March 2020

Future Energy Scenarios

Bridging the gap to net zero

nationalgridESO

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Foreword

As the Electricity System Operator for Great Britain, our mission is to enable the transformation to a sustainable energy system and ensure the delivery of reliable, affordable energy for all consumers. In doing so, we are working alongside stakeholders to tackle some of the biggest energy challenges facing our generation.

The new UK target to reach net zero greenhouse gas emissions by 2050 will require far reaching change across all areas of society. We'll need to work together in new ways, and move quickly if a rapid reduction in emissions is to be achieved. Our Bridging the gap to net zero work is a new pilot programme in response to this challenging goal, seeking to move beyond the areas of uncertainty identified in our Future Energy Scenarios, and working with stakeholders to identify areas for action.

We are delighted to be working with Laura Sandys on this programme. Laura has been instrumental in catalysing debate with stakeholders across and beyond the energy industry, bringing new perspectives to our work.

As discussed in the recommendations of this report, the ESO will be taking forward a number of specific actions. We will also be seeking to partner and collaborate with other organisations as part of our 2025 ambition of a whole system strategy that supports net zero by 2050.

Since preparing this report, we have all been faced with huge changes in our home and business lives as a result of COVID-19. It is clear that disruption will continue during the months ahead and, as we aren't quite clear on the impact on our business and the energy industry just yet, we haven't currently changed the contents of this report or the planned actions. However, we will be constantly reviewing our plans taking into account changing priorities for the ESO and our stakeholders as we work to continue operating a secure and reliable electricity system.

Fintan Slye
Director
Electricity System Operator

The Future Energy Scenarios (FES) are well known and widely used and respected across the industry.

They provide a really helpful framework for exploring uncertainty facing the energy sector. I am excited to be working with the Electricity System Operator on this new programme, examining new energy drivers of the future that are more contentious, less certain, require more evidence or are just unknown as we move towards a net zero Great Britain in the next 30 years.

Thank you to all those who have worked with us on this programme, sharing information, evidence and opinions. Likewise, thank you to all those from the energy sector and other industries to help us develop the conclusions and recommendations in this report.

We look forward to hearing your thoughts and reflections on this report, and to working together on the journey towards net zero.

Laura Sandys CBE
Independent chair and guest editor of the Bridging the gap programme

Executive summary

FES: Bridging the gap to net zero explores the ‘so what’ of our Future Energy Scenarios analysis, to **collaboratively identify immediate actions** for policymakers and industry to meet the UK net zero decarbonisation target.

We are trialling a **new approach to engagement** across and beyond the energy industry, using novel means to engage with different stakeholders, and working with Laura Sandys as our guest editor and chair to help us reach new audiences.

Our Bridging the gap programme was launched in November 2019, **identifying three topics** which the FES 2019 key messages and analysis highlighted as being particularly important to meeting net zero, and where significant uncertainty remains:

- The role of bioenergy in a net zero world.
- How electric vehicles could facilitate greater growth of renewable generation.
- Managing peak electric heat demand.

For each topic, we worked with stakeholders to tackle areas of uncertainty, build consensus and recommend next steps needed to meet net zero.

Recommendations:

Whole system

- A common ‘whole society’ definition is needed for net zero.

Bioenergy

- Primary up to date research is needed to reduce uncertainty on supply.
- Government and industry should work towards a clear ‘best use’ hierarchy for bioenergy.
- Common and clear greenhouse gas accounting is needed across the supply chain.

Electric vehicles

- Continued incentives are needed to ensure EVs and other flexible assets can scale to support renewable growth.
- Industry change needs to be coherent to ensure the case and incentives for system flexibility are clear.
- Commercial trials of distinct V2G business models are required to explore their viability and likely provision of system services.
- Industry is aligned on the value of smart charging, and identified actions should continue to be progressed at pace.

Peak electric heat demand

- Heat decarbonisation research and decision making needs to be coordinated with a whole system / whole home lens.

Next steps:

Where possible, the ESO will be taking specific actions forwards in line with these recommendations, including the following:

- Work with all stakeholders on the development of a shared definition for net zero across the whole system - with initial thoughts published by July 2020.
- Progressing bioenergy recommendations through collaborative industry engagement in Spring 2020.
- Move towards a single market platform with closer to real time auctions for ESO markets, as discussed in our RIIO2 ESO business plan.
- Continue work on the NIA residential response innovation project to looking at new ways to onboard, test and commission large numbers of electric vehicles and other residential scale assets.
- Collaboratively develop a framework for coordinating the “whole system” view on heat decarbonisation, including issues and evidence around flexibility of peak heat electricity demand.
- Explore the impact of extreme cold weather on GB electricity demand in a scenario with high heat pump deployment.
- Use all of the information gathered through this pilot to further refine our Future Energy Scenarios analysis, to be published in July 2020.

We will also be seeking to partner and collaborate with other organisations as part of our 2025 ambition of **a whole system strategy that supports net zero by 2050**.

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Introduction to the FES: Bridging the gap to net zero programme

What is the purpose of the FES: Bridging the gap to net zero programme?

FES: Bridging the gap to net zero explores the ‘so what’ of our Future Energy Scenarios analysis to collaboratively identify immediate actions for policymakers and industry to meet the UK net zero decarbonisation target.

In June 2019, the UK government announced a new goal to reduce net greenhouse gas emissions to zero by 2050. This will require wholesale and deliberate change. Our Future Energy Scenarios (FES) explore what could happen in the future of the energy landscape, and this report aims to move the conversation on with stakeholders, to what needs to happen now in order to meet the challenging goal of net zero by 2050. We have reflected this aim in the name of our programme - FES: Bridging the gap to net zero.

This work tackles **some of the most urgent uncertainties** in decarbonising the whole energy system. It aims to **gather and challenge evidence** and experts in a constructive and collaborative way, to **build consensus** and further understand uncertainty. And ultimately, it seeks to **recommend specific actions and decisions** for the coming year which will progress the UK towards its 2050 net zero target.

No one organisation has all the answers to the challenges of meeting net zero. The energy industry is becoming increasingly complex, with more non-traditional organisations becoming impacted by or involved in the energy system, and more parties right across society needing to consider their greenhouse gas emissions. This vast range of organisations will therefore need to work together in new ways.

FES: Bridging the gap to net zero is a pilot, and as well as exploring different topics, we are looking to trial different types of stakeholder engagement - seeking to co-create ideas and solutions in a nimble and inclusive way. We are delighted to be working with Laura Sandys on this programme, who has acted as an advisor, chair and guest editor.

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What did we do in 2019 / 2020?

We launched our Bridging the gap programme in November 2019, identifying three questions which the FES 2019 analysis highlighted as being particularly important to meeting net zero, and where significant uncertainty remains.

The focus of our work lay in clarifying the issues and identifying important next steps for industry and policymakers. An important secondary benefit from progressing these issues is that clearer evidence is available to refine analysis such as FES 2020, which in turn underpins better decisions in the future.

1 Bioenergy

The first focus area was the use of bioenergy in a net zero world.

On 26 November, 20 industry experts gathered in London with ESO colleagues and Laura Sandys to examine the use of bioenergy across the supply chain. Presentations from 3 expert organisations set the scene and highlighted the diversity of views and uncertainty. Structured discussions then explored these and identified a number of issues and next steps. Follow up research with other stakeholders was also conducted after the event to further test and build upon the actions identified[1].

2 Electric Vehicles

The second focus area considered how electric vehicles (EVs) might be able to facilitate the increased growth of renewable generation[2].

We built upon planned industry engagement for FES 2020 analysis with a series of 'deep dives' with eleven leading organisations in the electric vehicle sector to explore this question[3].

3 Peak Electric Heat Demand

The third focus area looked at the management of peak electric heat demand in the future.

In the future, there will be a mixed heat economy, with all net zero pathways involving significant electrification of heat to some extent. The level of flexibility of this demand will be an important factor in determining the extent to which heat can be electrified. This question required a dual approach of broad engagement across a wide range of technology providers, and deep dive engagement with system operation experts from the gas and electricity networks to understand the system implications of heat demand[4].

[1] See pages 9 to 12 for more information. [2] In FES 2019, we discussed the potential oversupply of renewable electricity at certain days or seasons across the year, and how EVs may be able to absorb this power for use at other times, thereby enabling greater growth of renewable generation see pages 31 to 33 for more information. [3] See pages 14 to 18 for more information [4] See pages 20-22 for more information.

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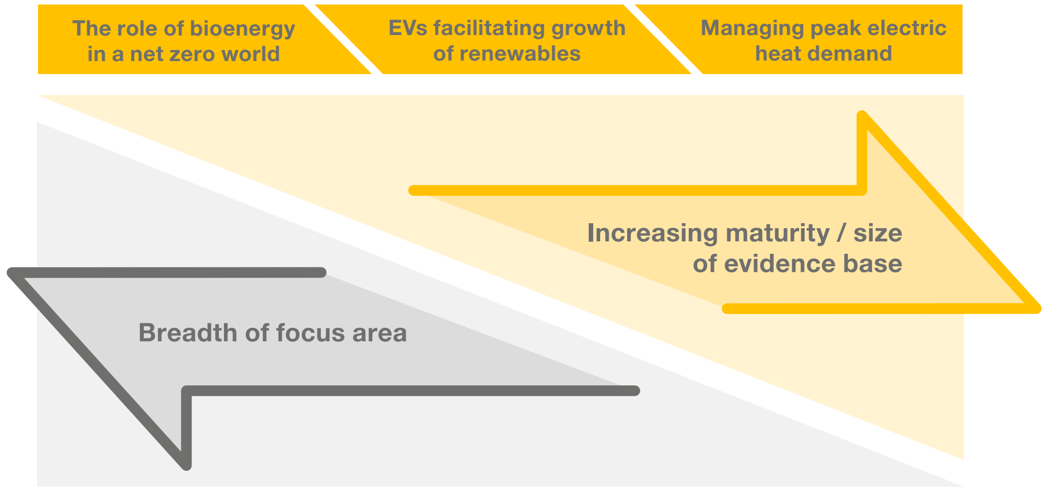
What did we do in 2019 / 2020?

The breadth of each focus area question was deliberately tailored to the level of maturity and existing evidence for each topic.

For each topic, you can read the key conclusions and recommended actions in the main body of this report. For supporting detail and more information on the work carried out with stakeholders, you can read the 'further detail' section for each topic in the appendix.

The more mature the knowledge and evidence base in each area, the more specific our focus area question was made, in order to progress the journey towards net zero.



Bioenergy in a net zero world

Bioenergy in a net zero world

Why is this topic of strategic importance?

The UK's new net zero legislation brings a new challenge to various sectors across society. The use of unabated fossil fuels will no longer be an option for hard to decarbonise areas, and any emissions of greenhouse gases will need to be offset by negative emissions elsewhere.

By bioenergy, we mean turning biomass feedstocks like energy crops, forestry and agricultural residues and organic wastes into fuels, gases or electricity.

Various industries have been examining the use of these low carbon or carbon neutral bioenergy resources to meet their future energy needs. Beyond the obvious benefit of reducing emissions, bioenergy has specific valuable attributes for different users, such as a relatively high energy density, the potential to offer negative emissions[5], and the chemical properties of industrial combustion processes (which can be more difficult to electrify).

This critical resource is nuanced, and has interactions right across society, including some that may not have been considered by energy analysts to date.

For example:

- The production of crops for bioenergy can introduce competition for land and water which might otherwise be used for reforestation or food production.
- Potential users of bioenergy include global sectors such as aviation and shipping which often fall outside of national level energy system analysis.
- As a finite resource, high bioenergy use in one sector or country may necessarily imply less or no use in another.
- Bioenergy is an important route to negative emissions, but the scale of negative emissions needed to reach net zero across society will depend on decisions made in many different areas.

Deeper understanding of the potential scale, opportunities and impacts of deploying bioenergy across the whole system is required.

[5] For example, bioenergy with carbon capture and storage (BECCS) represents one of the few technologies that can offer negative carbon emissions, actively removing carbon from the atmosphere.

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Bioenergy in a net zero world

Key conclusions from this work

1. The supply of bioenergy is highly uncertain, and influenced by several factors:

- Imported feedstock for bioenergy is critical for some net zero pathways but underlying assumptions for this are not well understood or tested. Primary research on feedstock availability is limited and quickly becoming outdated, and a lack of policy incentives add to this uncertainty.
- Waste for use in bioenergy will continue to be available into the future, but the scale is uncertain and nuances around transportation and homogeneity of waste have implications on its conversion into energy.
- Domestic production of bioenergy has the potential to provide higher levels than today. A whole-system approach must be taken to ensure that this increase is sustainable across all sectors.

2. Definitions of "whole system" vary across existing analysis, creating different definitions for net zero.

This creates difficulty in comparing across research, and risks inconsistent or incompatible decisions across industry and policy.

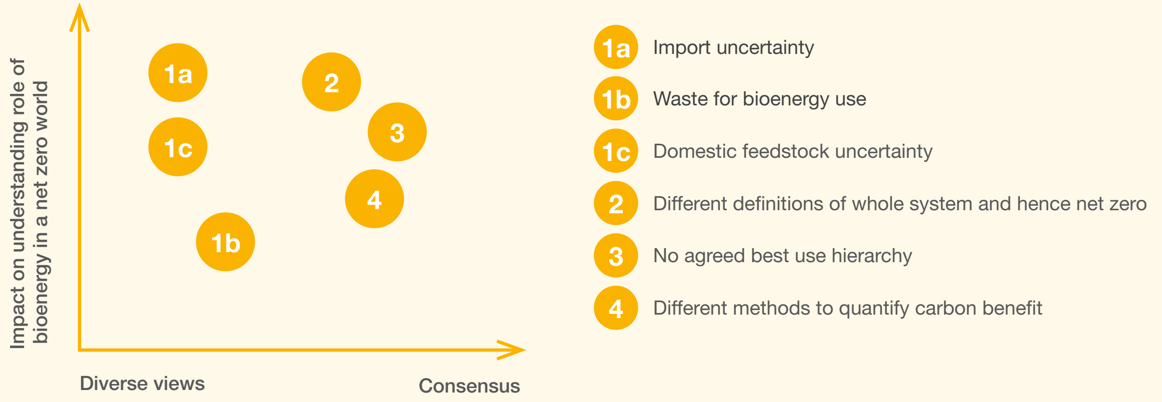
3. There is no consensus on the "best use" of biomass.

More fundamentally, there is currently no shared view on how to assess 'best' use of biomass across competing options. Some stakeholders have stated a position in this area[6] and factors to consider could include where no decarbonisation alternatives exist, where the greatest amount of carbon can be displaced or captured, and what the counterfactual of any other uses of the biomass might be. This has implications for the coherence of future policy or market measures for biomass use.

4. Different methods are being used to quantify the carbon benefits of different biomass feedstocks used.

Key issues include whether the full supply chain or impacts beyond energy are taken into account. In the UK, all bioenergy technologies that receive subsidy support via Contracts for Difference, the Renewables Obligation, Renewable Heat Incentive or Renewable Transport Fuel Obligation use an established method that does account for supply chain emissions and is third party audited.

The following diagram illustrates the level of shared perspective across industry experts, researchers and policymakers on these points, and the perceived impact on understanding the use of bioenergy in a net zero world:



[6] For example, the 2012 UK Bioenergy Strategy provided a government view of best use at the time, and the 2018 CCC Biomass in a low carbon economy report highlights likely best uses for bioenergy from now until 2050.

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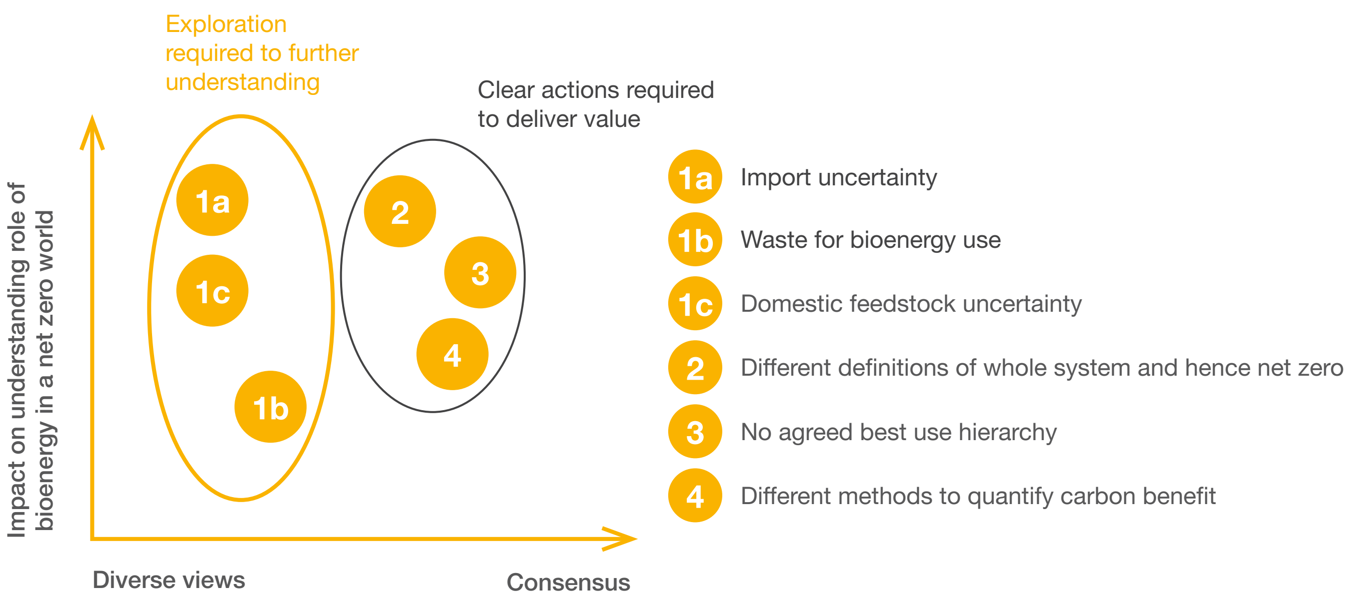
Bioenergy in a net zero world

Actions towards net zero

Our stakeholders built on these conclusions to identify actions and opportunities to progress the understanding of bioenergy use in a net zero world. These will be best led by different parties across industry, government, research bodies, with a collaborative approach across all stakeholders being a necessity in most instances.



Exploration to further understanding

1. **Primary, up to date research to explore the drivers of feedstock availability over time is needed**, with a particular focus on how imports of international biomass feedstocks might change to 2050. This should also include analysis of drivers of supply, with a focus on physical and policy factors.

Clear actions required to deliver value

2. **A common definition for "net zero across the whole system"** must be applied to ensure that decisions across industry and policy are being made using consistent foundations.
3. **A best use hierarchy for bioenergy.** This is a resource with wide ranging interactions across many sectors, and government and industry must collaboratively develop criteria for assessing its "best use". This would then inform future planning, policy decisions, market design, and innovation, with review points over time.
4. **Clarity of carbon accounting standards, including consideration of whole supply chain emissions.** All increases in biomass use (not just those receiving subsidy) should be accompanied by consideration of carbon emissions across the supply chain and beyond the energy sector, with certification schemes to guarantee sustainable provenance. For bioenergy imports, consideration needs to be given not only to whether a country implements a regulation, but also how well this is enforced and audited, ideally by a third party. The Sustainable Biomass Program[7] is an example of best practice here.

What you will see from the ESO

ESO will work with stakeholders to produce a 'Defining net zero' thought piece (or section in FES) by July 2020. This will address these issues in an accessible way, and illustrates the importance of measuring net zero across all areas of society. We will work with all stakeholders on the development of a shared definition for net zero across the whole system.

Our FES 2020 scenarios will explore a range of biomass supply and use assumptions. These will include:

- The potential for higher biomass imports in the Leading the Way scenario (aligned with the assumption that the UK is a first mover in any global market).[8]
- Medium case supply projections for net zero by 2050 scenarios, with lower levels of imports.
- Explanation of non-energy assumptions that have influenced biomass supply in each scenario, with emissions data broken down by sector.
- Likely prioritisation of biomass towards harder to decarbonise areas or to provide high carbon sequestration / negative emissions, depending on the parameters of each scenario.

[7] www.sbp-cert.org
[8] Further information on the FES 2020 scenarios can be found here

How electric vehicles can facilitate greater growth of renewable generation

How electric vehicles can facilitate greater growth of renewable generation

Why is this topic of strategic importance?

2050 could see over 75% of the 35m electric vehicles in GB using smart charging, creating the potential for roughly one fifth of GB's solar generation to be stored for when it is needed. This level of storage could be hugely valuable in providing flexibility to the energy system and reducing costs for consumers. A deeper understanding of the potential flexibility from EVs will help to inform the market, regulatory and technological change required to realise this value.

In the past 3 years huge strides have been made in understanding and modelling future electric vehicle (EV) behaviour. However to date, much of the research and analysis in this area has looked at how the flexibility from EVs can be used to reduce their peak load. We discuss this in depth in the Future Energy Scenarios 2019.

Bridging the gap is instead looking at how the flexibility from EVs could be used to support the electricity system more widely – specifically, how EVs can facilitate greater growth of renewable generation.

In the past 1-2 years an emerging theme in FES has been that in faster decarbonising scenarios, there are likely to be periods of significant excess supply of renewable power, particularly from 2030 onwards. These periods of excess electricity supply are caused by different factors such as high solar output, high wind output, bank holidays depressing electricity demand etc. Some of these periods may be more predictable than others, and initial analysis suggests many periods may be short duration but high volume. This excess generation is considered a potential opportunity for storage solutions, including EVs.

The potential value to the system and end consumer is significant and clear steps need to be identified now to ensure the full benefits of electric vehicles to the electricity system can be realised.

This "double decarbonisation" effect is the second focus area for this pilot of FES: Bridging the gap to net zero.

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How electric vehicles can facilitate greater growth of renewable generation

Key conclusions from this work

Smart charging is the "low-hanging fruit"

1. Smart charging is the 'low hanging fruit' and can provide much of the flexibility required to support more renewable generation on the electricity system as demand and renewable generation grow. It must be in place for EVs to scale without system challenge. The concept is easily understood by most consumers, and there are low additional technology costs.

Vehicle to Grid (V2G) is nuanced, and more uncertain

2. Large scale V2G operations which have vehicles connected throughout the day - such as airport and urban parking lots, but not commercial fleets - could be well placed to offer system services.
3. Bi-directional charging of EVs on-premise (but not exporting power to the grid) could provide valuable demand shifting or reduction for the customer and system, with lower barriers to entry than offering system services.
4. V2G fleet charging is more likely than residential models, due to scale, but there is some question whether vehicles will be available for (dis)charging at the time of day when flexible assets are most scarce. This is because many fleet vehicles will be charged overnight, when there is likely to be less demand for export of electricity, and greater availability of residential smart charging already in place.
5. There is a minority view that residential V2G charging will offer additional system value in integrating renewables that outweighs the cost of implementation. However, uncertainty in key areas such as technology cost, battery degradation and consumer acceptance means there are a range of opinions here. New technologies such as in car inverters (allowing vehicles to feed AC power back onto the electricity system using a standard charging cable) could offer new and more commercially viable opportunities.

Electric vehicles / Key conclusions from this work 15

How electric vehicles can facilitate greater growth of renewable generation

Key conclusions from this work

Market change required to support flexibility from EVs

6. Coherent change across the whole electricity system is essential to ensure that clear price signals reflect system needs, and to allow the flexibility available from EVs to be utilised positively. Current examples include interactions across different charging regimes (as explored in two current Significant Code Reviews), timings of policy changes, and coherence between DNO and national flexibility markets.

7. ESO ancillary service markets must evolve to support the fundamental attributes of EVs, such as the scale, dynamic location and availability of EVs. Whilst these may not be the largest proportion of revenue for such assets, they could be particularly important for early projects as part of wider revenue stacking.

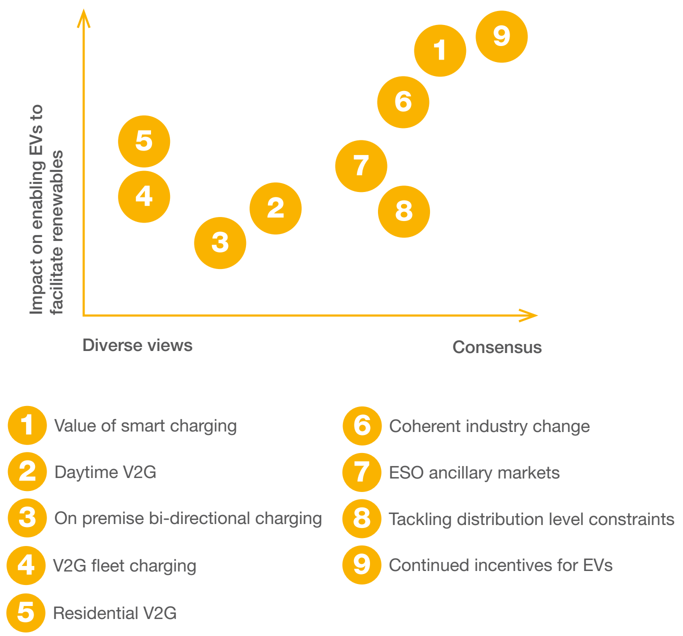
8. EV access to distribution network markets is seen as providing significant potential value to manage local constraints and hence could be a valuable revenue stream for EVs. This supports the growth of renewable generation where such growth is causing local system constraint.

   Related to point 8 (outside scope of report): Many of the opportunities for EVs to provide support to the wider electricity system will be dependent on their ability to access this, and hence dependent on the management of constraints in their local area. In addition, demand shifting can at a local level reduce peak capacity due to local wires being based on a cyclic rating.

EV adoption rates

9. Incentives for the adoption of EVs need to continue if they are to scale at a rate that facilitates increased renewable generation, and optimises network costs for consumers. The potential bringing forward of a planned ban on conventional vehicle sales would accelerate adoption.

The following diagram seeks to summarise these points in terms of perceived impact on facilitation of renewable growth, alongside the diversity or consensus of views from stakeholders:



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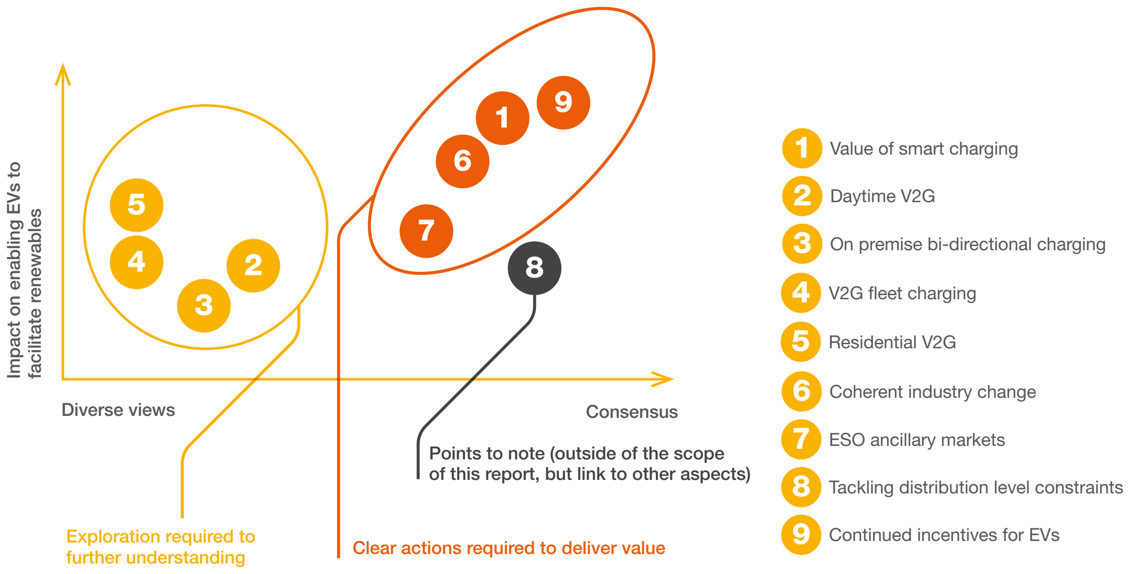
How electric vehicles can facilitate greater growth of renewable generation

Actions towards net zero

As part of our discussions, stakeholders identified a number of steps that could be taken to reduce uncertainty, and better capture the potential impacts of electric vehicles for renewable generation growth.



Clear action required to deliver value

- **Continued incentives for EVs:** Government policy should continue to focus on encouraging adoption of EVs by consumers.
- **Coherent industry change:** All industry change programmes should review any recommendations which risk dampening electricity market price signals, as clear price signals will enable the greatest level of flexibility to be harnessed from smart charging. This will have an impact on those unable to be flexible in their demand, requiring appropriate targeted protection safeguards for vulnerable customers. A holistic implementation plan is also needed across changes in the energy sector (e.g. SCRs, ESO roadmaps etc.), with sufficient lead times, to allow parties to understand and react to changes, and minimise policy gaps.
- **ESO ancillary markets:** GB electricity flexibility markets should evolve to enable participation of small scale flexible assets which will not be consistently connected to the electricity system and which may not always connect at the same network location.
- **Smart charging:** Given industry alignment in the area of smart charging, it is imperative that identified actions to support this continue to be progressed. As National Grid ESO we advocated for the inclusion of mandatory smart charging capability in the Automated and Electric Vehicles Act, and add our support to the further actions outlined in the EV Taskforce report to support the growth of smart charging.

Exploration required to further understanding

Residential V2G / Fleet charging / Daytime V2G / On-site bi-directional charging:

- Innovation and commercial ventures should continue to explore the viability, consumer appetite for, and future likely behaviour of distinct V2G business models, including:
  - On-premise (i.e. “behind-the-meter”) optimisation and demand shifting that include EVs with other flexible on-premise assets such as batteries and appliances.
  - Different scales of V2G provision of system services. For example, residential vs commercial fleets.
  - Different commercial models for large scale V2G (e.g. fleet, airport parking, railway parking etc.) and impact on potential system services offered.

Electric vehicles / Key conclusions from this work 17

How electric vehicles can facilitate greater growth of renewable generation

What you will see from the ESO

- We will review our V2G assumptions in FES 2020 to consider a wider range in this area given current uncertainty.
- In line with our wider FES engagement, we will review our smart charging assumptions in FES 2020 to increase rates of engagement in some scenarios.
- We will explore sharing further information on dispatch modelling of excess renewable power where possible.
- In our RIIO2 ESO business plan, we have committed to moving towards a single market platform with closer to real time auctions in the next 3 years, which should enable smaller assets such as groups of EVs to access ESO markets more easily.
- As part of the NIA residential response innovation project, the ESO and a number of partners will be looking at new ways to onboard, test and commission large numbers of residential-scale assets so that parties can meet ESO requirements more easily and cheaply. This could include, for example, moving away from testing individual assets that provide services, to 'type testing', and looking at alternatives to current metering arrangements to see if there may be cheaper alternatives for smaller assets.
- We are producing a number of materials to support consumer understanding and education in the area of smart charging.

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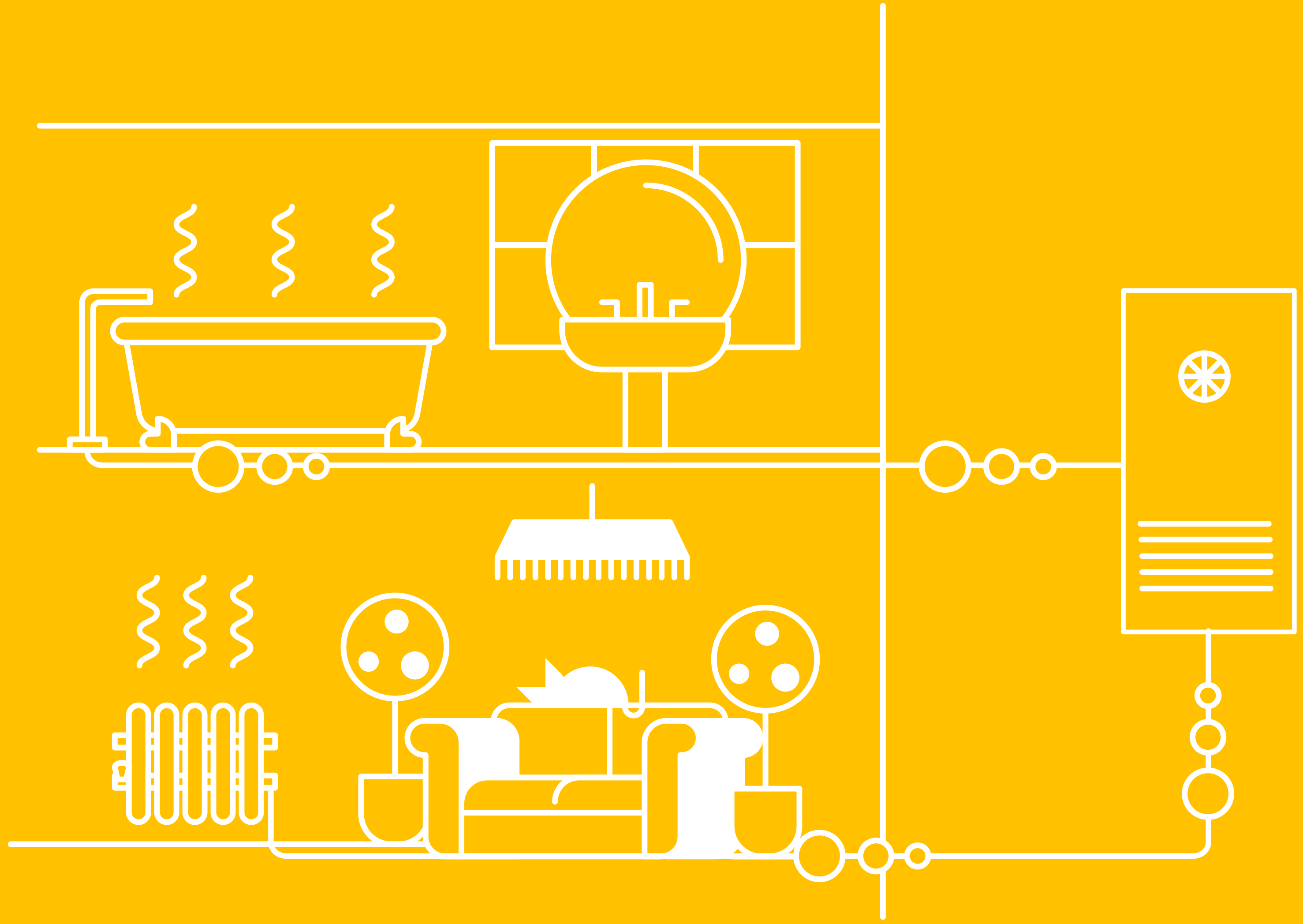
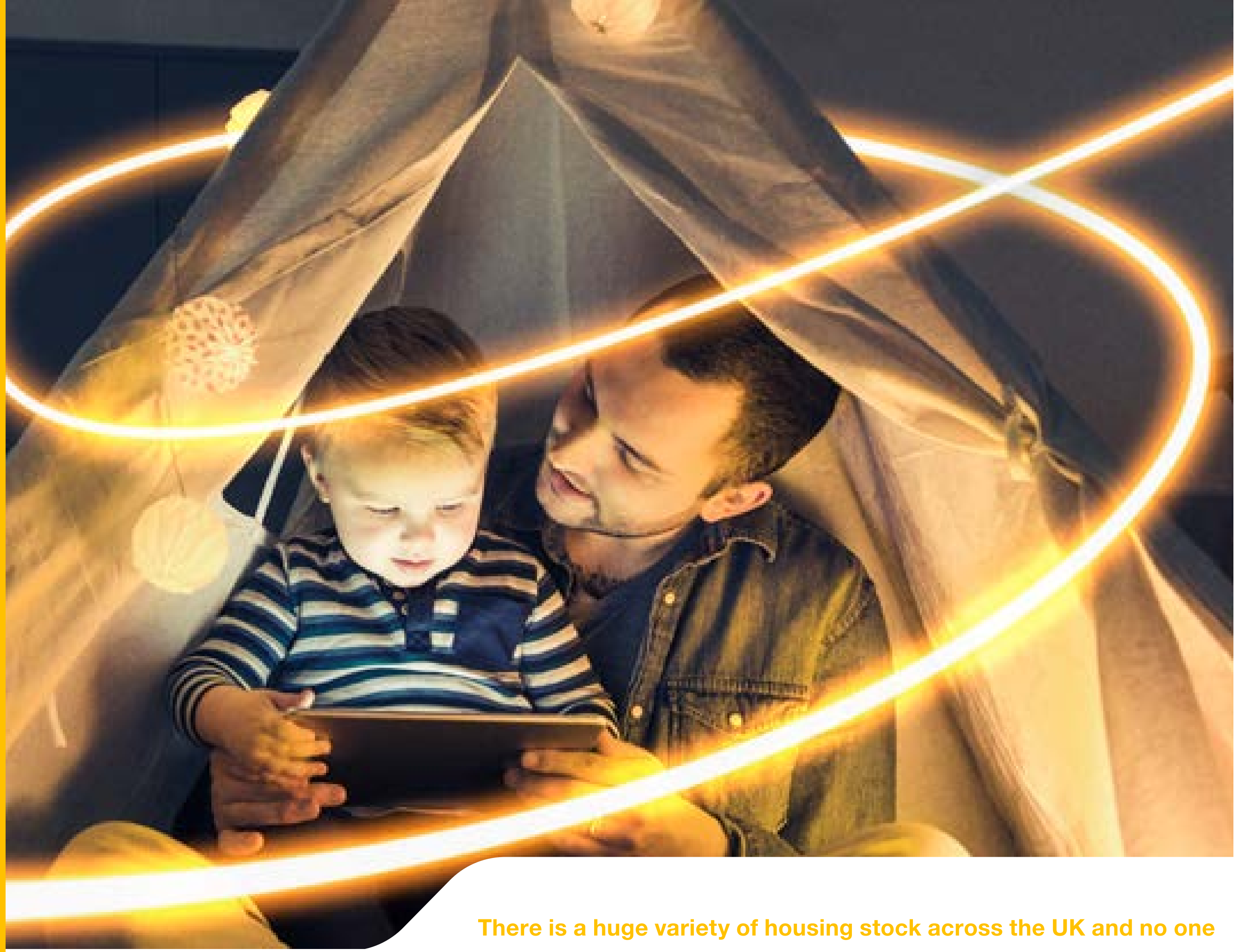
Managing peak electric heat demand



Managing peak electric heat demand

Why is this topic of strategic importance?

Decarbonising heat is the biggest challenge in reaching net zero, and all net zero pathways involve significant increases in the electrification of heating. Understanding the flexibility of this electricity demand for heat will be an important factor in determining the viability and scale of heat electrification.



There is a huge variety of housing stock across the UK and no one technology solution is best suited to decarbonise the heating of every household. Existing natural gas boilers must be replaced, and a range of technologies will be available, including heat pumps, biogases, hydrogen, district heating, and combinations of these such as hybrid heat pumps.

Electric heating solutions feature in all FES 2019 scenarios, and in our net zero sensitivity analysis. What's less certain is exactly how this electric heating might operate and impact the electricity system more widely. Understanding the performance and operational aspects of electric heating options will help to inform decisions around other heat solutions which can either complement or substitute for electrified heating, such as hydrogen boilers, hybrid heat pumps, district heat networks, and insulation.

Peak electric heat / Why is this topic of strategic importance? 20

Managing peak electric heat demand

Key conclusions from this work

1. The performance of air source heat pumps in Great Britain is not well understood. This can be considered both through a consumer and a system lens:

- Consumers can't easily assess whether their home is suitable for a heat pump. Heat pumps are suited to better insulated, more thermally efficient homes, but their performance across the diverse range of UK housing stock, thermal efficiency ratings, and climates is not well understood. Consumer investment decisions (and any policy support for these) need to be able to understand different heating options, such as choosing between a heat pump and complementary investment (e.g. significant insulation) or a hydrogen boiler with relatively less insulation.
- The consumer experience will fundamentally change as heat is electrified, due to the characteristics of how heat pumps provide heat at a lower and more steady rate than natural gas boilers. This will have implications for services, markets, and regulations across the sector.
- System operators and network companies need to better understand electricity demand of heat pumps at different performance levels, housing stocks, and in different weather conditions. This will inform decisions around investing in system flexibility options or network reinforcement to ensure that peak demand for heat can be met in the future.

2. The interactions between elements of home heat flexibility solutions are critical in understanding potential flexibility at peak.

The ability of homes to flex demand for heat relies on a number of levers and the interaction between them can vary, particularly at times of peak demand. These levers can be categorised as:

- The inherent heat storage in a building, including insulation levels, airtightness, and thermal mass of materials.
- Heat storage solutions, including hot water tanks and other heat storage technologies such as phase change materials.
- Electricity storage solutions, including bi-directional vehicle charging and stationary batteries.

3. Consumer preferences are relatively untested and are important in confirming the parameters of the decarbonised heating "challenge" which is to be solved through significant investment at household and system levels.

Low carbon heating technologies have fundamentally different characteristics to natural gas boilers, and consumer preferences can be efficiently met by different technology combinations depending on the preference.

Peak electric heat / Key conclusions 21

Managing peak electric heat demand

Actions towards Net zero

Coordinate heat decarbonisation research and decision-making with a "whole system" lens to ensure that decisions balance direct consumer benefit (e.g. heat technology or service provision) and indirect benefit (e.g. lower system costs via consumers' bills). The challenge of decarbonising heat is being tackled by a vast number of studies and trial projects, often at either a very broad and high level, or in a very detailed and narrow way. There is a need for coordination of this work to ensure that the interactions across emerging conclusions are properly captured, and that a whole system lens is brought to decisions which may not have previously benefited from one (e.g. future reviews of heat pump design standards).

Coordinate heat decarbonisation research and decision making with a "whole home" lens to ensure that interactions between different energy uses and efficiency measures in the home are understood[9]. While disparate data and evidence is available for specific technologies or services, there is a clear need to understand how consumers might invest in combinations of technologies, and how these different technology combinations might interact to meet consumer preferences on a day-to-day basis.

What you will see from the ESO

Our 2025 ambition of a whole system strategy that supports net zero by 2050[10] will develop a framework for coordinating the "whole system" view on heat decarbonisation, including issues and evidence around flexibility of peak heat electricity demand. This framework will be shared and tested with stakeholders as work progresses.

We will look for a partner who is best placed to coordinate the "whole home" perspective on heat decarbonisation, to ensure that the "whole system" and "whole home" perspectives inform each other.

In our 2020 Future Energy Scenarios:

- We will consider increasing the amount of heat storage in some of our FES 2020 scenarios to reflect stakeholder feedback received
- Our new FES 2020 scenario matrix incorporates the 'level of societal change' required for distinct scenarios. This will enable FES 2020 to explore the potential trade off between consumer and system changes required for different future heating approaches.

Via a NIA innovation project, we are developing a model with several stakeholders that incorporates regional differences in UK housing stock, the suitability of different low carbon heating technologies across the country and that captures competition between low carbon technologies. This will map heat demand to the GB gas and electricity networks, informing our 2021 Future Energy Scenarios, options for regional heat pathways and network planning. You can read more here.

We will explore the impact of extreme cold weather on GB electricity demand in a scenario with high levels of heat pump deployment.

[9] For example, the extent to which electric vehicles might be able to provide electricity to support peak heat demand
[10] See Towards 2030: An Electricity System Operator for GB's Energy Future

Continuing the journey

No one organisation has all the answers to the challenges of meeting net zero emissions. Every area of society needs to consider greenhouse gas emissions, and a whole system approach will be critical to ensure that interactions across different areas are understood and accounted for.

This challenge means that new organisations need to connect with each other in conversations about decarbonisation, and all parties will need to work together in new ways.

Connecting with new stakeholders and diverse perspectives

A key element of the Bridging the gap pilot was to explore ways of bringing new stakeholders and perspectives together, with a focus on building consensus to drive action on net zero. We used stakeholder workshops, webinars, bilateral conversations, interviews and social media and film to engage with different parties, collect information and identify actions.

We managed to connect with stakeholders and experts who we hadn't previously spoken with, which in turn led to some of this reports most important conclusions. We also learned many valuable lessons which we look forward to building on in the future, and welcome your ideas on how to further improve this work as it continues.

Next steps: A whole system strategy towards net zero

Since the launch of the FES: Bridging the gap programme, the Electricity System Operator has launched a new strategic ambition: the development, by 2025, of a whole system strategy that supports net zero by 2050.

Bridging the gap to net zero, along with a number of other workstreams, will drive towards this goal and ensure we are engaging with stakeholders in a holistic and coordinated way. Relevant activities will include:

- Progressing bioenergy recommendations through collaborative industry engagement in Spring 2020.
- Launch of the Future Energy Scenarios 2020 (July 2020).
- The second iteration of FES: Bridging the Gap (autumn 2020).

Appendix

Appendix

More information on the Future Energy Scenarios

What are the Future Energy Scenarios?

Every year, National Grid Electricity System Operator publishes the Future Energy Scenarios (FES) document in July. The energy system is rapidly transforming, and our FES document comprises a set of credible future energy pathways in the form of 4 scenarios.

These scenarios are not forecasts - rather, the future of energy could combine elements of different scenarios. Rather, the four scenarios taken together represent our view of where the credible possibilities may lie for the future of energy. We expect that the future energy world in Great Britain will fall somewhere within our four scenarios.

In FES 2019, we used a 2 x 2 matrix to explore four scenarios. The two axes in the diagram here are speed of decarbonisation, and level of decentralisation. Scenarios to the right-hand side of the diagram are worlds that are highly decarbonised, and see an 80% reduction in carbon emissions (compared to 1990 levels) by 2050. Scenarios that are in the upper two quadrants are worlds where there are more smaller scale, local energy solutions, that are closer to the end consumer - for example domestic solar panels.

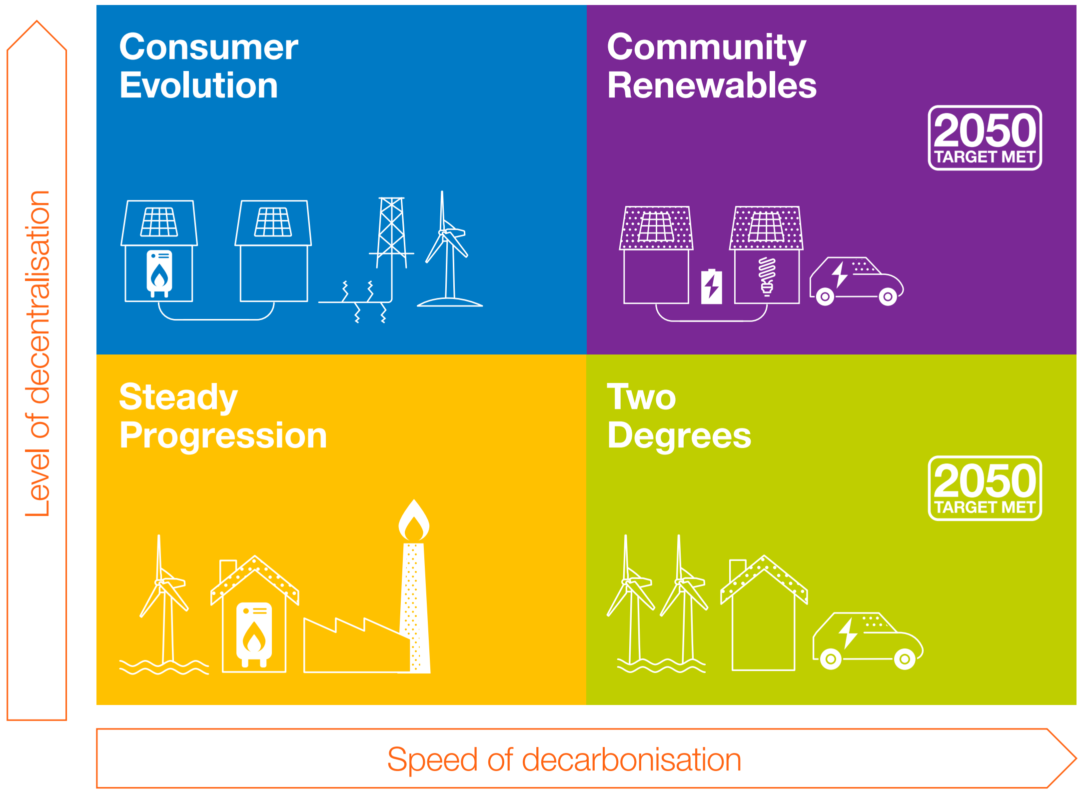
In FES 2019, in addition to our core scenario analysis, we undertook some smaller scale sensitivity analysis to consider a world in which net zero carbon emissions were achieved by 2050. We will be looking at net zero scenarios in much greater detail in FES 2020 (see below).

Although the Future Energy Scenarios document is published by the Electricity System Operator, it looks at a number of fuels, including gas, electricity, hydrogen and biofuels.

Why do we publish FES?

We speak to hundreds of organisations in preparing the Future Energy Scenarios, and combine this intelligence with our own expertise and robust analysis.

The Future Energy Scenarios therefore provide a consistent and holistic starting point for planning long term investments in the gas and electricity systems. As the electricity system operator, we want to understand what assets, skills and markets we might need to manage the energy systems of the future. Network operators build assets (like overhead lines and underground pipelines) that can sometimes be used for more than 30 years, so it's important to understand for them what will be needed by energy consumers a long way into the future. And many other stakeholders use FES for other purposes - such as business planning, for academic studies or to inform investments.



FES Scenario Framework 2019

FES 2019 and our Bridging the gap work

The key messages in FES highlight areas of uncertainty or convergence across the scenarios, in a number of strategically important areas. Our topics for exploration in FES: Bridging the gap to net zero link to these key messages:

- How might bioenergy be used in a net zero world? (linking to key messages 1 and 4 on net zero and whole system thinking).
- How can electric vehicles (EVs) facilitate greater growth of zero carbon electricity? (relating to the FES19 key message on electric vehicles).
- How can managing peak electric heat demand help us meet decarbonisation targets? (relating to the FES19 key message on the decarbonisation of heat).

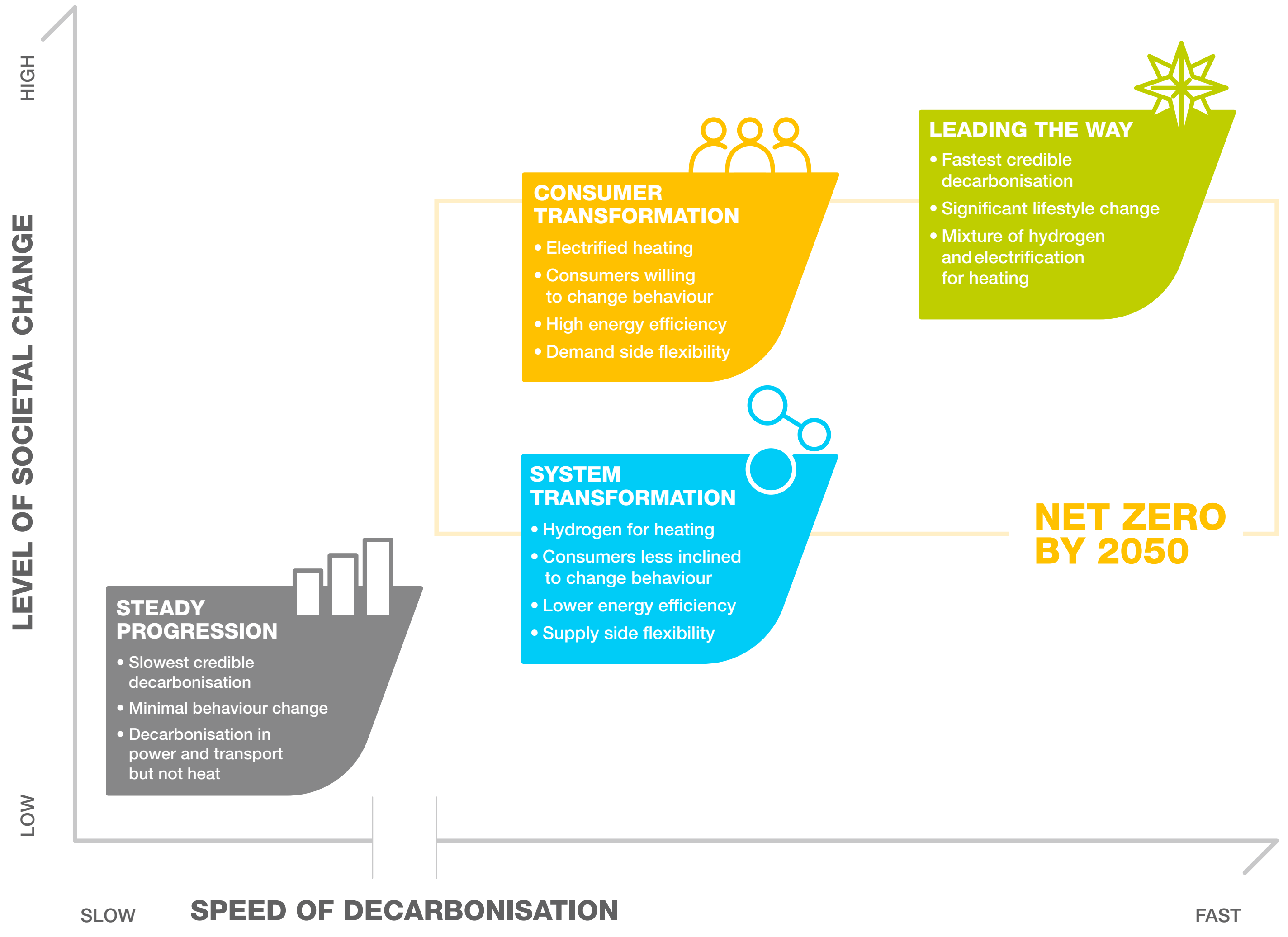
What will FES 2020 consider?

We have worked with stakeholders across industry and government to develop a new set of scenarios for FES 2020. These scenarios reflect the UK government's new legally binding target to achieve net zero emissions by 2050, with three scenarios that achieve this ambition. One of these scenarios will consider in greater detail whether this ambition could be reached before 2050.

The framework keeps the speed of decarbonisation as a key uncertainty to explore, and introduces the level of societal change as a new uncertainty that will help us to explore a diverse range of credible decarbonisation pathways. You can read more in our Stakeholder Feedback Document which summarises the wide range of stakeholder feedback gathered and the reasons behind these changes.

Where can I find out more detail, data etc?

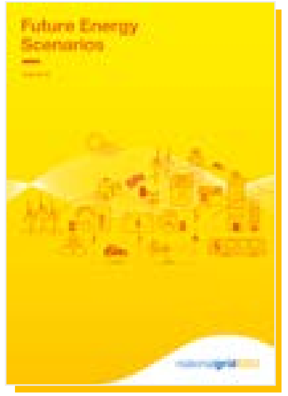
All of the analysis that supports our FES documents, plus supporting material, can be found on our website: fes.nationalgrid.com/fes-document/



FES Scenario Framework 2020

Introduction - Industry publications informed by FES

Future Energy Scenarios



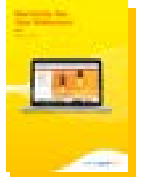
July
A range of credible pathways for the future of energy from today to 2050. Scenarios are unconstrained by network issues.

Bridging the gap

The Bridging the gap work looks at some of the key uncertainties and areas of strategic importance in the Future Energy Scenarios Exploring these with partners to identify recommended actions towards net zero.

The ETYS and GTYS take the unconstrained scenarios in FES to develop requirements for planning and operating the electricity and gas transmission systems over the next 10 years.

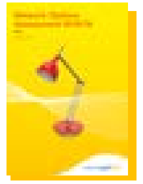
Needs case



Electricity Ten Year Statement

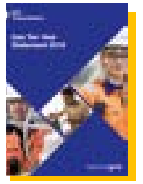
November
The likely future transmission requirements on the electricity system.

Options



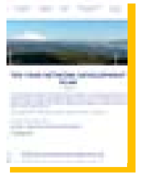
Network Options Assessment

January
The options available to meet reinforcement requirements on the electricity system.



Gas Ten Year Statement

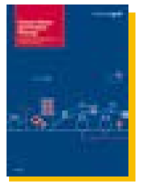
November
How the gas network is planned and operated, with a ten-year view.



Ten Year Network Development Plan

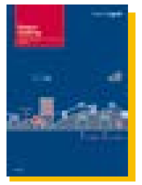
Overview of the European gas and electricity infrastructure and its future developments.

Ad-hoc reports that develop shorter-term plans for more specific elements of operational assets and services, where the need arises.



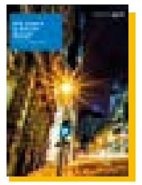
System Needs and Product Strategy

Our view of future electricity system needs and potential improvements to balancing services markets.



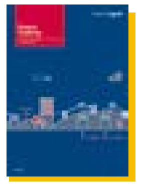
Product Roadmap for Restoration

Our plan to develop restoration products.



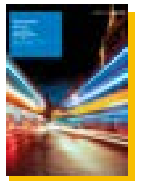
Wider Access to the Balancing Mechanism Roadmap

Our plan to widen access to the balancing mechanism.



Product Roadmap for Reactive Power

Our plan to develop reactive power products.



Product Roadmap for Reactive Power

Our plan for the management of thermal constraints.

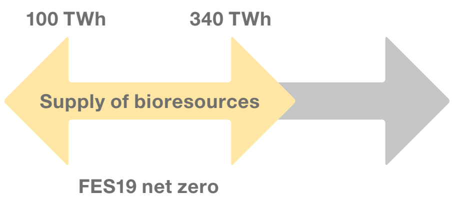
Bioenergy in a net zero world

Detail of work with stakeholders and emerging findings

What did we do?

On 26 November 2019, we gathered around 20 stakeholders from across the bioenergy supply chain, plus ESO employees and Laura Sandys CBE, in London to discuss the role of bioenergy in a net zero world.

Richard Millar from the Committee on Climate Change, Sacha Alberici from Navigant and Mark Sommerfield from the Renewable Energy Association started the morning by presenting their recent work on bioenergy. This gave us a really useful overview of current research and different perspectives. For example, different scenarios from these 3 organisations showed a potential range of 100 to more than 340 TWh of biomass feedstocks in 2050 - with either very little or up to half of this coming from imports.



We then discussed certainties and uncertainties in the supply and use of biomass, approaching this discussion by considering feedstock, processing of biomass and finally the end use of bioenergy in turn. Across all these discussions, we sought to understand whether there were key next steps that might help to reduce uncertainty, and help the UK move towards net zero. Materials from the workshop can be found here.

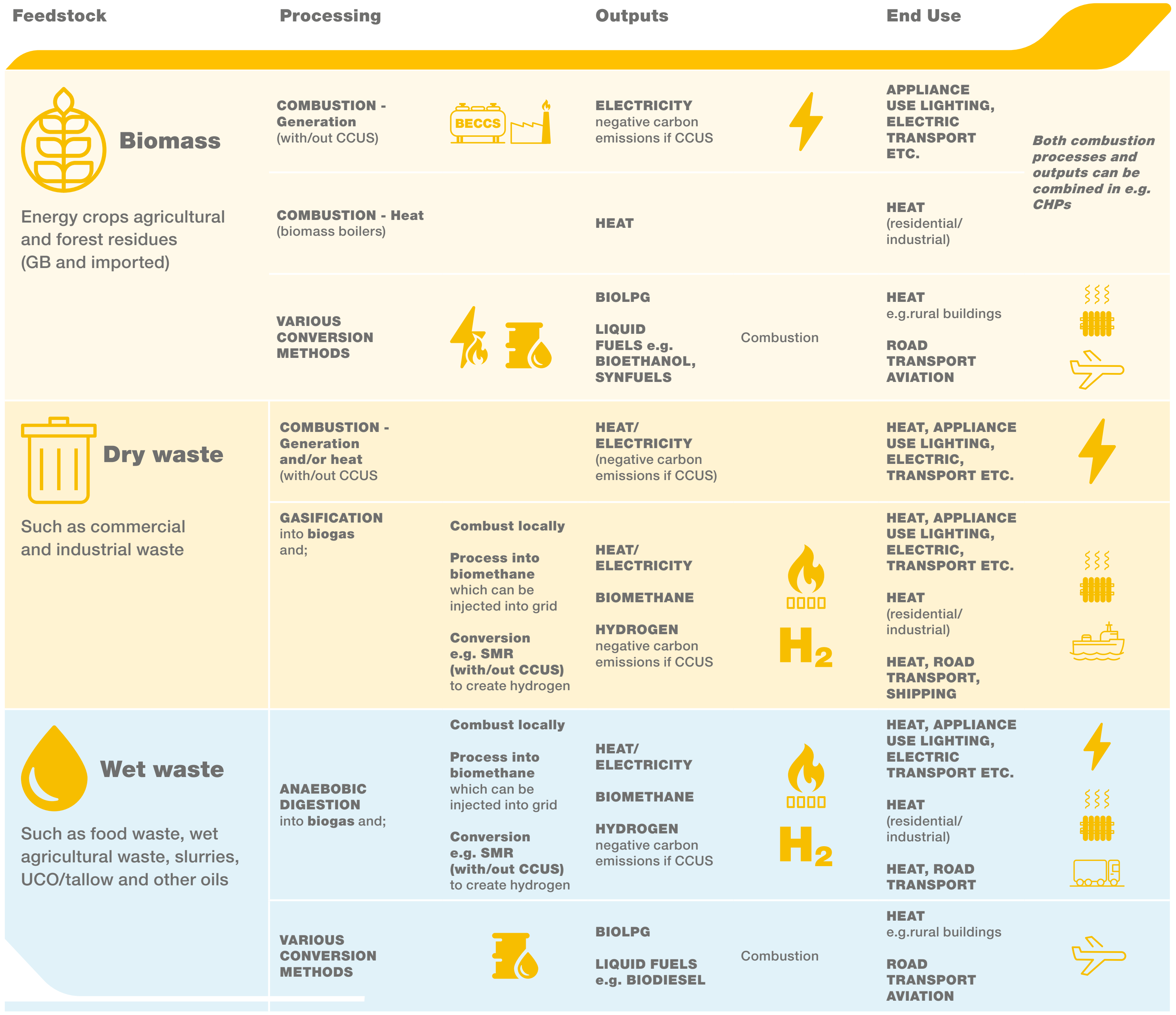
After the workshop, a further six stakeholders got in touch and four offered further information to add to our work.

Discussion themes

A number of different biomass inputs can be used to create biofuels, biogases or electricity. To guide our discussions on the day of the workshop, we used this graphic which was later further refined by participants, to help illustrate the bioenergy supply chain and how various resources could be used. To the left, different 'feedstocks' (inputs) are shown that can be used for bioenergy purposes. On the right hand side, the potential end uses are shown.

Whilst not completely comprehensive of all possible bioresource production / uses, this helps to illustrate the overall supply chain and diversity of ways these resources can be used.

The bioenergy value chain



How much bioenergy might be available overall in a net zero world? (Key conclusion 1)

A key question when thinking about how the use of bioenergy could help GB meet a net zero target has to be how much bioenergy might be available.

As shown in the graphic above, there are various sources of feedstock for bioenergy use - including domestic energy crops and waste products from other processes. A further potentially important source of feedstocks or biogases / biofuels could include imports from other countries.

In discussing the potential range of feedstocks for bioenergy use, workshop attendees noted a number of topics.

Development of a global market for bioenergy

Probably the area of greatest uncertainty when considering the total amount of future biomass is whether a global market could develop. We have already seen countries with smaller populations and large amounts of land exporting biomass such as wood pellets to the UK.

In our discussions, attendees noted that as more countries look to become net zero, they are likely to become less willing to export resources that could help them achieve these targets. On the other hand, the UK has excellent potential for future carbon storage in the form of depleted gas fields in the North Sea - which many other countries do not have. With the right incentives in place, **a [bigger] market could therefore develop where countries export biomass to the UK,** so that they can be used in negative carbon processes. However, how any carbon credits associated with such a market would be distributed would remain to be seen.

In discussing the current research into biomass availability, attendees did note that a lot of industry research was reliant on a fairly small number of primary research reports, many of which were more than 2 years old.

GB waste - availability and quality of inputs

It's clear that some **'minimum' level of GB wet and dry wastes for bioenergy use will remain into the future,** as these wastes are by-products of other processes and hence will not disappear completely. However, a number of factors could affect how much waste is available for this use.

For example, household food waste can be converted into bioenergy via processes such as anaerobic digestion. Whilst the rate of recycling of household food waste is expected to increase, consumer education and a continued drive to reduce waste could also mean that the total amount of waste from household and industry decreases.

Moreover, the type of waste we produce as a society is affected by the seasons, and the quality and homogeneity of waste will impact how much of it can be used for bioenergy purposes. Attendees also highlighted that the transporting of waste can be expensive, which can mean that some processing of waste for energy use is only viable within the local area.

Some organisations noted research is ongoing to consider different waste products that could be used for some bioenergy purposes, for example peanut husks. This could **increase the range of domestic feedstock for bioenergy in the future.**

Growth of domestic energy crops

The amount of domestic crops available for energy purposes will necessarily interact with wider decisions about land use and agricultural developments. In particular, attendees discussed the **potential for further efficiencies and innovation** in the growth of crops, such as sequential cropping, and that other countries are innovating in these areas.

Moreover, as several attendees noted, **supportive policies and market mechanisms** have the potential to increase the domestic supply of bioenergy crops. Most recently, the CCC's Land Use: Policies for a Net zero UK report published on 23 January 2020 makes a number of supply and demand side policy recommendations to support the sustainable increase in domestic bioenergy crops. These include long term change in diets and incentives for farmers to release land to grow bioenergy crops, as well as continuation of existing support mechanisms and a suggestion that UK biomass combustion facilities agree to source a minimum proportion of feedstock from the UK.

Whole system interactions: Defining net zero (Key conclusion 2)

Attendees also discussed the different definitions of net zero, and how this could lead to a lack of clarity, particularly when discussing competing uses for biomass.

Our FES 2019 net zero sensitivity illustrates the importance of taking a whole system definition / account of net zero, to understand the potential need for negative greenhouse gas emissions / bioenergy use in different sectors.

The table below shows how greenhouse gas emissions are attributed across different sectors of the economy in our FES 2019 Net zero sensitivity. Remaining emissions in hard to decarbonise sectors such as agriculture, aviation and industry mean that negative emissions are required elsewhere. In this sensitivity analysis these negative emissions are provided by BECCs and hence require significate amounts of biomass.

(Mt CO2 equivalent)	2017	Net zero 2050
Heat for buildings	85	0
Electricity before BECCS	73	0.35
BECCS in power sector	0	-37
Industry	105	10
Road transport	117	0
Hydrogen production	0	3
Other (non energy related)	123	59
Total	503	35
Relative to 1990Emissions (1% reduction)	39%	96%

How might bioenergy be used in a net zero world? (Key conclusion 3)

Processing of biomass

When thinking about processing of biomass and wastes, many attendees discussed the importance of gasification due to the diverse range of fuels it can create - but noted barriers to commercialisation.

Others noted the reliance of many (future) processes on Fischer-Tropsch technologies. Similarly, for carbon negative technologies these will rely on carbon capture use and storage, which is not yet widely commercialised.

Is there a 'best' use for biomass?

We discussed what might constitute 'best use' of limited biomass feedstocks in a net zero world. Some noted principles such as prioritising biomass for areas where it can sequester or displace the most carbon, and / or where no other decarbonisation alternatives exist. Attendees also noted the importance of considering the counterfactual and wider benefits of some of these production methods.

For example, some waste that could be used to produce biofuels etc. could otherwise be left unprocessed and emit greenhouse gases in landfill, and some biomass production has the potential to improve carbon sequestration in soil. It was also noted that bioenergy can provide security for other more widespread decarbonisation methods - for example providing additional secure electricity generation, which can help with greater electrification.

Transitions and final use

Others noted that even if there was an agreed best use for biomass in [2050], infrastructure, supply chains etc. involved in other 'non-best' uses may need to be supported ahead of this. Otherwise these could disappear or not grow at the required rate to sustain future agreed best use cases.

Understanding the carbon impact - clear carbon accounting and supply chain governance

A key theme in all stakeholder discussions was the need for clear governance across biomass supply chains, to ensure tangible societal and carbon benefits.

In particular, we discussed the need for agreed carbon accounting methods that consider all elements of a supply chain (e.g. transport), with this being seen as particularly important for imports into the UK. The importance of seeking to quantify counter factual uses of bio-resources was also seen as critical.

As one of the first countries to make a commitment to net zero, there is an opportunity for the UK to lead the way here, with a parallel to discussions around measuring consumption-based emissions. In the UK currently, all bioenergy technologies that receive subsidy support via the Renewables Obligation and other schemes use an established method that does account for supply chain emissions and is audited.

How electric vehicles can facilitate greater growth of renewable generation

Detail of work with stakeholders and emerging findings

Context for our work

To date, much of the research and analysis in the EV space has looked at using the opportunities from EVs to mitigate the challenges that they bring - specifically how the flexibility from EVs can be used to reduce their peak load.

We have some excellent information from a recent innovation project (discussed on pages 89 to 92 of FES 2019) about how different types of EV users are charging today at an aggregated level, most of whom are not being incentivised to smart charge / move their charging demand. This has shown us that, for example,

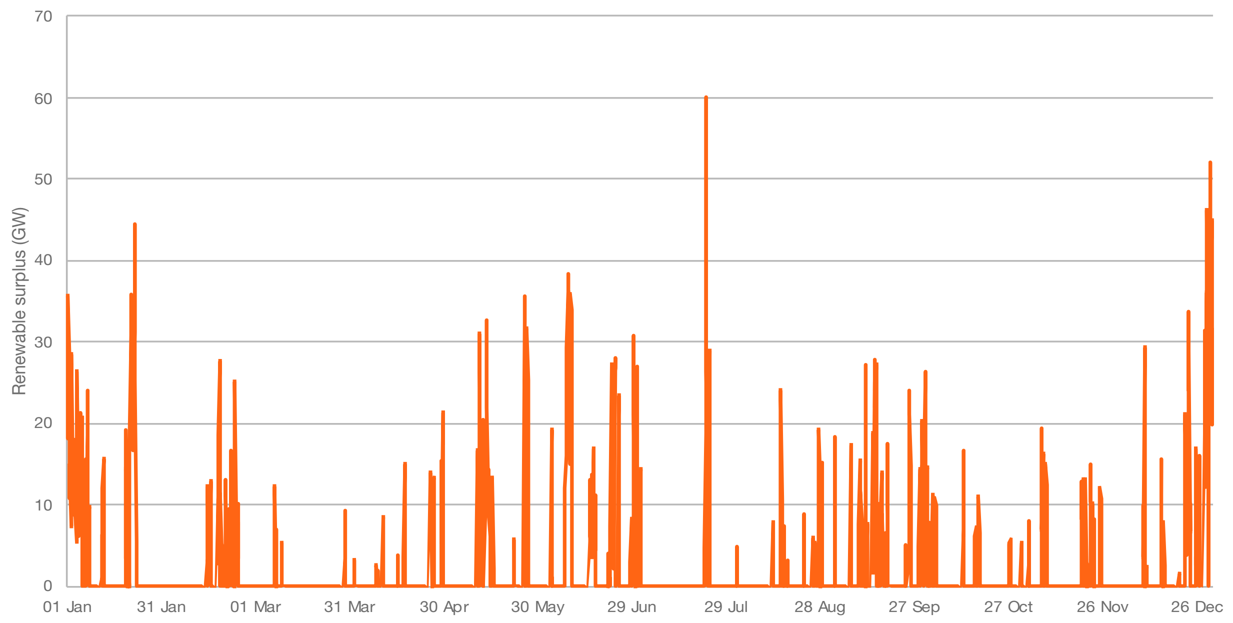
- residential EV users charge most often from Monday to Thursday, with a peak in demand from 7 to 8pm.
- workplace charging peaks around 9am as people arrive at work, and tails off in the afternoon, with little or no charging on weekends.
- public charging peaks slightly later in the morning, with other secondary peaks across the day.
- across all types of EV user, charging is significantly reduced over the weekend.

At the same time, our FES 2019 modelling suggests that from 2030 onwards there may be periods of significant excess supply of renewable power, potentially caused by different factors such as high solar output, high wind output, bank holidays depressing electricity demand etc. Some of these periods may be more predictable than others:

Documents such as our Operability Strategy Report highlight some of the changes that rapid renewable generation growth can bring to the electricity system. For example, system frequency is moving away from target frequency more rapidly in low inertia situations, and reserve needs are changing.

A key question to explore in our work is therefore the extent to which EVs could be used to address some of the changes arising from renewable generation growth - and where they may be a less suitable solution.

Illustration of hourly oversupply in 2040



What did we do?

From December 2019 to February 2020, alongside our usual FES engagement, we undertook 'deep dives' with eleven leading organisations working in the electric vehicle space. Stakeholders were sent a pre-read document with outline messaging, analysis and questions ahead of the deep dive.

Discussion themes

The size of the flexibility market opportunity for EVs (Key conclusions 1, 8)

Stakeholders highlighted several areas where electric vehicles can gain revenue whilst supporting the system needs arising from a growth in renewable generation, notably:

- Reducing electricity costs via smart charging
- Price arbitrage via Vehicle to Grid
- DNO services / managing local constraints
- ESO balancing services

Of these, a number of stakeholders noted that **distribution level markets** would potentially be the **key areas of revenue opportunity** for electric vehicles. However, these are still at trial stage and revenue opportunities are likely to be time limited.

Others noted the recent fall in price, particularly for shorter timeframe balancing services such as fast frequency response. In addition, some of the people we spoke to felt that future reserve and response markets would likely not be big enough to support large numbers of EVs, meaning that potential revenues could be small or non-existent.

The majority of stakeholders believe **smart charging will have the biggest system benefit** in terms of reducing use of thermal generation at times of high demand and making best use of available renewable electricity at other times. Many stakeholders noted even static tariffs for charging electric vehicles (e.g. economy 7 type or similar) will bring huge benefits to the system (for example absorbing excess power overnight). Moreover, as the additional cost of smart technology is minimal and smart charging is 'hands off' for consumers, only small financial gains are needed for consumers to participate.

Rollout of smart charging and Vehicle to Grid (Key conclusions 1, 2-5)

In terms of future development of smart charging, stakeholders in general were **very positive about the future rollout of smart charging,** noting the recent requirement for all new charge points to be smart enabled, the minimal additional cost to do this and the fact that smart charging is an easily understood concept for consumers.

There were **more mixed views on the potential roll out of Vehicle to Grid, particularly in a residential context:**

- Some stakeholders have successfully trialled V2G projects with residential consumers, often using ESO carbon intensity data to align vehicle import / export of power with times of excess / low renewable generation. Different models have included tariffs where consumers were simply rewarded for making their battery available, thereby reducing revenue risk to the consumer, and also where batteries were leased to avoid any concerns over battery degradation.
- New technologies such as in car inverters (allowing vehicles to feed AC power back onto the electricity system using a standard charging cable) could also offer new and more commercially viable opportunities, as this technology is cheaper than bi-directional chargers.
- Others noted concerns around the current and future cost benefit case for V2G, and how this might affect rollout in the future. In particularly there were a range of views on the potential for bi-directional charging technology to fall in cost, and potential battery degradation. Others noted current market structures that erode the revenue case for Vehicle to Grid or make it more difficult to access markets (see below).
- Lastly, Vehicle to Grid was felt to be a more difficult concept for consumers to grasp, entailing a greater perceived loss of control than smart charging.

Consequently, some noted **commercial operators** (such as fleet operators, long term parking providers etc.) **may be more likely to participate in V2G than residential customers.** As these parties will have different charging profiles and availability compared to households, this is likely **to impact the kinds of services they could provide** to support renewable generation growth. For example, airport parking or railway station models are likely to be available for (dis)charging across most of the day, whilst vehicle fleets are more likely to be plugged in at night.

Smart engagement vs. smart availability / EV availability at times of system challenges (Key conclusion 1)

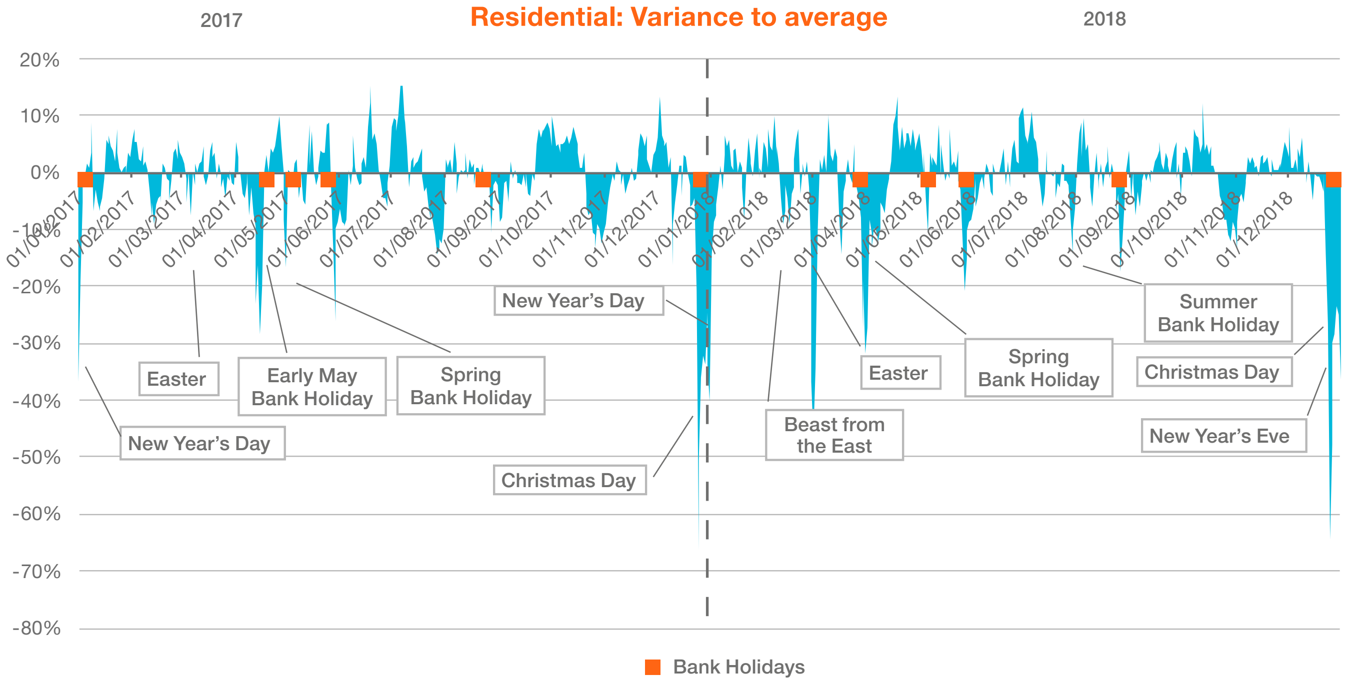
Some stakeholders distinguished between the roll out of smart or V2G technology, and **actual availability of assets for flexible use.** For example, it was noted that at the start of some V2G trials, consumers frequently used a manual override function to ensure charging availability. However, over time as they became more familiar with the technology and concept of V2G, they used this function less.

Similarly, a consumer may have all the assets for smart charging installed, but lifestyle events may dictate whether they can shift their demand or sell power on a particular day - as will factors such as whether it is the only car in a household.

One stakeholder noted how wireless charging can change behaviour as the 'hassle factor' of plugging a vehicle in to make it available to (dis)charge is removed.

Further, one stakeholder commented that as public charging infrastructure becomes more available, EV batteries could become smaller with more use of 'top ups' - potentially shifting some charging from night to day. Electrification of heavy transport is also more likely to require daytime rapid charging.

As National Grid ESO we have started to form a picture of how EV charging demand can change across the year due to different events, which may give some indication of where consumers may be less able or willing to engage in smart charging or V2G:



Interactions across flexible residential assets (Key conclusions 3-5)

Some stakeholders were keen to note **that EVs should not be seen as the first or only choice for shifting electricity demand** or exporting electricity across time.

A number of trials are in place looking at a **whole home approach,** optimising smart response across a number of assets. Understanding these potential interactions will be crucial in our FES modelling to ensure we are not double counting or underestimating potential residential response in different sectors e.g. heat and transport.

Some stakeholders noted the potential for vehicle to home as perhaps being greater than vehicle to grid. Similarly **at a commercial level, bi-directional charging of EVs on-site** (but not exporting power to the grid) could provide valuable demand shifting or reduction for the customer and system.

Barriers to EVs facilitating renewable generation growth (Key conclusions 6 - 8 and 9)

Asset roll out

Most stakeholders believed that **sustained incentives for EVs, chargepoints and flexible assets are needed for growth to continue** - for example continuation of the plug-in car grant and of benefit in kind tax incentives. This is particularly important as some stakeholders perceived the UK to be a riskier market for EVs than the rest of Europe, due to aspects such as exchange rate risk.

Market access

Stakeholders noted **difficulties for residential assets in general (not just EVs) to access ancillary and other markets:**

- The lack of synergies between ESO and distribution level markets / transmission and distribution level charging (being addressed through Significant Code Reviews, speed of change across industry and need for coherence.
- That bringing auctions closer to real time would make it easier for residential assets to access these markets.
- Supporting smaller parties to trial new approaches.
- Concern that future reserve and response markets will not be big enough to support large numbers of EVs.
- The difficulty in managing the registration, consolidation and access to services for smaller assets like EV batteries, for example requirements to test individual assets.
- Trial stage of distribution level markets and the potential for revenues to be time limited.

Financial incentives and revenue streams

Stakeholders noted how the direction of some charging reforms, for example reforms to how the transmission demand residual will be collected in future, are likely to reduce dynamic pricing and the opportunity to arbitrage at least in the shorter term. Specifically, reforms to residual charges coming in 2021 will reduce the incentives to load shift away from peak times.

Reforms to access and forward-looking charges, designed to send a signal to market participants, will take place in 2023 and could increase these incentives, but there is a clear policy gap between 2021 and 2023.

Consumer engagement

Two stakeholders noted that they felt the **use case** of a vehicle (e.g. residential vs commercial) and whether it's the only car in a household were the main drivers of demand patterns - over and above season. Other stakeholders shared data that showed **differences in rural and urban patterns** of driving and charging and how these impact networks. In future these could impact whether different flexibility services could be offered in distinct areas.

For both smart charging and V2G, several people noted that **point of purchase** is a real opportunity to engage with customers, explain concepts and set up, for example, smart charging defaults that suit their lifestyle.

Managing peak electric heat demand

Detail of work with stakeholders and emerging findings

What did we do?

We filmed a series of short videos with our heat experts, looking at why managing peak electric heat demand is important in a net zero world, explaining our assumptions in FES 2019, and asking for specific feedback from stakeholders in the areas of heat storage, insulation and consumer and technology behaviour.

Stakeholders across the industry and beyond were invited to comment or write to us with their views. We would like to thank all the organisations who took the time to send us detailed information, or who took part in follow up bilateral conversations.

The videos were publicised across a number of social media platforms including YouTube, LinkedIn groups and Twitter:

Why is peak electric heat demand important in a net zero world?

How do we model peak electric heat demand in the Future Energy Scenarios?

Inviting your views

We also conducted our own research on clean heat pathways and conducted expert interviews to seek a range of views on this important topic.

Themes from stakeholder discussions and research:

Heat pumps: further detail (Key conclusion 1c)

There are two types of heat pump, air source heat pumps (ASHP) and ground source heat pumps (GSHP). We anticipate that ASHPs will be the more prevalent type of heat pump in the UK in the future, as they require less space to be installed and are suitable for more types of home. Weather has a greater effect on ASHP than GSHP.

Peak heating demand from heat pumps will be lower and longer than peak heat demands from gas boilers, as they provide lower levels of heat over longer periods of time.

Electricity demand at different levels of heat pump performance is not well understood.

The electricity demand of heat pumps in GB is not well understood. Whilst a number of research projects and trials are underway, we do not yet have enough data from real heat pumps in a full range of UK homes, going through the full range of UK winters, to be able to confidently forecast how the technologies perform and how consumers will respond to different factors.

There are limitations in existing data in understanding heat pump performance in GB.

Studies from across Europe (from countries with greater penetration of heat pumps) will provide some limited information on performance of ASHP in GB. However significant differences in aspects such as housing stock (particularly fabric / insulation levels) and types of weather as noted above mean that these will not always be an accurate prediction of how these technologies behave in GB.

Heat pumps can work in extremely cold temperatures, but installation and sizing guidelines will impact this performance.

In cold weather ASHPs performance will drop due to having to work harder to extract useful heat from colder air. This leads to an increase in electricity demand to generate the same amount of heat. Winters in GB tend to be wetter than countries where heat pumps are already common. On cold, damp days droplets of water can freeze on the exchanger causing a large drop in performance - to counteract this ASHPs normally have a de-icing function such as an electrical coil again leading to period increases in electricity demand.

There is evidence to demonstrate that heat pumps can handle extreme cold down to minus 20 degrees Celsius, and there are heat pumps in operation in countries with more extreme cold temperatures than the UK.

However, heat pumps work more efficiently with warmer outside temperatures, and installation and sizing guidelines affect the performance. The current UK installation guidelines require heat pumps to provide sufficient heating on all but the coldest one per cent of days. Based on current installation guidelines UK households would have to be willing to accept that, for about 3.5 days a year, they may need additional heating to maintain a comfortable temperature.

Heat storage: further detail (Key conclusions 2 and 3)

Novel thermal storage technologies are emerging, but their role in zero carbon heating is unclear.

Heat storage can take a number of forms, each providing different services, needing different amounts of space and being better suited to different types of homes. Stakeholders have identified a range of options. A tank in an airing cupboard storing a few hundred litres of hot water is a well-known example. Very large heat stores built into foundations of homes could provide heat for many days but would only be suitable for new build homes. Novel storage technologies could fit in the same space as a traditional hot water tank and hold enough heat to provide hot water and space heating, but even these could still be too large for very space constrained homes.

Heat stores could also be outside the home in the style of a heat network connecting local communities. Further work is needed to understand how different heat storage solutions could best suit different homes, the value of the services these products could provide, and their role in a net zero energy system.

There is inherent heat storage in the fabric of all buildings, but the rate of heat loss (and hence impact on electric heating performance) is uncertain.

All buildings contain some heat storage in the thermal mass of the building. Building age, material, whether the home is airtight, and level of insulation are all factors in how quickly heat is lost from a building. There is limited information available about the performance of electric heating, particularly heat pumps, in buildings with differing levels of thermal mass / heat loss, but in the UK it is likely that air permeability in particular is a barrier to building heat storage. This is important as such information will impact whether future consumers are likely to want to switch off their heating for (short) periods of time without discomfort.

Societal change and consumer acceptability in heating (Key conclusions 1, 2 and 3)

Many of the electric heating solutions and storage options discussed here assume a certain level of societal change, whether that is society accepting a heating solution that provides sufficient heat on only 99 per cent of days, or adoption of new building standards to include heat storage options in all homes.

Some technological solutions may improve the consumer acceptability of different heating options. For example, heat storage could help heat pumps to provide a large amount of heat quickly on demand, similar to how gas boilers operate at the moment. This may make their operation more familiar and acceptable to consumers.

Further, the interaction across the ‘whole home’ in terms for example, heat storage, batteries (including EV batteries), smart appliances etc. need to be further understood, particularly from a consumer preference point of view. Similarly, the level of consumer understanding around the need to change heating options to meet a net zero future is low, making it more difficult to assess future behavioural preferences in both technology choice and how these technologies are used.

Thank you for reading our FES: Bridging the gap to net zero report.
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