effective implementation will require a fundamental step-change in our approach to building homes:

- **Performance and compliance.** The vital first step is addressing building regulation compliance, and the performance gap between how homes are designed and how they perform when occupied. Tightening standards will have little effect otherwise. It is critical that stronger compliance and enforcement procedures, with greater levels of inspection and appropriate penalties, are in place, ensuring that new and existing buildings are safe, and deliver the energy and ventilation standards expected of them. 'As-built' performance should be formally integrated into the standards and enforcement framework. Closing the energy performance gap could deliver £70-£260 in annual bill savings per household, and around 2 $MtCO_2e$ in annual carbon savings by 2030.[271]
- **Skills gap.** The chopping and changing of Government policy has inhibited skills development in critical areas. Government must use the initiatives announced under the Construction Sector Deal to tackle the low-carbon skills gap, and develop a world-class construction sector which can realise the domestic and international industrial opportunities related to low-carbon building.
- **Building regulations.** The technology exists to deliver homes that are low-carbon, energy efficient and climate-resilient, with safe air quality and moisture levels. The costs are not prohibitive, and getting design right from the outset is vastly cheaper and more feasible than having to retrofit later. From 2025 at the latest, no new homes should be connected to the gas grid. They should instead be heated through low-carbon sources, have ultra-high levels of energy efficiency and, where possible, be timber framed. A statutory requirement for reducing overheating risks in new builds is urgently needed, alongside greater focus on ambitious water efficiency standards and property-level flood protection in areas at current or future high risk of flooding.
- **Retrofitting existing homes.** The 29 million existing homes across the UK must become low-carbon and resilient to a changing climate. This is a UK infrastructure priority and should be supported as such by HM Treasury. Homes must be made ready for low-carbon heating (heat pumps and heat networks). The uptake of energy efficiency measures such as loft and wall insulation must be increased. Upgrades or repairs to homes should include increasing the uptake of passive cooling measures (i.e. shading and ventilation), reducing indoor moisture, improving air quality and water efficiency, and, in homes at risk of flooding, installing property-level flood protection.
- **Finance and funding.** There are urgent funding needs which must be addressed now with the support of HM Treasury: low-carbon heating (currently only funded up to 2021), resources for local authorities and in particular building control. The UK Government must implement the Green Finance Taskforce recommendations around green mortgages, green loans and fiscal incentives to help finance upfront costs, as well as improving consumer access to data and advice. It should widen the scope of these measures to include resilience, for example by introducing house resilience surveys which assess water efficiency, flood risk and overheating.
- **Local authority action.** Local authorities can contribute through the services they deliver, their role as social landlords, and through their regulatory and strategy functions. However, climate change has been de-prioritised in the land-use planning system and funding for such measures

[271] Regulations and monitoring metrics are focussed substantially on the modelled performance of dwellings as designed, rather than their actual performance 'as-built'. There is a large body of evidence which points to a substantial gap between the two. This is the 'performance gap'.

Key messages

remains extremely limited. The regulatory and policy framework must incentivise and enable local and regional authorities to take action and be ambitious, through Government clarifying rights and obligations, and adequately funding local authorities. Clarity is needed on how far local and regional authorities are permitted to go in setting tighter new build standards. Planning frameworks and guidance should advise local authorities to take a strategic approach to planning for the creation and protection of green spaces and Sustainable Drainage Systems. Local authorities should consider how to shape demand for travel throughout the planning process, with the ultimate goal of reducing the need to travel, alongside making walking, cycling and the use of public transport straightforward and pleasurable.

4.1 Purpose of this chapter

This chapter sets out cross-cutting issues and recommendations for housing, building on the advice of previous chapters.

We consider four cross-cutting areas: addressing compliance issues and closing the 'performance gap'; building regulations; wider principles to guide the retrofit of existing homes**;** and local authority action to deliver low-carbon, resilient homes.

4.2 Addressing compliance issues and closing the 'performance gap'

New and existing homes often do not perform in line with the minimum standards of performance expected of them by law. Failure to perform in line with standards means locking in colder homes, higher bills and greater risk of flooding for generations. The consumer is cheated when stated building standards are not delivered. Consumers should not be paying the price for poor quality build.

These issues should be addressed as a matter of urgency. The Government has committed to building 1.5 million new homes in the UK by 2022 and evidence suggests that when house building rates increase, levels of homebuyers' satisfaction with quality falls.[272] Millions of existing homes must also be retrofitted if we are to meet legally binding carbon targets. As we prepare to build and retrofit more homes, we must do so to higher standards. This will require a fundamental step-change in our approach to building.

In the following sections we consider a range of drivers for buildings not performing as they should:

- Compliance issues: issues relating to the monitoring and enforcement of regulatory requirements.
- The 'performance gap': the gap between the performance of buildings as-designed and how they perform as-built, and the range of drivers which contribute to this, including challenges relating to knowledge and skills, measurement and householder behaviour.

Addressing these issues is a very significant challenge, requiring coordinated action across the industry, Government, enforcement bodies and also involving a role for householders.

[272] BEIS (2018) *Industrial strategy - Construction Sector Deal*; Analysis by the Chartered Institute of Building, published in All Party Parliamentary Group for Excellence in the Built Environment (2016), *More Homes, fewer complaints.*

Tightening standards will not be effective if they are left unresolved and bills and carbon emissions will not reduce as a result.

4.2.1 Compliance

Following the Grenfell Tower fire in June 2017, Dame Judith Hackitt was commissioned to review building standards and safety. The review was published in May 2018, and highlighted the systemic compliance issues in the current Building Standards regime. In her foreword to the Independent Review of Building Regulations and Fire Safety, Dame Judith Hackitt summarised the scale of the challenge: "it has become clear that the whole system of regulation, covering what is written down and the way in which it is enacted in practice, is not fit for purpose, leaving room for those who want to take shortcuts to do so."[273]

The Hackitt Review identified a range of issues with current building practice and the regulatory system:[274]

- **Ignorance** – regulations and guidance are not always read by those who need to, and when they do the guidance is often misunderstood and misinterpreted.
- **Indifference** – the primary motivation is to do things as quickly and cheaply as possible rather than to deliver quality homes which are safe for people to live in.
- **Lack of clarity on roles and responsibilities** – there is ambiguity over where responsibility lies, exacerbated by a level of fragmentation within the industry, and precluding robust ownership of accountability.
- **Inadequate regulatory oversight and enforcement tools** – the size or complexity of a project does not seem to inform the way in which it is overseen by the regulator. Where enforcement is necessary, it is often not pursued. Where it is pursued, the penalties are so small as to be an ineffective deterrent.

These issues must be addressed urgently.

We support the principles for resolution identified in the Hackitt review, in particular: an outcomes-based approach that sees buildings as a system; a clear model of risk ownership (with risk placed with those able to control it); transparent information and a clear audit trail; and effective oversight and sanctions underpinning the framework. 'As-built' performance should be formally integrated into the standards and enforcement framework. It is critical that stronger compliance and enforcement procedures, with greater levels of inspection and heavy penalties where appropriate, are in place, making sure that new and existing buildings are not only fire-safe, but also deliver the energy, ventilation and water economy standards expected of them.

Recommendation: Overhaul the compliance and enforcement framework so that it is outcomes-based (focussing on performance of homes once built), places risk with those able to control it, provides transparent information and a clear audit trail, with effective oversight and sanctions. Fund local authorities to enforce standards properly across the country.

(Owner: MHCLG, devolved administrations, HMT. Timing: by 2019).

[273] MHCLG (2017) *Independent Review of Building Regulations and Fire Safety: interim report.*
[274] MHCLG (2018) *Independent Review of Building Regulations and Fire Safety: final report.*

4.2.2 The 'performance gap'

A large body of evidence points to a substantial gap between the theoretical performance of buildings as measured at design stage, and the actual performance when built.

There is a lack of robust data, based on large sample sizes, to quantify the precise scale of the gap. Nevertheless there is a large body of evidence that points to it being substantial (Box 4.1). When a similar performance gap was uncovered in the automotive sector, this led to a widespread loss of trust in car manufacturers.[275]

Box 4.1. Evidence on the scale of the performance gap

A range of studies have examined the discrepancy between designed and 'as-built' heat loss performance in homes, providing evidence of a pattern of over-optimism in design estimates. Poorer than expected outcomes in terms of the building fabric thermal performance, airtightness and services contribute to this.

A study by Johnston et al. in 2015 examined 25 new build dwellings finding the measured Heat Loss Coefficient (a measure of heat flow through the building envelope) to be almost 1.5 times that predicted. Some studies find the performance gap on fabric heat loss can exceed 100%. The scale of the performance gap on fabric heat loss varies with build form and construction type, with larger performance gaps for mid-terrace houses relative to detached houses and masonry constructions relative to timber-frame builds.

Gupta et al. (2018) find a widespread airtightness gap in their UK sample of new build properties, but with a far less significant issue in Passivhaus properties than non-Passivhaus properties. Innovate UK's Building Performance Evaluation Programme found around a third of their sample did not meet airtightness expectations, but also noted that many of their sample did not aim to go beyond the minimum requirements of building regulations.

Innovate UK's Building Performance Evaluation Programme examined data from a subset of 76 homes where low-carbon design was a priority and suggested that carbon emissions from new homes are two to three times higher than design estimates (before adjusting for energy use from cooking and appliances not included in SAP). They found significant teething problems in the first year, but even in the second year found little correlation between the predicted emissions from SAP and actual emissions.

A study in London found that new homes built to a standard of 105 litres per person per day (l/p/d) actually tend to be using between 110-140 l/p/d, 5-25% more than expected. The water use performance gap is not well understood and needs to be investigated further.

Sources: Zero carbon hub (2010) *Carbon compliance for tomorrow's new homes - Topic 4, closing the gap between designed and built performance*; Gupta, R. and Kotopouleas, A. (2018) *Magnitude and extent of building fabric thermal performance gap in UK low energy housing. Applied Energy, 222, 673-686*; Johnston, D. Miles-Shenton, D. & Farmer, D. (2015) *Quantifying the domestic building fabric 'performance gap.' Building Services Engineering Research and Technology, 36(5), 614–627;* Innovate UK (2016) *Building Performance Evaluation Programme: Findings from domestic projects, Making design match reality;* Policy Connect (2018) *Bricks and water*.

[275] Element Energy and ICCT (2015) *Quantifying the impact of real-world driving on total CO_2 emissions from UK cars and vans.*

The energy performance gap has very material impacts for bills and emissions.

Assuming a central estimate that new build homes lose 50% more heat than they should, closing the gap now could deliver £70-£260 in annual bill savings per household, and save around 2 $MtCO_2e$ in annual emissions by 2030.[276] In addition to delivering bill and carbon savings, closing the performance gap is critical in preparing the ground for tighter standards.[277]

The performance gap is created by a number of interacting problems, all of which need to be addressed. These present a major challenge to the construction industry.

In 2014 the Zero Carbon Hub conducted a comprehensive study on the energy performance gap and the factors that drive it. The study found a wide range of issues spanning the delivery process, and falling into three cross-cutting themes:[278]

- **Knowledge and skills:** a lack of integrated design between fabric, services and renewables; inadequate consideration of skills and competency at labour procurement; poor installation and commissioning of services; and concern over the consistency of some test methodologies and the interpretation of data.
- **Responsibility:** a lack of adequate energy performance-related quality assurance on site; a lack of robust energy performance-related verification; and a reliance on third-party information (e.g. by building control or warranty providers).
- **Communication:** as-built SAP calculations being produced without the inclusion of amendments to the design specification during the procurement or construction process, and a lack of clarity over the documentary evidence required for Part L and Part F compliance.

Whilst developed in relation to the energy performance gap, a number of these issues are also relevant to the performance gaps relating to ventilation and adaptation measures more broadly.

Behavioural factors can also have a significant impact on the performance gap. There is evidence of significant differences in energy consumption, ventilation performance and water use between homes built to the same specification.[279] A range of factors influence this, for instance how different people use domestic appliances and lighting, our use of hot water, when we open windows or use ventilation systems in our homes, and how much we shade our homes from the sun.

We have set out a range of steps that need to be taken to close this gap in previous reports including our 2016 report, Next steps for UK heat policy, and our 2018 Progress Report to Parliament.

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[276] Based on modelling outputs from Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings*. Assumes heat loss coefficients 1.5 times higher than those which would theoretically be achieved by building to the National House Building Council specification for new homes, with a gas boiler. Relationship between heat loss coefficients and space heat demand derived from SAP modelling. Split of stock archetypes for future build assumed to remain constant from present day.

[277] The introduction of low-carbon, low-temperature heating systems increases the importance of heating systems performing as intended to deliver affordable comfort. Where heat losses are higher than estimated this would require the heating system to be run at higher operating temperatures, incurring a material efficiency penalty. Closing the performance gap for current standards is also an important precursor to delivering homes with ultra-high thermal efficiency.

[278] Zero Carbon Hub (2014) *Closing the gap between design and as-built performance, Evidence review report.*

[279] For example, Zero Carbon Hub (2015) *Post occupancy evaluation, Rowner Research Project Phase two;* Waterwise (2018) *Advice on water efficient new homes for England.*

We build on these below, drawing also on recommendations from the Zero Carbon Hub's 2014 report, 'Closing the Gap between designed and as-built performance':

- **Monitoring metrics and certification** should be reformed to reflect real-world performance. For example, EPCs are not currently a good reflection of the expected running costs of a home (Box 4.2). An alternative framework should be based around more direct and objective metrics of performance, which provide a form of guarantee to householders - committing developers to the standard they advertise, and enabling consumer redress where these are not met. This should be expanded to include resilience measures such as property level flood protection where appropriate. In addition to shifting mind-sets and incentives in the design and construction process towards actual performance, this would provide reliable indicators of performance to grow the Green Finance market, and could empower consumers to choose homes which have been built to the highest standards.
- The **methodology underpinning building regulations**, currently the Standard Assessment Procedure, should be reviewed and revised. Action should be taken to put in place the Zero Carbon Hub recommended revisions to energy modelling practices, SAP processes and verification procedures, together with a strong regime to ensure that only suitably qualified persons carry out energy modelling and assessment.
- The chopping and changing of Government policy has inhibited **skills development** in critical areas.[280] Government must use the initiatives announced under the Construction Sector Deal to tackle the low-carbon skills gap, and develop a world-class construction sector which can realise the domestic and international industrial opportunities related to low-carbon building.
  - This will require a nationwide training programme to upskill the existing workforce, along with an increased focus on incentivising high 'as-built' performance.
  - The Government should also ensure the new Code for Practice for flood resilience is fully implemented to improve skills of property-level flood resilience and resistance measures.
  - The development of appropriate accreditations will help build consumer trust and drive demand for high-quality build. Uptake of relevant qualification and accreditation schemes can be supported by requiring them for developments on public land.
- Appropriate **guidance** can also play a role in disseminating best practice. In 2014 the Zero Carbon Hub recommended the development of an industry-owned and maintained set of best practice construction details covering major fabric junctions and systems in buildings. This should include ventilation systems.
- There should be a drive to **design buildings around the needs and preferences of the people that live in them**, and policy and regulation should support householders in using their homes effectively.
  - The concept of 'design for sustainable behaviour' works on the basis that if appropriate strategies are applied to the design of a product, the designer can positively influence the sustainable use of the product.[281] Examples could include having intuitive controls and standardised settings for thermostat and hot water temperatures in heating systems,

[280] Policies to support low-carbon measures have been weakened or withdrawn, including Zero Carbon Homes and the Code for Sustainable Homes.
[281] Delzendeh, E. et al. (2017) *The impact of occupants' behaviour on building energy analysis: A research view. Renewable and Sustainable Energy Reviews, 80, 1061-1071.*

and designing ventilation systems in ways that make them easier for occupants to use (e.g. having easily accessible filters, and alarm systems to make occupants aware of when filters need changing). In some cases, design approaches could remove the need for occupant intervention altogether.

  - Policy and regulation should support householders in using their homes effectively. This includes helping people understand what strategies can be used to manage overheating risks (for example through shading and window opening at night), and how to operate heating and ventilation systems efficiently.

- Government and industry should undertake further research, based on large-scale studies, to robustly **quantify and benchmark the performance gap** for energy, ventilation and water and develop commercially viable methodologies for demonstrating performance. Industry could play a role in funding this, with the outputs preparing the ground for ongoing monitoring and improvement.

A number of comprehensive studies set out further details on the steps that are needed, including Zero Carbon Hub's 2014 report 'Closing the gap between designed and as-built performance', and the Building Performance Evaluation Programme's 2016 report on findings for domestic buildings, alongside a number of research studies on mechanical ventilation.[282]

Box 4.2. Reforming monitoring metrics and certification

Energy Performance Certificates (EPCs) are a widely used measure of the energy performance of buildings. They are required when selling or letting a property and are intended to provide information to householders on the performance of a home and to promote energy performance improvements in buildings. EPCs underpin a number of current government policies. They frame the current fuel poverty targets and Government aspirations for as many homes as possible to be EPC band C by 2035, and underpin the regulations around minimum energy efficiency standards (MEES) for the private rented sector. They are also beginning to play an increasing role in Green Finance markets.

EPCs are based on the Standard Assessment Procedure (SAP) methodology which quantifies a dwelling's performance in terms of energy use per unit floor area (kWh/m^2), a fuel cost-based energy efficiency rating (the EPC rating, in £/kWh/m^2) and emissions of CO_2 (the Environmental Impact (EI) rating, in CO_2/m^2). The EPC reports both the EPC rating and the EI rating on a scale from A (highest) to G (lowest).

Since the EPC rating is cost-based, it is more suited to issues around fuel poverty rather than energy efficiency improvements or emission savings. It is subject to fuel price variations over time and can lead to perverse incentives where emission saving measures involve a switch in fuels. For example, the nature of the metric means that a switch to heat pumps is disincentivised.[283]

There are also serious concerns over both the accuracy and reliability of EPCs. The SAP method is a normative calculation (e.g. assuming a standard occupancy) using expert knowledge on the main factors in determining home energy efficiency. Estimates are likely to be inaccurate where there are issues with assumptions (as has been the case with solid wall thermal transmittance assumptions), or

[282] Zero Carbon Hub (2014) *Closing the gap between design and as-built performance: End of term report*; Innovate UK (2016) *Building Performance Evaluation Programme: Findings from domestic projects, Making design match reality*; Gupta, R. Gregg, M. Sharpe, T. McGill, G. and Mawditt, I. (2017) *Characterising the actual performance of domestic mechanical ventilation and heat recovery systems. In: AIVC 2017, 6th TightVent Conference, 13-14 September 2017, University of Nottingham, UK.*

[283] Discussed in more detail in CCC (2016) *Next steps for UK heat policy.*

Box 4.2. Reforming monitoring metrics and certification

where what is constructed does not match what has assumed to have been constructed.[284] There are difficulties comparing assessments made at different times with changes in assumptions and a lack of transparency in the data.

There can be major discrepancies in the rating for an individual property when assessments are conducted by different assessors. Recent research has quantified some of the reliability issues faced by EPCs, particularly for existing homes:

- Mystery shopper research for DECC found the range of EPC ratings spanned at least two EPC bands for almost two-thirds of the dwellings analysed.
- CREDS (2018) estimated the error in EPC reliability to be equivalent to 10 EPC points on average (which is enough to move many properties into a different EPC band). They find the error to be larger for poorer performing properties with an estimated error on a dwelling at the E-F band boundary of about 24 points, and the error on a dwelling at the C-B band boundary of about 4 points.
- Concerns have also been raised around EPCs being less reliable for larger, older and rural (off-gas) homes.

Grounding estimates in real-world data, such as from smart meters, should be the basis for reform of monitoring metrics and certification.

Sources: CCC (2016) *Next steps for UK heat policy*; Centre for Research into Energy Demand Solutions (2018) *Energy Performance Certificates in buildings: consultation response;* DECC (2014) *Green Deal Assessment Mystery Shopping Research;* All Party Parliamentary Group for the Private Rented Sector (2016) *Improving the Energy Efficiency of Private Rented Housing;* Hamilton et al. (2016) *Valuing energy performance in home purchasing: an analysis of mortgage lending for sustainable buildings.*

A range of industry and Government initiatives are in train to try to address build quality issues, and improve 'as–built' performance and measurement.

These include the Government's Construction Sector Deal and Buildings Grand Challenge Mission (both of which include commitments to drive up quality); the commitment to consult on skills and training as part of the Future Framework for Heat in Buildings; Government's innovation competition for methods to measure the thermal performance of homes; BRE's Home Quality Mark (HQM);[285] the Design for Performance pilot being led by the Better Buildings Partnership;[286] and CIBSE's updated Health and Wellbeing guidance document.[287]

However many of these initiatives are still in initial stages, and further detail is needed on how the full range of challenges will be addressed. Government should ensure a clear and comprehensive set of initiatives is put in place to close the gap, building on best-practice approaches internationally (Box 4.3).

[284] Centre for Research into Energy Demand Solutions (2018) *Energy Performance Certificates in buildings: consultation response.*
[285] See: https://bregroup.com/products/home-quality-mark/
[286] See: http://www.betterbuildingspartnership.co.uk/node/360
[287] Discussion with CIBSE. This will provide a summary of guidance on design, construction and facilities management. For a range of environmental factors it will also provide recommended performance criteria (e.g. pollutant levels) which could be used as targets in new designs or to reference the performance of existing buildings.

Box 4.3. Examples of international good practice in build quality

Germany

The German construction market is more regulated than the UK one, with a higher rate of housebuilding. Builders must train for three years before becoming 'Master Craftsmen'. About 15% - 20% of family homes are pre-manufactured in factories (like HUF houses), which means there may be less chance of things going wrong on site.

Netherlands

Purchasers are able to withhold 5% of the price of a newly built house for six months to cover any snagging or build issues. The final amount due to the builder is then determined through an independent inspection.

France

Where a defect arises, the homeowner is not obliged to prove the fault and the builder is presumed to be responsible. Homeowners can bring legal action against the developer for up to 30 years if the property does not meet the specification in the sale contract. This compares with up to ten years in England and Wales.

Source: https://www.ippr.org/files/publications/pdf/German-model-homes-Dec16.pdf; https://www.dw.com/en/skilled-crafts-boom-stretches-capacities-in-germany/a-41902114; https://www.huf-haus.com/en-uk/; Vereniging Eigen Huis https://www.eigenhuis.nl/huis-kopen/nieuwbouw/oplevering#/; https://www.french-property.com/guides/france/purchase-real-estate/off-plan/guarantees/building/.

Recommendation: Reform monitoring metrics and certification to reflect real-world performance, rather than modelled data (e.g. SAP). Accurate performance testing and reporting must be made widespread, committing developers to the standards they advertise.

(Owner: BEIS, MHCLG, devolved administrations, industry. Timing: 2020-2025).

Recommendation: Review professional standards and skills across the building, heat and ventilation supply trades with a nationwide training programme to upskill the existing workforce, along with an increased focus on incentivising high 'as-built' performance. Ensure appropriate accreditation schemes are in place.

(Owner: BEIS, industry. Timing: 2019).

Recommendation: Undertake a large-scale study to provide robust quantification and benchmarking of the performance gap for energy, water and ventilation.

(Owner: BEIS, industry. Timing: 2019).

4.3 Building regulations

Building regulations set out the framework of standards for new build homes and for new work to existing properties. Standards must evolve to deliver homes which are low-carbon, affordable to run, comfortable to live in and better for our health.

4.3.1 Trajectory for tighter standards

Building and retrofitting homes to these high standards will require a fundamental step-change in our approach to building. The Government has already recognised the need for a drastic

overhaul in building practices.[288] The trajectory for standards development must be carefully planned and staged to support high-quality delivery at scale.

As a first step, and as considered above, compliance issues must be addressed and the performance gap must be closed.

Alongside this there is a need for a focus on revising the regulatory framework to address issues and gaps, and ensure it is fit for purpose as we prepare for future uplifts to standards:

- **Methodologies underpinning standards.** The framework underpinning standards, the Standard Assessment Procedure, must be reviewed and revised to ensure it is fit for purpose in facilitating the delivery of ultra-energy efficient, low-carbon, well-adapted, moisture-safe, and well-ventilated homes which perform as designed. We have considered a range of issues with SAP that will need to be considered and addressed, including ensuring it accurately values the benefits of low-carbon technologies.
- **Requirements for standards to be met.** The provisions in the Town and Country Planning Act 1990 currently allow for circumstances where homes built now need only remain subject to the standards in place at the date planning permission was granted. In some cases this can be a number of years prior to when homes are actually built.[289] Changes to permitted development rights in England also mean that it is permissible to convert light industrial and commercial units to residential dwellings, without the need to ensure those properties meet the standards set out in Approved Documents L and F for new dwellings.[290] These loopholes mean new homes are still being built which do not meet the minimum standards for new dwellings set out in current regulations. The latest Government data shows that 12% of the homes built in 2018 were rated EPC C, whilst 7% were rated D or below.[291] These loopholes must be closed.
- **Ventilation.** Ventilation requirements must evolve to keep pace with improvements in energy efficiency and to deliver excellent levels of indoor air quality in homes. All ventilation systems should be designed, commissioned, and installed properly and householders supported to use them effectively.

[288] This is reflected in the Grand Challenge Mission to have the energy use of new buildings, and in the package of commitments set out in the Construction Sector Deal, including the Industrial Strategy Challenge Fund Transforming Construction Programme, and the package of work in train with the Construction Industry Training Board.

[289] Section 91 of the Town and Country Planning Act 1990 requires that development must begin within three years of the date planning permission is granted (unless an alternative timeframe is set by the relevant authority). After this time planning permission expires. However Section 56 of the Act provides a broad definition of what it means for development to have 'begun', allowing for circumstances where negligible work can be undertaken in the first three years following planning permission being granted, with substantive build happening up to years later. This means homes are being built now, to the standards that were in place a number of years ago.

[290] In October 2017, to help with the lack of homes in England, permitted development rights were extended, allowing owners to change light industrial and commercial units to residential dwellings without the need for planning permission. See: *The Town and Country Planning (General Permitted Development) (England) Order 2015*, Schedule 2, Part 3. The Raynsford Review of Planning has gathered examples which illustrate the impacts of this permitted development right, including the lower standards secured through building regulations on energy efficiency. For further discussion see: TCPA (2018) *Planning 2020 Raynsford Review of Planning in England, Final Report*.

[291] MHCLG (2018) *Live tables on Energy Performance of Buildings Certificates.*

- **Overheating.** A standard or regulations must be introduced to ensure overheating risk is managed from a thermal comfort and health perspective. Passive cooling strategies should be installed before consideration of active (mechanical) cooling.
- **Water efficiency.** Review new build regulation standards to allow local authorities to set more ambitious standards, especially in current and future water-stressed areas.
- **Property-level flood resilience and resistance**. Regulations should ensure that all new developments in flood risk areas demonstrate reduced exposure and vulnerability to flood damage as well as broader benefits to the resilience of the local area.
- **Electricity demand reduction and peak management.** Government should examine the potential role that could be played by the new-build standards framework in incentivising technologies to support demand reduction and peak management.
- **Whole-life carbon.** Policies should be developed to support a substantial increase in the use of wood in construction and mechanisms should be strengthened to drive whole-life carbon savings in new buildings, incorporating embodied emissions and carbon sequestration.
- **Electric vehicle charging infrastructure**. Government should consult on plans to include electric vehicle charging infrastructure requirements for parking spaces in new developments.

A framework must be in place by 2020 to signal the trajectory for future standards, and to support early movers. Clear forward trajectories for the evolution of standards should be set well in advance. This will encourage innovation, learning, and minimise costs to developers. A targeted package of measures should be developed to incentivise and support early movers:

- There is a role for a nationwide training programme to develop professional standards and skills, alongside the provision of guidance to support skill development and disseminate knowledge on best practice approaches.
- Fiscal incentives can be used to encourage the purchase of low-carbon and well-adapted homes. This could include rebalancing stamp duty or council tax to provide a discount for homes which are lower-carbon, more energy-efficient and better adapted. There is scope to do this in a revenue-neutral way where penalties are also levied for higher-carbon or less well-adapted homes.
- There is potential for incentives to be linked to current Government initiatives such as Help to Buy and Homes England. Homes England are responsible for increasing the number of new homes built in England and, amongst other things, work to increase the supply of public land. In return for the benefits associated with the permission to develop land, developers could be required to commit to delivering higher quality homes.
- Those procuring and purchasing buildings should have better access to information that allows them to consider the quality of design and built performance in purchasing decisions. Monitoring, ratings and accreditation procedures should be developed to assess the quality of built performance, empowering purchasers to choose contractors who demonstrate high performance. Performance metrics, including those on indoor air quality and water efficiency, as well as energy, should be required to be displayed more prominently when a house is sold or rented, and lenders could go further to support better consideration of energy and water costs in mortgage affordability calculations (e.g. through quoting running costs alongside mortgage offers).

- Green finance can facilitate access to capital, enabling consumers to respond to incentives. Government should implement the Green Finance Taskforce recommendations around green mortgages and green loans to encourage uptake and support financing of high-quality homes. The Government should also look to widen the scope of green finance, for example including water efficiency, flood and other resilience in digital green passports and EPC ratings.
- Enabling frameworks can support Local and Regional Authorities in driving up standards in their localities. Greater clarity is needed around the rights and obligations of local authorities with regard to standards. We consider these issues further in the next section.
- Additional support for small and medium-sized house builders is likely to be important to help minimise the additional costs they face, and support competition and high-quality build.[292]

Recommendation: Close loopholes allowing homes to be built which do not meet the current minimum standards for new dwellings. This includes provisions around the expiry of planning permission, and permitted development rights relating to change of use.

(Owner: MHCLG. Timing: 2019).

Recommendation: Implement tighter standards for new buildings to ensure they are designed for a changing climate, properly ventilated, moisture-safe, are future-proofed for low-carbon heating and deliver ultra-high levels of energy efficiency. The whole life-carbon and peak demand impacts of new homes should be minimised.

(Owner: MHCLG, devolved administrations. Timing: in force and forward trajectory set out by 2020).

Recommendation: Government should develop a targeted package of new measures to incentivise and support those developers and individuals who wish to take early action in building low-carbon and resilient homes.

(Owner: MHCLG, BEIS, HMT, devolved administrations. Timing: in force by 2020).

4.3.2 Preventing measures from being 'value-engineered out' of new homes and community design

Even when sustainability measures are included in designs for new homes, they do not always end up in the finished development.

The Adaptation Committee's 2017 Progress Report summarised evidence about the barriers to installing adaptation measures such as green sustainable urban drainage, passive cooling and property-level flood protection measures. A survey of housing industry professionals found that although these measures are often included in the design stage, lack of awareness and client demand for measures meant that even when issues were raised they were more often than not 'value-engineered out' of the build project as it progresses, in order to keep costs down. The survey also found that there are perceived costs associated with installing resilience measures in new builds, although highlighting that costs at build stage would be cheaper than at retrofit stage.

[292] Research by the Federation of Master Builders in 2017 found that consumers were twice as likely to be 'very satisfied' with the quality of their new home if it was built by a small and medium-sized (SME) house builder. For further information see: https://www.fmb.org.uk/about-the-fmb/newsroom/consumers-twice-as-likely-to-be-satisfied-with-homes-built-by-small-house-builders/.

The costs of building high-quality, low-carbon and resilient homes are not prohibitive.

Recent modelling suggests that the incremental costs of delivering homes in 2020 that meet ultra-high levels of energy efficiency, whilst incorporating low-carbon heating, are in the region of £1,300-£6,900 representing a 1.1-4.3% increment on build costs. For small developers in higher cost locations costs could be around 130% of base prices (£1,800-£9,100), representing a 1.4-5.7% increment on build costs.[293]

Research conducted for this report has found that low-regret adaptation measures to improve new homes for overheating and water efficiency would cost an additional £1,600-£2,600 for a semi-detached house.[294] However, there are a number of simple design and construction solutions for resilience which would have zero additional cost to builders, for example: ensuring windows provide natural cross ventilation, installing low-flow showers and taps, and raising electrics above floor level in homes at risk of flooding.

Viability impacts are an important consideration in the standard setting process. Local planning authorities could play a role in determining which adaptation measures must be implemented, reflecting local needs. There is evidence to suggest that policies such as energy standards generally represent modest costs as a proportion of development value, and would, at least in part, be passed back to land owners in reduced land value uplift with limited impacts on overall viability and the supply of new homes. A range of steps can also be taken to reduce viability risks associated with tightened standards (Box 4.4).

Box 4.4. Evidence relating to the impact of more ambitious new build standards on development viability

Concerns over more ambitious standards for new homes have historically focused on risks that the supply of housing could be impacted or that standards will exacerbate affordability issues for buyers.

The viability impacts associated with measures will vary with policy design and economic conditions amongst other things. They will also vary nationally, with greater impacts expected to be in areas with low land value/house prices. However it is notable that past impact assessments and viability studies examining the impact of more ambitious energy standards have generally found risks associated with these standards to be limited. The impact assessment for Zero Carbon Homes anticipated that 'additional costs of zero-carbon homes will be largely passed back to land owners in reduced land value uplift', estimating 'the potential to supress the supply of new homes by between 0.5-1.3%, on top of the 1.2% impact on supply caused by other policies' (such as the Section 106 agreements).[295]

Figure B4.4 illustrates the very significant land value growth seen in recent years. The Greater London Plan viability study found that policies such as energy standards 'represent modest costs as a proportion of development value and typically have limited impact on overall viability'.

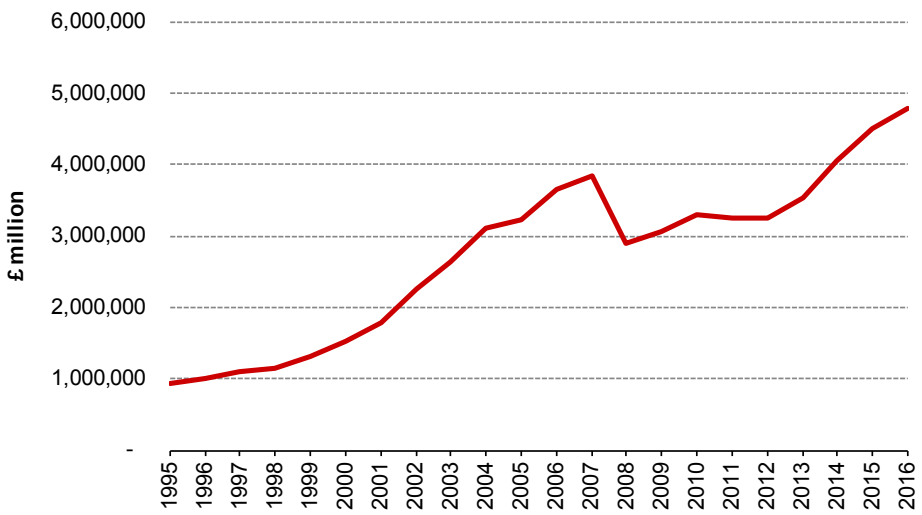
A range of steps can be taken to reduce viability risks, including actions to drive market demand for low-carbon, climate resilient homes, e.g. through fiscal incentives (such as stamp duty or council tax

[293] Currie & Brown and Aecom for the CCC (2019) *The costs and benefits of tighter standards for new buildings.* Range reflects difference between a small flat and a detached home.
[294] Low-regret measures include: high-thermal mass walls and floors, externals shutters, and a water efficiency package of 105 litres per person per day. Homes at risk of flooding could be improved with low-regret resilience and resistance measures for a further £700-1,500. Wood Plc et al. for the CCC (2019) *Updating an assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.* David Langdon for the CCC (2011) *An assessment of the costs and benefits of low-regret climate change adaptation options in the residential buildings sector.*
[295] Communities and Local Government (2011) *Zero Carbon Homes Impact Assessment.*

Box 4.4. Evidence relating to the impact of more ambitious new build standards on development viability

rebalancing) and greater public awareness of the benefits. Costs to developers can also be minimised through a clear and robust policy framework set well in advance, and a targeted package of measures to incentivise and support early movers.

Figure B4.4. Changes in the value of land underlying buildings and structures (1995-2016)



Source: Office for National Statistics (2018) *Aggregate Land Values, 1995 to 2016.*
Notes: Representative of total value of land underlying buildings and structures

Source: Communities and Local Government (2011) *Zero Carbon Homes Impact Assessment*; Three Dragons, Turner & Townsend and Housing Futures Ltd on behalf of the Greater London Authority (2017) *London Plan Viability Study Technical Report*; Office for National Statistics (2018) *Aggregate Land Values 1995 to 2016;* discussions with Pat McAllister, Henley Business School, University of Reading (2019).

4.4 Wider principles to guide the retrofit of existing homes

Building regulations are a key lever for driving up standards in new homes, and play an important role in setting standards for new work to existing homes. However, the retrofit challenge requires a much broader package of policies and actions from developers and homeowners. Given the scale of the challenge, retrofit should be supported by HM Treasury and the Devolved Governments as a national infrastructure priority.

Here we review a range of the recommendations made in previous chapters, in the context of principles for policy development.

Four out of five homes that will be occupied by 2050 have already been built. These householders will generally face the greatest challenges in decarbonising, and adapting to the changing climate.

Unlike new builds, the impetus to, and responsibility for retrofitting existing homes comes largely from the individual householder or landlord. Decision making will be influenced by a

range of factors, including cost, social norms and the inconvenience or 'hassle' associated with retrofitting.

A householder's willingness to take action depends on a number of issues, including:[296]

- Awareness of need.
- Availability of information on appropriate measures, their costs and benefits.
- Availability of funds to make the changes.
- Local, skilled installers willing to undertake work.
- Availability of technologies.

In our 2016 report Next steps for UK Heat Policy, we set out a number of principles to guide the development of effective policy.

We have updated these below, also incorporating adaptation needs:

- A stable framework and direction of travel, backed up by evolving standards for the performance of buildings.
- A joined-up approach to energy efficiency, low-carbon heat, ventilation and cooling that works across the building stock, and focuses on real-world performance.
- Simple, highly visible information and certification alongside installer training to ensure that low-carbon and adaptation options are understood by consumers and that installers are effective and trusted.
- A well-timed offer to households and SMEs that is aligned to 'trigger points', such as when a house is sold or renovated.
- Consistent price signals that clearly encourage affordable, low-carbon, and sustainable choices.

Alongside their relevance to new homes, these principles should remain guiding considerations for the development of policy to drive retrofits in existing homes.

A stable and clear policy framework set far in advance, can deliver long-term policy certainty, encourage innovation, reduce delivery costs and minimise risks associated with ambitious policies.

The need for a stable and clear policy framework relates to areas including:

- **A UK strategy for decarbonised heat**, including clear signals on the future use of the gas grid in the UK and a trajectory of energy efficiency standards covering owner occupied, social and private-rented homes.
- **A long-term strategy to manage flood risks** down to tolerable levels in each part of the country.
- **An action plan to develop a market for resilience measures** including research and development, innovation, support for early movers, and the development of resilience standards.

[296] London Climate Change Partnership (2008) *3 Regions Retrofitting.*

- **Action to assess and reduce the risks of overheating in existing homes**, prioritising passive cooling and behaviour change.
- **Per capita consumption targets for water** which can address future supply-demand deficits resulting from both 2 and 4 degree climate change scenarios.
- **A strategy for retrofitting green sustainable urban drainage** in existing developments to reduce risk of surface water flooding and bring wider benefits.
- **A strengthened approach to locate and design new housing developments around sustainable transport** to increase levels of walking, cycling and use of public transport.

Policy frameworks must also demonstrate a joined-up approach to energy efficiency, low-carbon heat, ventilation and cooling which focuses on real-world performance. 'Whole-house' approaches to retrofit can support efficient long-term investments, in place of piecemeal incremental change.

The Green Finance Taskforce (GFT) recommendation on Green Building Passports offers potential to bring together a number of data sources to provide a holistic and long-term view of renovation needs. Each building would have a digital passport, transferable between building owners, which sets out a customised retrofit roadmap for the building based on fabric and operational data. The intention is to capture EPC data digitally and augment it with other data over time. We support the recommendation that the platform should be expanded to cover issues such as indoor air quality, flooding and overheating.

Area based programmes, such as Local Heat and Energy Efficiency strategies in Scotland, can also play an important role in enabling holistic solutions and efficient implementation. Many of the barriers to action (e.g. disruption from changes, the need to find a trusted installer, financing constraints) are shared across types of measure, and improvements in one component of the building fabric can have important interactions with another (for instance the synergies between improved energy efficiency and low-carbon heat, and interactions between thermal efficiency, overheating and indoor air quality).

Simple, highly visible information and certification are needed alongside installer training.

Awareness of low-carbon heating, energy efficiency and adaptation options is generally low. A key policy focus must be improved information. Green Building Passports and a new Code of Practice for property-level flood protection can play a role.

We have already considered the critical role of installer training, and appropriate accreditation schemes to build consumer trust and help consumers select trusted and competent installers. There is also a need for expert advisors to be available to support households in planning and undertaking works.

Consistent price signals, with offers aligned to trigger points, are needed to drive uptake of measures.

In the area of energy efficiency, a survey by EEVS Insight and Bloomberg New Energy Finance finds that 21% of energy efficiency suppliers see policy uncertainty as their primary issue of concern.[297] Results from the Low Carbon and Renewable Energy Economy Survey run by the

[297] EEVS insight and Bloomberg New Energy Finance (2018) *Energy Efficiency trends Vol. 21*.

Office of National Statistics also show that full time employees working on 'energy efficient products' in the construction industry dropped from 67,000 in 2014 to 37,000 in 2016.[298]

While many energy efficiency improvements are already financially attractive, some other measures, including most low-carbon heat options, would not currently be attractive without public subsidy or incentives. Actions will be needed to provide consistent price signals in order to drive uptake, including:

- **Reviewing the balance of tax and regulatory costs across fuels** in order to improve alignment with implicit carbon prices and reflect the progressive decarbonisation of electricity.
- **An appropriate support framework for low-carbon heating** including financing for heat pumps, biomethane, and networked low-carbon heat.
- **Implementing the Green Finance Taskforce recommendations** to facilitate access to capital for low-carbon and resilience improvements.

Frameworks must create an attractive package for householders, aligned to 'trigger points' such as when a home is purchased, a boiler breaks down, or when other renovations are taking place.

Recommendation: Improve consumer access to data and advice by implementing the GFT proposal on Green Building Passports, improving EPCs and access to data underpinning EPCs and SAP, and identifying options to go further in particular to include resilience measures. Water efficiency, flood resilience and other resilience measures should be considered in digital 'green passports', and resilience surveys or Flood Protection Certificates developed alongside EPCs.

(Owner: BEIS, HMT, devolved administrations. Timing: 2019-2020).

Recommendation: Implement GFT recommendations around green mortgages and fiscal incentives to encourage uptake and support financing of upfront costs. To help drive the market for resilient products and services the Government should also look to widen the scope of green finance to include resilience.

(Owner: BEIS, HMT. Timing: 2019).

4.5 Local authority action to deliver low-carbon, resilient homes

Local and regional authorities are well placed to drive and influence emissions reductions, and adapt their localities to a changing climate, through the services they deliver, their role as social landlords, trusted community leaders and major employers, and their regulatory and strategy functions.

Local and regional authorities have a number of key levers in reducing emissions and adapting localities to a changing climate, including planning functions and enforcement. They are also uniquely placed to join up and support the chain of decision-makers (e.g. householders, social landlords, installers and suppliers).

With regard to reducing emissions, local and regional authorities have a critical role in decarbonising heating in buildings and in leading the reduction in emissions from transport:

- **Heat.** Supply and demand for heat is by nature more specific to local areas than electricity production and consumption, due to the relative difficulty in transporting heat over long

[298] Office for National Statistics (2018) *Low carbon and renewable energy economy final estimates.*

distances. Long-term national planning relies on regional spatial planning together with coordination, support, capacity-building and public engagement at a local level.

- **Energy efficiency.** Local authorities have an important role in ensuring new housing is energy-efficient. Under the planning system, local authorities can prepare Local Development Plans which identify sites for specific land uses (e.g. new housing) and set out the criteria for approving planning applications, including energy efficiency standards for new homes that exceed current building regulations.[299] The Scottish Government has consulted twice on a statutory requirement for Local Authorities to prepare Local Heat and Energy Efficiency Strategies (LHEES). These would set the strategy and a framework for reducing energy demand and decarbonising the heat supply of buildings in the area covered, across the timeframe of the Scottish Government's Energy Efficient Scotland programme. Approaches are being piloted across Scotland's local authorities at present. Across the UK, local authorities have a general duty to enforce building regulations, as well as duties to enforce Energy Performance Certificate (EPC) legislation.[300]
- **Transport.** Local authorities are responsible for local transport plans, and play a key role in applying for funding for new infrastructure for walking and cycling, defining transport requirements for those in new homes and influencing travel demand through parking charges and other levies to deter people from driving into busy town centres. In some cases, local authorities, local enterprise partnerships and local MPs have been able to lobby for new rail stations to be opened in areas of housing growth. Other local authorities have led initiatives to promote electric vehicle uptake.

Local and regional authorities have an equally critical role in climate adaptation. In England, local authorities are key partners in delivering many aspects of the National Adaptation Programme (NAP). Addressing climate change is a key component of delivering sustainable development and is a strategic priority in the NPPF.[301] Local authorities are well placed to understand the short and longer term risks faced by their communities, and to lead and facilitate action to address them:

- **Minimise flood and coastal erosion risk.** In line with the National Planning Policy Framework (NPPF), local authorities are advised to avoid inappropriate development in areas at risk of flooding and coastal change. Where such development is unavoidable, it should be delivered in a way which does not increase the risk of flooding elsewhere. The NPPF also requires local authorities to prioritise the use of sustainable drainage systems (SuDS) in developments (see Chapter 3).
- **Retain and enhance green infrastructure.** The NPPF advises local authorities to take a strategic approach to planning for the creation and protection of green spaces. This can include measures such as green roofs, targeted urban tree planting, and constructed wetlands. Such measures can help to keep urban areas cool in summer and manage storm water in periods of heavy rainfall.
- **Address overheating risk.** Local planning policies can reinforce the need for new developments to be planned and designed (e.g. orientation, shading, window design and

[299] In Scotland, Local Development Plans are also required to include a greenhouse gas policy that seeks to achieve emissions reduction through the use of low and zero-carbon generating technologies. See The Town and Country Planning (Scotland) Act, 1997, section 3F.
[300] EPCs, which provide an assessment of the energy efficiency of a home, are mandatory on re-letting or a sale of a property, and compliance is carried out by local authority trading standard departments.
[301] DCLG (2014) *Climate Change Planning Practice Guidance.*

ventilation) to manage internal temperatures. The NPPF now includes a requirement for local plans to consider overheating risks.

- **Deliver resilient infrastructure.** Local Planning Authorities (LPAs) are responsible for ensuring that new infrastructure is designed and appropriately located to take current and future climate change risks into account.

The devolution of powers and budgets to core city regions in England has changed the way that services can be funded and needs prioritised by the local government sector. There are 10 core city regions across the UK and six 'metro mayors' for combined authorities. They offer opportunities for local leadership on climate change as part of policies that promote regional growth and investment in housing and transport, and in some cases also public health and social care.[302]

Local and regional authorities have played a valuable role in driving improvements (Box 4.5).

Box 4.5. Examples of local and regional authorities driving improvements

Better Homes Yorkshire: Better Homes Yorkshire is a joint programme managed by the West Yorkshire Combined Authority and Leeds City Region Enterprise Partnership. It aims to help residents (owners, tenants and landlords) in the participating ten local authority areas to take advantage of Government funding options to make energy efficiency improvements to their homes.

Greater London Authority's London Plan: A zero-carbon target for major residential developments has been in place for London since October 2016, and is planned to apply to major non-residential development from 2019. The new draft Plan also includes requirements for planners to ensure buildings are designed to adapt to a changing climate, through making efficient use of water, and reducing impacts from natural hazards like flooding and heatwaves.

Climate Ready Clyde: Climate Ready Clyde is a place-based adaptation initiative, set up by Adaptation Scotland in 2012. The partnership includes 13 funding institutions: the University of Strathclyde, Scottish EPA, Transport Scotland, Strathclyde Partnership for Transport, Scotia Gas Networks, NHS Greater Glasgow and Clyde, University of Glasgow and six unitary authorities. The partnership has produced a regional climate change risk assessment building on the method used for the UK CCRA, which considered risks to the housing stock in the region. This assessment will feed into a regional adaptation strategy and action plan.

Greater Manchester: Greater Manchester plans to locate new housing in and around existing town and regional centres, easily served by public transport with key local facilities within walking and cycling distance. Developers will also be encouraged to provide space for car clubs and charging points for electric vehicles.

Source: For further information of Better Homes Yorkshire see: https://www.betterhomesyorkshire.co.uk/; for the London Plan see: https://www.london.gov.uk/what-we-do/planning/london-plan; the Greater London Authority had also planned to require the operational energy use of new development to be reported after completion, although this requirement has recently been removed following consultation; AECOM for the CCC (2018) *Adaptation actions in cities: what works?*; Transport for Greater Manchester (2017) *Greater Manchester: Transport Strategy 2040: Our Vision*.

[302] The ten core city regions are: Birmingham, Bristol, Cardiff, Glasgow, Leeds, Liverpool, Newcastle, Nottingham and Sheffield. The six metro mayors elected are for: Cambridgeshire and Peterborough; Greater Manchester; Liverpool City Region; Sheffield City Region, Tees Valley; West Midlands; and the West of England.

These examples illustrate the considerable ambition of some local authorities, but many struggle to assemble capacity and resources at the scale necessary to make material impacts.[303]

Local authority funding remains extremely limited. There is also evidence that climate change has been de-prioritised in the land-use planning system.

In 2012, we recommended a clear statutory duty and/or additional funding to ensure local authorities have stronger incentives to act. However, there is still no clear statutory requirement for local authorities to take action on climate change and funding remains extremely limited. There have been a number of recent changes to planning frameworks for local authorities:

- Where local authorities are pushing ahead with low-carbon programmes (such as low-carbon heat networks) and adaptation, this is non-statutory. The same is true of the UK's 39 Local Enterprise Partnerships (LEPs). The indicators which LEPs are monitored against are in terms of outputs such as new homes and jobs created, rather than low-carbon growth, efficiency savings or resilience, meaning that any focus on the opportunities for low-carbon growth (as seen in Leeds) and adaptation is effectively voluntary. Revisions to England's NPPF in 2018 have clarified and improved some aspects of planning for transport, flood management and overheating, but have removed the requirement for active support of energy efficiency improvements to existing buildings, and have failed to clarify how far local and regional authorities are permitted to go in setting tighter standards for new build homes.
- There is evidence that **climate change adaptation has been de-prioritised** in the land-use planning system. The resilience projects that are undertaken are focussed on flood risk management to address immediate issues. A published study by the Town & Country Planning Association (TCPA) concluded that local authorities are not using planning policy, as they are required to by law, to make progress on climate change mitigation or adaptation, and that for most local authorities there continues to be a focus on flood risk management with little attention paid to other aspects of adaptation.[304]
- The **central government funding** that was in place to engage and support local authorities on climate change adaptation in England has come to an end. This has resulted in the closure of the Environment Agency's Climate Ready Support Service, the Local Government Association's 'Climate Local' initiative, Climate UK, and more than half of Climate UK's regional climate change partnerships in England. Scotland and Northern Ireland still maintain an adaptation research and advice function through SNIFFER and Adaptation Scotland. Appropriate funding is also required to discharge responsibilities around enforcement of building regulations and wider government policies (for example EPC certificate requirements). A recent report by the National Audit Office found a 49% reduction in government funding for local authorities between 2011 and 2018, with a 48% reduction in spending on building control between 2011 and 2017.[305]
- Greener Journeys, a submission of evidence to the Health and Bus Market Inquiry, suggest that local authorities do not have the funding and structures required to develop integrated strategies for transport, employment and housing.[306] Fragmented competitions for funding,

[303] Webb et al. (2016) *Sustainable Urban Energy Policy: heat and the city.*
[304] TCPA's assessment of 64 Local Plans published since England's NPPF was introduced in 2012 highlighted a "large-scale failure" to implement the requirements of national planning policy, and specifically the policy requirements underpinned by the 2008 Climate Change Act.
[305] National Audit Office (2018) *Financial sustainability of local authorities 2018.*
[306] Greener Journeys (2018) *Written evidence in submission to the Health of the Bus Market Inquiry.*

run across a variety of government departments, have provided only short term funding and little long-term certainty, with a significant proportion of council resource being devoted to the application process.

- The decision to leave the European Union will impact local authorities' access to **EU funding sources** and networks, such as the European Investment Bank[307] and European Structural and Investment Funds (ESIF). The last Government committed to maintain funding to ESIF projects signed before the UK leaves the EU. It is not yet clear what domestic measures, if any, will replace ESIF in the longer-term.

Our 2017 Adaptation Committee Progress Report concluded that the current and future outlook for local government funding remains extremely challenging.

The regulatory and policy framework must incentivise and enable local and regional authorities to take action and be ambitious.

The local planning and development system should support the transition to a low-carbon future in a changing climate, and be capable of dealing with the complex interrelationships between people and their environments. Local authorities should be ambitious with local action or, at a minimum, facilitate those who wish to be. The policy and regulatory framework should support this, including enabling action across authority boundaries (such as public transport, cycling networks or low-carbon district heating systems) where necessary. For example:

1. Public bodies have a duty to co-operate on planning issues, particularly those that relate to the strategic priorities for Local Plans as set out in the NPPF. Local authorities should exercise this duty as part of their plan making function, and apply it to address climate change risks that cross administrative boundaries. In the absence of sufficient integration there is a risk that responses to climate change will be event-led and piecemeal, with opportunities missed to reduce emissions and adapt effectively at low cost.
2. There is significant potential for Local and Regional Authorities to drive up the quality of our homes. There are a number of authorities who are taking the lead (for example the Greater London Authority and its Zero Carbon Plan), and many more who would like to play a stronger role. To do this, Government urgently needs to clarify how far Local and Regional Authorities are permitted to go in setting more ambitious standards for new build homes.[308]
3. There is a potential role for the development of a building standards framework, similar to the Energy Step Code in British Columbia (Box 4.6). This could allow Local Government to play a leadership role in energy and water efficiency whilst providing some degree of standardisation to minimise administrative costs for developers.
4. Local authorities must be given appropriate support, funding and frameworks to take action and enforce regulations. Local authorities should have access to the technical expertise, guidance and practical tools they need to fully exercise their responsibilities. The Hackitt

[307] In April 2018 the European Investment Bank agreed a €1.1 billion investment in energy and the environment
[308] Following the publication of a Written Ministerial Statement in March 2015 (see: https://www.gov.uk/government/speeches/planning-update-march-2015), there has been uncertainty over whether local authorities are permitted to set energy performance standards which exceed the equivalent of Code for Sustainable Homes Level 4. In its summary response to the draft revised National Planning Policy Framework consultation the Government stated that 'local authorities are not restricted in their ability to require energy efficiency standards above Building Regulations'. See MHCLG (2018*) Government response to the draft revised National Planning Policy Framework consultation*. However a more formal statement explicitly clarifying the ability of local authorities to set standards which exceed the equivalent of Code for Sustainable Homes Level 4 is needed in order to provide local authorities with the confidence to act.

review identified the need for more rigorous enforcement power and more serious penalties, including powers to require changes to work that fail to meeting Building Regulations.

Box 4.6. British Columbia Energy Step Code

In Canada, British Columbia has a goal for all new buildings to be net-zero energy ready by 2032. In 2017 it introduced the British Columbia (BC) Energy Step Code, a voluntary provincial standard that paves the way for this progress. The BC Energy Step Code provides an incremental and consistent approach to achieving more energy-efficient buildings. It establishes a series of measurable, performance-based energy-efficiency requirements for construction that builders can choose to build to and communities may voluntarily choose to adopt in bylaws and policies when ready. The first step is the base BC Building Code and the highest represents a net-zero energy ready standard.

The Code does not specify how to construct a building, but identifies an energy efficiency target that must be met and lets the builder decide how to meet it. This supports consumer choice, empowers builders to pursue innovative, creative, cost-effective solutions, and allows them to incorporate leading-edge technologies as they become available.

The Code provides a consistent approach that allows the market to gradually build capacity and skills and reduce costs over time. The policy has benefitted from industry support, as a result of the clarity it has provided around defined standards, communicated well in advance. It is expected to further BC's role as a green building and construction leader.

Source: British Columbia (2017) *BC Energy Step Code: A Best Practice Guide for Local Governments*; https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/energy-efficiency/energy-step-code

Recommendation: MHCLG must clarify the rights and obligations of local and regional authorities in relation to climate change mitigation and adaptation. This includes clear statutory duties, and clarification of how far local and regional authorities are permitted to go in setting tighter new build standards.

(Owner: MHCLG. Timing: 2019).

Recommendation: Fund local and regional authorities adequately to drive and influence emissions reductions and adapt their localities to a changing climate, and to discharge their responsibilities in relation to the enforcement of building regulations and wider Government policy.

(Owner: HMT. Timing: 2019 spending review).

Glossary

Climate change adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Climate change mitigation: A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Energy Performance Certificate: The Energy Performance Certificate provides details on the energy performance of the property and what householders can do to improve it. This includes an estimate of energy costs (using the Standard Assessment Procedure) and a measure of carbon efficiency. An Energy Performance Certificate is required for UK properties when constructed, sold or let.

ECO: Energy company obligation. A Government energy efficiency scheme in Great Britain to help reduce carbon emissions and tackle fuel poverty.

Flexibility: Modifying generation and/or consumption patterns in reaction to an external signal (such as a change in price) to provide a service within the energy system.

Heat pump: High efficiency electric heating which uses a vapour compression cycle (also used in fridges) to upgrade ambient heat. This process means that it can typically produce three units of heat (or more) for every unit of electricity used, with very low overall carbon emissions.

Heat network: Also known as district heating, it is the practice of piping hot water between buildings for space heating and hot water ('central heating for cities').

Household: One person living alone, or a group of people (not necessarily related) living at the same address who share cooking facilities and share a living room, sitting room or dining area.

Low-carbon heat: This covers efficient non-fossil-fuel based heating such as electric heat pumps, geothermal heat, biomass boilers and low-carbon gas such as hydrogen and biomethane. It also typically refers to the use of district heating systems in heat dense areas (e.g. cities) to distribute low-carbon heat.

Low-regret adaptation measure: An adaptation measure that is cost-effective to implement today; where the benefits are less sensitive to precise projections of the future climate; and where there are co-benefits or no difficult trade-offs with other policy objectives.

Peak demand: Peak demand is the maximum amount of energy required at any one moment in a year, typically around 17.30 on a winter weekday evening.[309]

Property: An individual dwelling (e.g. house, flat, studio, either owned or rented).

Property-level flood resilience and resistance: Measures to homes that reduce the impact of flood water on the building. These include measures that stop water entering properties (e.g. door guards), and materials that allow a building to be restored more quickly such as waterproof plaster or placing sockets higher up on walls.

SAP (Standard Assessment Procedure): The methodology used by the Government to assess and compare the energy and environmental performance of dwellings. It is the basis for establishing compliance with Building Regulations, and for Energy Performance Certificates.

SuDS: Sustainable Drainage Systems. SuDS aim to alleviate surface water flooding by storing or re-using surface water at source, by decreasing flow rates to watercourses and by improving water quality.

[309] See: http://fes.nationalgrid.com/media/1264/ev-myth-buster-v032.pdf

Glossary

Urban heat island: A man-made area that is significantly warmer than the surrounding countryside. Heat islands exist because the land surface in towns and cities, which is made of materials like tarmac and stone, absorbs and stores heat. This is coupled with concentrated energy use and less air flow than in rural areas, creating a heating effect that is especially pronounced at night.

Vulnerable person: Someone who is susceptible to and unable to cope with adverse impacts of climate change, including climate variability and extremes.

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