A Day in the Life 2035

How a fully decarbonised electricity system might operate

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Interactive navigation

The Day in the Life 2035 is an **interactive document**, allowing you to decide how deep to dig into the energy system explored over the day.

Click on 'expands', in the form of highlighted yellow text or yellow boxes, for extra information or context, then click again to go back.

Click on 'drilldowns', in the form of orange boxes with a plus symbol, to 'deep dive' into key technologies, systems and participants in the future energy system.

Click orange hyperlinks to jump to supporting external resources or references.

The menu bar at the base of each page will help you navigate through the four sections of the document. Click the Home button at any time to return to this navigation page, or the Contents button to go to a full table of contents.

Click one of the four sections below to start exploring a Day in the Life of the 2035 energy system:

Introduction and summary

An introduction to the Day in the Life, and a summary of the key messages and learnings.

Day in the Life 2035

Explore how a net zero electricity system could operate on a cold, calm, still winter day.

See how the system components work together and the key role played by many system participants.

The winter week

Understand the calm, cloudy winter week that the Day in the Life sits within, and how weather conditions before and after the Day in the Life have been considered.

The 2035 net zero system

Dive into the system components of energy supply, demand, flexibility, storage and interconnection.

Explore the role played by digitalisation to help optimise system outcomes.

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Introduction

In order to meet the UK's climate change commitments and to enable other sectors to decarbonise, the UK Government has set a target that the power sector should be net zero carbon by 2035.

Achieving this ambition will require a revolution in how the energy system is operated at both a national and local level. It will also require sustained investment in both infrastructure and supporting technology.

The Day in the Life 2035 provides a snap-shot narrative of how a net zero power system could function on a cold, calm and cloudy, winter day. It will provide an insight into the whole-system challenges that must be addressed: balancing supply and demand, ensuring system operability, managing constraints, maintaining security of supply and ensuring that markets work efficiently to minimise costs across the whole energy system.

The narrative is deliberately illustrative and not prescriptive. The final form of the future net zero energy system is still evolving. The intention is to convey a view of how the system could operate, explore options to meet the biggest challenges, and to point to some of the innovative solutions that are beginning to provide answers.

The Day in the Life 2035 draws from several net zero enabling projects and initiatives. Click this box to find out more.

The Day in the Life 2035 has been produced by Regen and National Grid ESO as part of the Bridging the Gap 2022 programme.

We would like to thank all those at the ESO, Regen and industry experts who contributed their expertise to help create the Day in the Life.

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Executive summary

Executive summary

The Day in the Life 2035 presents an illustration of what a net zero power system could look like on winter's day with low winds and very little sunshine.

The analysis suggests that, even on such a winter day, the delivery and operation of a net zero power system is achievable, albeit with some legacy fossil fuel generation as a reserve. The technology needed is available today or will be attainable with continued innovation.

But it is a massive endeavour and success is uncertain. The critical requirement is a comprehensive net zero strategic delivery plan to accelerate the investment in low carbon generation, sources of flexibility, network infrastructure and digitalisation, as well as new system and market capabilities.

Achieving net zero will require the mobilisation of all parts of the energy industry and a myriad of market actors and stakeholders. It will also require the consent and active participation of businesses, energy consumers and communities in the wider society.

The prize is a decarbonised electricity system that remains both secure and reliable, and a major milestone towards net zero economy. It is also the opportunity to create a far more resilient and secure energy system, new consumer-based energy services and a range of enabling technologies and business solutions that will establish the UK as a world leader in the delivery of low carbon energy.

A net zero power system for a calm, cloudy winter day…

Despite good progress over the last decade, the race to build the necessary renewable generation to power a net zero electricity system is far from over. There is a huge challenge ahead to commission new wind, solar and other renewable energy projects, and to ensure that the infrastructure, systems and markets are in place to bring abundant low carbon energy to consumers in a cost-optimal way.

Energy storage is key, alongside development of low carbon dispatchable generation

The Day in the Life demonstrates that energy storage, especially long-duration storage, will be critical to make best use of low-cost energy, balance demand and supply, and to operate the system. The system will also need a significant capacity of low carbon dispatchable generation, potentially using fossil gas or bioenergy generation with carbon capture and storage or fuelled by low carbon hydrogen. New modular nuclear reactors could also play a role. However, the deployment pathway for these technologies is unclear

All types of demand-side flexibility will be needed

Energy consumers can play a critical role to deliver net zero in a way that is equitable and cost effective; they must be enabled to become active system participants. Domestic consumers play an important role, as do industrial clusters where concentrations of high energy demand, low carbon electricity generation, energy storage, heat recovery and hydrogen production could provide opportunities for multi-vector energy optimisation.

Smart technologies and agile markets unlock flexibility from across the energy system

There is an opportunity for new sources of energy demand to become active system participants, helping to balance the system and reduce energy costs. Smart electric car chargers, smart heat pumps with thermal storage, data centres and other energy users all play a major role throughout the Day in the Life, flexing their demand in response to price and/or system signals.

Integration, interconnection and diversity of supply will be critical.

During the Day in the Life, the net zero energy system is resilient because it is able to draw on energy from different technologies from different regions across GB, and from neighbouring energy markets. Diversity and market integration will help to reduce generation and price volatility caused by the weather. Interconnectors allow electricity to be imported during days like the Day in the Life, while allowing GB to become a net exporter of low carbon energy to neighbouring markets throughout the rest of the year.

Executive summary

… continued

System operability is critical

Managing the quality and continuity of power supply will become more challenging, but good progress is being made in this area with exciting new technical and market solutions coming forward. The Day in the Life points to a wide range of industry initiatives and innovation projects that are addressing this issue. However, it is important that the operability challenge remains at the centre of the sector's thinking to ensure that the GB electricity system remains reliable.

Markets must also be efficient

Markets must demonstrate high levels of information transparency, good forecasting, competition, price discovery and transactional/market efficiency to enable a net zero system.

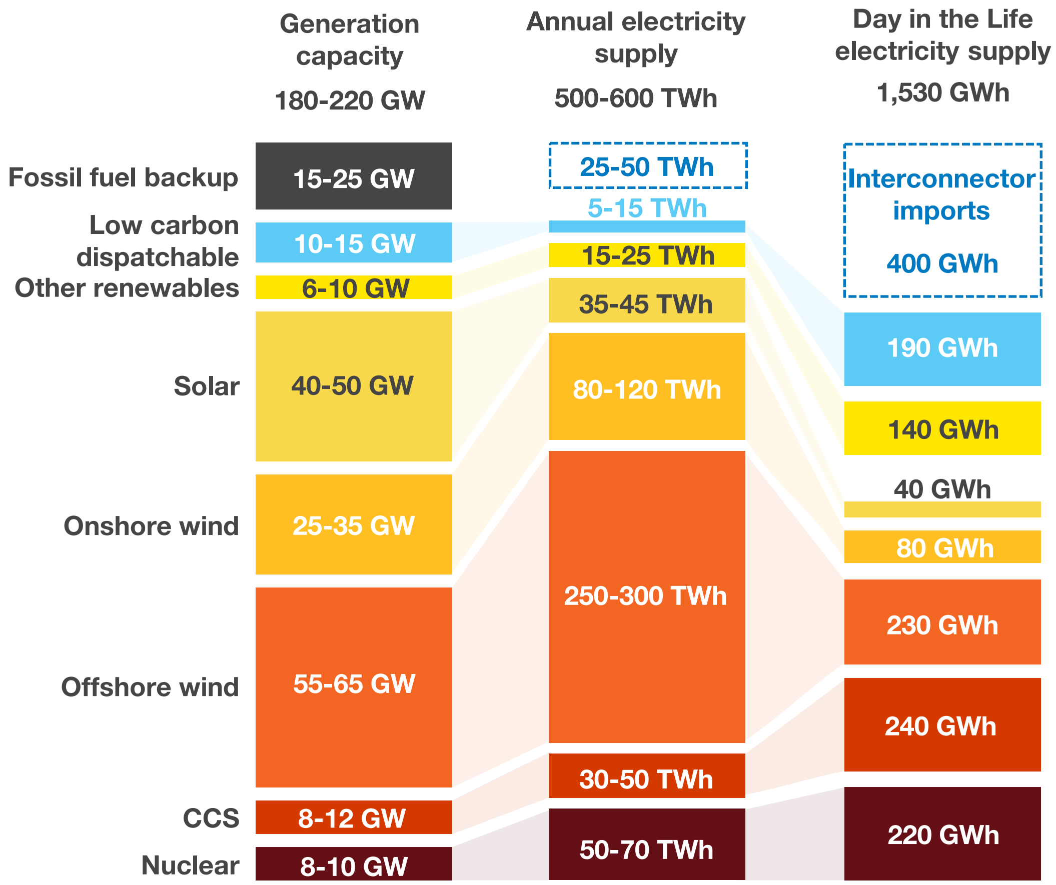
Collaboration and coordination between system operators, markets and actors is needed to ensure that the energy system works effectively and fairly

The technical and market solutions to operate a resilient net zero electricity system can only work if there is close collaboration between the ESO, network operators and the wider industry. Digitalisation and shared data will enable collaboration between these energy system actors, but there is still an organisational, regulatory and business process challenge to ensure that different system functions work effectively together.

Throughout the transition to net zero, there is an imperative to address wider socio-economic and equality issues. This includes, for example, tackling fuel poverty through energy efficiency, creating new green jobs while helping carbon-intensive industries to transition, ensuring costs are distributed fairly, and that access to new energy products and market services is open to everyone. In a more decentralised energy system, local and regional stakeholders have a greater governance and delivery role.

The Day in the Life 2035 reflects an energy system that will have undergone an unprecedented level of change in a little over a decade. Although there is a broad agreement on what is needed to make this happen, the nature of the transition will inevitably change and evolve as new solutions and opportunities present themselves.

The Day in the Life 2035 power system



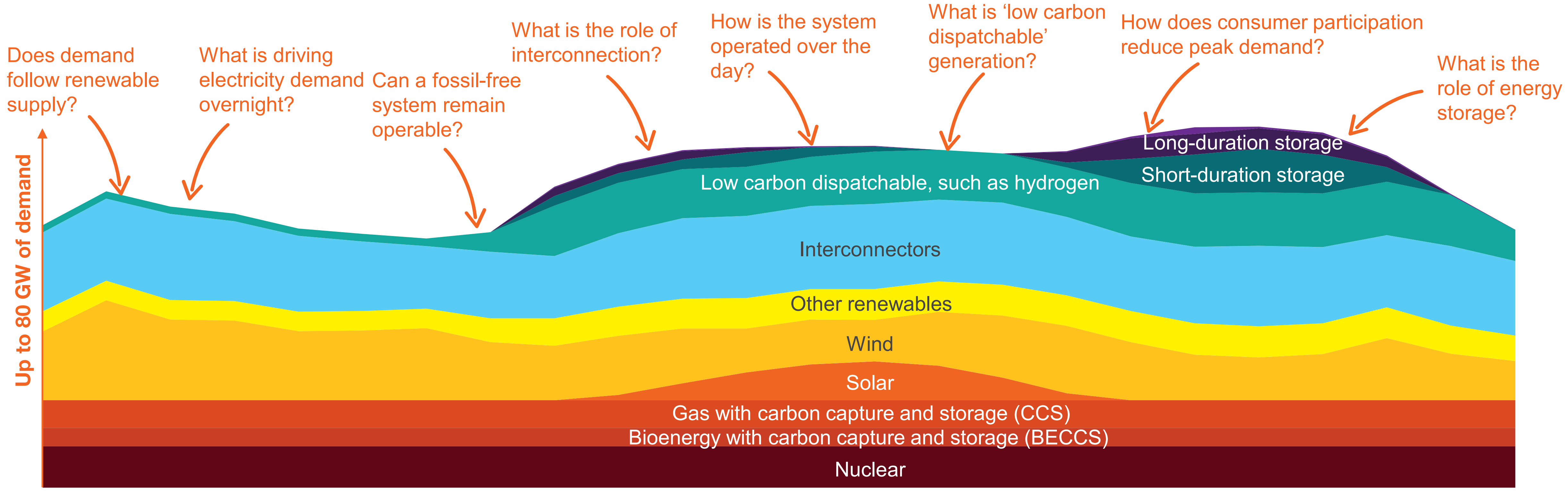
Annual electricity supply in 2035 is dominated by renewables. However, on the winter Day in the Life, with low renewable output and high demand, supply draws heavily on carbon capture and imports, alongside energy storage and demand-side flexibility.

The Day in the Life

The Day in the Life 2035 takes an illustrative look at how a fully decarbonised electricity system might operate on a cold, cloudy and calm winter day.

The following section goes through the day hour-by-hour, looking at the interaction between various elements of the energy system.
Investigate the Day in the Life across the four sections of the day by clicking the tabs below:

Overnight
Morning
Afternoon
Evening



The Day in the Life - Overnight

Morning

00 01 02 03 04 05 06

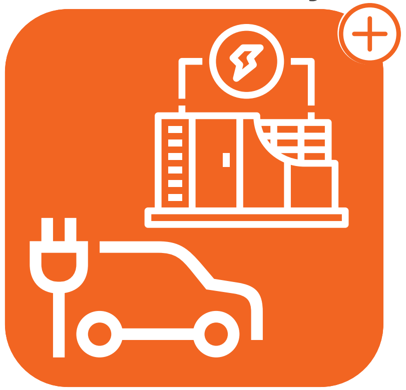
Overnight recharging
- Energy storage and EVs charge up on lower-cost electricity
- Low wind generation is bolstered by interconnection

The quiet hours
- Demand falls to its lowest as EVs finish charging
- Heat pumps preheat buildings ahead of the morning peak

Tap to expand

Click to drill-down

Demand for low-cost electricity



Operability: reactive power needed

The Control Room analyses the day ahead

Consumers' smart devices are busy

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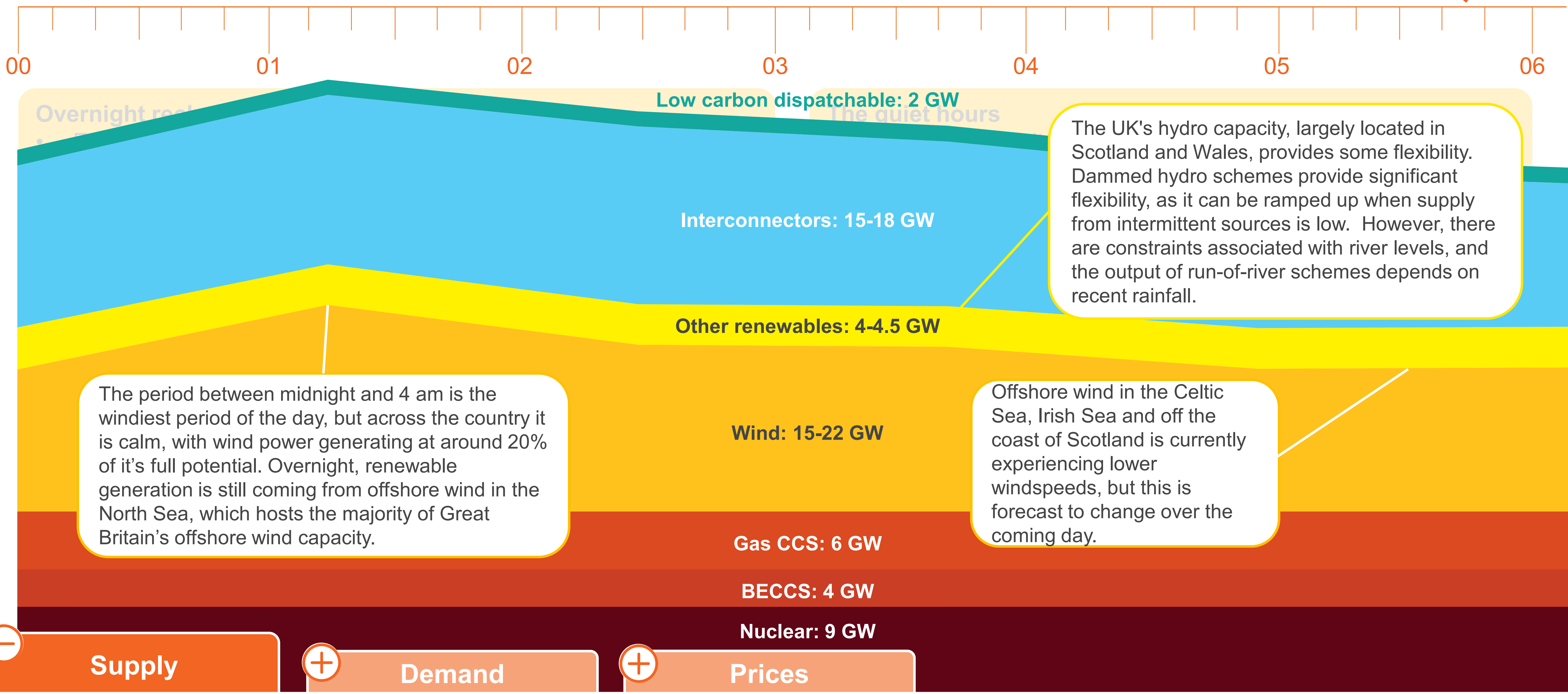
The Day in the Life - Overnight

Morning



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The Day in the Life - Overnight

Morning

00 01 02 03 04 05 06

The quiet hours

Storage and electrolysis

Energy storage stocks up on electricity when prices are anticipated to be lowest. In this case, this aligns with periods of higher wind output and low demand, peaking between 1 am and 2 am around 15 GW.

During the summer months, storage and electrolysis demand responds directly to periods of solar and wind oversupply, and is not confined to overnight periods.

Conventional demand, heat and EVs

‘Conventional demand’, from lighting, appliances and commercial and industrial activity reduces significantly overnight, lowering demand and electricity prices. Smart technologies take advantage of this and shift demand to lower cost periods. This can also be during periods of high renewable supply. This consumer demand remains at around 45 GW throughout the night.

Smart electric car chargers that avoided demand during the previous evening now draw on cheaper overnight electricity. Depending on the customer’s tariff, this might at a simple off-peak rate, or a dynamic tariff with half-hourly pricing.

Demand for appliances and lighting decreases steadily over the night, as night-owls head to bed and appliances finish their cycles. EVs that only needed a small top-up are now fully charged, further reducing demand.

In response to anticipated price signals around the morning peak, smart heat pumps pre-heat energy efficient buildings or charge thermal storage, delivering heat earlier to subsequently reduce demand.

The Day in the Life - Overnight

Morning

00 01 02 03 04 05 06

Overnight recharging
- Energy storage and EVs charge up on lower-cost electricity
- Low wind generation is bolstered by interconnection

The quiet hours
- Demand falls to its lowest as EVs finish charging
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In 2035, electricity markets are highly digitalised, responsive and open. Month, week and day-ahead wholesale prices based on forecast supply and demand anticipate that these early hours may be the cheapest of the day. As this materialises, energy storage and electric vehicles charge up throughout most of this period, particularly in the windier period between midnight and 3 am.

Short-term spot prices are more volatile, allowing agile assets like storage and DSR to operate more profitably. Avoiding 'bullwhip' effects is key, mitigated through better forecasting and transparency in a data-driven electricity system, and rapidly responding assets using automation and artificial intelligence (AI) to make decisions.

In addition to balancing, flexible generation and demand such as interconnectors and batteries may provide ancillary services to support grid frequency, grid inertia and grid voltage throughout the night, through reducing electricity import or even exporting for short periods, despite spending most of the night charging up.

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Demand for low-cost electricity

While electricity prices are generally high during the Day in the Life week, overnight prices dip slightly.

Tap on the concepts and technologies below to explore some of the key uses of low-cost electricity during the Day in the Life and throughout the year.

- Shifting demand to exploit low-cost renewables electricity
- Smart charging and smart appliances
- Electricity storage
- Thermal storage
- Interconnector export
- Hydrogen electrolysis

Click on the six topics on the right to read more

System operability: reactive power

Working closely with distribution networks, the ESO has a responsibility to manage the voltage levels of the system within safe operational limits. Voltage issues, caused by an increase or loss of reactive power, can appear quickly and, without intervention, move from one part of the system to another. This aspect of operability is highly dependent on specific regional and local conditions, including the generation mix, sources of demand, power flows and events like network outages.

Reactive power services are required to make sure voltage levels on the system remain within a given range. In simple terms, the right level of reactive power is needed to maintain stable power supply across both the transmission and distribution networks.

In the past, the primary role of distribution operators was to maintain voltage controls within their network area, while reactive power services were provided mainly by transmission network demand customers and generators managed by the ESO. However, this is significantly different in an electricity system free from unabated fossil fuels.

By 2035, the requirement for reactive power management has changed in a more dynamic and decentralised net zero energy system. Distribution networks have needed to develop additional tools and options to maintain voltage levels on their networks, requiring a much more integrated, whole system approach. As is currently being investigated through the ESO's Future of Reactive Power project and Voltage Pathfinder project, low-cost solutions to maintaining voltage and regional markets for reactive power services have been developed alongside Distribution System Operators. Adoption of a whole system approach, backed by technology innovation and market development, ensures that voltage stability does not become a barrier to achieving a 2035 net zero electricity system.

During the Day in the Life, many options for reactive power services will be available at both a regional and national level. Reactive power services are provided by a wide range of assets, including batteries, compensators renewable generators with converters, HVDC interconnectors and synchronous generators such as gas CCS and pumped hydro. Overnight, with demand low and wind power higher than the rest of the day, these services may be called upon.

For more on reactive power in the future energy system, follow the links below:

Current reactive power services
Voltage Pathfinder
Future of Reactive Power
Power Potential

The Control Room of the future

A physical control room has traditionally been at the heart of any network operation. People actively using a combination of network tools, expertise and experience to assess risks, dispatch assets and take a range of actions to provide the most secure and economic solution for the end consumer.

In 2022, the role and capability of the ESO control room is already changing in response to the continued growth of renewable energy, the massive expansion in the number of system assets and actors, changes in energy flows and the imperative to not only maintain energy security and reduce costs, but also to support the transition to net zero.

Within the ESO and GB's distribution networks, work is underway to digitalise, automate and integrate control room functions. The ESO is overseeing the transformation of the Electricity National Control Centre, with the aim of having the capability to operate a carbon free electricity network by 2025.

By 2035 it is expected that the way control rooms work will have radically changed. Key features of the new control function will include:

- Use of data integration and digitalisation to create new markets, improve situational awareness and inform decision making.
- Higher levels of automation to streamline processes and utilise new services from thousands of potential system actors. The Day in the Life strongly features complex interactions such as V2G, aggregated smart appliances and dynamic electricity pricing, all of which depend on data and digitalisation to work most effectively.
- Use of virtual energy systems with 'Digital Twin' simulation tools and Artificial Intelligence capability to increase system learning and inform decision making. During the Day in the Life, the control room uses these tools to identify energy system risks, assess their impact and prepare an appropriate response, avoiding the fallback option of unabated fossil fuel generation to ensure security of supply.
- Far greater levels of integration and collaboration between transmission and distribution system operation functions to ensure alignment of system actions and optimisation across networks
- Greater integration and cooperation with neighboring energy systems in Ireland and the rest of Europe, through interconnection and the use of dispatch and other control room functions.

Future of the Electricity National Control Centre

A strategy for a Modern Digitalised Energy System

Introducing the Virtual Energy System

Consumer flexibility

Consumer participation is a key aspect of the Day in the Life. Overnight, as electricity prices dip, smart chargers and appliances respond to dynamic price signals to charge vehicles and fill up heat stores. This saves the consumer money and helps to reduce demand during peak day-time and evening periods.

The motivation and ability to change their behaviour will vary. Some consumers may be very proactive, adjusting their behaviour to minimise energy costs or their carbon footprint. The majority of consumers are likely to be more passive, preferring to let smart technologies control the shift of energy demand where this benefits them.

There will also be some consumers who are unable, or unwilling, to participate in the same way. This could create potential energy inequality which must be addressed.

Possible consumer responses

	Price-driven	Carbon-driven	Revenue-chaser
Passive	Happy with a simple time-of-use tariff, but lets a smart app or third party do the work. Might sign up for an EV charger, or use storage heaters, with an off-peak tariff.	Signs up to a low carbon smart app/tariff but relies on technology to respond to changing carbon intensity throughout the day.	Responds to system flex signals, allowing their assets to be directly used for demand flexibility, but only if smart appliances, an application or an aggregator do the work.
Active	Has a dynamic/agile tariff with half-hourly electricity pricing, and pro-actively changes behaviour to avoid peak costs. Uses smart appliances and apps but also manages energy consumption where feasible.	Has a green tariff and responds to carbon intensity signals, such as through a carbon intensity app. Proactively avoids peak carbon periods, tracks carbon emissions, and may engage in local clean energy markets.	Actively changes behaviour to maximise revenue from flexibility markets. Participates in active Demand-Side Response alone or via an aggregator. May sell power from generation or a battery for an added revenue stream.

Consumer participation is a gradient, and many consumers will fall somewhere between these categories.

Implicit flexibility (price driven) — Price-driven and Carbon-driven

Explicit flexibility (Income driven) — Revenue-chaser

The Day in the Life - Morning

07 08 09 10 11 12

Waking up
- Demand rises rapidly
- Dispatchable generation ramps up

The morning peak
- System responds to demand rise
- Local flexibility plays a role

Steady morning
- Demand levels off but remains high
- A little solar, but North Sea wind falls

Operability: frequency is managed

Electric transport takes to the road

Hydrogen-fuelled generation kicks in

Balancing occurs at a local level

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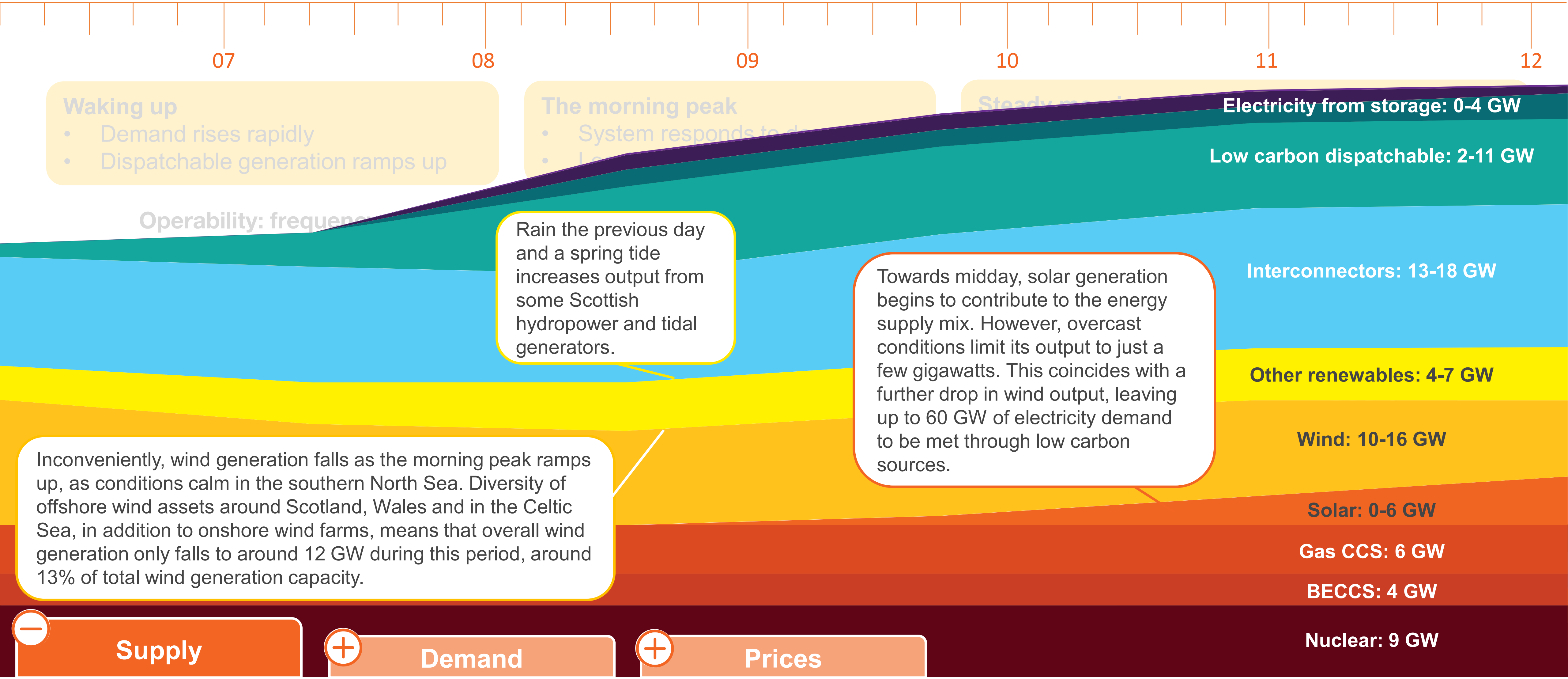
Afternoon



Rain the previous day and a spring tide increases output from some Scottish hydropower and tidal generators.

Towards midday, solar generation begins to contribute to the energy supply mix. However, overcast conditions limit its output to just a few gigawatts. This coincides with a further drop in wind output, leaving up to 60 GW of electricity demand to be met through low carbon sources.

Inconveniently, wind generation falls as the morning peak ramps up, as conditions calm in the southern North Sea. Diversity of offshore wind assets around Scotland, Wales and in the Celtic Sea, in addition to onshore wind farms, means that overall wind generation only falls to around 12 GW during this period, around 13% of total wind generation capacity.

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Waking up
- Demand rises rapidly
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The morning peak

Storage

Conventional demand, heat and EVs

Smart technology is used to control flexible demand like smart heat pumps, to turn down or defer demand to avoid morning peak prices. This ensures that demand does not rise too quickly during the morning peak, and therefore easier to manage. A small proportion of electric vehicles may even export energy back to the grid through Vehicle-to-Grid technology.

Demand for lighting, hot water, electronics etc. inevitably increases at the start of the day. While substantial strides have been made in deferring demand for EVs and electrified heat, many uses of electricity are less deferable – unless the building has small-scale battery storage, which in 2035 is not yet commonplace.

With the morning peak negotiated and the working day well underway, demand settles at around 70-75 GW. This is significantly higher than winter daytime demand in 2022, which typically sits just around 45 GW.

The Day in the Life - Morning

07 08 09 10 11 12

Waking up
- Demand rises rapidly
- Dispatchable generation ramps up

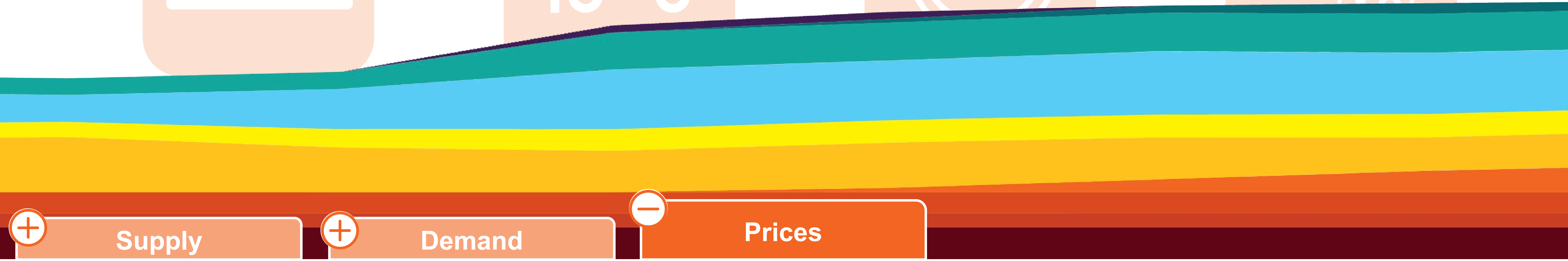
The morning peak
- System responds to demand rise
- Local flexibility plays a role

Steady morning
- Demand levels off but remains high
- A little solar, but North Sea wind falls

As demand increases during the morning, generation from nuclear, renewables, gas CCS and bionenergy cannot fully meet demand.

As a result of this potential shortfall, short-term wholesale prices rise, providing a signal for interconnectors and higher-cost hydrogen-fuelled generation to increase supply to meet demand. Some energy storage and demand-side response also enters the market, capturing high prices during this peak period.

Prices stabilise during the rest of the morning but remain higher than average. Higher-cost hydrogen and other low carbon dispatchable generation is incentivised to provide higher levels of output.



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System operability: frequency

Throughout the Day in the Life, maintaining the system frequency is critical to protect the electricity system, as well as customer assets and equipment.

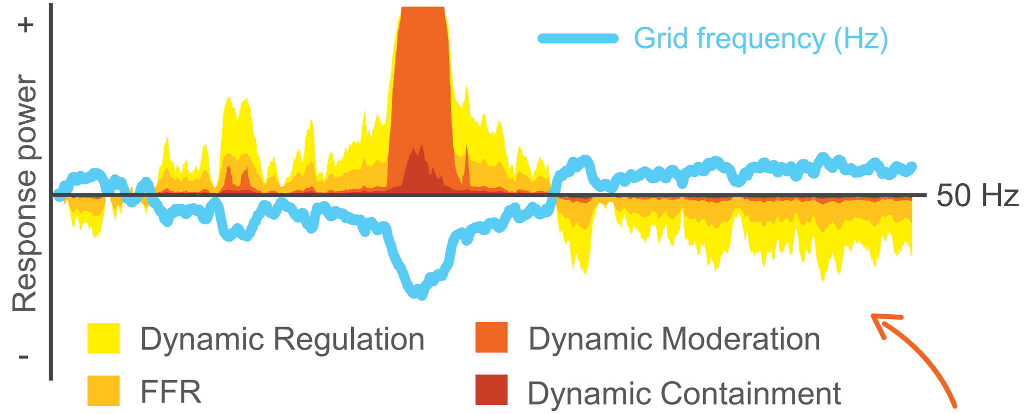
Previously, frequency was aided by the system inertia provided by large fossil fuel generation assets. During the Day in the Life, frequency must be prevented from 'wandering' above or below the 50 Hz target, without the aid of these unabated fossil fuel assets.

Frequency control is about having sufficient power response on the system to manage the deviations between supply and demand and ensuring that this capability is maintained at all times. The speed of response is important; the faster frequency is brought back within tolerances, the lower the level of power adjustment that is needed. The Day in the Life morning peak, where demand is rising substantially based on the decisions of millions of individual consumers, is a prime example of where frequency could deviate if not carefully managed.

During the morning peak, dynamic response assets such as batteries are deployed in just milliseconds to make small adjustments in their electricity import and export. Additional assets and service providers are ready to make larger power changes if a greater response is needed. These frequency response solutions are now well established and efficient. Artificial intelligence allows the ESO to better anticipate system conditions that could lead to rapid changes in frequency, while automated controls and rapid response assets maintain frequency control even on days which have large swings in generation or demand.

Despite the lack of unabated fossil-fuelled generation, and a potential increase in frequency deviation events, the stability of the 2035 net zero electricity system is maintained by battery storage and innovation that has allowed low carbon technologies to also provide new forms of inertia.

The graphic below illustrates how the ESO's new suite of Dynamic Services could work together to respond to the morning peak, where demand rises rapidly ahead of supply. Follow the signposted links for even more information about frequency services.



Thanks to Open Energi for the graphic!

Dynamic Containment
NOA Stability Pathfinder

Electric transport in 2035

By 2035, the electrification of transport could add 50-80 TWh to annual electricity demand. Fulfilling this demand will require investment in both charger and network infrastructure, but it also requires that transport consumers charge their vehicles in a way that is smart and works with the energy system.

Charging for electric vehicles will introduce a major new demand challenge for electricity network operators. However, the flexibility of when people charge vehicles also creates an opportunity to balance electricity supply with demand and could even offer new forms of energy system services.

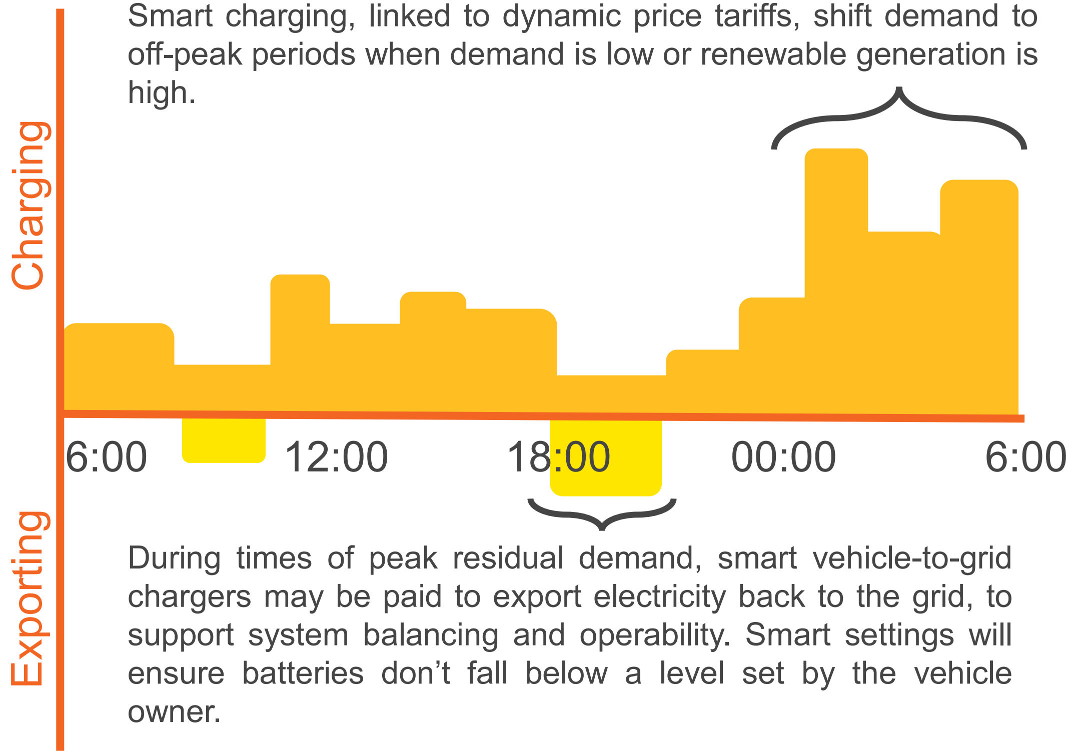
The principal incentive for transport users to charge during off-peak periods will come in the form of price signals from the electricity market, linked to smart chargers and dynamic tariffs. The Day in the Life assumes a very high uptake of this type of tariff.

Although not expected to be widespread in 2035, chargers fitted with Vehicle-to-Grid or Vehicle-to-Home technology could even export electricity back to the grid or the home, helping to increase supply during peak times or when renewable generation is lowest.

Vehicle owners will be able to sell their demand flexibility and energy storage capacity to provide electricity network services, including for example, through local flexibility markets to help manage local network constraints.

EV charging will dynamically respond to available supply and market prices

Smart charging, linked to dynamic price tariffs, shift demand to off-peak periods when demand is low or renewable generation is high.



During times of peak residual demand, smart vehicle-to-grid chargers may be paid to export electricity back to the grid, to support system balancing and operability. Smart settings will ensure batteries don't fall below a level set by the vehicle owner.

Hydrogen-fuelled generation

Low carbon hydrogen could be used as a dispatchable generation fuel in generation sites that are either 100% hydrogen or are able to operate with a blend of hydrogen and biomethane or fossil gas.

Hydrogen-fuelled power generation could play an important role as part of the UK's net zero and industrial strategy. Whether sufficient generation capacity is available by 2035 is a key uncertainty.

Already there are manufacturers offering hydrogen blend turbines, with a promise to supply 100% hydrogen turbines soon. There are also several large-scale hydrogen power demonstration projects in the pipeline.

At present, however, there are no large-scale hydrogen generation plants in operation, and a switch to hydrogen will require a step change in localised hydrogen production, investment in new plants and to retrofit existing generation assets. Such as shift would require a rise in carbon prices as well as the introduction of revenue support both for hydrogen production and power generation.

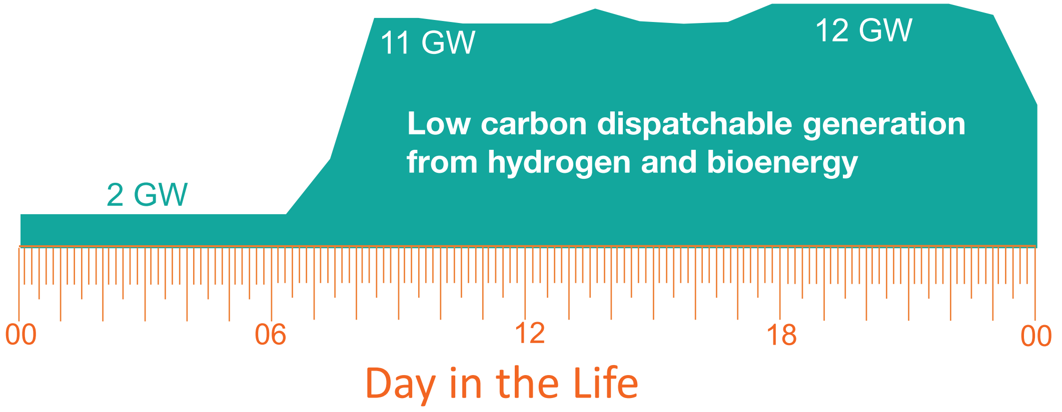
At a smaller scale there is potential for generators operating 'peaking plant' within industrial clusters to switch to 100% hydrogen fuel or a hydrogen blend. Hydrogen generation is also likely to feature in areas of very high renewable energy production, for example Scottish Islands, to provide an alternative to fossil fuel generators. Imported hydrogen in the form of hydrogen or ammonia could also be an option for hydrogen supply.

While the future of hydrogen is one of the key uncertainties, its use to provide dispatchable power features in several net zero scenarios including the Climate Change Committee's 'Balancing' pathway that informs the Sixth Carbon Budget.

Hydrogen-fuelled generation during the Day in The Life

Flexible, dispatchable, low carbon generation plays a major role in the Day in the Life, providing extra power during the peak demand periods when renewable generation is low.

During the morning peak, hydrogen and other low carbon dispatchable generation such as biomethane is providing over 11 GW of power and remains at around this level throughout the day. This generation is situated in hydrogen-based industrial clusters, and in areas of high renewable output where green hydrogen production is concentrated.



Local and regional flexibility

The Day in the Life features high volumes of renewable energy to meet growing demand from electrified transport, heat and industrial processes. This complex, decentralised electricity system requires active management of thermal load constraints on the distribution networks, to avoid having to curtail generation and reduce infrastructure upgrades.

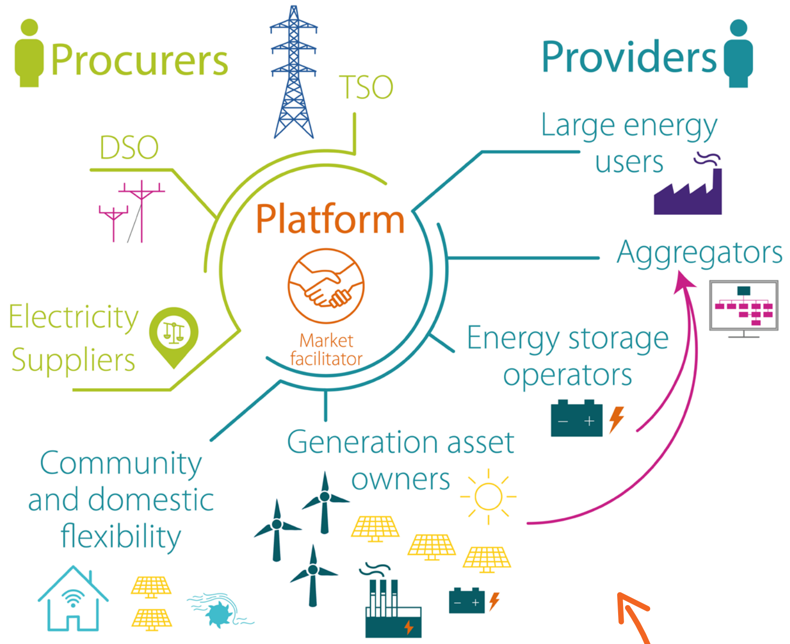
While network constraints are a significant barrier to renewable energy deployment, distribution networks can offer a range of connection agreements including the use of Active Network Management, to speed up connections and maximise available capacity.

During the Day in the Life, Distribution System Operators utilise local flexibility services as an alternative solution to manage constraints and optimise the use of network capacity. The distribution networks have contracted flexibility services from storage operators, energy users and (via aggregators or community groups) from a wide range of small-scale consumers and asset owners, including individual households.

The use of consumer flexibility is commonplace, and allows every consumer to participate in some form, with the aid of smart meters and appliances. Consumers with a smart EV charger, domestic battery, heat pump or storage heater are able to participate and be paid accordingly for their assets providing key flexibility to the local distribution network, helping to balance energy flows on a local level and avoiding balancing actions being passed on to the transmission system.

Investment in local network infrastructure will also be needed, to support the substantial increase in electricity demand across the country. This is especially true on the low voltage network, including transformers and feeder cables at street level, which support the growth of home-charging for EV vehicles and the use of electrified heat. Integration between local energy plans and network planning is key to make sure this investment is well targeted.

The role of a local flexibility market



The role of a local flexibility market, from Regen's local flexibility markets guide

The Day in the Life - Afternoon

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Renewables up slightly
- Solar output peaks
- Wind output rises slightly

Consistent demand
- Heat pumps run steadily during the afternoon
- Workplace and business demand is significant

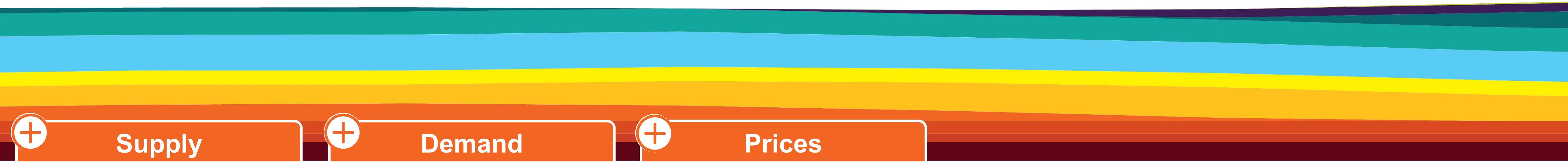
Heading home
- Start of the evening peak
- Risk of system imbalance

Diverse generation aids the system

Commercial and industrial flexes

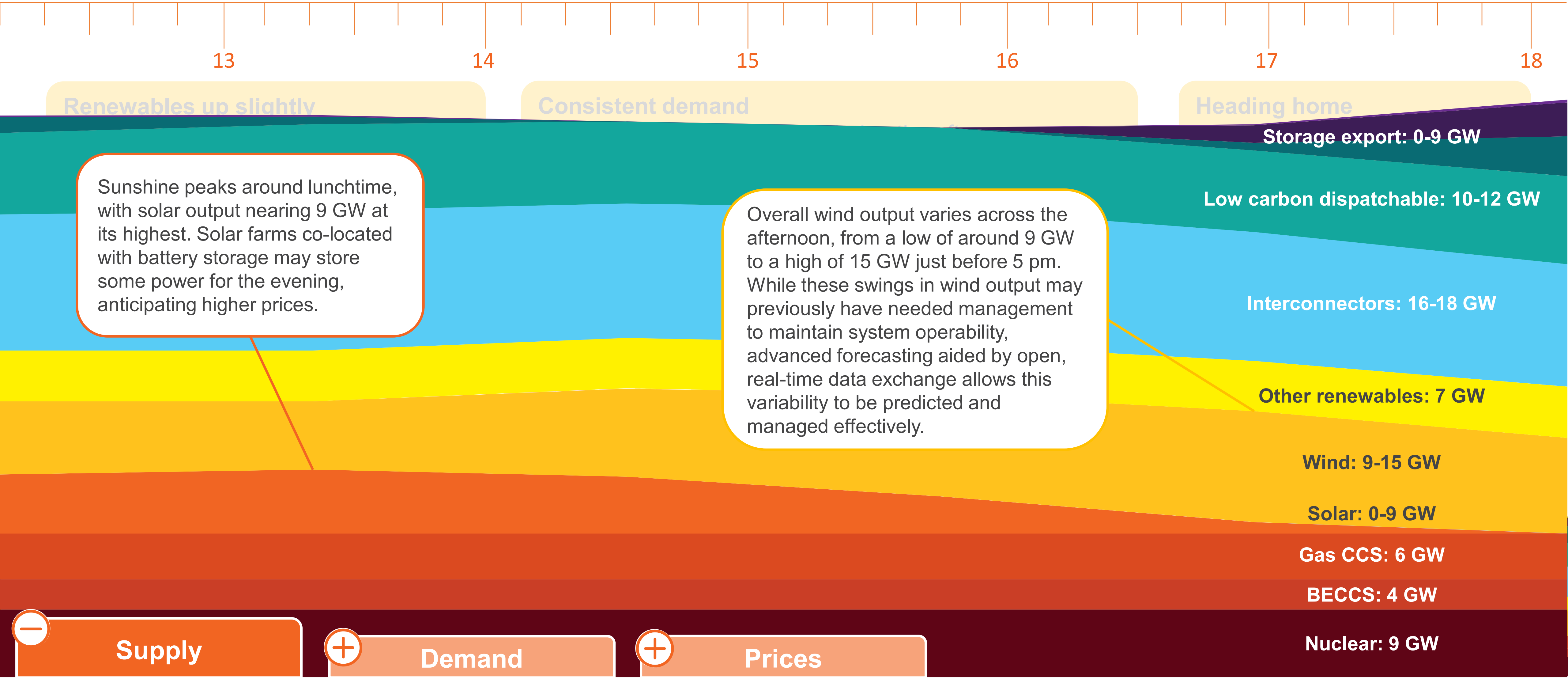
Operability: constraints are managed

Distribution networks manage high demands



The Day in the Life - Afternoon

Morning
Evening



Sunshine peaks around lunchtime, with solar output nearing 9 GW at its highest. Solar farms co-located with battery storage may store some power for the evening, anticipating higher prices.

Overall wind output varies across the afternoon, from a low of around 9 GW to a high of 15 GW just before 5 pm. While these swings in wind output may previously have needed management to maintain system operability, advanced forecasting aided by open, real-time data exchange allows this variability to be predicted and managed effectively.

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The Day in the Life - Afternoon

13 14 15 16 17 18

Renewables up slightly

Consistent demand

Heading home

Conventional demand, heat and EVs

Demand across the afternoon is relatively consistent at a national level. Locally, especially along major trunk roads and commercial hubs, there is a significant spike in demand for EV charging from vehicles that have been on the road.

After 3 pm, with sunlight rapidly fading, sources of Demand-Side Response (DSR) such as large commercial consumers, industrial consumers and aggregators of smaller assets are financially incentivised to reduce demand.

Over the last two hours of the afternoon, demand rises to around 80 GW. Without demand side flexibility, the day's 'unmanaged' peak could have breached 100 GW, which would be impossible to meet without the use of unabated fossil fuel generation.

The Day in the Life - Afternoon

Morning
Evening

13 14 15 16 17 18

Renewables up slightly
- Solar output peaks
- Wind output rises slightly

Consistent demand
- Heat pumps run steadily during the afternoon
- Workplace and business demand is significant

Heading home
- Start of the evening peak
- Risk of system imbalance

While wholesale electricity prices are relatively high, co-located solar and storage sites may choose to store their solar output to export later in the evening.

Short-term wholesale prices are lower during the mid-afternoon, where renewable output is at its highest. Data centres tailor their data processes and cooling load with dynamic tariffs, aware of the upcoming higher early evening costs.

The wholesale price begins to rise at the start of the evening peak, as anticipated by electricity storage asset owners. Storage begins to export, capturing these higher prices.

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Diversity of renewable supply

The 2035 energy system utilises a wide array of renewable energy sources, many of which rely on environmental conditions to generate energy. For an efficient, low carbon energy system, renewables need to be geographically diverse and generating electricity at different times.

This geographic diversity helps avoid the risk of having a high concentration of wind turbines within the same weather window, for example, when a low-wind high-pressure system sits over the east coast and southern North Sea.

Hydro, wind, solar and marine energy in Scotland

Offshore wind and marine energy in the Celtic Sea, and interconnection to Ireland

Click the orange circles for more!

Other forms of renewables, such as tidal and geothermal

Solar farms and rooftop solar across the country

Interconnectors to continental Europe

Industrial clusters

The net zero energy transition will create opportunities for new and existing industrial clusters to develop in areas with access to low carbon energy.

Industry has always located next to sources of energy supply; many of GB's industrial clusters have historically been located near to sources of coal, for example. The green industrial revolution will be no different, with high energy users developing around locations with access to abundant low carbon energy.

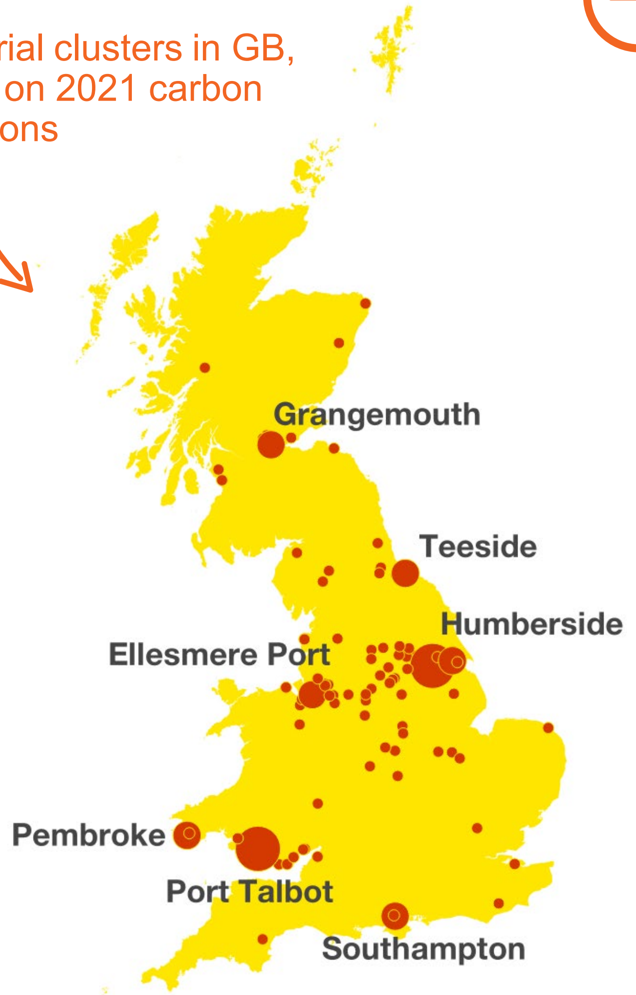
New industries, such as tech and data industry, may choose to locate near to low-cost renewables. This could bring more industry to places such as in the north of Scotland, Wales, along the east coast and in South West England.

As well as renewables, clusters are well suited to host other low carbon energy technologies, such as carbon capture, waste heat recovery and energy storage. The development of hydrogen electrolysis is an example of complimentary industry and low carbon technological development.

How new and existing industrial clusters generate, procure and consume energy will be critical for the development and operation of the net zero energy system. The ability to generate and store energy, as well as to flex energy demand will make clusters important participants in the energy system. The development of hydrogen electrolysis, for example, is a great example of complimentary industry and low carbon technological development.

During the Day in the Life, industrial clusters feature existing energy intensive industry, such as steelworks and chemicals, alongside newer industries such as electric vehicle manufacturing, battery gigafactories and data centres. To varying degrees, these are all able to ramp demand up or down in response to market signals, providing a vital source of demand-side response.

Industrial clusters in GB, based on 2021 carbon emissions



System operability: constraints

A key challenge for the Day in the Life energy system is managing the high variability of renewable energy generation, especially in areas of high generation capacity relative to energy demand such as northern Scotland. The 2035 system is based on significant infrastructure investment throughout the 2020s and early 2030s, and other non-network solutions, without which the system would incur constricting thermal constraints, higher system balancing costs and the loss of valuable energy resource.

The occurrence of constraints, and increasing balancing costs, is typically seen across "boundaries" between the transmission network zones, the most notable of which is the Scottish to North of England boundary. During the afternoon in the Day in the Life, hydropower and wind power from Scotland is moved to the rest of Great Britain, to meet electricity demand in areas of the country with less renewable resource.

It would be extremely costly, and sub-optimal, to alleviate all constraints. There are, however, a number of infrastructure and complimentary non-infrastructure solutions that will reduce the occurrence of constraints, and their cost and carbon impact. One of the key steps is to adopt a more Holistic Network Design to identify the best investment options for onshore and offshore infrastructure.

The Day in the Life features key network infrastructure-based solutions such as:

- Upgrades to transmission network capacity based on a Holistic Network Design and strategic planning at a national and local
- Development of a more integrated offshore transmission network
- Greater interconnectivity to adjacent markets in Ireland, Scandinavia and Europe.

Complementary solutions not based on network infrastructure also feature during the Day in the Life, including:

- A wider range of flexibility assets, including long-duration energy storage and demand-side response
- More efficient balancing processes, aided by higher levels of automation and digitalisation
- Greater integration and coordination between transmission and distribution networks
- Flexible connection agreements and use of Active Network Management (ANM)
- Encouraging and incentivisng energy generators and major demand users to co-locate in areas with strong networks – e.g. hydrogen electrolysers and data centres.

Network Options Assessment
Constraint Management Pathfinder

Distribution networks & operators

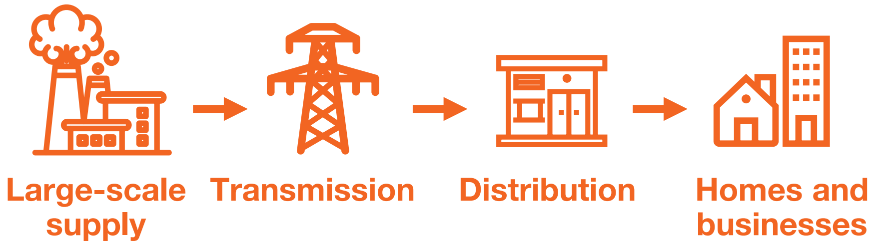
Millions of electric vehicle chargers, heat pumps and other forms of new electricity demand have connected to the electricity distribution networks. Alongside this, a much greater proportion of generation and flexibility is likely to be distribution-connected, including solar PV, onshore wind and battery storage.

By 2035, the electricity system has become highly decentralised. The previous linear electricity system, with generation, flexibility and balancing driven by large, transmission-scale assets, has been transformed. Now, distributed generation from renewables and distributed energy storage, dispatchable generation, and demand-side flexibility mean that an increasing proportion of power flows and balancing happen entirely on the distribution networks, facilitated by Distribution System Operators (DSOs).

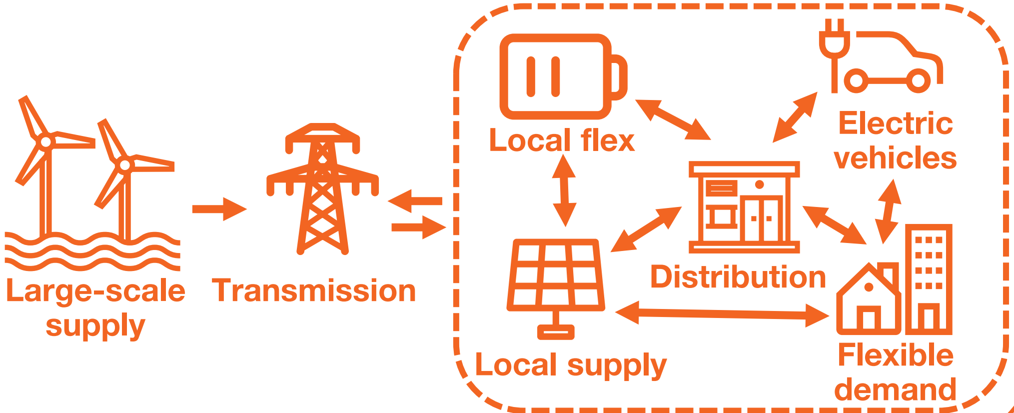
Real-time data sharing between system operators, combined with smart, digitalised network infrastructure, will allow the DSOs, transmission operators and ESO to coordinate network functions such as investment planning, constraint management, reactive power, balancing actions and flexibility markets to operate an efficient system.

During the Day in the Life, the low levels of onshore wind and solar output mean that a significant proportion of electricity supply comes from transmission-scale assets such as nuclear power plants, interconnectors and offshore wind. However, many of the balancing actions are provided by energy storage and demand-side flexibility on the distribution networks, including millions of household-level actions such as smart EV charging.

The energy system has previously been linear and centralised



The 2035 electricity system is decentralised, with more balancing on a local level



The Day in the Life - Evening

Afternoon

19 | 20 | 21 | 22 | 23 | 00

The evening peak
- Highest demand
- Highest prices

Drawing on storage
- Wind drops out
- Storage dispatches

A puff of wind
- Sharp rise in wind output
- High-cost generation drops

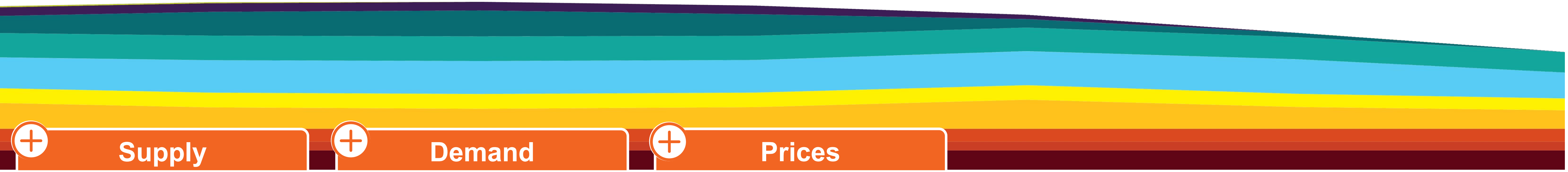
Dwindling demand
- Demand drops down
- Smart devices start up

Electricity demand for heat is highest

Consumers impact the peak differently

Bioenergy generation remains online

Gas-fired power with carbon capture keeps going



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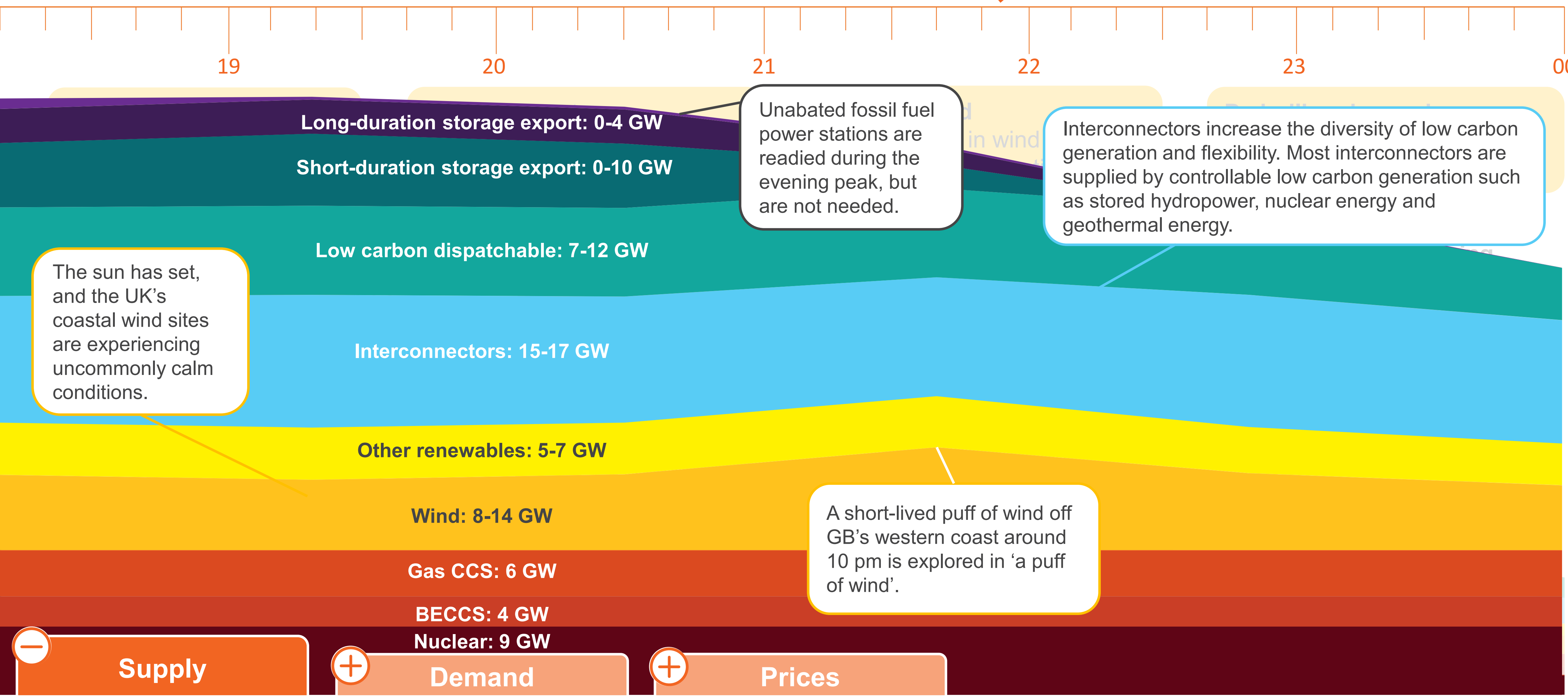
The Day in the Life - Evening

Afternoon



Supply
Demand
Prices

The Day in the Life - Evening

19 20 21 22 23 00

A puff of wind

Dwindling demand

- Demand drops down
- Smart devices start up

Conventional demand, heat and EVs

The evening peak continues past 7 pm before tailing off. This contrasts to a high-demand winter day in 2022, where peak demand is typically a shorter period between 6 pm and 7 pm due to the lack of smart devices and dynamic tariffs.

Many aspects of demand turndown ‘shimmy’ demand by a small amount. For example, smart appliances that may have avoided drawing electricity during the peak, come back online in the later evening.

The late evening sees demand tailing off as people across the country wind down and go to bed. Consumers of low-cost electricity like storage, EVs and electrolysers wait for the cheaper, overnight hours of the next day.

The Day in the Life - Evening

Afternoon

19 20 21 22 23 00

The evening peak
- Highest demand
- Highest prices

Drawing on storage
- Wind drops out
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A puff of wind
- Sharp rise in wind output
- High-cost generation drops

Dwindling demand
- Demand drops down
- Smart devices start up

Gas-fired power with carbon capture keeps going

The wait is over for storage providers, who export stored electricity to the grid throughout the evening peak, capturing high prices as forecast at the start of the day. This ‘buy-low, sell-high’ approach by storage providers is key to a low-cost, efficient, net zero electricity system.

Dynamic tariffs align to the wholesale price. During the evening, dynamic tariff prices are higher, encouraging consumers to defer demand to cheaper periods where possible.

Supply

Demand

Prices

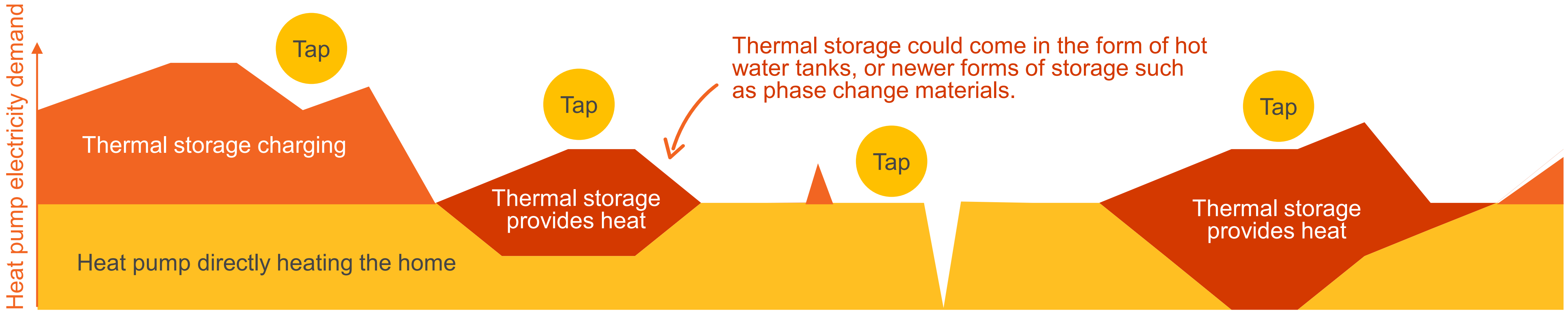
Electric heat in 2035

The Day in the Life sees millions of heat pumps, fed by low carbon electricity to provide heat and hot water to homes and businesses across the country. In addition to this significant technological shift, buildings are also more thermally efficient, reducing electricity demand and enabling more flexible use of heat, as buildings can retain a comfortable temperature for longer.

Smart operation of heat pumps, some in combination with thermal storage, allows this huge source of flexibility to avoid high-price and high-demand periods of the day, and soak up low carbon and low-cost electricity. Smart heat pumps individually respond to price signals to avoid high price periods and run during low prices. Households may sign up with an aggregator, who oversees a large number of heat pumps to directly provide flexibility and ancillary services to the electricity grid, sharing the financial benefits with the heat pump owner.

In urban areas, heat networks driven by a heat pump could operate in a similar way, with the added benefit of a diversified heat demand and the ease of managing a single large asset rather than many smaller assets.

The below graphic illustrates how a smart heat pump with thermal storage could operate during the Day in the Life. Tap on the numbers for more details:

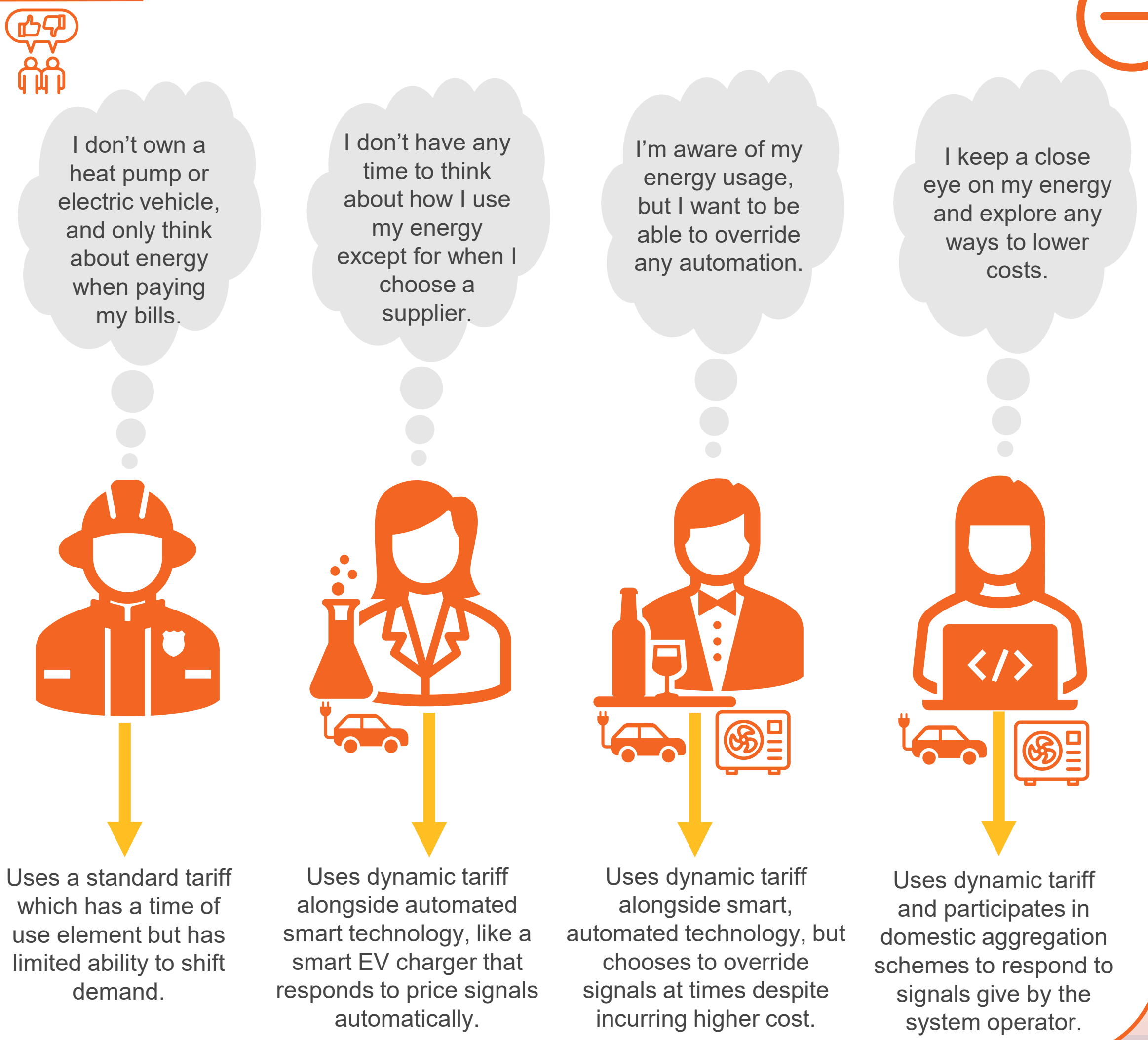


Different types of consumer

Domestic supply-side flexibility plays a vital role in system balancing throughout the Day in the Life, especially in the high-price and high-demand periods of the day such as the evening peak. Different consumers are able and willing to participate in the energy system to different extents, with the end result being a more efficient energy system. For this to work effectively, there is trust and openness between networks, suppliers, regulators and consumers.

By 2035, work by community energy organisations, local authorities and energy suppliers has resulted widescale rollout and acceptance of smart devices. Dynamic electricity tariffs are standard, and smart chargers, appliances and heat pumps automatically shift demand to cheaper periods without detriment to the end consumer. This tailors demand to available supply and flattens demand peak, benefitting the system and consumer simultaneously.

However, consumers have differing levels of engagement with the energy system, varying ability to shift demand in response to price signals, and different motivations to reduce bills through flexibility. Whilst households with heat pumps, electric vehicles and smart charging appliances inevitably have the greatest means to shift demand, the system benefits should ensure that all consumers, including fuel-poor households, benefit from widespread domestic and commercial supply-side flexibility.



Bioenergy with carbon capture

Bioenergy generation with carbon capture (BECCS) could provide an alternative source of low carbon dispatchable generation. Bioenergy could come in the form of biomethane produced from waste, agriculture and advanced conversion processes, or biomass from energy crops and as a by-product from forestry industries.

The sustainability and low carbon benefits of bioenergy are heavily dependent on both the source of bioenergy fuel and on the commitment to replant crops and trees that have been used in fuel production. The long-term sustainability of bioenergy needs to be firmly established if BECCS is going to play a key role in the net zero energy system.

The carbon-cycle basis of bioenergy is complex and can be controversial. It relies on the adoption of sustainable practices in agriculture and forestry, and a robust method of certification and carbon tracking.

When combined with carbon capture, the bioenergy carbon cycle can result in an overall negative emission, however it must be emphasised that the negative emissions comes from the replanting of energy crops and trees not at the point of generation. This raises a challenge that short-term emissions, that threaten climate targets and add to damaging global warming, are offset by a long-term commitment to manage energy crops and forests which are themselves subject to climate change impacts, as well as other land-use pressures.

The use of bioenergy for power generation is therefore likely to be limited to a scale that is sustainable and ideally be sourced from agriculture, energy crops and forest by-products from within the UK. Any imported bioenergy feedstocks must come from sustainably managed and certified schemes, delivered without substantial carbon emissions from shipping.

BECCS generation is relatively costly and, without subsidy payments or other forms of support, is likely to be targeted to times of higher electricity prices when demand exceeds the output of lower running cost nuclear and renewables. High carbon prices could provide an extra revenue stream for BECCS, helping it to be more cost-competitive.

During the Day in the Life, around 4 GW of BECCS power generation is running continuously throughout the day helping to meet high levels demand while wind and solar output is lower. At other times of the year, BECCS generation is more likely to act more flexibly, ramping up during high price periods and dovetailing with the power output of renewables.

In a net zero power system, BECCS combined with sustainable agriculture, energy crop and forestry practices, could provide a form of long-term negative carbon emission to net-off the residual carbon emissions that might escape carbon capture processes, or the infrequent use of fossil fuel generation needed to maintain security of supply. More broadly, in a net zero scenario, the Committee on Climate Change has projected that the UK may need to achieve negative emissions of circa 100 million tonnes of carbon per annum, mainly through tree planting and other forms of carbon sequestration.

Carbon capture and storage

Over one-third of current GB electricity generation is provided by unabated fossil gas power stations, which provides flexible, dispatchable generation when needed. In 2035, dispatchable generation will be needed to provide extra power during periods of peak demand and/or low renewable generation, but will need to be entirely low carbon. One option is to use carbon capture and storage technology to abate fossil gas power station emissions.

The 2035 net zero electricity system is reliant on dispatchable generation, especially during the peak time periods. However, there is uncertainty about which types of low carbon generation will be available in 2035. Currently, the frontrunners are:

- Fossil gas with carbon capture and storage (CCS). With effective carbon capture and storage, this could result in very low carbon electricity generation. However, no current carbon capture process is able to capture 100% of carbon emissions.
- Bioenergy, with carbon capture and storage (BECCS). With effective carbon capture and storage, this type of dispatchable generation could result in negative carbon emissions if bioenergy resources are sustainable and their carbon content is certified.
- Bioenergy-fuelled generation without carbon capture, using fuels such as biomethane produced through anaerobic digestion.
- Hydrogen-fuelled generation, using low carbon blue or green hydrogen.

All these technologies could be available at scale by 2035, but they each face a number of commercial, technology and sustainability challenges.

If low carbon dispatchable generation is not developed at scale, the alternative net zero solutions would include far more long duration storage and greater interconnection capacity.

Carbon capture technology has already been trialled but faces a number of challenges, including the overall efficiency of the carbon capture process, the capital and operating costs and the cost of the subsequent removal and storage of carbon. The UK government has provided significant funding for CCUS development with the ambition to have two operational industrial CCUS clusters by the mid-2020's and to capture 30 $MtCO_2$ annually by 2030.

For most of the year, gas-fired power with CCS generation can act somewhat flexibly, providing balancing generation during periods when demand exceeds the output of lower running cost nuclear and renewables. However, during the Day in the Life, around 6 GW of gas-fired power with CCS is running continuously, utilising gas generation plant that has been equipped with technology to capture carbon at the point of combustion.

The winter week

The Day in the Life is set within a mid-January week in 2035.

While the Day in the Life focuses on a specific 24-hour period in the future energy system, the conditions leading up to and following the day must be considered.

The week is set in the middle of winter, when days are short, and temperatures are low. This particular week sees a prolonged spell of low sun and low wind conditions, representing one of the major challenges for a net zero electricity system.

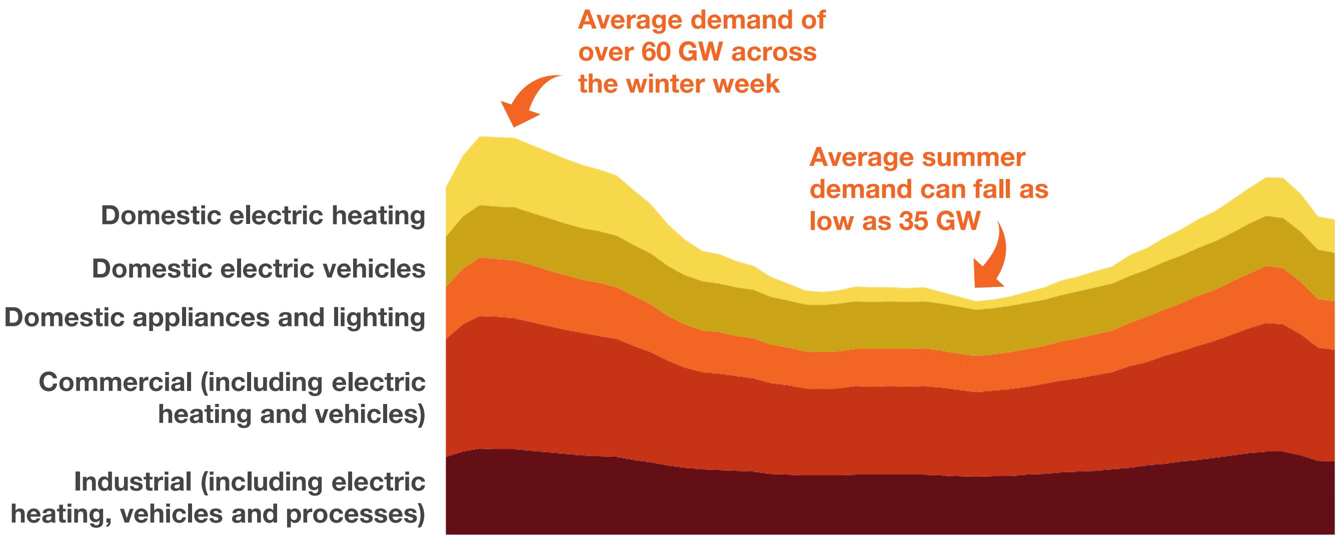
The modelling behind the Day in the Life is based on a similar winter week in January 2017.

Why this week?

Weather Conditions

Throughout the year, a decarbonised and decentralised electricity system will face different challenges based on differing weather conditions, and changes in demand for energy. For example, in the summer, when the sun is shining but demand is lower, the system will need to find ways to store the surplus energy and remain balanced.

On the other hand, one of the biggest difficulties the system will face is balancing supply and demand during periods of high demand and lower variable renewable generation. The week explored in the Day in the Life has the highest average residual demand in 2035, with over 60 GW of demand left to be met from sources other than wind and solar generation.



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Why this week?

Weather Conditions

Owing to a winter high pressure system sitting over the east coast of the UK and parts of northern Europe, low winds and cloudy weather limit renewable generation throughout the week.

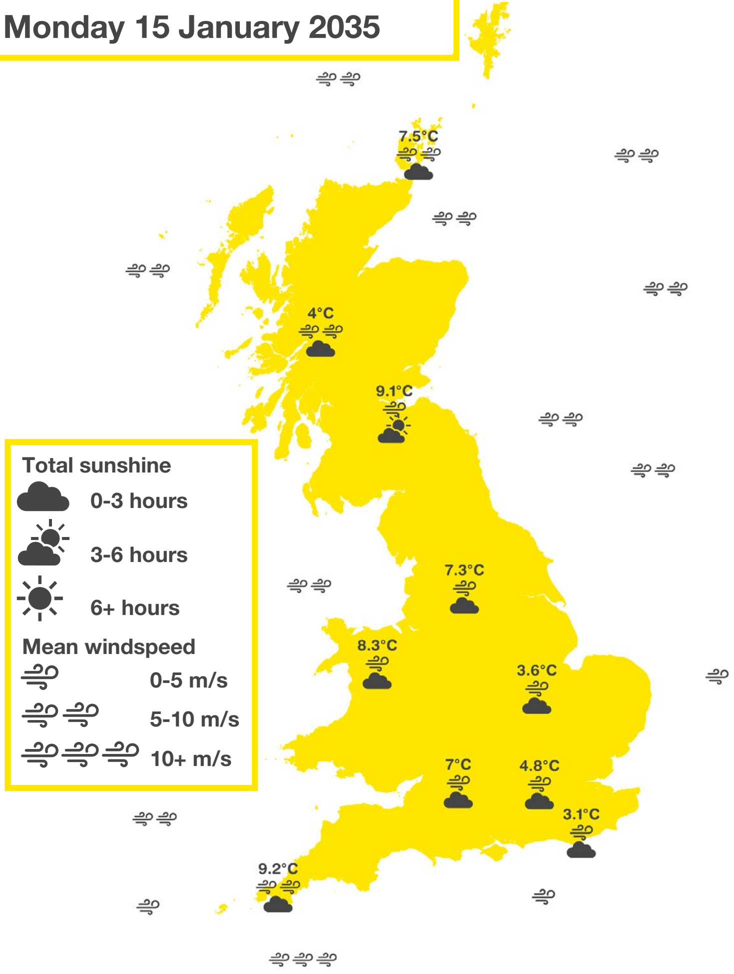
It is not an extreme cold week. Temperatures vary regionally, but during the daytime they stay slightly above freezing throughout the week.

Thursday 18 January 2035, the Day in the Life, is a cloudy, calm and cold day. There is, however, some wind in the west and north of the UK, allowing some offshore wind generation in the Celtic sea, Irish Sea and off the Scottish coast.

Tap the tabs above the map to see the onshore and offshore weather conditions during the winter week.

Mon | Tues | Wed | Thurs | Fri

Monday 15 January 2035



The net zero system

Click to explore eight key aspects of the 2035 net zero electricity system

A net zero power system will be radically different.

The Day in the Life system is based on the National Grid ESO Future Energy Scenarios 2021, amended to reflect the Climate Change Committee's Sixth Carbon Budget analysis and the UK Net Zero Energy Strategy.

In 2035, electricity supply is almost entirely from renewable and low carbon sources. The decarbonisation of transport, heat, manufacturing and primary industries has increased electricity demand.

This transformation in the way that electricity is generated, delivered and consumed will impact the whole energy system.

New technologies, smarter and digitalised systems, new processes and the participation of an array of new system actors will be vital to meeting this goal.

- The net zero power system
- Electricity consumption
- Peak electricity demand
- Electricity generation
- Sources of flexibility
- Smart systems and digitalisation
- System operability
- What if? Key uncertainties

The net zero power system

Decarbonisation of power by 2035 is critical to achieving the UK's carbon reduction goals. It will enable the decarbonisation of major sources of energy demand including transport, heat and other industrial sectors.

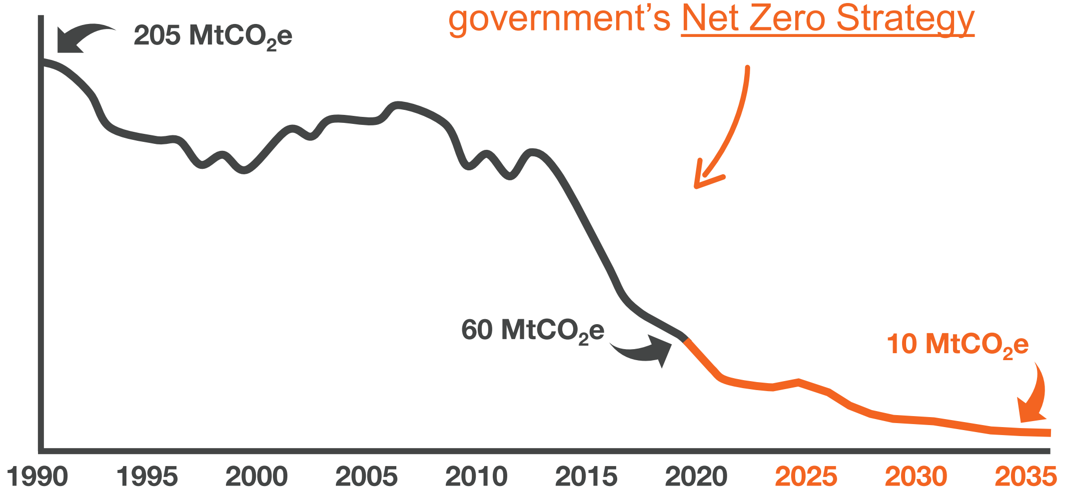
By 2035, the UK must have met the carbon reduction targets of the Sixth Carbon Budget and achieved the goal set out in the Net Zero Strategy that "all electricity will come from low carbon sources, subject to security of supply".

Key differences in a net zero power system in 2035 will include:

- Electricity will overwhelmingly be sourced from renewable technologies, delivered by massive investment in offshore wind, onshore wind, solar energy and other innovative technologies.
- Renewables will be complemented by other sources of low carbon generation such as nuclear, bioenergy and fossil gas plants equipped with carbon capture and storage (CCS). Electricity generated from low carbon hydrogen could also play a key role, as flexible generation and a possible form of long-term energy storage.
- Coal will have dropped out of the energy mix completely and many legacy fossil gas plants will be in the process of conversion to run on low carbon fuels, retrofit of carbon capture and storage, or decommissioning. As part of the on-going transition, some fossil gas plants may be retained to provide additional security of supply.

The net zero power system in 2035 will also feature many more sources of flexibility, such as energy storage and consumers who are able to shift demand to periods of lower cost and lower carbon electricity. The electricity system will be far more integrated, with increased investment in both transmission and distribution networks, development of offshore transmission networks and high-voltage interconnectors to Ireland, Europe and beyond.

Power emissions pathway from the UK government's Net Zero Strategy



Electricity consumption

In a net zero future, the demand for power is expected to increase as low carbon electricity replaces fossil fuels.

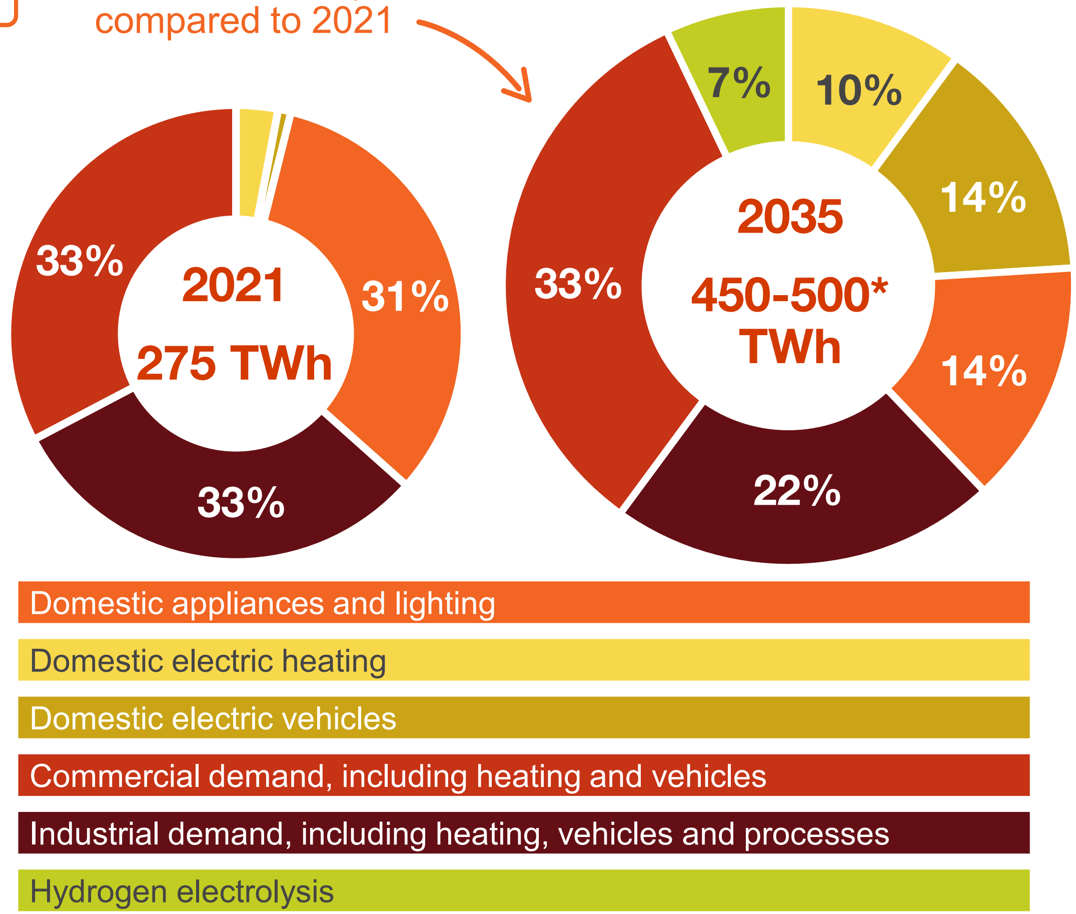
The rate of electrification may vary, but it will be led by the growth of electric vehicles and by the increased uptake of heat pumps and other forms of electric heating. Electricity is also expected to become more widely used for industrial processes and to produce hydrogen via electrolysis.

By 2035, consumption of electricity in GB could almost double to between 450 and 500 TWh, requiring a substantial increase in generation capacity as well as investment in the electricity transmission and distribution networks. It is also likely that GB will become a net exporter of low carbon electricity to neighbouring countries, further increasing demand for electricity by 50-100 TWh.

As more drivers charge their vehicles at home, in workplaces and at local charging stations there will be a need to upgrade local networks, including the low-voltage substations that bring energy to our homes and businesses.

To optimise this investment, the electricity system needs to become smarter and more efficient, using data and analysis tools to maximise the use of available capacity. The energy system must also make far greater use of solutions such as local flexibility services and active network management, as well as promoting energy efficiency.

Electricity consumption in the 2035 net zero system, compared to 2021



* Plus 50-100 TWh of interconnector export

Peak electricity demand

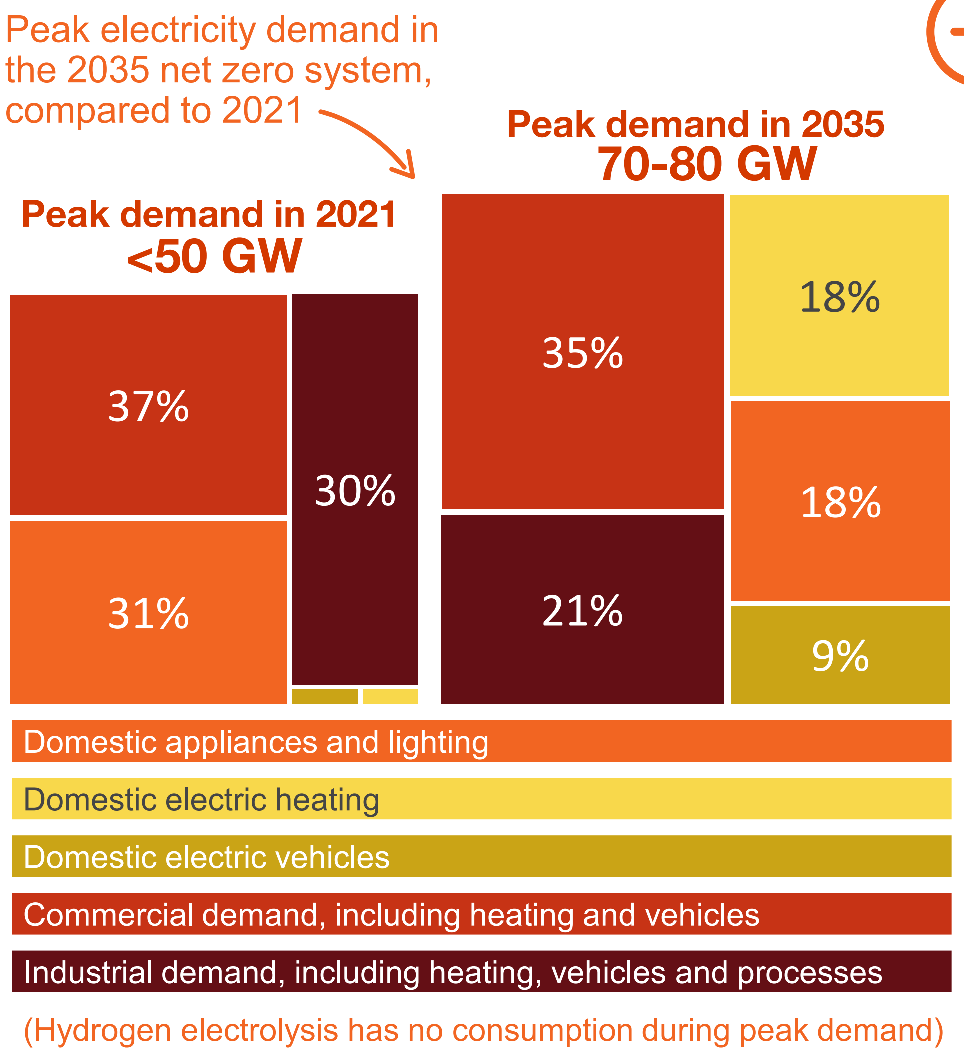
Electrification of the UK economy has the potential to significantly increase the peak demand for electricity, especially during the winter when demand for heating buildings is greatest.

The requirement to fulfill peak demand has been a key driver for the size and redudancy, and therefore the cost, of the overall energy system. In addition, managing the energy balance and operability of the energy system, even on a cold winter day with relatively low renewable energy generation, is one of the critical challenges to achieving a net zero power system.

Modelling undertaken by the ESO's Future Energy Scenarios team has estimated that, in a highly electrified scenario such as Consumer Transformation, peak electricity demand could increase to over 70 GW by 2035.

The general principle and reality of peak demand is already changing. The normal pattern of an 'early evening peak' is already less definitive and by 2035 the period of peak demand could be much less fixed, reflecting new sources of electricity demand and daily patterns of consumption.

The Day in the Life features energy efficiency and smarter devices linked to dynamic tariffs enable domestic consumers to manage their energy use, shifting consumption to times when electricity costs are lower. In addition, demand-side flexibility services are provided by commercial and residential consumers who are incentivised to sell their flexibility as a form of energy system service.



Click to explore eight key aspects of the 2035 net zero electricity system

Electricity generation

There are a number of potential pathways to achieve a net zero power sector.

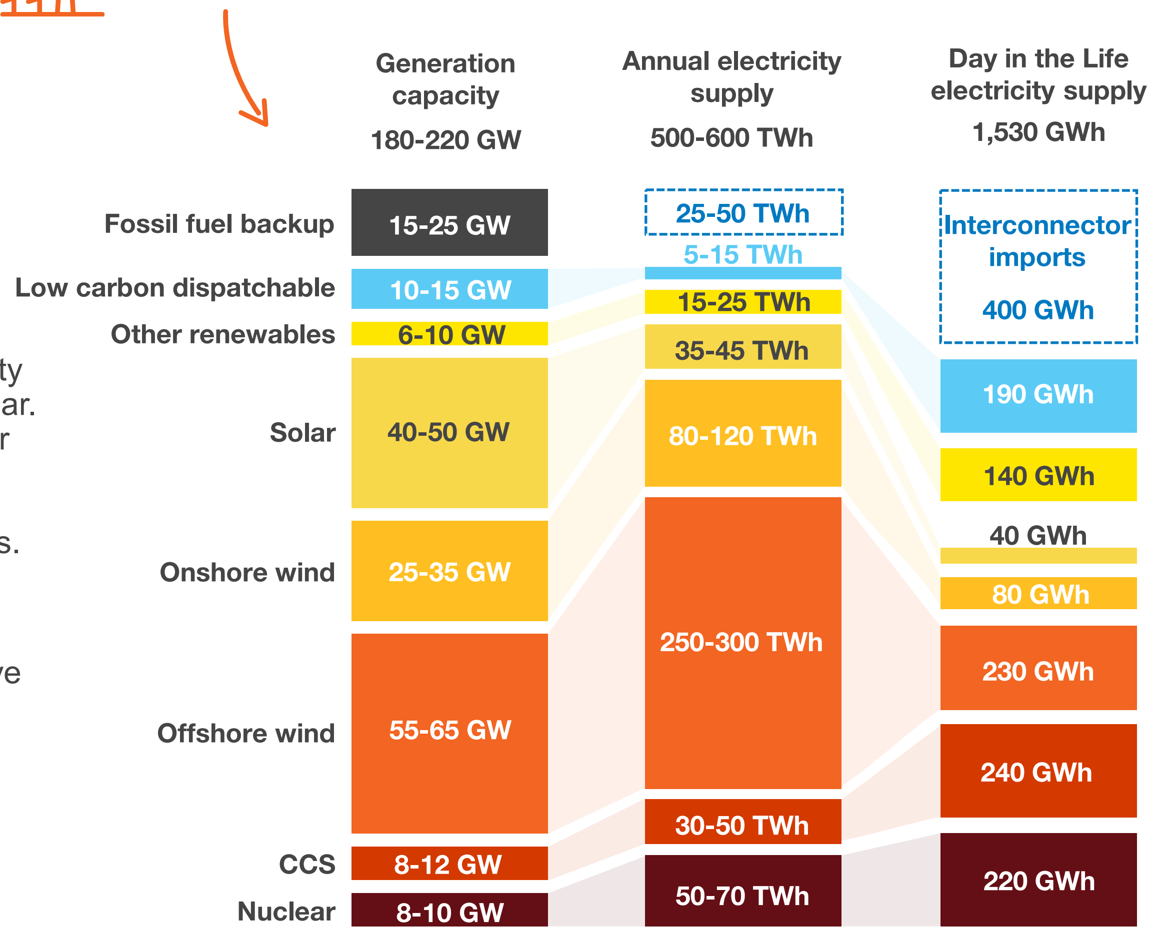
All of these pathways envisage very high levels of renewable energy generation, with 75-80% of electricity supply sourced from variable technologies such as wind, solar and hydro energy. Tidal energy, geothermal, biomethane and other innovative renewable technologies may also play a role. Diversity of supply, in terms of technology and geography, will help maintain system resilience and price stability.

For the Day in The Life narrative, over 55 GW of offshore wind capacity is deployed alongside up to 35 GW of onshore wind and 50 GW of solar. However, during this winter week, generation from both wind and solar is particularly low. Nuclear power provides up to 10 GW of electricity generation throughout most of the year, assuming the UK replaces its retiring nuclear fleet with the Sizewell C and Bradwell B power stations.

Maintaining system resilience during periods of high demand with low wind and solar output will be a key challenge. Sources of low carbon dispatchable generation will be required. In the Day in the Life narrative this is provided by fossil gas and bioenergy generation with carbon capture and storage, and potentially hydrogen generation.

Unabated fossil fuel generation will almost certainly be present on standby, as a further backup to ensure security of supply, but in a reduced capacity compared to 2022.

Capacity and annual supply of electricity in the 2035 net zero system, and on the Day in the Life



Sources of energy flexibility

All forms of energy flexibility will be critical in the net zero energy system; to manage variable generation, to meet peak demand, to ensure security of supply, to manage network constraints and to maximise the economic value of abundant renewable energy.

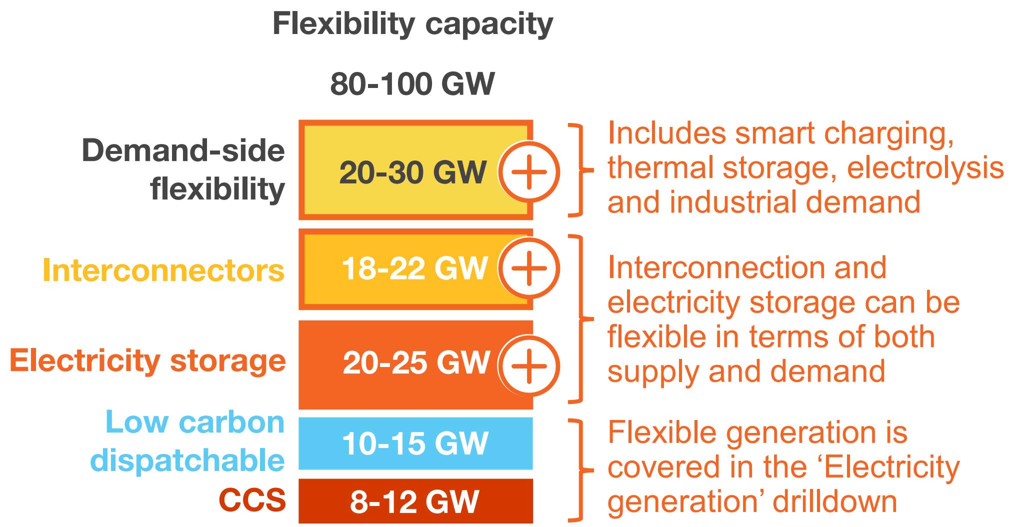
As well as generation and energy storage, the role of demand-side flexibility will become increasingly important. The ability of energy consumers to shift demand based on market signals will provide system benefits and a new source of value for consumers.

The expansion of flexibility services and markets is already underway and will have become embedded by 2035. Short-term and rapid-response flexibility will help to ensure system operability and manage network constraints, particularly at tricky 'pinch points'.

The Day in the Life highlights how the energy system will develop to harness the value of low carbon electricity to improve system balancing and resilience, by shifting low carbon electricity in three ways:

- **Time shift**, such as using longer duration storage to store energy when it is cheap and provide energy when it is needed, or consumers using smart chargers to charge EVs when electricity prices are lowest.
- **Location shift**, such as using interconnectors, Offshore Transmission Networks and greater grid integration within GB will allow electricity to be shifted to where it has most value.
- **Vector shift**, such as using electrolysis to convert low cost or constrained electricity into green hydrogen. Green hydrogen could also be used as a low carbon fuel for electricity generation, as long-term storage.

During the Day in the Life, the net zero power system hosts over 80 GW of flexibility. Click the buttons below the explore three further forms of flexibility that are vital to achieving a net zero power system throughout 2035, even on the Day in the Life:

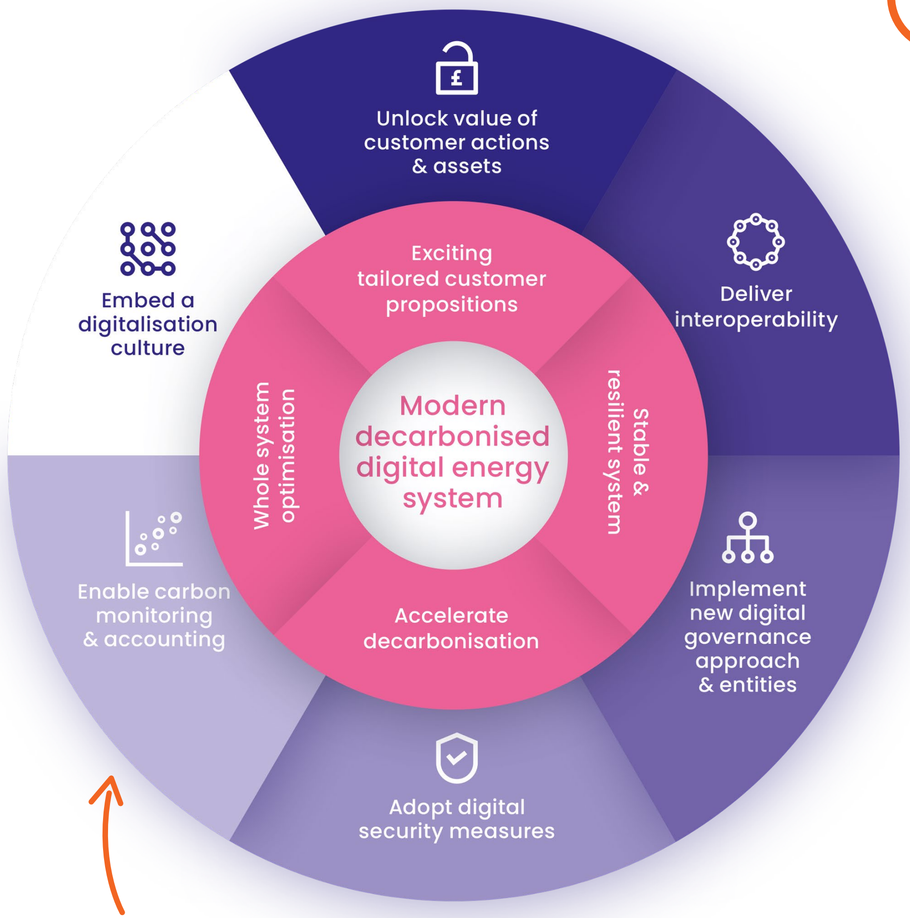


Smart systems and digitalisation

Our energy system in 2035 will be complex with many more actors and assets than today. We will need much greater visibility and automation, plus seamless interactions between participants in dynamic markets. Digitalisation of our energy system is essential to achieve this.

Digitalisation, as detailed in the government's Energy Digitalisation Strategy, will be integral to all aspects of the future energy system, for example:

- System visibility at all voltage levels through real-time monitoring, made available to all from open data sources. This will enable better use of existing infrastructure and greater efficiency in decision making, such as dispatching flexibility at local levels.
- Interoperable digital twins that enable whole system optimisation and support planning, forecasting and operations through the ability to model outcomes and support decision making (see the Virtual Energy System for more information).
- Dynamic and joined-up flexibility markets with participation from millions of assets and actors. Real-time data will enable the automation of operational decisions, therefore increasing efficiency and creating greater coordination across national and local markets.
- Enabling consumers to support system operability and reduce energy costs using smart tariffs and smart devices. Smart devices can be registered within a systemwide database and incorporated into system modelling and planning.
- Network data is open and available to all, enabling innovators to create new products and services to support the energy transition.



Six recommendations from the Energy Digitalisation Taskforce to deliver a digitalised energy system

System operability

Whole system energy balancing is critical, ensuring that electricity demand is matched by electricity supply on a minute-by-minute basis. It is also essential that the electricity system functions effectively within its operational tolerances, meaning that the system can provide electricity at the correct frequency, voltage and power quality to ensure reliability and customer service.

Decarbonisation, decentralisation and digitalisation are driving significant change across the electricity network, impacting how the GB electricity system is operated. The ESO has set out a strategy to provide technology solutions and commercial models that will enable the operation of a net zero electricity system. The strategy is based on the digitalisation of network solutions and the creation of new markets for network services.

There are five key areas of system operability:

Frequency: maintaining system frequency at 50 Hz has become more critical as system inertia historically provided by fossil fuels generators falls. This has created a requirement for new markets and business models to provide very rapid frequency response and dynamic containment services.

Stability: the growth of invertor-based (asynchronous) generators has increased the need for stability services. Currently provided mainly by synchronous gas and biomass generators, by 2035, new sources of stability and system inertia will be required.

Voltage: voltage levels are managed through the injection and absorption of reactive power. This aspect of operability is highly dependent on specific regional conditions including the generation mix, sources of demand, voltage levels and flow rates. Voltage issues can appear quickly and, without intervention, move from one part of the system to another. As energy becomes more decentralised this requires greater integration between distribution and transmission system operators. New solutions to provide reactive power, such as battery storage and synchronous compensators, are being developed.

Thermal/network capacity: thermal limits of network infrastructure means that managing constraints is critical to ensuring the integrity of network assets. Constraint management costs, mainly from actions to curtail generation, are increasing. They also have potential carbon impacts. By 2035, network infrastructure investment combined with improved forecasting, more efficient markets and greater use of flexibility services is expected to lead to an overall cost reduction.

Restoration: historically, the electricity system has been dependent on large, transmission connected fossil fuel generators to provide restoration services. The decline in this traditional generation mix and the increasing penetration of distributed energy resources means that new whole system sources of very rapid restoration services will be required on both distribution and transmission networks.

While these operability challenges are managed 24/7, they are individually detailed during the Day in the Life where most relevant.

What if? Key uncertainties

The Day in the Life story is based on an illustrative 2035 energy system. Some key questions considered while constructing the Day in the Life have been detailed below:

- What if consumers don’t participate in the energy system as much as expected?
- What if digitalisation is restricted, such as through lack of available, open data?
- What if markets fail to appropriately value low carbon energy?
- What if efficient Carbon Capture and Storage does not happen at scale?
- What if investment in interconnectors falters, leading to less integration between GB and overseas energy markets?
- What if low carbon dispatchable generation such as hydrogen-fuelled generation is not available at scale, due to lack of low carbon hydrogen or lack of generation capacity?

National Grid ESO’s Future Energy Scenarios

Climate Change Committee’s Sixth Carbon Budget

Back to the start

Net zero enabling projects

The Day in the Life sits within the overall Bridging the Gap To Net Zero programme, which explores some of the key messages from the ESO's Future Energy Scenarios and makes recommendations for actions now to meet net zero.

Regen's modelling and analysis for the Day in the Life is underpinned by the ESO's Future Energy Scenarios 2021, the UK government's Net Zero Strategy and the Climate Change Committee's Sixth Carbon Budget.

The research and thinking behind the narrative has been informed by other initiatives including:

- The ESO Net Zero Market Reform Project
- The Electricity Networks Association Open Networks programme
- The Energy Data Taskforce, and subsequent Energy Digitalisation Taskforce
- Development of new flexibility services and business models by Distribution Network Operators (DNOs) and their service providers.

It also draws on the work being done by the network operators, innovative businesses, community energy organisations, local authorities and numerous other stakeholders who are engaged in the energy transition.

managing constraints, maintaining security of supply and ensuring that markets work efficiently to minimise costs across the whole energy system.

contributed their expertise to help create the Day in the Life.

Introduction

In order to meet the UK's climate change commitments and to enable other sectors to decarbonise, the UK Government has set a target that the power sector should be net zero carbon by 2035.

Net zero carbon power
As a key benchmark, total annual emissions from the 2035 power system must be below 10 $MtCO_2e$. For this to occur, the average carbon intensity of electricity must fall to around 10-20 gCO_2 per kWh - a tenfold reduction compared to 2021.

The Day in the Life 2035 provides a snap-shot narrative of how a net zero power system could function on a cold, calm and cloudy, winter day. It will provide an insight into the whole-system challenges that must be addressed: balancing supply and demand, ensuring system operability, managing constraints, maintaining security of supply and ensuring that markets work efficiently to minimise costs across the whole energy system.

The narrative is deliberately illustrative and not prescriptive. The final form of the future net zero energy system is still evolving. The intention is to convey a view of how the system could operate, explore options to meet the gest challenges, and to point to me of the innovative solutions that beginning to provide answers.

he Day in the Life 2035 draws from everal net zero enabling projects nd initiatives. Click this box to find ut more.

The Day in the Life 2035 has been produced by Regen and National Grid ESO as part of the Bridging the Gap 2022 programme.

We would like to thank all those at the ESO, Regen and industry experts who contributed their expertise to help create the Day in the Life.

nationalgridESO

regen transforming energy

Executive summary ›

Executive summary

The Day in the Life 2035 presents an illustration of what a net zero power system could look like on winter's day with low winds and very little sunshine.

The analysis suggests that, even on such a winter day, the delivery and operation of a net zero power system is achievable, albeit with some legacy fossil fuel generation as a reserve. The technology needed is available today or will be attainable with continued innovation.

But it is a massive enc
The critical requireme
strategic delivery plan
low carbon generation
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and market capabilitie

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energy system, new c
and a range of enablin
solutions that will establish the UK as a world leader in the delivery of low carbon energy.

A net zero power system for a calm, cloudy winter day…

Despite good progress over the last decade, the race to build the necessary renewable generation to power a net zero electricity system is far from over. There is a huge challenge ahead to commission new wind, solar and other renewable energy projects, and to ensure that the infrastructure, systems and markets are in place to bring abundant low carbon energy to consumers in a cost-optimal way.

Energy storage is key, alongside development of low carbon dispatchable generation

The Day in the Life demonstrates that energy storage, especially long-duration storage, will be critical to make
to operate the system. The system will also need
otentially using fossil gas or bioenergy generation
ogen. New modular nuclear reactors could also
ologies is unclear

a way that is equitable and cost effective; they
stic consumers play an important role, as do
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opportunities for multi-vector energy optimisation.

m across the energy system

become active system participants, helping to
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e critical.

ent because it is able to draw on energy from
om neighbouring energy markets. Diversity and
market integration will help to reduce generation and price volatility caused by the weather. Interconnectors allow electricity to be imported during days like the Day in the Life, while allowing GB to become a net exporter of low carbon energy to neighbouring markets throughout the rest of the year.

Net zero strategic delivery plan

A plan that brings together and aligns the elements of:

- Systems architecture and modelling – what needs to be built
- Infrastructure planning, including Holistic Network Design (HND) for transmission, distribution, offshore networks and interconnectors
- Strategic network investment
- Leasing (offshore) and terrestrial land-use planning
- Future markets design, especially for flexibility, demand side response and storage elements
- System resilience and energy security
- Investment support policies (CfDs, asset return based, and other forms of revenue support)
- Finance (public and private)
- Industrial strategy – skills, supply chain and industrial clustering
- Innovation and technology development
- Regional and local energy planning, including the role of community energy organisations
- Consumer protection, energy equality and fuel poverty
- Public engagement and communications
- Energy system governance and coordination between national and regional bodies

The Day in the Life - Overnight

00 01 02 03 04 05 06

Overnight recharging
- Energy storage and EVs charge up on lower-cost electricity
- Low wind generation is bolstered by interconnection

The quiet hours
- Demand falls to its lowest as EVs finish charging
- Heat pumps preheat buildings ahead of the morning peak

Electricity demand across the UK is currently at its lowest overnight, with most domestic and non-domestic demand occurring during the day. Millions of EVs are plugged in to charge, and millions of heat pumps are providing households with heat. With smart controls and dynamic tariffs, demand is shifted to these night-time hours to take advantage of lower cost electricity. In many cases this shift is automated by smart technologies facilitated by energy suppliers or other energy service providers, shifting flexible demand into hours of the day with more renewable generation. The concept of fixed “peak” and “off-peak” times has been replaced by a dynamic, real-time, digitalised energy.

On this particular day, overnight, wind generation is fairly low. Electricity prices remain above average overnight but are anticipated to be lower than upcoming day-time prices. This creates an opportunity for generators, interconnectors and storage providers.

Generation with carbon capture and storage, which typically operate during higher price periods for most of the year, run consistently throughout the night alongside nuclear power. Interconnectors continue to import during these hours, bringing in low carbon generation from overseas.

Simultaneously, grid-scale batteries and other forms of energy storage charge up on comparatively lower cost electricity, ready to provide energy when needed over the coming day. Advanced forecasting of the day ahead allows storage providers to anticipate the cheapest times to recharge, and when they expect to export energy back to the grid, or directly to their customers, at a higher value.

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Supply | Demand | Prices

The Day in the Life - Overnight

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Overnight recharging
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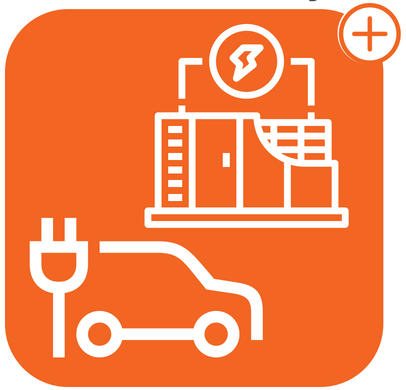
Tap to expand

Click to drill-down

Demand for low-cost electricity



Between 3 am and 6 am, demand and energy flows on the electricity system reach their lowest point. Falling output from wind power coincides with a drop in demand for storage and EV charging, as many shorter-duration batteries have fully charged. On days where more renewable generation is anticipated later in the day, some charging may be saved to coincide with these periods. Energy storage operators see this opportunity and continue to charge their large-scale storage assets.

This period is a chance to bring forward demand ahead of the more expensive morning peak, when electricity demand rises as people and businesses begin to use appliances and lighting. In well-insulated homes, heat pumps bring buildings up to desired temperatures, while thermal storage technologies replenish their heat reserves ready for morning space heating and hot water.

Intelligent forecasting, facilitated by a highly digitalised and data-driven electricity system, means that system operators and market participants can plan ahead to optimise the use of markets and assets to ensure that, even in these particularly challenging winter conditions, the electricity system continues to be fully low carbon throughout the day.

Explore tabs

The Day in the Life - Overnight

Morning

00 01 02 03 04 05 06

Overnight recharging
- Energy storage and EVs charge up on lower-cost electricity
- Low wind generation is bolstered by interconnection

The quiet hours
- Demand falls to its lowest as EVs finish charging
- Heat pumps preheat buildings ahead of the morning peak

In 2035, electricity markets are highly digitalised, responsive and open. Month, week and day-ahead wholesale prices based on forecast supply and demand anticipate that these early hours may be the cheapest of the day. As this materialises, energy storage and electric vehicles charge up throughout most of this period, particularly in the windier period between midnight and 3 am.

Short-term spot prices are more volatile, allowing agile assets like storage and DSR to operate more profitably. Avoiding 'bullwhip' effects is key, mitigated through be… forecasting and transparency in a… electricity system, and rapidly resp… assets using automation and artifi… intelligence (AI) to make decisions…

Bullwhip effects
The amplification of supply/demand imbalances (and therefore price) caused by system participants' overreaction to system signals. Bullwhip effects are worse in markets which lack full transparency, inefficient processes and poor forecasting.

In addition to balancing, flexible generation and demand such as interconnectors and batteries may provide ancillary services to …l inertia and grid …t, through …or even exporting …pending most of

Supply
Demand
Prices
Introduction
The Day in the Life
The winter week
The net zero system

Demand for low-cost electricity

While electricity prices are generally high during the Day in the Life week, overnight prices dip slightly.

Tap on the concepts and technologies below to explore some of the key uses of low-cost electricity during the Day in the Life and throughout the year.

- Shifting demand to exploit low-cost renewables electricity
- Smart charging and smart appliances
- Electricity storage
- Thermal storage
- Interconnector export
- Hydrogen electrolysis

Demand for low-cost renewable electricity

An electricity system hosting well over 100 GW of wind and solar capacity will inevitably have periods of abundant renewable electricity. In the summer, high levels of solar energy and lower demand will provide low-cost electricity. In the winter, while demand will be higher, windier conditions could also provide very cheap electricity, especially during off-peak periods.

Even during the Day in the Life week there will be periods when lower cost electricity is available.

High energy users in industry and domestic consumers will increasingly tailor their demand to make use of low-cost electricity when it is available, saving themselves money and helping to balance the energy system.

Demand for low-cost electricity

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Smart charging and smart appliances

Encouraged by dynamic electricity tariffs, smart chargers and appliances will enable consumers to shift their energy use to low-cost periods where possible. Charging up EVs and using appliances when wind or solar generation is high helps individual consumers save money and benefits the energy system, reducing costs for everyone.

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Electricity storage

Electricity storage will take advantage of intelligent price forecasting to charge up during the cheapest hours of each day, soaking up wind and solar energy which can then be provided at times of peak demand. Renewable generators may be directly co-located with onsite battery storage or linked to long duration storage technologies.

During the Day in the Life, electricity storage charges up overnight when wind output is highest, and exports during the day, especially in the early evening when prices are highest.

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- Thermal storage
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- Hydrogen electrolysis

Thermal storage

Thermal storage has been around for a long time, in the form of hot water tanks and night storage heaters using heated bricks.

By 2035 we expect that there will be many new forms of thermal storage in operation. These will range from domestic thermal batteries and heat stores, to larger scale thermal storage schemes associated with heat networks and shared heating systems. Denmark, for example, already converts excess wind generation into thermal energy for its heat networks.

Industry will also invest far more in heat recovery systems to capture and supply waste heat for use within industrial plants or to neighbouring heat consumers.

During the Day in the Life, heat storage, and the use of waste heat, is one of the most important ways the system can manage periods of high demand and lower generation.

Demand for low-cost electricity

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- Thermal storage
- Interconnector export
- Hydrogen electrolysis

Interconnector export

During the Day in the Life, the GB energy system is importing electricity from neighbouring countries.

By 2035, however, the GB and Irish energy systems are expected to become significant net exporters of electricity. Undersea high-voltage interconnectors will export low carbon electricity to European markets to earn higher revenues and help to decarbonise their economies. Offshore wind farms may even export electricity to Norway, for example, for use in large scale pumped hydro energy storage schemes.

Demand for low-cost electricity

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- Hydrogen electrolysis

Hydrogen electrolysis

The process of hydrogen electrolysis, using electricity to split water molecules to obtain large amounts of hydrogen fuel, is expected to become a major new source of demand for renewable electricity.

This could then be used to provide a low carbon fuel for industrial processes and for heavy transport including marine vessels. It could even be converted into a synthetic fuel, or 'eFuel', for aviation.

Hydrogen, or a hydrogen blend, could also be used to generate electricity. Although there would be a conversion loss, hydrogen would in effect be another means to shift low-cost electricity to times of greater demand.

During the Day in the Life, electricity prices are higher than average, and as such most hydrogen electrolysers are not in operation.

System operability: reactive power

Working closely with distribution networks, the ESO has a responsibility to manage the voltage levels of the system within safe operational limits. Voltage issues, caused by an increase or loss of reactive power, can appear quickly and, without intervention, move from one part of the system to another. This aspect of operability is highly dependent on specific regional and local conditions, including the generation mix, sources of demand, power flows and events like network outages.

Reactive power services are required to make sure voltage levels on the system remain within a given range. In simple terms, the right level of reactive power is needed to maintain stable power supply across both the transmission and distribution networks.

In the past, the primary role of distribution operators was to maintain voltage controls within their network area, while reactive power services were provided mainly by transm
generators managed by the ES
in an electricity system free from

By 2035, the requirement for rea
in a more dynamic and decentra
Distribution networks have need
options to maintain voltage leve
more integrated, whole system
investigated through the ESO's Future of Reactive Power project and Voltage Pathfinder project, low-cost solutions to maintaining voltage

Future of Reactive Power
To address the current and future challenges to managing system voltage, National Grid ESO is undertaking a project to explore what solutions can enable more technologies and connection types to provide reactive power services in the right locations.

and regional markets for reactive power services have been developed alongside Distribution System Operators. Adoption of a whole system approach, backed by technology innovation and market development, ensures that voltage stability does not become a barrier to achieving a 2035 net zero electricity system.

During the Day in the Life, many options for reactive power services will be available at both a regional and national level. Reactive power services are provided by a wide range of assets, including batteries, compensators renewable generators with converters, HVDC interconnectors and synchronous generators such as gas CCS and pumped hydro. Overnight, with demand low and wind power higher than the rest of the day, these services may be called upon.

For more on reactive power in the future energy system, follow the links below:

Current reactive power services
Voltage Pathfinder
Future of Reactive Power
Power Potential

System operability: reactive power

Working closely with distribution networks, the ESO has a responsibility to manage the voltage levels of the system within safe operational limits. Voltage issues, caused by an increase or loss of reactive power, can appear quickly and, without intervention, move from one part of the system to another. This aspect of operability is highly dependent on specific regional and local conditions, including the generation mix, sources of demand, power flows and events like network outages.

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In the past, the primary role of distribution operators was to maintain voltage controls within their network area, while reactive power services were provided mainly by transmission network demand customers and generators managed by the ESO. However, this is significantly different in an electricity system free from unabated fossil fuels.

Voltage Pathfinder
ESO's Voltage Pathfinder results in multi-million-pound consumer savings and delivers engineering solutions needed for tomorrow's greener grid.

er management has changed
zero energy system.
elop additional tools and
networks, requiring a much
As is currently being
Reactive Power project and
Voltage Pathfinder project, low-cost solutions to maintaining voltage and regional markets for reactive power services have been developed alongside Distribution System Operators. Adoption of a whole system approach, backed by technology innovation and market development, ensures that voltage stability does not become a barrier to achieving a 2035 net zero electricity system.

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For more on reactive power in the future energy system, follow the links below:

- Current reactive power services
- Voltage Pathfinder
- Future of Reactive Power
- Power Potential

The Control Room of the future

A physical control room has traditionally been at the heart of any network operation. People actively using a combination of network tools, expertise and experience to assess risks, dispatch assets and take a range of actions to provide the most secure and economic solution for the end consumer.

In 2022, the role and capability of the ESO control room is already changing in response to the continued growth of renewable energy, the massive expansion in the number of system assets and actors, changes in energy flows and the imperative to not only maintain energy security and reduce costs, but also to support the transition to net zero.

Within the ESO and GB's distribution networks, work is underway to digitalise, automate and integrate control room functions. The ESO is overseeing the transformation of the Electricity National Control Centre, with the aim of having the capability to operate a carbon free electricity network by 2025.

By 2035 it is expected that the way control rooms work will have radically changed. Key features of the new control function will include:

- Use of data integration and digitalisation to create new markets, improve situational awareness and inform decision making.
- Higher levels of automation to streamline processes and utilise new services from thousands of potential system actors. The Day in the Life strongly features complex interactions such as V2G, aggregated smart appliances and dynamic electricity pricing, all of which depend on data and digitalisation to work most effectively.
- Use of virtual energy systems with 'Digital Twin' simulation tools and Artificial Intelligence capability to inc decision making. During the Day in these tools to identify energy syster prepare an appropriate response, a unabated fossil fuel generation to e
- Far greater levels of integration and transmission and distribution syster alignment of system actions and op
- Greater integration and cooperation in Ireland and the rest of Europe, through interconnection and the use of dispatch and other control room functions.

Digital twin

The ESO has launched an industry-wide initiative to develop a virtual energy systems. This will be used, amongst other things, to model future energy scenarios, system constraints and the optimisation of system operations. Forward looking system models will be used to plan for network events including shifts in the demand/supply balance.

[Future of the Electricity National Control Centre]

[A strategy for a Modern Digitalised Energy System]

[Introducing the Virtual Energy System]

The Day in the Life - Morning

07 08 09 10 11 12

Waking up
- Demand rises rapidly
- Dispatchable generation ramps up

The morning peak
- System responds to demand rise
- Local flexibility plays a role

Steady morning
- Demand levels off but remains high
- A little solar, but North Sea wind falls

Demand rapidly increases as much of the UK wakes up, using electricity for hot water, kettles and lighting. Non-domestic demand increases as schools and workplaces start the day. Between 7 am and 8 am, demand rises by around 10 GW.

By this point, most electric vehicles will be fully charged. However, with temperatures nearing zero in some areas, electric heat pumps are still needed to supply heat and hot water. Increased levels of insulation, and some thermal storage, means that heat pumps can be operated in a flexible mode to avoid demand at peak times.

Despite the calm weather in the east, wind power is still providing some electricity as a result of its geographic diversity, including new offshore wind farms in the Celtic Sea and off Scotland. However, with relatively low wind and the sun not yet risen, other forms of low carbon generation must be called upon to meet demand for electricity across the country.

'Flexible' generation, which can ramp output up and down when required, will need to be very low carbon in 2035. During the morning peak, this is provided by gas power stations with carbon capture and storage, generators using low carbon fuels like biomethane and hydrogen, and drawing on interconnectors from Ireland, Norway and other countries.

Balancing occurs at a local level

The Day in the Life - Morning

07 08 09 10 11 12

Waking up
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While flexible demand has been encouraged towards quieter periods, there is still a significant increase in electricity demand on the network associated with the morning peak. Morning routines of showers, breakfast and boiling kettles add to the demand for lighting and heating on a winter day. Commercial premises are also opening for business, using motors and pumps for industrial processes. Data centers and IT systems increase their load as computers and laptops fire up. The shift to home working, virtual meetings and digitalisation places additional load on both communication and energy systems.

For energy system operators, this rapid morning transition from low to high demand requires careful management of grid frequency and voltage.

In the summer months, this increased morning demand is likely to coincide with increasing solar output. However, in the winter Day in the Life, renewable generation remains low. Overnight rain and a spring tide have increased output from some Scottish hydropower and tidal generators, but other forms of dispatchable low carbon electricity are required.

An increase in electricity price encourages greater flows through interconnectors and allows hydrogen powered generation to ramp up. Some long-duration storage asset operators see the opportunity to use their pumped hydro and compressed air technology to make additional revenue. On the distribution networks, local flexibility and demand side response (DSR) providers are called upon to help balance local demand and avoid network constraints.

The energy system responds very rapidly to higher market prices, thereby maintaining the energy balance and reducing price volatility. Although the Day in the Life will likely be one of the more high-cost days for electricity supply, the overall system is working efficiently with each participant playing their role to ensure system resilience.

The Day in the Life - Morning

07 08 09 10 11 12

Waking up
- Demand rises rapidly
- Dispatchable generation ramps up

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Operabilit
is m

Electricity demand across the UK is now consistently high, with over 70 GW of demand throughout the morning. Nuclear, biomass and gas CCS power stations are able to provide high levels of low carbon generation throughout the winter, albeit at higher costs than most renewables, whilst interconnectors and low carbon flexible generation make up most of the remaining supply, as wind output falls.

After 9 am, solar panels on rooftops and on solar farms are now producing some electricity, although this coincides with a further drop in wind generation. In 2035, it is likely that many solar farms will be co-located with electricity storage technologies, such as batteries. With more data instantly available, and improved forecasting and modelling of the energy system, many solar asset operators aim to maximise their revenues by storing produced electricity for the evening, when electricity market prices are anticipated to be higher. Many of these solar farms may also be supplying companies and corporations with renewable electricity through Power Purchase Agreements.

With dynamic tariff price signals discouraging demand during the morning peak, avoided through the use of thermal storage and smart devices, the increase in demand across the morning is flatter and more evenly spread than in the 2020s, continuing almost to midday.

System operability: frequency

Throughout the Day in the Life, maintaining the system frequency is critical to protect the electricity system, as well as customer assets and equipment.

Previously, frequency was aided by the system inertia provided by large fossil fuel generation assets. During the be prevented from 'wandering' above or the aid of these unabated fossil fuel ass

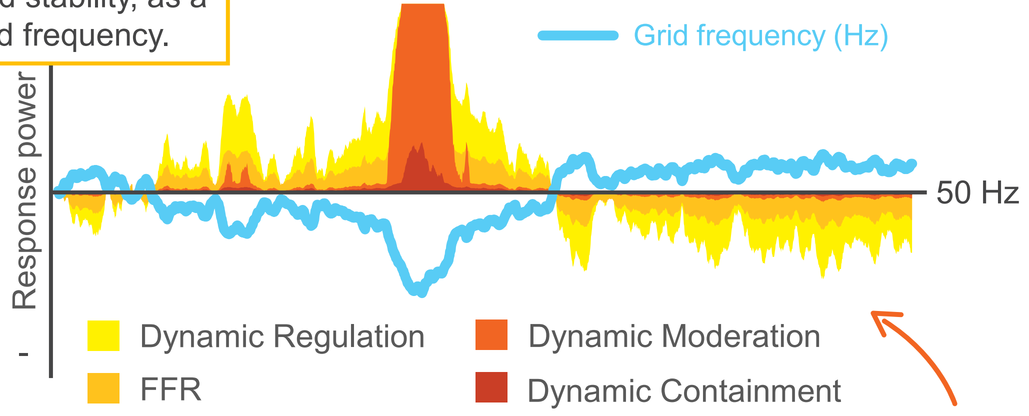
System inertia
Generators, such as gas and coal fired turbines with heavy spinning parts that synchronise with the grid, create inertia. This aids grid stability, as a 'buffer' against rapid changes to grid frequency.

Frequency control is about having suffic system to manage the deviations betwe ensuring that this capability is maintained at all times. The speed of response is important; the faster frequency is brought back within tolerances, the lower the level of power adjustment that is needed. The Day in the Life morning peak, where demand is rising substantially based on the decisions of millions of individual consumers, is a prime example of where frequency could deviate if not carefully managed.

During the morning peak, dynamic response assets such as batteries are deployed in just milliseconds to make small adjustments in their electricity import and export. Additional assets and service providers are ready to make larger power changes if a greater response is needed. These frequency response solutions are now well established and efficient. Artificial intelligence allows the ESO to better anticipate system conditions that could lead to rapid changes in frequency, while automated controls and rapid response assets maintain frequency control even on days which have large swings in generation or demand.

Despite the lack of unabated fossil-fuelled generation, and a potential increase in frequency deviation events, the stability of the 2035 net zero electricity system is maintained by battery storage and innovation that has allowed low carbon technologies to also provide new forms of inertia.

w illustrates how the ESO's new suite of Dynamic ork together to respond to the morning peak, where pidly ahead of supply. Follow the signposted links for nation about frequency services.



Thanks to Open Energi for the graphic!

Dynamic Containment
NOA Stability Pathfinder

System operability: frequency

Throughout the Day in the Life, maintaining the system frequency is critical to protect the electricity system, as well as customer assets and equipment.

Previously, frequency was aided by the system inertia provided by large fossil fuel generation assets. During the Day in the Life, frequency must be prevented from ‘wandering’ above or below the 50 Hz target, without the aid of these unabated fossil fuel assets.

Frequency control is about having sufficient power response on the system to manage the deviations between supply and demand and ensuring that this capability is maintained at all times. The speed of response is important; the faster frequency is brought back within tolerances, the lower the level of power adjustment that is needed. The Day in the Life morning peak, where demand is rising substantially based on the decisions of millions of individual consumers, is a prime example of where frequency could deviate if not carefully managed.

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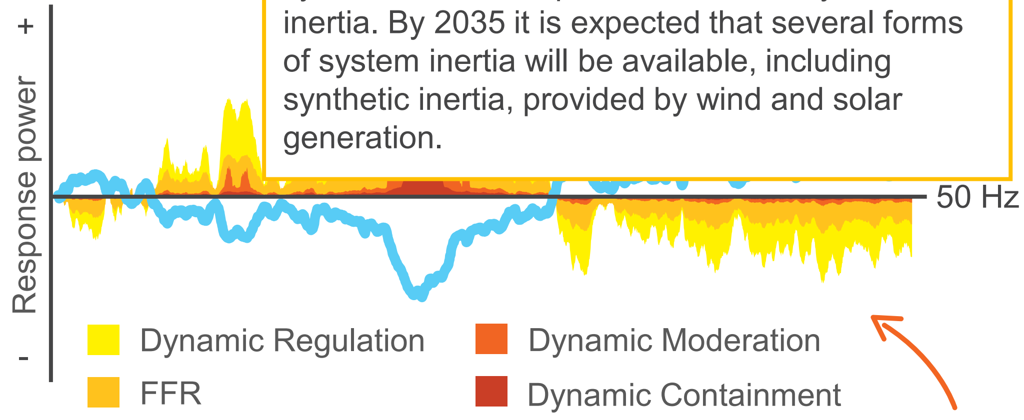
The graphic below
Services could wor
demand rises rapid
even more informat

New forms of inertia

Several innovation projects are already looking at ways in which renewable generators and other system assets can provide a form of system inertia. By 2035 it is expected that several forms of system inertia will be available, including synthetic inertia, provided by wind and solar generation.



Thanks to Open Energi for the graphic!

[Dynamic Containment]

[NOA Stability Pathfinder]

Electric transport in 2035

By 2035, the electrification of transport could add 50-80 TWh to annual electricity demand. Fulfilling this demand will require investment in both charger and network infrastructure, but it also requires that transport consumers charge their vehicles in a way that is smart and works with the energy system.

Charging for electric vehicles will introduce a major new demand challenge for electricity network operators. However, the flexibility of when people charge vehicles also creates an opportunity to balance electricity supply with demand and could even offer new forms of energy system services.

The principal incentive for transport users to charge during off-peak periods will come in the form of price signals from the electricity market, linked to smart chargers and dynamic tariffs. The Day in the Life assumes a very high uptake of this type of tariff.

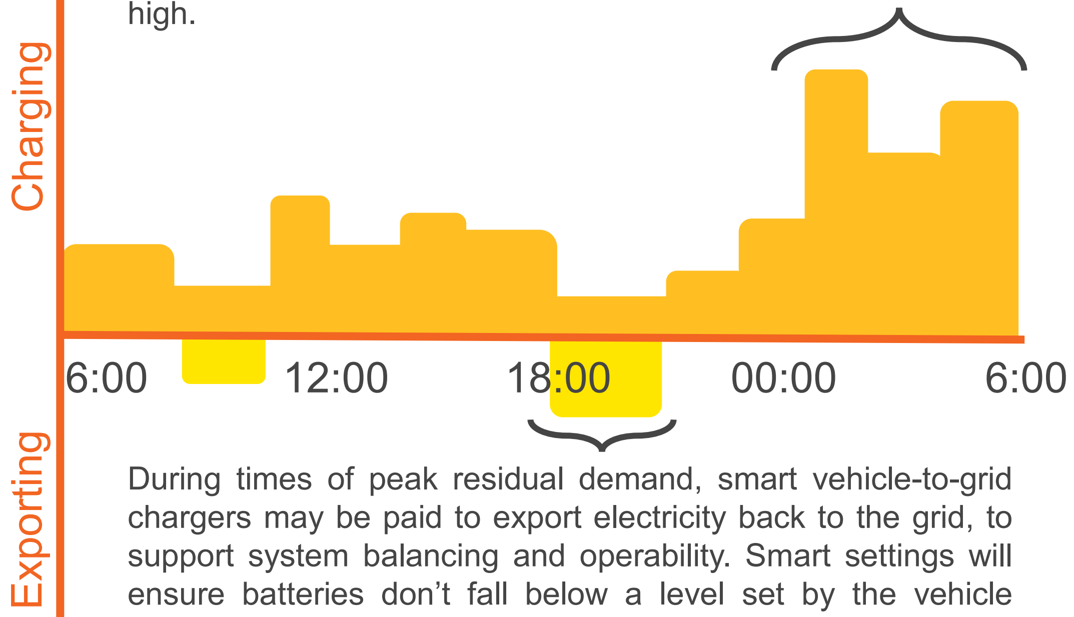
Although not expected to be widespread in 2035, chargers fitted with Vehicle-to-Grid or Vehicle-to-Home technology could even export
rease supply
west.

Vehicle-to-grid (V2G) charging
This is a type of charger that allows two-way flows of electricity from the grid to the battery, and from the battery to the grid.

ility and energy
s, including for
age local
network constraints.

EV charging will dynamically respond to available supply and market prices

Smart charging, linked to dynamic price tariffs, shift demand to off-peak periods when demand is low or renewable generation is high.



During times of peak residual demand, smart vehicle-to-grid chargers may be paid to export electricity back to the grid, to support system balancing and operability. Smart settings will ensure batteries don't fall below a level set by the vehicle owner.

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during peak times

Vehicle owners wi
storage capacity t
example, through
network constraints.

Vehicle-to-home (V2H) charging
This is a type of charger that allows a plugged-in vehicle to supply electricity direct to the home, such as when dynamic tariff prices are high.

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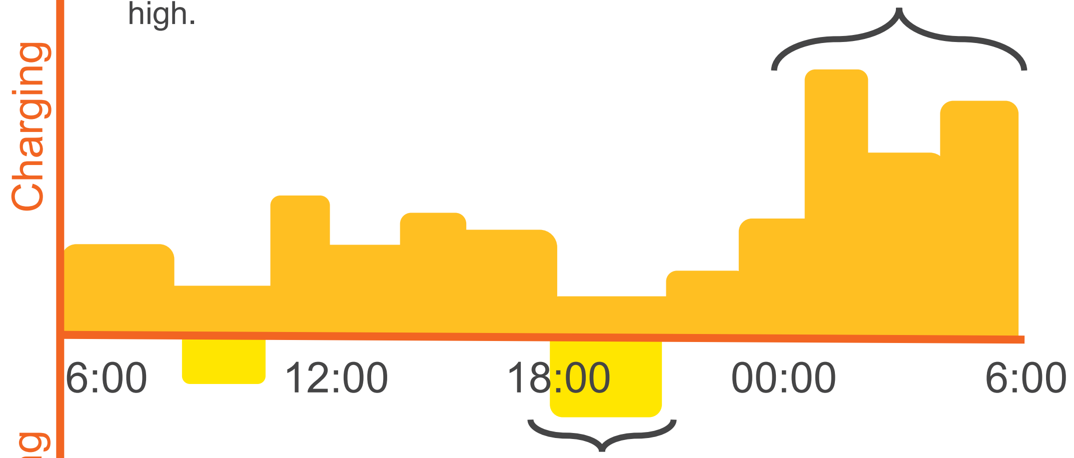

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Hydrogen-fuelled generation

Low carbon hydrogen could be used as a dispatchable generation ...ogen or are able to ...e or fossil gas.

> **Low carbon hydrogen**
> Hydrogen produced from electrolysis using renewable electricity, or from methane reformation with efficient carbon capture and storage.
>
> From a power system perspective, hydrogen electrolysis could provide a balancing demand load to use low-cost renewables, which would then be used to generate electricity during times of low renewable output. This would therefore operate as a form of long-term energy storage.

...portant role as part of ...fficient generation

...end turbines, with a ...ere are also several ...n the pipeline.

...en generation plants ...tep change in ...nts and to retrofit ...e a rise in carbon prices as well as the introduction of revenue support both for hydrogen production and power generation.

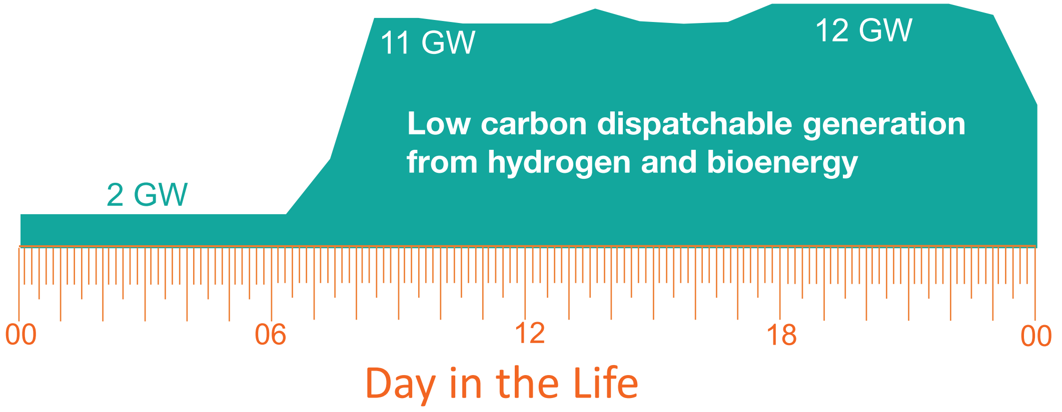
At a smaller scale there is potential for generators operating 'peaking plant' within industrial clusters to switch to 100% hydrogen fuel or a hydrogen blend. Hydrogen generation is also likely to feature in areas of very high renewable energy production, for example Scottish Islands, to provide an alternative to fossil fuel generators. Imported hydrogen in the form of hydrogen or ammonia could also be an option for hydrogen supply.

While the future of hydrogen is one of the key uncertainties, its use to provide dispatchable power features in several net zero scenarios including the Climate Change Committee's 'Balancing' pathway that informs the Sixth Carbon Budget.

Hydrogen-fuelled generation during the Day in The Life

Flexible, dispatchable, low carbon generation plays a major role in the Day in the Life, providing extra power during the peak demand periods when renewable generation is low.

During the morning peak, hydrogen and other low carbon dispatchable generation such as biomethane is providing over 11 GW of power and remains at around this level throughout the day. This generation is situated in hydrogen-based industrial clusters, and in areas of high renewable output where green hydrogen production is concentrated.



Local and regional flexibility

The Day in the Life features high volumes of renewable energy to meet growing demand from electrified transport, heat and industrial processes. This complex, decentralised electricity system requires active management of thermal load constraints on the distribution networks, to avoid having to curtail generation and reduce infrastructure upgrades.

While network constraints are a significant barrier to renewable energy deployment, distribution networks can offer a range of connection agreements including the use of Active Network Management, to speed up connections and maximise available capacity.

Active Network Management

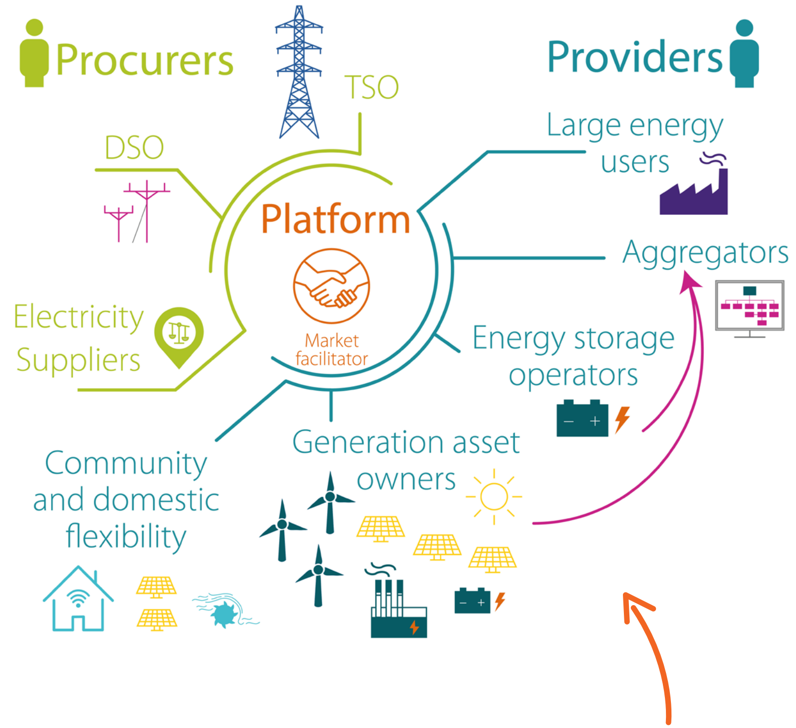
An example of digitalisation. ANM systems are distributed control systems that continually monitor the limits in a given area on the network (normally a high-voltage or intermediate-voltage substation) and then allocate the maximum amount of capacity to customers in that area.

Schemes operate in real-time and monitor inputs, outputs, network flows and voltages at key points within the controlled zone. If the network is approaching limits, the ANM controller instructs actions to be taken. ANM schemes are expected to be temporary, pending network investment or the provision of flexibility services.

...ocal flexibility services as ...e of network capacity. ... storage operators, ...wide range of small-scale

...nsumer participates in ...ers with a smart EV ...o participate and be paid ...tribution network, helping ...ctions being passed on to

...support the substantial ...ly true on the low voltage ...which support the growth of home-charging for EV vehicles and the use of electrified heat. Integration between local energy plans and network planning is key to make sure this investment is well targeted.



The role of a local flexibility market, from Regen's local flexibility markets guide

The Day in the Life - Afternoon

Morning | Evening

13 14 15 16 17 18

Renewables up slightly
- Solar output peaks
- Wind output rises slightly

Consistent demand
- Heat pumps run steadily during the afternoon
- Workplace and business demand is significant

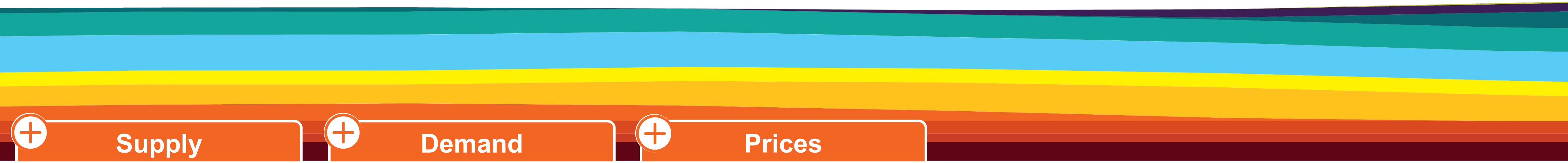
Heading home
- Start of the evening peak
- Risk of system imbalance

Calm and cloudy conditions mean that only around 30% of demand is met by renewables. Rooftop solar on homes and businesses has the benefit of effectively bypassing the electricity network, directly providing the building it is located on with low-cost electricity. During a high-demand day like the Day in the Life, almost all of this production is consumed directly, with any excess funneled into topping-up electric vehicles, charging electric and thermal storage, or other means of tailoring demand to available supply.

With over 40 GW of solar on the system and almost 100 GW of wind and other renewables, summer days in 2035 are very different. With peak early-afternoon solar supplying a significant proportion of daily demand, and almost all the rest met by wind and other renewables, the challenge and opportunity in this case is to utilise as much of this abundant renewable energy as possible.

: constraints
anaged

Distribution networks manage high demands



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Diverse generation aids the system

Ahead of the upcoming evening peak, the mid-afternoon sees consistent high demand of around 70-75 GW. Heat pumps are running to maintain indoor temperatures, although their demand may still be flexed up or down by an aggregator or energy services provider to provide local network services throughout the day.

Electric vehicles that have been on the road, including commercial and goods vehicles, may need to top up during the day at workplaces, destinations, and at rapid chargers along motorways and A-roads.

Previously carbon-intensive industrial processes, now decarbonised through electrification, contribute to higher daytime demands. These industrial processes represent large point-sources of demand flexibility, and can turn down production at points during the day, if the financial benefits of avoiding demand outweigh the benefits of continuing production over that time period.

n networks h demands

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Demand begins to ramp up after 4 pm, representing the start of the evening peak. In the control room, AI-aided forecasting in the digital twin modelling have allowed the anticipated evening peak to be planned and stress-tested. System operators and market participants are prepared for the upcoming increase in demand and coincident drop in wind generation through highly visible real-time data from grid-connected assets, weather stations, distribution networks and transmission substations.

Increasing demand and falling renewable output results in another opportunity for demand-side flexibility to play its part. Smart devices, linked to dynamic tariffs that reflect market prices, are alerted that the next few hours are going to be the most expensive of the day. On top of automated demand reduction, facilitated by aggregators controlling a block of assets such as EVs and heat pumps, price information allows consumers to determine the best time to use appliances such as dishwashers and washing machines.

Importantly, when potentially over 20 million EVs are plugged in after returning home, only vehicles that are nearly out of charge are likely to start drawing power immediately, with the remainder waiting for much lower cost periods later in the evening and overnight.

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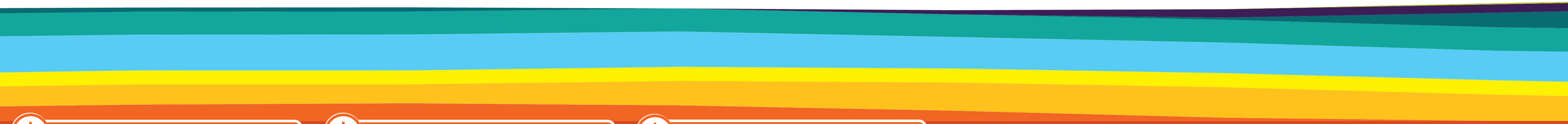

Diversity of renewable supply

Hydropower and wind power in Scotland are key features in the net zero electricity system. Solar power from farms and rooftops, plus marine energy around the northern coast, supply diverse renewable energy throughout the year.

Image source: SSE Renewables

Hydro, wind, solar and marine energy in Scotland

Offshore wind and marine energy in the Celtic Sea, and interconnection to Ireland

Click the orange circles for more!

Other forms of renewables, such as tidal and geothermal

Solar farms and rooftop solar across the country

Interconnectors to continental Europe

Diversity of renewable supply

The 2035 energy system utilises a wide array of renewable energy sources, many of which rely on environmental conditions to generate energy. For an efficient, low carbon energy system, renewables need to be geographically diverse and generating electricity at different times.

This geographic diversity helps avoid the risk of having a high concentration of wind turbines within the same weather window, for example, when a low-wind high-pressure system sits over the east coast and southern North Sea.

Click the orange circles for more!

Tidal marine energy off the coast of Scotland, geothermal power in Cornwall, and floating offshore wind around the country also provide low carbon electricity to the grid that is less correlated with the output of solar, onshore wind and fixed offshore wind

Image source: Orbital Marine Power

Hydro, solar marine e in Scot

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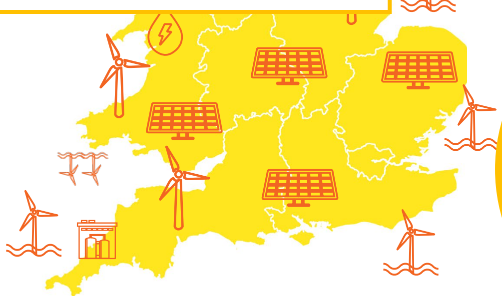
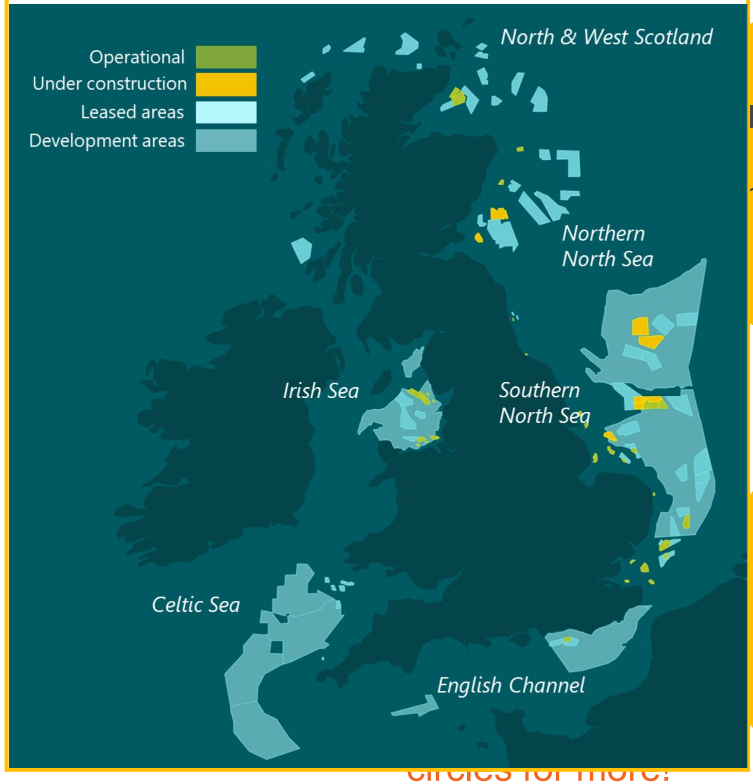


Interconnectors to continental Europe

Offshore wind forms the backbone of the 2035 electricity system. Existing windfarms off the east of England have been added to by projects in the Celtic Sea, and off the Scottish and Welsh coasts. Interconnectors will link to wind resources in Ireland and northwest Europe. The below graphic from Regen illustrates the operational and potential offshore wind area around GB:



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Hydro, wind, solar and marine energy in Scotland

Offshore wind and marine energy in the Celtic Sea, and interconnection to Ireland

Other forms of renewables, such as tidal and geothermal

Solar farms and rooftop solar across the country

Interconnectors to continental Europe

While not playing a huge role in the Day in the Life, solar power is likely to be a key source of low carbon electricity in 2035. Not only concentrated in the south and midlands, solar farms and rooftop PV will be in place across the UK.

Image source: Low Carbon

Diversity of renewable supply

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Click the orange circles for more!

Hydro, wind, solar and marine ener... in Scotland

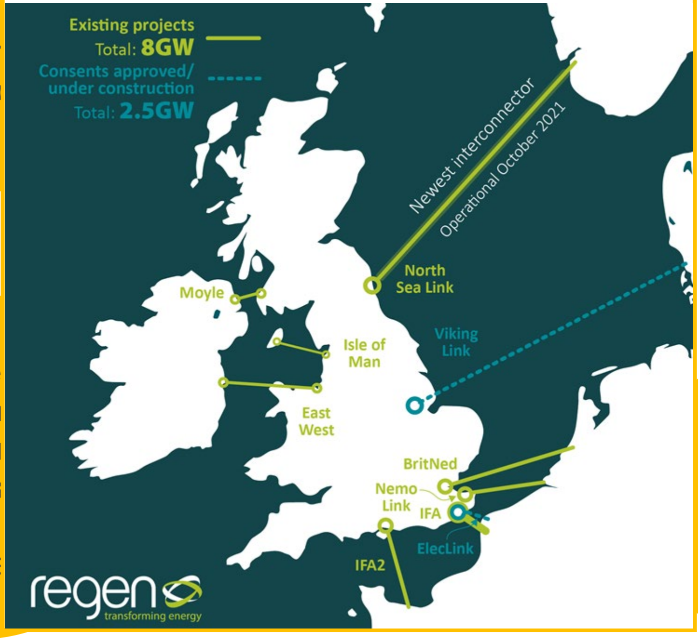
Offshore ... and ma... energy i... Celtic Sea... interconn... to Irela...

Other forms of ...bles, ... tidal ...ermal

Solar farms and rooftop solar across the country

Interconnectors to continental Europe

Interconnectors to neighbouring countries provide access to an even more diverse pool of renewable and low carbon generation. The below graphic from Regen illustrates operational and imminent interconnectors between GB and Europe:



System operability: constraints

A key challenge for the Day in the Life energy system is managing the high variability of renewable energy generation, especially in areas of high generation capacity relative to energy demand such as northern Scotland. The 2035 system is based on significant infrastructure investment throughout the 2020s and early 2030s, and other non-network solutions, without which the system would incur constricting thermal constraints, higher system balancing costs and the loss of valuable energy resource.

The occurrence of constraints, and increasing balancing costs, is typically seen across "boundaries" between the transmission network zones, the most notab
boundary. During the a
wind power from Scotl
electricity demand in a

It would be extremely
There are, however, a
infrastructure solutions
and their cost and carb
more Holistic Network
onshore and offshore i

Network boundaries

Although GB is considered as one single energy system there are a number of integration pinch points between different transmission zones. The most notable is the network boundary between the north of Scotland and the rest of GB. Boundary constraints also occur in South Wales, North East and South East.

The Day in the Life features key network infrastructure-based solutions such as:

- Upgrades to transmission network capacity based on a Holistic Network Design and strategic planning at a national and local
- Development of a more integrated offshore transmission network
- Greater interconnectivity to adjacent markets in Ireland, Scandinavia and Europe.

Complementary solutions not based on network infrastructure also feature during the Day in the Life, including:

- A wider range of flexibility assets, including long-duration energy storage and demand-side response
- More efficient balancing processes, aided by higher levels of automation and digitalisation
- Greater integration and coordination between transmission and distribution networks
- Flexible connection agreements and use of Active Network Management (ANM)
- Encouraging and incentivisng energy generators and major demand users to co-locate in areas with strong networks – e.g. hydrogen electrolysers and data centres.

Network Options Assessment

Constraint Management Pathfinder

System operability: constraints

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The occurrence of constraints, and increasing balancing costs, is typically seen across "boundaries" between the transmission network zones, the most notable of which is the Scottish to North of England boundary. During the afternoon in the Day in the Life, hydropower and wind power from Scotland is moved to the rest of Great Britain, to meet electricity demand in areas of the country with less renewable resource.

It would be extremely costly, and sub-optimal, to alleviate all constraints. There are, however, a number of infrastructure and complimentary non-inf f constraints, an is to adopt a mo ment options for on

Th based solutions su

Upgrades to Transmission Network Capacity
For example, the plans set out in the Network Options Assessment to upgrade major links between the north of Scotland and the rest of GB, including new HVDC subsea links down the east and west coast.

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It would be extremely costly, and sub-optimal, to alleviate all constraints. There are, however, a number of infrastructure and complimentary non-infrastructure solutions that will reduce the occurrence of constraints, and their cost and carbon impact. One of the key steps is to adopt a more Holistic Network Design to identify the best investment options for onshore and offshore infrastructure.

The Day in the Life features key network infrastructure-based solutions such as:

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Offshore transmission networks
BEIS, Ofgem, National Grid ESO and the Crown Estate are currently conducting a review of the offshore transmission network, alongside the ESO's holistic review of network requirements to support the deployment of renewable energy.

Network Options Assessment

Constraint Management Pathfinder

Distribution networks & operators

Millions of electric vehicle chargers, heat pumps and other forms of new electricity demand have connected to the electricity distribution networks. Alongside this, a much greater proportion of generation and flexibility is likely to be distribution-connected, including solar PV, onshore wind and battery storage.

By 2035, the electricity system has become highly decentralised. The previous linear electricity system, with generation, flexibility and balancing driven by large, transmission-scale assets, has been transformed. Now, distributed generation from renewables and distributed energy storage, dispatchable generation, and demand-side flexibility mean that an increasing proportion of power flows and balancing happen entirely on the distribution networks, facilitated by Distribution System Operators (DSOs).

Real-time data sharing between sys digitalised network infrastructure, w operators and ESO to coordinate n planning, constraint management, r flexibility markets to operate an effi

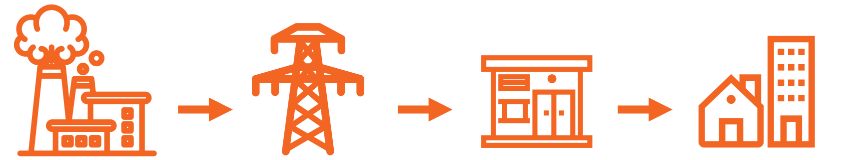
During the Day in the Life, the low l mean that a significant proportion o transmission-scale assets such as and offshore wind. However, many energy storage and demand-side fl including millions of household-leve

Distribution System Operators

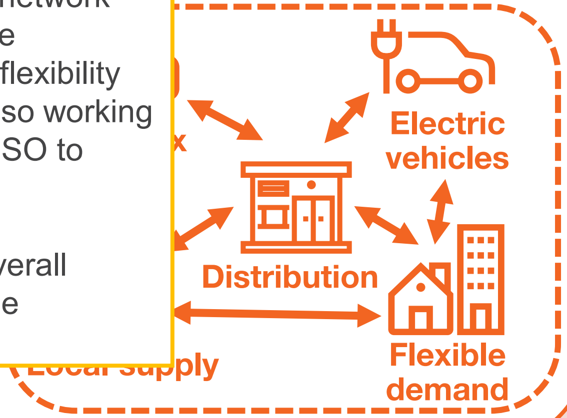
The role of distribution network operators is already changing. Increasingly, network operators are taking proactive steps to work with their customers and service providers to manage a range of system elements, such as contracting local flexibility and demand-side response to manage network constraints. Networks are also working more closely with transmission network operators, other networks and the ESO to share data and manage power flows across the networks.

The umbrella term for this new role is Distribution System Operators. The overall objective of the DSO role is to use network capacity more efficiently, optimise investment and to reduce whole system costs.

The energy system has previously been linear and centralised



The 2035 electricity system is decentralised, on a local level



The Day in the Life - Evening

Afternoon

19 | 20 | 21 | 22 | 23 | 00

The evening peak
- Highest demand
- Highest prices

Drawing on storage
- Wind drops out
- Storage dispatches

A puff of wind
- Sharp rise in wind output
- High-cost generation drops

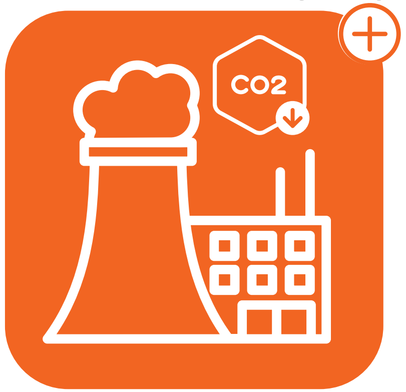
Dwindling demand
- Demand drops down
- Smart devices start up

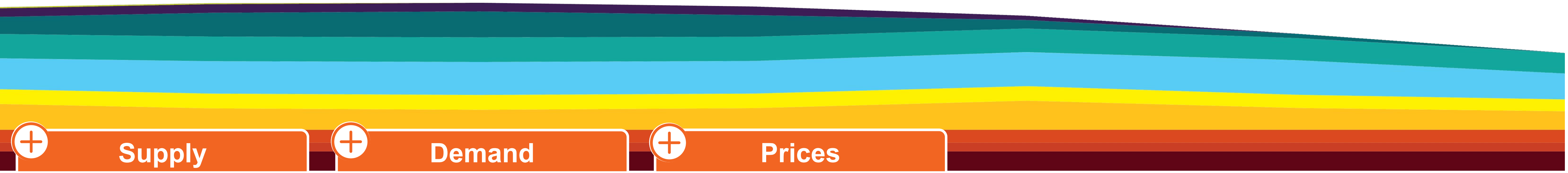
People come home and turn on lighting, electronics, kettles and cookers, causing demand to rise, on top of commercial and industrial demand which is still high during the early evening.

Dynamic tariffs are directly linked to smart devices, which in many cases automatically reduce demand, saving money for the consumer and reducing the peak. However, some households may choose to overrule automated smart devices, when the electricity is needed immediately.

Bioenergy generation remains online

Gas-fired power with carbon capture keeps going





Supply | Demand | Prices

Introduction | The Day in the Life | The winter week | The net zero system

The Day in the Life - Evening

Afternoon

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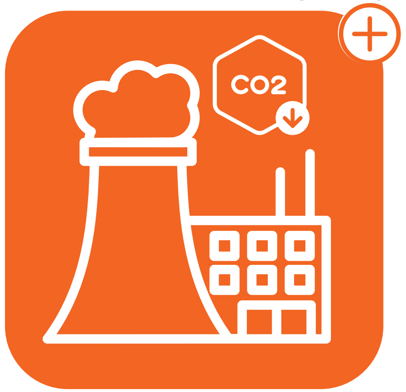
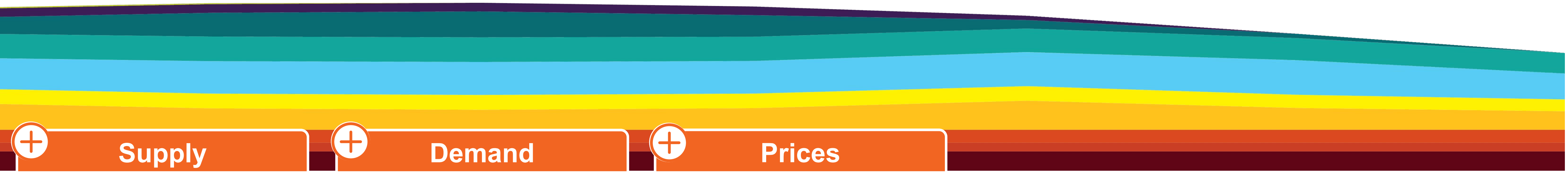
Around 8 pm, wind generation is at just 9 GW and demand is nearly 80 GW, despite the widespread usage of smart charging, dynamic tariffs and other forms of peak-avoidance. Providing this 70 GW of residual demand through purely low carbon energy sources is a huge challenge for the 2035 system.

Dispatchable and firm generation, in the form of biomass and gas with carbon capture and storage, nuclear, and hydrogen or other low carbon gases, provide another 30 GW of supply. Interconnectors add a further 17 GW to the mix, and other renewables like Scottish hydropower provide another 7 GW. However, this still leaves a shortfall of around 15 GW which is where electricity storage comes in to play.

Electricity storage asset owners export electricity across the evening peak to take advantage of the day's highest price periods. Some electric vehicles, especially commercially owned fleet vehicles, may also export some charge back to the grid.

Gas-fired power with carbon capture keeps going





Supply
Demand
Prices
Introduction
The Day in the Life
The winter week
The net zero system

The Day in the Life - Evening

19 20 21 22 23 00

The evening peak
- Highest demand
- Highest prices

Drawing on storage
- Wind drops out
- Storage dispatches

A puff of wind
- Sharp rise in wind output
- High-cost generation drops

Dwindling demand
- Demand drops down
- Smart devices start up

Electricity de
for heat is hi

Around 10 pm, offshore wind farms in the Celtic Sea and around Scotland experience a short burst of blustery conditions, increasing wind output by almost 50% in less than an hour, from under 10 GW to nearly 14 GW.

With the balancing system and markets operating with real-time data, this puff of wind results in a decrease of the highest-cost dispatchable generation, which ramps down at relatively short notice.. Electricity storage is mostly empty, having exported during the previous hours of particularly high prices, but has some charge in reserve to provide services to the grid if needed.

On another day, an increase in wind output may result in a turn up of smart and flexible demand, as opposed to generation turning down.

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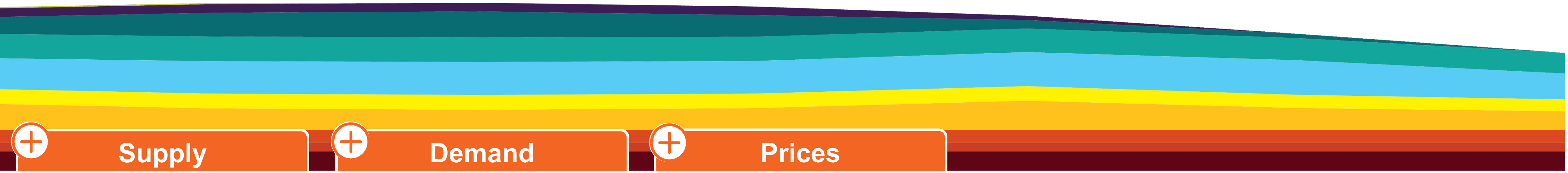

Supply
Demand
Prices

The Day in the Life - Evening

Afternoon

19 20 21 22 23 00

The evening peak
- Highest demand
- Highest prices

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A puff of wind
- Sharp rise in wind output
- High-cost generation drops

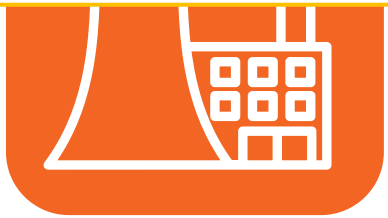
Dwindling demand
- Demand drops down
- Smart devices start up

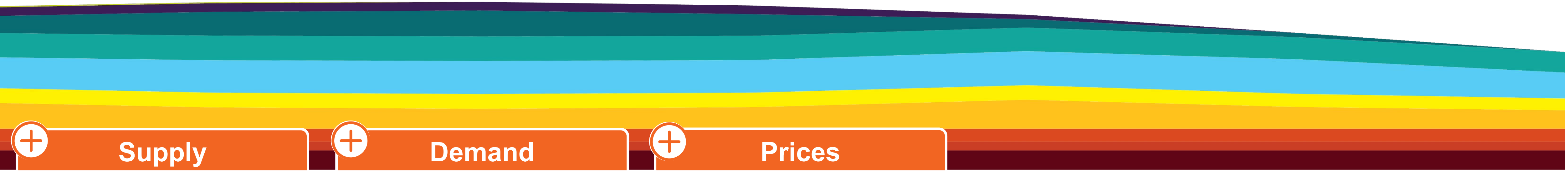
Electricity demand for heat is highest

Consumers impact the peak differently

In the final period of the Day in the Life, demand falls as people head to bed. Smart appliances and chargers begin to ramp up, but the overall demand falls back to the overnight levels seen right at the start of the day.

While the rest of the week is also calm and cloudy, the upcoming days are forecast to be slightly easier on the electricity system, with milder temperatures and slightly windier conditions across the UK.





Supply Demand Prices

Electric heat in 2035

The Day in the Life sees millions of heat pumps, fed by low carbon electricity to provide heat and hot water to homes and businesses across the country. In addition to this significant technological shift, buildings are also more thermally efficient, reducing electricity demand and enabling more flexible use of heat, as buildings can retain a comfortable temperature for longer.

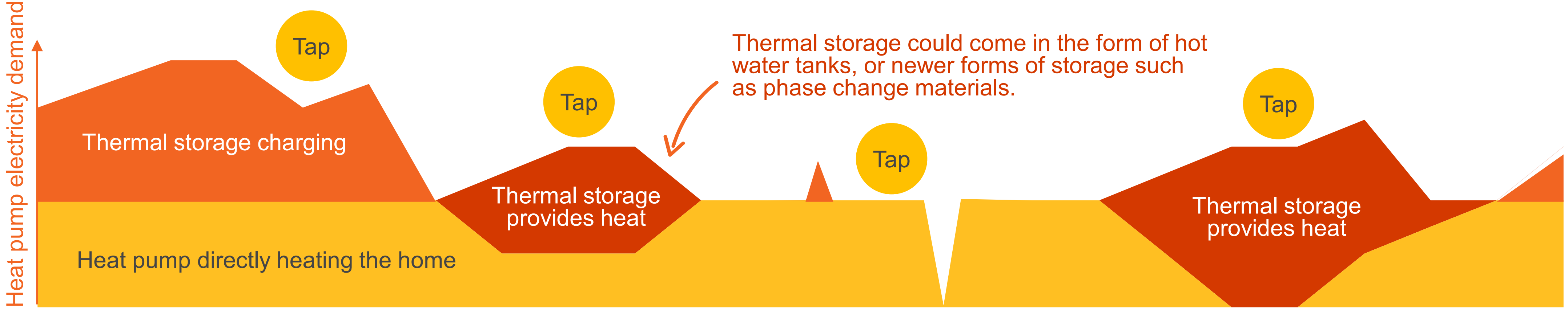
Smart operation of heat pumps, some in combination with thermal storage, allows this huge source of flexibility to avoid high-price and high-demand periods of the day, and soak up low carbon and low-cost electricity. Smart heat pumps individually respond to price signals to avoid high price periods and run during low prices. Households may sign up with an aggregator, who oversees a large number of heat pumps to directly provide flexibility and ancillary services to the electricity grid, sharing the finan

In urban areas, ... n a similar way, with ... the ease of managi ... ts.

The below grapl ... storage could o ... for more details:

Flexibility from electric heat

In 2021, this is already performed through night storage heaters and Economy 7 tariffs. In 2035, a more digitalised and data-driven electricity system will allow a much more refined, supply-led form of electric heat flexibility.



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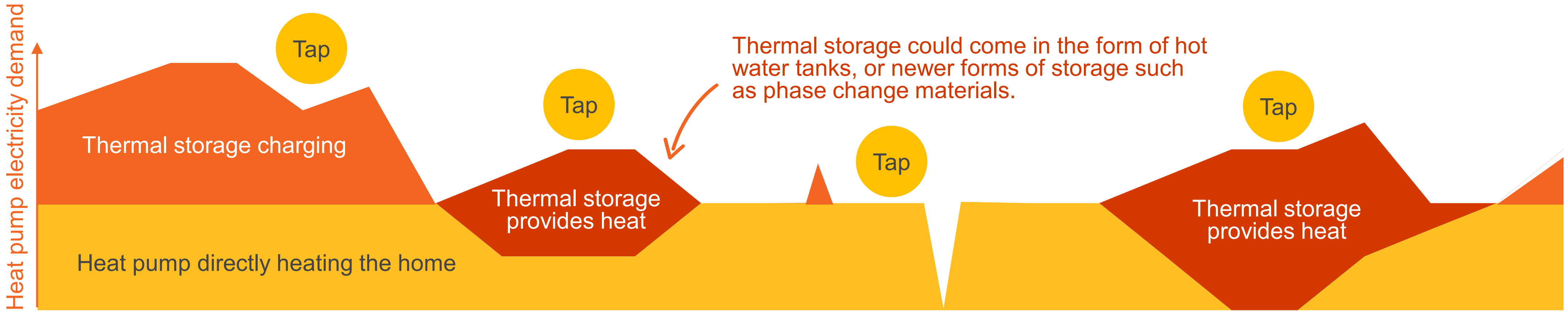
In urban areas, heat networks driven by a heat pump could operate in a similar way, with the added benefit of a diversified heat demand and the ease of managing a … assets.

The below graphic i… …nal storage could opera… …nbers for more details:

Diversified heat demand
As people use heat at different times, the maximum demand from a group of households or businesses is lower than the combined maximum demand of each individual building.



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Smar with thermal
storag high-price and high-
dema nd low-cost
electr price signals to
avoid ouseholds may sign

Thermal storage charging
While a heat pump operates best with steady, consistent generation of heat, the addition of thermal storage would allow the storage to be charged up overnight on lower cost, low carbon electricity.

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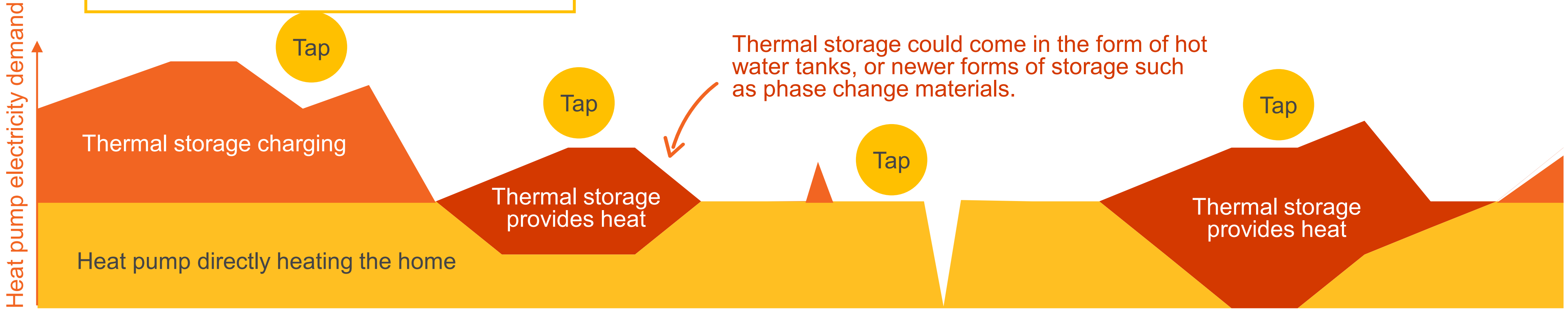
In urban areas, heat networks driven by a heat pump could operate in a similar way, with the added benefit of a diversified heat demand and the ease of managing a single large asset rather than many smaller assets.

The below graphic illustrates how a smart heat pump with thermal storage could operate during the Day in the Life. Tap on the numbers for more details:



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Morning peak

Improved energy efficiency, and running the heat pump throughout the night, means that the traditional 'morning peak' of heat demand is mainly avoided. However, demand for hot water for morning showers is hard to defer! Depending on the price of electricity and forecast evening prices, smart thermal storage may kick in to provide hot water, reducing the electricity demand during these hours.

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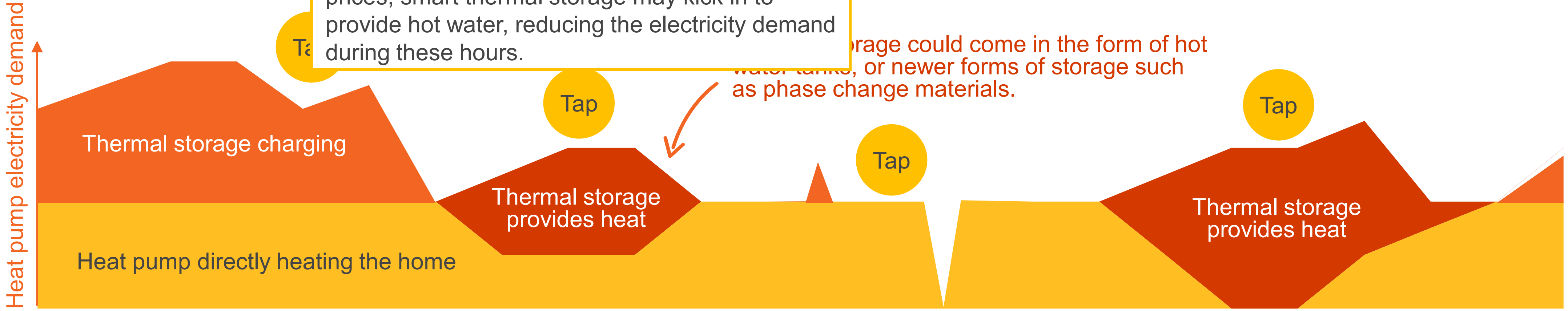

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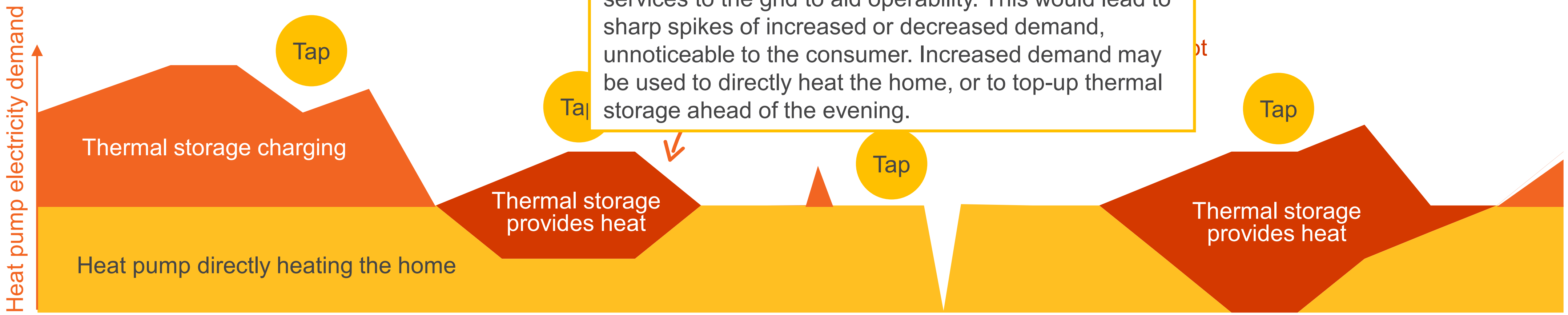
nart heat pump with thermal in the Life. Tap on the numbers for

Flexible demand to provide grid services

Throughout the daytime, heat pumps are likely to steadily provide space heating to homes, businesses and public buildings. However, if controlled by an aggregator, heat pumps could be used to provide services to the grid to aid operability. This would lead to sharp spikes of increased or decreased demand, unnoticeable to the consumer. Increased demand may be used to directly heat the home, or to top-up thermal storage ahead of the evening.



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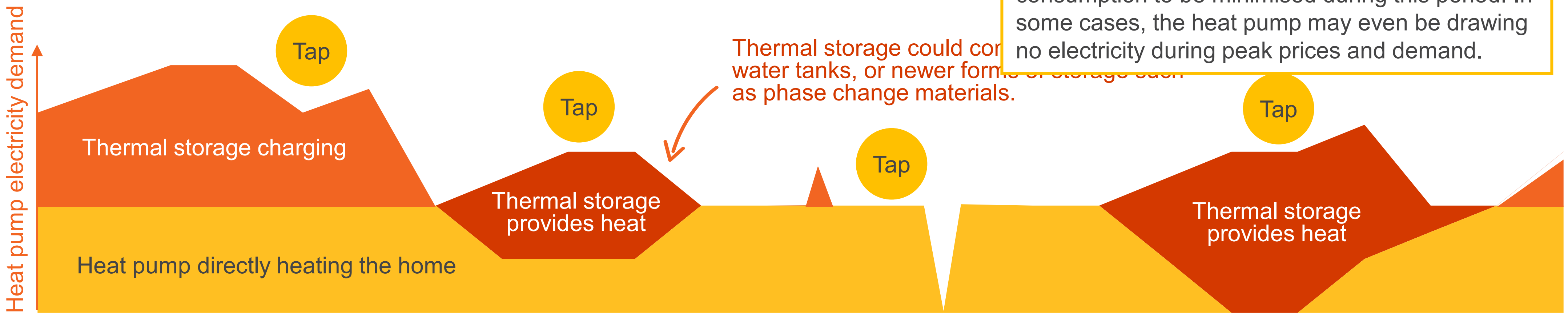
Evening peak

As with the morning peak, the evening sees higher electricity prices and demand for space heating and hot water. Again, thermal storage and improved energy efficiency allows electricity consumption to be minimised during this period. In some cases, the heat pump may even be drawing no electricity during peak prices and demand.



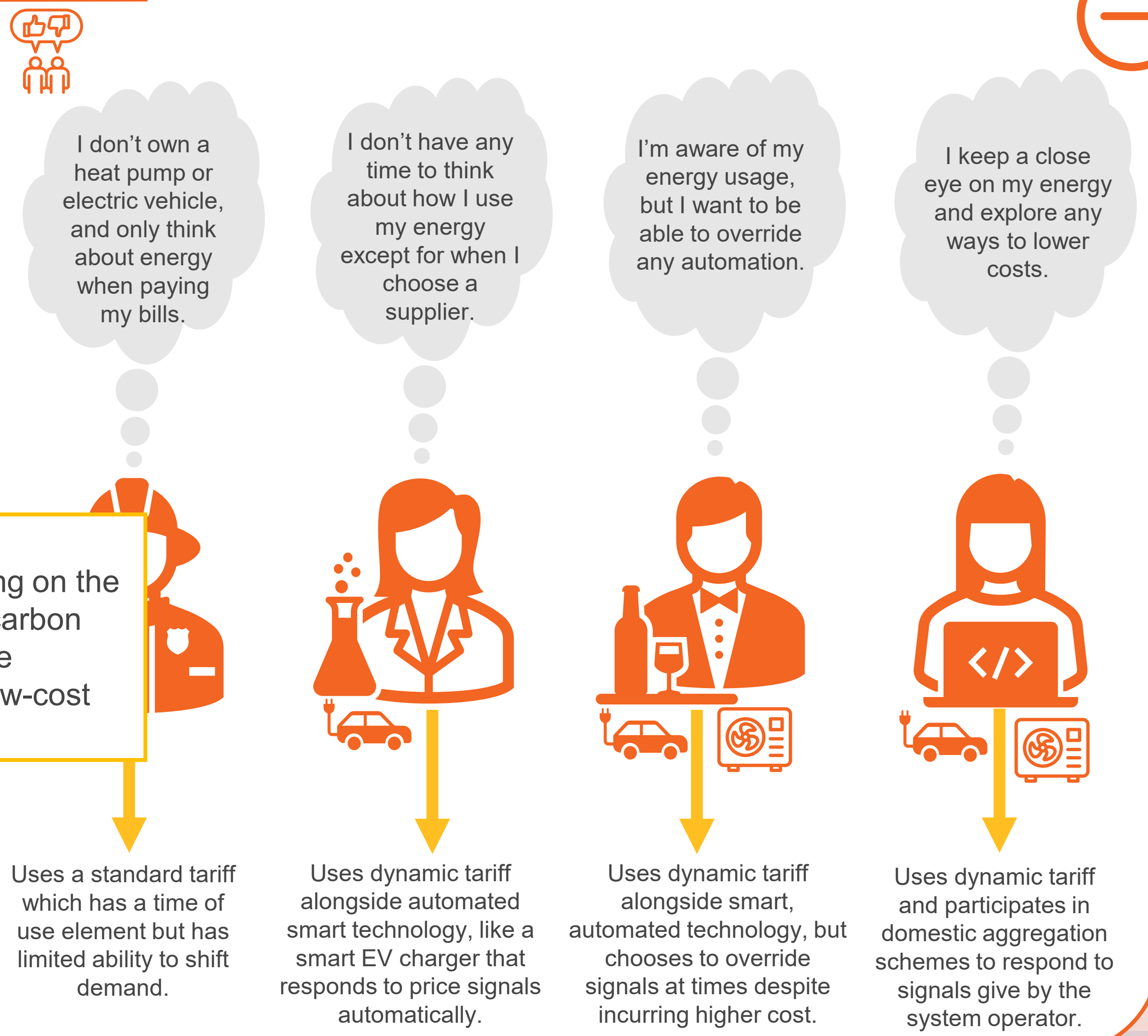
Different types of consumer

Domestic supply-side flexibility plays a vital role in system balancing throughout the Day in the Life, especially in the high-price and high-demand periods of the day such as the evening peak. Different consumers are able and willing to participate in the energy system to different extents, with the end result being a more efficient energy system. For this to work effectively, there is trust and openness between networks, suppliers, regulators and consumers.

By 2035, work by community energy organisations, local authorities and energy suppliers has resulted widescale rollout and acceptance of smart devices. Dynamic electricity tariffs are standard, and smart chargers, app
automatically shift demand to chea
to the end consumer. This tailors d
and flattens demand peak, benefit
simultaneously.

Dynamic electricity tariffs
Electricity tariffs that vary depending on the electricity price (or potentially the carbon intensity of electricity) to encourage consumers to take advantage of low-cost periods.

However, consumers have differin
the energy system, varying ability to shift demand in response to price signals, and different motivations to reduce bills through flexibility. Whilst households with heat pumps, electric vehicles and smart charging appliances inevitably have the greatest means to shift demand, the system benefits should ensure that all consumers, including fuel-poor households, benefit from widespread domestic and commercial supply-side flexibility.



Bioenergy with carbon capture

Bioenergy generation with carbon capture (BECCS) could provide an alternative source of low carbon dispatchable generation. Bioenergy could come in the form o[f] waste, agriculture and advanced co[…] from energy crops and as a by-prod[…]

Dispatchable generation

Generation assets that can be dispatched relatively quickly (within minutes) and run for several hours or even days on a banked fuel source.

The sustainability and low carbon bene[…] dependent on both the source of bioen[…] to replant crops and trees that have be[…] long-term sustainability of bioenergy ne[…] BECCS is going to play a key role in the net zero energy system.

The carbon-cycle basis of bioenergy is complex and can be controversial. It relies on the adoption of sustainable practices in agriculture and forestry, and a robust method of certification and carbon tracking.

When combined with carbon capture, the bioenergy carbon cycle can result in an overall negative emission, however it must be emphasised that the negative emissions comes from the replanting of energy crops and trees not at the point of generation. This raises a challenge that short-term emissions, that threaten climate targets and add to damaging global warming, are offset by a long-term commitment to manage energy crops and forests which are themselves subject to climate change impacts, as well as other land-use pressures.

The use of bioenergy for power generation is therefore likely to be limited to a scale that is sustainable and ideally be sourced from agriculture, energy crops and forest by-products from within the UK. Any imported […]stocks must come from sustainably managed and certified […]ered without substantial carbon emissions from shipping.

[…]tion is relatively costly and, without subsidy payments or […]upport, is likely to be targeted to times of higher electricity […]mand exceeds the output of lower running cost nuclear […]. High carbon prices could provide an extra revenue […]CS, helping it to be more cost-competitive.

During the Day in the Life, around 4 GW of BECCS power generation is running continuously throughout the day helping to meet high levels demand while wind and solar output is lower. At other times of the year, BECCS generation is more likely to act more flexibly, ramping up during high price periods and dovetailing with the power output of renewables.

In a net zero power system, BECCS combined with sustainable agriculture, energy crop and forestry practices, could provide a form of long-term negative carbon emission to net-off the residual carbon emissions that might escape carbon capture processes, or the infrequent use of fossil fuel generation needed to maintain security of supply. More broadly, in a net zero scenario, the Committee on Climate Change has projected that the UK may need to achieve negative emissions of circa 100 million tonnes of carbon per annum, mainly through tree planting and other forms of carbon sequestration.

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The sustainability and low carbon benefits of bioenergy are heavily dependent on both the source of bioenergy fuel and on the commitment to replant crops and trees that have been used in fuel production. The long-term sustainability of bioenergy needs to be firmly established if BECCS is going to play a key role in the net zero energy system.

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It rel ... ture and
fores ... racking.

Carbon-cycle basis
Bioenergy is not a renewable energy resource in the same way as wind and solar.

Bioenergy can only be classed as low carbon on the basis that carbon that is embedded in bioenergy fuels is removed by the sustainable replanting of energy crops and trees. It also requires that the processes to produce, harvest and transport bioenergy are also low carbon.

Whe ... on cycle can
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other form

Residual carbon emissions

Targets of 90-95% carbon capture at source have been set, however trials to date have achieved much lower rates. In addition, there may be carbon emissions associated with the energy required to run the capture process, and subsequent transportation and storage of carbon.

Carbon capture and storage

Over one-third of current GB electricity generation is provided by unabated fossil gas power stations, which provides flexible, dispatchable generation when needed. In 2035, dispatchable generation will be needed to provide extra power during periods of peak demand and/or low renewable generation, but will need to be entirely low carbon. One option is to use carbon capture and storage technology to abate fossil gas power station emissions.

The 2035 net zero electricity system is reliant on dispatchable generation, especially during the peak time perio[d] uncertainty about which types of low carbon gene[ration] in 2035. Currently, the frontrunners are:

- Fossil gas with carbon capture and storage (C[CS]) carbon capture and storage, this could result i[n] electricity generation. However, no current carb[on capture process is] able to capture 100% of carbon emissions.
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- Bioenergy-fuelled generation without carbon capture, using fuels such as biomethane produced through anaerobic digestion.
- Hydrogen-fuelled generation, using low carbon blue or green hydrogen.

Dispatchable generation
Generation assets that can be dispatched relatively quickly (within minutes) and run for several hours or even days on a banked fuel source.

All these technologies could be available at scale by 2035, but they each face a number of commercial, technology and sustainability challenges.

If low carbon dispatchable generation is not developed at scale, the alternative net zero solutions would include far more long duration storage and greater interconnection capacity.

Carbon capture technology has already been trialled but faces a number of challenges, including the overall efficiency of the carbon capture ...perating costs and the cost of the subsequent ...rbon. The UK government has provided ...S development with the ambition to have two ...S clusters by the mid-2020's and to capture ...0.

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Funding for CCUS development

The UK government announced the East Coast Cluster and HyNet in the Northwest as the winners of the CCS infrastructure fund. This grants the two projects access to the £1 billion investment pot predominantly funding CAPEX for carbon transport and storage, and industrial carbon capture projects. Other clusters are in development.

The winter week

The Day in the Life is set within a mid-January week in 2035.

While the Day in the Life focuses on a specific 24-hour period in the future energy system, the conditions leading up to and following the day must be considered.

The week is set in the middle of winter, when days are short, and temperatures are low. This particular week sees a prolonged spell of low sun and low wind conditions, representing one of the major challenges for a net zero electricity system.

The modelling behinc
Day in the Life is bas
a similar winter week
January 2017.

Why this week?

Weather Conditions

Similar winter week
The weather conditions over the winter week are based on Met Office and Shipping Forecast data for the week beginning 16th January 2017.

Owing to a winter high pressure system sitting over the east coast of the UK and parts of northern Europe, low winds and cloudy weather limit renewable generation throughout the week.

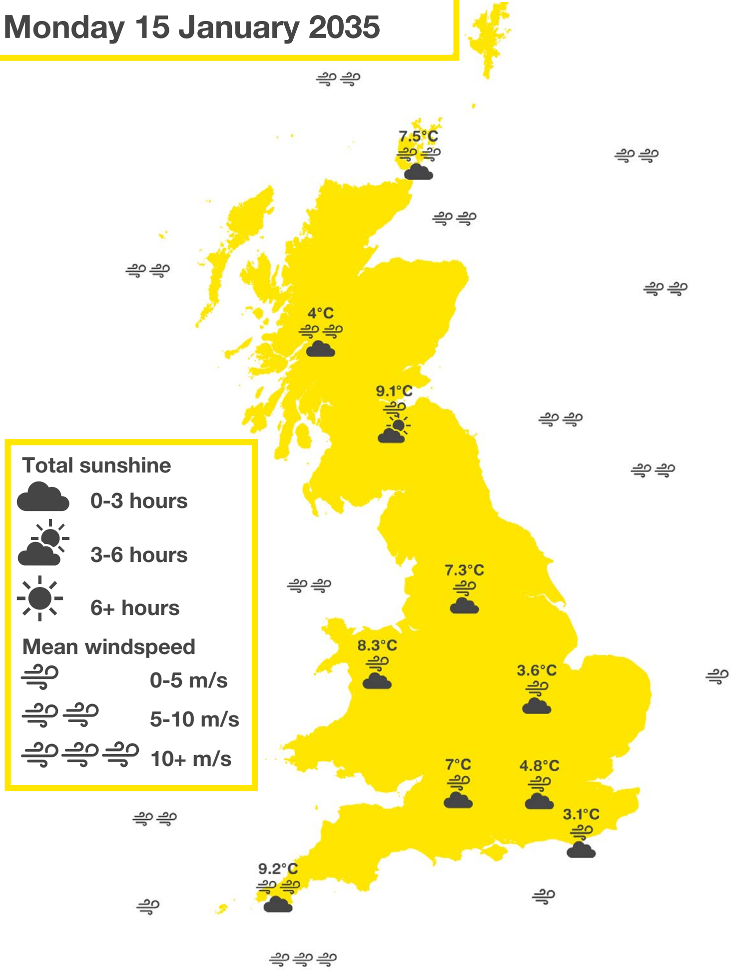
It is not an extreme cold week. Temperatures vary regionally, but during the daytime they stay slightly above freezing throughout the week.

Thursday 18 January 2035, the Day in the Life, is a cloudy, calm and cold day. There is, however, some wind in the west and north of the UK, allowing some offshore wind generation in the Celtic sea, Irish Sea and off the Scottish coast.

the tabs above the map to see
onshore and offshore weather
ditions during the winter week.

Mon | Tues | Wed | Thurs | Fri

Monday 15 January 2035



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Why this week?

Weather Conditions

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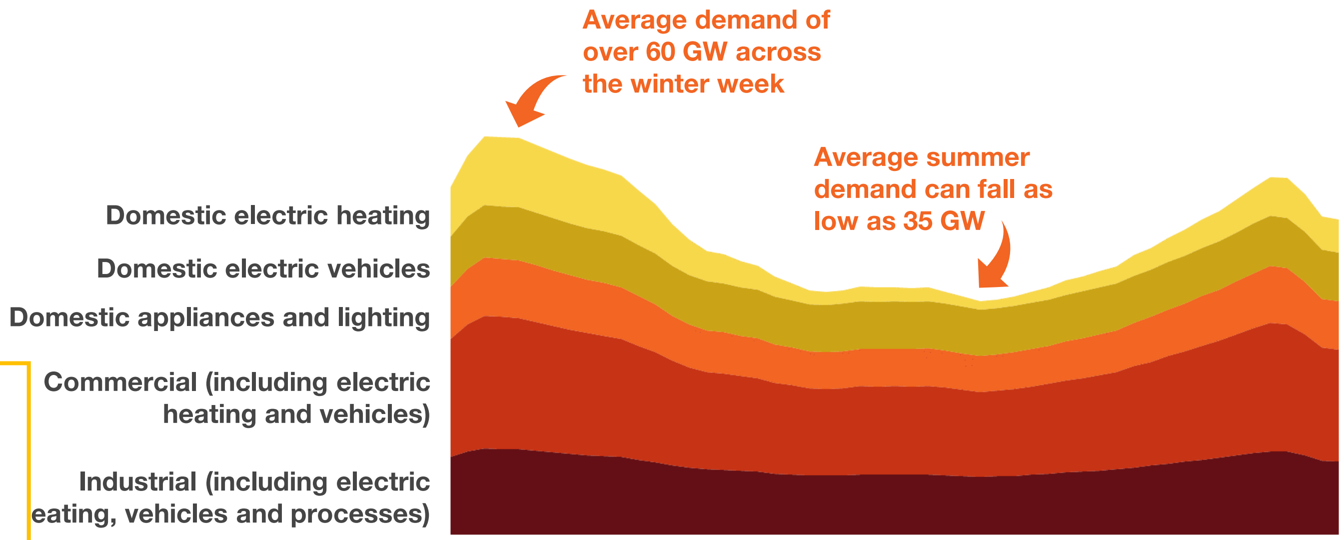
Throughout the year, a decarbonised and decentralised electricity system will face different challenges based on differing weather conditions, and changes in demand for energy. For example, in the summer, when the sun is shining but demand is lower, the system will need to find ways to store the surplus energy and remain balanced.

On the other hand, one of the biggest difficulties the system will face is balancing supply and demand during periods of high demand and lower variable renewable generation. The week explored in the Day in the Life has the highest average residual demand in 2035, with over 60 GW of demand left to be met from sources other than wind and solar generation.



Introduction
The Day in the Life
The winter week
The net zero system

The winter week

The Day in the Life is set within a mid-January week in 2035.

While the Day in the Life focuses on a specific 24-hour period in the future energy system, the conditions leading up to and following the day must be considered.

The week is set in the middle of winter, when days are short, and temperatures are low. This particular week sees a prolonged spell of low sun and low wind conditions, representing one of the major challenges for a net zero electricity system.

The modelling behind the Day in the Life is based on a similar winter week in January 2017.

Why this week?

Weather Conditions

Owing to a winter high pressure system sitting over the east coast of the UK and parts of northern Europe, low winds and cloudy weather limit renewable generation throughout the week.

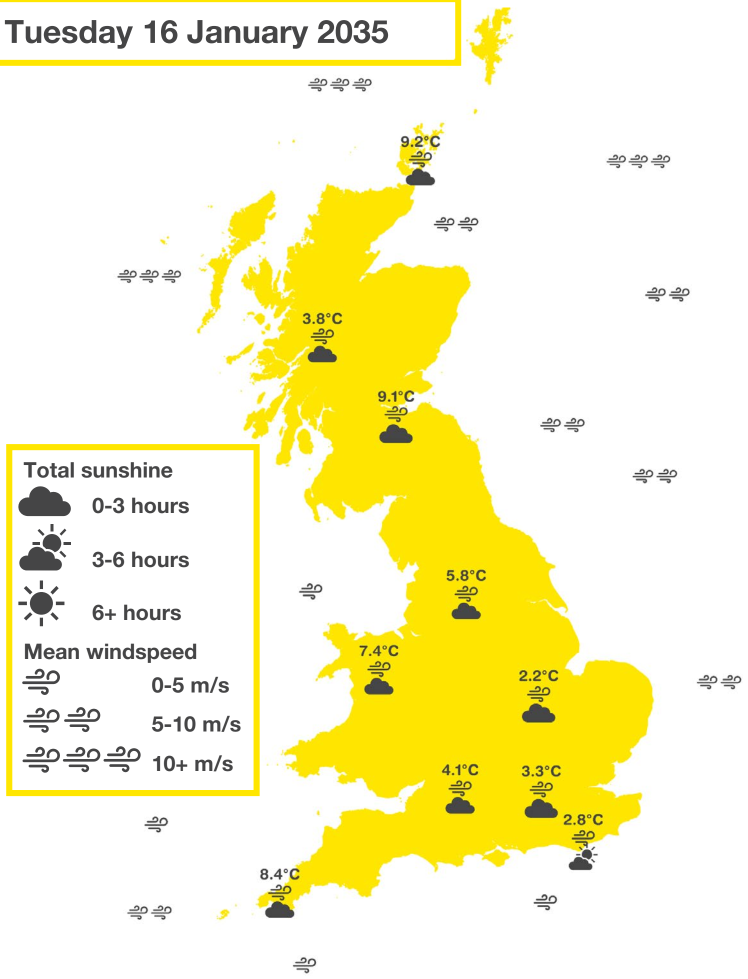
It is not an extreme cold week. Temperatures vary regionally, but during the daytime they stay slightly above freezing throughout the week.

Thursday 18 January 2035, the Day in the Life, is a cloudy, calm and cold day. There is, however, some wind in the west and north of the UK, allowing some offshore wind generation in the Celtic sea, Irish Sea and off the Scottish coast.

Tap the tabs above the map to see the onshore and offshore weather conditions during the winter week.

Mon | Tues | Wed | Thurs | Fri

Tuesday 16 January 2035



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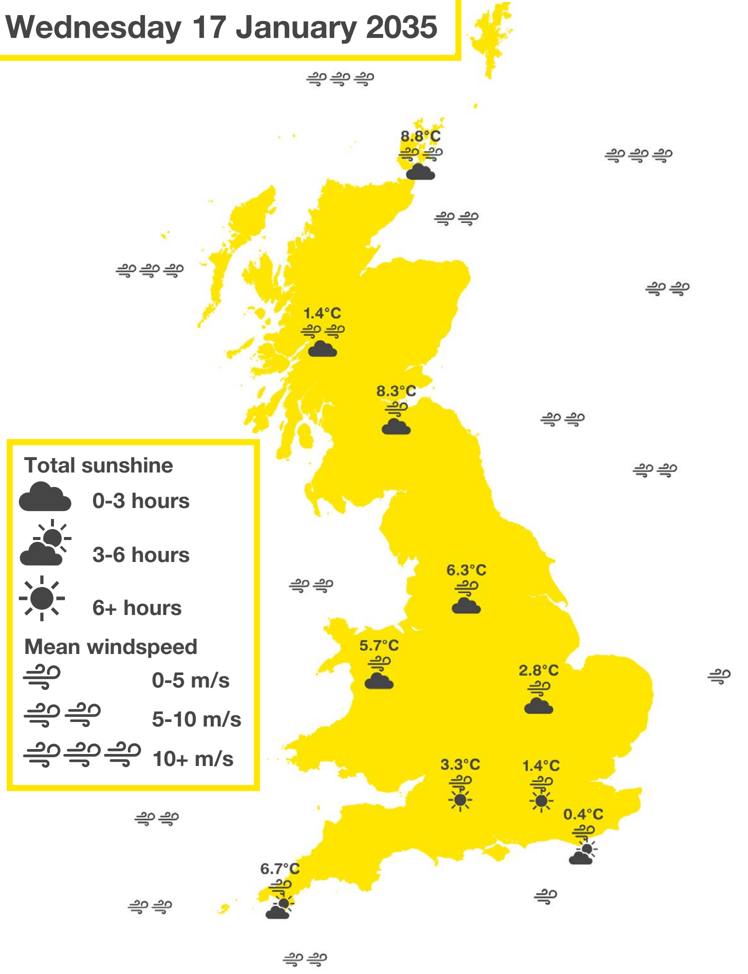

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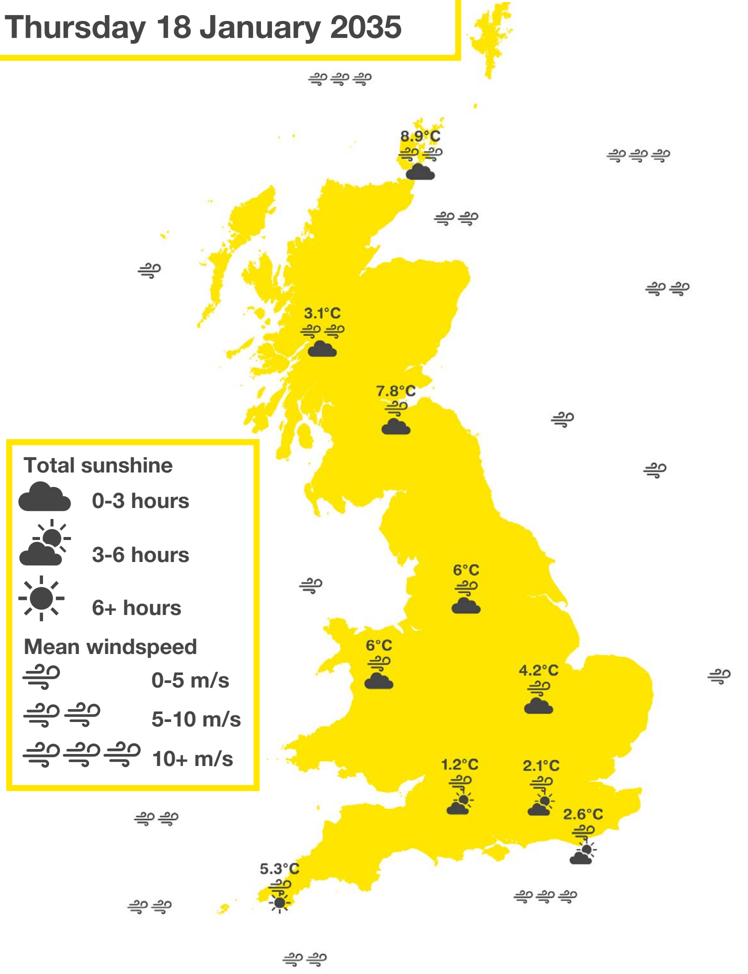

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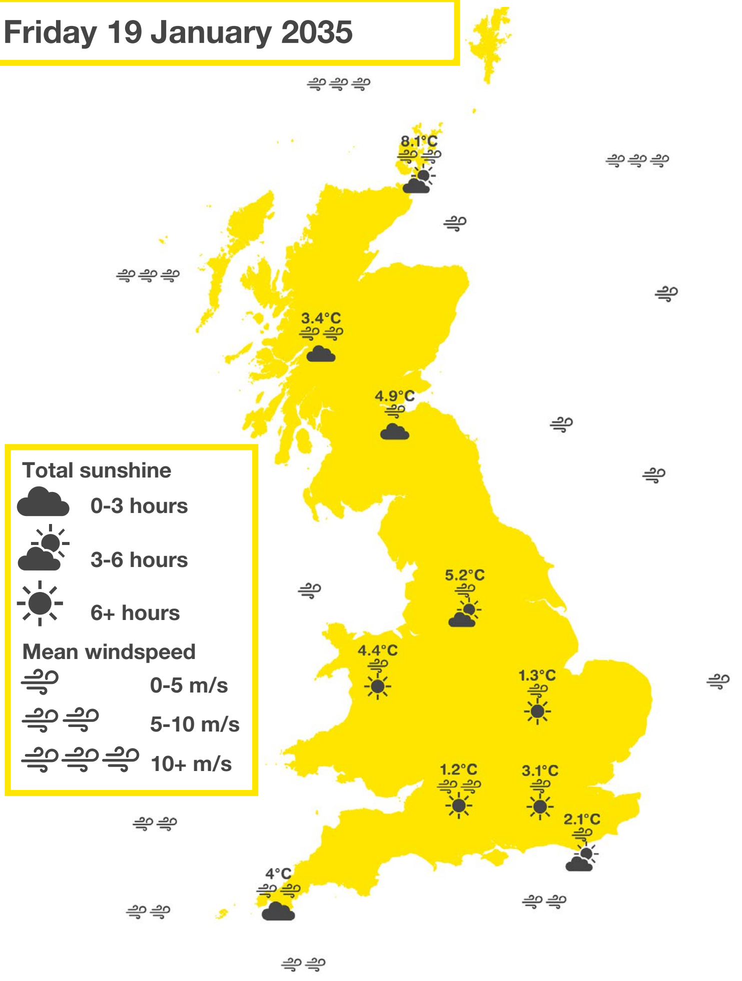

The net zero system

Click to explore eight key aspects of the 2035 net zero electricity system

A net zero power system will be radically different.

The Day in the Life system is based on the National Grid ESO Future Energy Scenarios 2021, amended to reflect the Climate Change Committee's Sixth Carbon Budget
UK Net Zero Er

Sixth Carbon Budget
The Sixth Carbon Budget sets the UK's carbon emission target for the period from 2033 to 2037.

In 2035, electri
almost entirely
and low carbon
decarbonisation of transport, heat, manufacturing and primary industries has increased electricity demand.

This transformation in the way that electricity is generated, delivered and consumed will impact the whole energy system.

New technologies, smarter and digitalised systems, new processes and the participation of an array of new system actors will be vital to meeting this goal.

The net zero power system

Electricity consumption

Peak electricity demand

Electricity generation

Sources of flexibility

Smart systems and digitalisation

System operability

What if? Key uncertainties

The net zero system

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The Day in the Life system is based on the National Grid ESO Future Energy Scenarios 2021, amended to reflect the Climate Change Committee's Sixth Carbon Budget analysis and the UK Net Zero Energy Strategy.

Net Zero Strategy
Published in 2021, the 'UK Net Zero Strategy: Build Back Greener' report sets out the UK's strategy to achieve net zero, including a target to deliver a decarbonised power sector by 2035.

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Decarbonisation of power by 2035 is critical to achieving the UK's carbon reduction goals. It will enable the decarbonisation of major sources of energy demand including transport, heat and other industrial sectors.

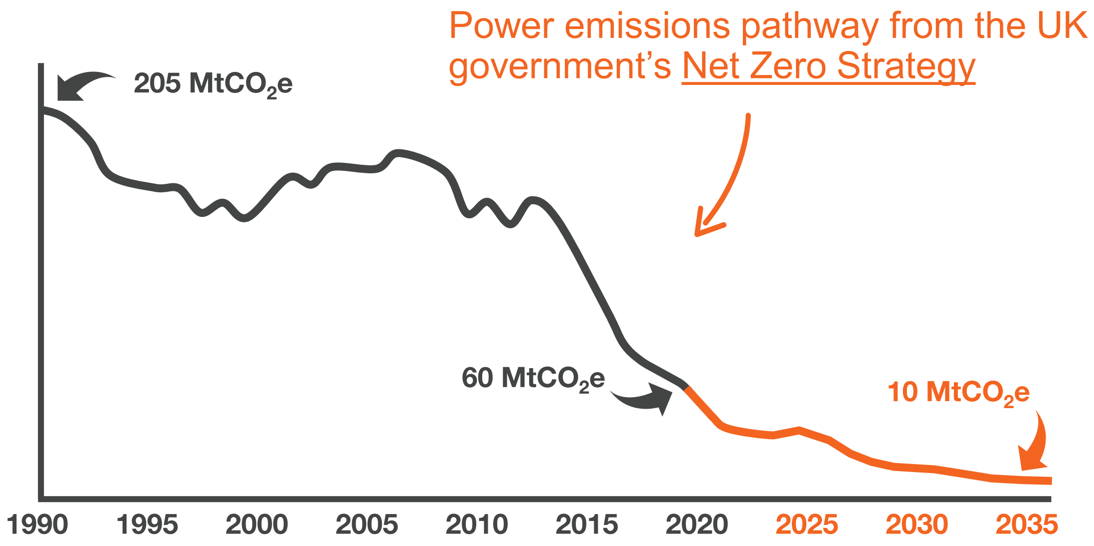
By 2035, the UK must have met the carbon reduction targets of the Sixth Carbon Budget and achieved the goal set out in the Net Zero Strategy that "all electricity will come from low carbon sources, subject to security of supply".

Key differences in a net zero power system in 2035 will include:

- Electricity will overwhelmingly be sourced from renewable technologies, delivered by massive investment in offshore wind, onshore wind, solar energy and other innovative technologies.
- Renewables will be complemented by other sources of low carbon generation such as nuclear, bioenergy and fossil gas plants equipped with carbon capture and storage (CCS). Electricity generated from low c[...]e gene[...]ge.
- Coal [...]nd many legac[...]n to run on low c[...] deco[...] fossil gas plant[...]pply.

Carbon Capture and Storage (CCS)
If CCS technologies prove cost effective, they could be used to reduce carbon emissions from gas or biomass power plants. The extent to which this is truly low carbon depends on the efficiency of carbon capture process.

The net zero power system in 2035 will also feature many more sources of flexibility, such as energy storage and consumers who are able to shift demand to periods of lower cost and lower carbon electricity. The electricity system will be far more integrated, with increased investment in both transmission and distribution networks, development of offshore transmission networks and high-voltage interconnectors to Ireland, Europe and beyond.



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- … ely and many … ersion to run on … ge, or … some fossil gas … of supply.

Low carbon hydrogen
'Green' hydrogen produced via electrolysis using renewable electricity or, 'blue' hydrogen produced using methane reformation with carbon capture and storage.

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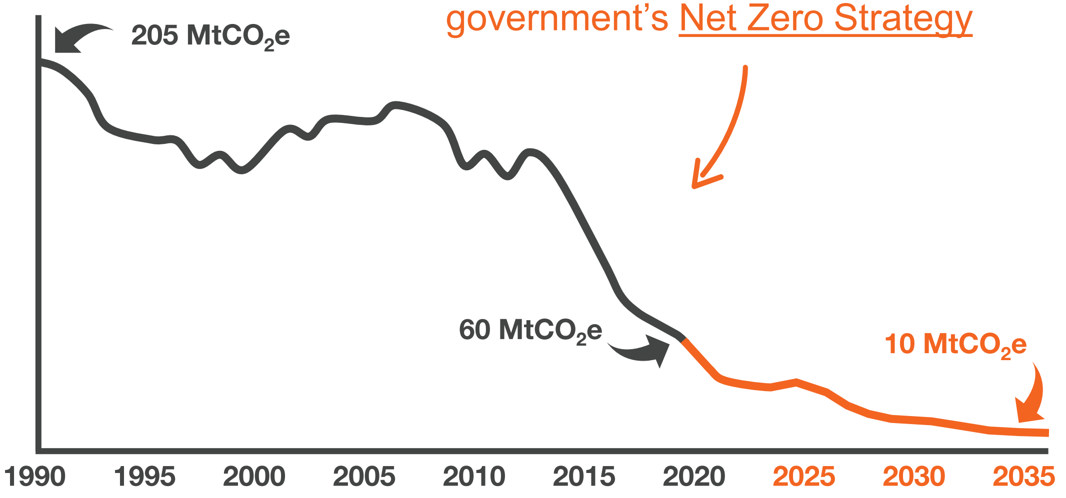
Power emissions pathway from the UK government's Net Zero Strategy



Electricity consumption

In a net zero future, the demand for power is expected to increase as low carbon electricity replaces fossil fuels.

The rate of electrification may vary, but it will be led by the growth of elect … ps and other form … come more wide … gen via elect …

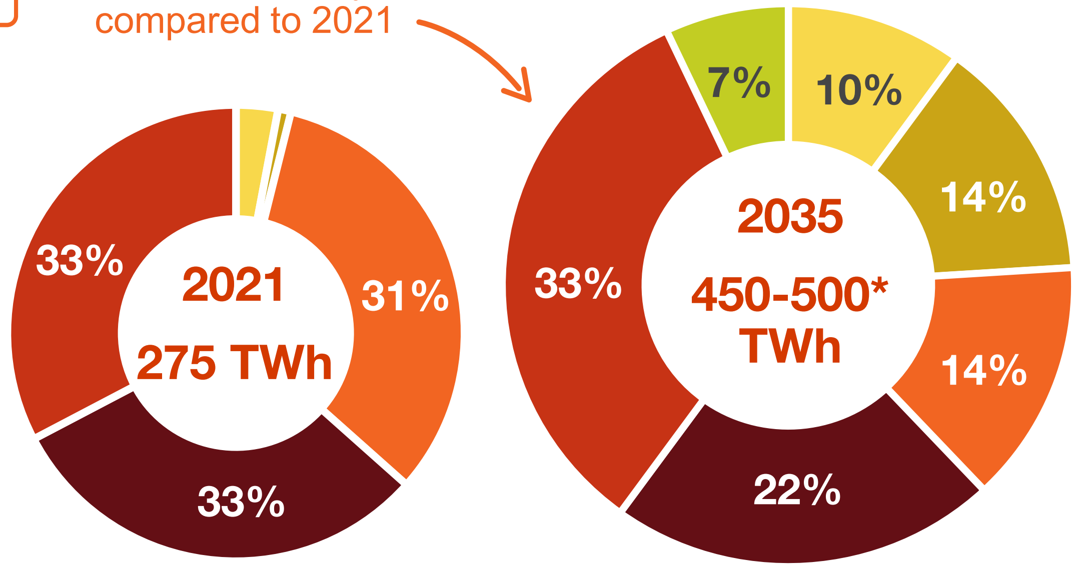
> **Rate of electrification may vary**
> The ESO's Future Energy Scenarios illustrate the difference between a high electrification scenario, such as Consumer Transformation, and scenario with more emphasis on varied low carbon fuels including hydrogen such as System Transformation.

By 2 … uble to betw … se in gene … transmission and … me a net exp … s, further increasing demand for electricity by 50-100 TWh.

As more drivers charge their vehicles at home, in workplaces and at local charging stations there will be a need to upgrade local networks, including the low-voltage substations that bring energy to our homes and businesses.

To optimise this investment, the electricity system needs to become smarter and more efficient, using data and analysis tools to maximise the use of available capacity. The energy system must also make far greater use of solutions such as local flexibility services and active network management, as well as promoting energy efficiency.

Electricity consumption in the 2035 net zero system, compared to 2021



- Domestic appliances and lighting
- Domestic electric heating
- Domestic electric vehicles
- Commercial demand, including heating and vehicles
- Industrial demand, including heating, vehicles and processes
- Hydrogen electrolysis

* Plus 50-100 TWh of interconnector export

Electricity consumption

In a net zero future, the demand for power is expected to increase as low carbon electricity replaces fossil fuels.

The rate of electrification may vary, but it will be led by the growth of electric vehicles and by the increased uptake of heat pumps and other forms of electric heating. Electricity is also expected to become more widely used for industrial processes and to produce hydrogen via electrolysis.

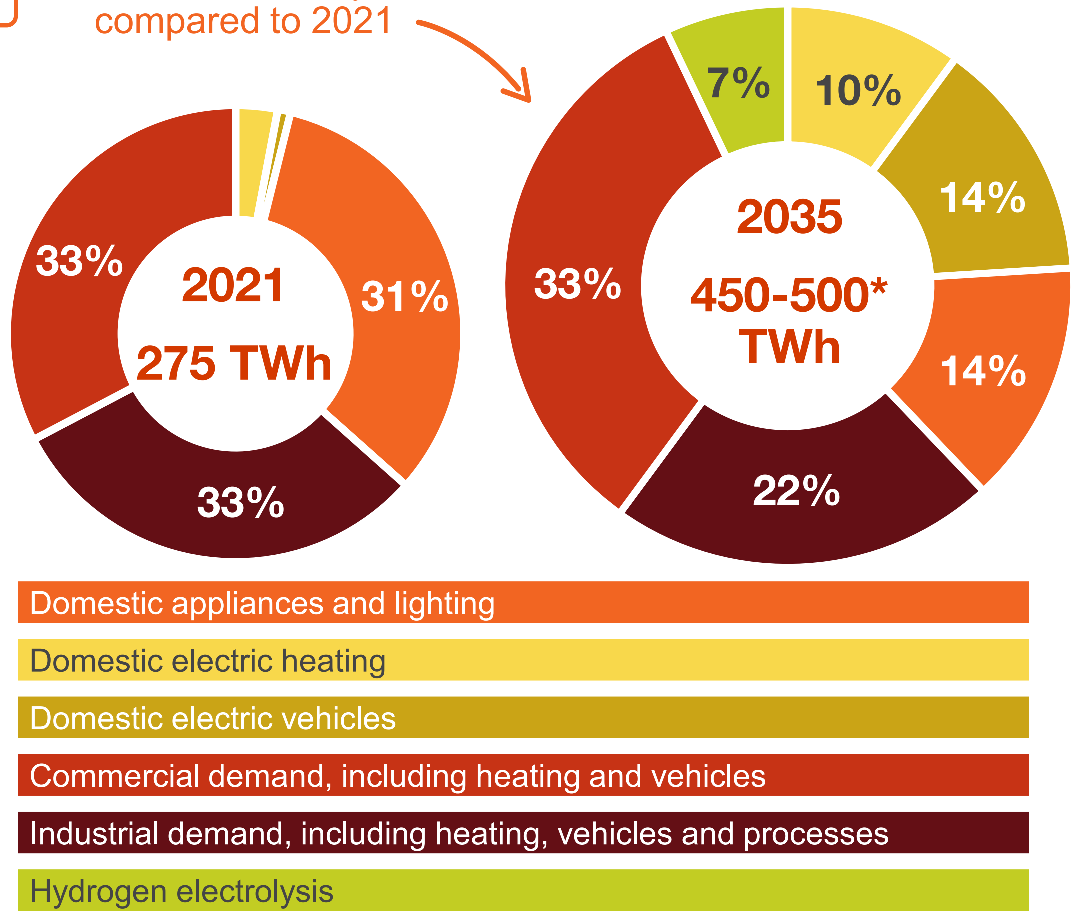
By 2035, consumption of electricity in GB could almost double to between 450 and 500 TWh, requiring a substantial increase in generation capacity as well as investment in the electricity transmission and distribution networks. It is also likely that GB will become a net exporter of low carbon electricity to neighbouring countries, further increasing demand for electricity by 50-100 TWh.

As more drivers charge their vehicles at home, in workplaces and at local charging stations there will be a need to upgrade local networks, includin… homes and bus…

To optin… become smarter… maximise the use… make far greater… active network management, as well as promoting energy efficiency.

Active Network Management
A smart solution, using voltage monitoring and control systems, to enable customers to connect to a constrained ahead of network investment or the use of flexibility.

Electricity consumption in the 2035 net zero system, compared to 2021



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Peak electricity demand

Electrification of the UK economy has the potential to significantly increase the peak demand for electricity, especially during the winter when demand for heating buildings is greatest.

The requirement to fulfill peak demand has been a key driver for the size and redudancy, and therefore the cost, of the overall energy system. In addition, managing the energy balance and operability of the energy system, even on a cold winter day with relatively low renewable energy generation, is one of the critical challenges to achieving a net zero power system.

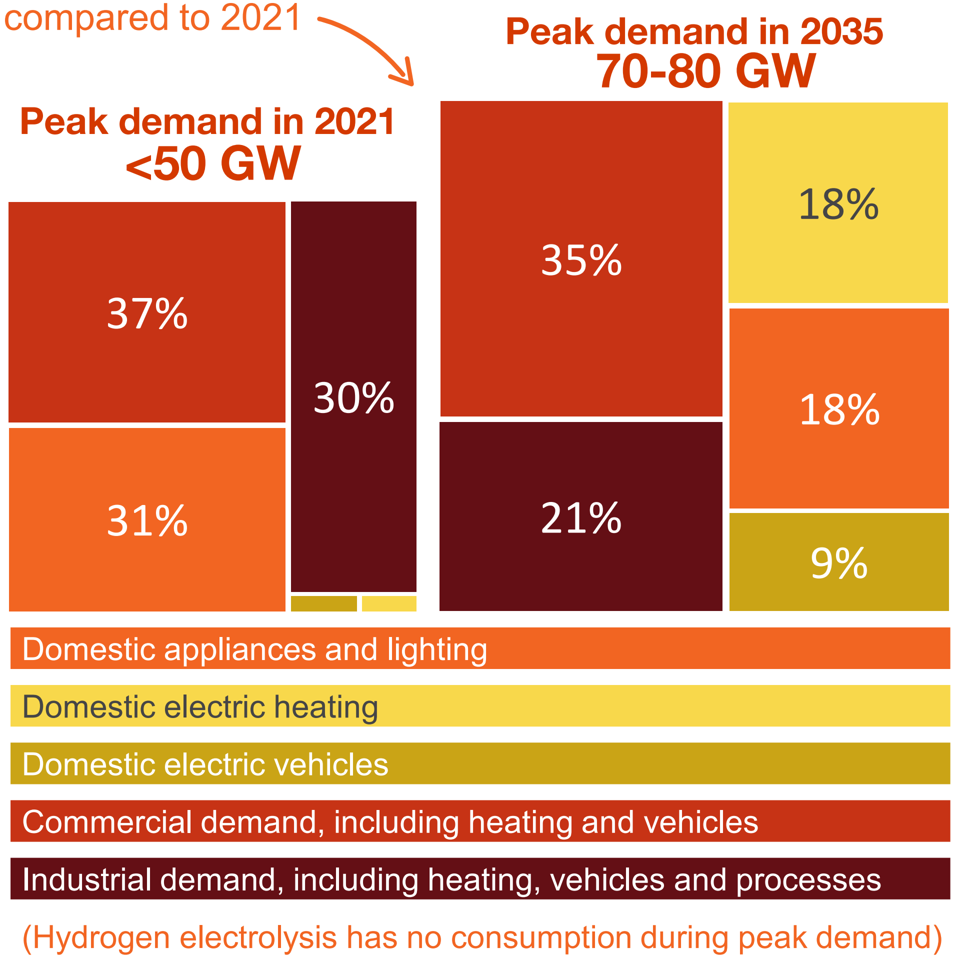
Modelling undertaken by the ESO's Future Energy Scenarios team has estimated that, in a highly electrified scenario such as Consumer Transformation, peak electricity demand could increase to over 70 GW by 2035.

The general principle and reality of peak demand is already changing. The normal pattern of an 'early evening peak' is already less definitive and by 2035 the period of peak demand could be much less fixed, reflecting new sources of electricity demand and daily patterns of consumption.

The Day in the Life features energy efficiency and smarter devices linked to dynamic tariffs enable dor
shifting consumption to times
demand-side flexibility servic
consumers who are incentivi
system service.

Energy efficiency
Reduction in overall electricity demand, such as low energy appliances, will also reduce peak demand. More thermally efficient homes are able to be more flexible with their heat demand, as they lose heat less quickly.

Peak electricity demand in the 2035 net zero system, compared to 2021



Click to explore eight key aspects of the 2035 net zero electricity system

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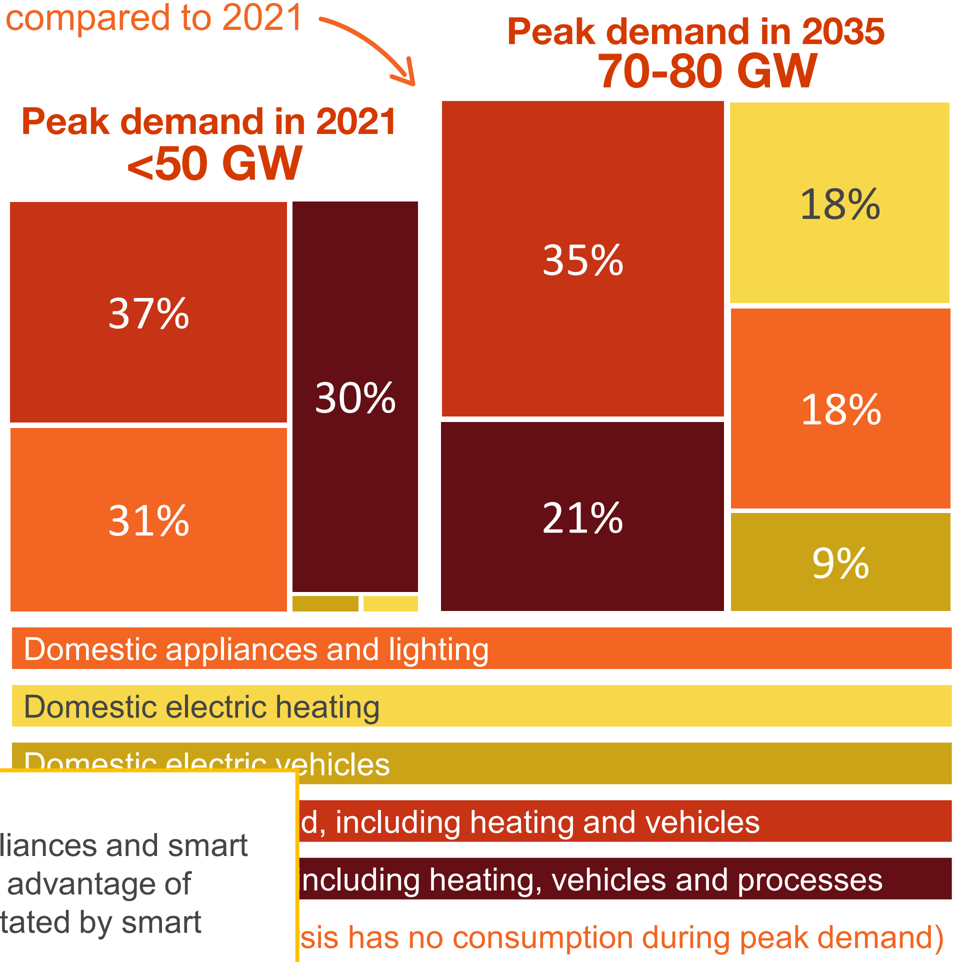
Peak electricity demand in the 2035 net zero system, compared to 2021



Smart devices
Smart EV charging, smart appliances and smart heat pumps can be set to take advantage of dynamic electricity tariffs, facilitated by smart meters.

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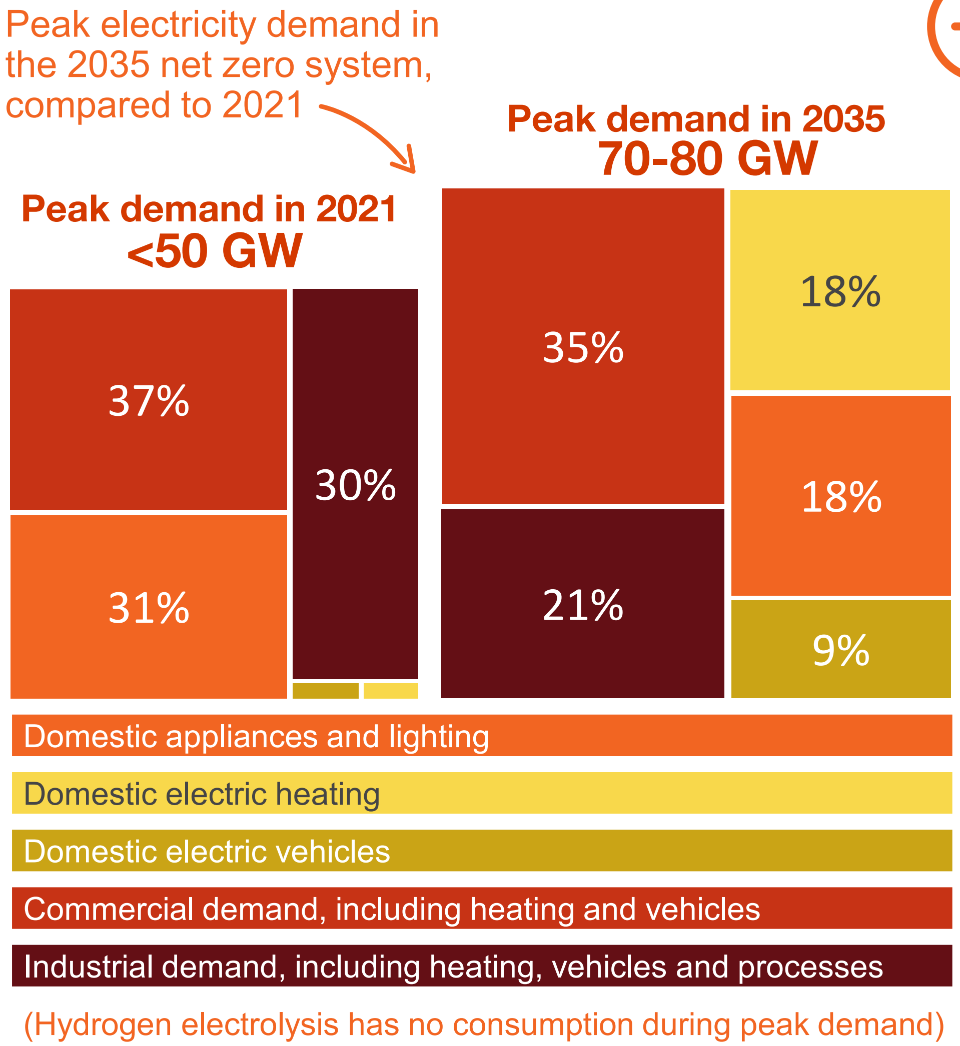
Dynamic tariffs
Electricity tariffs that vary depending on the electricity price (or potentially the carbon intensity of electricity) to encourage consumers to take advantage of low-cost periods, when renewable supply is high or demand is low.



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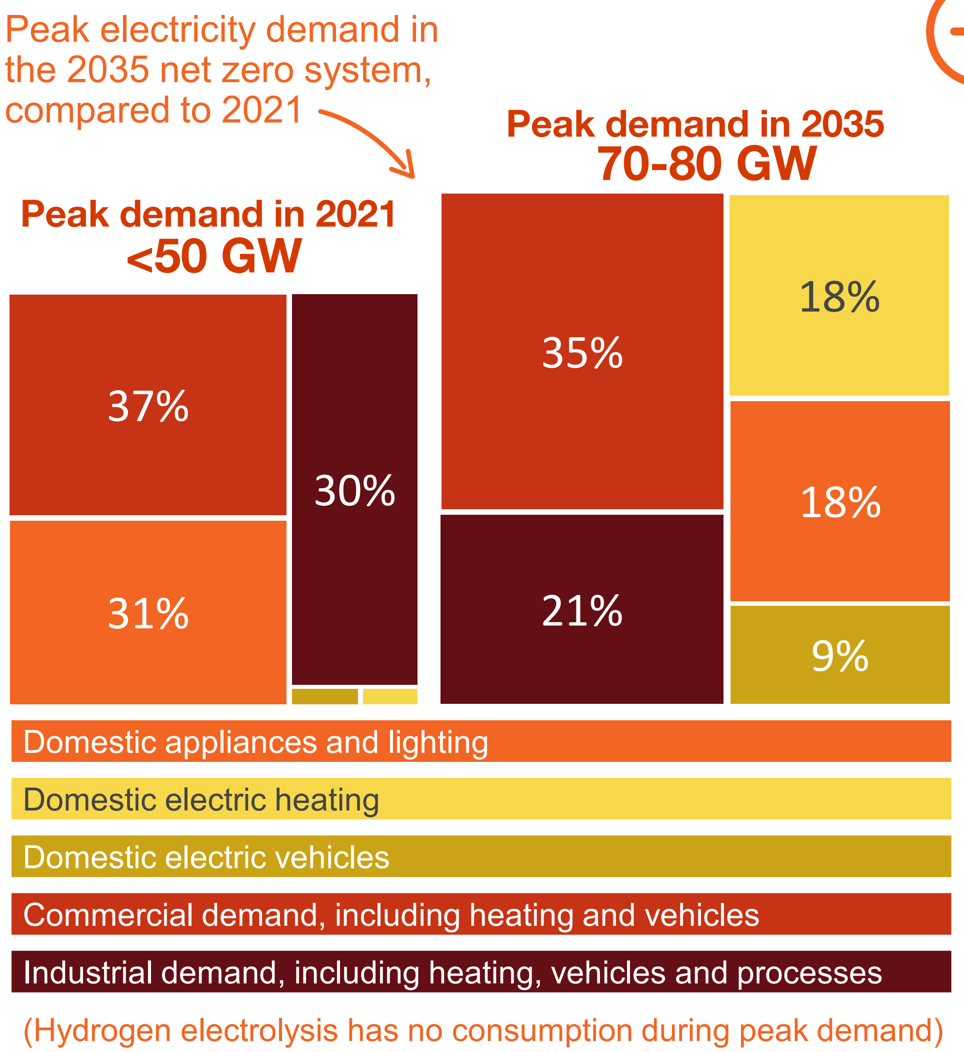
The Day in the Life fea... to dynamic tariffs enab... shifting consumption t... demand-side flexibility... consumers who are in... system service.

Demand-side flexibility

Previously only provided by large energy users, there are already examples of commercial and domestic consumers being paid to their demand up or down to support the energy system.

During the Day in the Life, demand-side flexibility is vital to help balance energy demand at a national level and mitigate local network constraints.



Electricity generation

There are a number of potential pathways to achieve a net zero power sector.

All of these pathways envisage very high levels of renewable energy … from variable … idal energy, … ble technologies … echnology and … rice stability.

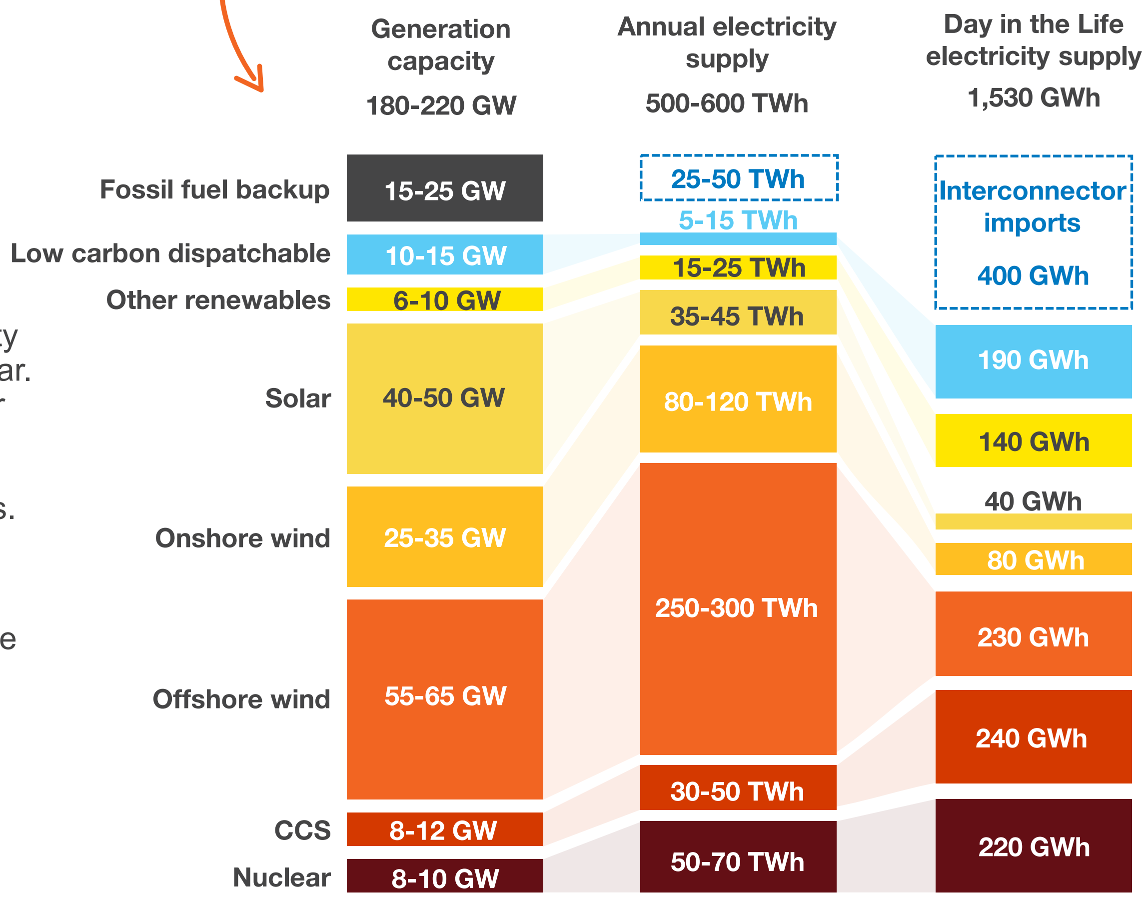
… nore wind capacity … nd 50 GW of solar. … th wind and solar … W of electricity generation throughout most of the year, assuming the UK replaces its retiring nuclear fleet with the Sizewell C and Bradwell B power stations.

> **Pathways**
> The Day in the Life model mainly draws on the National Grid ESO Future Energy Scenarios 'Consumer Transformation' scenario, and the Climate Change Committee's Balanced Pathway. However, aspects of other net zero pathways, and market insight from project pipelines are also considered.

Maintaining system resilience during periods of high demand with low wind and solar output will be a key challenge. Sources of low carbon dispatchable generation will be required. In the Day in the Life narrative this is provided by fossil gas and bioenergy generation with carbon capture and storage, and potentially hydrogen generation.

Unabated fossil fuel generation will almost certainly be present on standby, as a further backup to ensure security of supply, but in a reduced capacity compared to 2022.

Capacity and annual supply of electricity in the 2035 net zero system, and on the Day in the Life



Electricity generation

There are a number of potential pathways to achieve a net zero power sector.

All of these pathways envisage very high levels of renewable energy generation, with 75-80% of electricity supply sourced from variable technologies such as wind, solar and hydro energy. Tidal energy, geothermal, biomethane and other innovative renewable technologies may also play a role. Diversity of supply, in terms of technology and geography, will help maintain system resilience and price stability.

For the Day in The Life narrative, over 55 GW of offshore wind capacity is deployed alongside up to 35 GW of onshore wind and 50 GW of solar. However, during this winter week, generation from both wind and solar is particularly low. Nuclear power provides up to 10 GW of electricity generation throughout most of the year, assuming the UK replaces its retiring nuclear fleet with the Sizewell C and Bradwell B power stations.

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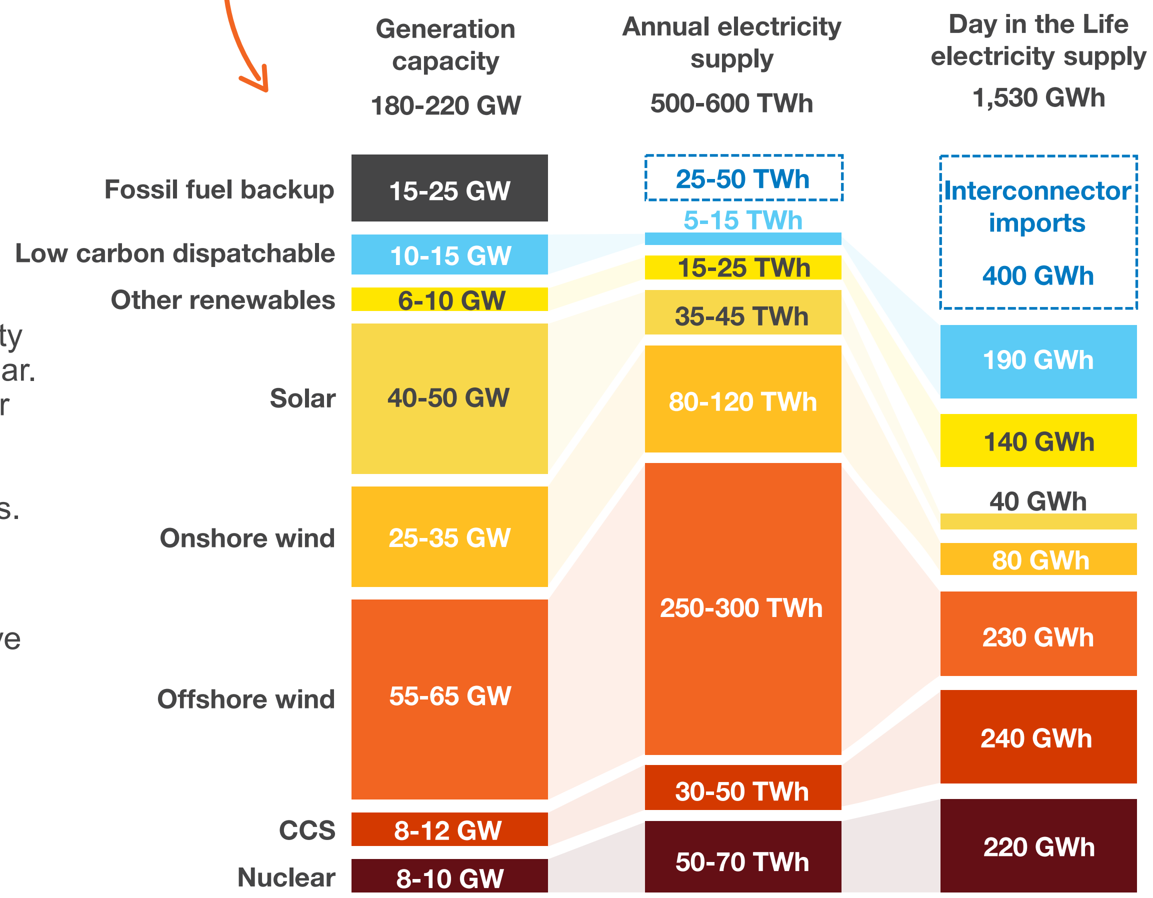
… e present on … pply, but in a

Dispatchable generation
Sometimes called 'flexible generation', dispatchable generation can turn output up or down in response to system or price signals. This compares to 'firm' generation like nuclear which is relatively inflexible, and 'variable' generation like wind and solar which is dependent on external conditions.

Capacity and annual supply of electricity in the 2035 net zero system, and on the Day in the Life



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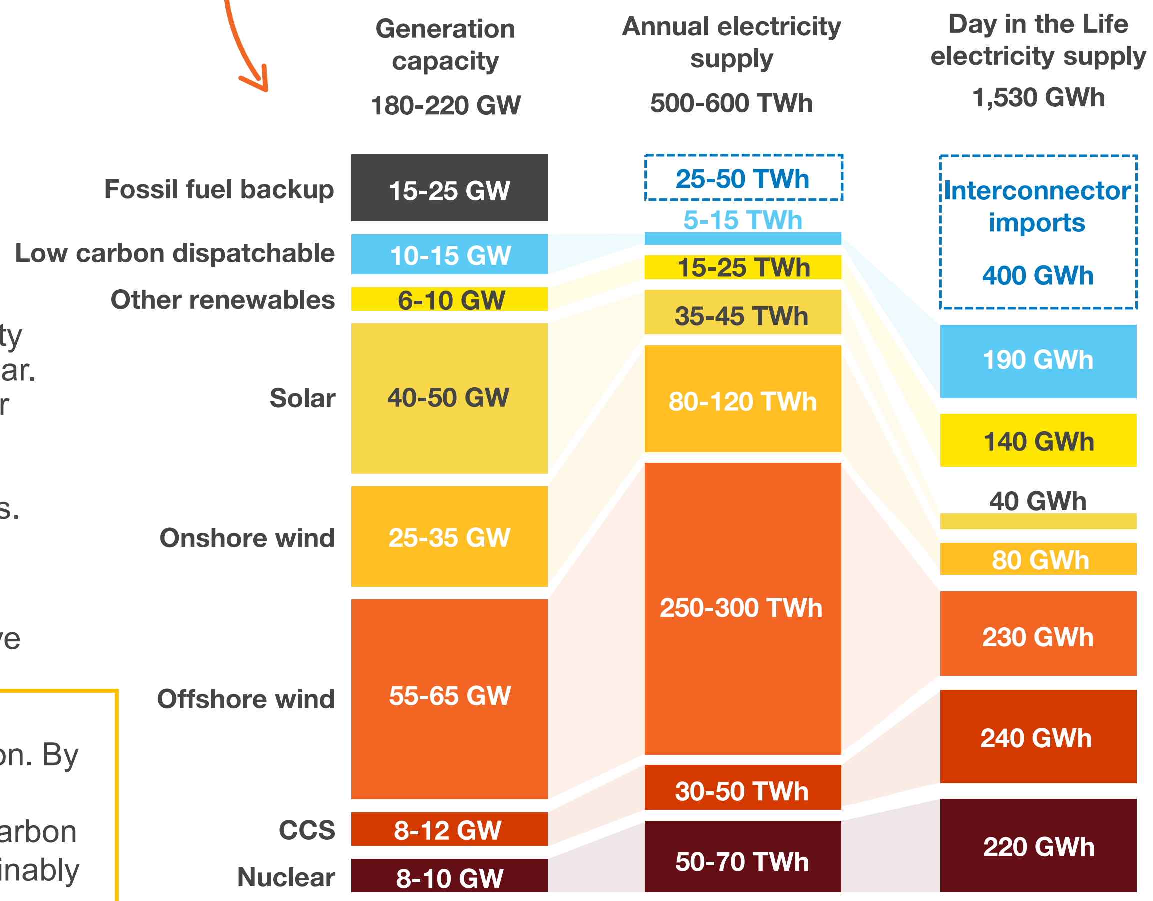
Bioenergy
Biomethane and biomass generation. By 2035, it is likely that all large-scale biomass generation must include carbon capture and storage and use sustainably sourced biofuels.

Capacity and annual supply of electricity in the 2035 net zero system, and on the Day in the Life



Sources of energy flexibility

All forms of energy flexibility will be critical in the net zero energy system; to manage variable generation, to meet peak demand, to ensure security of supply, to manage network constraints and to maximise the economic value of abundant renewable energy.

As well as generation and energy storage, the role of demand-side flexibility will become increasingly important. The ability of energy consumers to shift demand based on market signals will p[…] benefits and a new source of value for consumers.

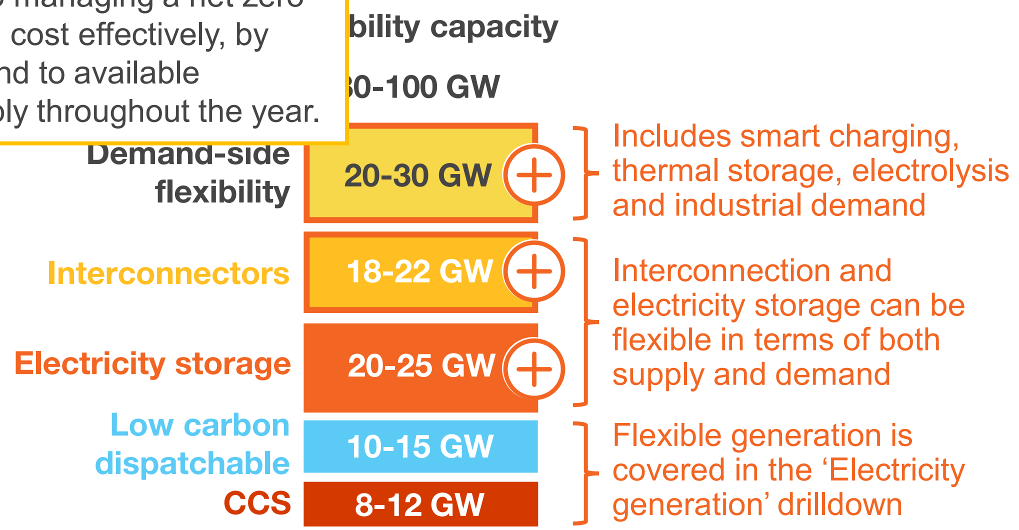
The expansion of flexibility services and markets is already […] and will have become embedded by 2035. Short-term and […] response flexibility will help to ensure system operability a[…] network constraints, particularly at tricky 'pinch points'.

Energy consumers
Unlocking end-consumer flexibility is fundamental to managing a net zero carbon system cost effectively, by tailoring demand to available electricity supply throughout the year.

The Day in the Life highlights how the energy system will develop to harness the value of low carbon electricity to improve system balancing and resilience, by shifting low carbon electricity in three ways:

- **Time shift**, such as using longer duration storage to store energy when it is cheap and provide energy when it is needed, or consumers using smart chargers to charge EVs when electricity prices are lowest.
- **Location shift**, such as using interconnectors, Offshore Transmission Networks and greater grid integration within GB will allow electricity to be shifted to where it has most value.
- **Vector shift**, such as using electrolysis to convert low cost or constrained electricity into green hydrogen. Green hydrogen could also be used as a low carbon fuel for electricity generation, as long-term storage.

During the Day in the Life, the net zero power system hosts over 80 GW of flexibility. Click the buttons below the explore three further forms […] to achieving a net zero power system […]n the Day in the Life:



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The expansion of flexibility services and markets is already underway and will have beco
response flexibility
network constrain

Flexibility services and markets
Initiatives like Power Responsive, Balancing Mechanism Wider Access and local flexibility tenders on the distribution network have stimulated increased participation in the different forms of flexible technology including energy storage and demand-side response (DSR).

The Day in the Lif
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and resilience, by

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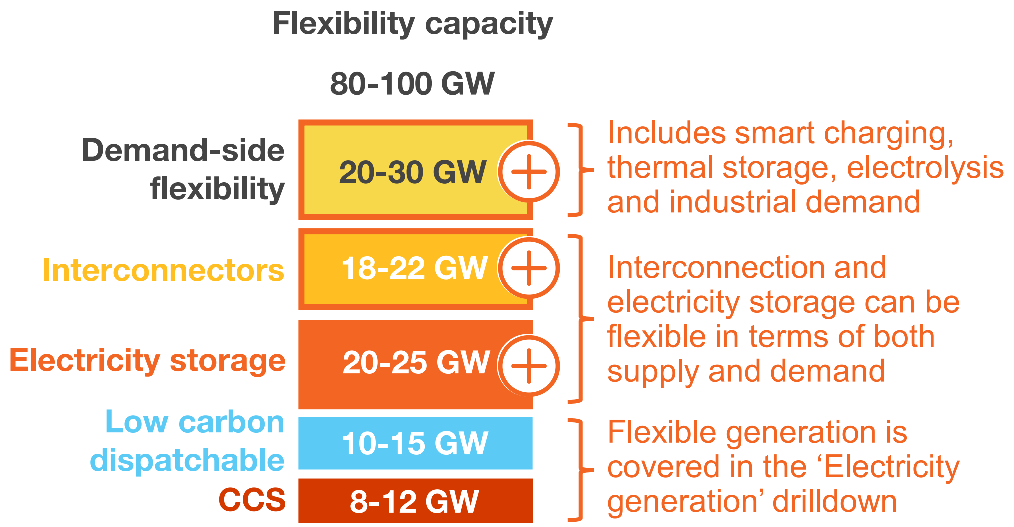


Sources of energy flexibility

Electricity storage

Electricity storage plays a critical role in the net zero power system. In addition to providing system services at both transmission and distribution level, energy storage will be critical to maximise the value of renewable electricity through 'price arbitrage': when electricity is cheaper, typically during periods of low demand and/or high renewable output, energy is stored. Electricity is then supplied when prices are highest, either when demand is high, available generation is low, or there is a requirement for system services.

In this way, energy storage, especially longer-term storage, helps to balance the system. Storage also helps to capture the value of what might have been 'wasted' excess renewable energy.

As technology costs reduce, and the business model for storage operators shifts from the provision of highly responsive network services to arbitrage, reserve and system balancing, it is expected that the duration of energy storage plants will increase. There is already a noticeable shift towards multi-hour batteries underway.

For the Day in the Life over 20 GW of battery storage is available, with an average storage duration of at least three hours, which is charged overnight and discharged at peak times during the winter day. This includes new liquid air and gravity-based storage, alongside new pumped hydro. Storage assets will often be co-located alongside sources of generation, and potentially near new forms of energy demand such as data centres and hydrogen electrolysis plants.

- **Location shift**, such as using interconnectors, Offshore Transmission Networks and greater grid integration within GB will allow electricity to be shifted to where it has most value.

Flexible generation is covered in the 'Electricity generation' drilldown

Sources of energy flexibility

Interconnectors

The UK's newest interconnector, the North Sea link to Norway, came online in 2021. This interconnector enables the UK to benefit from Norway's fast responding hydropower, such as during the Day in the Life, and in return, the UK can send excess wind power to Norway.

The total capacity of interconnectors is currently around 8GW. In the next few years, total capacity should rise to over 10 GW as new interconnectors to Denmark and France are commissioned.

Ofgem stated that to support offshore wind targets, next year's investment round will aim to double the current interconnector capacity by 2030. Analysis from BEIS and Ofgem as part of the 2021 Smart Systems and Flexibility Plan endorses this further interconnection; it suggests that increasing our interconnector capacity would save around £1 billion/year in system costs (2012 prices) in a fully decarbonised energy system.

The role of interconnectors is not only to provide electricity to GB, such as throughout the Day in the Life when wind and solar output are low, but also to provide a route to market for UK exports. By 2035, it is expected that interconnector capacity could reach over 20 GW, providing a diverse supply of low carbon energy for both balancing and energy resilience. This could include hydro power from Norway and Iceland, nuclear and offshore wind from France, solar from southern Europe and North Africa, and wind from Ireland and Western Europe.

The net zero system

Sources of energy flexibility

Demand-side flexibility

The massive increase in renewable energy capacity will lead to periods when the supply of low carbon electricity greatly exceed demand. Storing energy or shifting it to higher demand location are two potential solutions. Alternatively, hydrogen electrolysis could provide flexible demand, while converting electricity into a low carbon fuel that can be efficiently stored and used in a range of high value applications.

By 2035, green hydrogen production via hydrogen electrolysis, could become a significant source of electricity demand, making use of low-cost electricity as well as helping to balance the overall electricity system and manage local network constraints.

Low carbon hydrogen could then be used for industrial processes, heavy transportation or converted into other forms of fuel including ammonia and synthetic fuels.

The Day in the Life features actions by industrial clusters whose demand for electricity for hydrogen production is responsive to electricity system and price, helping to balance energy demand.

Hydrogen could also be used as a low carbon fuel for dispatchable electricity generation. Although this technology is still at an early stage of commercialisation there are already a number of manufacturers offering blended hydrogen turbines and several hydrogen generation projects in development.

Smart systems and digitalisation

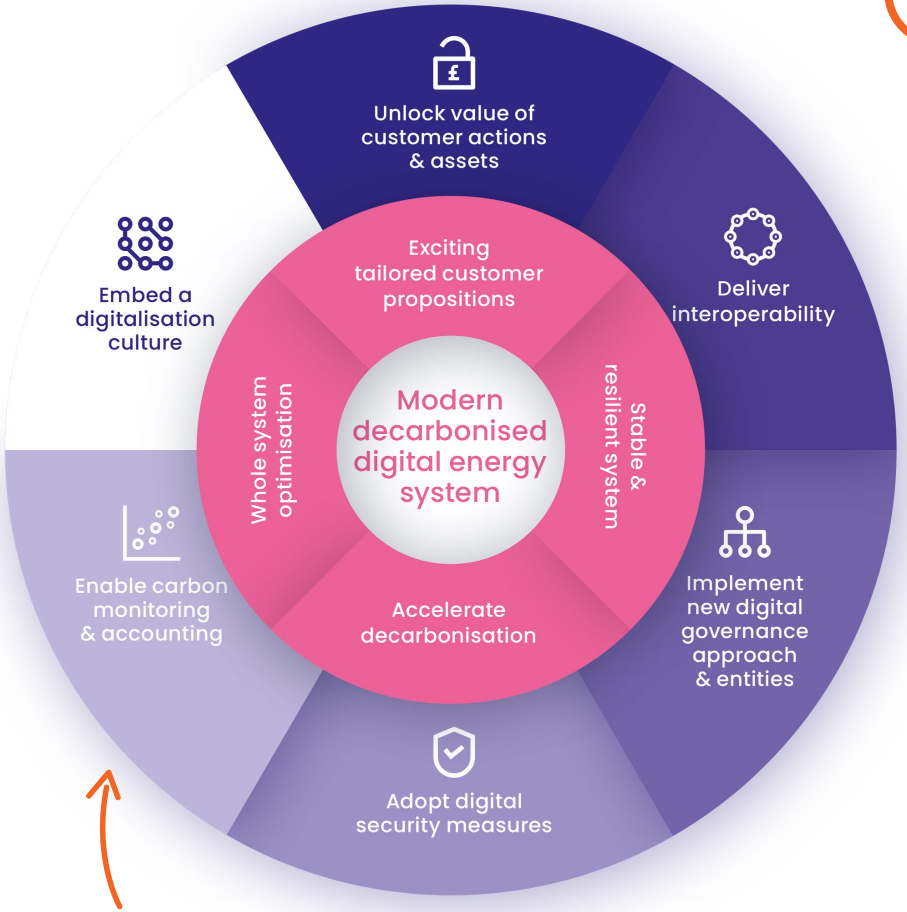
Our energy system in 2035 will be complex with many more actors and assets than today. We will need much greater visibility and automation, plus seamless interactions between participants in dynamic markets. Digitalisation of our energy system is essential to achieve this.

Digitalisation, as detailed in the government's Energy Digitalisation Strategy, will be integral to all aspects of the future energy system, for example:

- System visibility at all voltage levels through real-time monitoring, made available to all from open data sources. This will enable better use of existing infrastructure and greater efficiency in decision making, such as dispatching flexibility at local levels.
- Interoperable digital twins that enable whole system optimisation and support planning, fore… …tcomes and support decisi… …nformation).
- Dynamic and … …lions of assets and ac… …rational decisions, the… …dination across nation…
- Enabling cons… …gy costs using smart ta… …red within a systemwide c… …planning.
- Network data is open and available to all, enabling innovators to create new products and services to support the energy transition.

Digital Twin

The ESO has launched an industry-wide initiative to develop a virtual energy system. This will be used, amongst other things, to model future energy scenarios, system constraints and the optimisation of system operations. Forward looking system models will be used to plan for network events including shifts in the demand/supply balance.



Six recommendations from the Energy Digitalisation Taskforce to deliver a digitalised energy system

Click to explore eight key aspects of the 2035 net

System operability

Whole system energy balancing is critical, ensuring that electricity demand is matched by electricity supply on a minute-by-minute basis. It is also essential that the electricity system functions effectively within its operational tolerances, meaning that the system can provide electricity at the correct frequency, voltage and power quality to ensure reliability and customer service.

Decarbonisation, decentralisation and digitalisation are driving significant change across the electricity network, impacting how the GB electricity system is operated. The ESO has set out a strategy to provide technology solutions and commercial models that will enable the operation of a net zero electricity system. The strategy is based on the digitalisation of network solutions and the creation of new markets for network services.

There are five key areas of system operability:

Frequency: maintaining system frequency at 50 Hz has become more critical as system inertia historically provided by fossil fuels generators falls. This has created a requirement for new markets and business models to provide very rapid frequency response and dynamic containment services.

Stability: the growth of invertor-based (asynchronous) generators has increased the need for stability services. Currently provided mainly by synchronous gas and biomass generators, by 2035, new sources of stability and system inertia will be required.

Voltage: voltage levels are managed through the injection and absorption of reactive power. This aspect of operability is highly dependent on ... mix, sources of de... an appear quickly... system to and... uires greater integra... operators. Ne... storage and s...

> **Reactive power**
> Reactive power services aim to keep voltage levels on the system within a given range. Managing voltage levels comes from maintaining a balance between elements on the system, instructing assets owner to either absorb reactive power (decreasing voltage) or generate reactive power (increasing voltage).

Thermal/netw... ... means that m... of network assets. Constraint management costs, mainly from actions to curtail generation, are increasing. They also have potential carbon impacts. By 2035, network infrastructure investment combined with improved forecasting, more efficient markets and greater use of flexibility services is expected to lead to an overall cost reduction.

Restoration: historically, the electricity system has been dependent on large, transmission connected fossil fuel generators to provide restoration services. The decline in this traditional generation mix and the increasing penetration of distributed energy resources means that new whole system sources of very rapid restoration services will be required on both distribution and transmission networks.

While these operability challenges are managed 24/7, they are individually detailed during the Day in the Life where most relevant.

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Voltage: voltage levels are managed through the injection and absorption of reactive power. This aspect of operability is highly dependent on specific regional conditions including the generation mix, sources of demand, voltage levels and flow rates. Voltage issues can appear quickly and, without intervention, move from one part of the system to another. As energy becomes more decentralised this requires greater integration between distribution and transmission system operators. New solutions to provide reactive power, such as battery storage and synchronous compensators, are being developed.

Thermal/network capacity: thermal limits of network infrastructure means that managing constraints is critical to ensuring the integrity of network assets. Constraint management costs, mainly from actions to curtail generation, are increasing. They also have potential carbon impacts. By 2035, network infrastructure investment combined with improved forecasting, more efficient markets and greater use of flexibility services is expected to lead to an overall cost reduction.

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Restoration services
Assets that can support partial or system-wide restart services.

..., they are individually detailed during the Day in the Life where most relevant.

What if? Key uncertainties

The Day in the Life story is based on an illustrative 2035 energy system. Some key questions considered while constructing the Day in the Life have been detailed below:

- What if consumers don't participate in the energy system as much as expected?
- What if digitalisation is restricted, such as through lack of available, open data?
- What if markets fail to appropriately value low carbon energy?
- What if efficient Carbon Capture and Storage does not happen at scale?
- What if investment in interconnectors falters, leading to less integration between GB and overseas energy markets?
- What if low carbon dispatchable generation such as hydrogen-fuelled generation is not available at scale, due to lack of low carbon hydrogen or lack of generation capacity?

National Grid ESO's Future Energy Scenarios

Climate Change Committee's Sixth Carbon Budget

What if consumers don't participate in the energy system as much as expected?

A high degree of customer participation is needed to help balance the system and manage peak demand efficiently, keeping bills lower for everyone.

Without it, the system experiences higher peaks and lower troughs. For example, if the majority of EV owners charged their car immediately in the early evening after returning home, the evening peak would skyrocket. This would require more generation and network infrastructure to be built, leading to an inefficient and expensive electricity system.

Fortunately, consumer participation is already happening, and there are a number of new market developments, such as the use of dynamic tariffs, that are well advanced.

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Digitalisation, including the adoption of smart technologies, enhanced data processing, monitoring and control systems, and the use of simulation tools is an essential part of the future energy system.

Lack of digitalisation will make a complex, decentralised electricity system much harder to operate and manage effectively, likely keeping the GB electricity system structured around large-scale transmission-connected generators and restricting the potential of all assets connected to the system.

This is a critical area of energy system investment and market development.

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What if markets fail to appropriately value low carbon energy?

Carbon pricing on its own will not achieve net zero, but a properly functioning and universally applied carbon price can provide an additional stimulus to encourage a shift to low carbon energy.

For example; a carbon price can encourage asset owners to reflect the carbon intensity in their electricity system decisions. As has already happened with coal, this will begin to push higher carbon generators into a more marginal role.

Without an appropriate carbon price stimulus, the transition to net zero would be more reliant on regulatory measures, such as banning certain technologies, and subsidy support schemes.

Carbon prices have recently risen across the EU and in the GB Emissions Trading Scheme.

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What if efficient Carbon Capture and Storage does not happen at scale?

The Day in the Life energy system relies heavily on the use of Carbon Capture and Storage for both low carbon gas and bioenergy dispatchable generation.

The future of CCS is, however, far from certain and, despite recent innovation funding support, still faces a significant cost and technical challenges to reach the scale needed.

Without CCS, a net zero energy system would require far more long duration storage, interconnectors and demand flexibility, or would rely on the development of alternative low carbon fuels like hydrogen.

Alternatively, the electricity system would still have to use unabated fossil gas as both a balancing and backup source of generation, especially on cold winter days. This would make achieving a net zero power system by 2035 extremely difficult.

Click to explore eight key aspects of the 2035 net zero electricity system

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What if investment in interconnectors falters, leading to less integration between GB and overseas energy markets?

The energy system in 2035 will be far more integrated with neighbouring energy systems. This integration is already underway through market reform and investment in a new wave of high voltage interconnectors. Interconnection provides an alternative source of energy and, importantly, access to markets to sell generated electricity during times of over supply, especially from GB's substantial offshore wind resources.

The Day in the Life modelling assumes that interconnectors continue to develop and that the GB energy system benefits from access to a wide variety of imported electricity including hydro from Norway, nuclear from France, wind from Ireland and even potentially solar from North Africa. This investment is not certain and will be subject to international factors, as well as planning and other development risks in the UK.

Without a high level of interconnection, the UK energy system would have to find even greater sources of dispatchable generation, as well as alternative uses for low carbon electricity during times when supply exceeds demand. While not impossible, fewer interconnectors would make achieving net zero more difficult and more costly to the consumer.

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What if low carbon dispatchable generation such as hydrogen-fuelled generation is not available at scale?

Hydrogen-fuelled low carbon generation features in the Day in the Life. While technically achievable, this is perhaps the biggest uncertainty. The UK has a small number of hydrogen generation demonstration projects in development; however, these are being supported through innovation funding and do not necessarily point to an expanding market.

There is also uncertainty about how much low carbon hydrogen production will be in place by 2035. Significant government support will be required, as well as a rapidly increasing carbon price, to help shift generators from fossil fuels to low carbon hydrogen by 2035.

Without hydrogen generation, the net zero electricity system will be further reliant on other technologies such as long-duration storage, CCS and bioenergy. Without these alternatives the GB energy system would still be reliant on unabated fossil gas in 2035. If its use was extremely limited, to meet absolute peak demand on cold, cloudy days, it may still be possible to substantially decarbonise electricity. However, carbon intensity of 10 gCO2/kWh would be very difficult to achieve.