PROJECT REDMAST: FUTURE MARKET REQUIREMENTS

Research and Development of Market Structure report WP2

20 APRIL 2022

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CONTENTS

1 INTRODUCTION

The UK has a commitment to deliver net zero by 2050, supported by an interim requirement to reduce greenhouse gas emissions by 78% compared to 1990 baseline levels by 2035.[1] Delivery against these targets depends on a series of transitions across the whole energy sector, including decarbonisation of heat, electrification of transport, and greater demand-side flexibility.

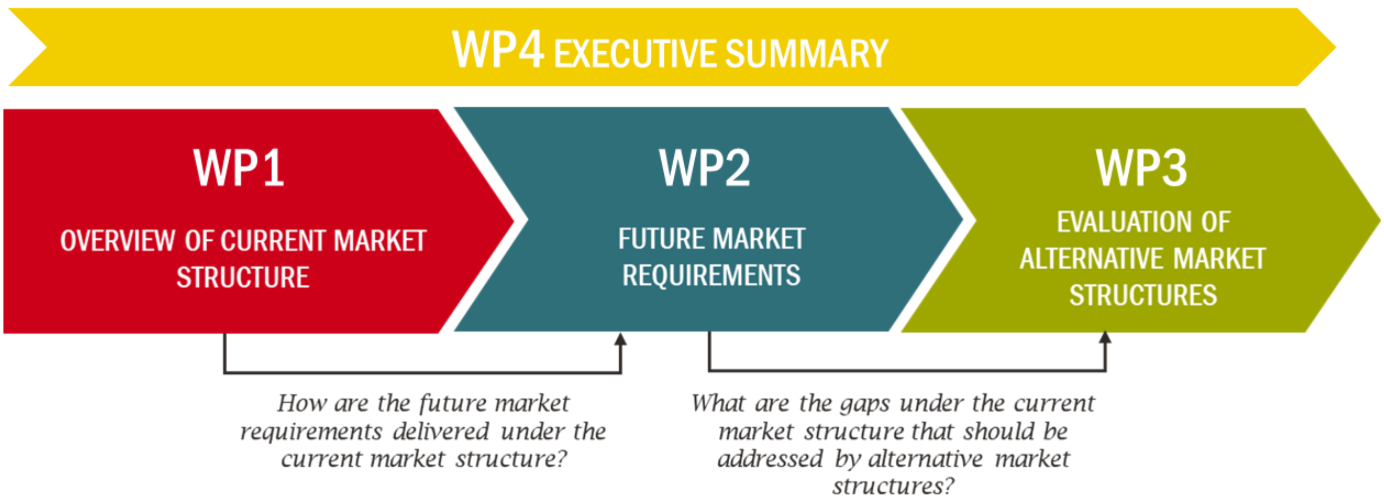
In this context, it is time to review whether the current market structure and supplier-hub model remain the best option to meet these challenges or whether the market structure will need to adapt alongside our energy system.

1.1 PURPOSE OF THIS WORK

Western Power Distribution (WPD) has asked Frontier Economics to review the current structure of the market and evaluate this against future market requirements in the context of the net zero transition. This project, referred to as project REDMAST (Research and Development of Market Structure) will inform an evaluation of potential future market structures to understand whether the current structure needs to be adapted going forward. This is the second stage of this analysis.

This report is the second stage of this analysis. It examines the key transitions facing the energy sector between now and 2050, drawing on National Grid ESO's Future Energy Scenarios (FES)[2]. It then identifies the current market structures (discussed in WP1) and incentives in place to support these transitions, and identifies potential gaps that could hinder net zero ambitions. This will form the basis of the next stage of work (WP3) which will assess potential alternative market models in the context of these gaps.

FIGURE 1 INTEGRATION OF WORK PACKAGES



Source: Frontier Economics

This work is focussed on how key transitions impact domestic customers. We keep in mind that customers not only expect a decarbonised system by 2050 in line with the UK's net zero commitment, they expect this

[1] Climate Change Act (2050 Target Amendment) Order 2019, section 1

[2] At the point of drafting the latest FES was the FES 2021. This has since been update to the FES 2022 (accessed here) which is broadly consistent with FES 2021.

to be delivered alongside a secure supply of energy at affordable costs. Furthermore, it is important to remember that whilst the final decarbonisation pathway may differ across market structures and technology, what ultimately matters to customers is their experience of receiving final outputs such as heat, milage, and comfort.

1.2 STRUCTURE OF THIS DOCUMENT

The remainder of this document is organised as follows:

- **Section 2** sets out the physical transition that the system will need to undertake to meet the net zero target. As with WP1, we focus on those parts of the system which relate to domestic customers including technologies within their homes as well as upstream assets supplying them with electricity and gas. Where there are transitions on the network side that impact customers (e.g. the use of flexibility to manage the electricity networks) these will also be covered.

- **Section 3** discusses the extent to which the current market structure and policies[3] are likely to facilitate the transition, including the current role of suppliers under the supplier-hub model. This section also identifies key inter-dependencies between transitions such as the relationship between energy efficiency and low-carbon heating.

- **Section 4** draws out the broad issues which will need addressing, highlighting where gaps are common across the transitions and should be addressed as part of any changes to the future market structure.

[3] This document reflects the state of the market and government policy at the time of drafting.

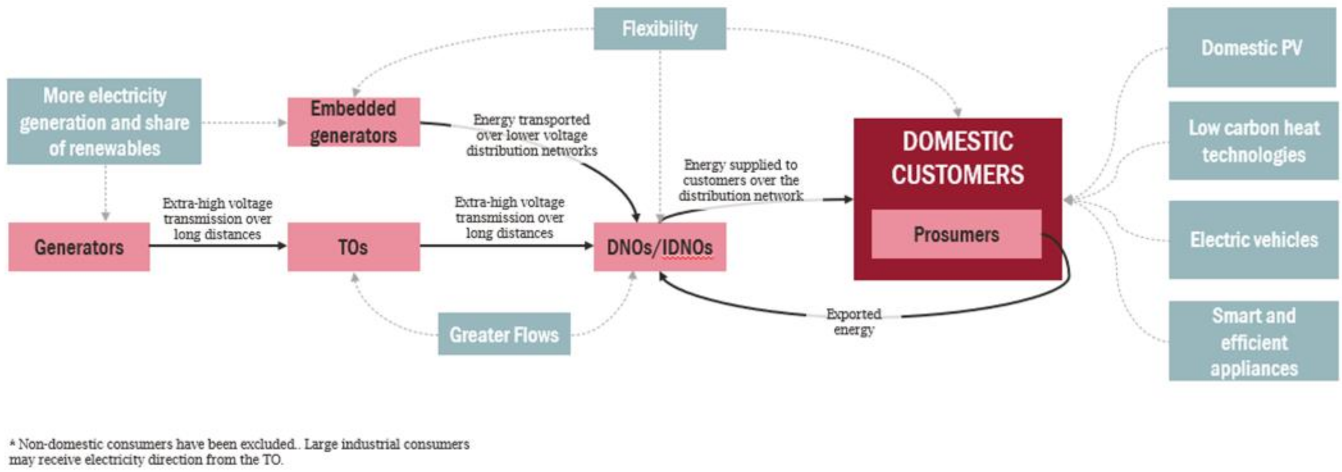
2 THE TRANSITION TO NET ZERO

The UK has a binding target to achieve 'net zero' emissions of greenhouse gases (GHG) by 2050, supported by an interim target of a 78% reduction compared to 1990 baseline levels by 2035.[4] These targets are underpinned by a series of carbon budgets which place statutory caps on total GHG emissions across five-year periods. In response to these targets, and to the Climate Change Committee's (CCC) sixth carbon budget, the government published its Net Zero Strategy in 2021. This sets policies and high level pathways for delivering net zero across the economy.[5]

While there are a number of key transitions that will be essential to delivering net zero by 2050, there remains uncertainty around the way in which the targets will be achieved and the solutions that will be used to achieve them. Furthermore, these changes are unlikely to be uniform across customers or geographies, with local clusters emerging across different technologies.

Figure 2 shows the impact that the net zero transition will have for each part of the electricity supply chain. The main changes are highlighted in light blue boxes. We discuss these issues as they relate to domestic customers in the sections below.

FIGURE 2 IMPACT OF THE TRANSITION ON EXISTING ELECTRICITY PHYSICAL FLOWS



Source: Frontier Economics

The impact on the gas system itself may be even more transformational: Depending on the scenario, the gas network (or areas of it) may be decommissioned entirely, or converted to convey hydrogen. However, from the point of view of consumers, much of this change will happen 'behind the scenes', other than the need to replace gas appliances like boilers with hydrogen-compatible versions.

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[4] Climate Change Act (2050 Target Amendment) Order 2019, section 1

[5] HM Government (2021). Net Zero Strategy: Build Back Greener

2.1 FUTURE ENERGY SCENARIOS

A wide variety of projections have been made for the transitions required for net zero. In this report, we have used the Future Energy Scenarios (FES) developed by National Grid ESO (NG ESO) as a starting point.

FES is widely used by stakeholders in the GB energy sector, and is the foundation of the local Distribution Future Energy Scenarios (DFES) created by DNOs. These scenarios map out four credible pathways for the energy sector between now to 2050 and identify the physical transitions under each of these pathways, such as the establishment of local hydrogen networks or the adoption of heat pumps. However FES does not set out the necessary policies, regulations, and changes in market structures required to enable each pathway, which we will be qualitatively exploring in section 3 of this report and further within WP3.

As illustrated in Figure 3, FES sets out four pathways for decarbonisation.

- **Leading the way**. This scenario relies on a combination of high customer engagement and world-leading technology and investment to deliver the fastest credible decarbonisation journey. This is the most ambitious scenario and assumes that customers are strongly engaged in managing and reducing their own energy consumption alongside supply-side changes such as the set-up of local hydrogen networks to decarbonise the most challenging areas.

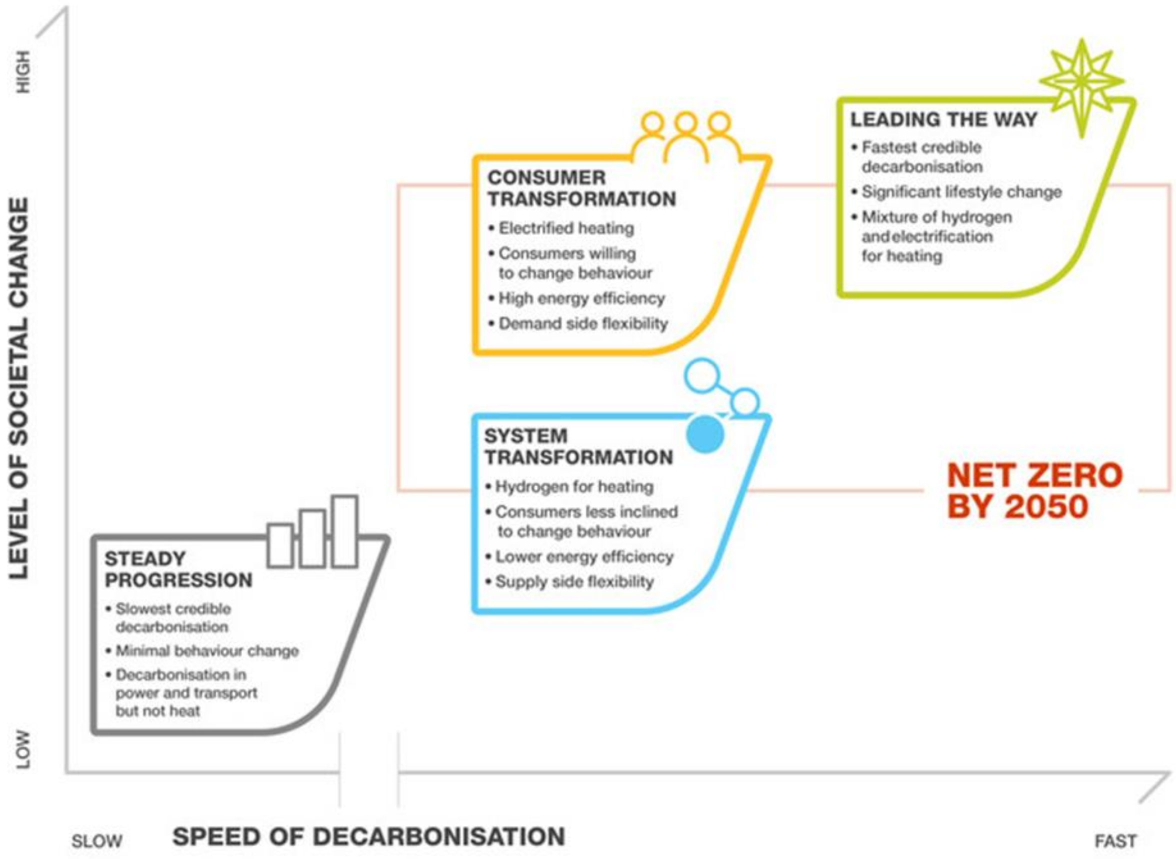
- **Customer transformation.** This scenario delivers decarbonisation by primarily changing the way that consumers use energy. It assumes greater levels of consumer engagement with homeowners switching to electric heat pumps and electric vehicles, making significant improvements in their energy efficiency, and greater demand-side response (DSR) enabled by smart energy management.

- **System Transformation.** This scenario focuses on changing the way in which electricity is generated and supplied. It has less disruption for domestic customers as the majority of significant changes will be on the supply-side e.g. establishment of a national hydrogen network to enable to switch to hydrogen boilers. It also relies on fewer energy efficiency improvements and customers provide less flexibility through DSR.

- **Steady progression.** In this scenario there is minimal behavioural change amongst consumers and while there is decarbonisation in power and transport there is not full decarbonisation of heat. This scenario does not achieve the 2050 net zero target, instead reducing emissions by 73% of 1990 levels.

For the purposes of this report we only consider pathways that enable the Government’s 2050 net zero target to be met. We therefore exclude the ‘steady progression’ scenario.

FIGURE 3 FUTURE ENERGY SCENARIOS



Source: National Grid ESO
Note: This work will not consider the "steady progression" scenario which does not enable the UK to deliver net zero by 2050

The remainder of this section sets out the key consumer-facing transitions identified by FES for achieving a net zero energy sector by 2050.

2.2 DECARBONISATION OF DOMESTIC HEAT

Heating accounts for almost one third of the UK's annual carbon footprint and the majority of this is from homes.[6] At the same time, heating has been recognised as "arguably the most difficult of the major energy consuming sectors of the economy to decarbonise".[7]

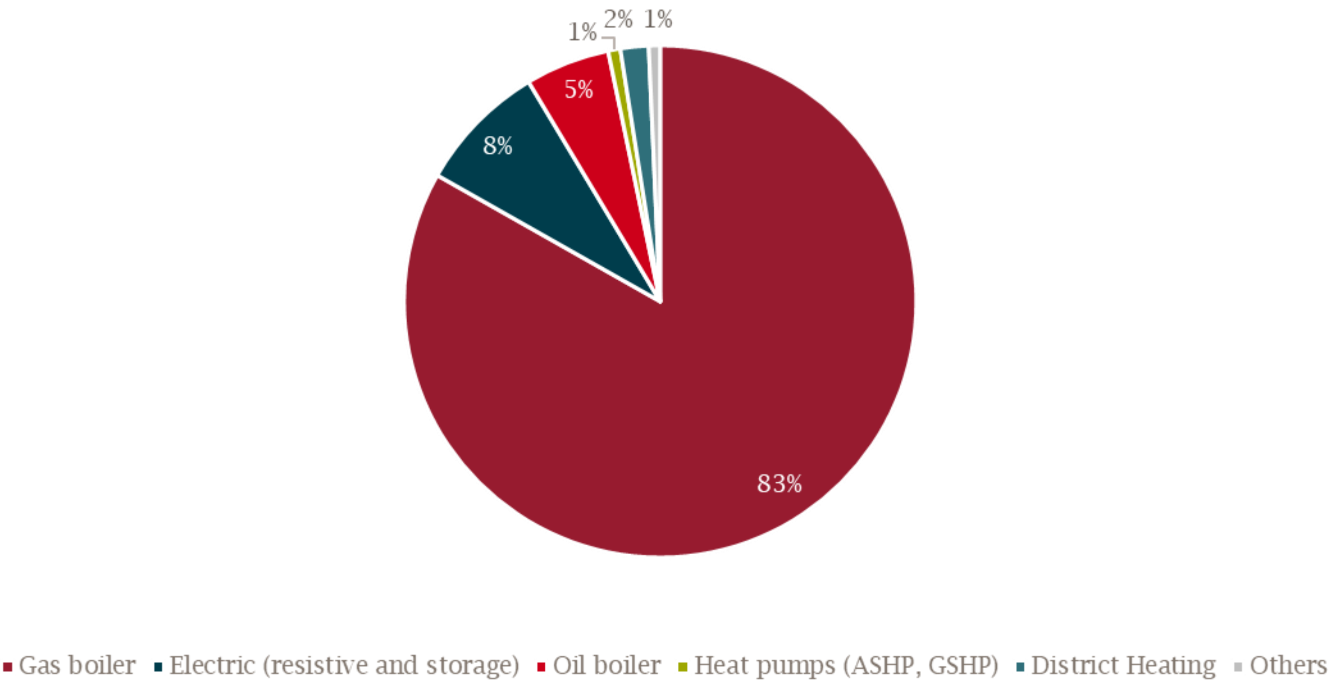
Domestic heating is currently dominated by the use of natural gas boilers. In 2020, 83% of homes used a natural gas based boiler as their main heating system. Of the rest, 8% relied on electric resistive or storage heating, 5% on an oil-fired boiler, with the remainder split between district heating, heat pumps and other technologies.[8]

[6] HM Government (2021). Heat and Buildings Strategy.

[7] Department for Business, Energy and Industrial Strategy, Clean Growth Transforming Heating, December 2018, p 23

[8] National Grid ESO (2021). Data workbook FES v08

FIGURE 4 RESIDENTIAL HEATING TECHNOLOGY MIX IN 2020: % OF HOMES



Source: National Grid ESO, FES (2021). Figure CV.16

In the following section, we describe the technologies that will replace gas boilers, and the pathways for their deployment set out in FES.

2.2.1 LOW CARBON HEAT TECHNOLOGIES

Decarbonisation of heat is expected to be delivered via four main types of low-carbon technology:

- **Heat pumps**. Heat pumps (either ground or air source) use electricity to transfer heat from outside a building into the building. The amount of heat they transfer into the building is more than the amount of energy they use and therefore they act as an efficient and effective form of low carbon heating[9]. Depending on the type of heat pump, they may require changes to be made to the property before they can be installed such as installing additional insulation or under-floor heating (energy efficiency measures are described below in section 2.3.1). Hybrid heat pumps combine heat pumps with a gas or oil boiler to provide additional heating when a heat pump alone may not be sufficient.

- **Low carbon district heat**. District heating is a community based heating solution which uses a single central hub to heat water which is then pumped around multiple homes and buildings via insulated pipes. Provided that the fuel for the central hub is low-carbon (e.g. a central heat pump), the overall district heating system will be low-carbon. District heat networks are only likely to be cost-effective for new-build developments and when properties are densely populated.

[9] This (and other references to electrification) assumes that the power sector has been decarbonised, something which we cover in the section on generation.

- **Hydrogen boilers.** Hydrogen boilers burn hydrogen rather than natural gas for heating and hot water. Unlike natural gas, burning pure hydrogen does not emit carbon dioxide[10] meaning that, assuming hydrogen production can be decarbonised, hydrogen boilers are a zero or low-carbon fuel.[11] From the perspective of a consumer, a hydrogen boiler would function identically to a gas boiler and hydrogen ready boilers, which can handle both fuels, may be made available as part of any transition. However hydrogen production, storage, transmission and distribution systems would need to be put in place to transition consumers from natural gas.

- **Direct electric heating.** In this report we use this term to refer to any heating system that uses electricity as a direct source for heating the home (rather than transferring heat from another source, as a heat pump does).[12] This includes direct resistive heaters without storage, storage heaters, electric boilers, underfloor heating, and infrared heaters.

The technology used to decarbonise heat is expected to vary across households based on regional factors such as proximity to hydrogen and renewables installations, housing density, and housing stock.[13] For example, FES forecasts a higher concentration of hydrogen boilers in South Wales due to high housing density and few alternative technologies for this area.

In addition to these low carbon heating technologies, thermal storage is likely to emerge as a complementary technology. Thermal storage allows customers to store energy when it is available e.g. during peak wind or solar hours, and use this energy later. This provides flexibility for homes relying on heat pumps and direct electric heating. Such storage could include water tanks for heat pumps, or the storage materials built in to electric storage heaters.

2.2.2 FES PATHWAYS FOR THE DECARBONISATION OF HEAT

Both the CCC and the Government's Heat and Buildings strategy forecast heat pumps to play a key role in the decarbonisation of heat and this is reflected in the 'customer transformation' and 'leading the way' scenarios where heat pumps, either standalone or as part of a hybrid system, are forecast to account for 78% of homes and 66% of homes respectively by 2050.[14] In comparison, the 'system transformation' scenario assumes less behavioural change amongst consumers to adopt heat pumps (e.g. 35% of homes are expected to use a heat pump by 2050) and sees hydrogen boilers emerging as the leading low carbon heat technology. It assumes the establishment of a national hydrogen network supported by growth in hydrogen-ready boilers and appliances from 2025 in readiness for switching from natural gas to hydrogen from 2030.

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[10] Hydrogen itself produces no carbon dioxide when burned, but some nitrogen oxides can be produced as a by-product of combustion, which can combine with volatile organic compounds in the air to form ozone, a greenhouse gas. However even including this effect, the warming potential of burning hydrogen is orders of magnitude less than natural gas.

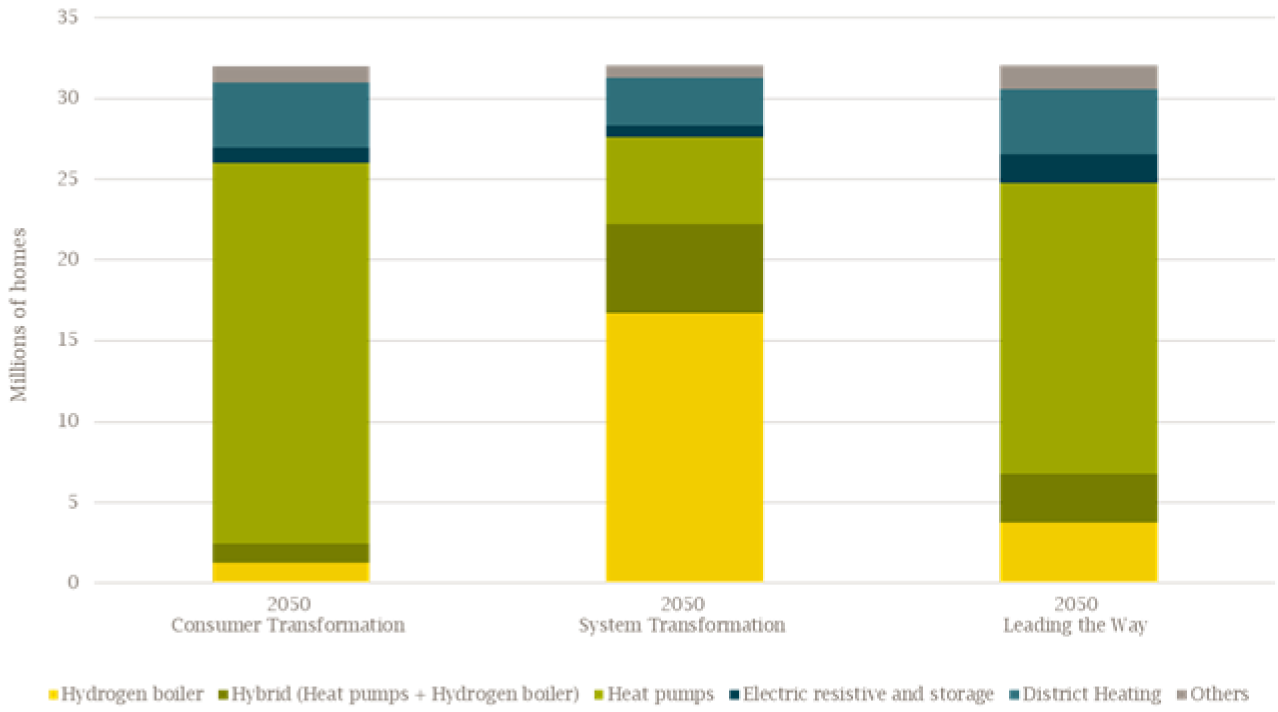
[11] Scenarios like 'leading the way' or 'consumer transformation' assumes that hydrogen production will be decarbonised. Low-carbon hydrogen can be produced by techniques including electrolysis ("green hydrogen") and steam methane reformation ("blue hydrogen").

[12] This follows the definition used in Element Energy for CCC (2021*), Development of trajectories for residential heat decarbonisation to inform the Sixth Carbon Budget*, pp14. We note that some other publications exclude storage heaters from this definition.

[13] National Grid ESO (2021). Future Energy Scenarios.

[14] National Grid (2021). FES 2021 databook, based on CV.16 heat pump categories, including hybrids

FIGURE 5 OVERALL HOME HEATING TECHNOLOGY MIX IN 2050 BY DIFFERENT SCENARIOS



Source: National Grid ESO, FES (2021). Figure CV.16

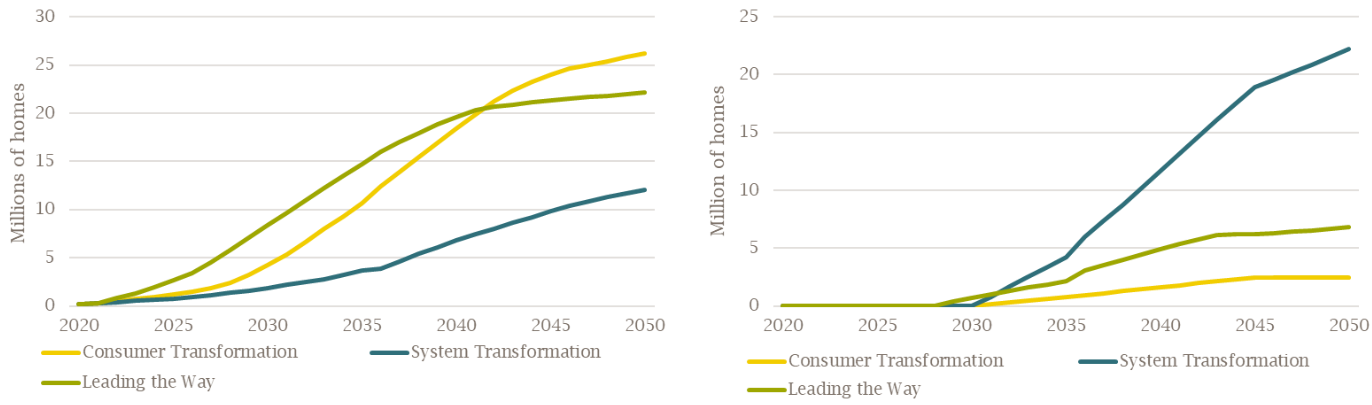
Note: Heat pumps includes air source heat pumps, ground source heat pumps and hybrid heat pumps with electric resistive heaters. Others include BioLPG/BioLiquid boiler, Hybrid (Heat pump and BioLPPG/BioLiquid), Gas and oil boilers.

This trend can be seen in Figure 6 by the steep increase in the number of households acquiring hydrogen boilers over time in comparison with other scenarios. Under this scenario, 69% of homes are forecast to use a hydrogen boiler, either standalone or alongside an air source heat pump, compared to 8% under the 'customer transformation' scenario and 21% under the 'leading the way' scenario which assumes the development of local rather than national hydrogen networks by 2050.

Unlike hydrogen and heat pumps which vary more significantly across the scenarios, the share of homes serviced using a district heat network is relatively stable across all scenarios, making up 13% of homes under the 'customer transformation' and 'leading the way' scenarios and 9% under the 'system transformation' scenario.

Finally, standalone direct electric systems are expected to account for 3% of homes under the 'customer transformation' scenario, 5% under the 'leading the way' scenario and just 2% in the 'system transformation scenario.

FIGURE 6 RESIDENTIAL HEAT PUMP (LEFT) AND RESIDENTIAL HYDROGEN BOILERS (RIGHT) UPTAKE



Source: National Grid ESO, FES (2021). Figure CV.14 and Figure CV.15
Note: Both include hybrid versions

2.3 DOMESTIC ENERGY EFFICIENCY UPGRADES

Achieving decarbonisation at the lowest cost will require greater adoption of energy efficiency measures,[15] in order to reduce requirements for new generation and network capacity.

Energy efficiency can refer to either to thermal efficiency (i.e. efficiency measures associated with the demand for heat), or efficiency of appliances (i.e. how much energy they require to run). The focus of this report is thermal efficiency. As described above, domestic heating is responsible for a significant portion of UK's total emissions, and so the adoption of thermal efficiency measures is crucial to ease the transition to net zero emissions by 2050. Low-carbon heat cannot be deployed cost-effectively unless buildings are well insulated. This is true regardless of the technology pursued.[16] FES notes that bill reductions from insulation may be particularly great for homes heated by hydrogen, which are likely to have higher fuel costs than electricity used for more efficient heat pumps.[17] However heat pumps themselves can also be particularly inefficient if used in homes which are not well insulated (in such homes a high flow temperature[18] is required to meet heat demand, which comes at the cost of efficiency).[19]

[15] This includes continuing improvements in the energy efficiency of domestic appliances, although they are not the focus of this report. For example, the FES forecasts show a reduction in appliance demand by 2050, compared to 2020, of between 14% (for System Transformation) and 39% (Leading the Way) (FES (2021), Figure CV.25).

[16] House of Commons – BEIS Committee (2022). Decarbonising heat in homes

[17] FES pp51. While FES expects that hydrogen may be two-thirds the price of electricity, a hydrogen boiler will require approximately three times as much input energy than a heat pump, and so the boiler will have higher fuel costs overall.

[18] The flow temperature refers to the temperature of water in the supply pipe in a heating system. Heat pumps are most efficient at lower flow temperatures, typically below 55°C. High temperature heat pumps are designed to operate at 80°C but are not as efficient as low temperature heat pumps.

[19] Carbon Trust for GLA (2020), Heat pump retrofit in London

2.3.1 ENERGY EFFICIENCY MEASURES

Retrofitting an existing home to become more thermally efficient may require the following types of measures to be undertaken.[20] Some of these efficiency measures are lower cost and cause less disruption, such as draught-proofing or loft and cavity wall insulation. Other measures such as solid wall insulation can result in significant savings but at higher cost and hassle factor.

- **Draught-proofing:** This can increase comfort and slightly reduce energy bills by using simple and cheap methods to prevent cold draughts. Methods might include blocking or sealing gaps around windows, doors, and skirting boards, and chimneys when they are not in use.

- **Loft and floor insulation:** Insulating lofts, roofs and under floorboards (especially on the ground floor) can significantly reduce heat loss and reduce heating bills.

- **Insulating heating systems:** Insulating behind radiators, lagging pipes and hot water tanks can help heating systems operate more efficiently and reduce the amount of heat lost in a building's heat storage and distribution system.

- **Insulating walls:** Many buildings, such as houses built before 1990, were not constructed with wall insulation, though this can be retrofitted later. The difficulty and expense of the retrofits depends on the construction of the walls:

  - Cavity walls have a gap between the inner and outer brickwork. About 70% of domestic properties in Great Britain have these types of walls at the end of 2020.[21] An installer can fill this cavity with insulating material by drilling small holes in the brickwork, which are then repaired afterwards. According to the Energy Saving Trust, an installer can do this in around two hours for a regular-sized home with easy access and it will not create any mess.[22]

  - The remaining properties have solid walls and therefore need to be insulated on the inside or the outside of the wall. The heat loss through uninsulated solid walls is greater than cavity walls and so the gains from insulation are great. However this typically costs much more than insulating cavity walls, and either requires disruption to the inside of the property and a slight reduction in floor area (for interior insulation), or recladding the property for external insulation, which may not be permitted or desirable for heritage properties.

  - As shown in Figure 7, the majority of cavity wall properties have been insulated, while fewer than 10% of solid wall properties have been retrofitted. This illustrates how, going forward, thermal efficiency will require a greater emphasis on properties that are harder and more expensive to treat.

- **Windows and doors:** Both double and triple glazing can decrease energy loss and save money on bills. There can be other benefits too, such as soundproofing and reducing condensation.

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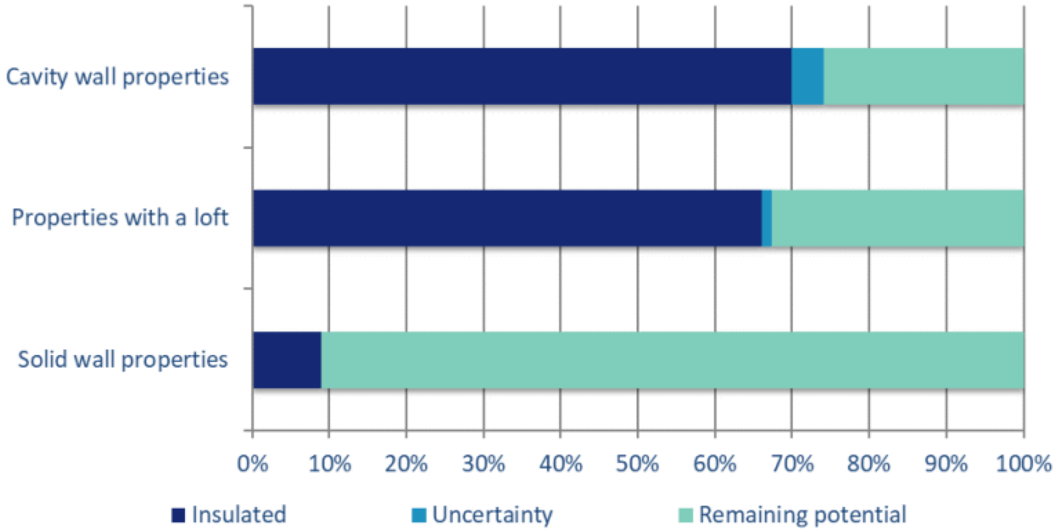
[20] HM Government (2021). Heat and Buildings Strategy.

[21] BEIS (2021) Household Energy Efficiency detailed release

[22] Energy Saving Trust. Cavity wall insulation

FIGURE 7 REMAINING POTENTIAL TO INSULATE THE HOUSING STOCK IN GREAT BRITAIN IN 2020



Source: BEIS - Household Energy Efficiency detailed release: Great Britain Data to December 2020

2.3.2 FES PATHWAYS FOR ENERGY EFFICIENCY

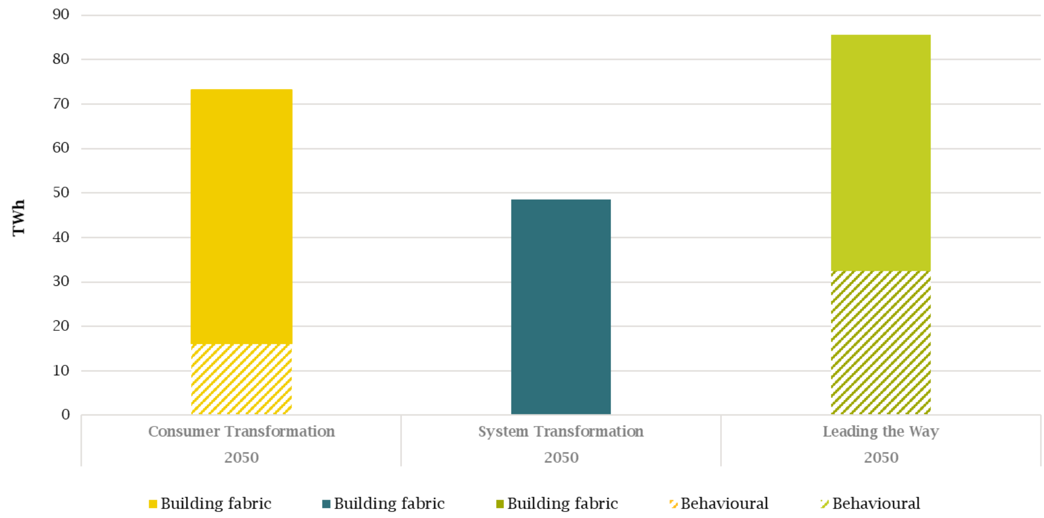
All three of the FES scenarios that we consider assume that the majority of buildings will be retrofitted by 2035, although they vary in the extent to which more expensive forms of intervention will be required.

Both the 'leading the way' and 'consumer transformation' scenarios forecast high levels of insulation measures such as extensive insulation in lofts and walls. In 'leading the way' new buildings will be very well insulated from 2025 onwards, making the uptake of heat pumps suitable. This is accompanied with behavioural change, where consumers would turn their thermostats down resulting in lower indoor temperatures. On average, consumers are expected to turn down their thermostats by 1˚C under 'leading the way' and 0.5˚C under 'consumer transformation' compared to today's indoor temperature levels.

As a consequence of higher investment in insulation and a greater degree of behavioural change amongst consumers, 'leading the way' and 'consumer transformation' presents the highest levels of energy savings for households by 2050 as shown in Figure 8.

By contrast, in the 'system transformation' scenario, consumers are not expected to change their behaviour towards their indoor temperature. In this scenario, consumers may see more of an economic benefit insulating homes that have a hydrogen boiler (which is assumed in this scenario) compared to a heat pump, considering that hydrogen boilers are less efficient than heat pumps and hydrogen fuel costs may therefore be high. As shown in Figure 8, consumers are expected to have lower savings in 'system transformation' in comparison with 'leading the way' and 'consumer transformation', despite that the retail price of the hydrogen used as a fuel is expected to be about two thirds cheaper than retail electricity prices on average.

FIGURE 8 BREAKDOWN OF SAVINGS IN UNDERLYING HEAT DEMAND DUE TO BUILDING FABRIC IMPROVEMENT AND CONSUMER BEHAVIOUR CHANGE IN 2050

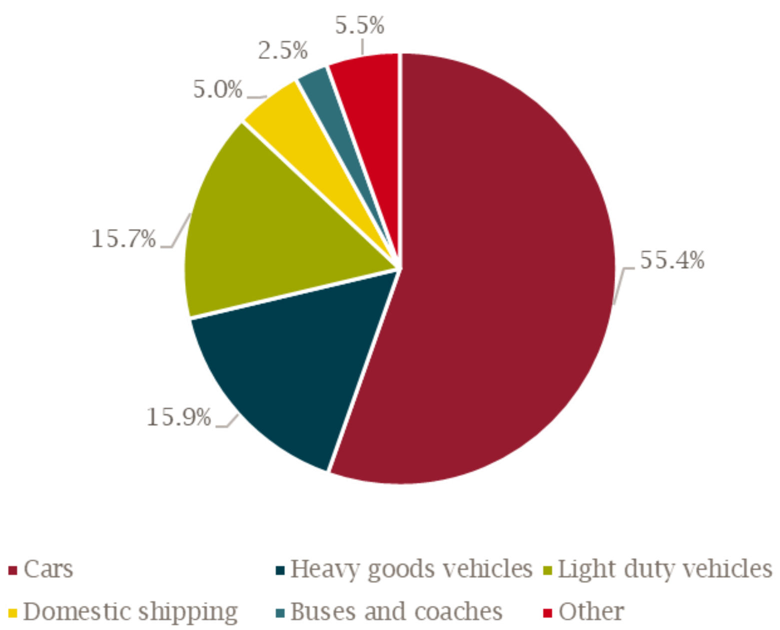


Source: National Grid ESO, FES (2021). Figure CV.13

2.4 ELECTRIFICATION OF DOMESTIC TRANSPORT

Historically domestic transport has been one of the largest contributors to GHG in the UK. The main source of emissions from this sector comes from the use of petrol and diesel vehicles. This has changed relatively little in recent years, with emissions only 5% lower in 2019 than they were in 1990.[23]

FIGURE 9 UK DOMESTIC TRANSPORT EMISSIONS 2019



Source: Department of Transport (2019) Decarbonising Transport

[23] BEIS (2022). [2020 UK Greenhouse Gas Emissions](), National Statistics

This report is concerned with the domestic energy market. We focus on cars, which are bought and refuelled by end-consumers and, as shown above, account for the majority of UK domestic transport emissions.

Due to the impact of the COVID-19 pandemic on road transport, transport emissions fell by 19% between 2019 and 2020[24]. Separate research by Frontier Economics for WPD showed that the reduction in car usage tended to be greater in areas with a lower population density, and higher income. DfT statistics show that, as of 2022 Q2, the distance travelled by private car was still around 12% lower than in 2019 Q2. We expect that there is likely to be some persistent reduction in car travel going forward, particularly in certain groups. For example, ONS research suggests that older workers may prefer to continue with some form of hybrid working or working from home, while young professionals may prefer to return to the office and the socialising opportunities that come with it. Nevertheless, even during 2020, transport was still responsible for 24% of UK domestic greenhouse gas emissions, the highest share of any sector[25]. Decarbonisation of domestic transport will therefore continue to be a prerequisite for reaching net zero – and the move to electric vehicles has the potential to place significant strains on the system.

2.4.1 DIFFERENT TYPES OF EVS AND CHARGE POINTS

Currently, the vast majority of cars on the road use internal combustion engines (ICE) fuelled by either petrol or diesel. The main alternative technologies available are as follows:

- **Battery Electric Vehicle (BEV).** Powered solely by batteries and electric motors, it produces zero emissions and can currently have up to around 280 miles range per charge. Charging time ranges between 0.5 to 12 hours. It is assumed to be the most adopted car in all FES scenarios.

- **Plug-in Hybrid Electric Vehicle (PHEV).** Cars capable of being powered by both fossil fuels (petrol or diesel) and electricity. Emissions depend on the mixture of fuel being used. PHEVs are likely to be a transitional technology, as fossil-fuel powered vehicles are not consistent with net zero.

- **Hydrogen fuel cell vehicle (HFCV).** Rather than being powered by electricity stored in a battery, these cars are powered via hydrogen. Refuelling is comparable to ICE cars. However, there are currently very few public hydrogen refuelling stations in the UK.[26]

Within this report we focus on battery electric vehicles, both because they make up the vast majority of the zero-emission cars in the FES scenarios, but also because homeowners will have the option to charge them from their domestic supply. This potentially brings them into the scope of the domestic energy market, unlike hydrogen fuel cell vehicles, which would be refuelled at privately run points like current petrol stations.

For electric vehicles, chargers can be categorised based on their location:

- **Private chargers.** Charging the EV at home or private office space.

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[24] BEIS (2022). 2020 UK Greenhouse Gas Emissions, National Statistics

[25] ibid

[26] GLPAutogas website. Accessed at: Hydrogen Stations in UK United Kingdom Map and List (glpautogas.info)

- **Public chargers.** Public charge points can be found on the street or in key places such as at shopping centres or in supermarket car parks. Public charges also includes motorways.

Charge points are also categorised by their power, reflecting the speed at which they can charge an EV:

- **Slow chargers.** Four to eight hours to fully recharge depending on the vehicle and its battery size. Suitable in locations where EVs are parked for a long time or overnight. These chargers typically provide power at 3 kW – 6 kW.[27]

- **Fast chargers.** Two to four hours to fully recharge depending on the vehicle. Suitable for places where EVs are parked for a few hours (e.g. shopping centres). These chargers typically provide power at 50 Kw.

- **Super-fast chargers.** 25-40 minutes for 80% recharge, depending on the vehicle. Cannot be installed in homes due to a lack of sufficient network connection capacity. These chargers typically provide power at 100 kW or more.

2.4.2 FES PATHWAYS FOR EV TRANSITION

Under all scenarios in FES, no new ICE or PHEVs are sold after 2040 and all cars on the road will be ultra-low emission by 2050. This is in line with Ten Point Plan for a Green Industrial Revolution, which expects that all petrol, diesel and hybrid cars will cease to be used by 2050.[28] Note that all scenarios show a faster uptake of low-carbon transport than the uptake of low-carbon heating systems discussed in section 2.2.

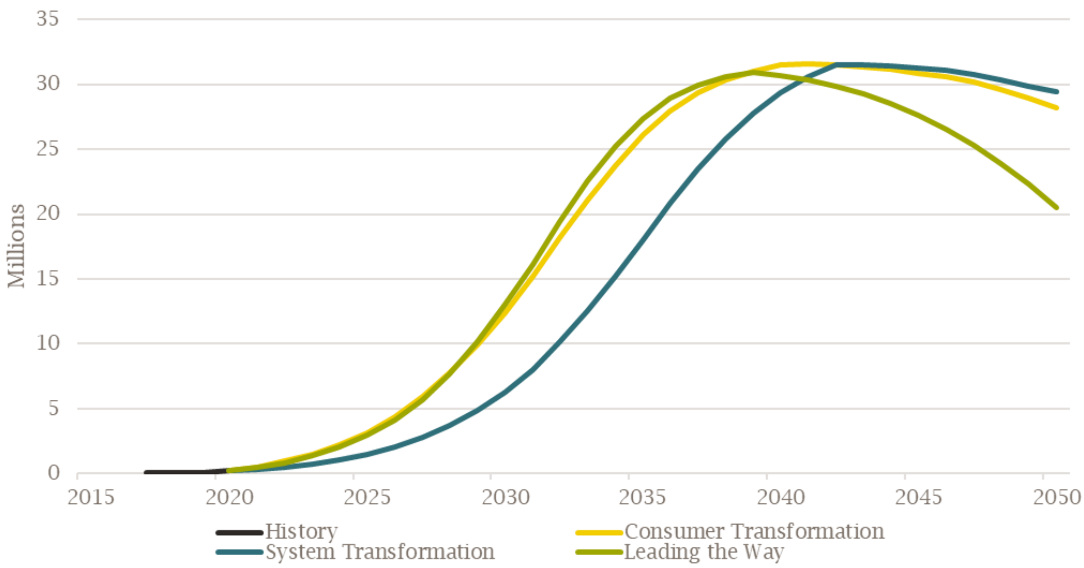
Both the 'consumer transformation' and 'leading the way' scenarios expect high levels of consumer engagement in the mid-2020s resulting in more people opting to use public transport where feasible or walking and biking. In Figure 10, 'leading the way' and 'consumer transformation' account for 26 and 27 million BEVs on the road respectively by 2035. In comparison with these scenarios, under 'system transformation' consumers are not as actively encouraged to ride share, walk or cycle and accounts for 18 million BEVs by 2035.

Another key difference of the 'system transformation' scenario is that it assumes 7.5 times more hydrogen cars, vans and lorries compared to the other two net zero scenarios we consider. Despite this scenario showing a higher number of HFCVs, it is still assumed that there would be far more BEVs than HFCVs on the road, going from approximately 5 million in 2030 to 30 million by 2040. The 'consumer transformation' scenario assumes the lowest amounts of HFCVs and instead assumes that most forms of road transport will be powered by electricity. Under 'leading the way' scenario, cars and vans are mainly electric, supported by the widespread national rollout of charging infrastructure, as well as smart charging devices at home or at the office, frequently paired with on-site solar PV and batteries to encourage self-consumption. However, it is assumed that around 2040, consumers will shift from cars to more public transport alternatives, such as trains, bike or walking, which reflects the decrease in BEV cars after 2040 under this scenario.

[27] Zap Map website. Accessed at: EV Charging connectors - Electric car charging speeds (zap-map.com)

[28] HM Government (2020). The Ten Point Plan for a Green Industrial Revolution, point 4.

FIGURE 10 NUMBER OF BEV CARS ON THE ROAD



Source: National Grid ESO, FES (2021). Figure CV.35

2.5 INSTALLATION OF DOMESTIC PV

Photovoltaic (PV) solar panel systems, capture the sun's energy using photovoltaic cells and convert this into electricity for self-consumption and/or export to the grid.[29] PV is likely to be a key part of the net zero transition and the Climate Change Committee (CCC) has suggested that solar generation capacity will increase to 54GW by 2035 to achieve net zero[30] in comparison with today's levels of only 13GW.[31]

While a large amount of this increase in installed PV capacity will come from utility-scale 'solar farms', there is also a significant role to play for domestic installations. These are typically mounted on the roofs of houses and sometimes installed alongside battery storage allowing customers to store energy for later use.

2.5.1 FES PATHWAYS FOR DOMESTIC PV

Both 'consumer transformation' and 'leading the way' present ten times more domestic solar PV by 2050 compared to today. In comparison, 'system transformation' has a more moderate view with the lowest levels on domestic PVs across all scenarios.

However it is worth noting that, even under the two highest scenarios, installations of domestic solar PV might affect roughly 30% of households by 2050.[32] While an extremely large number of buildings, this is

[29] House of Commons Library (2020). Q&A: solar panels- Briefing paper

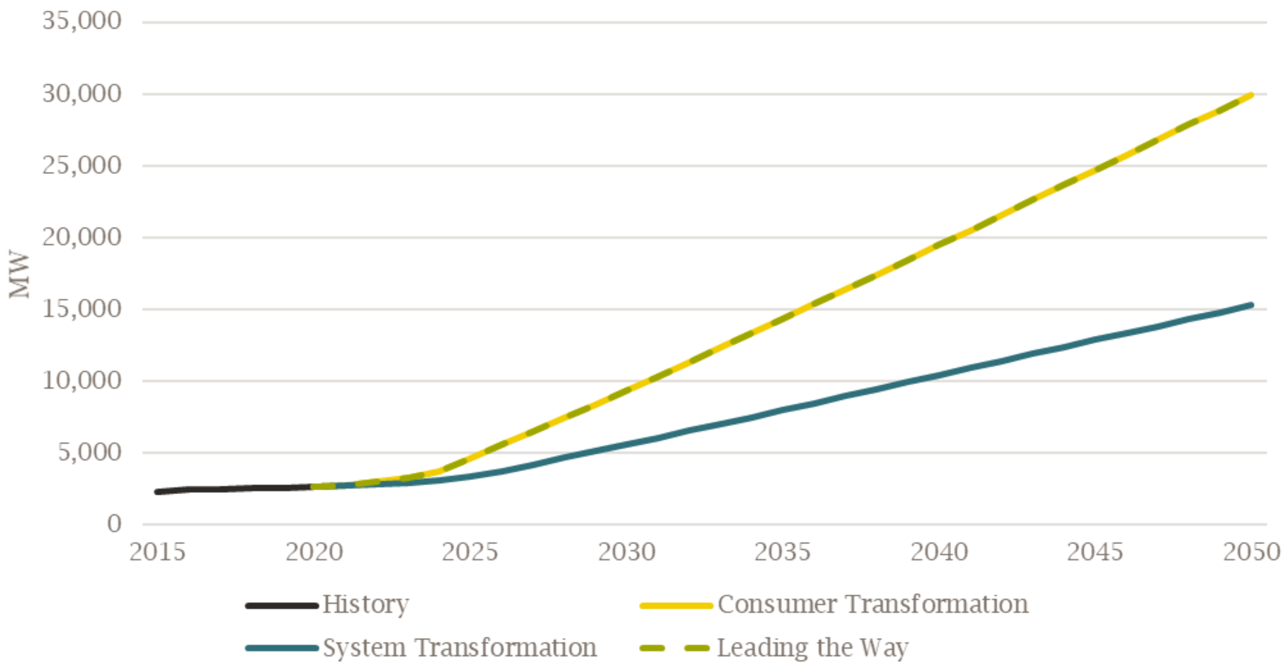
[30] CCC (2019) Net Zero Technical report

[31] UK National Statistics (2021). Solar photovoltaics deployment (Excel)

[32] Based on assuming an average installation size of 3.5kw, from European Commission (2017), *Study on "Residential Prosumers in the European Energy Union"*

less all-encompassing than the transitions in heat and transport, which will directly affect the vast majority of households.

FIGURE 11 DOMESTIC SOLAR PV INSTALLED CAPACITY



Source: National Grid ESO, FES (2021). Figure CV.24

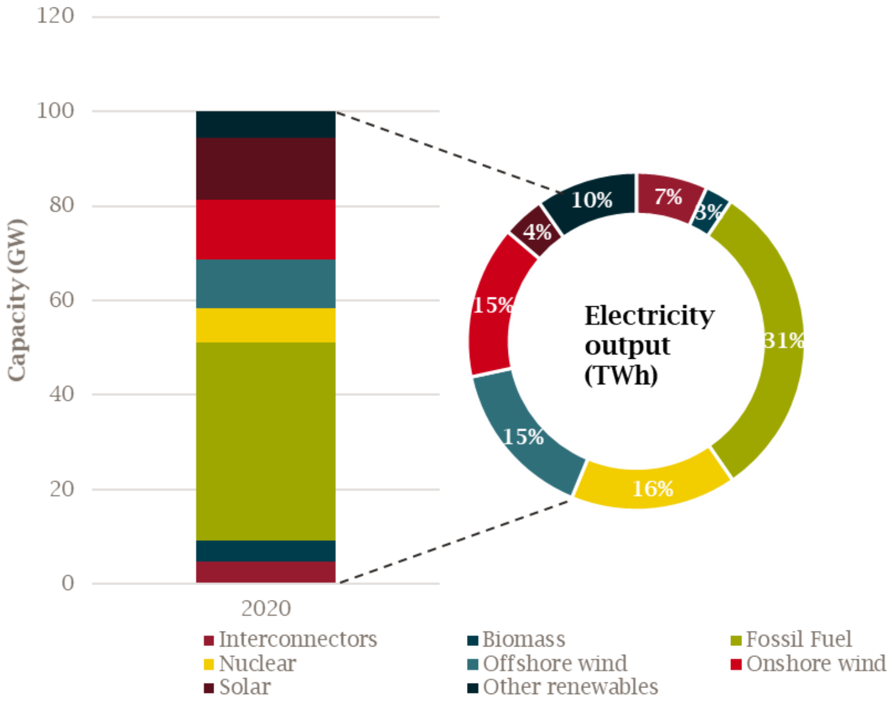
2.6 MORE ELECTRICITY GENERATION AND INCREASED SHARE OF RENEWABLES

The role of electricity generation within the whole energy system is changing as consumers choose new technologies for heat and transport. Decarbonisation of the electricity sector is essential for the decarbonisation of other sectors. Without decarbonisation of electricity, changes made by consumers such as use of electric vehicles and electrified home heating would not lead to a net reduction of emissions. The share of renewables for generation of electricity is crucial to the transition of net zero in 2050. As shown in Figure 12, fossil fuel generation still accounted for almost a third of the electrical energy used in GB in in 2020.

Renewable electricity generation had made significant progress in recent years. Wind and solar capacity has increased fivefold over the past 10 years. However, there is still a way to go. The CCC estimates that wind and solar energy will need to provide 90% of the UK's electricity in 2050 to achieve net zero, which is a more than four times higher than current levels.[33]

[33] CCC (2019) Net Zero Technical report

FIGURE 12 ELECTRICITY GENERATION CAPACITY AND OUTPUT IN 2020



Source: National Grid ESO, FES (2021). Figure SV.23

2.6.1 LOW-CARBON ELECTRICITY GENERATION TECHNOLOGIES

Figure 13 shows the FES assumptions about the changes to generation mix over time. There is not only an increase in generation capacity but also a greater share of biomass, wind, solar, hydrogen and other electricity technologies such as nuclear. Wind and solar energy show the biggest increases.

Both of these technologies are intermittent, meaning that electricity is not continuously available due to external factors that cannot be controlled (i.e. when the wind blows or the sun shines). Therefore the amount of electricity that can be generated from wind and solar can vary significantly over time, including within day and within season. This intermittency needs to be managed, for example through other generation capacity being able to flex in response to renewable availability, or through storage capacity being able to charge when renewable capacity is available and discharge when it isn't, or through customers moving their demand to times when renewable capacity is available. We discuss this further in the section on flexibility below.

Another feature of these renewable technologies is that they have high fixed costs associated with the manufacture and installation of wind turbines and PV panels, but then low or negligible costs of operation, as they are "fuelled" by the wind and the sun. This is in contrast to fossil fuel generation, where the ongoing fuel costs (e.g. gas) are high. These cost structure differences may be important for customers as – if they are to face cost reflective charges for the energy that they use – it would mean that the way they pay for energy may change, with less emphasis on charges for the units of energy they consume and more emphasis on the peak capacity of energy they take.

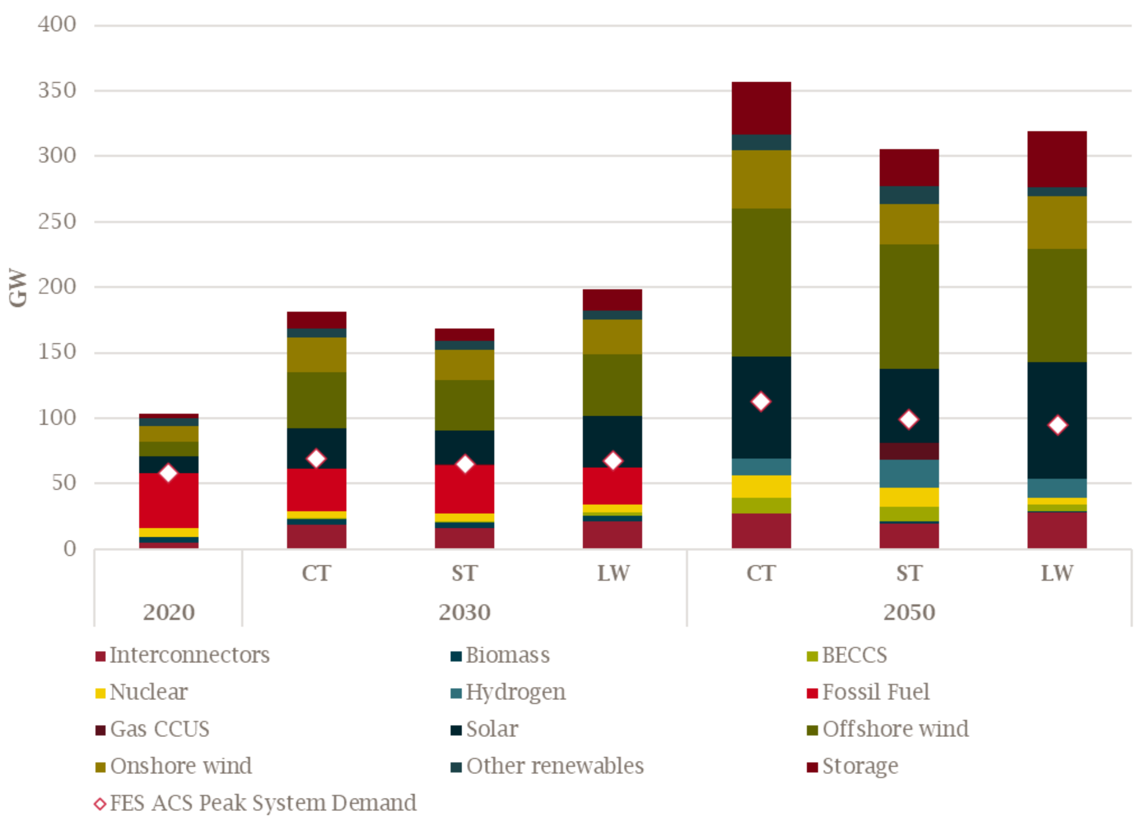
The ‘consumer transformation’ and ‘system transformation’ scenarios also show a significant increase in nuclear generation capacity by 2050. While nuclear power is not intermittent, it has high fixed costs and relatively low running costs. This means it is most economic to run nuclear plants continuously at maximum capacity. Again, this increases the benefits to flexible demand which can take advantage of the steady output from nuclear plants.

2.6.2 FES PATHWAYS FOR ELECTRICITY GENERATION

Whilst the increase in electricity peak demand varies across the scenarios based on the amount of electrification assumed, an increase in total generation capacity is required under all scenarios to meet this demand. This is driven by an increase in renewable generation, particularly from wind generation which accounts for over half of electricity generation by 2030 under all scenarios.

There are differences in the mix and amount of generation installed under each scenario. The strongest growth of renewables from off-shore wind is assumed under the ‘leading the way scenario’. This scenario also has no growth of nuclear, and natural gas generation is phased out rapidly. By 2050, wind, solar, nuclear and bioenergy with carbon capture and storage (BECCs) provide 96% of generation output. A steep increase in renewable generation is also assumed under the ‘consumer transformation’ scenario but this one retains natural gas generation to help to manage the renewable intermittency issue and support security of supply. Growth in renewable generation is slowest under the ‘system transformation’ scenario, albeit still rapid, with more limited growth in decentralised technologies such as onshore wind and solar. This scenario sees the greatest increase in hydrogen generation from 2030.

FIGURE 13 INSTALLED ELECTRICITY GENERATION CAPACITY, STORAGE AND INTERCONNECTION TO 2050



Source: National Grid ESO, FES (2021). Figure SV.22

2.7 CONSUMER FLEXIBILITY AND SMART HOMES

The transitions described above will place stresses on the electricity system. The electrification of heat and transport will lead to higher overall demand for electricity and greater peaks (particularly if consumers tend to charge their cars and heat their homes at the same time). Absent other interventions, this would require costly reinforcement to build additional capacity.

Greater peak demand will also require additional generation capacity, which could be unused for much of the year. The presence of much greater intermittent generation capacity will mean that times of peak generation will not necessarily coincide with peak demand. Absent changes to the demand for electricity, this will require flexibility on the generation side, through the provision of costly back-up capacity. Intermittent generation may also itself cause areas of the network to come under strain – for example if a cluster of domestic PV panels increases output without a corresponding increase in demand, and leads to excessive voltage on the local network.

Managing these issues at lowest cost to consumers will require increases in the flexibility of the system. This flexibility can take a variety of forms – for example:

- **Network flexibility** – adopting "smart grid" techniques such as dynamic asset ratings, automated voltage reduction, and automated load transfer to allow the networks to cope with more variable power flows.

- **Storage** – the use of systems such as utility-scale batteries or pumped storage hydroelectric plants to smooth out demand.

However the focus for this report is **consumer flexibility**: The use of DSR to enable consumers to reduce or shift their demand to where it will have least cost to the system as a whole.

As noted by BEIS in its Smart Systems and Flexibility Plan,[34] a smart, flexible energy home could reduce consumer energy bills, as well as giving consumers greater control over their energy. However participation in flexibility from domestic consumers in smart homes remains at an early stage. While there are 26.4 million smart and advanced meters in homes and small businesses in Great Britain[35], there are relatively few smart tariffs available to consumers. Likewise, the smart appliance market is relatively nascent, although the number of electric vehicles is increasing fast, and this is expected to provide a significant source of flexibility over the next decade and beyond.

2.7.1 CONSUMER FLEXIBILITY TECHNOLOGIES

A variety of technologies are required to enable consumer flexibility. A key one is **smart meters.** Unlike traditional meters, which simply register a running total of energy used, smart gas and electricity meters can record half-hourly price and consumption data and provide automatic meter readings to energy suppliers (and potentially other entities). Since the value of demand flexibility depends on when demand is shifted from and to, these capabilities will be required to measure load shifting.

In theory, consumers could adjust their consumption patterns manually. This already occurs to some extent – e.g. customers on Economy 7 may choose to run dishwashers and washing machines overnight. However

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[34] BEIS (2021). Transitioning to a net zero energy system: Smart Systems and Flexibility Plan 2021

[35] BEIS (2021). Smart Meter Statistics in Great Britain: Quarterly Report to end September 2021

responding to more complex signals (e.g. moving demand based on the real-time output of intermittent generators) is likely to require additional automation technology. This includes:

- **Smart appliances.** These could automatically respond to market signals and shift electricity demand away from peak periods. Such appliances may include heating technologies such as heat pumps, as well as washing machines, dishwashers and refrigerators or freezers, which can be turned off for short periods of time.

- **Smart Home Energy Management Systems.** These type of systems can be installed by customers to manage the use of smart appliances in a way which lowers cost, while maintaining the services (such as adequate heating) valued by consumers.

- **Smart Charging for EVs.** As more consumers start to own Electric Vehicles (EVs), smart charging will increase, helping to manage higher renewable supplies on the electricity system. With this technology, EV owners can have some control on the best time to charge or this could be automated based on price signals.

- **Bi-directional BEV chargers** allow power flows from and to the electricity grid and can provide even more flexibility through the use of Vehicle-to-Grid (V2G) where BEVs can supply surplus energy back to the grid.

2.7.2 FES PATHWAYS FOR CONSUMER FLEXIBILITY AND SMART HOMES

Whilst FES does not explicitly discuss the smart meter rollout, the latest Government framework sets domestic smart meter penetration targets for 2022 and 2023 of 58.5% and 66.9% respectively. [36]

DSR is expected to occur in all scenarios, although in lower levels for 'system transformation' scenario. In contrast, 'consumer transformation' and 'leading the way' have highly engaged consumers, and can see total peak demands reduced by 47% and 68% respectively due to domestic DSR technologies in Figure 14. This figure also shows how FES expects the vast majority of domestic DSR to occur from heating and transport:

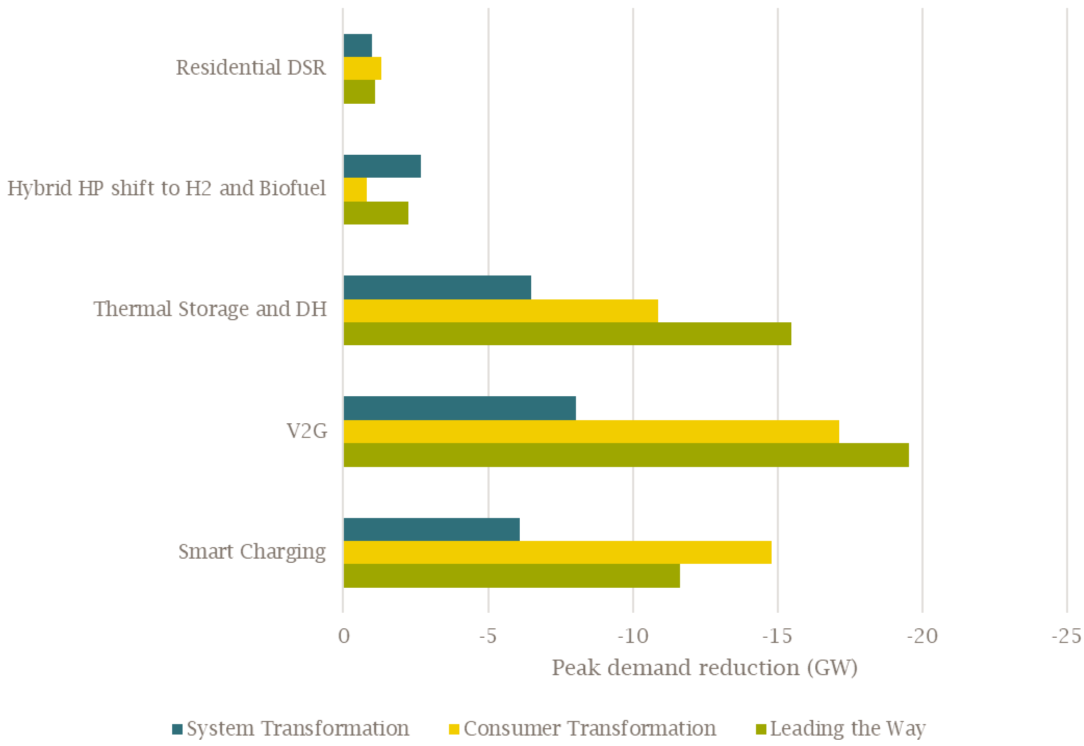
- **Heating** – the use of thermal storage in domestic heating technologies and district heating systems to enable power use to be temporarily switched off, as well as the ability of hybrid heat pumps to switch from electricity to gas or hydrogen.

- **Transport** – both smart charging (to allow the times when EVs are charged to be changed flexibly) and vehicle-to-grid (V2G) technologies.

Other residential DSR, while important, is projected to deliver a much lower reduction in peak demand. This shows how, while the electrification of heat and transport will lead to a substantial increase in peak demand, they are also the largest source of flexibility.

[36] BEIS (2021). Smart Meter Policy Framework Post 2020: Government Response to a Consultation on Minimum Threshold Annual Targets and Reporting Thresholds for Energy Suppliers

FIGURE 14 IMPACT OF FLEXIBLE DSR TECHNOLOGIES ON PEAK DEMANDS IN 2050



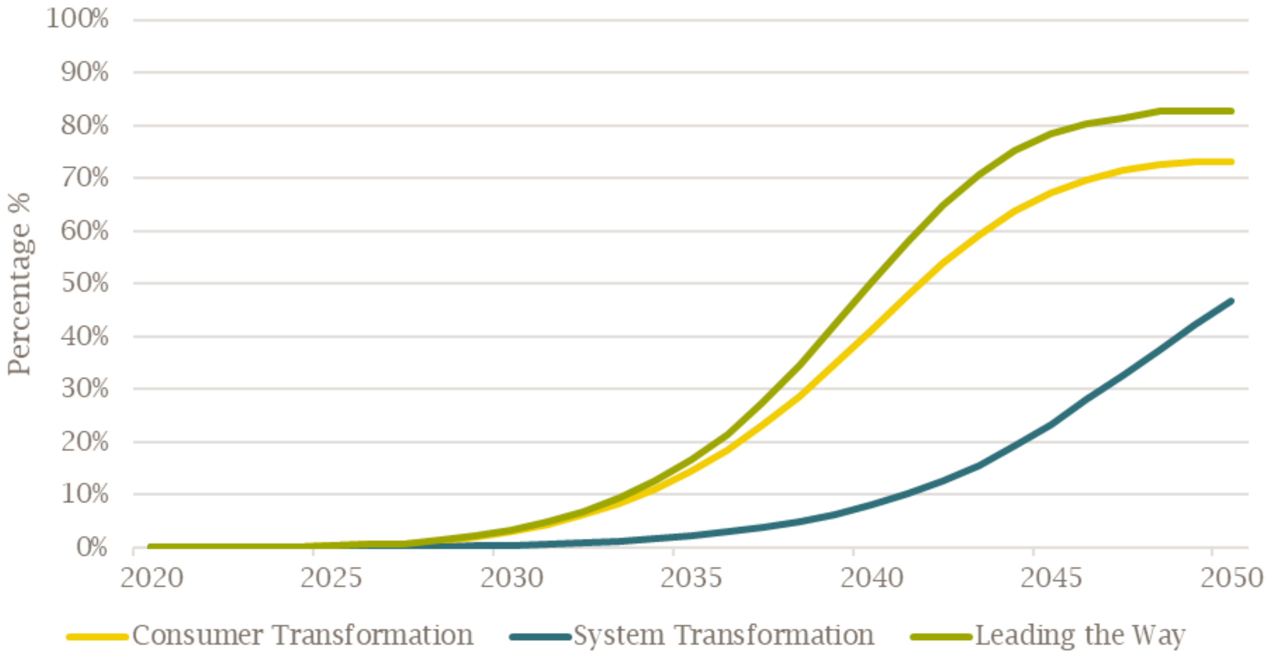
Source: FES 2021 Workbook.

Note: Flexibility provided by exporting energy from EV batteries to the grid captured by the 'V2G' column. V2G and Smart charging also includes commercial fleet. Residential DSR refers to any DSR that does not relate to heat or transport.

The remainder of this section will discuss FES assumptions for each of the flexibility automation technologies outlined above.

- **Smart appliances.** Widespread adoption of smart appliances is strongest in the 'leading the way' scenario closely followed by 'consumer transformation'. Adoption is both slower and lower in the 'system transformation' scenario which has the lowest amount of customer driven change. In all scenarios, the rapid up-take of smart appliances doesn't really begin until after 2035.

FIGURE 15 SMART APPLIANCE UPTAKE IN EACH SCENARIO

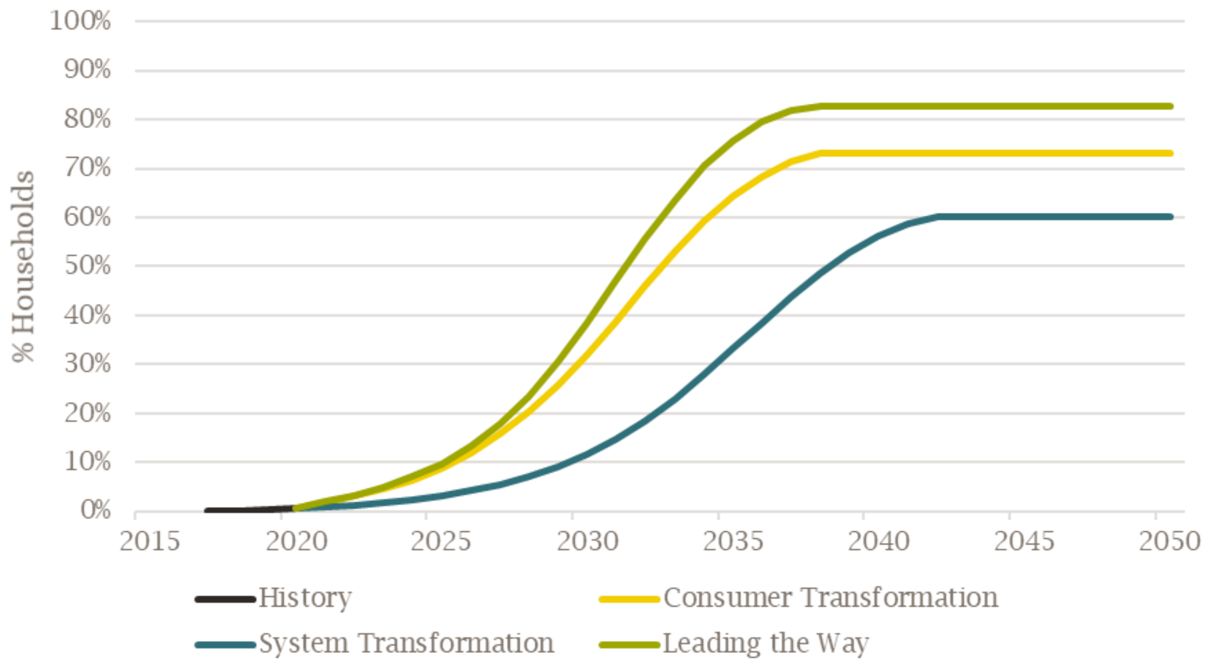


Source: NG ESO FES (2021) Figure CV.26. This does not relate to smart heating appliances like heat pumps.

- **Smart home management systems.** Strong uptake of smart appliances in the 'leading the way' and 'customer transformation' scenarios lay the groundwork for adoption of smart home management systems. Many customers are assumed to have invested in home energy management systems under the 'leading the way' scenario by 2050. Under the 'customer transformation' scenario, the majority of electricity demand for a typical homeowner is assumed to be smartly controlled to provide flexibility.

- **Smart charging for EVs.** Smart charging is assumed under all scenarios, although the speed with which it is taken up and the ultimate level varies. Under the 'Leading the Way' scenario, over 83% of customers are ultimately assumed to engage in smart charging with most of this transformation happening between 2025 and 2035. This is a similar pattern under 'customer transformation', albeit to a lower peak of 73%. 'System transformation' shows a slower path, with a more gradual increase from 2030 to 2040 and a peak of only 60%.

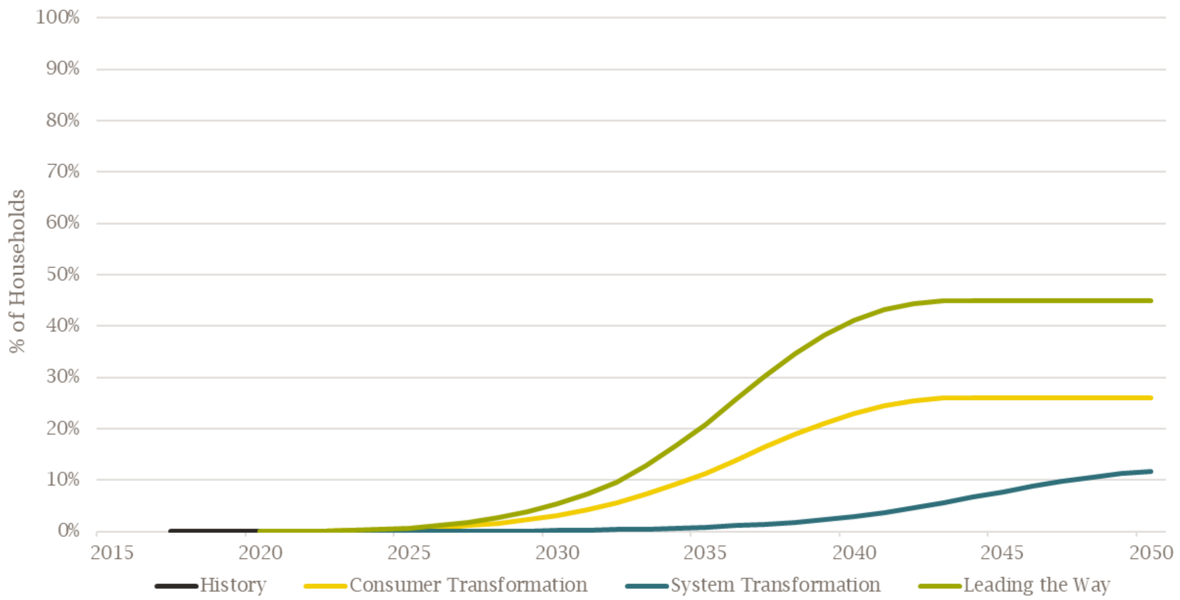
FIGURE 16 CONSUMER ENGAGEMENT IN SMART CHARGING



Source: National Grid ESO. FES 2021

- **Bi-directional BEV chargers.** Customer participation is highest under the 'leading the way' scenario where 45% of households are expected to engage with V2G from 2040 onwards. This falls to 26% under the 'customer transformation' scenario and just 12% under 'system transformation' in 2050.

FIGURE 17 CONSUMER ENGAGEMENT IN V2G

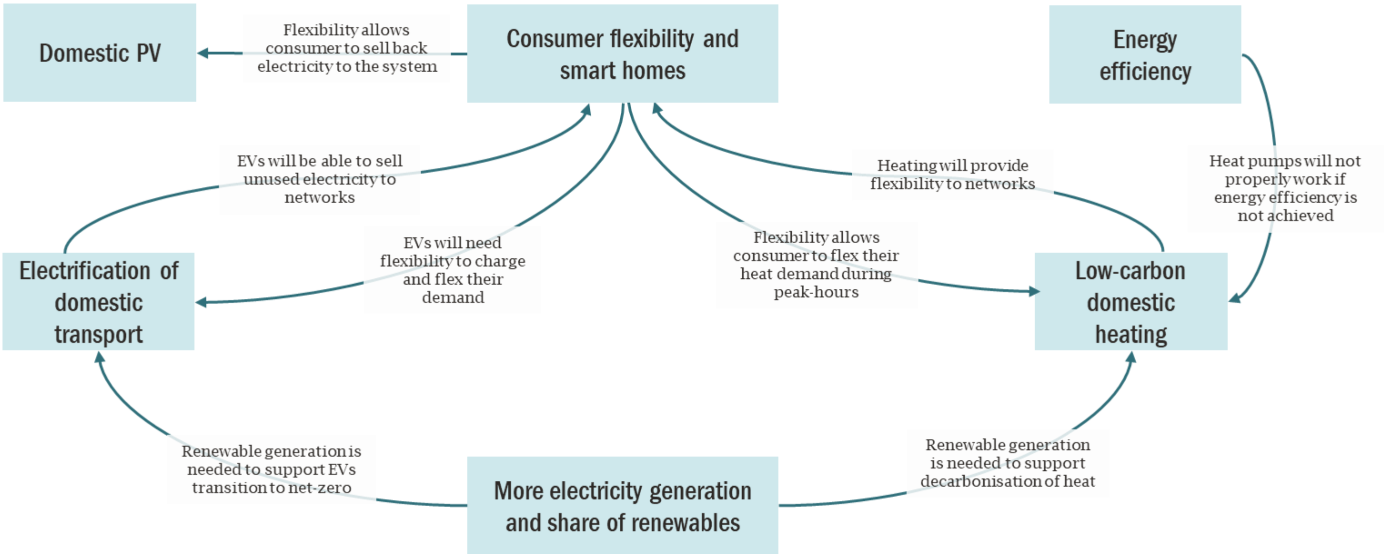


Source: NG ESO FES (2021) Figure CV.42

2.8 INTERDEPENDENCIES BETWEEN TRANSITIONS

These transitions cannot be considered on a standalone basis. Instead, they are linked with one another, with some transitions enabling, and being enabled, by others. We set out the key interdependencies in the figure below and provide an overview. Each arrow points from a transition to another transition which it enables.

FIGURE 18 INTERDEPENDENCIES BETWEEN TRANSITIONS



Source: Frontier Economics

- **Energy efficiency enables low-carbon heating.** Decarbonisation of domestic heat is inexorably linked with greater energy efficiency of homes. Regardless of the technology in place, greater energy efficiency will reduce overall energy demand and make future installation of low-carbon heating more cost-effective. Furthermore, energy efficiency of a property directly impacts the performance of heat pumps. This is because conventional boilers are designed to operate around 65˚C to 75 ˚C whereas heat pumps perform most efficiently at lower temperatures (35˚C to 55˚C) placing greater reliance on insulation. Consequently, customers are often advised to upgrade their home insulation before the installation of heat pumps as well as considering the installation of underfloor heating rather than radiators.

- **Consumer flexibility enables low-carbon heating.** Decarbonisation of heat is also enabled by the increase in flexibility and use of thermal storage. The adoption of heat pumps is expected to increase significantly the overall level of electricity demand.[37] In order to avoid unaffordable network reinforcement costs, this demand must be met by increasing demand-side flexibility where customers shift electricity use to off-peak times.

[37] The UK Government expects that installation of 600,000 heat pumps will be required by 2028 irrespective of the ultimate path to net zero. This is forecast to increase overall electricity demand by 5% by 2030[37] - See in BloombergNEF (2021). [Heating could add 5% to U.K. Electricity Demand in 2030.]

- **Low-carbon heating enables consumer flexibility.** Low-carbon solutions can offer flexibility to networks, supported by the increase adoption of thermal storage which allows customers to store heated water generated during off-peak times for use at a later on-peak time.

- **Renewables enables low-carbon heating.** Decarbonisation of heat associated with electrification (heat pumps, district heating, direct electric heating) relies on an increase in the share of renewable electricity generation to be considered low-carbon.

- **Consumer flexibility enables EVs.** As discussed above, mass transition to EVs will significantly increase electricity demand and shifting charging will help to reduce peak demand i.e. charging EVs overnight rather right after people arrive home from work.

- **EVs enables flexibility**. EVs can also form part of the solution for increasing DSR and flexibility via vehicle to grid (V2G) which is discussed in section below

- **Renewables enables EVs.** As is in the case with decarbonisation of heat, EVs also require the share of renewable generation to increase in order to be considered low-carbon.[38]

- **Consumer flexibility enables domestic PVs.** Installation of PV is not highly dependent with any other transitions, although the growth of local flexibility business models could make the installation of PV more attractive. Equally, PV combined with batteries could play a key role in delivering flexibility and DSR, as well as meeting some of the increased demand for electricity.

[38] We note there are wider questions around the impact of embedded emissions associated with EV manufacture but this is outside the scope of this work.

3 DOES THE CURRENT MARKET SUPPORT THE TRANSITION?

Having introduced the key transitions required to deliver net zero by 2050, this section considers whether the current market structure enables these transitions. For each transition, we provide:

- an overview of the current state of the market, including existing market trends and policies that will accelerate the transition;
- a description of the role (if any) that suppliers currently play; and
- a summary of potential barriers to each transition e.g. high upfront capital cost, or where the current market structure could result in unintended consequences, such as regressive distributional impacts.

The focus of project REDMAST is on domestic consumers. The markets and policies we discuss are therefore only those that directly impact domestic consumers and/or interact with the current supplier hub model. This includes existing policies and those that have been announced at the time this report was written (March 2022) e.g. the ICE phaseout. It does not include potential future policies that are yet to be determined e.g. any potential additional levy on fossil fuels.

This section is not intended to be an exhaustive summary of all issues or policies relating to each of the transitions, nor will it quantify the extent to which the current market may or may not deliver each transition. Instead our focus is on factors that may influence the delivery of the transition for domestic customers.

3.1 DECARBONISATION OF DOMESTIC HEAT

As described above, the path to net zero will involve replacing gas boilers, the technology used by the vast majority of homes in GB, with a mixture of heat pumps, electric heating, district heating, and potentially hydrogen boilers.

3.1.1 CURRENT MARKET AND POLICY STRUCTURE

Replacement of heating systems in existing homes typically occurs when the previous system fails (or is in the process of failing) and the responsibility falls to the property owner.[39] This also applies to rental properties where landlords have a legal responsibility for repairs to heating and hot water.[40] The majority of properties currently use gas boilers for heating (Figure 4) and homeowners will typically rely on the services of a gas engineer for the repair, maintenance, and installation of new gas heating systems. For new builds, the property developer is typically responsible for the choice of heating system.

Where customers wish to replace their gas based heating system with a low-carbon option, their options are typically limited to the installation of a heat pump or move to direct electric heating unless they are already connected to a district heat network. This is because district heat networks are complex to set up and typically require an organisation to design, promote, and fund the costs of building the source and connection of multiple properties. Consequently they are not typically initiated by individual building

[39] DECC (2013). Homeowner's willingness to take up more efficient heating systems.

[40] Landlord and Tenant Act 1985. Accessed here: https://www.legislation.gov.uk/ukpga/1985/70

owners.[41] The use of hydrogen for home heating is currently limited to neighbourhood and village trials. There is currently no national network for hydrogen heating and the Government is not due to come to a decision on the use of hydrogen for home heating until 2026.

Until 31 March 2022, customers who have installed low-carbon heating technologies were eligible to receive quarterly payments over seven years under the domestic renewable heat incentive (RHI). This is being replaced by the boiler upgrade scheme which was announced as one of the policies in the Government's recent Heat and Buildings Strategy.[42] The strategy introduced several policies designed to accelerate the uptake of low-carbon heating technologies for existing properties and new properties.

TABLE 2 SUMMARY OF HEAT AND BUILDINGS STRATEGY POLICIES

POLICY	APPLICABILITY	PROPOSED START DATE
Boiler upgrade scheme. The Government is replacing the current domestic renewable heat incentive (RHI) scheme with the boiler upgrade scheme (BUS) which provides households with a £5,000 grant for an ASHP or biomass boiler and £6,000 for a GSHP. The Government has allocated £450m to the scheme which suggest that around 90,000 households will benefit from this scheme over three years.	Existing homes and self-built new builds	April 2022
Heat network transformation programme. Provides £338m of capital funding to develop heat networks across England and Wales and support them move to low-carbon heat sources	Existing homes	2022 (and lasts till 2025)
Manufacturer obligation. The Government is proposing to introduce a market based mechanism for low carbon heat that would require fossil fuel boiler manufacturers to sell a certain level of heat pumps proportional to their fossil fuel boiler sales.	New builds and existing homes	2024
Future homes standard. The Future Homes Standard for England will require new build homes in England to use low carbon heating (and higher energy efficiency).	New builds	2025
Heat network zoning and Heat Network Transformation Programme. Introduction of heat network zones in England by 2025 within which certain buildings would be required to connect to heat networks. Local authorities would have the power to require buildings within heat network zones to connect to the network. This is intended to provide greater certainty for the demand for heat networks, reducing uncertainty and promoting investment.	New builds	2025
Gas Boiler phase out. Phase out the installation of new natural gas boilers.	New builds and existing homes	2035

Source: Heat and Buildings Strategy (2021)

[41] HM Government (2021). Heat and Buildings strategy

[42] Ibid.

The Heat and Buildings Strategy also introduced measures targeted at building a better understanding of the role of hydrogen in heating, including a series of trials, with a strategic decision due in 2026. It also signalled that the government is considering further measures such as expanding carbon pricing and removal of costs from electricity bills.

In addition to these policies, the Energy Systems Catapult has recently explored new business models to deliver 'heat as a service' (HaaS). Under this model, customers would pay for the temperature that a home is heat to or paying flat-rate tariffs for a home to be heated rather than paying for the amount of energy they consumer. Under this model, suppliers could package provision of heat alongside installation of low-carbon heat systems and would be incentivised to do so if it is more energy efficient. However, HaaS is not currently a mainstream model in the UK.[43]

3.1.2 THE CURRENT ROLE OF SUPPLIERS

Suppliers currently play a limited role in promoting the switch to low-carbon heating:

- **Innovative tariffs that promote low carbon heating systems**. A small number of suppliers offer tariffs that promote low carbon technologies. For example, OVO's Smart Heat Offer includes a discounted 12-month finance offer for customers to purchase smart storage heaters coupled with a single time-of-use tariff (Economy 7) and smart heat optimisation.[44] However these examples are limited.

- **Expansion into provision of low-carbon heating solutions.** Some supplies have expanded into home heating business e.g. British Gas recently launched a ASHP installation business[45] as has Octopus energy.[46] However, this is not a regulated activity for suppliers (see WP1) and is largely separate from their retail activities.

It is worth noting that whilst suppliers also have a revenue collection role and a proportion of customer energy bills are to fund social and environmental policies, none of these policies are related directly to the decarbonisation of heat.[47] For example, heat decarbonisation costs associated with the RHI were funded via general taxation rather than a levy on customer energy bills.[48]

3.1.3 POTENTIAL ISSUES FOR TRANSITION

The UK Government Heat and Buildings strategy sets out several policies designed to enable to adoption of LCT heating primarily via a market-based approach. However, the CCC has identified several gaps that will need to be addressed in order for decarbonisation of heat to be successful.[49]

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[43] Energy Systems Catapult (2021). The potential of Heat as a Services as a route to decarbonisation for Scotland

[44] Energy Systems Catapult (2021). The potential of heat as a service as a route to decarbonisation of Scotland.

[45] Centrica News release (2022). British Gas launches new air source heat pump offering.

[46] Octopus energy website. Accessed at: https://octopus.energy/blog/heat-pump-revolution/

[47] Further information on environmental and social policies that are funded via a levy on customer bills can be found here: https://assets.publishing.service.gov.uk/media/559fb5bf40f0b61567000045/Appendix_7.1_Social_and_environmental_obligations_and_policy_costs.pdf

[48] ClimateXChange (2021). Review of gas and electricity levies and their impact on low carbon heating uptake

[49] CCC (2022). Independent Assessment: the UK's Heat and Buildings Strategy

- **Rebalancing levies from electricity to gas.** The majority of options for low-carbon heat rely on the use of electricity. However, the current allocation of policy costs within customer bills[50] means that electricity is more expensive than natural gas or oil reducing customer incentives to switch. This is reflected in the fact that replacing an old gas boiler with an ASHP or GSHP is not expected to save customers money compared to a new gas boiler (based on November 2021 fuel prices)[51]. Whilst the Government has committed to look at options to rebalance energy levies from electricity to gas, there has been no progress on the issue which is complicated by the current energy bills crisis.

- **Upfront capital costs for consumers.** High costs of heat pumps is one of the major barriers to installation and only 25% of customers are willing to buy a heat pump at its current price range.[52] Whilst the Government has provided limited subsidies as part of its BUS, this will only fund 90,000 installations over 3 years vs. the estimated 600,000 installations per annum forecast to be required.[53] Based on current heat pump costs, the upfront cost even with a subsidy is substantial (£5,000 subsidy for ASHP vs. upfront costs of £7,000 - £13,000[54], and £6000 subsidy for GSHP with an average cost of £14,000 - £19,000[55]). In order for heat pumps to be affordable, this will largely rely on the success of the proposed manufacture obligation to stimulate the market for heat pumps and reduce costs.

- **Upfront cost for investors.** One of the key barriers to heat networks is that they are not currently cost competitive and rely on high-carbon heat generation in most areas. The Government's heat transformation programme provides upfront capital funding for low-carbon heat networks between 2022 and 2025 but assumes that this will be accompanied by significant private investment. If this is not the case and strong market conditions do not emerge by 2025, this could be a major barrier to expansion of low-carbon heat networks. We note that Scotland has additional policies to support heat networks as part of the Heat Networks (Scotland) Act 2021.

- **Skills and resource gap.** There is a risk even if the right policies and incentives are in place, the skills and resource gap to deliver these policies is a major barrier. This includes insufficient capacity to enforce new building standards at local levels in addition to a shortage of skilled installers of low carbon heating technologies.

- **Public buy-in.** Adoption of low-carbon technologies in the 'customer transformation' and 'leading the way' scenarios both rely on behavioural change to adopt technologies such as heat pumps. Further targeted engagement may be required to support adoption, similar to the Smart GB campaign for the adoption of smart meters.

- **Co-ordination of local plans.** Whilst the government strategy lays out a high-level national approach to the decarbonisation of heat, FES recognises that there are likely to be local clusters and regional differences in the final technology adopted. This means that organisations will need

[50] Based on an average bill in August 2019, environmental and social obligation costs made up 2.46% of an average gas bill vs. 25.48% of an average electricity bill. For more information see: Costs in your energy bill | Ofgem

[51] Energy Savings Trust. Accessed March 2022. Air-to-water heat pumps. Ground-to-water heat pumps

[52] Nesta, The Behavioural Insights Team (2022). Estimating the willingness to pay for a heat pump

[53] HM Government (2021). Heat and buildings strategy

[54] Energy Savings Trust. Accessed March 2022. Air-to-water heat pumps.

[55] Energy Savings Trust. Accessed March 2022. Ground-to-water heat pumps

to co-ordinate at a local level to develop Local Area Energy Plans (LAEPs) which is currently challenging.

- **Distributional issues.** Finally, the low-carbon transition must take into account distributional fairness and affordability. Where local clusters emerge, differences in energy costs must be taken into account particularly for vulnerable customers and fuel-poor households e.g. if an area is designated a district heating zone rather than part of a local hydrogen network and there are significant differences in energy costs, this will lead to distributional issues.

In addition to the CCC's assessment of the Heat and Buildings Strategy, the recent Industry and Regulators Committee report on net zero identified the current customer-supplier relationship as a barrier to 'as a service' models. Customers currently receive energy as a commodity and are encouraged to switch as often as possible. This makes it difficult to develop the long-term relationships required for customers to hand over greater control of their homes or devices.[56]

3.2 DOMESTIC ENERGY EFFICIENCY UPGRADES

Improving energy efficiency can refer to one of two concepts. Improving thermal energy efficiency means reducing the amount of heat lost from homes whereas improving the energy efficiency of appliances refers to reducing the amount of energy required to use the device. The majority of this section will focus on thermal efficiency although we provide a brief overview of the current market and policies for energy efficiency of appliances below.

3.2.1 CURRENT MARKET AND POLICY STRUCTURE

Encouraging improvement of energy efficiency of appliances is primarily carried out via supply-side product policies. There are regulations that prevent the sale of highly energy inefficient options such as the ban on incandescent and halogen light bulbs and 2018 Boiler Plus Standards which set a minimum efficient standard for domestic gas boiler replacements in England. Some appliances are also required to display energy labels under Ecodesign requirements that rate how energy efficient it is. Customers are free to choose to purchase more energy efficiency appliances and devices. Previous supplier led schemes such as the Carbon Emission Reduction Target (CERT) which predated the ECO did involve suppliers handing out large numbers of energy efficient lightbulbs, although this is no longer the case.[57]

In the case of thermal efficiency, the decision to install energy efficiency upgrades is typically up to the homeowner. This is sometimes prompted by third party installers, contracted by energy suppliers, to provide energy company obligations (ECO) services. These installers will pro-actively contact households to offer energy efficiency upgrades. In other cases, customers may choose to install energy efficiency measures as part of wider works e.g. replacing broken windows with double or triple glazing.

For new build properties, all homes are given an Energy Performance Certificate (EPC) rating which scores the property on energy efficiency. There is currently no legal requirement for a minimum EPC rating although all new builds are subject to minimum standards for draught proofing, lighting, and heating.[58]

[56] House of Lords. Industry and Regulators Committee (2022). The net zero transformation: delivery, regulation and the consumer

[57] Citizens Advice Scotland (2016). Taking the Temperature: A review of energy efficiency and fuel poverty schemes in Scotland

[58] Part L of Schedule 1 of the Building Regulations 2010.

There is some evidence to suggest buyers may be willing to pay a premium for energy efficient houses[59] which may lead developers to voluntarily invest in energy efficiency measures and 84% of new-builds built between October and December 2021 had a EPC rating of A or B.[60]

The main policy to promote retrofit of energy efficiency measure in existing homes is the ECO scheme which requires suppliers to install energy efficiency measures in eligible homes either for free or at a subsidised rate. It is currently a "100% Affordable Warmth" scheme focused on alleviating fuel poverty[61] and is therefore targeted at vulnerable and low-income households. ECO4, which will run from 2022-2026, plans to introduce additional EPC requirements to focus on the least energy efficient homes.[62]

The Government previously offered financing for energy efficiency upgrades as part of the Green Deal. Under this scheme, the government provided loans for households to finance energy efficiency improvements, with subsequent repayments made as part of energy bills. The scheme was based on the 'golden rule' that the expected financial savings from these energy efficiency measures should be equal or greater to the repayment costs attached to customer energy bills.[63] Government funding for the scheme was cancelled in 2015 due to low-takeup.[64] Customers can still apply for Green Deal finance through a private company but in practice very few private firms are willing to offer loans without Government support.[65] Other policies include minimum energy efficient standards for rentals which require landlords to improve the EPC rating to E or register a valid exemption before starting a new tenancy.[66]

Customers may receive energy efficiency upgrades via grants targeted at Local Authorities such as the Green Homes Grant Local Authority Delivery Scheme which aims to raise the energy efficiency of low-income and low energy performance homes. Under this scheme Local Authorities apply for grant funding. Successful applicants can then establish local schemes for funding energy efficiency retrofits[67] e.g. Ealing Council allows low-income households with poor EPC ratings to apply for funding.[68] The Home Upgrade Grant and Social Housing Decarbonisation Fund also provide funding for energy efficiency improvements via Local Authorities.

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[59] Savills (2020). Delivering new homes resiliently.

[60] Buy Association (2022). Latest EPC findings show new-builds significantly outperform old homes

[61] BEIS (2019). Energy Company Obligation 2018-2022. Policy guidance for obligated suppliers, manufacturers and installers on applying for Demonstration Actions, Innovation Score Uplifts, and In-situ Performance.

[62] This includes a minimum delivery requirement of improving band F or G homes to reach at least band D, and band D or E home to at least band C. It is also proposing to introduce a minimum number of band E, F, and G homes to be upgraded. BEIS (2021). Energy Company Obligation ECO4: 2022-2026 Consultation.

[63] DECC (2010). The Green Deal. A summary of the Government's proposals

[64] BEIS (2015). Green Deal Finance Company funding to end

[65] MoneySupermarket. Accessed at: https://www.moneysupermarket.com/gas-and-electricity/the-green-deal-explained/

[66] The Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015

[67] The Government previously offered grants directly to customers via the Green Homes Grant Voucher scheme which was launched in 2020 but this was closed in March 2021.

[68]

Ealing Council website. Accessed at: https://www.ealing.gov.uk/info/201098/energy_efficiency/2764/green_homes_grant

Looking forward, the Government's heat and buildings strategy lays out several upcoming policies:

- **The Future Homes Standard.** The Future Homes Standard will be introduced in England by 2025 and will require all new-build homes to have higher levels of energy efficiency. In the interim, the government plans to introduce an uplift to insulation standards to be introduced in June 2022.

- **Improving home performance through lenders**. The Government has consulted on proposals to require mortgage lenders to disclose energy performance across their property portfolio and the introduction of voluntary targets to improve average performance across their portfolio to EPC band C These targets would be made mandatory if insufficient progress is being made.

The Government has also signalled its intention to consult on additional proposals in its Heat and Building Strategy. This includes measures for raising minimum energy performance standards for appliances between 2022 and 2023, with final policies being implemented in 2025, as well as setting a long-term regulatory standard to improve social housing to EPC band C.

3.2.2 CURRENT ROLE OF SUPPLIERS

The main role of supplies with regards to installation of energy efficiency measures is via the ECO scheme. Obligated suppliers have minimum targets they must meet, and they will typically partner with energy installers to identify potential eligible households and carry out ECO installations (see WP1 for further information).

Where customers have accessed Green Deal financing, repayments are collected via customer energy bills. The Green Deal provider will pass on the relevant details to the customer's supplier who would pass on charges to customers as part of their bills throughout the repayment period.[69] Energy suppliers are not typically involved in other schemes such as the Green Homes Grant Authority Delivery Schemes.

3.2.3 POTENTIAL ISSUES FOR TRANSITION

The CCC evaluation of the Government's heat and building strategy identifies several policy gaps and delivery risks associated with promoting energy efficiency improvements.[70] We summarise these below along with some additional challenges that we have identified.

The CCC identifies policy gaps where new policy is required as well as policy areas with significant risk where further work is required to overcome uncertainties and delivery or funding risks:

- **Lack of local resource.** The CCC's assessment of the heat and buildings strategy found that skills shortages and lack of local resource is a major barrier to enforcing new policies. Local Authorities will need the necessary resource to carry out inspections and enforce new standards, or to deliver energy efficiency upgrade schemes funded via local authority grants.

- **Challenging housing stock for retrofits.** Some properties have particular challenges to retrofitting energy efficiency measures including leasehold property owners who have legal restrictions on how much they can change, multi-tenure multi-use buildings, and traditional buildings that may have listed status. The Government has indicated that it is 'exploring how to prevent [leasehold

[69] DECC. The Green Deal. A summary of the Government's proposals

[70] CCC (2022). Independent Assessment: The UK's Heat and Buildings Strategy

restrictions] from acting as a barrier to upgrading homes' but have not yet proposed any policies.[71] However, there is no currently no clear policy that would support improvements to the social-rented sector and the mortgaged provider obligation is currently voluntary.

- **Reliance on market-based mechanisms.** The Government's proposals for accelerating decarbonisation of heat rely primarily on market-based mechanisms alongside obligations on heat pump manufacturers but it is uncertain whether this will be sufficient to reach the levels of low-carbon heat adoption required to deliver against the 2050 net zero deadline.

In addition to the policy gaps and risks identified by the CCC, we summarise a number of additional gaps:

- **Upfront costs and long payback periods.** The primary demand-side scheme for promoting uptake of energy efficiency measures remains ECO. This is targeted primarily at vulnerable and low-income households to reduce fuel poverty. However, the upfront cost of installing energy efficiency measures may be a barrier for a wider range of households. Research on consumer attitudes found that customers were sceptical that they would recoup the cost in bill savings or increased value in the property. This can be a particular issue for rented accommodation where landlords are unwilling to invest in energy efficiency measures.[72] Research has also shown homeowners struggled to look further than five years ahead and were concerned they would potentially move home in the future. Some also reported that improving energy efficiency was simply a lower priority, preferring instead to spend the money on other things e.g. holidays.[73]

- **Hassle factor and perceived lack of trusted installers.** One of the major barriers to retrofitting properties is the perceived hassle factor of works. Recent research found that 39% of customers wanted to avoid any renovations or alterations while 34% strongly agreed that researching and managing the installation of energy efficiency upgrades would take a lot of effort.[74] The same research found that 32% of customers felt that it was difficult to find skilled tradespeople to deliver energy efficiency installations.[75]

- **Misalignment of supplier incentives.** There is limited incentive for suppliers to encourage energy efficiency improvements outside of their obligations under ECO. As described in section 3.1, one way of encouraging the take-up of low-carbon technologies (including energy efficiency measures) would be a "heat as a service" business model, where a consumers' energy supplier takes on the task of installing the interventions that will lead to the lowest bill, passing this through to consumers. However such a business model is difficult under the current market structure for two main reasons:

    - Suppliers charge per MWh of energy, and so any reduction in energy usage would reduce their margins. In theory this should not be an issue: A supplier could install an intervention (e.g. insulation) which reduces consumption, and increase its per-MWh charge to account for the cost of the insulation, while leaving a saving that can be split between the supplier and the consumer. However such tariffs would be difficult to compare, and

[71] HM Government (2021). Heat and buildings strategy.

[72] BEIS (2019). Energy efficiency: building towards net zero.

[73] Accent (2016). Driving Installation of energy efficiency measures: Customer research findings. Final report.

[74] NESTA (2021). Decarbonising homes. Customer attitudes towards energy efficiency and green heating in the UK

[75] Ibid.

would require consumers to make an active choice to take up a new type of contract. Many customers are currently on default tariffs, which are subject to a per-MWh cap which would not account for the suppliers' investment costs.

- Fixed-term energy supply contracts are typically for a year, and can often be left mid-term without a large penalty, while default tariffs can be left at any point. This is problematic for energy efficiency investments which may take years to pay off, and cannot easily be removed by the supplier if the consumer chooses to end the contract. While the Green Deal sought to provide a mechanism to avoid this, it was not widely successful. "Value-add" tariffs are emerging in the EV space with some suppliers offering bundled tariffs with other EV services such as charger installation, although these costs are likely to be much lower than the types of energy efficiency interventions which are required.

3.3 ELECTRIFICATION OF DOMESTIC TRANSPORT

3.3.1 CURRENT MARKET AND POLICY STRUCTURE

Consumers face two choices when it comes to electric vehicles: (1) the decision to purchase or lease an EV rather than a hybrid or ICE vehicle and (2) their EV charging arrangements. These two decisions are interlinked, with the possibility of at home-charging often influencing the decision of whether or not to switch to an EV.

Currently customers can freely choose between an EV, hybrid, or ICE vehicle, although under current plans the sale or lease of new petrol and diesel cars will be banned from 2030 and hybrid cars from 2035.[76] Whilst EVs typically have a higher upfront purchase price than ICE cars, prices are expected to equalise by mid-2020s[77] and they have lower running costs due to lower fuel costs and maintenance costs[78], and zero emissions cars are currently exempt from vehicle excise duty (VED).[79] Furthermore, customers purchasing an electric car with a recommended retail price of £32,000 or less can receive a grant of 35% of the purchase price up to £1,500.[80] Specific locations may offer other incentives e.g. Hounslow council has emissions-based parking charges[81] and EVs receive a cleaner vehicle discount for the London Congestion Charge zone.[82]

Once a customer has purchased an EV, they face several options for charging. Ofgem's recent guide to the supply of electricity for EV charging identifies eight scenarios.

[76] Department for Transport (2021). Outcome and response to ending the sale of net petrol, diesel and hybrid cars and vans.

[77] House of Commons (2021). Electric vehicles and infrastructure

[78] Behavioural Insights Team and Transport Research Laboratory (2020). Driving and accelerating the adoption of electric vehicles in the UK.

[79] HM Government. Transitioning to zero emissions cars and vans: 2035 delivery plan.

[80] Office for Zero Emission Vehicles (2021). Plug-in car grant. Vehicle application form and guidance notes. Version 8.

[81] Hounslow Council News (2020). Council approves introduction of emissions-based parking charges

[82] TfL. Accessed at: https://tfl.gov.uk/modes/driving/congestion-charge/discounts-and-exemptions

TABLE 3 OFGEM EV CHARGING SCENARIOS

SCENARIO	DESCRIPTION	COMMERCIAL ARRANGEMENT
Home	Customers with access to off-road parking such as a garage or driveway can charge their cars at home via their standard domestic electricity supply. This is typically done vial the installation of a wallbox which charges cars much faster than via the standard 3-pin plug.	EVs charged at home will be via the customer's standard licensed electricity supplier although some customers may also have PVs that generate their own electricity and batteries to store this. Most suppliers offer time of use (TOU) EV tariffs that provide customers with lower prices to charge their EVs during off-peak times. This would require a secondary meter to be installed to identify EV specific consumption.
Destination	Public charging offered at locations where EVs can be left for an extended period of time e.g. public car parks, supermarkets, workplaces, train stations, cinemas etc.	Under this model organisations such as supermarkets will resell electricity provided to them by a licensed supplier to the charge point operator. In some cases they may have excess electricity from their own PVs that they also sell to the charge point operator.
Forecourt	Public charging offered at stand-alone petrol stations, dedicated EV garage forecourts or motorway services.	The motorway services provider takes its supply from a licensed electricity supplier. This is then conveyed via an onsite private distribution network (microgrid) and resold by the motorway services provider to the service station owner. The service station owner then resells this power, also via the microgrid, to their tenant the charge point operator, who sells this on the EV driver.
On-street	Roadside charging that is particularly useful where EV drivers lack off-street parking.	Power is conveyed to the charge point operator typically via the local DNO system. In a minority of cases it might be conveyed via a microgrid not operated by the DNO. In this case the charge point operator may receive electricity from an onsite exempt supplier. Several business models exist for on-street parking including subscriptions, fuel cards and pay as you go.
Home and roam	Customers can charge at home and on-the-go but receive a single bill for all their EV charging activity.	A licensed electricity supplier will combine a standard domestic supply with a roaming package as part of a bundled product. Electricity suppliers will have commercial agreements with fuel card vendors or chargepoint operators for the use of public chargepoints.
Peer-to-peer	Individuals or businesses make their chargepoints available for	In most cases the electricity provided by the host will be sold to them by their licensed supplier and

SCENARIO	DESCRIPTION	COMMERCIAL ARRANGEMENT
	other EV driers to use. This can be enabled by an app that matches chargepoint providers with a driver.	they are reselling this power. In some cases, hosts may generate their own power e.g. using PVs meaning the host will resell power they have bought from their supplier and that they've generated themselves.
Mobile on demand	EVs are charged without a fixed chargepoint via portable EV chargers provided by a third party. This is normally using fast-charging batteries, or charge may be taken directly from another EV. The batteries are transported to the EV driver via the road network.	Most batteries are charged in advance at the provider's business premises. Unless it's generating power itself, it will buy its electricity from a supplier. Alternatively the mobile charging provider could be based at an industrial site with its own private distribution network and power comes via an onsite supplier.
Fleet	Many businesses are transitioning their fleet to EVs. Fleet based solutions typically utilise the other charging scenarios described above but use a fleet management service provider to co-ordinate charging across infrastructure providers.	When employees charge their fleet EV at home, they pay via their domestic bill. Many employers are looking at affordability solutions such as third-party fast track reimbursement services delivered via payroll or bundling reimbursement with domestic supply.

Source: Ofgem (2022). Taking charge: selling electricity to electric vehicle drivers. What the supply regulations mean for different charging scenarios.

Of these models, charging cars at home overnight is generally the most convenient and cheapest option for consumers, and in 2019 80% of electric car charging happened at home.[83] The Government's electric vehicle home charge service subsidises the installation of a chargepoint for customers with dedicated off-street parking at home although this is being updated to limit the scheme to homeowners who live in flats or in rental accommodations in April 2022.[84] It also offers grant funding for local authorities for the installation of on-street charge points via the On-Street Residential Chargepoint Scheme.[85]

If a customer chooses to charge their EV at home, and installs a home EV chargepoint rather than using a standard 3-pin charger, they have the option to take an EV-tariff which often offer cheaper off-peak power for charging. This requires the installation of a MID-compliant secondary meter. Customers can make the most of TOU EV tariffs by installing a smart EV charger which can automatically respond to price signals and adjust the time and speed at which an EV charges depending on the current price of electricity.

[83] HM Government (2019). Electric vehicle charging in residential and non-residential buildings

[84] Office for Zero Emission Vehicles (2019). Electric Vehicle Homecharge Scheme: guidance for customers

[85] Office for Zero Emission Vehicles (2021). On-street residential chargepoint scheme guidance for local authorities.

3.3.2 CURRENT ROLE OF SUPPLIERS

Suppliers currently have no role in a customer's decision on whether or not to purchase an EV car or the fuelling of ICE vehicles.

When it comes to EV charging, suppliers have three key roles. Firstly, they retain their role in the provision of electricity for EV charging, either directly to the end customer (home-charging) or under a resale model (forecourt, destination, mobile on demand, peer-to-peer).[86] Secondly, suppliers play a key role in delivering or enabling new tariff types and reimbursement models for customers (further information on these models can be found in Table 3):

- **Home charging**. Most suppliers offer dedicated EV charging tariffs designed to shift EV charging to off-peak periods through TOU tariffs. These can be offered either as a bundled product, a multi-rate tariff, or a combination of the two. Bundling is common and seven out of the 12 EV tariffs offered in 2020 were bundled with services such as EV charger installation, EV 'free miles', and reduced costs at certain chargepoints.[87] Customers taking an EV specific tariff will require a secondary meter as normal smart meters do not distinguish between devices.

- **Home and roam.** Some licensed electricity suppliers are combining standard domestic electricity supply with a roaming package, allowing their customers to receive a single bill for at home and on-the-go EV charging. The supplier will enter into a commercial agreement with fuel card vendors or chargepoint operators for the use of public chargepoints, who will collect data each time a customer charges their EV and submit this to the supplier. This is then included in the customer's final bill.

- **Fleet.** Some supplies are working with employers to bundle domestic supply with reimbursement processes for employees charging fleet EVs at home. Under this model, the fleet operator will need to make arrangements with each employees' electricity supplier, or could instead negotiate a bespoke tariff with one supplier that employees then switch to for their whole domestic electricity supply. As most domestic properties only have a single grid connection, it is not currently possible for a fleet operator to have a dedicated EV supply contract separate to the customer's main domestic supply contract.[88]

Finally, suppliers play a key role in enabling smart EV charging. Customers engage directly with suppliers to take an EV-specific tariff. However, they will also take out a separate contract for the installation and ongoing services of a home chargepoint with the chargepoint manufacturer. Most times this is a different company from the supplier, although some suppliers have started to offer EV charger installation. Automatic optimisation of when and the speed at which a customer's car charges requires the supplier to exchange data with the chargepoint operator. For example, the Ohme Home charger can automatically sync with a customer's tariff and automatically charge their car at the cheapest electricity rates. This is enabled via APIs that allow suppliers to send price signals to the charger e.g. for Octopus Agile the API provides them with a price curve each day at 4pm.

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[86] Some EV charging models may not rely on the use of licensed suppliers e.g. forecourt charging will rely on microgrids.

[87] Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

[88] Ofgem (2021). Enabling the transition to electric vehicles: the regulator's priorities for a green fair future

3.3.3 POTENTIAL ISSUES FOR TRANSITION

Whilst the higher upfront price of EVs is currently cited as one of the biggest barriers to EV uptake[89], prices are expected to converge with ICE engines by the mid-2020s.[90] Although there are concerns about the availability and cost of materials to manufacture EVs, given the focus of our study we don't consider barriers to uptake further and instead consider the issues for transition as they relate to EV charging.

- **Limited public charging infrastructure.** Over a quarter of drivers do not have access to a driveway or garage and cannot rely on home charging for their EV. Take-up of EVs by these drivers will depend on availability of public charging.[91] Rollout of on-street charging has been slow and lack of public EV charging has frequently been cited as a barrier to EV uptake. Due to the weak commercial business case for on-street charging, investment is typically driven by local authorities via grant funding. However, local authorities are required to apply for this funding and one third of this has gone unspent. The CMA's review of the EV charging market also found a risk of 'charging deserts' e.g. remote areas like rural areas or tourist spots where connection cost are high.[92] The lack of public charging infrastructure feeds into 'range anxiety' where customers fear that their EV will run out of power without being able to find a charging station and is a common barrier to uptake.

- **Complex public charging system.** In addition to the lack of public infrastructure charging points, the CMA also found that it is often frustrating to find and access working chargepoints. Drivers are often required to navigate multiple apps, fuel cards, and memberships in order to access charging compared to the far simpler process of refuelling using petrol or diesel.

- **Complex regulatory system for charging.** Provision of EV charging does not fit neatly into the current energy supply regulatory structure and the applicable regulation varies significantly across charging models and charging technology. This is because provision of electricity to an EV chargepoint, or the premises it's located at, is considered electricity supply but charging of the EV from the chargepoint is not. Other differences include the application of Maximum Resale Price (MRP) rules in domestic settings, which applies if customers resell electricity using a standard plug and socket under a peer-to-peer model but does not apply if the resale of electricity comes from dedicated EV charging structure.[93] This complexity can act as a barrier to charging business model innovation. It also risks divergence between EV charging prices across models and the CMA recent investigated competition concerns around the supply of EV charging near motorways.[94] It can also result in distributional concerns for households that are unable to access home charging (discussed below).

- **Cost recovery for EV-related network upgrades.** Whilst there is currently sufficient power to meet demand for EVs, there is a need for grid upgrades in some areas. However, these are costly

[89] Behavioural Insights Team and Transport Research Laboratory (2020). Driving and accelerating the adoption of electric vehicles in the UK. Final Report.

[90] House of Commons (2021). Electric vehicles and infrastructure

[91] Behavioural Insights Team (2020). Driving and accelerating the adoption of electric vehicles in the UK.

[92] CMA (2021). Electric Vehicle Charging market study. Final report

[93] Ofgem (2022). Taking charge: selling electricity to Electric Vehicle drivers

[94] CMA (2022). Open letter to motorway service area operators and electric vehicle chargepoint operators

and chargepoint operators report that the process to install EV charging infrastructure is both lengthy and very costly, reducing rollout of charging.[95] This falls into a wider challenge of how best to recover costs associated with EV related network upgrades fairly, particularly if some areas are less dependent on EVs e.g. urban areas with high public transport use.

- **Distributional concerns.** There are concerns that low-income households will be left behind in the EV transition, resulting in greater disparities between customer groups. EVs have lower running costs and switching to an EV could save low-income households £3,000 - £5,000 per cars compared to the cheapest diesel vehicle.[96] However, low-income households mostly buy second hand cars and only 2.3% of second-hand sales in 2018 were electric.[97]

3.4 INSTALLATION OF DOMESTIC PV

3.4.1 CURRENT MARKET AND POLICY STRUCTURE

Installation of a PV system is the main way that domestic homeowners can generate their own electricity for personal use, including export of surplus energy back to the grid or direct resale e.g. via peer-to-peer EV charging schemes. Customers may choose to install a battery alongside their PV in order to store energy for use later. The choice of whether or not to install a PV is up to the homeowner.

Financial support for the installation of PV panels has been primarily via tariff-based schemes. Until 2019, this was under the Feed-in Tariff (FIT) scheme which paid customers two tariffs, one for all energy generated and one for energy exported to the grid. This was replaced by the Smart Export Guarantee (SEG) which only pays customers for the energy they export. For a limited time, customers could apply for loans to invest in renewable technologies for homes via the Green Deal. In many areas, community energy schemes have been set-up to reduce the cost of solar panel installation via collective bargaining e.g. the Solar Together London scheme. Following the introduction of the FIT scheme, a new business model emerged where customers would effectively lease their roofs in exchange for free installation of solar panels. Under this model, customers would receive free electricity generated by the PV while the company received the FIT payment.

There are a growing number of options for customers with PV to export their energy beyond the SEG. As discussed above, customers may offer excess electricity generated by PVs for EV charging as part of a peer-to-peer model. More generally, peer-to-peer models allow customers to trade stored electricity generated from PVs with one another although this is currently limited primarily to local trials.[98]

Looking forward, whilst aggregators are currently focused on commercial properties, the need for increasing DSR means that aggregators may increasingly engage with residential households with PV to provide local flexibility.

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[95] CMA (2021). Electric Vehicle Charging market study. Final report

[96] Green Alliance (2019). Going electric. How everyone can benefit sooner.

[97] Ibid.

[98] IRENA (2020). Peer-to-peer electricity trading. Innovation landscape brief.

3.4.2 ROLE OF SUPPLIERS

For the majority of customers considering installing PVs, the role of suppliers is limited to provision of the SEG. All suppliers with more than 150,000 domestic customers are required to provide at least one tariff to any eligible exporter, and smaller suppliers can participate on a voluntary basis.[99]

In some cases, suppliers may partner with other organisations to run local pilots for new business models e.g. EDF partnered with UK Power Networks and other organisations to trial peer-to-peer trading of energy generated from PV and stored in batteries.[100] Another example is Social Energy which, prior to giving up its supplier licence, installed PV alongside battery storage systems for its customers in addition to acting as their energy supplier. It used software to aggregate energy storage and provide DSR, including provision of balancing services to the ESO. However, these activities are outside the scope of what the supply licence requires or regulates.

3.4.3 POTENTIAL ISSUES FOR TRANSITION

The Government carried out a review of factors that affect the adoption of PV in 2021 and identified a number of barriers for households:[101]

- **High upfront capital costs and long payback periods.** Upfront capital costs was identified as a clear barrier to installation and this is not currently mitigated by the SEG provides payback over time. A typical household would only achieve annual savings of c.£100-£200 compared to average costs of £5,000 in 2019. Whilst community schemes are expected to reduce costs by c.20%, this still represents a long payback period that could exceed the duration that customers expect to remain in their home. This is an even greater consideration when it comes to installing battery storage alongside a PV, which will be key to delivering flexibility or peer-to-peer business models, due to higher costs.

- **Long-term issues associated with financing business models.** As discussed above, the introduction of the FiT led to new business models where customers would lease their rooftops in exchange for free installation of solar panels and electricity generated. Whilst these business models help to overcome the barriers of high upfront capital costs, some customers have reported that these lease agreements have created issues when trying to sell or re-mortgage their homes, leaving customers forced to buy-out the panels for a fee. [102] This fee could be higher than the original cost of installation.[103]

- **Barriers for specific properties.** As is the case for the installation of insulation and new heating systems, installation of PV is more difficult for leasehold properties, rented properties, and properties with specific planning permission restrictions. The research reported that 23% of leaseholders required consultation with their landlord to install a PV.

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[99] BEIS (2019). The future for small-scale low-carbon generation.

[100] The renewable energy hub (2019). People Power in Local Energy Market Trial

[101] BEIS (2021). UK Rooftop Behavioural Research

[102] House of Commons (2020). Q&A: Solar panels.

[103] See https://www.theguardian.com/money/2018/nov/25/homeowners-trapped-solar-panels for an example.

- **Risk aversion.** Installation and maintenance of PVs is perceived to be difficult and research found that introducing a risk mitigation scheme such as a Guarantee Scheme and approved solar panel suppliers and installers would be the strongest incentive to increase PV uptake.

3.5 MORE GENERATION CAPACITY AND INCREASED SHARE OF RENEWABLES

3.5.1 CURRENT MARKET POLICY AND STRUCTURE

Aside from installation of small scale domestic PV, customers do not play a significant direct role in the increase in generation capacity and share of renewables. Instead, this is primarily driven by policies such as the climate change levy, the renewables obligation, the emissions trading scheme, the introduction of renewable contracts for differences and the carbon price floor.[104]

However, customers are likely to be affected by the renewable transition. Without a significant increase in DSR and other flexibility services, the increase in intermittent generation will lead to an increase in both price volatility and energy bills. As we describe in the section on flexibility, the introduction of half-hourly settlement is expected to increase the use of time-of-use tariffs[105] which, in combination with storage or EV smart charging, should deliver greater DSR flexibility to the system.[106] Whilst this is expected to deliver significant savings for customers overall, there is a risk that some customers will face higher bills either because they switched to a TOU tariff without being able to significantly shift their demand, or because flat-rate tariffs will become more expensive.[107] Where this disproportionately impacts vulnerable customers, this would increase consumer detriment.[108]

3.5.2 CURRENT ROLE OF SUPPLIERS

Suppliers play two key roles in the shift to renewable generation. First, they are subject to the Renewables Obligation (RO) which places an obligation on suppliers to source an increasing proportion of their electricity from renewable sources.

Second, their revenue collection role means they are responsible for collecting the cost of environmental obligations supporting renewable schemes via customer bills including the RO, renewable contract for difference, and feed-in-tariffs. These costs are accounted for in the default tariff cap calculation (see WP1). This role also includes passing on balancing costs which are higher for intermittent renewable energy generation.

It should be noted that the absence of mandatory half-hourly settlement means that customers are not billed in a cost-reflective way i.e. settlement charges are currently based on average rather than actual customer usage. We discuss this further in the flexibility section below.

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[104] Further information on the individual policies supporting the renewables transition can be found in the UK's Integrated National Energy and Climate Plan (2020)

[105] Settlement refers to the reconciliation of differences between a supplier's contractual purchase of electricity and the demand of its customers. Most customer are currently settled on a non-half hourly basis which uses estimates of when they consume electricity based on average customer usage and their meter readings. Half hourly settlement will require suppliers to move away from using estimated usage for settlement to actual usage and is enabled by the rollout of smart meters that can provide half hourly readings.

[106] Ofgem (2021). Electricity retail market-wide half-hourly settlement: Decision document

[107] Ofgem (2021). Market-wide half hourly settlement: Final impact assessment

[108] Citizens Advice (2020). Citizens Advice response to 'Electricity retail market-wide half-hourly settlement: consultation

3.5.3 POTENTIAL ISSUES FOR TRANSITION

Many of the barriers to increased generation and the renewables transition are not focused on consumers and are therefore out of the scope of this work.[109] Issues relating to flexibility are discussed in the next section.

3.6 CONSUMER FLEXIBILITY AND SMART HOMES

As described in section 2.7, increasing customer flexibility will be key to delivering the net zero transition in an affordable way. Without an increase in DSR, customers are likely to see higher bills in the future due to higher balancing costs arising from intermittent renewable generation, higher network costs due to greater need for reinforcement investment, and higher wholesale and capacity costs for generating electricity when it is needed.

3.6.1 CURRENT MARKET POLICY AND STRUCTURE

While the markets for consumer flexibility are still relatively nascent, a number of different arrangements currently exist. There is considerable overlap, however they can be broadly differentiated based on:

- **The party which is controlling the DSR**. Which entity is ultimately responsible for telling the customer when and how it should change its demand?
- **Where in the system the value of the DSR is coming from.** Flexibility can reduce costs across the energy system. How does the entity controlling the DSR obtain value from these cost reductions? For example, is the flexibility being dispatched in a way which reduces wholesale energy costs, network costs, balancing costs, or a combination of multiple costs?
- **How the DSR is being controlled**. What type of signal does the controlling party send to consumers? For example, is it a price which consumers are expected to react to, or is the controlling party able to directly influence the use of consumer appliances?

The table below describes the broad types of arrangement which currently exist, which are then described in more detail.

[109] See CCC (2021). Independent Assessment: The UK's Net Zero Strategy for further details.

TABLE 4 EXISTING FORMS OF CUSTOMER FLEXIBILITY

Service	Controlling party	Source of value	Method of control
Time-of-use tariffs	Supplier	Reduced wholesale energy costs; some reduction in network costs	Price signal
Supplier direct load control	Supplier	Reduced wholesale energy costs; some reduction in network costs	Direct control
Independent aggregator direct load control	Aggregator	Reduced network and balancing costs	Direct control

Source: Frontier Economics

TIME-OF-USE TARIFFS

Suppliers can encourage consumers to shift their demand by providing a tariff where the unit rate paid for electricity varies throughout the day. Such time-of-use (TOU) tariffs can be static or dynamic.

- Static TOU tariffs are determined in advance and do not vary with actual demand or supply conditions on the day e.g. pre-set on-peak and off-peak hours.
- Dynamic TOU tariffs are set in real time based on actual system conditions including grid demand and intermittent generation output. As the transition to more renewable and intermittent generation continues, there will be an increasing need for dynamic rather than static TOU tariffs. This is because the wholesale price of electricity will depend more and more on the output of wind generation, which cannot be forecasted far in advance.
- There are also options between these two positions where prices are set a period (say a day) ahead of being applied.

Basic static TOU tariffs have been around for many years. Economy 7 (E7) has been available to customers since 1978[110] and provides cheaper off-peak electricity during night-time hours. It was primarily targeted at customers who used electricity rather than gas for hot water and heating coupled with storage heaters. Economy 9 (E9) and Economy 10 (E10) were subsequently introduced with different off-peak periods. These type of static TOU tariffs make up approximately 14%[111] of the GB market.

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[110] UK Parliament. Volume 386: debated on Wednesday 22 November 1978

[111] Citizens Advice estimates that around 4 million of a total of 29 million domestic electricity customers in Great Britain have a restricted "profile class 2" meter. (CA, 2020). Approximately 90% of profile class 2 meters are E7 meters, with the remaining 10% consisting of other restricted meters with more complex rates and heating arrangements such as E10 or dynamic teleswitched meters, both of which are used with static TOU tariffs (Ofgem 2020).

The default tariff price cap is compatible with E7 tariffs, but not the more complex forms of TOU pricing described below. As a result, it is not currently possible for a supplier to offer a more complex TOU tariff as a default option to customers who have not actively chosen another tariff.

Some suppliers such as EDF[112] are now phasing out E7 tariffs and have introduced more complex static TOU tariffs. These TOU tariffs are often linked to specific products, the most common being EV specific tariffs. Suppliers may also offer TOU tariffs for specific technologies such as batteries, solar panels, and GSHPs although these are less common: there were only four such tariffs in 2020.[113]

In comparison to static TOU tariffs, dynamic TOU tariffs are still relatively scarce. One example is the "Agile Octopus" tariff from Octopus Energy, which passes through half-hourly wholesale prices (which may sometimes be negative) to consumers. However even this is not a true dynamic tariff, as the prices are announced the day before. Research from Citizens Advice found that as of December 2020, only two of the seven non-EV smart-enabled tariffs were dynamic TOU tariffs which adjust prices according to wholesale prices.[114]

The controlling party in all of these cases is the supplier. This has to be the case under the current market structure, as it is only the supplier that can set the unit rate paid by consumers for their energy.

The source of value being targeted by the supplier is primarily wholesale energy costs, but also an element of network costs. This is as the DSR encouraged by these tariffs (moving consumption from peak to off-peak) will directly reduce the following costs to suppliers, which reflect wider costs on the system:

- Wholesale energy costs. By passing through these costs to consumers, suppliers can encourage them to use energy at times when it is less expensive.

- Network costs. Both DUoS (for distribution networks) and TNUoS (for the transmission network) charges vary by time of consumption. In particular, customers on E7-type tariffs incur lower DUoS charges during off-peak hours, and incur lower TNUoS charges (as they are assumed to use less electricity during the 4pm – 7pm peak window). Note that these costs reflect long-term, average network costs, rather than the costs of constraint on a particular segment of the network at a particular time.

In principle a supplier could set a time-of-use tariff in a way which delivered balancing actions, or responded to more fine-grained network issues (e.g. encouraging customers to reduce demand during a fault condition on the local network). We are not currently aware of any suppliers which do this, and in any event these types of tariff would need to be highly dynamic. Without some form of automation, described below, it is unlikely that a customer would be able to manually shift their load in response to a short-notice price change. Furthermore, an aggregator we spoke to suggested that the current flexibility products procured by DNOs may not be a good fit for the 'shape' of DSR provided by sources such as residential EVs.

112

EDF website. Accessed at: https://www.edfenergy.com/for-home/energywise/all-you-need-know-about-economy-7#:~:text=In%20a%20nutshell%2C%20Economy%2010,known%20as%20'complex%20meters'.

113 Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

114 ibid

The method of control is a price signal, and it is up to the customer whether or not to shift their demand to take advantage of savings. Customers can choose to manually shift their demand (e.g. by setting a dishwasher or washing machine to run on delay overnight). However, trials have found that interventions to automate customer response have the greatest and most long-term shift in demand.[115] Most customers with E7 or similar tariffs are likely to have heating appliances set on a timer, which automates the use of energy during off-peak hours. There also number of more advanced smart devices available for customers to purchase, although Ofgem research found that there was low awareness of automated smart technology solutions.[116] For example, smart chargers exist that can sync with a customer's tariff and automatically charge their car at the cheapest electricity rates based on their TOU tariff.

SUPPLIER DIRECT LOAD CONTROL

As noted above, it is difficult for a consumer to manually shift their demand in response to short-term changes in price under a dynamic TOU tariff. One solution is for the consumer to use appliances which automatically respond to the price signal, as described above. Alternatively, the control of the appliances can be delegated entirely to the supplier. This can be alongside a TOU tariff (with the supplier simply sending a signal for appliances to turn on once the price is low), but this need not necessarily be the case.

Historically, a form of supplier direct load control that has taken place in GB has been dynamically teleswitched (DTS) meters. These can be used alongside a tariff similar to E7, however the supplier sends a radio signal to let the meter know when the "off-peak" period starts, and to turn on the heating system. However the system was developed prior to the liberalisation of the market, and is designed in such a way that only the formerly incumbent supplier for a region (which may not be a customer's current supplier) can control the heating system.[117] The DTS system is scheduled to be switched off in March 2023.[118]

Smart meters can have an auxiliary load control switch built-in which allows switching of loads on and off by a customers' current supplier, and so do not suffer from these legacy issues. For smart meters without the switch, a home area network (HAN) connected auxiliary load control switch can be added which communicates with the smart meter over then HAN and provides similar functionality. Updates to the SMETS2 standard now allow more precise control of loads such as electric vehicles and heat pumps.[119] However we are not aware of this functionality being widely used. One issue is that SMETS2 is a GB-only standard, while other standards such as the OCPP (Open Charge Point Protocol) are also implemented in other countries.[120] This may limit the extent to which SMETS2-based DSR solutions are developed.

Indeed, there appear to be relatively few examples of suppliers which have carried out direct load control. We understand that Social Energy, which was formerly a supplier directly controlled consumers' batteries and solar PV export. However this company now no longer has a supply license, and so operates as an aggregator (see below).

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[115] Frontier Economics and Sustainability First (2012). Demand Side Response in the domestic sector – a literature review of major trials

[116] Ofgem (2020). Energy consumers' experiences and perceptions of smart 'Time of Use' tariffs

[117] CMA (2016) *Energy Market Investigation Final Report* pp517

[118] Ofgem (2022) Smart Meter Rollout: *Open letter on Energy Suppliers' Delivery of the Rollout and Regulatory Obligations*

[119] BEIS (2019) *Response to Consultation on Smart Metering System Proportional Load Control*

[120] BEIS (2021), *Electric Vehicle Smart Charging* pp27

The controlling party for this type of DSR is the supplier. As with TOU tariffs, **the source of value** could theoretically relate to any part of the electricity system that the supplier could obtain a revenue (or cost reduction) from, but in practice for DTS meters it is likely to be wholesale market costs and "high-level" long-run (not granular) network costs. The **method of control** is some form of communication network to signal to consumers' appliances – whether the legacy DTS system, smart meters, or over the internet.

INDEPENDENT AGGREGATOR DIRECT LOAD CONTROL

As noted above, most DSR carried out to date by suppliers has been targeted at reducing the wholesale and network costs suppliers are exposed to, rather than providing shorter-term balancing or network services.

DSR for these purposes is already in use in the industrial and commercial sector (I&C). For the provision of national balancing services, larger I&C customers can directly participate in the national Balancing Mechanism. Firms can also provide flexibility services to DNOs: The Energy Networks Association has standardised a set of flexibility products which firms can provide, and information is available from sources such as Flexible Power.[121] These types of contract will become increasingly important as DNOs transition to DSOs, with responsibility for local balancing. There is also an existing market for aggregators that can pool flexibility across smaller firms where individually they cannot offer enough flexibility alone (or choose not to participate directly for other reasons). Aggregators contract with individual demand sites and aggregate them together to operate as a single flexibility provider, and retain a share of the value generated from these services.[122] Aggregators can either be integrated with suppliers, or independent.

In comparison, DSR for network and balancing services is less developed in the residential sector. Due to the limited amount of DSR that a single residential residence could provide, they require an aggregator to participate in flexibility markets. Aggregators are not currently widespread for residential consumers and Ofgem had indicated in the past that DSR markets consisted only of I&C consumers due to the high cost of reaching and contracting with residential consumers.[123] However, the market has recently introduced changes designed to make it easier for smaller assets to participate in the Balancing Mechanism under the Wider Access programme. The Wider Access programme created a new Virtual Lead Party (VLP) role that allows independent aggregators to participate in the Balancing Mechanism. Prior to the creation of the VLP, only energy suppliers and licensed generators could participate in the Balancing Mechanism.[124] These changes could help to increase the number of residential aggregators in the future.

There are more, although still limited, options for customer-side flexibility via the export of distributed energy resources. Increased adoption of PV and EVs has allowed new residential focused business models to emerge via the concept of a 'virtual power plant' (VPP). A VPP aggregates smaller scale generation such as customer installed PV or energy stored in EV batteries and exports this back to the grid when required.

Several trials are currently ongoing to explore the role of V2G in the Balancing Mechanism. For example, SSE has recently partnered with Jedlix, an EV charging provider, to create a virtual power plant and sell flexibility services in the Balancing Mechanism.[125] Octopus energy is also trialling their own V2G project

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[121] https://www.flexiblepower.co.uk/

[122] Emissions-EUETS website. Accessed at: https://www.emissions-euets.com/internal-electricity-market-glossary/855-demand-side-response-aggregator-dsr-aggregator

[123] PA Consulting (2016). Aggregators – Barriers and External Impacts.

[124] Elexon (2021). Virtual Lead Party (VLP) – entering the market

[125] SSE website. Accessed at: https://www.sseenergysolutions.co.uk/news-and-insights/jedlix-partnership-agreement

Powerloop that customers can sign up to participate in.[126] For PV, Tesla has launched the Tesla Energy Plan in conjunction with Octopus Energy for customers with solar panels and a Tesla Powerwall battery. Under this plan, Tesla has control of the customer's Powerwall and manages when and how they use their solar and stored energy including export of energy to the grid during peak demand. Social energy operated a similar model to offer flexibility services to the national Balancing Mechanism.[127] Trials are currently ongoing for automation of DSR including the Government sponsored domestic demand-side response competition.[128] These often involve the use of some kind of app that provides alerts to reduce consumption or automates reductions using smart devices. For example, the commercial aggregator Kiwi Energy is trialling this as part of its Greenwich Energy Hero project.[129]

3.6.2 CURRENT ROLE OF SUPPLIERS

As we have described above, suppliers currently facilitate flexibility by offering their customers TOU tariffs, either targeted at specific devices (e.g. specific EV tariffs) or for domestic energy use as a whole (like E7). However, currently very few suppliers offer dynamic TOU tariffs and only two were available in December 2020.[130]

In order for suppliers to have the incentives to shift demand in a way that lowers whole system costs, they need to face cost-reflective dynamic pricing based on their own customers' use of energy throughout the day. For wholesale energy, this is not currently the case, but will change with the introduction of mandatory market-wide half hourly settlement (MHHS) in October 2025. MHHS, described below, is therefore expected to encourage tariff innovation amongst supplier and increase the availability of TOU tariffs, creating incentives for suppliers to encourage their customers to shift consumption.

Suppliers do not currently receive fully cost-reflective signals elsewhere in the system. For example, network and balancing charges are based on broad averages, and a supplier would therefore not obtain a benefit from moving a customer's consumption to a specific time that alleviated a local constraint on the network. We are not aware of any reason why a supplier could not (for example) contract directly with a DNO to provide flexibility services of this type. Some potential reasons why we do not currently see this activity include:

- More data is required to provide the system operator and DNOs confidence that consumers will respond to signals in a reliable way.[131]
- Electric vehicle and heat pump uptake is currently low. As a result, DSR from domestic customers may not be "concentrated" enough to provide services for DNOs.

[126] Octopus energy website. Accessed at: https://octopusev.com/powerloop

[127] Social energy website. Accessed at: https://social.energy/commercial/services/balancing-mechanism/#:~:text=With%20our%20support%2C%20assets%20of,by%20minute%2C%20in%20the%20sector.

[128] BEIS. BEIS innovative Domestic demand-side response competition.

[129] Cornwall Insight (2020). All mod cons: Routes to market for household flexibility

[130] Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

[131] Projects such as *Crowdflex* are helping to develop this.

Market-wide half hourly settlement

Electricity consumption for the majority of households is currently estimated based on average usage profiles rather than actual profiles. These estimates are updated after meters have been read to reflect actual consumption over a period of time, but not the actual profile of consumption within this period. This means that settlement processes can take over a year to complete and suppliers do not face cost-reflective charges for their customers.

There is a separate load profile used for consumers on E7 tariffs, reflecting the expected shift of consumption towards the off-peak period. Suppliers are therefore able to receive the benefits of this type of static TOU tariffs and share them with their customers. However, a supplier does not have an incentive to develop more advanced TOU tariffs for customers settled on standard load profiles, as any change in consumption pattern will not be reflected in the costs paid for the energy.

The rollout of smart meters means that it is now possible to record actual half-hourly consumption in homes where these are installed. This has prompted Ofgem to introduce mandatory market-wide half hourly settlement from October 2025. Not only will this speed up the settlement process, it also means that suppliers will be charged the actual cost of serving their customers throughout the day. This is expected to generate 'powerful incentives to offer new tariffs and products that encourage more flexible use of energy'[132] including TOU tariffs.

Suppliers can also partner with smart device manufacturers to automate consumption shifting based on a customer's TOU tariff e.g. the Ohme EV charger which receives TOU tariff charges form suppliers and can automate customer EV charging profiles based on the cheapest time to charge.

As described above, DSR can be provided by independent aggregators which do not hold a supply license. In some cases, suppliers work with these organisations: We have noted several examples of suppliers working in partnership with non-traditional energy companies such as PV and EV charger manufacturers to offer balancing services via VPPs.

However, suppliers can also come into conflict with independent aggregators. In order for an independent aggregator to participate in the national Balancing Mechanism, they must either work with a supplier or become a Virtual Lead Party (VLP).[133] If an independent aggregator chooses to partner with a supplier, this would require reaching an agreement on the revenue sharing model. If instead they choose to participate in balancing markets as a VLP, suppliers may seek compensation from aggregators for loss of revenue if an aggregator activates a DSR event that reduces consumption of electricity.[134] This is because suppliers purchase generation in advance based on forecast demand which is no longer correct. This creates two costs for suppliers. First, they may not be able to sell-on all the energy they purchased. Second, they may face higher balancing costs even if the DSR event reduces overall system costs.[135]

[132] Ofgem (2021). Market-wide Half-Hourly Settlement: Full Business Case

[133] Further information on VLP can be found here. National Grid ESO (2020). Use of System – Virtual Lead Party

[134] University of Exeter Energy Policy Group (2019). Barriers to Independent Aggregators in Europe

[135] Ibid.

3.6.3 POTENTIAL ISSUES FOR TRANSITION

There are several potential issues associated with the flexibility transition. These are split into two categories: (1) barriers to increasing DSR and flexibility, and (2) Unintended consequences of increasing DSR.

The main customer facing barriers to increasing DSR and flexibility are discussed below:

- **Slow smart meter uptake.** Customers require a smart meter in order to take a TOU tariff. However, the smart meter rollout has faced significant delays. The original deadline for 100% coverage was 2020.[136] As of March 2021 just 44% of homes and small businesses in Great Britain had a smart meter.[137] The deadline has now been pushed back under the new smart meter rollout framework.

- **Limited take-up of TOU by customers.** Even if half-hourly settlement does increase the availability of TOU tariffs, there may be limited take-up by customers or response to price signals. Consumers will need to switch to non-standard tariffs, or contract with an aggregator which may be unfamiliar to them.

- **Lack of inter-operability standards for smart devices.** The Electric Vehicle (Smart Charge Points) Regulations 2021 does not require smart chargepoints to retain smart functionality in the event that the chargepoint operator changes.[138] Similarly, there is no guarantee that customers will retain smart functionality if they wish to either switch automation services or the manufacturer or communications operator goes out of business if they are using a proprietary system for control. A similar issue was a major issue with SMETS1 meters. (the early version of smart meters) where a customer switching supplier could find that the meter switched into "dumb" mode, and reduced confidence in the rollout.

- **Conflicting supplier incentives.** Without half-hourly settlement, if suppliers invest in promoting uptake of DSR among its customers under a TOU tariff, this does not currently increase their own profitability. The introduction of half-hourly settlement may re-align supplier and network incentives as suppliers will face the true settlement costs of their customers and will have a greater incentive to encourage customers to modify their consumption patterns. As we discuss above, supplier incentives can also conflict with independent aggregators if DSR reduces overall customer energy consumption or increases balancing costs for them, even if it reduces overall system costs.

- **Lack of smart meter information for network companies.** Smart meter data is a valuable resource for DNOs to optimise their network management activities. It would allow them to identify areas where additional flexibility would be valuable as well as additional reinforcement. Under the Data Access and Privacy Framework DNOs can access half-hourly smart meter consumption date

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[136] House of Commons Library (2018). The smart meter roll-out: Will the 2020 deadline be met?

[137] BEIS (2021). Smart Meter Policy Framework Post 2020: Government Response to a Consultation on Minimum Annual Targets and Reporting Thresholds for Energy Suppliers

[138] HM Government (2021). Electric Vehicle Smart Charging. Government Response to the 2019 Consultation on Electric Vehicle Smart Charging.

without customer consent to support network investment.[139] However, they are required to have an Ofgem approved privacy plan which sets out how they will aggregate and anonymise the data and how the data will be used. DNOs have previously raised concerns that the current requirements to anonymise smart meter data limits their ability to use this information for network management which could include where to invest in increasing local flexibility.[140]

In addition to these barriers to the general provision of flexibility, the Government's call for evidence on V2G has highlighted specific barriers to the use of EVs to deliver system flexibility. [141] This is important given the scale of V2G assumed in some of the FES scenarios (see Figure 14):

- **Technological barriers and lack of interoperability.** As of March 2021, the UK had less than 5 EV models capable of V2G, which is a significant barrier to mass adoption. There are also currently two charging systems capable of V2G and vehicles are designed to one of these standards rather than being interoperable. This means that consumers can restrict future consumer choice on car manufacturers if they purchase a V2G capable of home charges as well as limiting the availability of public chargepoints.

- **Low customer awareness and range anxiety.** There is currently low awareness amongst customers of V2G and a perception that the process is highly complex. V2G can also exacerbate range anxiety, particularly for customers without home-charging. There is little evidence yet about how customers will respond in the longer term to the idea of allowing their batteries to be discharged.

- **Regulatory barriers.** Customers adding generation or storage may need to limit their net exports to avoid paying costs for network reinforcement which can be costly and time consuming. Even if this is unlikely to impact the majority of customers, the perceived cost may act as a barrier to customer uptake.

Even if these barriers were addressed to enable widespread uptake of DSR, this should be carefully designed in order to avoid unintended consequences and adverse impacts on consumer outcomes:

- **Customer protection for bundled services.** Many TOU tariffs are currently bundled with other services such as EV charger installation. Whilst bundled tariffs can be more convenient for customers, it also makes tariffs harder to compare. Many comparison sites do not currently compare EV and smart-enabled tariffs.[142] Bundled tariffs can also have more expensive exit fees e.g. to cover the cost of the installation of an EV charger, and consumers may not be protected for services that fall outside of the supply licence.

- **Selecting the best tariff.** Customers must have a realistic understanding of their ability to load shift for customers and the system to benefit from TOU tariffs and DSR. Issues such as optimism bias or lack of information may lead customers to over-estimate the extent to which they can change their consumption patterns, particularly in the absence of automation.

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[139] Sustainability First (2021). Smart Meter Energy Data: Public Interest Advisory Group.

[140] BEIS (2018). Smart metering implementation programme. Review of the Data Access and Privacy Framework

[141] BEIS (2021). Role of Vehicle-to-X Energy Technologies in a Net Zero Energy System

[142] Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

- **Distributional impacts.** The widespread adoption of TOU tariffs will inevitably create winners and losers and the industry will need to consider the fairest way to distribute costs e.g. if capacity upgrades account for a large share of overall costs, how should this be reflected in customer charges? Other issues such as digital exclusion could mean that some people are left behind on more costly fixed-tariffs.[143] Where this coincides with vulnerable consumers, this could result in significant consumer detriment.

[143] ibid

4 CROSS-CUTTING THEMES

We have discussed the key barriers facing each of the transitions required to deliver net zero by 2050 and have identified a number of cross-cutting themes. These themes will be used to guide the evaluation of the current market in WP3 and develop options for alternative market structures which should focus on addressing these barriers. We anticipate that any alternative market model will require trade-offs to be made when trying to address these barriers and ultimately the right balance will need to be found to maximise the success of net zero by 2050.

4.1 UPFRONT CAPITAL COSTS

Our review has identified upfront capital costs as a key barrier to the uptake of heat pumps, energy efficiency measures, and PVs. Having a set of measures that address these barriers is key to enabling customers to take up low carbon technologies.

Whilst Government grants are available in some cases, they do not cover the whole cost of installation and the amount that must be financed by customers is still significant. Furthermore, unlike vehicles where there is a small but growing second-hand market for EVs, it is not possible to buy a second hand heating system or PV at lower prices, nor are financing arrangements standard as they are for vehicle purchases. This can lead to distributional issues if low-income households are left behind.

Solutions to overcome upfront capital costs via financing deals are challenging. In some cases installation of low carbon technologies are not expected to save customers money in the long term e.g. installation of a ASHP compared to a new gas boiler.[144] In these cases, it is unlikely that any financing business models are feasible without government funding. Even when moving to a low-carbon technology is cost-saving for customers, this is often over long 10+ year payback periods. Once installed, technologies such as heating systems, PV, and insulation are difficult or impossible to remove and companies are faced with the challenge of how to secure this debt or guarantee payments in the event that the homeowner moves out. Previous government schemes such as the Green Deal or market based solutions such as leasing rooftops for PV have tried to overcome these issues but with limited success.

The CCC highlights the importance of making the process of investing in home and retrofit as easy and reliable as possible to increase uptake as well as the need for public demand to increase demand for green finance products and reduce costs by delivering at scale.[145] By maximising the opportunity for private capital to meeting upfront capital constraints, this could allow public support to be more targeted at consumer segments where market-based solutions are less likely to emerge e.g. low income families that struggle to access financing, customers in the rental sector, or particularly hard or expensive to address properties.

4.2 INCREASING COMPLEXITY OF CHOICE AND CUSTOMER HETEROGENEITY

Customer choice is becoming increasingly complex and this market will need to evolve in a way that means customers are presented with appropriate options and able to make an informed decision on the best one for them.

[144] Energy Savings Trust. Accessed at: https://energysavingtrust.org.uk/advice/air-to-water-heat-pumps/

[145] CCC (2022). Independent Assessment: the UK's Heat and Buildings Strategy

Whereas customers could previously replace their heating and cars like-for-like, they are now faced with multiple options each with different pros and cons, costs and payback periods, and technical requirements. The best option will differ between customer segments. As we progress further in the net zero transition, the national picture of low-carbon technologies is likely to be increasingly mixed with local clusters across regions and there may be no “one size fits all” business model. It is key to ensure that customers have both the ability to make an informed choice. The underlying market structure should allow for appropriate regional variations in solutions rather than mandating or biasing towards a one-size-fits all structure.

We are also likely to see an increasing number of non-traditional energy companies involved in providing energy services e.g. EV manufacturers and manufacturers of home energy management systems. These companies will increasingly deliver products that are complements or substitutes for traditional energy services and there is a question of how to ensure this remains manageable for customers.

We have already seen an increase in the number of bundled tariffs available to customers, with suppliers packaging energy supply with other value-add services such as discounted EV charging in partnership with non-traditional energy companies. These new business models can bring benefits for customers, reducing the hassle of arranging these services individually and in some cases overcoming the upfront capital cost issues with installation of new devices. However, bundled services are more difficult for customers to compare and price comparison websites are not currently set up to compare smart or bundled tariffs. In other cases customers may be unaware that tariffs are product specific. Citizens Advice has reported that some customers have ended up switching onto a tariff that is not right for them and subsequently face high exit fees.[146]

4.3 NEED TO ADDRESS INCREASING REGULATORY COMPLEXITY

As the energy ecosystem and products offered become more complex, the regulatory model will need to evolve to deal with this, ensuring that new business models can emerge – subject to constraints such as the need to provide consumer protection, described below.

For example, value-added services provided as part of bundled tariffs often fall outside of supplier licences and the emergence of ‘as a service’ models raise questions on how they interact with the existing supplier of last resort process. Ofgem’s recent publication on EV charging regulation has highlighted the complexities of applying the current regulatory framework to EV charging with different prices, licences, and exemptions applying for each different EV charging scenario.[147]

These regulatory complexities can act as barriers to the growth of new business models require to efficiently deliver net zero by 2050. Ofgem has already moved to identify and address regulatory barriers in some areas such as electricity storage[148] and other areas are likely to benefit from a more streamlined, consistent, and in some cases simplified approach.

[146] Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

[147] Ofgem (2022). Taking charge: selling electricity to Electric Vehicle drivers

[148] Ofgem (2021). Transitioning to a net zero energy system. Smart systems and Flexibility Plan 2021

4.4 EVOLVING REQUIREMENTS FOR CUSTOMER PROTECTION

New business models have the potential to cause consumer confusion or harm, and the solution that is arrived at needs to offer appropriate protection to customers .

Citizens Advice has already identified several gaps in regulation for new innovative tariffs that could lead to consumer harm.[149] Depending on the final technology solution, local or national monopoly hydrogen networks may also emerge which will require regulation to ensure that bills remain affordable, particularly early in the transition where hydrogen may be significantly more expensive than natural gas and a resulting increase in energy bills could increase fuel poverty. We have also discussed several distributional issues associated with the transition including for customers who live in hard-to-treat properties where insulation may be particularly expensive, or low-income families who rely on the second-hand market for EVs which is still emerging and have no option but to remain on more expensive ICE cars.

4.5 FLEXIBILITY

The market is already evolving to accommodate greater use of customer flexibility via the DSO transition as well as the creation of the VLP role in the Balancing Mechanism. Looking forward, the sector will need to identify remaining barriers and facilitate new options to increase provision of residential flexibility.

DSR for domestic customers beyond basic static tariffs (E7, E9, and E10) is currently extremely niche with few aggregators engaging with the domestic market outside of EV charging and only a handful of dynamic TOU tariffs offered by suppliers. Whilst the introduction of MHHS is expected to adjust supplier incentives to shift customer demand and increase the number of TOU tariffs, questions on how to encourage customer engagement and opt in to products like home automation remain. Research has shown that customers are less likely to opt into dynamic rather than static TOU tariffs although the former has the greatest benefits for DSR.[150] Other concerns such as interoperability, data security, and privacy can hinder customer confidence.

On the supply-side, there are also barriers to expansion of aggregation due to misaligned incentives. For example, suppliers have previously called for independent aggregators to make compensation payments to suppliers when DSR reduces overall energy consumption or results in higher settlement costs for individual suppliers.

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[149] Citizens Advice (2021). Innovation in the tariff market. Discussion paper on how new tariffs can work better for people

[150] Citizens Advice (2017). The Value of TOU Tariffs in Great Britain: Insights for Decision-makers.

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