Getting to Net Zero

Report for Shell Energy Retail

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Energy Systems Catapult was set up to accelerate the transformation of the UK's energy system and ensure UK businesses and consumers capture the opportunities of clean growth. We are an independent, not-for-profit centre of excellence that bridges the gap between industry, government, academia and research. We take a whole system view of the energy sector, helping us to identify and address innovation priorities and market barriers to decarbonise it at the least cost.

1. Executive summary

1.1. About this report

The UK was the first large economy to pass laws ending its contribution to global warming by 2050. Shell Energy asked Energy Systems Catapult what this means for how we all use energy at home. This is what we found.

1.2. Four steps to zero carbon homes

We can live rich, rewarding lives in a zero-carbon world, but we must find ways to travel and use energy at home without emitting any greenhouse gases. Today this emits about six tonnes of CO_{2e} per year and accounts for two thirds of our carbon footprint. To cut that to zero we need to:

1) Switch to a **zero-carbon energy** supply
2) Install a low carbon **heating system;** and
3) Drive **zero emissions vehicles** (if we have to drive); and
4) Be more **flexible** about when we use energy

It's relatively easy to switch to a zero carbon electricity supplier, but the rest is harder.

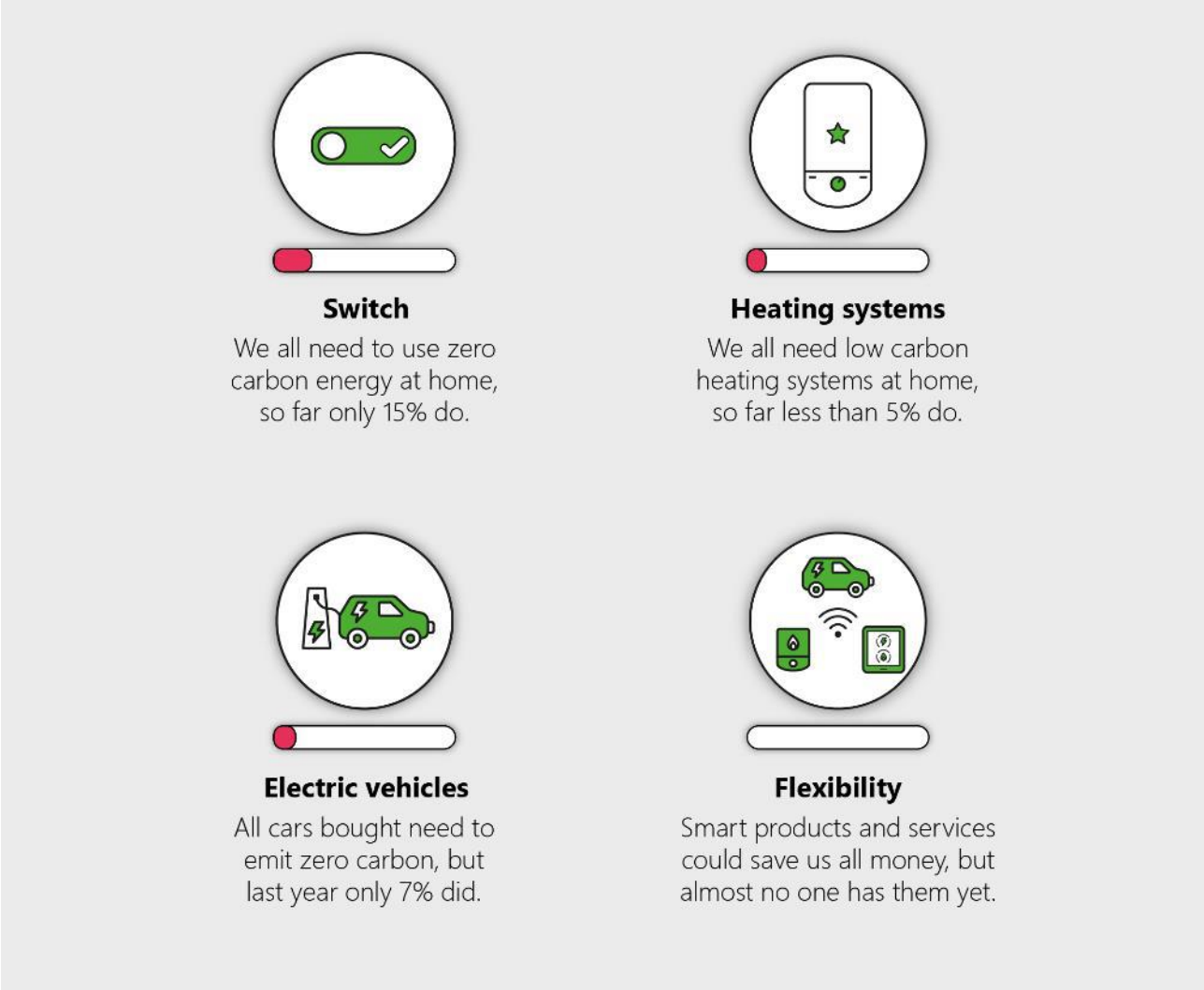

Figure 1 - Infographic showing what people need to do to cut their carbon emissions at home

1.3. How can people take those steps?

Today almost everyone **heats** their home with fossil fuels. Nearly 30m households need to replace their heating system with low carbon alternatives, rising to about 1.6m per year, or 10 a minute. Currently we install around 10 an hour (or 26,000 a year), so there is a long way to go.

We will urgently need to accelerate the pace of installations to meet the target of three million home-owners switching to low carbon heating by 2030.

People who try to do this face a maze of options – electric heat pumps, hydrogen boilers, heat networks and more. Many will also need to prepare their home (e.g. with insulation) before switching to low carbon heating systems. There is no silver bullet and the 'best' choice varies from place to place. It is hard to pick an option and get it installed so it works well in practice. People need clarity so they can do the right thing.

We must also change how we **travel**: reducing unnecessary trips; walking or cycling more for short trips; using public transport for longer trips (where it's available); and ultimately using electric vehicles where it is not. Long distance travel is tougher. We can still fly but need to halt recent rises in the amount we do. It would help if we substituted short-haul flights with train, coach or car trips.

Sales of battery electric vehicles are rising fast: we bought 110,000 last year. **That number could triple in three years and grow twenty times by 2030** (unless we start traveling in different ways). Most people will want to charge their cars at home. This could be tricky for the third of households who park their cars on the street. People will need charging options that get them from A to B.

Finally, we might need to be more **flexible** about when we use electricity. To understand why, we need to look at what happens as we switch to low carbon energy supplies.

Today when we flick a switch, jump in a shower, turn on our heating, or refuel our cars we generally get the energy we need straight away. Practically all of it (90%) comes from fossil fuels (gas, oil, petrol or diesel). These are easy to store, so we can use them when we need to.

In future we will use lots more renewable electricity to heat our homes and charge our cars. Solar and wind power will be cheap and plentiful when the sun shines or the wind blows. That means our energy supply will vary more with the weather.

This problem is we will want our homes warm when it's cold, our water hot when we take a shower and our cars charged when we go somewhere, but we can't make the sun shine or the wind blow when we need more electricity. Smarter homes could help us buy electricity when it is cheap and store it to use when we need it.

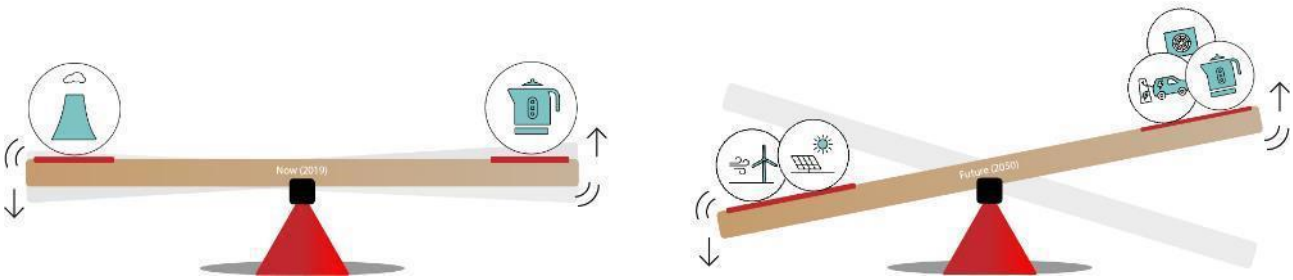

Figure 2 - It gets harder to balance energy supply (left of each seesaw) and demand (right of each seesaw) as we use more renewables to power more electric heating and electric cars.

To give a sense of scale, the amount of electricity we use at home could vary eight times as much as it does today. Making our energy system smarter can really help tackle this challenge.

Government estimates that smart flexibility and storage in our homes, on our electricity grid and connections to electricity grids in other countries could save the nation £12bn per year. That means a need for smarter homes that can vary their need for electricity to match the supplies available and use technologies like solar and household batteries to take pressure off the grid.

Making these changes will prove more challenging for some than others. Getting it right will be particularly critical for **vulnerable people** who cannot afford their energy or who need to use energy to maintain their health. There are also difficult decisions to take, for instance around how to share costs and how to make sure **local Net Zero plans** add up to meet the national target.

1.4. Progress is slow so far

Most people say *something must be done* about climate change and that *they will do their bit*. COVID has also shown that people can make huge changes when needed.

Unfortunately, lots of people are confused and do not know what they can do to help. About 15% are on 'green' or '100% renewable' *electricity* tariffs, but, half the nation does not even know that emissions from their home heating also drive climate change. Also, many say they have heard of low carbon heating systems and would consider installing them, but practically no one does (i.e. <5%) when they replace their boilers.

At first glance, the outlook looks similar for electric vehicles: many people say they are open to buying one, but uptake remains low (≈7%). However, prospects look far better than for heating as sales of electric vehicles are growing rapidly. Understanding why could drive more action on heat.

Far more people (77%) understand the link between transport and climate change so it would help to explain the link with heating. However, raising public awareness is just the simplest first step of a long and complex journey. We need much more major change to drive uptake of low carbon heat.

1.5. Rapid change is possible

Previous energy transitions **changed consumers' behaviour by offering people clear benefits**: cars were cleaner and faster than horses; gas central heating was simpler and safer than coal fires. People who prefer electric vehicles to their existing cars also think they are better in important ways. Could the smart home make low carbon heating as good as, or better than what we have?

Digitalisation has transformed many other parts of our lives: how we learn, shop, relax, travel and so much more. These sectors have invested in using digitalisation to understand what people want and driven change across complex supply chains to deliver improvements in their experiences. Could a similar transformation deliver the change we need in heating?

It is certainly possible to **design and deliver high quality heating solutions**. Smart thermostats can use weather forecasts and smart meters to improve consumers' control of their comfort and costs. Innovators have shown they can use this technology to offer consumers new propositions that drive uptake of low carbon heating systems, unlock flexibility, improve energy efficiency and help people afford their heating. However, these innovations will need to work alongside future energy policy if they are to transform heating at the scale needed.

Sectors that deliver radical change start out by asking what they can do to improve people's lives, rather than expecting people to change their lives to help that sector succeed.

Figure 3 - It will be easier to convince people to cut their carbon emissions if acting delivers clear benefits

Government has significant ambitions. 'Greener buildings' was the 7th of its 10-point plan for a green industrial revolution. The Energy White Paper set out twenty-three commitments on buildings and consumer protection. The Heat and Buildings Strategy will set out more detail soon.

1.6. Recommendations

We think there are four things Government should do to help people go to zero carbon at home.

1. Introduce a technology-neutral target focused on outcome, not delivery

Banning the sale of petrol and diesel cars by 2030 gives the transport sector a clear motive to design zero emissions vehicles that consumers want to buy. Contrast this with the twenty or so regulations, subsidies and standards that exist for heating. This leaves consumers to decide how to combine different components – insulation, heating systems, controls etc. – to decarbonise their home heating. Just imagine introducing taxes and subsidies for car components like batteries and motors, then expecting consumers to design their own electric vehicle: it would never work. Given the scale and pace of change needed, it must be worth trying a new approach. Technology-neutral heating targets would **give industry a reason to create appealing, effective, low carbon heating *solutions* that consumers want to buy** (i.e. that combine components holistically).

Consumers will also need help paying for low carbon solutions. Government could help by moving policy costs to more carbon intensive energy sources so that bills reward people for making low carbon choices, encouraging green finance products and subsidising *solutions*, not components.

Figure 4 - Great solutions combine lots of components to help people get around (left) and get comfortable at home (right)

Carmakers manage complex supply chains and combine lots of components to deliver what people want, great cars. Supermarkets and telecoms do much the same to deliver tasty, nutritious food and mobile phones. By contrast, when it comes to heating, home-owners must solve this highly

complex problem if they want to decarbonise their home heating. Very few do. **People will need low carbon heating solutions** that bring together lots of components to make sure they can easily get comfortable in their own homes.

2. Help people realise that their heating drives climate change

A lack of understanding exacerbates the challenges of decarbonising heat. **People need to know why they must act.** Imagine if they had annual **carbon MOTs** for their home, including their plan to get to Net Zero. Their energy supplier could use their smart meter data to report their annual carbon emissions. Asking people to make sure their home met a **minimum carbon standard** would help them realise they need to decarbonise their homes and create demand for solutions. They could shop around for an energy retrofit quote to get them to Net Zero any way they liked, just as they do for other home improvements like loft extensions, kitchens or bathrooms.

3. Use public funding to make sure we learn how to do this well

Both the public and private sectors need to act with vigour and creativity to decarbonise heating. They will work together to **rapidly test and learn to get it right**. Early setbacks would harm consumers' confidence in low carbon technologies and cost us time we do not have.

It would help to prime the market through **place-based low carbon energy programmes**. These should create Living Labs where innovators can find better ways of making progress without harming consumers, develop standards to share lessons, embed good practice and accelerate interoperability. Public funding should include vulnerable consumers, not just early adopters, so the sector can find effective ways to solve challenges like fuel poverty and prevent digital exclusion.

4. Ensure local areas publish their plan for getting to Net Zero

People will need to power their heating systems by connecting to a low carbon energy network. The choices available will vary from area to area. Places could upgrade their electricity grid, build heat networks, or convert their gas grid to use hydrogen. **Each area will need a clear plan** so the people who live there know what to prepare for (i.e. electric heat pumps, heat networks, hydrogen boilers or something else). Plans will be more popular if the people who live in areas are involved with developing them. They will also inform the investments needed to build Net Zero networks.

1.7. Enjoying the journey to Net Zero

Climate change represents an existential threat to our existence, but it also presents a unique opportunity to improve our lives. If we act now, we can ensure we all enjoy the Net Zero future.

We know what the target is, we need to make sure we hit it. There are many routes possible. Government could set us on a pathway by (1) introducing a technology-neutral target; (2) helping people realise that their home heating causes climate change; (3) using public funding to learn how to do it well; and (4) making sure local areas have a good Net Zero plan.

1.8. Next steps

Faced with such a daunting challenge it can be hard to know how to start. It would help to:

- Involve citizens in plans to decarbonise their area so they support action;
- Find out which homes are ready for low carbon heating and tell their owners;
- Learn how to deliver the quality that gives these people the confidence to act; and
- Discover how flexible people are about when they charge their cars and heat their homes, so we build enough energy supplies and networks to power the lives people want to lead.

2. What does the Net Zero target mean?

"We are facing a man-made disaster on a global scale. Our greatest threat in thousands of years."[1] The UK has committed to stop emitting the gases that are causing this risk to Net Zero by 2050. Net Zero means creating a society that lives without *adding* greenhouse gases to the atmosphere. Our choices – what we buy, what we eat, how we travel and how we use energy at home – matter. Shell Energy asked us what this means for how we all use energy at home.

To really understand the implications of Net Zero for consumers, it is helpful to have sight of the wider context. ESC does this through *whole systems* modelling[2], looking at the changes needed across different sectors including power, heat, transport, industry and land use. We run hundreds of simulations, exploring different pathways to find 'low-regrets' technologies which always feature.

The old 80% target provided enough 'slack' in the system for some sectors to 'hide' in the 20%. With Net Zero that slack has disappeared, and the set of possible pathways looks much smaller, so many more activities across the economy will need to be comprehensively decarbonised. We will also need to see societal change that reduces demand, technological change to enable deep decarbonisation and land use change to offset remaining carbon. A new interim target of 78% reductions by 2035[3] means a lot of this change will need to take place within just 15 not 30 years.

2.1. Energy

Let's start with energy because most of our greenhouse gas emissions come from how we use it.

We must completely decarbonise electricity generation by 2035[4] and use low carbon electricity to power heating and transport. We will certainly need lots more wind and solar PV (as they are now relatively cost-effective) and probably some other sources (e.g. nuclear power or gas turbines fitted with systems to safely capture and store the CO2, often called CCS).

Renewable electricity generation sources are intermittent: turbines and panels generate more electricity when the wind blows and the sun shines. With an 80% target there was enough 'slack' to use CO2 emitting gas turbines to balance supply with demand occasionally. The Net Zero target removes this 'slack' making it harder to match electricity supply with when customers want it.

To solve this problem, we will probably need some flexibility to rapidly adjust demand to match supplies. This flexibility will certainly need to exist at the grid level (e.g. through pumped storage or batteries). Consumers could also play a role by being flexible about how and when they charge their EVs, heat their homes and power their lives. So called demand-side-response options could even power the grid when needed using EVs (V2G) or home-PV-battery solutions. We discuss how our homes could help this transition to a more flexible, renewable energy grid later in the report.

Net Zero will probably also need a significant expansion of heat networks in more urban areas. Today, most UK heat networks use carbon intensive energy sources. They will need to switch to low

[1] David Attenborough: https://www.bbc.co.uk/news/science-environment-46398057
[2] ESC (2020) Innovating to Net Zero. https://es.catapult.org.uk/reports/innovating-to-net-zero/
[3] www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035
[4] CCC (2020) 6th Carbon Budget has carbon emissions from electricity falling to zero by 2035, see also: https://www.carbonbrief.org/ccc-uk-must-cut-emissions-78-by-2035-to-be-on-course-for-net-zero-goal. Electricity generation could even become 'net negative' if we used biomass or waste to generate electricity.

carbon options and there are various ones available.[5] Areas that roll out heat networks need robust plans to decarbonise them later or they could become stranded assets.

There is also a clear role for hydrogen in meeting Net Zero. The scale varies from about 60-100% of existing electricity generation depending on what you assume about the future. Hydrogen is likely to be particularly important for industry and heavy vehicles. It could also play a role for light vehicles, home heating and to support peak electricity generation. At present there are uncertainties about how to make low carbon hydrogen cheaply enough and at a large enough scale for the very large demands it might need to meet.

So, to summarise, we need to rethink energy. We need to generate low carbon electricity and hydrogen; then use it for heating, transport and so on. Every household will need to play its part.

2.2. Heat

The Net Zero challenge for heating is replacing all gas boilers with low carbon alternatives by 2050. Our initial modelling suggests that we might need to stop installing fossil fuel heating in 2030 to see emissions fall by 78% in 2035 in line with the new government interim target. That means installing around 1.5m low carbon systems each year by 2030. We currently only install around 26,000 each year, so this is a very significant change.[6]

A low carbon heating transition will involve different solutions for different homes, depending on the occupants, buildings, local planning priorities and decisions around gas distribution networks. The long lead times behind these drivers make it hard to change heat demand much before 2030. By 2050 our modelling shows we will likely rely on a mix of low carbon heating technologies. Electric heat pumps could provide around 60% of space heating in buildings; electric resistive heating 7-12%, district heating 20% and hydrogen boilers the remaining 8-16%.[7]

Given the lead times needed to build up supply chains, most of this transition will be back-ended, but scale up must begin urgently. Heat pumps will provide roughly 10% of space heat in 2030. This could mean 5.5m installed in the next decade, including 2.2m new homes and 3.3m replacements,[8] over 300,000 replacements a year if they were spread evenly, around 10 times the current rate.

There are also key decisions to take about how each area decarbonises. These choices come with complex consumer challenges. Will the public prefer to put up with the disruption of deep energy retrofits to insulate their homes, or would they prefer to pay for more low carbon energy supply? Would they prefer heat networks powered by small modular nuclear reactors or large heat pumps? Nuclear might be unpopular with some, but heat pumps would mean managing more pressure on the electricity grid probably increasing the need for flexibility.

2.3. Transport

A whole systems approach to transport includes walking, cycling, road, rail, shipping and aviation. Consumers can cut their emissions by avoiding unnecessary trips; walking or cycling short trips; using public transport (where it is available); and flying less. Given this report focuses on what

[5] Large-scale heat pumps could run on low carbon electricity, but this would put more stress on the grid. Small modular nuclear reactors could provide combined heat and power but would need some innovation support. Geothermal energy also looks attractive, but there is limited capacity in some parts of the UK.
[6] CCC (2020) Reducing UK emissions: 2020 Progress Report to Parliament, p110-111. Assuming this has risen to 30,000 it would be about 10 per hour, assuming a 6-day, 9-hour per day working week.
[7] ESC (2020) Innovating to Net Zero describes two scenarios to explore this in more detail.
[8] The CCC's 6th Carbon Budget balanced Net Zero pathway has 5.5m heat pumps in homes by 2030.

consumers can do and the current reliance on the car, it makes sense to look in more detail at the vehicles they buy and how they use them.

Our Net Zero pathways consistently show that we need to remove internal combustion engine (ICE) cars and vans from the fleet by 2050. They typically have a life of up to 15 years aligning well with the recent policy announcement banning sales of new petrol and diesel cars and vans from 2030.

Around 2m new vehicles are sold in the UK every year. In 2020, nearly 110,000 of these were battery electric vehicles (EVs), 7% of the total. In the next ten years, annual sales need to rise from 110,000 to 2m. All new cars will be pure electric, not hybrids, to make sure they use no fossil fuel.

So, vehicle owners will need access to EV charging. They will want access to convenient charging at home where they spend most evenings parked, a theme we return to later.

2.4. Flying and eating

Whilst this report focuses on how we use heat and charge our cars at home, it's worth noting that getting to Net Zero will also mean changing how often we fly and what we eat.

Prior to Covid-19, government forecast a 60% increase in demand for flying by 2050. Even so, improved aircraft efficiency and logistics could keep 2050 emissions at today's levels. To *reduce* carbon caused by flying, we need to curb our ever-increasing demand as there is limited potential to deploy low carbon aviation technologies at scale by 2050.

Elsewhere, we will need to change our diet to reduce emissions from livestock. If we ate 20% less red meat and dairy in 2050 compared to today, it would save 8MtCO2e per year. A more ambitious shift might see a 50% reduction in meat and dairy, with a total annual saving of 19MtCO2e.

Based on current public opinion, we are cautious about relying on people to completely stop flying, eating meat or dairy.[9] Only 40% would be willing to limit their flights to just one a year. Conversely, 34% said they would not be willing to restrict themselves to just one flight a year and 16% said that they would not even consider an alternative. Only 27% said they were likely to halve the amount of red meat they ate, and 20% said they were likely to halve their dairy intake. Innovation could help here, for instance through more sustainable aviation fuels or more popular meat substitutes.

[9] Evidence in this paragraph comes from surveys of a representative sample of the UK conducted before the outbreak of COVID in early 2020: https://es.catapult.org.uk/reports/net-zero-a-consumer-perspective/.

3. What are we expecting people to do?

This chapter explains how we can all live rich, rewarding lives in a Net Zero future.[10] It focuses on home heating and charging electric vehicles at home because this report is about the future of energy supply, not food or flying. It also explains why it might prove more difficult for some. We will need to take steps, as a society, to make sure everyone can enjoy a Net Zero future.

3.1. Heating

Today, most of us burn fossil fuels to stay warm at home: 85% have gas central heating and 5% use oil, LPG, or coal. [11] This accounts for 31% of our carbon footprint.[12] We need to replace these systems with low carbon alternatives. Figure 5 shows the scale of this challenge.

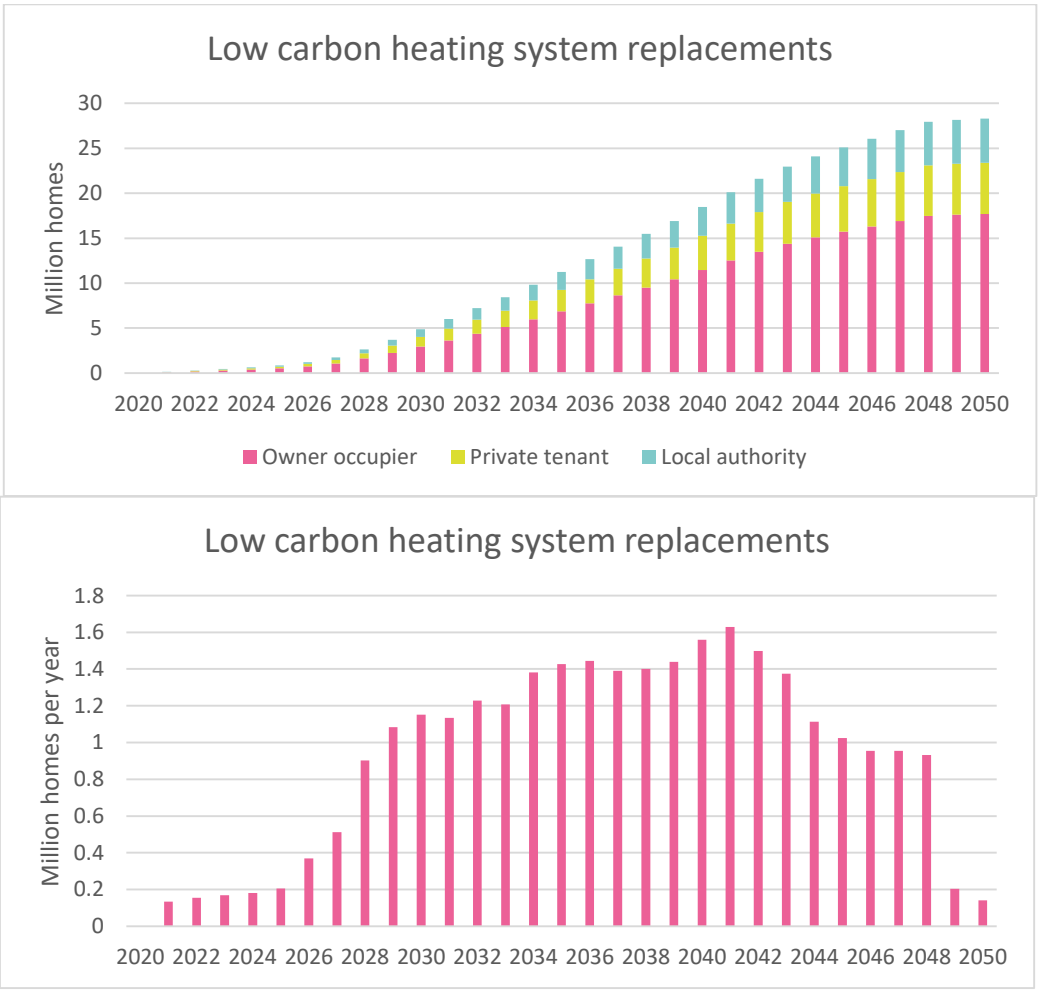

Figure 5 - Number of low carbon heating replacements needed to get to Net Zero per year as a function of property tenure (top) and per year (bottom) from from the CCC 6th carbon budget building pathways data. It shows that 3m owner-occupiers will have switched to low carbon heating by 2030 and the replacement rate gradually grows, peaking at 1.6m in 2041.

Households need to decide what sort of system to install. There is no 'silver bullet' but instead many options to choose from. Consumers can already buy ground source heat pumps, air source

[10] https://www.theccc.org.uk/publication/living-carbon-free-energy-systems-catapult/
[11] BEIS (2018) Clean Growth - Transforming Heating Overview of Current Evidence.
[12] ESC (2019) Living Carbon Free, figure 1.

heat pumps, biomass boilers, storage heaters and infra-red radiators. New systems are coming onto the market all the time.

Indeed, it is possible that different solutions will be available in different places. One area might choose to expand a district heat network. Another might decide to repurpose the natural gas grid to distribute hydrogen. This creates new options for households in these areas. They could choose to join an expanding heat network or buy a hydrogen-ready boiler.[13]

Many heating systems will work more efficiently with other adjustments, like larger radiators, or insulation. Smaller, cheaper heating systems can heat better insulated homes with larger radiators at lower temperatures using less energy and costing less to run. Logically it might make sense to insulate older UK homes before installing low carbon heating systems because they are less thermally efficient than newer homes.

Figure 6 - People may choose to retrofit their homes in different ways. Some may install lots of insulation and spend less on their heating (big scarf on the right). Others may install less insulation and more on their heating (small scarf on the left).

When it comes to heating, as with everything else, people also hold very different preferences which is one reason why they sometimes row about the thermostat[14]. The 'right' choice for any household will depend on what they want. Some might prefer to pay more to avoid the disruption of upgrading their home, or to tuck equipment out of sight. Others might be more focused on minimising the cost or saving time.

[13] https://ukerc.ac.uk/news/heat-decarbonisation-in-the-uk-national-scenarios-vs-practical-local-options/
[14] Sovacool et al. (2020) From thermal comfort to conflict: The contested control and usage of domestic smart heating in the United Kingdom. Energy Research and Social Science 69.

They certainly face some difficult questions: how much insulation do they need, which system is best, who can install it well? Perhaps a heat pump is their best choice today,[15] but they may lose out if their area repurposes the gas grid for hydrogen or installs a district heating scheme in future. Most will want to ask someone else for advice and leave it to an installer to make sure their system works well.[16]

3.2. Transport

Arguably, it is easier to decarbonise how we get around than how we heat our homes.

The choices are relatively clear, for instance: consider not travelling if it is not necessary; walk or cycle short journeys; use public transport for longer journeys (where it's available); use a low carbon vehicle where it's not. It could prove challenging to persuade people to drive less, even if this makes most sense from a carbon perspective. That's due to the sheer number of miles we drive.

In 2018 we travelled over 75% of our miles by car or van (Figure 7). Although we only made around 60% of our trips by car or van and walked 25% of them, people drive for relatively long distances (Figure 8). That means switching from car to other modes of transport requires enormous increases in the capacity of other modes.[17] To give a sense of scale, we drive around 400 billion person-miles by car each year. This is 10 times more than the distance we travel by rail and 20 times more than by bus or coach. So, taking just 10% of person-miles off the road and moving this to either of these modes would necessitate a doubling in rail capacity or a tripling of bus and coach capacity.

With certain modes, such as rail, we might not have enough time to build this capacity before 2050. Important practicalities also put people off alternatives to cars: the routes and timetables available; the need to transport luggage and/or family members; and the level of flexibility offered. That is why people give quite good reasons for not using public transport today (Figure 9). Ultimately, 75% of households own cars today. Many will drive electric vehicles in 2050.

This contrasts with heating where the choices are both less clear and more complex. Drivers can just buy a new electric vehicle, but most homeowners will need to upgrade their homes for low carbon heating. This is because 85% of homes standing in 2050 have already been built.[18] The 90% with fossil fuel boilers need to decide which low carbon heating system to install and how to improve the energy efficiency of their home. It will be very hard for them to know what is best without some help.

Drivers can also be confident their electric cars will perform as they expect, though they may worry about how they will charge it and what that will cost. The next section discusses this in more detail.

[15] ESC (2019) Pathways to Low Carbon Heating: Dynamic Modelling of Five UK Homes
[16] BEIS Public Attitudes Tracker Q7a www.gov.uk/government/collections/public-attitudes-tracking-survey
[17] Batterbee and Tuff (2013) An affordable transition to sustainable and secure energy for light vehicles in the UK
[18] Assuming there are 28.3m homes in Great Britain and we build at the average rate over the last decade. This would fall to 74% if we built at the fastest recorded rate, which was in 1969 when records began.

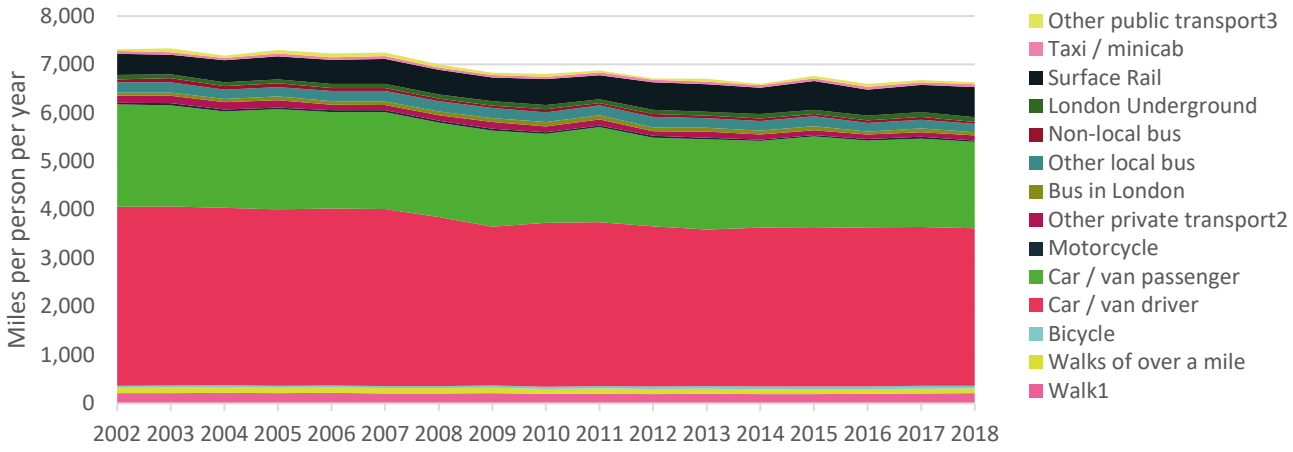

Figure 7 - Average distance travelled by mode in England, 2002-2018[19]

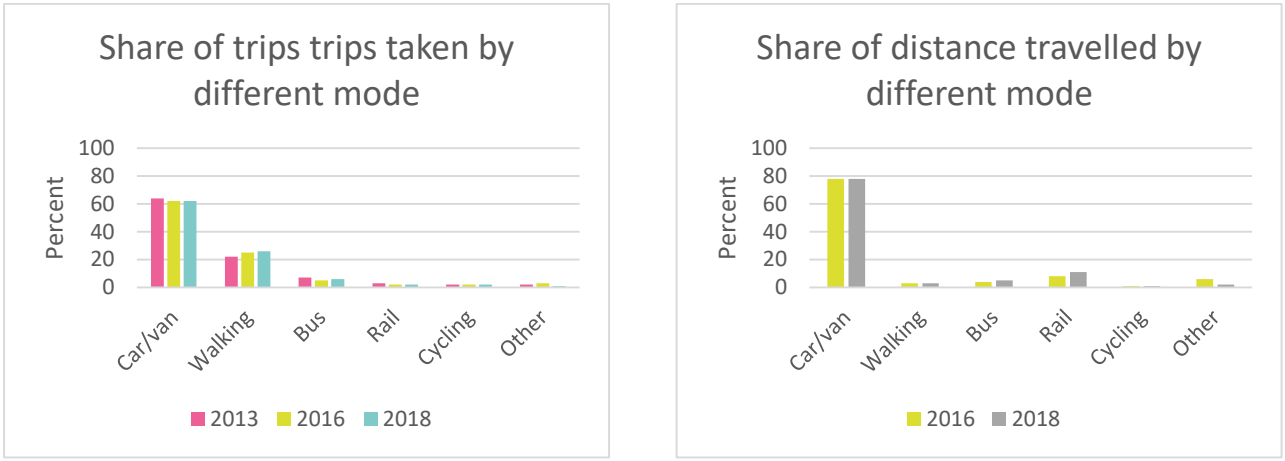

Figure 8 - Number of trips taken and share of distance travelled by different mode.[20]

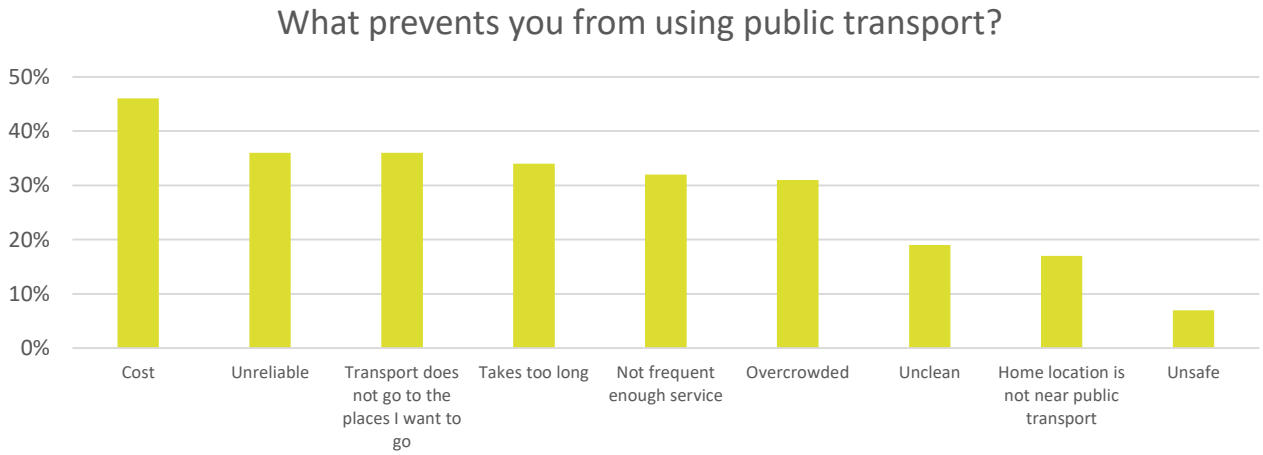

Figure 9 - ESC Net Zero survey responses (n=2,043)[21]

[19] Department for Transport (2019) Statistical data set NTS0303: Average number of trips, stages, miles and time spent travelling by main mode: England.
[20] DfT (2014, 2017, 2018) Transport Statistics Great Britain.
[21] ESC (2020) Understanding Net Zero: a consumer perspective. https://es.catapult.org.uk/reports/net-zero-a-consumer-perspective/

3.3. Flexibility

Today we use petrol, diesel and natural gas for transport and heating. This is easy to store until we need it. In 2050 we will rely more on low carbon renewable electricity supplies, like wind and solar, that vary with the weather. We will need to find new ways to store it and be more flexible about when we use it unless we want to spend more on energy infrastructure we rarely use.

Smart new energy products and services in our homes could help *if consumers want them*.

Appliances could turn themselves off for very short periods to reduce demand when supplies are low. People would probably not even notice if their heating, fridge, washing machine, tumble drier, or dishwasher had no power for a short time. They could store electricity in batteries on their walls or in their cars when supplies were plentiful and either use it later or sell it to neighbours in need. People could use smart controls to pre-heat their homes or hot water tanks when electricity was plentiful and enjoy the heat later when they needed it.

This might be cheaper than building generation and network capacity that is rarely used. Consumers like the idea that such smart energy schemes could save them money and reduce emissions but do have concerns about losing control of their appliances. Fundamentally, they want to be sure they will still get what they need from their energy (e.g. comfort or mobility).[22]

This change is already starting, but it is set to become far larger and more complex in future.

Today electricity is only a small part of energy demand. Electrifying a significant amount of transport and heating to meet Net Zero will radically increase the scale of the challenge. People will also want to be able to get the energy they need when they need it, as they can today. They will want to warm their homes up on cold days and light them when it is dark outside.

New challenges will also emerge as we decarbonise our lives. People with electric vehicles tend to plug them in when they get home. This could lead to large peaks in demand unless drivers let smart chargers fill their batteries when electricity supplies are plentiful. They will be reluctant to do so if they end up with too little charge to get where they want to go when they next use their car.

Figure 10 gives a sense of the scale of the challenge. Today our electricity use varies by up to 16GW per hour, but our gas use varies over 7 times more, by up to 61GW per hour.[23] Even though electric heating can be much more energy efficient than gas boilers, if we plug in 10m electric vehicles at the same time, we will need another 70GW of electricity. This means our future electricity use could vary much more than it does today, and we won't be able to just generate more by using fossil fuels. Being smarter about how we warm our homes, heat our hot water tanks, charge our cars and use electricity for other things will clearly help.

Smart storage and flexibility in our homes could certainly help cut the costs of getting to Net Zero. It is hard to know how exactly much as it depends on many other parts of the energy system.

For instance, if we used hydrogen to heat our homes and fuel our cars, we could rely less on smart technology to manage our demand (see the arrow in Figure 10). However, this comes with different challenges: generating enough low carbon hydrogen, creating a hydrogen supply network to refuel

[22] http://www.peoplelab.energy/2019/07/05/local-energy/

[23] Wilson et al., (2020) Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018.

our cars and so on. It would also help to use energy storage on the electricity grid and connect to electricity networks in other countries.

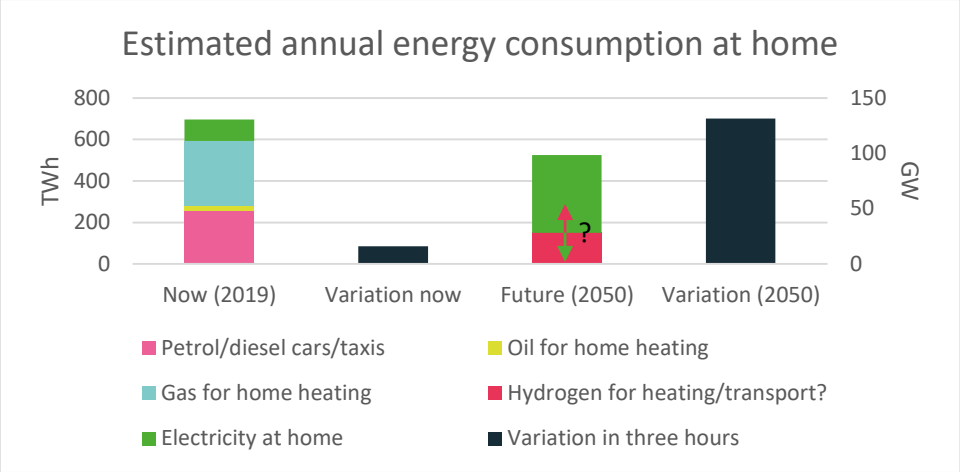

Figure 10 – The coloured bars show how much energy we use for travelling and heating now (from DUKES, 2020) and in 2050 (assuming 375TWh heat demand and 150TWh from EVs that use 60% the energy used today by petrol/diesel cars). The coloured arrow highlights uncertainty around how much hydrogen we will use in future. The black bars show how much electricity demand could vary over 3 hours. Today this varies by up to 16GW. In 2050 this could rise c.8 times to c.130GW, assuming heat demand increases by 60GW (as it did on the Tuesday afternoon of the 2018 Winter 'Beast from the East', Wilson et al. 2020) and heat pumps operated at a COP of 2.0 (their efficiency falls in cold temperatures); and that 1/3m of the 33m cars on the road get home between 3-7pm as they do today (DfT, National Travel Survey).

Smart storage and flexibility would mean we could spend less on new generation and networks. The overall value varies, for instance with the level of energy demand and how much hydrogen is available. The Department for Business, Energy and Industrial Strategy used modelling to explore various scenario and concluded flexibility was essential in bringing down costs. They estimated that flexibility from a combination of demand response in smart homes, battery storage and interconnections could save as much as £12bn per year.[24]

Sadly, there is no simple route to Net Zero. The next section discusses some of the key challenges.

3.4. Challenges

Some people will find it easier than others to heat their homes and get around in a Net Zero world. The challenges will differ from area to area, from home to home and from household to household. This section discusses some of the reasons why.

Let's start with **heating**.

Homes in different areas will probably have access to different low carbon energy networks. Some places will already have enough spare capacity in the local district electricity network to power heat pumps, but others will need upgrading (e.g. with larger cables). Homes connected to the gas grid could switch to hydrogen boilers if it was repurposed to transport hydrogen, but the 10% of homes without gas grid connections could not.

Some low carbon heating solutions are better suited to some places than others. Heat networks work well in dense urban areas where they can supply lots of homes without losing heat

[24] BEIS (2020) Modelling 2050: Electricity system analysis, page 12.

transporting it longer distances. Heat pumps might make more sense in more isolated areas where there are fewer homes with more space to install them.

Smaller, newer homes will need less energy to get warm than older, less energy efficient homes. It is possible to retrofit homes to improve their energy efficiency, but this will cost money and cause some disruption, particularly in older homes (see Figure 11). Around 20% of older, pre-1919 homes are in conservation areas.[25] Improving the energy efficiency of these 1.2m homes will be particularly hard as it must comply with planning rules designed to maintain their appearance.

Figure 11 - Comparing two types of home: There are twice as many pre-1919 mid terraces as there are post-1980 purpose build flats, but they account for more than four times as much CO2 and will be more expensive to insulate (as they have older solid walls and more bay windows).[26]

[25] Bottrill (2005) Homes in Historic Conservation Areas in Great Britain: Calculating the Proportion of Residential Dwellings in Conservation Areas.

[26] Replotted from analysis of the English Housing Survey reported in ETI (2015) Optimising thermal efficiency of English Housing.

In addition to these physical factors, households will find themselves in different circumstances. Some will have more time, money and technical knowledge than others. Tenants will also have to persuade their landlords to make upgrades. These factors can coincide: private tenants are far more likely to live in the oldest, least energy efficient housing than anyone else (Figure 12).

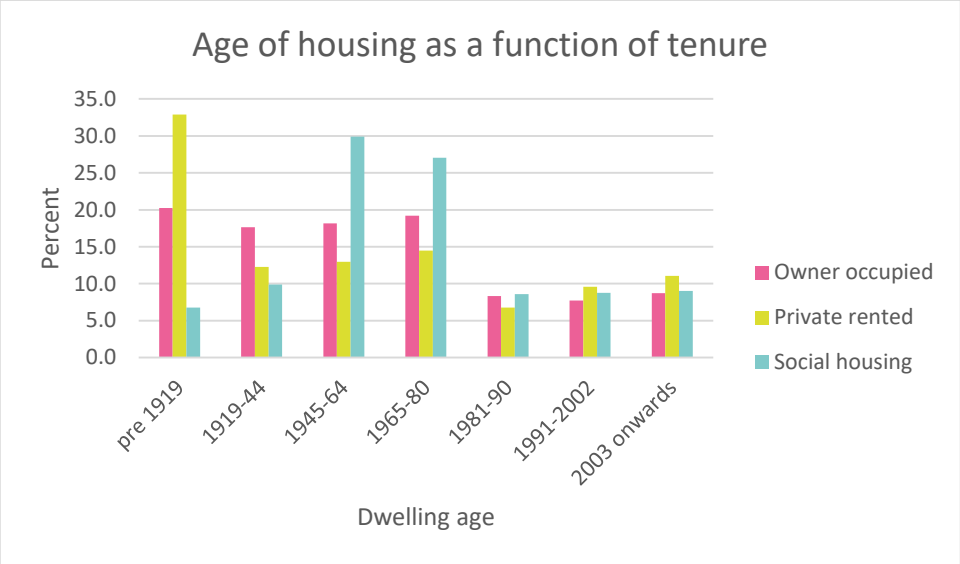

Figure 12 - Private tenants live in the oldest, least energy efficient housing[27]

Clearly then, the cost and convenience of switching to low carbon **heating** will vary widely from area to area and home to home. British housing is also amongst the least efficient in Europe (Figure 13) making this a particularly challenging problem to solve.

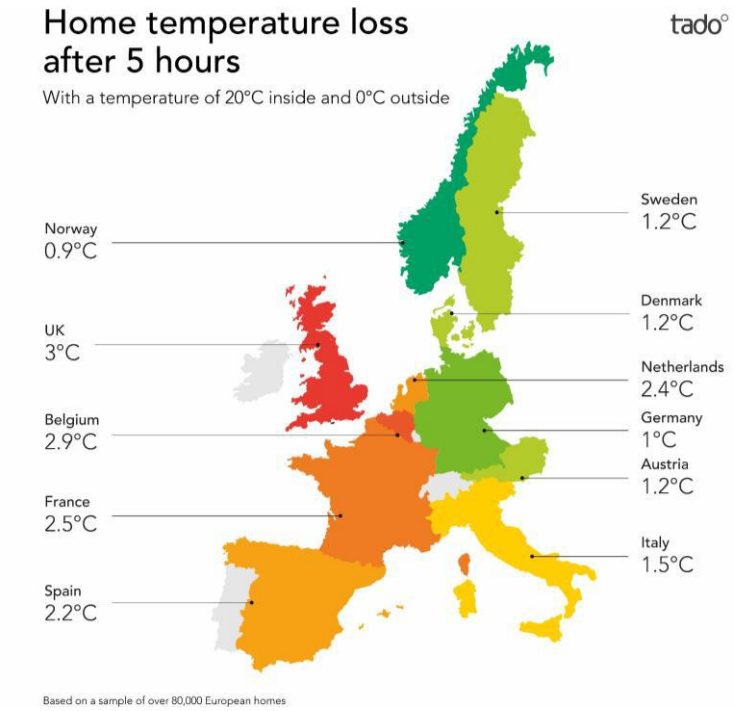

Figure 13 – Smart thermostat manufacturer Tado compared how much indoor temperatures fell from 20°C over five hours when the external temperature was 0°C. It found UK homes lost on average 3°C, the highest rate in Europe.[28]

[27] MHCLG (2020) English Housing Survey Headline Report, Annex Table 2.1.

[28] https://www.tado.com/t/en/uk-homes-losing-heat-up-to-three-times-faster-than-european-neighbours/

The situation is simpler for **transport**, but not without challenge. People living in the third of homes without off-street parking will have to find somewhere else to charge their EV (Figure 14). Rapid charging and public charging could cost more than slower home charging solutions, so the cost and inconvenience of refuelling EVs could be higher for households unable to charge at home.

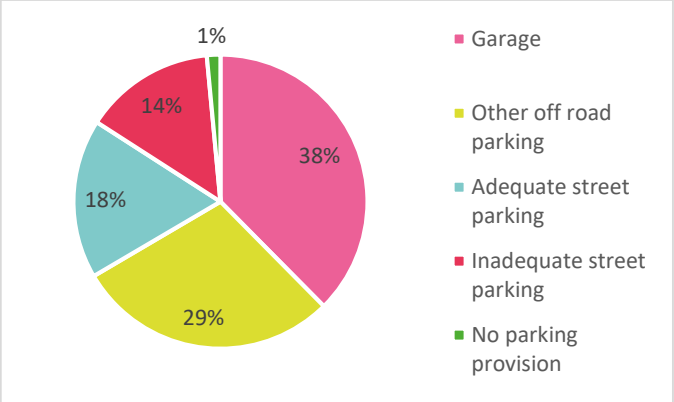

Figure 14 - Parking availability at UK homes[29]

People who cannot plug in an electric vehicle may also benefit less from providing flexibility to the grid, for instance through lower bills. The same goes for anyone unable to access or use other smart products and services to generate their own supply, manage their demand and sell flexibility. Some simply will have no space to install solar panels, or a battery. Others will have no time to engage with these opportunities or might struggle to understand how they work.

It may cost more for people who cannot be flexible to get the energy they need. Almost 1 in 5 people cannot use the internet by themselves or struggle to use it to its full potential.[30] How will they access this smart new energy future if it relies on internet access?

Around c.10% of households struggle to afford the energy they need today.[31] Millions with respiratory and cardio-vascular diseases are vulnerable to harm if they live in a cold home. This causes over 10,000 deaths each year.[32] The cost of treating illnesses caused and made worse by cold homes is over £1bn a year.[33] It also places additional burden on the NHS.[34]

If costs rise, more people without access to the capital or finance to buy low carbon products and services may not be able to afford the energy they need. Many people rely on energy for their work (e.g. transport for rural commuters, taxi drivers and tradespeople). The consequences could be particularly bad for the nearly 7 million households registered as needing non-financial services from their energy supplier or network operator as they rely on energy for their health needs.[35]

Clearly action is needed to make sure everyone can afford to live in a Net Zero future. The next chapter discusses the progress we are making so far.

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[29] English Housing Survey (2018) Table DA2201.
[30] www.lloydsbank.com/banking-with-us/whats-happening/consumer-digital-index.html
[31] BEIS (2020) Annual Fuel Poverty Statistics in England.
[32] UK Green Building Council (2016) Health and Wellbeing in UK Homes.
[33] Institute of Health Equity (2014) Local Action on Health Inequalities: Fuel Poverty and Cold Home-Related Health Problems.
[34] All party parliamentary group for healthy homes and buildings (2018) Building our Future Laying the Foundations for Healthy Homes and Buildings, White Paper.
[35] OFGEM (2019) Vulnerable consumers in the energy market.

4. Progress so far: the public are on board but not sure what to do

4.1. Where is the public mood on climate change?

In the UK, most people now think climate change is a global emergency (74%) and that something must be done: 84% think governments should act, but 77% think we all have a part to play.[36]

Unfortunately, people are confused about the cause, so they don't always know what's best to do. Most (72%) understand that our greenhouse gas emissions are warming the atmosphere, but they're not sure where these greenhouse gases are coming from. They realise that transport causes emissions (77%), but only 49% understand it also comes from gas central heating. Few people pick out home energy use as a main driver of UK carbon emissions.[37] That helps explain why many think they're doing everything they can by recycling (86%) and trying to buy less single-use plastic (71%).

People are happy to do something, just not necessarily the things we need.

4.2. With heat, the tough part is yet to come

Most people (64%) realise that power stations can cause climate change, but only 15% of consumers are on a 'green' or '100% renewable' electricity tariff.[38] People say they have heard of low carbon heating (Figure 15a), and would consider installing it (Figure 15b), but practically no one does when they decide to replace their heating system (Figure 15c).

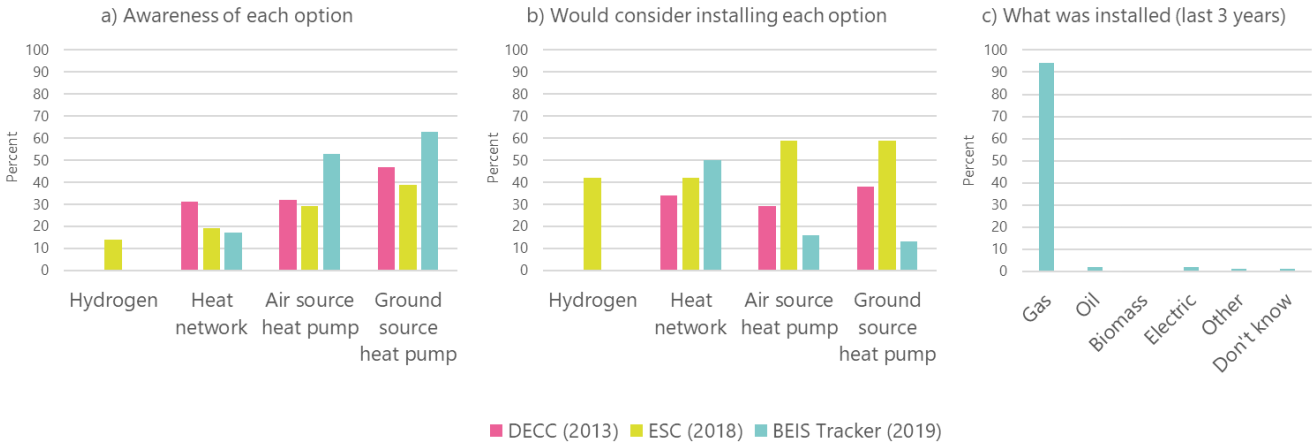

Figure 15 - A 2020 evidence review found that awareness of low carbon heating systems does not translate into uptake. This figure plots data from three previous studies on *(a) awareness of low carbon heating options, (b) those who say they would consider installing one and (c) those who do.*[39]

Hydrogen boilers and district heating are not realistic options for most people yet because they cannot access a hydrogen supply or connect to a heat network. Heat pumps are often the most

[36] Evidence in this paragraph comes from surveys of a representative sample of the UK conducted before the outbreak of COVID in early 2020: https://es.catapult.org.uk/reports/net-zero-a-consumer-perspective/.
[37] National Grid (2020) Heating our homes in a Net Zero Future: Understanding what matters to consumers.
[38] Ofgem (2019) State of the energy market.
[39] Caiger-Smith and Anaam (2020) Public awareness of and attitudes to low carbon heating technologies: An evidence review with primary focus on domestic consumers in Scotland; DECC (2013) homeowners' willingness to take up more efficient heating systems; ESC (2018) Consumer perceptions of low carbon heating systems in hypothetical future energy market scenarios; BEIS (2019) Public Attitudes Tracker.

cost-effective choice available.[40] However, 1.5m boilers are installed every year, compared with around 26,000 heat pumps.[41]

Why is uptake quite so low?

Given the choice, 90% of people with access to the gas grid say they would prefer a gas boiler. Oil boilers are the most popular choice for people living off the gas grid (40%).[42] Only 10% seriously consider a low carbon alternative when replacing their heating system.[43]

Most people replace their heating system because it has broken (30%) or is about to break (31%).[44] People will want to replace a broken heating system quickly, with something they know will work, especially during the winter. Heat pumps are not yet as convenient as a gas or oil boiler.

Most of the remaining 39% upgraded their heating to improve their home (15%) or the performance of the system (10%).[45] Few have the time, money and skill to get a low carbon heating system installed. Those who do take the trouble tend to live off the gas grid where heating with oil or LPG is relatively expensive and inconvenient already providing a suitable incentive to consider low carbon options.[46]

At that point they may discover that their home needs upgrading with insulation for a heat pump to deliver the comfort they want. Few have the time or money to go through with the energy efficiency upgrades needed, especially if their heating system has broken.

Those who can afford a heat pump, live in suitable homes, or are willing to invest in energy efficiency, can still be put off by uncertainty it will perform as expected. Explaining unfamiliar heating systems will perform as well as people's existing heating systems can significantly increase their willingness to switch. [47]

At present, the inconvenience, cost, and concerns about performance put the vast majority off low carbon systems when they replace their heating systems. [48]

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[40] ETI (2019) Pathways to Low Carbon Heating: Dynamic Modelling of Five UK Homes.
[41] Estimates of the number of boilers installed each year come from the Energy and Utilities Alliance: https://www.eua.org.uk/hhic-sees-the-devil-in-the-detail. Estimates of the number of heat pumps installed each year come from CCC (2020) Reducing UK emissions: 2020 Progress Report to Parliament, p110-111.
[42] DECC (2013) homeowners' willingness to take up more efficient heating systems.16% of off-grid homeowners said they would like to connect to the gas network and install gas boilers.
[43] ibid
[44] DECC (2013) Home owners' willingness to take up more efficient heating systems.
[45] DECC (2013) report various reasons people gave for replacing their heating system: 'it was no longer producing as much heat as it used to/heating the home adequately' (5%); 'it did not heat home/hot water quickly enough' (3%), 'I was concerned that it was no longer safe to run' (1%)'it was difficult to control the temperature of heating in different rooms' (1%), 'It was too noisy when it was operating' (<1%).
[46] ibid
[47] Parkhill et al. (2013) Transforming the UK Energy System: Public values, attitudes and acceptability – Synthesis Report. ESC (2019) Smart Systems and Heat programme: Phase 2 Summary of key insights and emerging capabilities
[48] Caiger-Smith and Anaam (2020) Public Awareness of and Attitudes to Low Carbon Heating: an Evidence Review.

4.3. Prospects for transport are more promising

At first glance, the outlook for EVs seems similar. People say they are open to switching to EVs, but uptake remains low. The pace will need to pick up significantly if we are to have 10m EVs on the roads by 2030, in line with the CCC's target.

To put that into context, that means nearly half of households will have to have an EV by 2030. Today it's closer to 1%. We need to add three times the number of EVs we already have on the roads every year for the next decade.[49] That means 1m new EVs per year, although the growth would be more likely to grow gradually over time as illustrated below in Figure 16. By comparison, in 2020, we added only 108,000 per year, barely a trickle.

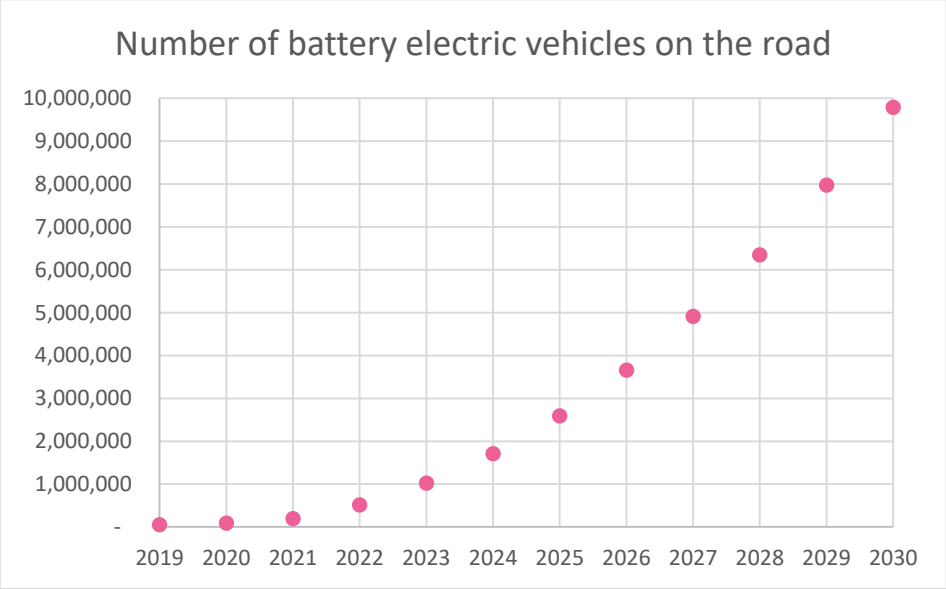

Figure 16 – Estimated number of battery electric vehicles from 2019-2030 assuming the proportion of electric vehicles sold increased linearly from current levels and we continue to buy 2m cars per year. [50]

People who buy EVs today are, by definition, pioneers or early adopters. To drive higher levels of uptake, adoption will need to spread to the mass majority. Most people say they are open to EVs *as long as* they're a sensible option. The only trial with mainstream drivers shows how EV appeal broadens as prices come down and ranges increase.[51]

In this trial mainstream consumers drove three models of VW golf, one with a petrol engine, another with a battery and a third that was a plug-in hybrid. Figure 17 shows that at their current prices 29% would buy the battery EV, 34% the hybrid and 37% the petrol car. If the BEV came dropped in price by 16% to, £24,000 more than 50% said they would choose it.[52]

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[49] Using data from DfT's National Travel Survey for car ownership in England and the ONS population statistics for number of households we estimate that there are 27.6M households in the UK. 73% (in England) have at least one car. Assuming a similar proportion in other UK countries and that each household only had one car, this would mean about 20M households have cars. So, a target of 10m cars means roughly half of households will have to have an EV. Today it's closer to 1%.

[50] The data for historic sales comes from the Society of Motor Manufacturers and Traders and DfT (2020) VEH0203: Licensed cars by propulsion or fuel type.

[51] https://es.catapult.org.uk/case-studies/consumers-vehicles-and-energy-integration/

[52] At the time of the study, the battery EV cost £28,690 (including a grant); the hybrid cost £30,635 and the petrol version cost £26,445.

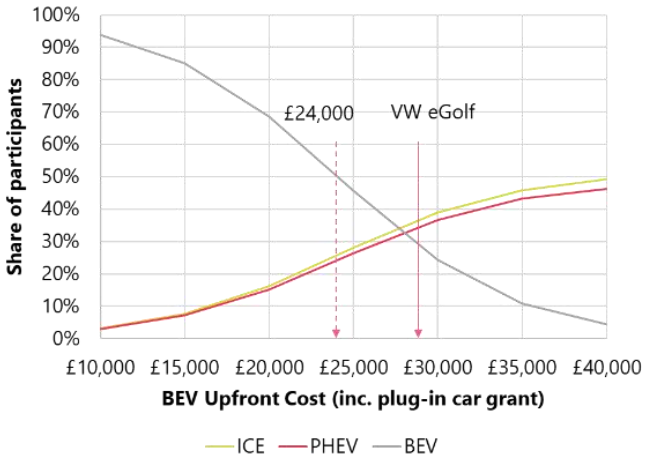

Figure 17 - Influence of BEV cost on mainstream consumers' vehicle choices

More participants said they would consider battery EVs as their range increased. Figure 18 shows that increasing the range of a battery EVs from 200 to 300 miles would increase its appeal from 50% to 90% of consumers. Limited range is probably of more concern to the small minority of cars that travel most miles. In the UK, only 5% of cars drive more than 20,000 miles per year. These cars account for 20% of all the miles driven.[53]

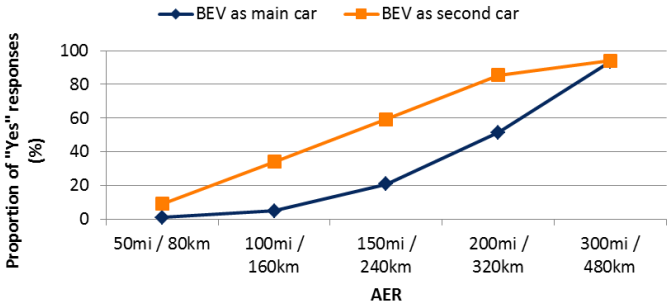

Figure 18 - The proportion of participants who would consider buying a battery EV.

EV battery range is increasing, prices are dropping and last year EV sales rose by 186%.[54] Challenges remain: not everyone can afford an EV and people without access to off-street parking will face challenges charging them. However, compared with heating, prospects for decarbonising transport seem to be progressing relatively well.

4.4. Flexibility has barely even got started

Around a third of homes had a smart meter by the end of 2020[55], but very few are on truly smart tariffs where the price of the energy varies dynamically with the cost on the market. Ten of the eleven 'smart' tariffs are quite simple, with different fixed prices being offered at different prices.[56] There is a long way to go before the energy market becomes *really* smart.

[53] From analysis of the DfT National Travel Survey reported in Haslett (2020) Constructing driver models with reference to the National Travel Survey.
[54] https://www.drivingelectric.com/news/678/electric-car-sales-uk-near-7-market-share-september-2020
[55] https://www.gov.uk/government/collections/smart-meters-statistics
[56] Ofgem (2019) State of the energy market.

4.5. What did we see during COVID?

COVID has shown that people can make huge changes when needed. People stopped travelling to work and started spending more time at home, whether working (29%) or on furlough (14%).[57] Many (40%) say that they started walking or cycling for exercise instead of driving,[58] though c.50% planned to avoid public transport and drive more[59] as shown in official travel statistics (Figure 19).

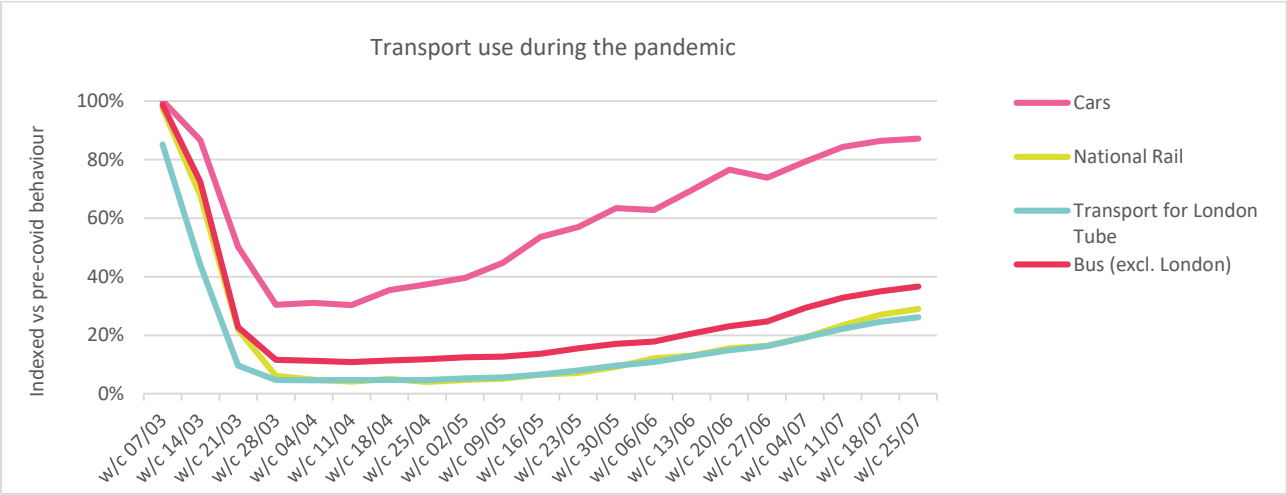

Figure 19 - Car, train, tube and bus travel before and after the pandemic where 100% means the same as pre-COVID.[60]

Despite the focus on COVID, most (66%) of the British public thought that climate change was just as important in the long term as tackling COVID (only 26% disagreed). Commentators speculated about whether COVID would see a return to listening to experts and a focus on preventing problems rather than relying on a cure. They highlighted how the country had come together to protect the most vulnerable, make enough PPE and ensure key workers could buy their food. [61]

Some people were more open to government making big interventions: 69% said the Government should have more power to make big decisions that affect the UK after COVID.[62] Alongside calls for a green recovery from business leaders,[63] artists,[64] and MPs,[65] this opens space up for action.

The next chapter turns attention to what we need to do to get to Net Zero. It focuses on heat because we are already beginning to see signs of change in transport.

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[57] Statistics are reported from a survey of ESC's Home Truths panel.
[58] Ibid.
[59] Ipsos (2020) Now what? Climate change and Corona Virus.
[60] https://www.gov.uk/government/statistics/transport-use-during-the-coronavirus-covid-19-pandemic Car travel is compared with the first week of February 2020, trains and tube to the same week in 2019, and buses to the third week in January 2020.
[61] This paragraph draws on Ipsos (2020) Now what? Climate change and Corona Virus. It describes how supermarkets reserved times for key workers to buy food and industry came together with the public to manufacture PPE.
[62] This statistic comes from a survey of the ESC's Home Truths consumer panel.
[63] https://www.ft.com/content/49cac3b5-6463-4a21-9452-643b750431d9
[64] https://www.theguardian.com/environment/2020/jun/22/uk-arts-leading-figures-join-call-for-green-recovery-from-coronavirus-crisis
[65] https://www.theguardian.com/world/2020/may/27/uk-green-recovery-covid-19-mps-climate-nature

5. Getting to zero: what needs to happen?

5.1. Why does heat need warming up, when transport is already motoring?

Only a tiny minority of people have installed low carbon heating systems or bought electric vehicles. The pace will need to rise sharply to meet our carbon targets. The prospects seem better for transport than for heating: uptake of electric vehicles is higher than for low carbon heating systems and growing faster. What can we learn from comparing progress in these two sectors?

Of course, the public are more aware of the link between transport and climate change, but awareness is relatively simple, cheap and quick to change. The public did not perceive a health pandemic as a particularly big threat before the recent COVID-19 outbreak.[66]

Table 1 contrasts the two sectors to unpick whether there is something more fundamental at play.

	Automotive	Heating
Clear and durable regulation to decarbonise?	Yes	No
Carbon pollution reflected in taxation?	Yes	No
Supply chain capable of delivery?	Yes	No
Desirable consumer proposition?	Yes	No

Table 1 - Comparing the status of decarbonising automotive and heating sectors

The automotive sector has a clear policy signal. The UK has announced a ban on the sale of new petrol and diesel vehicles from 2030, itself tightening a previous 2040 commitment made in 2017. There are similar plans emerging in most markets around the world. This creates a clear incentive for the transport sector. It needs to know how to integrate many thousands of components to create an electric (or hydrogen) car that sells.

Car-makers are also well placed to meet the target. The sales process provides data showing how much different types of consumer will pay for different features of a car from the colour of the paint, to the cover of the seats. In addition, computers inside engines provide performance data engineers can use to understand how each component performs. Taken together the automotive sector can manage the supply chain to design and deliver electric vehicles people want to buy.

Other sectors have developed similar capabilities. Supermarkets have introduced loyalty cards to learn how much shoppers would pay for different products. They can use this to decide how much to spend stocking different produce on their shelves. Similarly, telecoms operators and handset manufacturers have learnt how to use data to design call plans and mobile phones people will buy.

The heating sector stands in stark contrast. Policies have introduced many regulations, subsidies and standards, including:

- Affordable Warmth Scheme
- Decent Homes
- Ban on domestic coal and wet wood
- Boiler Plus Scheme
- Building Regulations (England and Wales) 2010

[66] Health pandemics barely made the 20 to global threats in the public mind in 2012, despite featuring highly on government treat watchlists: https://blogs.lse.ac.uk/politicsandpolicy/public-fear-and-awareness-before-covid-19/. Yougov showed how quickly this changed in 2020: https://yougov.co.uk/topics/health/articles-reports/2020/03/21/international-covid-19-tracker-how-public-opinion-.

- Building Regulations (Northern Ireland) 2010
- Building Regulations 2013 Part L
- Clean Heat Grant
- Energy Company Obligation (1,2 &3)
- Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015
- Energy Performance Certificates
- Future Homes Standard
- Green Homes Grant
- Heat Pump Keymark
- Energy Efficient Scotland
- Home Upgrade Grant (HUG)
- Renewable Heat Incentive
- Minimum Energy Efficiency Standards (MEES) for the private rented sector.
- Smart Meter Enabled Thermal Efficiency Ratings (SMETER)
- Half hourly settlement reform
- Smart Metering Implementation Programme
- Energy Labelling Regulation (2017/30/EU)

Industry has no clear signal that it needs to learn how to combine the many components of a heating system to design and deliver low carbon heating solutions consumers will want to buy. Property developers are planning to build homes with low carbon heating systems because of new regulations coming in 2025. But these new homes will probably only account for around 12% of homes by 2050.[67] Who will decarbonise the remaining 88%?

The current heating supply chain comprises heating engineers and builders often working as sole traders or in microbusinesses who work together to deliver specific projects. It has no means of discovering what consumers want, nor of integrating the various components **well** in peoples' homes. Those who have tried report many opportunities for improvement.[68] This is a symptom of an industry that is far earlier in its maturity than the automotive, food or telecoms sectors.

The suite of heat polices produces a piecemeal approach rather than a holistic solution. Homeowners have to assemble their own supply chain if they want to decarbonise their homes. Imagine if that was how we planned to decarbonise transport: separate policies for batteries and motors with consumers left to build their own low carbon cars. The UK probably needs a better approach if it is to successfully decarbonise heating.

5.2. Low carbon solutions need to be as good as or better than what we have

How can we make sure that when the public discover the need to decarbonise their heating, they are willing and able to do it? The answer is surely to make sure it is easy to get a low carbon solution that they find appealing. EV uptake will gradually accelerate as electric vehicle ranges rise and prices drop. What will drive improvements in the quality of low carbon heating solutions?

[67] Assuming we build new homes at the average rate over the last decade. New homes would account for 22% of homes in 2050 if we built at the fastest rate on record which was in 1969.
[68] https://www.eti.co.uk/programmes/smart-systems-heat/building-retrofit, https://retrofit.innovateuk.org/, https://www.theiet.org/media/5276/retrofit.pdf.

Studies of historic energy transitions have shown that new energy sources often start out more expensive. A small group of consumers take them up because they confer some benefits. Gradually the price falls and they become mass market.[69]

Transport got faster and cleaner moving from horse to car, heating became safer and easier going from coal fires to gas central heating. If we made low carbon as good as, or ideally better, than what we already have it would be the natural choice when people replaced their heating systems.

Conversely, history is littered with products or services that failed to grow beyond a tiny niche. Sweden found heat pump uptake stalled for years as consumers' early experiences were poor.[70] Clearly it is critical that we develop a highly skilled supply chain capable of delivering excellence.

5.3. There are opportunities for low carbon heating to improve people's lives

Most people can get by with their heating today, but there is plenty of room for improvement. Around two thirds of people experience problems like damp and drafts. A similar number take steps to prevent overheating, even in winter. This rises to 90% in summer.[71]

Other sectors seek out these sorts of problems as spurs to innovate. The automotive sector realised people would pay more for central locking and air conditioning. Despite spending more time in our homes and more money on them, few UK households have these sorts of convenience.

Of course, some people face far larger problems. Around 10% of households struggle to afford their energy.[72] The UK has spent more than £3bn per year every year for the last decade trying to help.[73] This is about £750 per home, enough to pay their heating bill. It is challenging to find people who need support and deliver help that really improves their lives.

If this problem was simple, we would already have solved it. There is no simple route to Net Zero. However, perhaps there is a chance to design solutions that also solve these other problems? People would value low carbon heating more if it helped them feel more comfortable at home. Similarly, better low carbon heating solutions could improve societal and health outcomes from public spending on schemes to address fuel poverty and improve public health.[74]

5.4. So, what is preventing progress?

Figure 20 below maps out the challenge of going from high carbon to zero carbon heating. Consumers and the supply chain will need a *motive* to try to go from left to right, a reason to act. Merely believing climate change is a major threat that we need to tackle may not be quite enough. We return to this in the next chapter. For now, let us assume they are highly motivated.

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[69] Foucquet (2010) The Slow Search for Solutions: Lessons from Historical Energy Transitions by Sector and Service, Energy Policy 38 (11), 6586-6596.
[70] Vivid Economics and Imperial College (2017) International Comparisons of Heating, Cooling and Heat Decarbonisation Policies.
[71] Lipson (2015) Consumer Challenges to Low Carbon Heat. ETI Report.
[72] BEIS (2020) Annual Fuel Poverty Statistics in England.
[73] This is an estimate from recent reports for 2019/2020 for Warm Home Discount, Winter Fuel Payment and Energy Company Obligation.
[74] Ibid and House of Commons Library (2020) Briefing Paper 8730: Fuel Poverty.

Even if they do have a reason to try, consumers and the supply chain will also need to be both willing and able to move from box to box. If they are not, these barriers will prevent them making progress. Solutions need to overcome these barriers before we see mass market uptake.

The next sections discuss each of these barriers in turn and how to overcome them.

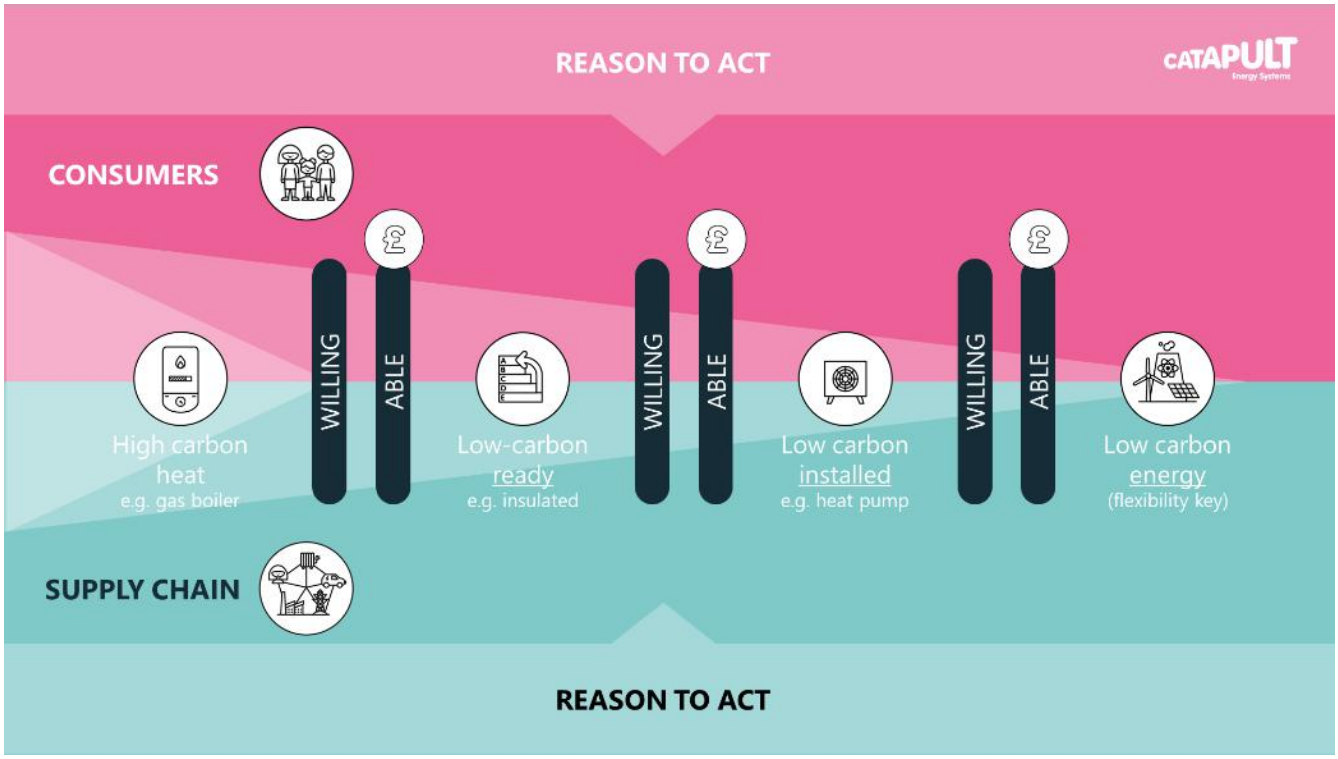

Figure 20 - To go from high carbon heating systems (middle left) both consumers and the supply chain need to be willing and able to prepare homes (e.g. with insulation) so they are ready for low carbon heating systems (e.g. heat pumps) and use low carbon electricity (right e.g. being smart and flexible enough to use electricity when renewables produce a lot).

5.5. Preparing homes for low carbon heating

It often makes sense to improve the energy efficiency of homes before installing low carbon heating systems. This can reduce the amount of energy needed to deliver the comfort people want. It can be particularly important for older homes because they are less energy efficient.

This can take several months to organise and complete. If a heating system breaks in the middle of winter, people will want a new heating system as soon as possible. That means it probably makes sense to prepare homes, so they are ready for low carbon heating when people decide to replace their systems.

There are no robust statistics on exactly how many homes will need preparing. It depends on many things: how well insulated the building already is, how the plumbing is arranged and what temperatures the residents find comfortable. What we do know is that millions of homes will probably need some form of preparation.

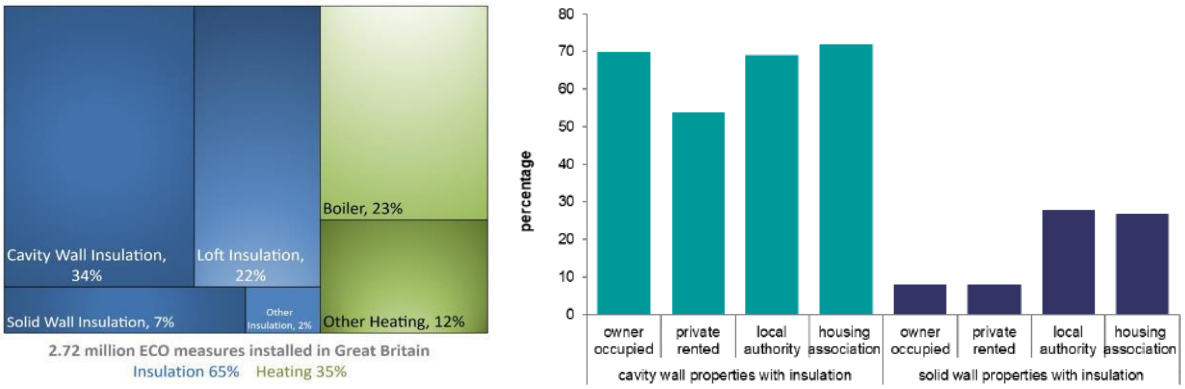

Figure 21 - Energy efficiency measures installed under ECO (left) and by tenure (right)

Historic energy efficiency programmes have delivered relatively simple, cost-effective measures that deliver immediate benefits (Figure 21 left)[75]. Of the 2.72m measures installed and paid for by ECO about 90% were new boilers, heating controls, cavity wall insulation or loft insulation. There has been far less progress delivering harder measures, like insulating the 8m homes with solid walls, especially in owner occupiers' and private rented homes (Figure 21 right)[76].

How will we persuade people to prepare their homes so it is simple and convenient to replace their heating systems with low carbon alternatives when they need to?

Almost all renovations (90%) are conducted to improve homes, not reduce what they cost to run.[77] This implies that people might be more receptive to things like insulation if it was designed to make their homes nicer places to live and if they could install it during broader home renovations.

The cost of all this work will vary significantly from home to home. It could be as high as £50k.[78] Many people will need help financing it, if they can be convinced to get it done. Lots of options are possible from adding the cost to a mortgage, making salary sacrifices (like the cycle to work scheme), green loans or grants.[79]

5.6. Areas will need a plan, so people can prepare for the right low carbon solution

Once the consumer is willing to get the work done and able to afford it, they'll need to find someone who can install it well, so it delivers on the promise. The renovation industry will be attracted by the potential returns, but energy retrofits are highly complex, so there needs to be an incentive to invest in learning how to do them well. People who spend their money paying for disruptive energy retrofits will complain if they cause damage (e.g. damp) or make their home uncomfortable (e.g. through overheating).

The home improvement sector needs a way to build demand for energy retrofits, spread the cost over time and provide data the supply chain can use to monitor, optimise and guarantee quality.

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[75] BEIS (2020) Household Energy Efficiency Statistics. 'Other Heating' breaks down into district heat, storage heating and (mostly) heating controls. 'Other insulation' is largely underfloor insulation.
[76] English Housing Survey 2018. It includes more than ECO.
[77] Wilson et al. (2013) Understanding Homeowners' Renovation Decisions: Findings of the VERD Project.
[78] The Existing Homes Alliance estimate eco-refurbishments can cost anywhere between £12-54k. BEIS estimate the cost of insulating a detached house as £40k (c.£20k for solid wall insulation, £10k for double glazing and £10k for floor insulation). Delta EE estimate it could cost £10k to install a heat pump.
[79] www.greenfinanceinstitute.co.uk/the-green-finance-institute-and-members-of-the-coalition-for-energy-efficiency-for-buildings-ceeb-highlight-further-pathways-to-uk-governments-energy-efficiency-goals/

Smart meters and smart thermostats could provide the data needed, if consumers are willing to share their data. That means they will need to trust the people who renovate their home.

Areas with more energy efficient buildings will need less energy to get warm. That means they can spend less on new energy networks and low carbon energy supplies. Some people may prefer to spend less insulating their homes, even if it means paying more overall because they need a larger supply. They may want to avoid the disruption or keep the original look of their old building.

The best way to prepare a home will also depend on what type of low carbon energy network it connects to. Some places may convert their gas grid to use hydrogen or build heat networks that can supply hot water on demand. Others may upgrade the electricity grid and use heat pumps so homes will need tanks to store their hot water. Areas will need to develop net zero energy strategies so the people who live there no what to prepare for.

Plans will be more popular if the people who live in areas are involved with developing them. Otherwise, they may be based on incorrect assumptions, for instance on how much insulation home-owners will install. Areas will also need to develop new processes to make sure decisions over shared networks have democratic accountability.

5.7. Replacing old polluting heating systems with new, low carbon alternatives

Once homes are ready for low carbon heating systems, owners will need to be willing and able to install them. They are more likely to be willing if they are confident, they will be able to get the comfort they want for a predictable price they are willing to pay. Once again, they may need help paying for these systems as many are more expensive than existing gas or oil boilers.

Heating engineers will learn how to install carbon heating systems when there is enough demand. They would be even more keen if this also gave them the prospects of a better job. Once again smart homes could provide data they need to monitor and optimise quality and once again, they'll need to know what consumers want and permission to use their data.

5.8. Power to the people?

All this change presents a huge opportunity. We could create jobs, improve the homes we live in and clean the air we breathe. Walking and cycling would improve our health, energy retrofits could make our homes healthier to live in.

People could own their own wind farms. Panels could cover roofs of homes, schools and hospitals. Those with more electricity than they need could sell the excess to neighbours near and far.

There will of course be challenges. In a Net Zero world, we will use more wind and solar to power our lives. These renewable sources generate more electricity when the wind blows and the sun shines. It could get harder to match this varying electricity supply with when consumers need it.

Here too there are opportunities.

People living in lower carbon homes with electric vehicles could help solve this problem by using storage and being flexible about when they use electricity. Smarter systems could control heating, charge batteries on walls and in cars and power appliances to use electricity when it is available. This could reduce the costs of delivering Net Zero and save customers money.

People *need to want these benefits* if they are to pay for all this smart, low carbon infrastructure. They will also need to *feel sure they can get what they want* from the energy they buy if they are to

be flexible about when they use it to help manage demand and balance the grid. They won't mind when they use energy, as long as they can get the outcomes they want when they want them.

Support for smart, low carbon technology will fall away if people cannot make their homes warm when they want or get from A to B because their car runs out of charge. It is also important that everyone can afford, access, understand and use this new technology or we risk many people becoming unable to get the energy they need to lead rewarding lives.

As before industry will be happy to build and operate infrastructure that the market pays for. The challenge will be knowing how much to build and where to put it. Investors will need to know how much capacity people want and what it needs to deliver.

5.9. Could businesses help people take these opportunities?

Digitalisation has improved almost every part of our lives, could it unlock this green new future? The internet has enabled tech-businesses to change how we shop, work, learn, travel and relax. How might it transform the way we use energy?

What if we bought our energy as a service, instead of buying fuel and a heating system? How might it help if consumers bought the outcomes they wanted – warm homes, charged cars?

The services people bought would reveal what they were willing to pay for different experiences. When they were unable to get what they wanted service providers could offer them improvements. If they could not get warm enough on a cold winter night, they might buy insulation to sit comfortably in their lounge. When they wanted to replace their heating system, they might upgrade to low carbon alternatives if their provider guaranteed they could get warm for a fair price.

If businesses sold warm homes, they would have to know how much this would cost to deliver. They could use this information to find people living in homes that were expensive to heat. We could target subsidies to make sure everyone could afford the comfort they needed. This could particularly help people who need a warm home to protect their health.

This idea has been around for some time.[80] Recent innovation trials have proved it can work.

Consumers paid 40% more for a service than for units of fuel.[81] They were hundreds of times more open to installing heat pumps.[82] Businesses learnt to sell these new services with heating systems, services and maintenance included.[83] Customers grew more loyal to their supplier and more open to insulation and district heating. They even let their provider control their heat pump, exactly as is needed to unlock flexibility upstream.[84]

These trials also showed how to make sure everyone benefits from smarter energy services.

Vulnerable consumers at risk of fuel poverty also enjoyed smarter heating controls, not just tech-enthusiasts. They found it easier to manage their heating and less time consuming. They wanted the peace of mind that they could afford to heat their home to get the comfort they wanted.[85] One

[80] Fell (2017) Energy Services: a conceptual review. Energy Research and Social Science 27, 129–140. ETI (2018) Domestic energy services. ETI (2018) How can people get the heat they want without the carbon? Fell (2021) History of HaaS for Promoting Domestic Demand-Side Flexibility. Journal of Energy History, 5.
[81] ESC (2019) Smart Systems and Heat: Phase 2 – Summary of Key Insights.
[82] ESC (2019) Decarbonising heat: How to increase the appeal and performance of heat pumps.
[83] ESC (2019) Using the Living Lab to sell heat services that encourage adoption of low carbon heating.
[84] ESC (2020) How to increase consumer confidence in gas boiler alternatives.
[85] ESC (2020) Fuel Poverty in a Smart Energy World.

trial explored how to target financial support to help them afford their heating. It showed that health professionals could prescribe warmth to people who they needed it to stay healthy. Patients who tried it out enjoyed being able to use smart controls to get comfortable.[86]

The benefits of selling energy as a service are not limited to heating, or to end consumers. Energy services could give EV owners the confidence they will have enough charge when they need it making them more open to their car battery helping to balance the energy system. Providers could manage EV charging (or heating) to match the supplies available on the grid. EV batteries could even power the grid or people's homes when supplies fall.

Service providers would have a motive for earning consumers' trust to access their data so they can sell higher value items like insulation and heating systems. Competition would drive up service quality and drive down cost over time. Network operators could work with service providers to heat homes and charge vehicles when supplies were plentiful and draw on batteries when they were not. Planners could work with service providers to build the networks consumers supported. This could give investors confidence that if they build new energy networks, like district heating, customers will come.

5.10. Can you change the rules of a game you're already playing?

There is growing interest from companies in the potential of new energy service business models. Early entrants are focusing on niches where they can enter the market to learn what works. Learning involves trying things out, failing fast and adapting based on experience. This standard process is unlikely to deliver fully on the promise.

Some businesses will be cautious, focusing on early adopters who are more interested in new technologies. This risks leaving some consumers behind. Other businesses who take more risks, could harm some consumers if new products and services are yet to reach full maturity. Innovators who succeed will try to hold on to their new customers, perhaps making it hard for them to leave.

Clearly this presents difficulties for regulators. Should they sit back, watch innovations cause some harm and struggle to promote competition amongst offers designed to keep customers hooked? Or should they attempt to protect consumers from risks that are yet to form and stifle innovation before it has even started?

There is so much potential, but this new market will not spontaneously appear just because there is a climate crisis to solve. Game-changing market developments do not come from nowhere. Silicon valley's tech giants sprung from a well of sustained and intelligent government investments.[87]

Other countries are exploring how they can accelerate the process. The Danish government have invested £2.4m to create a market of businesses competing to sell heat as a service with heat pumps to 1400 customers. Could the UK take similar steps to accelerate progress?

Looking back, the UK took significant efforts to create the current energy market. If we want to grasp the opportunity of emerging energy market innovations, we may need to emulate Denmark and take a more deliberate approach.

There is so much promise, but none of it will happen without the right kind of policy framework. The next section discusses what this might look like and how to bring it about.

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[86] http://www.peoplelab.energy/2020/07/21/warmth-on-prescription/

[87] Mazzucato (2018) The Entrepreneurial State: Debunking Public vs. Private Sector Myths.

6. Accelerating along the path to Net Zero

We will all need to play our part if we are to meet the challenge of getting to Net Zero in 30 years. The public will need to decarbonise their lives. They need to know what to do and help doing it.

What can our elected officials, policy-makers and regulators do?

They could start by telling the public that the way we heat our homes is causing climate change. Central government could devolve responsibility for planning how to decarbonise to local areas. Local authorities could establish the options in their area consulting the citizens they represent. Regulators could use local area energy plans to set levels of funding for decarbonising networks.

Policymakers could apply the same principles that have driven innovation in transport to heating. Technology neutral approaches like banning the sale of petrol and diesel vehicles hold potential. A carbon MOT for homes would encourage people to measure and reduce their footprint over time.

This will reward businesses who learn how to harness technology to integrate the complex chain of components and suppliers to deliver high quality, low carbon solutions people will want to buy. They will want to earn trust from customers, so they repay for energy retrofits gradually over time.

Consumers who make low carbon choices should not be penalised by higher bills if costs are lower. That means moving VAT from low carbon electricity to more polluting fuels like natural gas and oil. It means funding green infrastructure via taxation not by adding levies to low carbon electricity. Consumers will also need new finance products to help them afford to make the changes needed.

Creating a new low carbon market quickly will be hard. How can regulators create rules for new business models that have not yet formed? How can companies introduce new business models when they do not know the rules for a new smarter energy market? How can we make sure everyone can enjoy a Net Zero future, not just the affluent or early adopters?

One way to crack this chicken and egg problem is for business and regulators to come together, as they are in Denmark. They could use Living Labs, to find out what works together in the real world. These should involve all sorts of people, including those who struggle with their bills or new tech. The sector could co-create smarter consumer protections so everyone can benefit from innovation.

Fortunately, the technologies we need already exist as it would take too long to invent new ones and bring them to market.[88] The challenge is tying it together into enticing, effective solutions. Increasing investment in innovation means we can afford to do this. Indeed, we can't afford not to. But it means changing how we fund innovation; Innovate UK's design strategy is a great start.[89]

Climate change represents an existential threat to our existence, but it also presents opportunities. Let's take the opportunity to improve our lives, so that everyone can thrive in a net zero world.

[88] Gross et al. (2018) How long does innovation and commercialisation in the energy sectors take? Energy Policy 123, 682–699.
[89] Innovate UK (2020) Design in innovation strategy 2020-2024.

Energy Systems Catapult supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system.

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