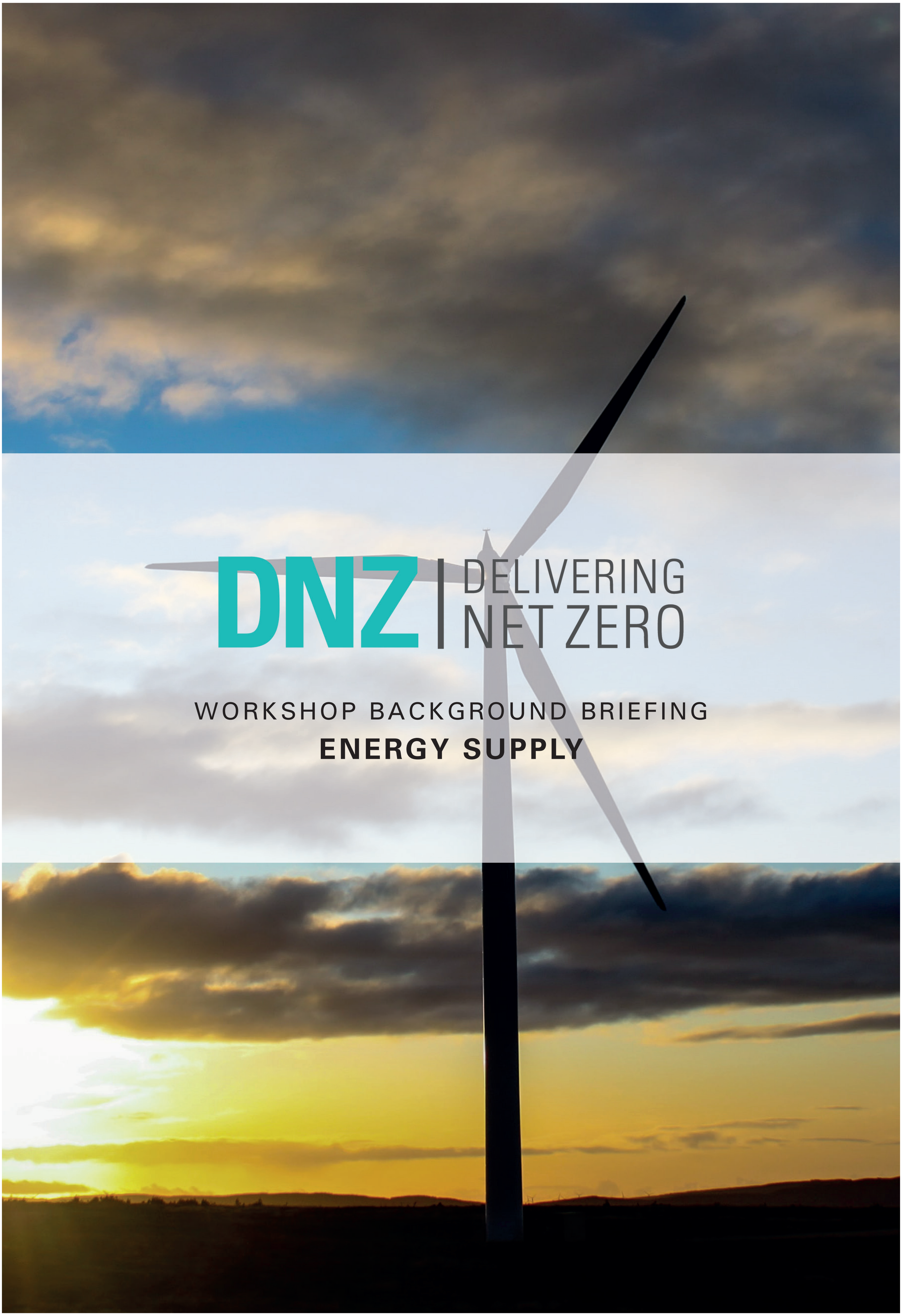

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WORKSHOP BACKGROUND BRIEFING

ENERGY SUPPLY

INTRODUCTION

Energy supply entails the extraction, transportation and transformation of primary energy sources like fossil fuels, biomass, solar radiation, wind and uranium, and the transportation of energy in a usable form to the point of consumption or storage. All the processes involved in supplying energy can release greenhouse gases (GHGs), for example petrol also embodies the carbon dioxide emissions embedded in extraction and refining. The UK's largest energy supply systems are electricity natural gas and liquid hydrocarbons, with the largest impact on GHG emissions coming from supply of energy in these three forms. Supply of energy as electricity, the use of liquid hydrocarbons in transport and the use of natural gas as a source of heat in buildings and industry, together cover almost 70% of the country's GHG emissions[1] and represent one of the greatest challenges to reaching the Net Zero target.

In 1990, renewables generated just 1% of the UK's electricity supply. Twenty years later in 2010, this had risen to over 6%[2] and in 2019 accounted for 37.1% of the electricity generated in the UK.[3] This transition has mostly been driven by an increase in offshore wind generation and a significant decrease in coal use.[4] However, low carbon electricity represented just 5% of the UK's total energy supply in 2019.[5] Heating and transport have lacked the same major shifts towards decarbonisation.[6] Figures 1 and 2[7] show the energy consumption and carbon intensity of each energy system and highlight the need for a transformation and continued transition in transportation, heating, and electricity.

Figure 1 – Final energy consumption per sector, per person.

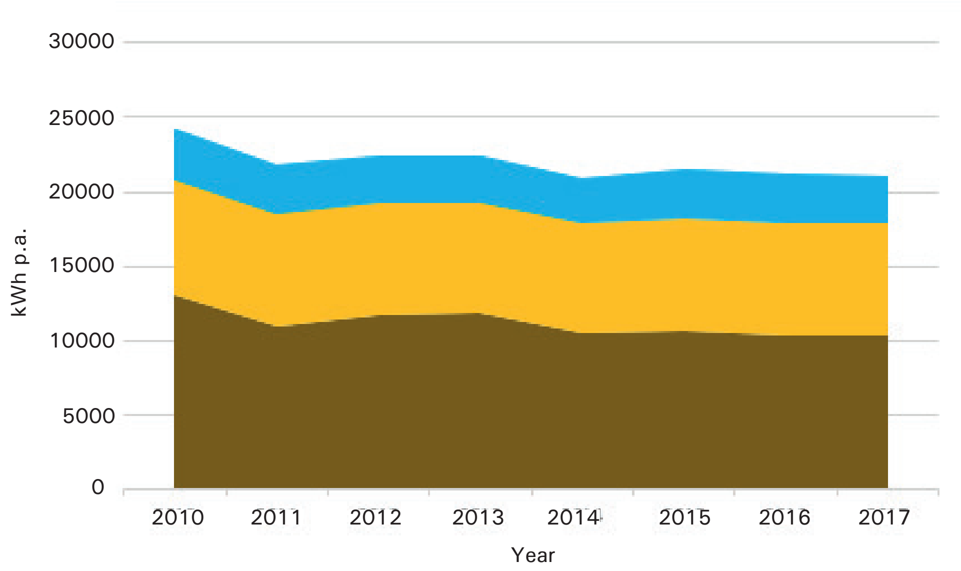
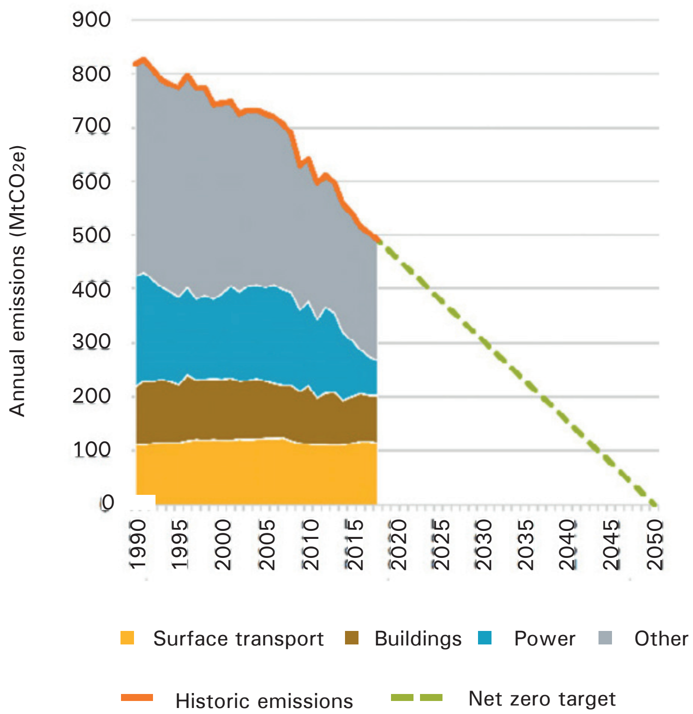


Figure 2 - GHG emissions per sector.



WHAT'S POSSIBLE BY 2050?

TRANSPORT

Two popular solutions for the decarbonisation of transport are a transition to vehicles that use energy with low emissions, such as hydrogen or electric vehicles (EVs),[8] and a decrease in road traffic[9] - a demand-side opportunity. Transitioning to owning a low carbon vehicle is seen by the public as one of the most influential ways that they can positively make a difference and be seen to be doing so.[11] A modal shift from fossil fuel cars and other vehicles to hydrogen or electric would represent a major change in both energy demand and supply in the transport sector.

The registration of EVs more than doubled in 2019 compared to 2018, making up 3% of all new car registrations[12] and set to account for around 10% in 2020.[13] The increase in EV sales has understandably risen with the number of public charging points increasing by nearly 5,000 since 2019, for a total of nearly 35,000 across the UK.[14] Ultra-low emissions vehicles (ULEVs), such as EVs, are currently exempt from road tax and the government's plug-in grant offers up to £3000 off the price of a new EV.

Modelling suggests that if all cars were electric, the UK's total emissions would drop by 12%.[15] Whilst this is an impressive reduction in GHGs, there needs to be billions of pounds worth of infrastructural investment across the UK to facilitate such a transition.[16]

The hydrogen vehicles market has even further to go to reach the mainstream. In 2018, the DfT awarded over £8 million for hydrogen fuelling stations,[17] with the government recognising that a *'lack of refuelling infrastructure remains a key barrier to the future roll out'* of hydrogen vehicles.[18] For cars there are currently only 11 stations across the UK, with six of these in London.[19]

For surface transport to be completely decarbonised, the balance of opinion seems to be that all cars and vans should be supplied using decarbonised electricity, and HGVs either electric or hydrogen fuelled by 2050. This should be achievable given the government's policy of no new petrol or diesel cars by 2030.[20]

Aviation and shipping are more difficult to decarbonise. There had previously been an expectation that their contribution to UK emissions would stay relatively stable,[21] however the Sixth Carbon Budget, sets out pathways for reducing aviation emissions from the pre-COVID level of 39.6 MtCO2e/year to 23 MtCO2e/year by 2050[22]. Additionally it is demonstrated that the shipping sector can achieve very close to full decarbonisation by 2050[23].

HEAT

Heat has been acknowledged as the largest "credibility gap" in the UK's Net Zero target.[6] Heat, which is mostly supplied from natural gas, accounts for over a third of the UK's greenhouse gas emissions, and around half of the energy consumed in the UK.[24]

One alternative heating scenario, backed by the National Infrastructure Commission, would see an additional 10 million electric heat pumps installed into homes across the UK by 2030.[25] Heat pumps extract and enhance ambient heat from water, air, or the ground, using electric powered compressors, and are highly efficient, producing up to three units of heat energy per unit of energy consumed.[26] The government's Clean Heat Grant has been proposed for 2022 and would see £100 million spent on heat pump installations, being offered as an alternative to the Renewable Heat Incentive. Heat pumps are a potentially sustainable alternative to natural gas, as they run on electricity, which in theory could be supplied from low carbon sources. Generally, less efficient or more expensive, resistance heaters are also available; when used for heat storage they can consume cheaper electricity during the night for use when needed, allowing for thermal energy flexibility and balancing of the grid. They currently account for 66% of electric heating in the UK.[25]

A second alternative to solving the UK's heating needs could come from hydrogen, where the existing gas infrastructure is repurposed or rebuilt to accommodate hydrogen. However, injecting hydrogen into the gas grid is not a simple switch from natural gas, due to *'the differing properties of the gases and the need for low-cost, low-carbon hydrogen supply chains'.*[27] At least initially, this hydrogen may come from natural or bio-gas reforming, combined with CCS to decarbonise the hydrogen supply chain, known as "Blue Hydrogen".[28] "Green Hydrogen" is also a possibility, whereby the formation process is powered entirely by low carbon electricity and the electrolysis of water, removing any need for carbon related supplies and CCS. Aside from use domestically, hydrogen could help decarbonise energy intensive industries like steel.[29]

Further zero and low carbon options for heat will come from increased investment and policy development in solar thermal, CHP, heat recovery, hydrogen boilers, thermal storage, and heat networks through the work of the Heat Networks Delivery Unit, and funding from schemes like the Heat Networks Investment Project (HNIP).[30]

One part of decarbonising heat in the UK involves reducing the amount of heat required by buildings, through increased insulation, and improving building efficiency standards for both new build and retrofit. Much of the policy and funding for this has been aimed at those who cannot afford home improvements, with research suggesting that those who are 'able-to-pay' have still not been convinced to pay for such energy saving measures.[31] Additionally, the CCC recommends that no new homes are connected to the gas grid by 2025, and almost all remaining heating in homes be low-carbon or ready for hydrogen. Low carbon heating should have moved from 5% today, to over 90% by 2050[21], with hydrogen potentially accounting for as much as 25-50% of final energy demand in heating and transport.[32]

ELECTRICITY

As a result of both global supply chain developments and domestic policy implementation, electricity decarbonisation has been so successful in the UK the Sixth Carbon Budget identifies a pathway for completely decarbonising electricity by 2035[33]. This work suggests that, despite electrification of the energy system as a whole requiring greater volumes of electricity supply, it should be possible to fully decarbonise these supplies by phasing out unabated fossil fuel generation, significantly increasing variable renewable generation, restoring nuclear capacity and by making other sources of low carbon electricity 'dispatchable'. These scenarios generally assume that the electricity system becomes more flexible with significantly more downstream energy storage, including hydrogen production from 'surplus generation'.

During parts of the initial COVID-19 lockdown both electricity and transport demand reduced by nearly 20%, which could provide an opportunity to learn about work and lifestyle practices which may reduce electricity demand.[34] As the UK's favoured renewable electricity generation technology, offshore wind has policies in place for the coming decade as part of the Offshore Wind Sector Deal.[4] This set a target of 30GW of offshore wind capacity by 2030, which has now been superseded by the UK Government's Energy White Paper[35], which increases this target to 40GW. The White Paper also commits the Government to running further Contracts for Difference (CfD) auctions that are open to a range of renewable generation technologies including offshore wind, onshore wind and solar photovoltaics.

An important concern for electricity generation will come from the removal of unabated natural gas as the main form of 'dispatchable generation' left in the system. Even with major demand side change, there will likely always be a need for dispatchable capacity in the electricity system. This could be provided by energy storage and thermal generation plants using fuels such as hydrogen, biomass, and natural gas with CCS[21] in a system configuration like the 'High Baseload Scenario' postulated by Aurora Energy Research in Figure 3. In contrast, a 'High Renewable Energy Systems Scenario' (see Figure 3) would require over 70% more installed generation capacity to deal with the lower load factors of such renewable generation assets. This scenario would also require significant volumes of energy storage to cope with periods of low renewable supply and to manage the peaks and troughs of demand as demonstrated in Figure 4.

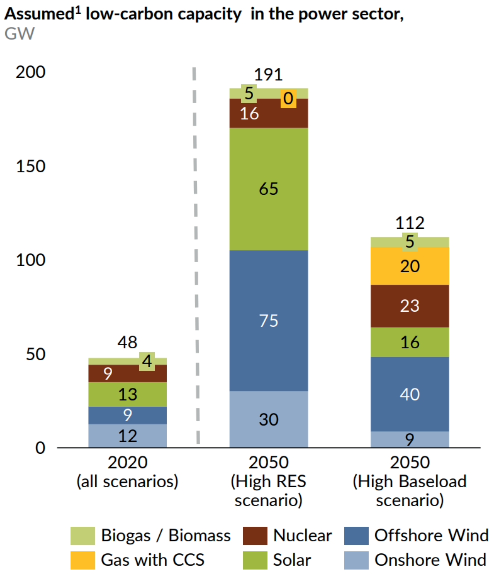


Figure 3 – Electricity generation Capacity in GW[32].

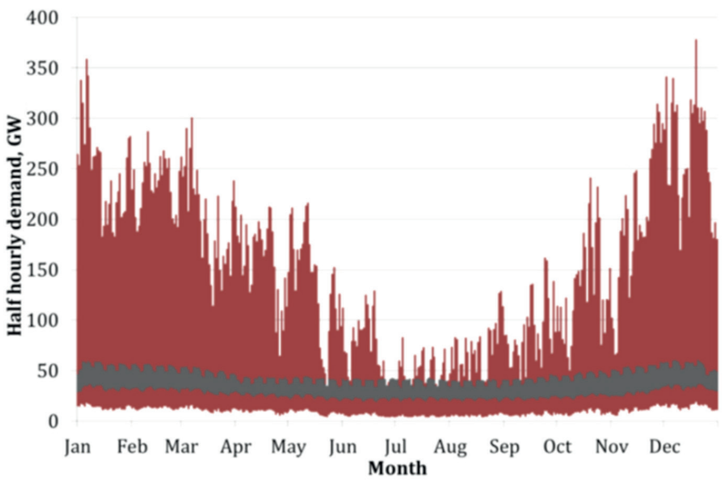


Figure 4 - UK half-hourly heat (red) and electricity (grey) demand for 2010 in GW.[36]

ENERGY SYSTEM DYNAMICS

The infrastructure that supports the delivery of electricity, transport and heat will also need to undergo change. Traditionally viewed as separate systems, a whole system approach is now being adopted as the increasing use of electricity, integration of hydrogen, decentralisation of generation and uptake in digital tools blurs the boundaries between electricity, transport, and heat provision. This focus is required to develop a coherent, cost-effective decarbonisation pathway for energy supply.[37]

Thus far, the UK's energy decarbonisation strategy has focussed on the addition of renewable electricity generation assets to a largely centralised electricity system, using existing infrastructure and regulatory approaches. This infrastructure however is coming under increasing strain due to ongoing integration of variable renewable generation coupled with the trends towards electrification of transport and heat described above. This places the electricity system under pressures it was not designed to face. Consequently, focus is now shifting toward the need for greater electricity system flexibility.

Electricity storage in the form of pumped hydro has been utilised since the 1960s, with installed capacity of 2,800MW.[38] More recent energy storage projects have primarily focused on battery capacity to support grid operations,[39] with 300MW of battery storage built in 2019, bringing battery storage up to a total of 900MW.[40] The Institution of Civil Engineers cite a growing desire for energy storage to be utilised for both shorter term grid balancing, and long term management and storage of the excess supply of intermittent renewables.[41] This could be provided by a combination of both long-term and medium-term energy storage technologies on the supply side, with short-term storage technologies located on the demand side.[42]

The ability of the energy system to manage greater variations in both demand and supply is part of the 'flexibility' that has conventionally been provided by dispatchable generation.[43] More recently, the network operators have been exploring storage, amongst the demonstration of other technologies and demand side solutions, as possible routes to providing such flexibility.[39] However, firms have experienced limited commercial success with entering the energy storage market due, at least in part, to high capital investment requirements and low prices for stored energy.[44] Equitable attribution of value to energy storage solutions will be required if storage is to be delivered on a large scale.

Some, but far from all, of the flexibility solutions being explored, include the idea of smart grids. These approaches encourage all resources, particularly distributed energy resources – small scale generation, demand and storage connected to the distribution network – to offer flexibility and help to make cost-effective use of network capacity, contribute to stable system operation and minimise the need for additional generation capacity to help meet peak electricity demand. One example of this might be the conversion of 'consumers' to 'prosumers', who generate electricity, usually through PV, and supply this into the network as well as taking power out.[45] However, this creates significant challenges around accommodating large amounts of converter connected resources and ensuring stable system operation leading to questions around the form of governance structures required for this type of power exchange.[46] It also raises questions of how to ensure that there is sufficient investment in an adequate mix of low carbon generation resources to meet demand sufficiently reliably.

Successful delivery of Net Zero will similarly require the 'flexibility challenge' to be embraced within the transport and heat systems. The transition to electric vehicles has the potential to enable 'smart' control of charging and potentially even 'vehicle-to-grid' options where owners allow their vehicle batteries to be used to provide system support services.[47] Pursuing options like these, however, creates additional challenges around the commercial structures needed to encourage such innovation, the governance structures needed to ensure that they delivers the intended benefits rather than adding complexity to the system, and the roll-out of EV charging infrastructure.

In the heat system, there is the possibility of adapting gas grids to accommodate hydrogen, which would 'take advantage of the inherent flexibility that gas grids provide'.[48] There also exist opportunities for producing and storing heat on a flexible basis close to the point of end use, for example in disused mine infrastructure.[50] However, the commercial viability of large scale heat energy storage is still uncertain, as with many storage technologies.[51]

BUILDING CONSENSUS

PUBLIC PERCEPTION OF DECARBONISATION

Studies have found that whilst the public will state a preference for using energy resources efficiently and adopting strategies to mitigate climate change, if they do not understand the technology before or after adopting it, then it is difficult to increase public engagement or use the technology effectively.[52] Researchers have looked in detail at the need for increasing energy storage, and how a lack of interest from consumers in investing in new energy solutions research and deployment, negatively affected its adoption;[53] a point echoed in the science, technology and society literature.[54 55 56] An 'ambivalence' towards energy supply solutions is set in the context of how important it is to have public perceptions of a technology be positive, not just ambivalent, if it is to be deployed successfully without being directly funded, by government.

This is a scenario in which citizens assemblies could be more widely used to increase people's understanding, acceptance, and positivity towards energy supply solutions. One major point to come out of the recent Climate Assembly was the desire for the public to be more educated on matters affecting society and the environment, with the participants citing this as more important than the need to act with 'urgency' on climate change. Until this process of education and information is undertaken, new energy supply technologies may suffer additional social challenges like those experienced by fracking and onshore wind turbines.[57]

POLICY

There is no question that the UK's success in decarbonising the electricity system has at least in part been due to the enactment of targeted and timely policy interventions on the part of successive governments. Taken in the context of the CCC's Sixth Carbon Budget[33], the announcements around CfDs and the other measures to further decarbonise electricity supplies identified in the recent Energy White Paper[35] suggest that there is determination to maintain this momentum. Efforts to create similar reductions of GHGs associated with the transport and heat sectors have been less successful, and in addition to the measures that have been put in place to support the decarbonisation of transport, there is a need to find appropriate successors to schemes like the Heat Networks Investment Project and the Renewable Heat Incentive.

It has been noted that *"a strongly market-oriented framework for energy infrastructure investment has been followed in the UK since the early 1990s".*[58] During this period there have been efforts to explore how the UK and its local councils fund energy projects, and how they might be conducted in alternative ways. More recently there has been a move towards looking for opportunities to influence the market's decisions or bypass market instruments entirely.[59] There is a need for continued collaboration between academics, businesses, and government to identify and deploy more appropriate models, policy and governance structures for energy supply companies and energy communities of various scales and socio-ethical persuasions.[60] [61] [62] These should be designed to deliver stable conditions for investment with appropriate levels of risk and return.

In some crucial ways popular consensus already exists, as seen in the Climate Assembly, but not necessarily consensus between the stakeholders most able to deliver change. For example, one poll found much of the population being in favour of a 2030 Net Zero target.[63] A Net Zero target related to a specific date may give policy designers the ability to make long-term planning decisions, by helping build consensus between all stakeholders on how to achieve a common goal. However, one of the most important factors going beyond 2020 is the need for urgency in decision making, while openly acknowledging that potentially inefficient but crucial choices need be made.[21]

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