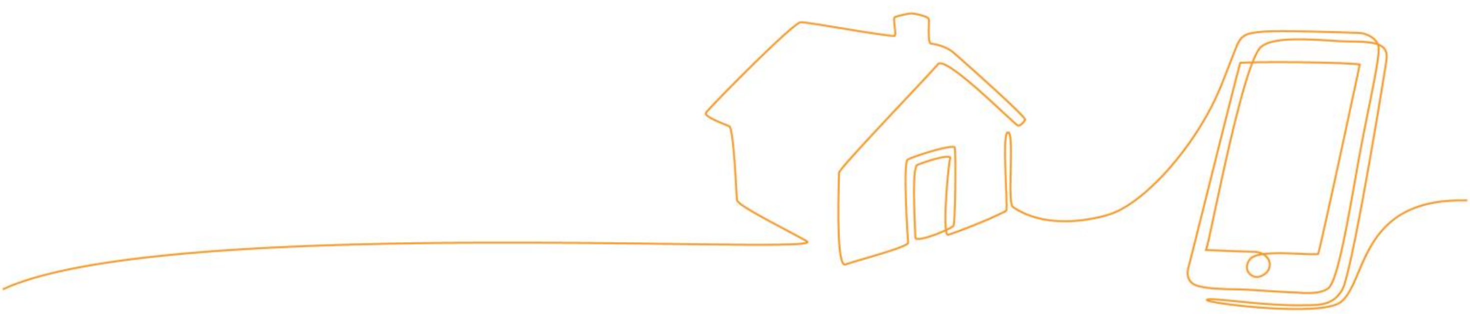
SMART METER BENEFITS

ROLE OF SMART METERS IN RESPONDING TO CLIMATE CHANGE

A DELTA-EE VIEWPOINT

MAY 2019



Delta-ee are a leading European research and consultancy company providing insights into the downstream "new energy" markets with a strong focus on the customer.

Our focussed research services include Flexibility and energy storage, Electrification of heat, Electric vehicles and electricity, Customer data value, Connected homes, and "New energy" business models. We also provide consultancy for clients including network companies and policy making bodies.

We've been asked to independently explore and communicate how smart meters are a central part of our vision for the low carbon energy system of the future, and to show the extent that smart meters are fundamental to achieving our climate obligations.

Smart meters, as a key piece of infrastructure themselves, are a facilitator which enables a large range of new and innovative energy products and services. They are part of the architecture of this new energy system. To understand the benefits, a broader spectrum of changes in the energy system must be explored and understood.

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Smart meters in our future low carbon energy system

The transition of the energy system to a more flexible, decentralised and decarbonised system is central to the UK reducing its CO_2 emissions whilst providing a reliable, sustainable and cost-effective solution for customers now and in the future. The increased complexity of the system and the need to be able to flexibly match supply and demand means that digitalisation is an important part of the transition. Central to digitalisation is the accurate measurement of customer energy demands so the system can provide energy in the most carbon-efficient and cost-effective way, and customers can accurately understand how they use energy.

The roll out of smart meters will provide the means to measure customers' energy demands, providing the vital information for many of the other changes to happen and support and reward them to shift demand to lower peak periods. For the first time, it will be possible to measure how much electricity is being used in real time by each customer. The consistent open approach used by smart meters to capture consumption data provides access to many innovative supply and services companies to offer customers better propositions whilst enabling the energy system to become decarbonised, improve its operational efficiency, and reduce the need for high levels of energy infrastructure investment. It is impossible to see how the UK can decarbonise as quickly without smart meters in place.

Without the national smart meter roll out, there will be a more fragmented market, stifling innovation, artificially creating winners and losers, and ultimately offering poor value to customers and making CO_2 reduction more challenging. Without smart meters, achieving high uptake of low carbon renewable generation could be limited due to lack of flexibility in the system, and alternative solutions such as fossil generation with CCS, or nuclear may be increasingly required. Given the current status of CCS, and the high cost and delay of new nuclear plant, this presents a significant risk to meeting the UK climate change targets.

Smart meter benefits are immediately apparent and there are very clear use cases for enabling decarbonisation. However smart meters are a facilitator for innovation and many of future use cases and benefits have probably not yet been thought of. In this respect they are very similar to the early versions of the internet or smart phones.

The evidence in this report and the accompanying report on cost savings draws on evidence from existing mechanisms, and shorter-term innovations and business models. Longer term, there are likely to be many more benefits realised through innovation, and so this report represents a conservative viewpoint which will probably only get better.

Summary and Highlights

Climate change is the largest challenge facing our generation. The UK has strong ambitions to reduce climate change causing emissions and alleviate the worst impacts of global warming. However, the recent IPCC (Intergovernmental Panel on Climate Change) special report on the impact of rising temperatures has given a clear message that we need to go even further, even quicker.

Changes in the energy system have already begun to put us on a trajectory of a clean, green future, but it is a big challenge. Ambitious targets have been set and it will take considerable effort and political will to get us there. The UK energy system is undergoing a transformation with low carbon generation replacing the burning of fossil fuels. We see smart meters as a key part of this future energy system and believe that they will enable us to decarbonise more quickly.

Smart meters are part of a flexible energy system which will allow for more renewable generation and less reliance on nuclear, CCS and fossil fuels. In the low carbon energy system of the future, we must more closely match demand to supply, especially with greater electrification of transport and heat. Smart meters will enable dynamic control of demand and for customers to be incentivised to use energy at times of high renewable supply.

Smart meters are already enabling households to better understand the energy they are using, and to reduce demand. Smart meters are already helping households engage with their energy use. As well as the direct CO_2 savings these behaviour changes enable, enabling consumers to be more aware of their energy use allows them to make better informed decisions, and participate in a range of new services aimed at reducing CO_2 and cost.

Smart meters will help accelerate the uptake of energy efficiency measures, low carbon heating and electric vehicles through adoption of new low carbon products and services. Low carbon technologies are not sufficiently attractive at present for households to be adopting them at the scale needed to tackle climate change. Innovative service models such as heat-as-a-service offerings could help householders get over barriers such as upfront cost and perceived risk. Smart meters will provide the data required for these services to be developed.

Without smart meters, the energy transition and carbon reductions will be higher cost, less supportive of renewable generation, and less well co-ordinated. This will result slower progress towards saving CO_2, reliance on higher risk CO_2 reduction strategies and technologies, and ultimately a higher risk of not achieving mitigation targets.

Introduction – a low carbon future

In the UK and in all other industrialised nations around the World, we are faced with the imperative to reduce climate change causing emissions[1] to prevent the worst effects of climate change. The adoption of the Climate Change Act[2] in 2008 committed the UK to reduce our green-house gas emissions by 80% by 2050 compared to a 1990 baseline. The recent IPCC special report[3] (published in October 2018) highlighted that we need to go further, to cut more carbon even more quickly to ensure a global temperature rise does not exceed 1.5 °C (more details of the policy landscape are given on page 6).

The IPPC report signals that we need to have a major decline in global emissions well before 2030 and be net zero carbon by 2050. This means:

- removing gas boilers from homes and replacing them with low carbon heating systems or providing all of the gas they are going to burn from carbon neutral biogas and hydrogen.
- no cars running on conventional petrol and diesel, instead replacing them with cars which run on renewably generated electricity or synthetic renewable fuels
- power generation no longer emitting carbon dioxide to the air, and electricity generation being made up of a combination of renewables, nuclear and conventional power stations with carbon captured and stored underground.

This is a huge challenge, and part of the answer is powering heat and transport with efficient electric technologies. These then need to be powered via a smart, flexible, electricity network, including smart meters in each home. Another part of the answer is reducing our demand, and smart meters can help households to improve their understanding of the energy they are using and to manage it better.

The aim of this report is to illustrate and evidence how smart meters can help us to meet our carbon reduction challenge by building a low carbon, smart, energy system.

Featuring in this report, we begin by identifying what is currently being done to meet our climate change targets, by looking at existing and future policy progress and ambition around decarbonisation (p6). We then present the key actions that are needed in the three sectors related to households - homes and heating (p11), personal transport (p13) and electricity generation (p15) – and how smart meters can accelerate these. We consider what the alternative would be without smart meters at the heart of the energy system transformation (p17). We then conclude by outlining what the challenges are in the short term, and what the impact will be in the long term (p18). Notes, references, and more details are given in the appendix (p19).

UK policy timeline and ambition

2008 — The UK Climate Change Act.

The Climate Change Act commits the UK government by law to reducing greenhouse gas emissions by at least 80% of 1990 levels by 2050. The Act has given a clear signal of political ambition and has helped to maintain cross-party consensus. The Act has inspired other countries to bring in similar legislation (such as Sweden) and it has shown the UK's position as an international leader in climate change action.

Ongoing — Committee on Climate Change Carbon Budgets

The Committee on Climate Change (CCC) is an independent body which has guided the UK's overall direction of travel on climate change, separate from political fluctuations and focused on the long-term target. They set a trajectory of 5 year aims, called carbon budgets, which are presented to and agreed by UK Parliament. The latest was the 5th carbon budget setting the ambition for the period 2027 – 2032[4].

2017 — Clean Growth Strategy

The Government's Clean Growth Strategy sets out how it intends to meet the 4th and 5th carbon budgets. It outlines ambitious actions across all sectors, but it has been criticised for lacking substance to meet the aims it has outlined. There are concerns[5] that without firm plans to flesh out the current proposals we are off track to deliver the required emission reductions in the 2020s and 2030s.

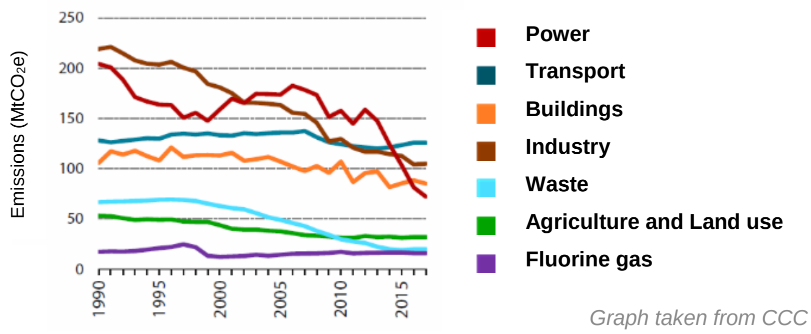
2018 — IPCC special report on 1.5°C Global Warming

The IPCC special report was prepared in response to the 2016 Paris Agreement[6] made by 192 countries to limit global temperature rise to 1.5 °C. It reiterated the importance of restricting warming to 1.5 °C compared to 2 °C highlighting that there is a substantial difference in the severity of impacts of climate change with higher levels of warming. Even a 1.5 °C warming still exposes most of the globe to sea level rise, biodiversity loss, climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth. The report presents the results of climate models concluding that we require deep emission reductions in all sectors to globally reach 45% reduction in greenhouse gas emissions from 2010 levels by 2030 and reaching net zero by around 2050. The UK's share of this higher ambition goes beyond the ambition of the Climate Change Act and the CCC have been asked to review the UK's climate change obligations in light of this report.

UK policy highlights

A review of current progress, plans and policy highlights three key items:

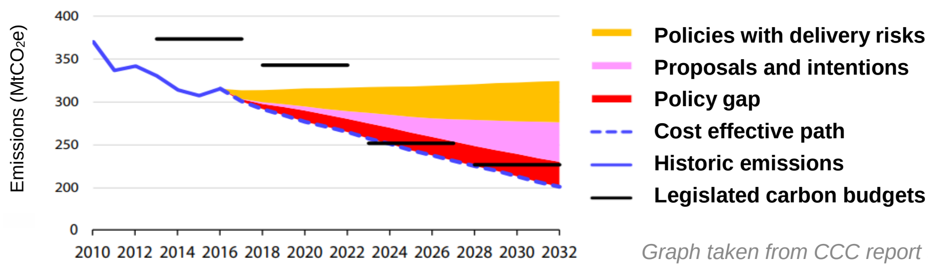
1) The main progress has been in electricity generation



Graph taken from CCC report to parliament (2018)[7]

Since 1990, the greatest decarbonisation in the UK has been through the increase in renewable generation (even since the dash for gas in the 1990s). In 2018, renewable generation installed capacity rose above fossil fuel generation capacity for the first time[8]. As buildings and transport decarbonise through electrification, the electricity sector will need to be even more ambitious. This leads to even greater challenges to understand a changing demand and match it to intermittent supply. Smart meters can play a key part in enabling greater flexibility.

2) Policy gap to most cost effective ambitious trajectory



Graph taken from CCC report to parliament (2018)[7]

This graph shows the path for decarbonisation recommended by the CCC compared to UK policy ambition. The pink sector shows the intentions that require policies and laws to back them up. The red sector shows the gap between current ambition and the most cost-effective path to decarbonisation. Clear policies are needed to close this policy gap and turn the ambitions into action. This means that even more action is needed in multiple sectors and plans need to be even more ambitious than they currently are. With 36% of emissions being related to homes and households, greater visibility of energy use and the ability to shift the time of day energy is consumed using smart meters could help this to be better managed and possibly contribute to closing this gap.

3) Ambition by 2030 is low for buildings compared to other sectors

The CCC's fifth carbon budget outlines only 24% CO_2 emission reductions in buildings by 2030 despite there being multiple co-benefits of improving energy efficiency of buildings including improved comfort and alleviation of fuel poverty. One reason for this is the challenge posed by action needed in millions of individual homes. This sector requires large changes in the types of heating systems installed and rates of energy efficiency retrofit need to increase significantly. We believe that to enable this scale of change, service-based heating propositions will be important. (see box on p12).

The role of smart meters in delivering low carbon policy

The UK has set out a clear decarbonisation trajectory based on the CCCs carbon budgets. Within these there is flexibility to deliver savings through a range of measures which broadly fall into supply side (such as renewable generation), or demand side (such as energy efficiency) measures.

The energy system must be configured to facilitate these supply and demand side measures, and the current networks, control systems, market mechanisms, and regulatory frameworks will need to evolve significantly to provide the necessary levels of flexibility and optimisation. Digitalisation will help deliver this transition and energy data from smart meters is a vital component of this. Without this transition in the system, many of the low carbon energy sources and efficiency measures will not be accessible.

The table below identifies the role of smart meters across major elements of supply and demand side decarbonisation.

	Decarbonisation scenario	Why smart meters are important	What may happen without smart meters
Supply – Electricity	**Renewable electricity generation** provides one of the lowest cost, highest CO_2 saving, and cleanest solutions. Technology costs have seen major reductions and a high renewables scenario could be the most reliable and lowest risk ways of delivering CO_2 savings using proven commercial technologies.	Smart flexible networks will be essential in facilitating a high renewables scenario to accommodate high levels of intermittent generation with storage and flexibility services. Smart metering of some form is essential to provide this flexibility and the national smart meter roll out provides the lowest risk, highest uptake and most inter-operable solution to this.	Without smart meters, it will be much harder to integrate high levels of renewable generation. The alternative solutions look risky, with nuclear generation having much higher costs and major issues in delivery of new schemes, and carbon capture and storage (CCS) being unproven at scale. It is likely that with or without CCS, the continued use of fossil fuels will feature including from new sources such as hydraulic fracturing.
Supply – Heat	**Electrification of heating** in the domestic and commercial sectors will provide a large element of heat de-carbonisation along with low carbon gas. Smarter electricity networks and generation will be required to meet this increased heating demand and there will be greater integration of the gas and electricity vectors to help balance loads.	In combination with a high renewable supply mix, smart meters are vital to enable the development of smart gas and electricity networks, Low carbon non-fossil gas sources are likely to be more limited in supply and expensive than natural gas, and smart meters will allow more efficient and optimised use.	Without smart meters, decarbonisation of heat will be more challenging and achieved at a slower pace. Lack of flexibility in the electricity system and less ability to balance loads between heat and electricity will make it more likely that high carbon natural gas is used longer into the future. There will be fewer incentives for customers to optimise their heating supply.

	Decarbonisation scenario	Why smart meters are important	What may happen without smart meters
Demand – energy efficiency	**Energy efficiency** forms the foundation of saving CO_2 through reducing baseline demands. Achieving future CO_2 targets requires major reductions in energy demands across all sectors, in particular heating demands.	Smart meters enabling data analytics and demand disaggregation will provide insight into where energy efficiency improvements can be made. Energy efficiency measures and services can be much better targeted and tailored to provide the right customer solution. Supply services enabled by smart meters (e.g. time of use tariffs) will allow customers to benefit more from the efficiency improvements.	Without smart meters, there will remain a lack of insight into where efficiency improvements can be made, and less benefit to customers from the energy savings possible. Improvements to energy efficiency are likely to remain slower with lower levels of penetration. The drivers will be weaker with less customer benefit and limited potential for innovative efficiency services.
Demand -Decentralised generation and storage	'Behind the meter' **distributed generation and storage** will increasingly be used to generate and balance energy at a local and customer level. Localised generation and balancing reduces the need for centralised generation and network reinforcement, allowing a quicker uptake of low carbon generation driven by consumers.	Smart meters are essential to provide the ability to flexibly manage generation and storage and ensure that customers get the most value. This local flexible management also allows greater uptake of large-scale renewables	Without smart meters, behind the meter generation and storage will not have access to the broader value they provide to customers and are likely to see lower uptake. This will result in slower decarbonisation of the energy system, and potentially maintaining the need for higher carbon or risk forms of generation such as fossil based (with or without CCS) and nuclear.
Demand – innovative energy services and business models	**Innovative energy services and business models** will transform the way energy is bought and sold. These will ensure that customers receive the outcome they need (for example homes heated to a comfortable temperature), but through optimisation of the energy supply to allow more flexible operation and high levels of decarbonisation.	Innovation in services and business models will be heavily reliant on demand profiles and the timing of energy demand. Smart meters are essential in obtaining this information in a coordinated and reliable manner.	Without smart meters, many of the innovative services and models aimed at optimising energy demand will not function. Proprietary solutions will be required which will stifle innovation, reduce uptake, and result in more controllable generation (potentially fossil with or without CCS) and nuclear.

This report focuses on activities across three sectors where significant CO_2 reduction will be facilitated by smart meters: Homes, Transport, and Electricity generation. The diagram below shows the importance of these sectors in delivering CO_2 savings facilitate by smart meters based on the CCC's carbon budget trajectories.

Homes: In our low carbon future, UK homes need to be more thermally efficient and electric heating will replace or supplement gas boilers in many houses.

Smart meters will contribute to a 25% CO_2 saving by 2035 (from 2015 levels). Smart meters can help households use energy more efficiently and reduce the impact of electric heating on the electricity grid. We think smart meters will help new business models to get established, which change the way we buy and operate heating systems and buy energy efficiency

Without smart meters, the combination of lower energy efficiency uptake and less demand optimisation and flexibility will result in higher overall energy demands, and reliance on higher carbon energy sources.

Transport: In our low carbon future, electric vehicles and low carbon fuels will replace petrol and diesel combustion engines.

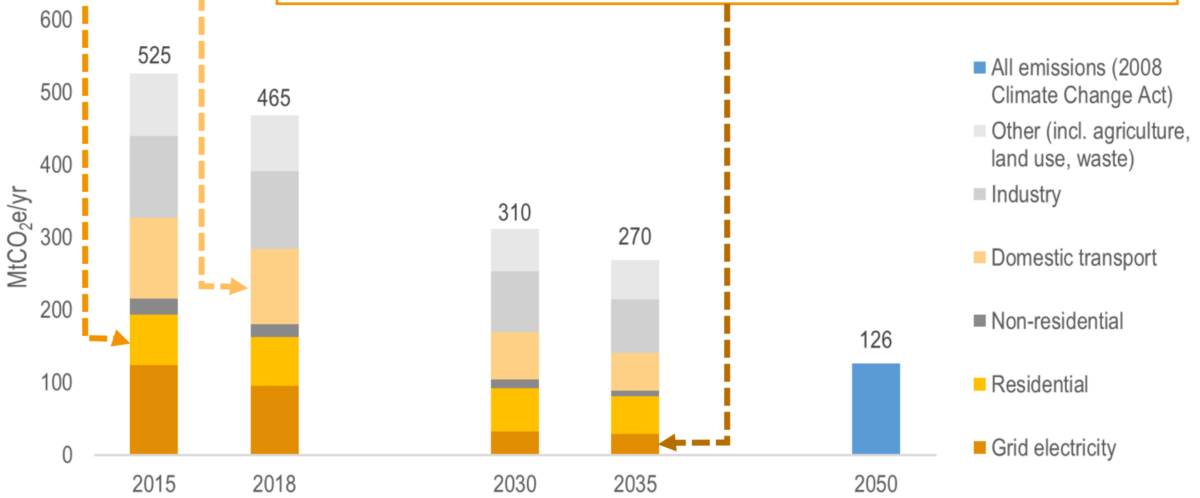
Smart meters will enable high levels of electrification delivering 54% CO_2 reduction by 2035 (from 2015 levels). Smart meters can help to enable car owners to charge at off peak times and could communicate dynamic price signals to smart chargers.

Without smart meters, high levels of transport electrification will be more challenging resulting in longer term use of fossil fuels and higher carbon electricity, with the associated CO_2 emissions and air quality issues.

Electricity generation: In our low carbon future, electricity generation needs to be almost zero carbon, despite demand being higher due to the electrification of transport and heat.

Smart meters are vital for smart networks and will contribute to 77% CO_2 reduction by 2035 (from 2015 levels). A flexible smart grid enables high uptake of intermittent renewables through better balancing of demand and supply.

Without smart meters, limited insight of energy demands, and the lack of consumer engagement though new tariffs and services will significantly impact on system flexibility and increase the reliance on higher carbon and non-renewable energy sources.



Data taken from CCC 5th Carbon budget[4]

Homes

Situation: Energy use in homes currently accounts for 14% of UK GHG emissions[9], mostly from burning gas (a further 6% comes from generating the electricity used in homes)

CO_2 Target: *24% decrease in emissions from buildings compared to baseline by 2030. Homes to be near carbon neutral by 2050.*

Policy snapshot:

- *Reducing energy demand through energy efficiency improvements and energy awareness.*
- *Replacing fossil fuel burning boilers with low carbon heating, including high efficiency electric heating (heat pumps).*

Smart meter role:

- *Improve awareness of energy consumption to enable people to reduce their energy use*
- *Improve energy performance measurements to promote and evaluate energy efficiency improvements*
- *Enabling dynamic pricing tariffs and automated smart heating to reduce impact on peak electricity demand.*

The clean growth strategy stated an aim for as many homes as possible to reach an energy performance rating of C by 2035. We calculate that this would reduce CO_2 emissions by around 10 $MtCO_2$/yr by 2035[10]. However, to achieve this target will require a step change in energy efficiency upgrades.

Smart meters are already helping households to reduce their energy demand

Smart meters are already helping households to reduce their energy usage, with evaluation of trials showing energy savings of 5-20%[11]. Long term effects are set in place by changing behavioural habits and informing decisions to buy more energy efficient appliances

Smart meters data can promote energy efficiency of homes by improving measurements of energy performance and allowing better verification of savings from efficiency measures

Smart meters enable new and improved ways to measure energy efficiency and with more rigorous measurement could strengthen the development of policy.

Smart meters will enable more rigorous evaluation of schemes and policies such as the energy company obligation (ECO) and the renewable heat incentive (RHI) to ensure funding is directed most effectively to maximise CO_2 savings whilst also considering cost.

The development of green mortgages[12] could fund energy efficiency improvements. Smart meter data will enable monitoring and verification of the effectiveness of energy efficiency measures with improved confidence, helping the green mortgage concept to be made available to more households. Eventually, house prices might more closely reflect the energy efficiency of the home, incentivising energy efficiency further.

Smart meter enabled dynamic pricing tariffs will enable adoption of efficient low carbon heating with a lesser impact on peak energy demand

Replacing 10% of heating with heat pumps by 2030 could save the UK around 7 $MtCO_2$/yr[13], but the high-level adoption of efficient electric heating technologies such as heat pumps will exacerbate peak electricity demand. A flatter demand profile makes it easier to match demand to low carbon supply of electricity and a peaky electricity demand increase the reliance on gas peaking plants to balance the electricity network. From our Delta-ee modelling, we anticipate that this level of heat pump penetration would cause a 6GW increase in the evening peak electricity demand on a cold winter day if heat pumps were deployed without smart control. Smart meter enabled time of use tariffs are a central part of the solution for smart control of electric heating, allowing them to draw electricity at times of high supply and respond to signals for reducing peak electricity demand. With smart heating control, we estimate that this peak electricity demand increase on a cold winter day would be reduced to around 4 GW[14].

Smart meter data will support existing and future policies promoting low carbon heat and energy efficiency

Smart meter data will enable a more rigorous approach to delivering policies funding renewable heating technologies and energy efficiency by measuring the outcomes instead of basing payments and targets on benchmark based assumptions (as is current practice). Smart meter data will also improve the methodology for policy evaluation and could inform future incentive regimes to be more targeted and effective.

Smart meters will be vital for unlocking new business models to remove barriers to low carbon heating

Better availability of energy consumption data could also enable new business models around selling heat-as-a-service to overcome barriers to household adoption of low carbon heating technologies. See box below.

Electric heating can help to protect against air pollution

Other alternatives to gas boilers are biomass boilers, but in areas of concentrated housing they can contribute to air pollution. Electric heating can therefore be a cleaner option for decarbonised heating in urban setting, along with district heating schemes.

Selling heat instead of kWh

The decarbonisation of heat has been described as "probably the biggest challenge in energy policy that we face" because of the direct impact it has on consumers[15]. Heat pumps tend to be viewed as a risky option for a household to adopt, worried that they might not heat the house properly and that they might be more expensive. We think that new business models to increase take up of low carbon heating technologies and energy efficiency measures is needed to enable deep decarbonisation of housing.

New "Heat-as-a-service" business models are being developed, shifting the focus away from customer buying a heating system and fuel, and towards buying heat and a warm home. These propositions could overcome barriers of high upfront cost of low carbon heating technologies by leasing the heat pumps to households or building the capital cost into a monthly payment. Some companies sell kWh of heat, thereby removing some of the risk of the performance of the heat pump from the household. More sophisticated propositions can also alleviate concern over performance by guaranteeing an outcome (e.g. a living room at 21 °C for 8 hours per day) and leaving it to the service provider to deliver this in the most efficient way for a fixed monthly fee. Ideally, service providers could also insulate homes as they benefit from a house being more efficient, allowing them to deliver the guaranteed performance at a lower energy cost

Selling energy services like this is much more well established in the commercial sector by energy service companies (ESCos). A key barrier to delivering in the domestic sector has been the high cost to monitor and verify energy savings which are part of the contract to guarantee performance. Smart meters provide the data needed to develop and deliver these more complex services and to overcome these barriers[16].

Example of businesses developing or selling heat-as-a-service

st1

Best Green

These companies install and maintain heat pumps and sell heat to the customer

CATAPULT Energy Systems

Leading a research trial aiming to understand households' demand for "warm hours", and testing how this can be delivered using a hybrid heat pump

Transport

Situation: Car travel currently accounts for 15% of UK climate change causing emissions[9].

CO_2 Target: *48% decrease in transport emissions compared to baseline by 2030. Surface transport to be near carbon neutral by 2050.*

Policy snapshot: *Replacement of conventional fuel vehicles with electric vehicles and charging infrastructure.*

Smart meter role: *Smart meters enable the uptake of smarter EV charging improving flexibility in supply and reducing peak demands, therefore enabling more renewable generation and lower CO_2 emissions.*

The uptake of electric vehicles as the predominant form of ultra low emission vehicle is expected to be the main policy for reducing emissions from personal travel. For personal travel, the government has committed funding to promote active travel for shorter journeys (cycling and walking) and to promoting low emission public transport[17], but both the 5th carbon budget and the clean growth strategy assume that there will be only modest reductions in the use of personal transport.

Electric vehicles will put a big increase of demand onto the electricity network…

Delta-ee modelling predicts that with an additional 2.5 million electric vehicles in 2030[18], peak electricity demand would increase by almost 17 GW. With fixed period smart charging, we predict the peak would only increase by 4.5 GW[19] (see graphs on the next page). With dynamic tariffs that vary the cost of electricity to best match demand to supply, the large demand from EVs could be moved to the time of day that renewable electricity generation is most available. It is more difficult to run a peaky electricity system in a low carbon way (see box on p14).

…and Smart meters can enable and incentivise drivers to charge their EVs at times that low carbon electricity is available

Dynamic time of use tariffs enable demand to be matched to when supply is available which will allow greater increases in the proportion of intermittent renewable generation. We expect that dynamic time of use tariffs will be widespread for EV owners, with smart meters passing signals from the electricity network to in-home chargers to automate when to charge. It is already possible for EV owners to control when their cars start to charge, but dynamic time of use tariffs give drivers the cost savings to incentivise this behaviour, rather than the same price being charged for the electricity at any time.

Vehicle to home or vehicle to grid capability will provide additional flexibility to the grid

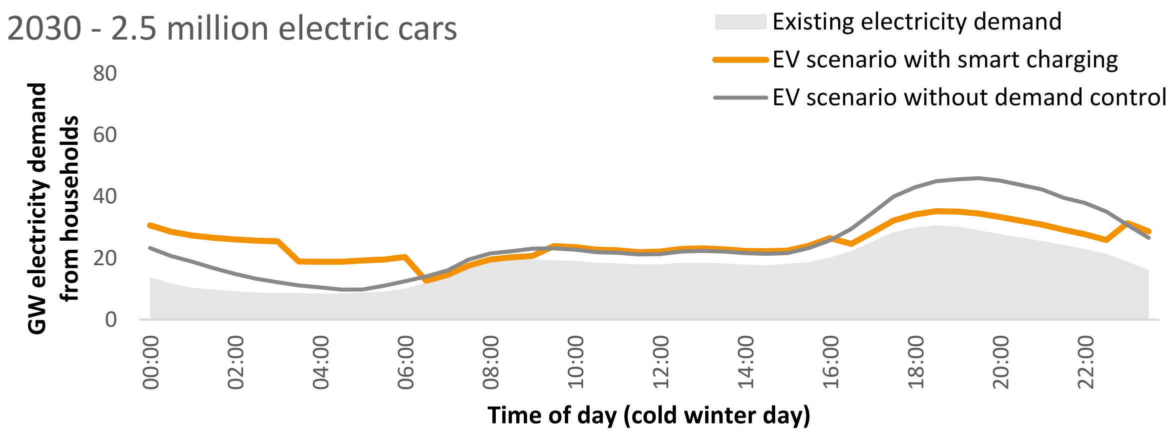
Going further, vehicle to home or vehicle to grid (V2G) capability would enable EV batteries to contribute to energy storage and reduce peak demand further. If households agree to share smart meter data with networks or grid balancing companies, EVs could contribute a further 0.8GW of storage to the network in 2030 and we predict with the right regulations in place, this could be in the region of 30 GW in 2050[20].

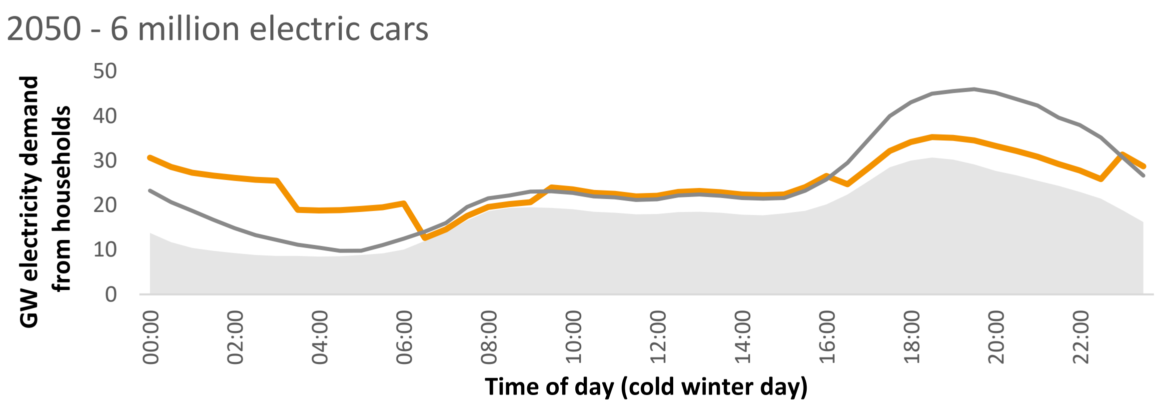
A co-benefit of electrification of vehicles will be an improvement of air quality which is most needed in cities

Air pollution is a big problem in UK cities, with air pollution estimated to cost the NHS and society over £6 billion per year[21]. Electric vehicles are well suited to urban driving, which is where the problems of air pollution are worst. By allowing a greater level of uptake of ultra-low emission electric vehicles, smart meters can help make cities less polluted too.

The effect of electric vehicle (EV) charging on peak electricity demand from homes on a cold winter day

Delta-ee modelled the impact of electric vehicles charging on electricity demand from homes. The two graphs below show that the increase in peak electricity demand is lower if cars can be charged using smart chargers





These graphs are modelled using fixed off peak tariff times (further details of modelling are given in appendix[19]). The most dynamic time of use tariffs will send signals for times that supply of renewable electricity is high and flexible demands will be able to respond to these. Within a future smart grid, the greater penetration of decentralised generation (such as solar panels on roofs and local electricity storage) will reduce the network capacity needed as local demand could be controlled to meet local supply.

Electricity networks need to be built to meet peak demand and therefore a large amount of network reinforcement work would be needed to meet unconstrained EV charging demand. This is expensive and would increase the cost of decarbonising the electricity network and the transport sector.

Less flexibility of electricity demand would also constrain the types of electricity generation that the UK would use, relying less on renewables and more on nuclear and CCS (see p16).

A reliance on costly network reinforcement work is likely to slow down the rate at which EVs can be adopted by UK households, therefore constraining the rate at which petrol and diesel cars can be replaced by low carbon alternatives.

Electricity

Situation: Electricity generation currently accounts for 19% of UK GHG emissions[9] (responsible for 75% of emission reductions since 1990)

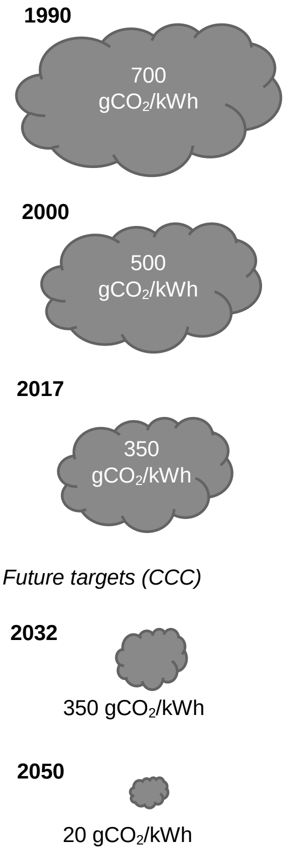
CO_2 Target: *A further 72% decrease in emissions from electricity generation compared to baseline by 2030.*

Policy snapshot: *Greater penetration of renewable generation, maximise grid flexibility.*

Smart meter role: *Smart meters are part of the method of grid flexibility, enabling dynamic time-of-use tariffs and with the potential to communicate network availability to end users.*

With no mention of fracking and CCS for the power sector, the clean growth strategy supports the high renewables and flexibility approach to a future electricity system. This has been shown to be the lower cost option in research by Imperial College (see p16).

Changing carbon intensity of UK electricity



The electricity generation sector has been the largest source of CO_2 emission reductions since 1990. First the "dash for gas" saw gas generation replacing coal as a feed stock to thermal power stations, reducing the emissions from electricity. Next, the increase in renewable capacity has reduced average carbon intensity of electricity generation. However, the CCC recommends even greater ambition is needed in the future to reach targets for 2032 and 2050.

Analysis by Imperial College for CCC (as detailed on p16) found that it was cost effective to have around 60% of electricity consumption from renewable sources by 2050 (compared to 28% in 2018).

Matching demand to supply of low carbon generated electricity is the challenge for the smart electricity network

As the penetration of intermittent renewable energy generation increases, the supply side becomes less able to adapt to changing demand and loads must become more flexible. As total electricity demand increases, the flexibility of new loads will dictate how much generation capacity must increase.

With 36% of electricity currently used in homes, and this proportion set to rise with EVs and electric heating, understanding household consumption is important

Network operators are uncertain how to predict the changes in usage patterns over the next decade, and without clearer profiles of how electricity demand is changing, they are having to rely on existing profile assumptions with modelled demand changes. If they could monitor how demand is changing over the next few years, as is enabled by the availability of smart meter data, for example as more EVs are being charged at home, they have a better chance of predicting the changes more accurately.

Signals via smart meters could communicate times of high availability of renewable generation, allowing households to match demand to low CO_2 electricity

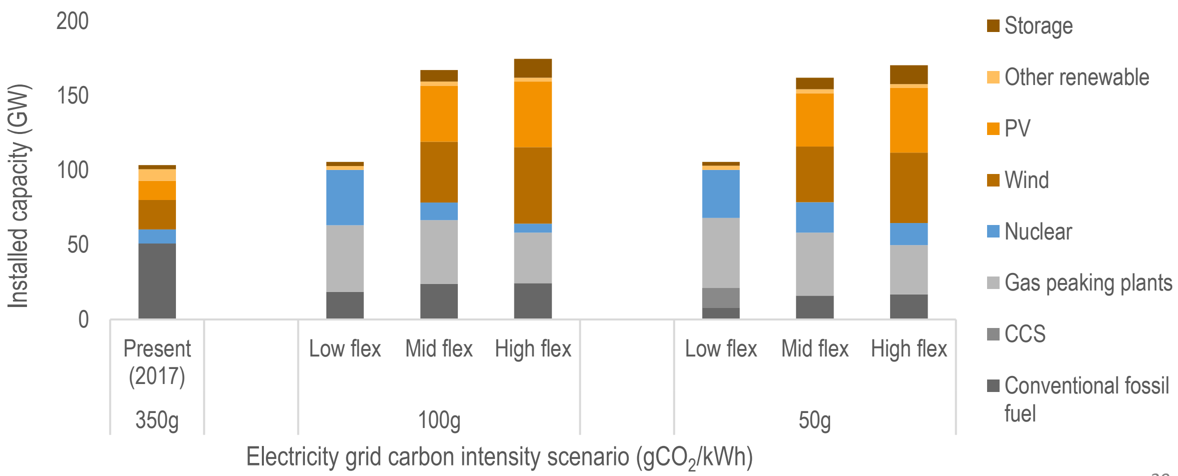
For households who are motivated to reduce their personal carbon footprint, smart devices and storage could give them the option to set their preference to use electricity when it is being generated by low carbon sources. If in the future carbon pricing accurately represents the carbon intensity of energy, incentivising low carbon periods, cost signals would incentivise more households to use green energy.

Renewable generation within a future flexible energy system

Work was commissioned by the Committee on Climate Change to (CCC) to investigate power sector scenarios for its fifth carbon budget[22]. The work was carried out by Imperial College London and headlines of the study were that:

- System integration costs of low carbon generation technologies will significantly depend on the level of system flexibility
- Enhanced system flexibility reduces system integration cost of renewables by an order of magnitude, making wind generation much more competitive compared to nuclear generation, and solar generation being lower cost than nuclear.
- Modelled scenarios for an electricity carbon intensity of 100gCO_2/kWh found a more flexible grid to give cost savings of £3.0bn - £3.8bn per year, and for an electricity carbon intensity of 50gCO_2, the cost savings are £7.1bn - £8.1bn per year.

In addition to testing the impact of flexibility on total cost, the analysis investigated what the cost-optimal low-carbon generation mix would be under the CCC's core 50gCO_2/kWh and 100gCO_2/kWh scenarios, shown in the figure below. The results show that without flexibility, renewable generation is not cost effective, and low carbon electricity generation would instead depend on nuclear and CCS. With increasing levels of flexibility, wind and PV dominate the generation capacity of a future network.



Data taken from CCC /Imperial report [20]

Grid flexibility is made up of demand side response (DSR), energy storage, interconnectors to mainland Europe, more efficient and flexible generation technologies and improved system management techniques including forecasting.

Smart meters enable better forecasting of demand by providing more granular insight into when households use electricity and gas and how that changes over time. Smart meters can also be used to manage demand side response. The analysis' scenario is based on 72% of DSR capacity being residential, with the high flexibility scenario relying on all that capacity being used. Similar analysis, led by the Carbon Trust[23] describes demand response in homes as the DSR technology with the greatest uncertainty in future uptake. It relies on high levels of customer uptake and there are barriers to overcome for customer uptake and behaviour change, and adoption of smart appliances. **It is hard to see how this scale of DSR could be enabled without a joined up smart system connecting dynamic generation to dynamic demand and smart meters are central to the way that households and business will be linked into this smart energy system**.

What are the alternatives?

Alternative low carbon generation

Without a more flexible energy system we will rely on more responsive means of generation, predominantly from additional gas generation (with or without CCS) and nuclear. These generation modes pose further environmental risks around decommissioning nuclear waste and continued reliance on “unconventional fossil fuel extraction” (fracking). Both options have a higher deployment risk than renewables, and it is likely that they will result in a slower rate of decarbonisation with longer time to build nuclear capacity, and CCS still yet to be fully demonstrated and commercialised. Achieving CO_2 reduction in the required timescales is therefore less likely.

Higher cost

A flexible electricity network isn’t the only way to meet our carbon reduction targets, but alternatives are likely to be more expensive. The analysis shown on the previous page shows that there is high value in the flexibility of a decarbonised electricity grid, estimated around £8bn per year by 2030. This is equivalent to each household facing higher costs of around £300 per year. The effect would be higher network costs and higher generation costs, as well as continued reliance on the rising wholesale cost of fossil fuels.

Less open

With the high value available from a more flexible energy system and shifting consumption to times of high supply, it’s possible that many aspects of demand response could still be accessed without a wide roll out of smart meters. However, we believe that this approach would be less co-ordinated, more complex, limit market competitiveness, and overall make it more difficult for innovation in the energy system. Companies could still install metering, monitoring or control equipment in houses, but it’s likely there would be limited and have no interoperability due to proprietary approaches. Delivering a low carbon energy system under this scenario would be more complex, slower, stifle innovation, and provide the customer with a worse deal.

Missing the targets

Ten years ago, the Climate Change Act committed the UK to reducing climate change causing emissions by 80% by 2050. Carbon budgets present interim targets for meeting this trajectory. This is still seen highly ambitious, but a number of scenarios highlight ways that this target could be met. On top of this aim, the IPCC report released in October 2018 highlighted the need to go further sooner, to take the scenario paths that enable even more ambitious carbon reductions. Smart meters open innovation, and without them we are significantly stifling the opportunity for new ways of improving energy efficiency and decarbonising the system. Without smart meters, meeting our existing targets will be made even more challenging and risky; smart meters are a key infrastructure to going further quicker.

Conclusion

Smart meters allow better measurement of energy use, and therefore greater opportunities to manage energy demand and improve utilisation of the energy system. This is imperative for decarbonising the parts of the energy sector that relate to households. If smart meters are not deployed, the energy transition and carbon reduction will be higher cost, less supportive of renewable generation, and less well co-ordinated. Without smart meters, CO_2 reduction will be slower and rely on higher risk CO_2 reduction strategies and technologies, ultimately increasing the likelihood of not achieving mitigation targets

In the short term

Smart meters will enable households to better understand their energy use, and to make behaviour changes to use their energy more efficiently and at times when it is available from renewable sources. This will mean reducing energy demand overall and using electricity when it in available from low carbon sources. Smart meters are also vital for the emergence of new innovative business models which will help households to use low carbon heat, use renewable energy and make their homes more efficient.

The key challenges are:

- Electrification of heat and transport. Smart meter enabled dynamic time-of-use control can reduce the peak electricity use which will allow for demand to be better met by low carbon renewable generation. Smart meter data could also accelerate the development of new innovative business models to get low carbon heating technologies into homes, thereby reducing the burning of fossil fuels.
- Enabling the electricity mix to be dominated by renewables. The greater flexibility necessary for high levels of renewable penetration can be supported by smart meters which can influence domestic consumption based on market signals for when demand needs to reduce and when it can increase.
- Energy efficiency and behaviour change to reduce overall demand. Smart meters can give real time information about what is using energy and help households change habits. This greater awareness of energy use can also help consumers better understand their energy use and become enablers of a future low carbon energy system.

In the long term

A more flexible energy system is key to reducing CO_2 emissions from electricity generation in the lowest cost way. With the electrification of many sectors, a low carbon electricity system will allow the UK to decarbonise and to meet climate change targets.

Our vision of a future low carbon energy system has consumers at the centre, with greater digitalisation allowing flexible demands to be met by intermittent low carbon, renewable generation. Smart meters are the essential link between consumers and the system.

For the greatest benefits to be realised, smart infrastructure in the form of smart meters is needed in as many homes as possible. We hope that the roll out will see all homes having smart meters installed so that all customers can access the benefits and support decarbonisation.

Appendix

Climate change policies in more detail.

	5th carbon budget	Clean Growth Strategy
Homes: Energy efficiency	• Increase insulation including around a further 1.5 million solid walls and 2 million cavity walls in the 2020s. • More use of heating controls and efficient lights and appliances."	• "An aspiration for as many homes as possible to be EPC Band C by 2035 where practical, cost-effective and affordable". • Promoting green mortgages to incentivise more energy efficient properties. • Consulting on strengthening energy performance standards for new and existing homes under building regulations, including futureproofing new homes for low carbon heating systems.
Homes: Low carbon heating	• Heat pumps and heat networks from low-carbon sources provide heat for around 13% of homes by 2032. • Alternatively, using hybrid heat pumps with back up heating via hydrogen added to the gas grid".	• Phase out the installation of high carbon fossil fuel heating in new and existing homes currently off the gas grid during the 2020s (14% of homes (3.7m)), starting with new homes. • Reforming the renewable heat incentive. • Build and extend heat networks across the country. • Improve standards on the new boilers. • Require installations of control devices to help people save energy". • Investing in innovation programmes to develop new energy efficiency and heating technologies.
Personal travel	• Deployment of electric vehicles - 9% of new car and van sales in 2020 and around 60% in 2030.	• Target to end the sale of new conventional petrol and diesel cars and vans by 2040. • Commitment of funding to subsidise the upfront cost of electric cars. • Commitment of funding to develop one of the best electric vehicle charging networks in the world and legislative change to support this.
Electricity	• Decrease carbon intensity of generation from around 450 gco2/kwh in 2014 to 200- 250 g/kwh in 2020, and to below 100 g/kwh in 2030. • Low-carbon generation (i.e. Renewables, nuclear and CCS), reaching a total share of around 75% of generation by 2030. • The demand side also has an important role in increasing the flexibility of the power system, alongside interconnection, storage and flexible back-up capacity". • Improvements to energy efficiency (e.g. Increased use of LED lighting and more efficient appliances) will support progress in the power sector.	• Smart systems plan to reduce electricity costs which will help consumers to use energy more flexibly and could unlock savings of up to £40 billion to 2050. Commitment to invest in smart systems to develop new ways of balancing the grid and reduce the cost of electricity storage and advance innovative demand response technologies. • Commitment to invest in further reduce the cost of renewables and phase out the use of unabated coal to produce electricity by 2025 and improve the route to market for renewable generation through phase two of the contract for difference auctions.

Acronyms:

CCS	Carbon capture and storage
CO_2	Carbon Dioxide
DSR	Demand side response
EV	Electric vehicle
GHG	Green house gas
IPCC	Intergovernmental Panel on Climate Change
RHI	Renewable heat incentive

Notes to accompany main report:

1 Climate change causing emissions are often referred to in short hand as carbon dioxide emissions, CO_2 emissions, or carbon emissions. Whilst carbon dioxide (CO_2) is the most prevalent greenhouse gas to be emitted in the UK, accounting for around 80% of climate change causing emission in 2016 (based on global warming potential of emissions, typically given in units of carbon dioxide emission equivalent (kgCO_2e)) *https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-2016* other greenhouse gases are methane (11% of climate change causing emission in 2016), nitrous oxide and fluorine gases.

2 The UK Government Climate Change Act (2008)
https://www.legislation.gov.uk/ukpga/2008/27/contents

3 Intergovernmental Panel on Climate Change (IPCC)'s Special Report (2018) on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty *https://www.ipcc.ch/sr15/*

4 The Committee on Climate Change (CCC) recommended that the UK's 5th carbon budget is set at 1,765 MtCO_2e per year for the period of 2028 – 2032. This would limit annual emissions to an average 57% below 1990 levels. *CCC (2015). The Fifth Carbon Budget: The next step towards a low-carbon economy. Committee on Climate Change. www.theccc.org.uk/wp-content/uploads/2015/11/Committee-on-Climate-Change-Fifth-Carbon-Budget-Report.pdf.* The UK government adopted the 5th Carbon budget in 2016.

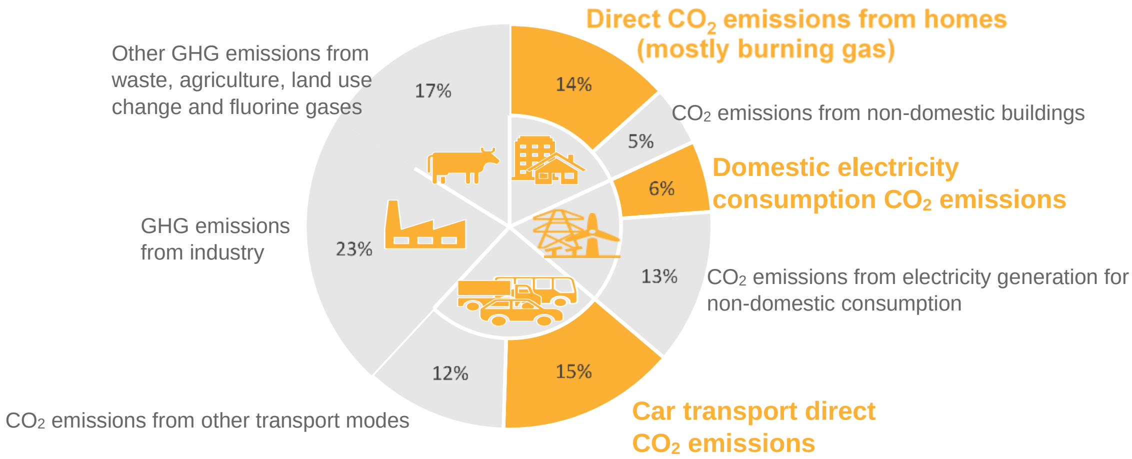
5 The clean growth strategy has been criticised for having gaps in the policies and proposals needed to deliver the ambitious targets. The CCC's independent assessment of the Clean Growth Strategy stated that "It is urgent that the Government sets out how the Strategy's ambitions and intentions will be delivered in full, and develops new policies to close the remaining gap… Development of policy in these areas (e.g. upgrading as many homes as possible to Energy Performance Certificate Band C by 2035, improved standards of new buildings, phasing out the sale of new conventional petrol and diesel cars and vans by 2040) will need to progress urgently". *https://www.theccc.org.uk/wp-content/uploads/2018/01/CCC-Independent-Assessment-of-UKs-Clean-Growth-Strategy-2018.pdf*

6 2016 Paris Agreement is a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. It has (at time of writing) been ratified by 184 parties, out of a total 197 who are parties of the convention. *https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement*

7 Graph taken from Committee on Climate Change report to Parliament (2018)
https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/

8 In 2018, UK installed electricity generation capacity was 41.9 GW of renewables compared to 41.2 GW of fossil fuel installed capacity. Low carbon electricity generation (renewable and nuclear) accounted for 57% of electricity generation between July and September 2018.*https://www.theguardian.com/environment/2018/nov/06/uk-renewable-energy-capacity-surpasses-fossil-fuels-for-first-time* Full report: *https://s3-eu-west-1.amazonaws.com/16058-drax-cms-production/documents/180809_Drax_Q2_Report.pdf*

9 Breakdown of UK greenhouse gas (GHG) emission sources (2016). Highlighted segments relate directly to households. *https://www.theccc.org.uk/publication/reducing-uk-emissions-2018-progress-report-to-parliament/*



10 Carbon reduction from improving energy efficiency of homes
This figure is based on the aims outlines in the Clean growth strategy to reduce as many homes as possible to an EPC rating of C. For this modelling, we have assumed 80% of homes achieve these improvements. The modelling calculates the difference in energy demand between different EPC bands, based on 2017 figures.

11 Energy savings from smart meters
A review of trials assessing savings from feedback give varying results of savings available. Generally, energy savings are quoted between 5-10% of energy consumption, with high variation within and between studies. In some trials or reviews the savings are quoted up to 20%. *https://eprints.qut.edu.au/58017/4/2013001547.pdf; https://aceee.org/files/proceedings/2016/data/papers/12_769.pdf ; https://www.eea.europa.eu/publications/achieving-energy-efficiency-through-behaviour/file; https://esmig.eu/sites/default/files/2011.10.12_empower_demand_report_final.pdf; https://www.researchgate.net/publication/281291249_Case_Study_of_Smart_Meter_and_In-home_Display_for_Residential_Behavior_Change_in_Shanghai_China; https://www.napier.ac.uk/research-and-innovation/research-search/outputs/energy-behaviour-change-by-coloured-inhome-display*

12 Green Mortgages The UK government intends to work with mortgage lenders to develop green mortgage products that take account of the lower lending risk and enhanced repayment associated with more energy efficient properties *https://www.gov.uk/government/publications/clean-growth-strategy/clean-growth-strategy-executive-summary#fn:15*

13 Replacing 10% of heating with heat pumps by 2030 could save the UK around 7 $MtCO_2$/yr
Delta-ee modelling calculates high level CO_2 savings based on replacing gas boilers with a spread of heat pump technologies in 10% of homes with assumed efficiencies and based on standard emission factors of gas and electricity.

- Annual thermal demand of homes is based on existing thermal demand across 22 segments of homes. Segments are categorised as low, medium and high and from this, average thermal demand for categories are calculated as: low (4,700 kWh/yr, 38% of installations), medium (11,300 kWh/yr, 53% of installations) and high (22,970 kWh/yr, 9% of installations)
- Proportion of heat pump types is based on National Grid's Future Energy Scenario 2050 installed base projections (45% air-source heat pump, 13% ground source heat pump, 41% hybrid heat pump (with natural gas boiler)
- Typical Seasonal Performance Factors (efficiency) Air-source heat pump: 2.5, Ground source heat pump: 3.5, Hybrid heat pump: 2.5 for proportion of heating by heat pump – assumed split of 75% of heating delivered by heat pump, 25% delivered by boiler (assumed 80% efficiency)
- Emission factors taken from updated SAP10 emission factors for the period 2018-2020 https://www.cibsejournal.com/general/sap-in-building-regulations/

Modelling results show CO_2 emissions from natural gas reduce by 8.7 $MtCO_2$/yr and CO_2 emissions from electricity increase by 1.8 $MtCO_2$/yr, giving a net decrease in CO_2 of 6.9 $MtCO_2$/yr

14 10% penetration of heat pumps could cause 6GW increase in evening peak if unconstrained or 4 GW increase if deployed with smart heating control
Modelling is based on average peak winter day temperature profile and electricity profile over a 24 hour period. Proportion of installed base of heat pumps are as in note 13 above. Average installed capacity of heat pump is based on a national level model of the UK housing stock. Scenario with smart control is based on 30% of load being shifted to off peak times.

15 *"Consumers pose biggest barrier to low-carbon heat"* Martin Crouch: Ofgem senior partner for improving regulation *https://utilityweek.co.uk/consumers-pose-biggest-barrier-to-low-carbon-heat/*

16 The UK government is exploring evidence for the energy performance certificates for buildings to be based on measured data *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/729853/epcs-call-for-evidence.pdf*

17 We think that active transport and public transport are also important and will enable a more successful shift to electric transport as a whole. We hope that more people will continue to make more journeys by foot, bike, bus and train, and these are certainly the ways to decarbonise transport at the rates we need. However, we don't expect the rates to be sufficient not to require a major replacement of petrol and diesel cars with something that can be decarbonised, and we predict that electric cars will have a bigger slice of the pie than hydrogen or biofuel powered cars.

18 Figure based on Future energy scenarios (FES). The two scenarios which are compliant with meeting the 2050 targets (Two Degrees and Community Renewables) both have the number of electric cars as approximately 2.5 million in 2030. *http://fes.nationalgrid.com/fes-document/*

19 An additional 2.5 million electric vehicles would increase peak electricity by almost 17 GW if unconstrained, or 4.5 GW with fixed period smart charging
Modelling is based on a fleet based on car fleet of 20 cars with different likelihood of time returning to the home and battery capacity at that point. The model assumes that for unconstrained charging, the cars are charged when they return home. For cars with smart charging, the car is charged until the battery is 50% capacity when it reaches home, and the remaining charge is applied at off peak time.

20 Through V2G, EVs could contribute a further 0.8GW of storage to the network in 2030 and 30GW in 2050. Figures based on Delta-ee modelling, assuming:

- 10.6 EVs in 2030 with 2% engaging in V2G services and 38.9 EVs in 2030 with 12% engaging in V2G services.
- 80% maximum simultaneous activity (i.e. some households have 1 V2G compatible charger but multiple EVs).
- average discharge speed of the two available charge speeds on the market 96 and 10 kW options on the market, therefore using 8kW).

21 In advance of Clean Air Day 2018, researchers at the University of Oxford and University of Bath have produced new research - "The health costs of air pollution from cars and vans".

https://www.cleanairday.org.uk/Handlers/Download.ashx?IDMF=7eb71636-7d06-49cf-bb3e-76f105e2c631

22 **Value of flexibility in the future energy system** has been investigated by Imperial College for the Committee on Climate Change (2015). *https://www.theccc.org.uk/wp-content/uploads/2015/10/CCC_Externalities_report_Imperial_Final_21Oct20151.pdf*

23 **Analysis led by Carbon Trust** “Capturing the Benefit of a Smart Flexible Energy System” (2016) *www.carbontrust.com/news/2016/12/capturing-the-benefit-of-a-smart-flexible-energy-system/*