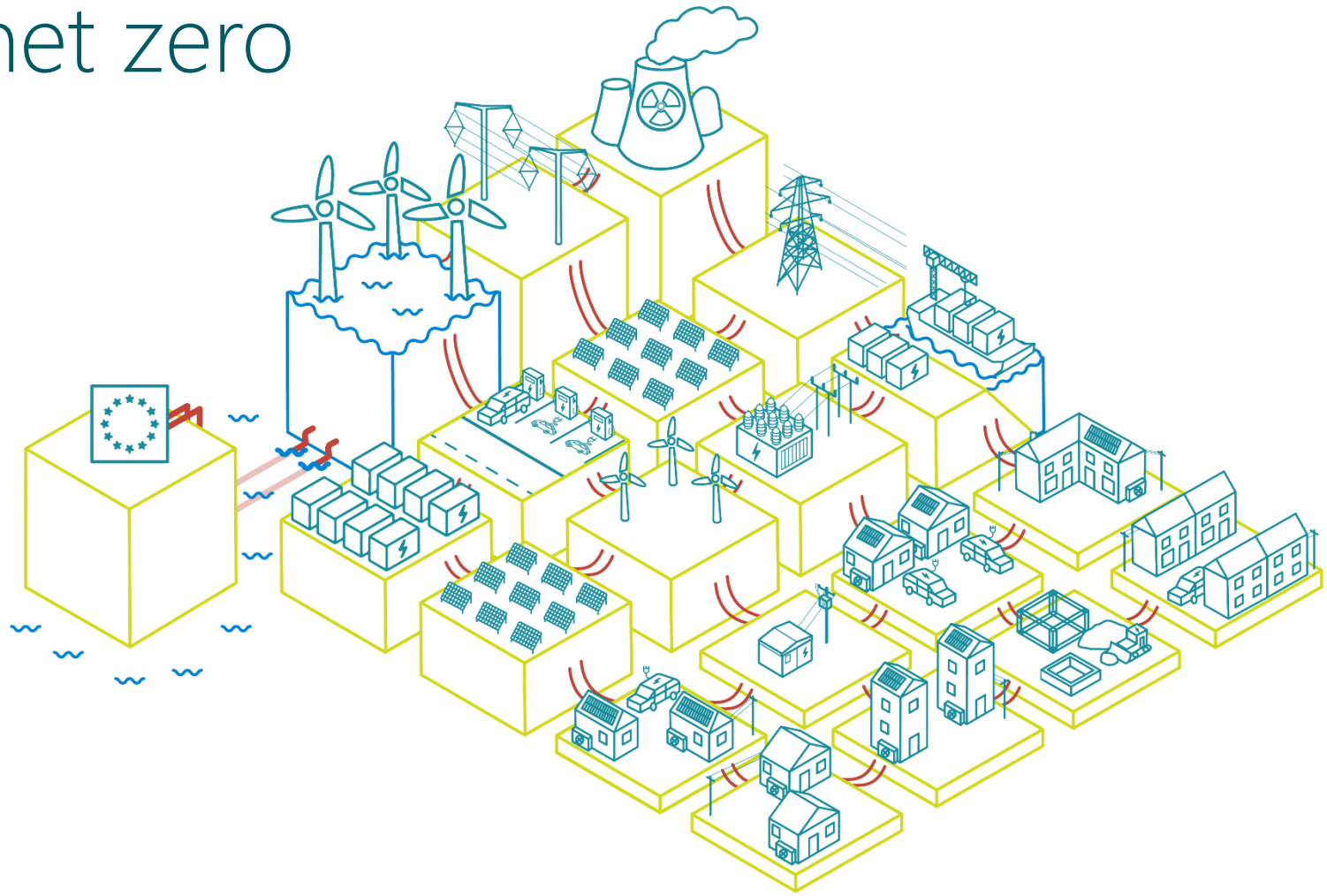
Building a GB electricity network ready for net zero



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Executive summary

Transforming the grid is critical to the UK's energy goals

Achieving net zero means our electricity network connecting gigawatts of new renewable generation and powering millions of electric vehicles and heat pumps across the country.

In recent months the importance of the grid has come into focus as policymakers have recognised our energy networks are critical infrastructure for the UK's energy goals.

The grid is not broken. We have successfully connected many GWs of wind farms, solar farms and batteries and there is a large pipeline of low carbon projects in development with grid connection agreements.

However, reform and investment are urgently needed. Lead times for critical new low carbon projects to connect are now over 15 years.

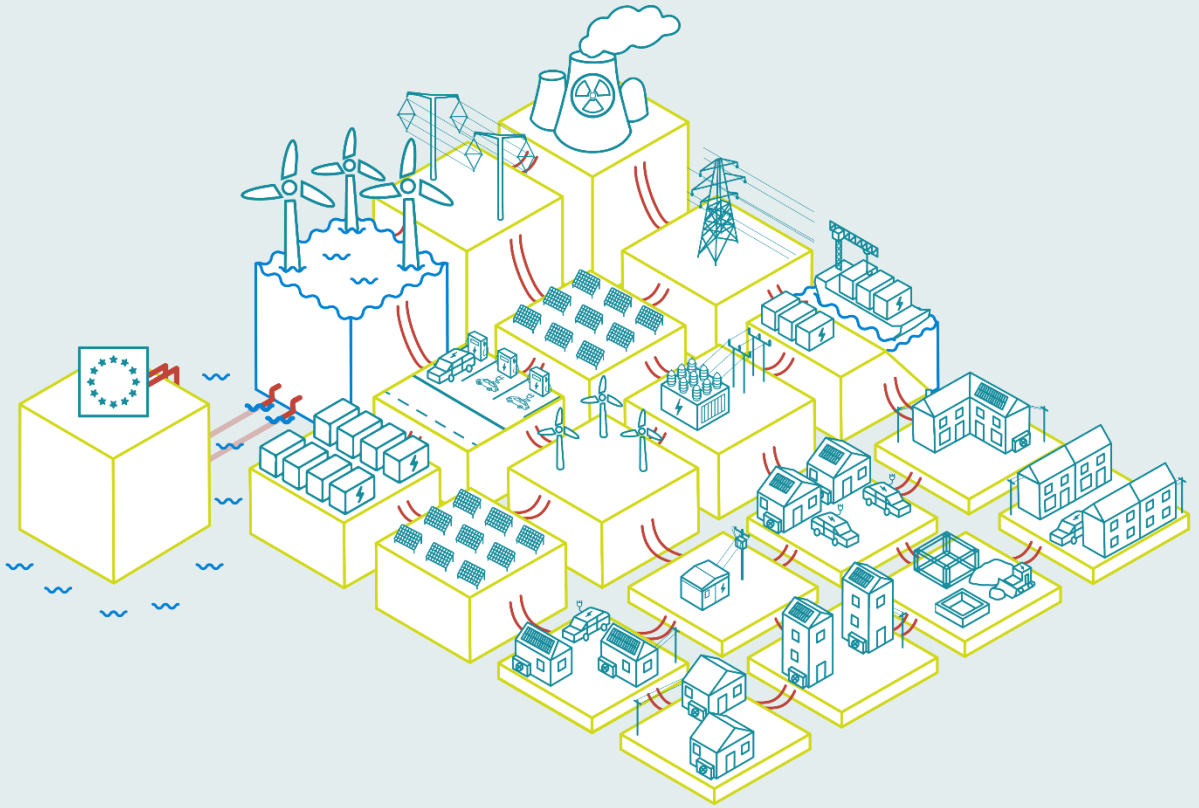
We have delivered rapid growth of electricity system infrastructure before - between 1950 and 1975 electricity generation and grid capacity increased almost five-fold. However, transforming the grid requires a clear strategy and focus on delivery.

The key players – Government, Ofgem, the Electricity System Operator and the network operators – have recognised the challenge and set out action plans. These initiatives provide a springboard for action.

The key message of this report is that a net zero ready grid is achievable. The priority now is moving from action plans to delivering reform and investment at pace.

This report sets out

- **the scale of the challenge to upgrade our networks**
- **the initiatives underway**
- **the key priorities to ensure network infrastructure is not a barrier to net zero**

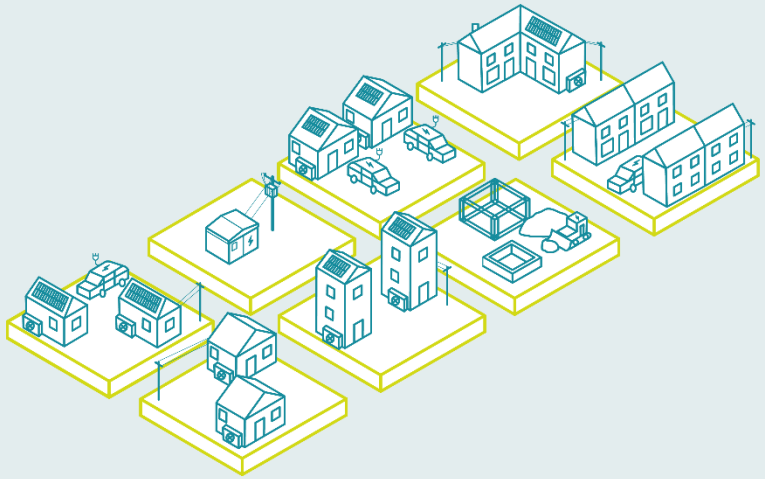


Low voltage distribution: preparing for a wave of consumer electrification

Readying the networks for heat and transport electrification requires a clear plan and investment

The transition to net zero will create a wave of consumer electrification as people switch to electric vehicles and heat pumps, the power for which will flow through the low voltage part of the grid. Upgrading the low voltage networks to prepare for this increase in electricity demand presents a major challenge. Without sufficient investment, the headroom for new connections at the street level will run out.

Network operators understand the scale of the challenge of consumer electrification. They have new business plans for 2023-2028 with strategic plans, innovation and increased investment. However, the pace of investment and innovation is not yet fast enough. A sustained commitment from the government, Ofgem and network companies will be necessary to ensure that consumers up and down the country can connect their electric car chargers and install their heat pumps quickly and easily.



Recommendations

1.1 Networks must invest ahead of increasing demand

Network operators have developed plans and initiatives to ensure people can connect. However, they need to step up the pace of change on strategic planning, digitalisation and development of their supply chain.

1.2 Ofgem must provide strategic leadership to enable net zero

The regulator has taken a gamble with net zero by cutting distribution network investment plans against draft budgets. They must ensure that the regulatory framework enables networks to invest strategically for net zero.

1.3 Government should commit to electrifying heat

It is increasingly clear from the evidence that hydrogen will play a limited role in home heating. However, until the government makes a clear decision it is difficult for networks to fully plan and invest for the electrification of heating through heat pumps.

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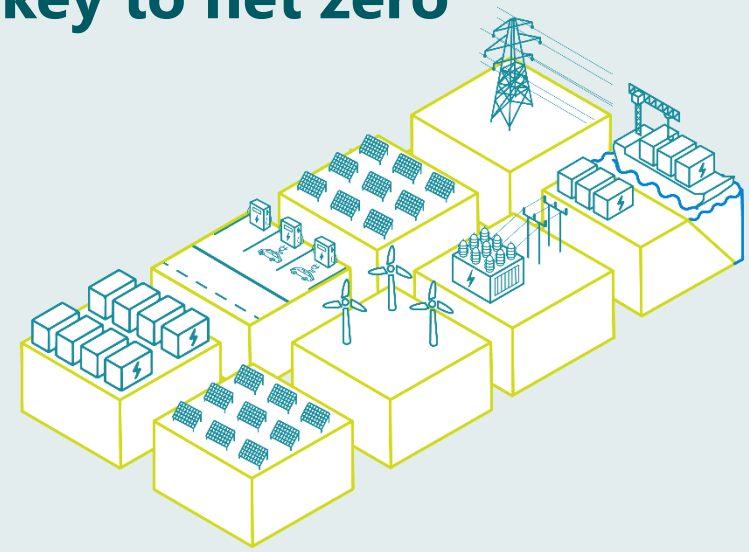
Transmission-distribution interface: connecting onshore renewables and storage

Ending 15-year connection lead times is key to net zero



Connecting a large volume of renewable generation and storage projects is critical to decarbonising the power system by 2035. Between 180 to 220 GW of grid-connected power generation capacity will be needed by 2035.

Developers are bringing forward storage and renewable projects at the scale we need and there is a large pipeline of projects with grid connection agreements. However, new projects are now stuck behind a long queue with transmission system connection lead times of over 15 years. These delays are a major barrier to net zero. The Government, system operator and networks have plans to speed up connection timelines – delivering on these is now urgent.

Recommendations

2.1 Deliver on investment ahead of need

Moving to a grid investment regime that delivers grid developments in coordination with and ahead of new generation connections is critical. The government and Ofgem must deliver on their proposal for "Invest and Connect" and ensure the new Future System Operator in up and running to lead a clear plan for grid investment.

2.2 Reform the connections process

Connecting the gigawatts of renewables and storage needed for net zero won't be possible without delivering a streamlined and effective connections process. The ESO and network operators must manage the queue of projects to ensure those able to connect are not blocked and implement a smarter connections process to get gigawatts of generation flowing onto the grid.

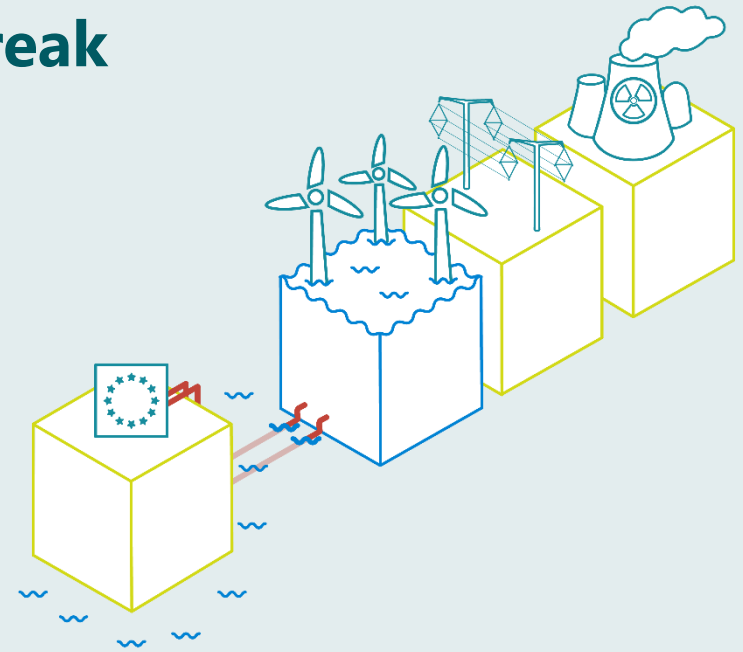
2.3 Reform the approach for interaction between transmission and distribution networks

The process for assessing how projects connecting at distribution will affect the transmission network is a critical barrier for connecting new generation.

The ESO and DNOs need to put in place a new process to resolve transmission barriers to distribution connections resulting in long queues to connect.

Transmission: connecting offshore and large-scale generation

Transmission investment will make or break the 50 GW offshore wind target



The grid will make or break the government's target to deploy 50 GW of offshore wind by 2030. Investment in transmission capacity is falling behind deployment leading to costs of managing constraints of over £1bn in 2022.

Ofgem has adopted a major policy shift by enabling networks to invest strategically based on a Centralised Strategic Network Plan. The challenge is now delivering the scale of investment required. The government should fully implement the recommendations of Nick Winser, the Electricity Networks Commissioner, to ensure network planning processes and supply chains are fit for purpose for critical transmission investment projects.

Recommendations

3.1 The Future System Operator needs a clear timeline and remit

The establishment of the FSO as a public body with a remit to oversee a clear strategic plan for the transmission network is a key step. The Government must ensure the FSO is up and running as soon as possible with a clear strategic direction to deliver net zero and the independence and capacity to deliver.

3.2 Ensure the supply chain has sufficient capacity to deliver projects

Investment in transmission networks is growing rapidly across the globe. The Government, the Future System Operator and transmission network operators need to put in place an effective supply chain plan to ensure that transmission projects are not delayed by the supply of critical components or the capacity of the supply chain to deliver.

3.3 Speed up the planning and consenting process

The Government needs to issue a national planning policy statement on the importance of electricity network infrastructure. This should ensure net zero is given proper weight in decision-making and that community benefits are delivered to areas hosting critical energy infrastructure.

Whole system: investment to achieve the transformation

Significant grid investment is required but this will deliver value to households

The government and Ofgem estimate that £170-210bn will need to be invested in the grid by 2050 to achieve our net zero and energy goals. £70 bn of this is baseline investment. The extra £100-£140bn will unlock massive net zero and energy security benefits for all of us.

Lower network costs per unit of electricity

By 2050 electricity networks will be providing more value to households by delivering the power we need to heat our homes and get around. Because of this, the cost of the network per unit of energy we use could fall despite the extra investment in the network required.

A net energy exporter by 2040

By doubling down on home-generated renewables Great Britain could turn its net import of 725 TWh today into 25 TWh of net export by 2040.

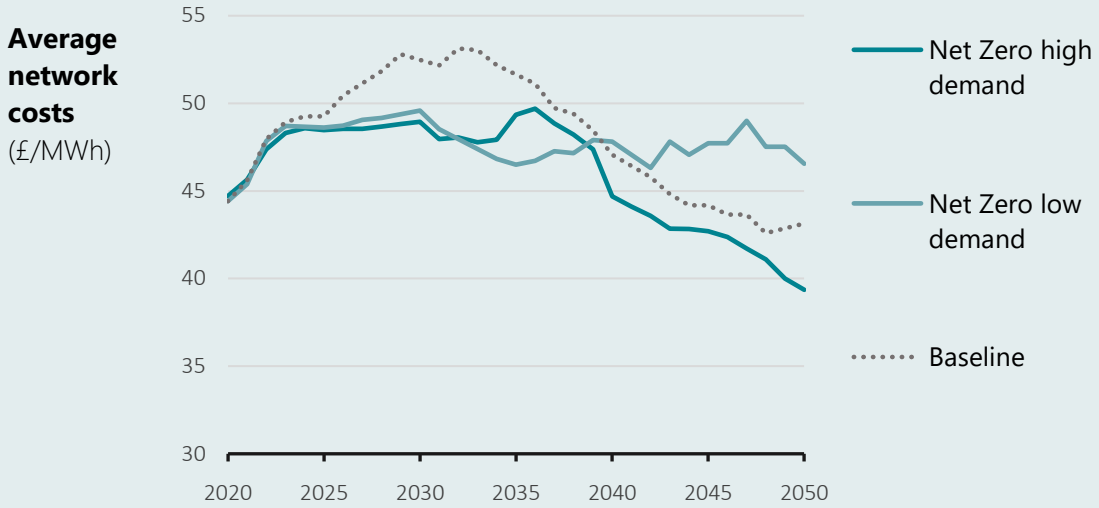
Lower cost electricity for consumers

Even before the fossil fuel price crisis, the cost of renewables had fallen below the cost of fossil fuel generation. Fit for purpose grid infrastructure and an efficient market will enable customers to benefit from these cost savings.

Economic opportunity of the 21st century

Secure, clean energy will provide a foundation for our economy. Government expects green industries will create 480,000 jobs by 2030.

As more electricity flows across the networks, investing for net zero will mean lower network costs per unit



Source: Electricity networks strategic framework Appendix I figure 13, Department for Energy Security and Net Zero.

Summary
There are challenges across the grid

Network	Critical challenges	Key initiatives	Recommendations
1. Low voltage distribution: preparing for a wave of consumer electrification	Upgrading the low voltage networks for millions of EVs and heat pumps is a major undertaking. The current network regulatory regime does not provide the framework to support this transformation.	• Ofgem is consulting on a new regulatory regime • Networks are carrying out strategic reinforcement informed by future demand modelling and asset monitoring	1.1 Networks must invest ahead of increasing demand 1.2 Ofgem must provide strategic leadership to enable net zero 1.3 Government should commit to electrify heat and transport
2. Transmission-distribution interface: connecting onshore renewables and storage	A failure to invest strategically in grid capacity means lead times for connecting large renewable and storage projects are over 15 years.	• Shift in Ofgem's investment regime so grid capacity is developed ready for new low carbon generation projects to connect • ESO's GB Connections Reform	2.1 Deliver on investment ahead of need 2.2 Reform the connections process 2.3 Reform the approach for interaction between transmission and distribution networks
3.Transmission: connecting offshore and large-scale generation	Ofgem has been slow to approve investment in large transmission projects. These projects are inherently challenging with long lead times.	• New framework for Accelerated Strategic Transmission Investment (ASTI) • Centralised Strategic Network Plan to be developed by the Future System Operator (FSO), a new public body	3.1 The Future System Operator needs a clear timeline and remit 3.2 Ensure the supply chain has sufficient capacity to deliver projects 3.3 Speed up the planning and consenting process

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Electricity network infrastructure is critical to net zero and energy security

The UK government has committed to achieving net zero carbon emissions by 2050 and to shift from imported fossil fuels to domestic renewables. By 2035, the government aims to have decarbonised the UK's electricity system.

Getting to net zero will increase electricity demand for heat, transport and industrial activities. This increase in demand will be met by greater domestic power generation, interconnectors and energy storage. Generation capacity will increase from about 100 GW to 180-220 GW in 2035.

There is a huge pipeline of generation and storage projects with agreements to connect to the grid.

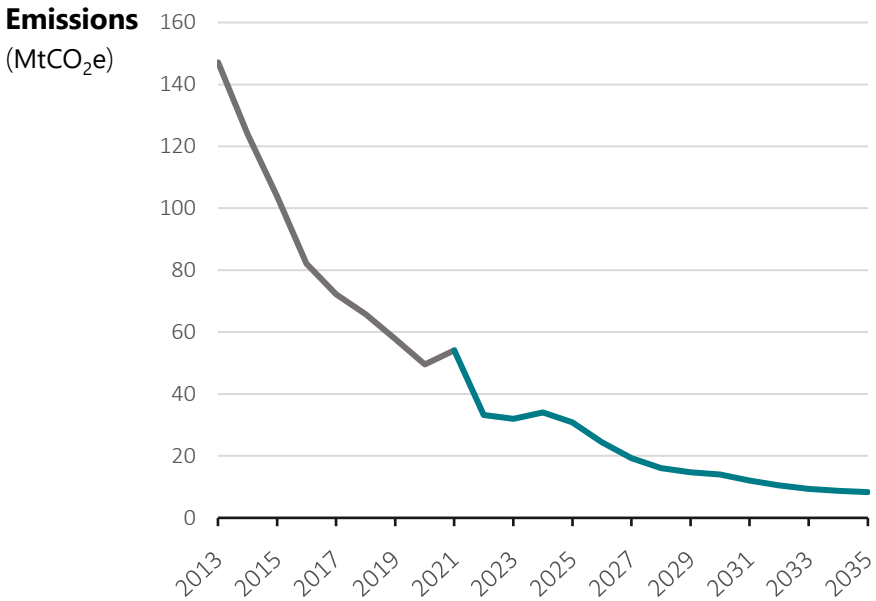
However, a failure to invest strategically means network infrastructure is now a significant barrier to our policy goals. The timescale for connecting a new project to the transmission network is now typically over 15 years.

The government and Ofgem has recognised the critical role of electricity networks and extensive changes in our approach to networks are underway.

This report aims to set out

- **the scale of the challenge to upgrade our networks**
- **the initiatives underway**
- **the key priorities to ensure network infrastructure is not a barrier to net zero**

Emissions pathway to a decarbonised power system in 2035



Source: Department for Energy Security and Net Zero, Net Zero Strategy.

Net zero requires a power system transformation

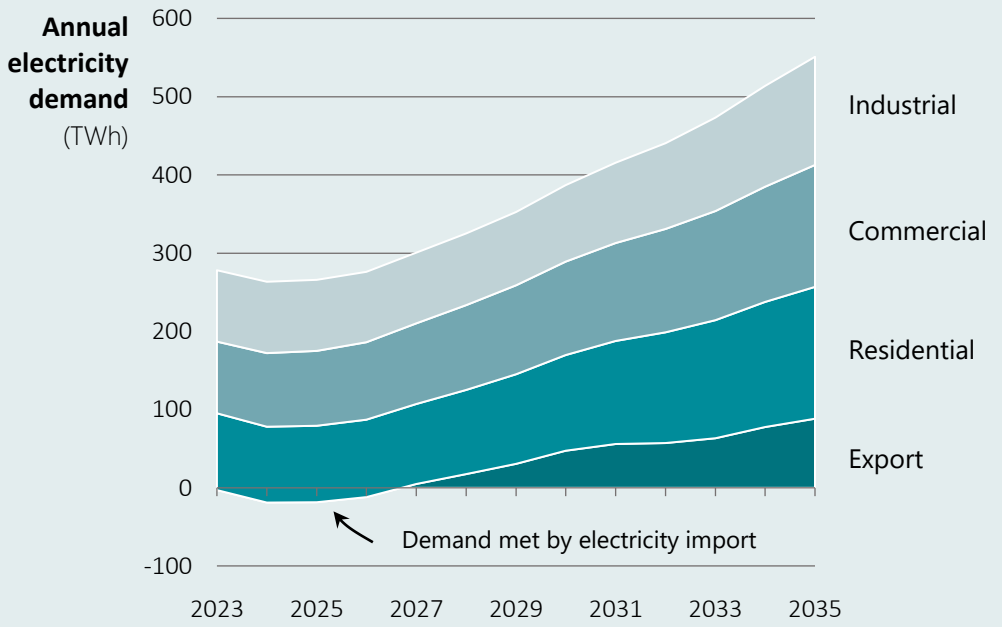
Electricity demand

Electricity generation

Electricity demand will nearly double by 2035

Demand for electricity will increase as it replaces fossil fuels for heating, transport and industrial processes. Whilst some decarbonisation pathways are still to be determined, we already know with high confidence that heating, transport and industrial demand for electricity will increase substantially by 2035.

Whilst electricity demand will increase, the higher efficiency of electric vehicles and heat pumps will enable consumers to travel and have warm homes using less energy and saving money.



Source: ESO Future Energy Scenarios 2022 (Consumer Transformation scenario).

Net zero requires a power system transformation

Electricity demand

Electricity generation

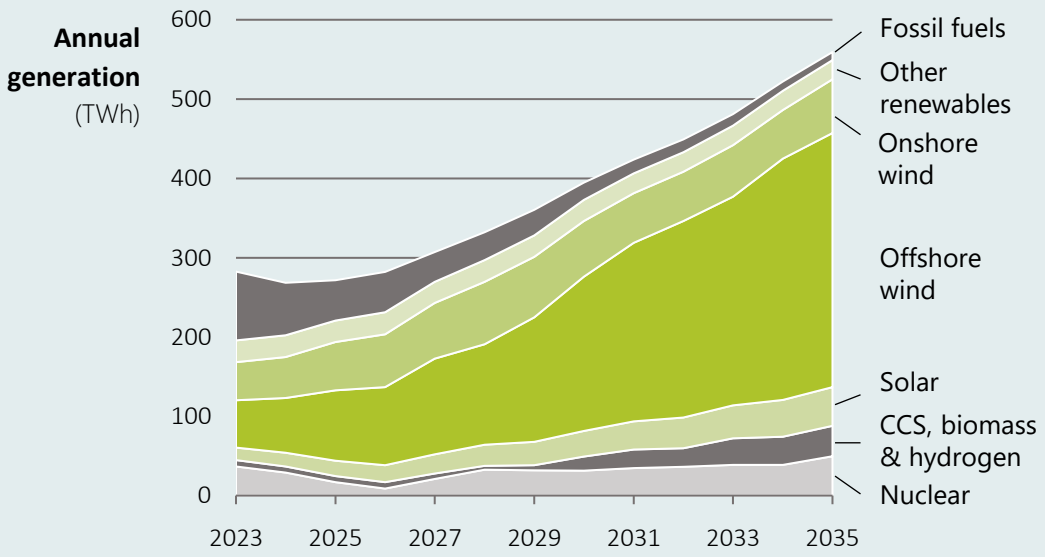
Demand will increasingly be met with renewable generation

All net zero pathways envisage very high levels of renewable electricity generation. By 2035, 75-80% of electricity supply will likely be sourced from renewables.

Resilience will be provided by both technological and geographical diversity of renewable generation as well as interconnection to neighbouring countries, flexible demand and electricity storage.

Combining these technologies will reduce the frequency and magnitude of times when there is too much or too little generation.

Regen's report with the Electricity System Operator a 'Day in the Life' of a net zero power system shows how the system could work.



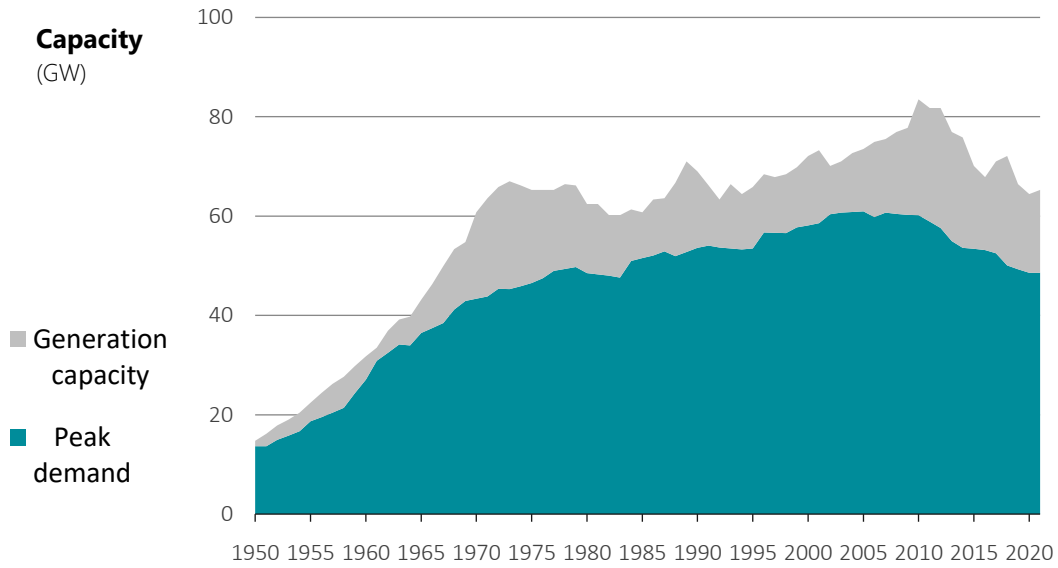
Note: 50-100 TWh of electricity will be exported annually via interconnectors by 2035. Source: ESO Future Energy Scenarios 2022 (Consumer Transformation scenario).

The scale of the challenge

The energy transition is still at a relatively early stage. However, there are already signs of the need to invest in the grid as a critical part of the transition. For example, the number of connection applications into the transmission network in the first three months of 2023 was more than two and a half times the total for the year in 2018.

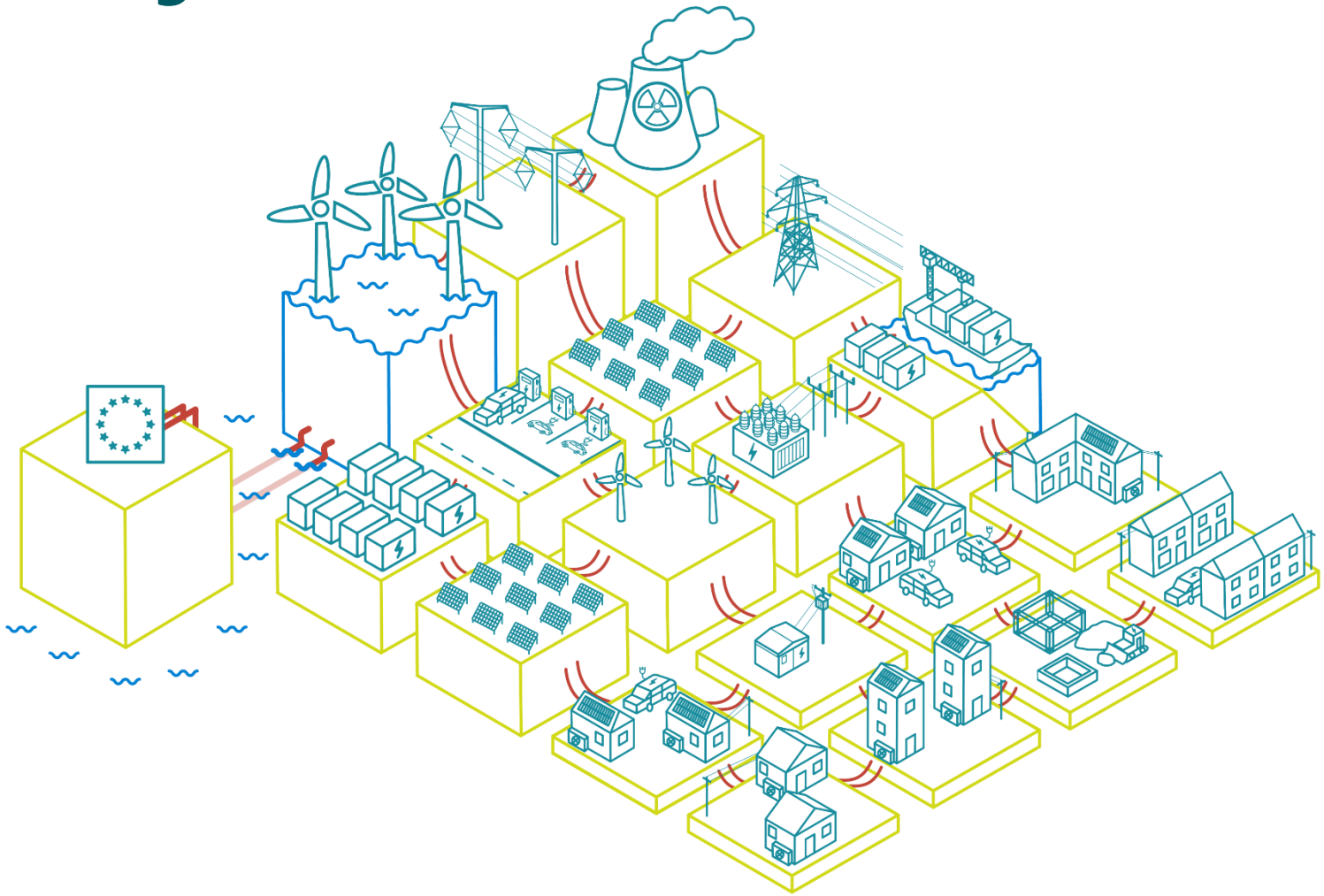
We know we can rise to the scale of the challenge. The UK has achieved rapid growth of electricity system infrastructure in the past. **Between 1950 and 1975 electricity generation and associated grid capacity increased almost five-fold.**

Rapid electricity system expansion has happened before



Source: Ofgem, Consultation on frameworks for future systems and network regulation: enabling an energy system for the future.

This report sets out the scale of the challenge across the grid



Key participants

Ofgem
Regulator

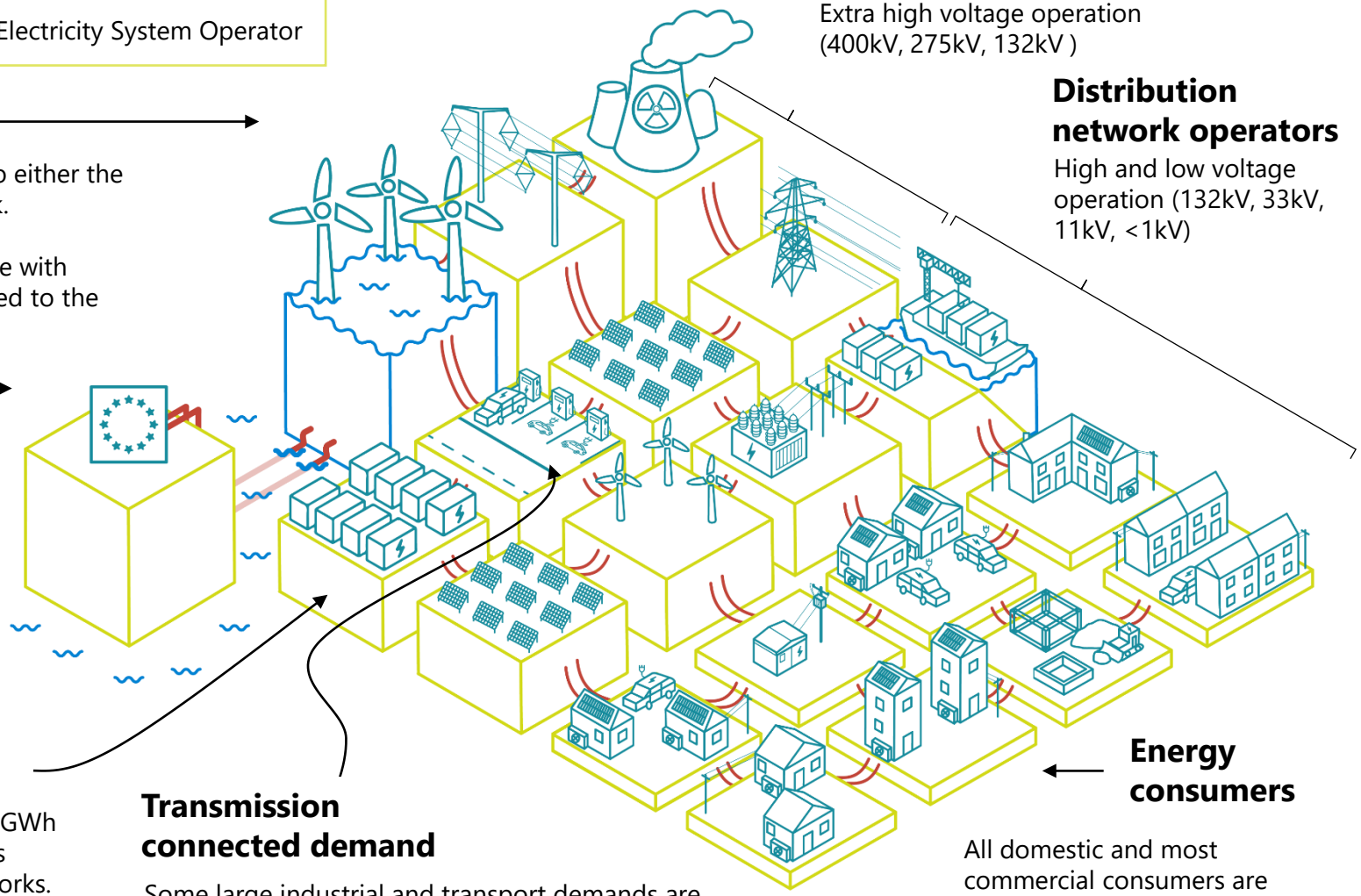
ESO
Electricity System Operator

Generators

Electricity generation can connect to either the transmission or distribution network. Generation over 50 MW tends to be connected to transmission and those with lower capacity are typically connected to the distribution network.

Interconnection

High-voltage cables connect GB to the electricity systems of neighbouring countries in Ireland and mainland Europe.



Transmission operators

Extra high voltage operation (400kV, 275kV, 132kV)

Distribution network operators

High and low voltage operation (132kV, 33kV, 11kV, <1kV)

Storage

There is currently about 2.5 GW / 3 GWh of battery storage connected across Transmission and Distribution networks. This capacity could double by 2024.

Transmission connected demand

Some large industrial and transport demands are connected directly to the transmission network.

Energy consumers

All domestic and most commercial consumers are connected to the distribution network.

Network operation and regulation

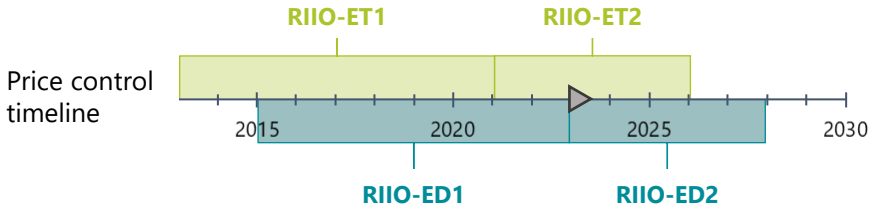
The electricity network in Great Britain consists of a high voltage onshore and offshore transmission network and a lower voltage distribution network.

The onshore electricity network consists of approximately 20,000km of high voltage transmission cables and 800,000km of lower voltage distribution lines. Electricity is transported at high voltage to minimise energy lost in the form of heat and substations transform the power to lower voltages for use by consumers.

The grid is owned and operated by privatised network operators under a framework of monopoly regulation set by Ofgem, the industry regulator. The networks are natural monopolies: customers are unable to switch to a different network without physically moving to a different licence area.

The regulator uses price control periods to set the allowed revenues for network companies. These revenues are set at a level that covers the companies' costs and allows them to earn a reasonable return subject to them delivering value for consumers and achieving their targets as set by the regulator.

The current regulatory model is called RIIO (Revenue = Incentives + Innovation + Outputs) and was introduced to incentivise networks to deliver a range of outputs and better overall performance. The transmission price controls and distribution price controls are managed separately over different periods.



ESO The **Electricity System Operator** (ESO) manages the electricity system in real time. Currently owned by National Grid, ESO will become part of the new Future System Operator (a yet to be established independent public sector body).

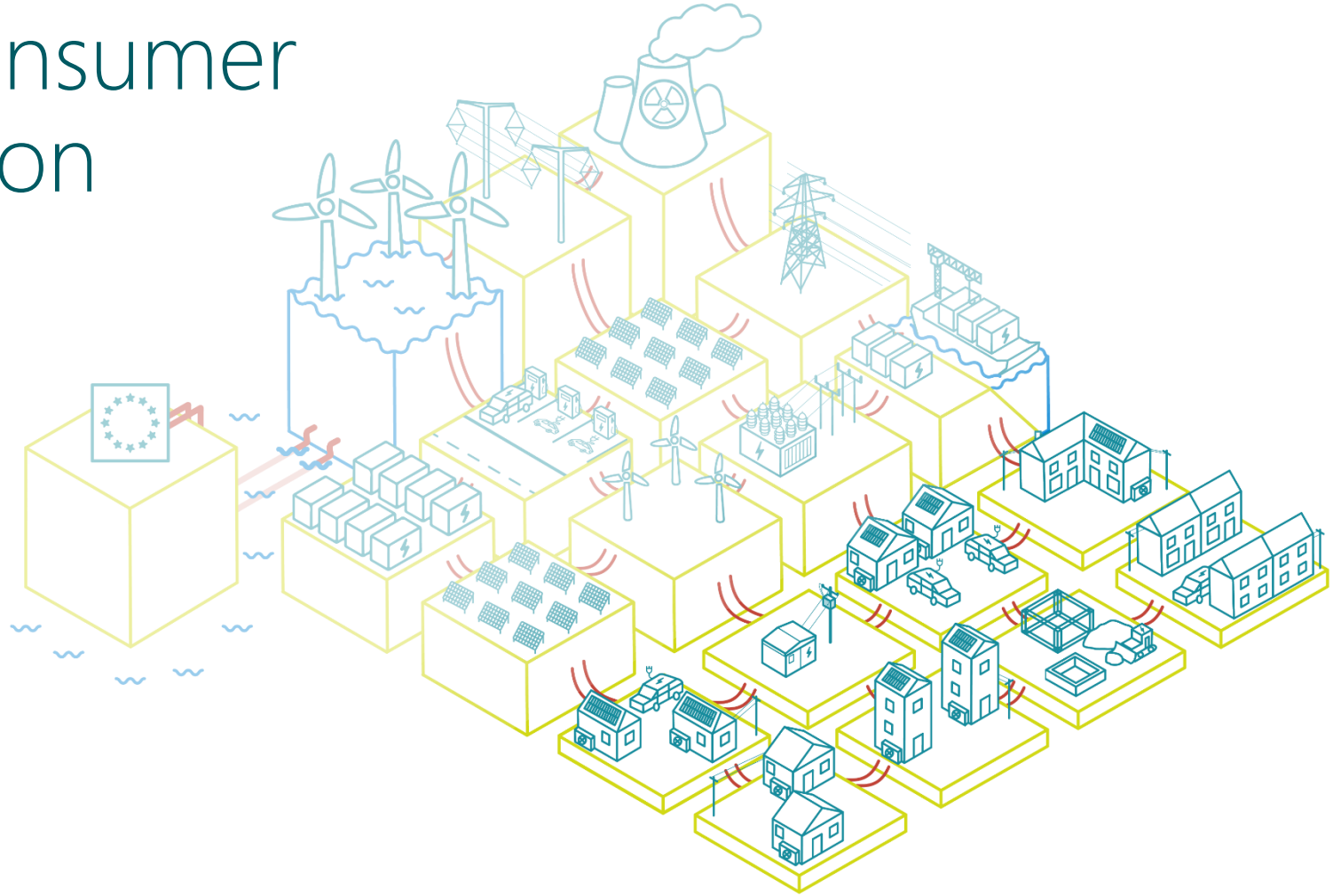
Electricity Transmission (ET)

1. Scottish & Southern Electricity Networks
2. SP ENERGY NETWORKS
3. nationalgrid

Electricity Distribution (ED)

1. Scottish & Southern Electricity Networks
2. SP ENERGY NETWORKS
3. electricity north west
4. NORTHERN POWERGRID
5. nationalgrid
6. UK Power Networks

1. Low voltage distribution: preparing for a wave of consumer electrification



EVs and heat pumps will drive consumer electricity demand

Domestic heating

Domestic vehicles

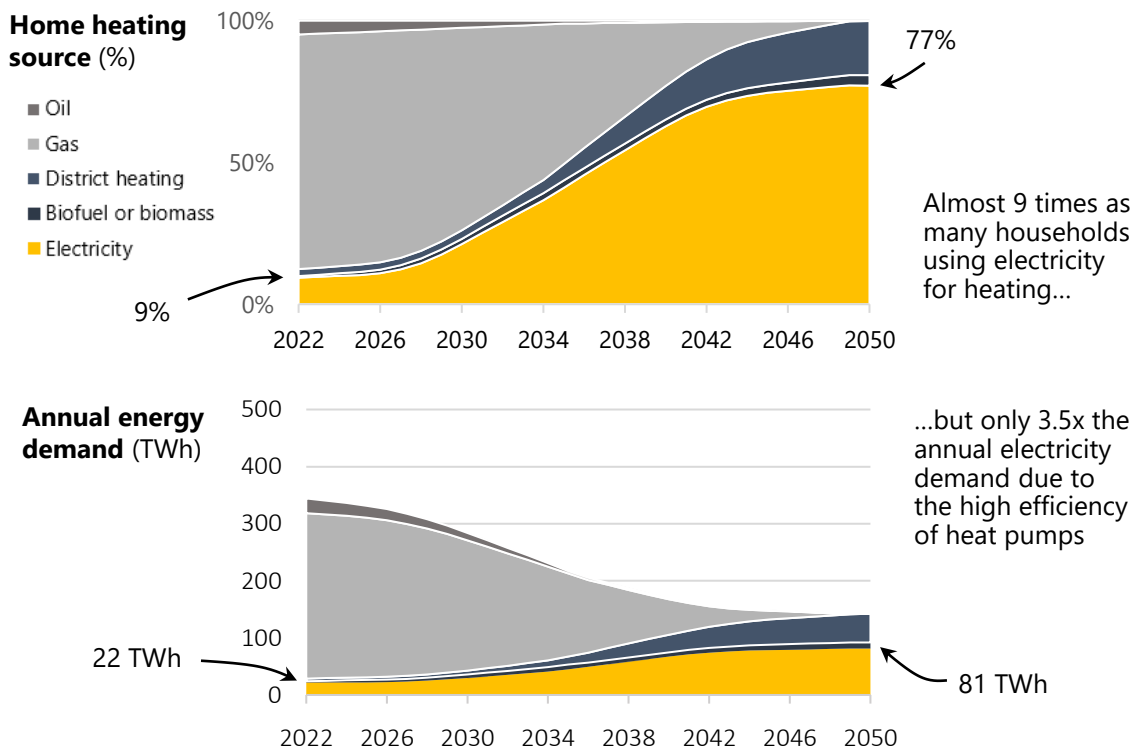
By 2035 80% of vehicles on the road could be electric and 41% of households could use electricity as their energy source for heating. This will increase electricity demand. However, overall primary energy demand for transportation and heating will fall due to high energy conversion efficiencies of electric vehicles (EVs) and heat pumps compared to internal combustion engines and gas boilers.

In a net zero scenario, it is possible that by 2035 over 7 million households (23%) will use a heat pump for their space and water heating. The government is aiming for over 600,000 heat pump installations per year by 2028.

Heat pumps deliver around 3 units of heat for each unit of electricity used. So, whilst the number of homes heated with electricity could increase ninefold, the annual electricity demand will only increase by a factor of 3.5.

There is still uncertainty over the rate of electrification but it is increasingly clear from the evidence that hydrogen will have a limited role in heating our homes. The grid must be ready for a very fast roll-out of heat pumps. Preparation for this has been at the heart of the distribution networks' five-year business plans.

Note: all figures from National Grid's Future Energy Scenarios (2022), Consumer Transformation scenario.



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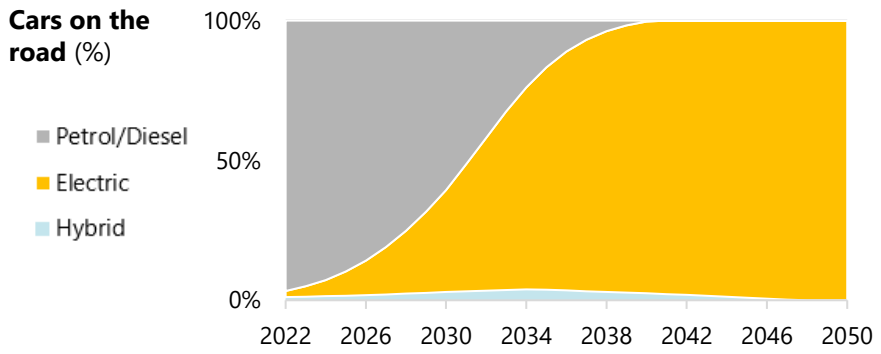
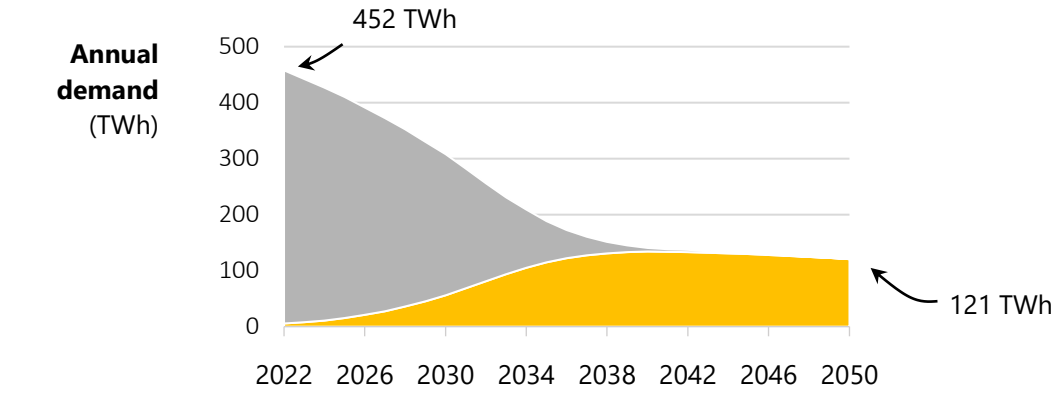
20% of all cars sold in January 2023 were battery-electric or plug-in hybrid and by the end of the year over 1.5 million cars on the road will have a plug. Sales of new petrol and diesel cars will end in 2030 under Government plans.

Most electric vehicles will be charged at people's homes. In 2035, almost 60% of domestic and commercial EV charging demand will be provided by residential charge points: all this power will flow through the low voltage part of the distribution network.

As use of EVs becomes more widespread, so will the adoption of smart charging (where vehicles are charged at times of low electricity demand) and vehicle-to-grid (where electricity is returned to the grid at times of high demand). Both smart charging and vehicle-to-grid will help the operation of the low-carbon power system.

Note: all figures sourced from National Grid's Future Energy Scenarios (2022), Consumer Transformation scenario.





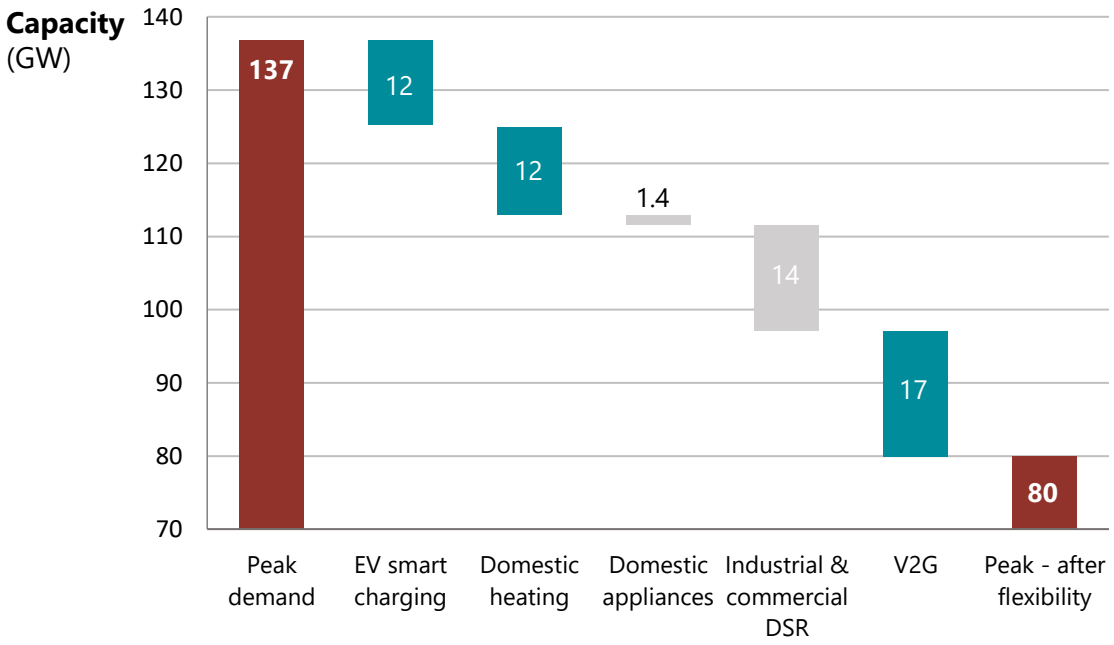
Flexible operation of EV chargers and electric heating will reduce costs

The government estimates that an electricity system that operates flexibly in response to renewable output could reduce costs by up to £10bn a year by reducing the amount of generation and network infrastructure that needs to be built meet peak demand.

Domestic devices connected to the low voltage part of the distribution networks will be a crucial part of this flexible demand. The bulk of domestic demand side response (DSR) will be sourced from smart controlled electric vehicle chargers and electric heating demand. The distribution network operators have all adopted a "flex first" philosophy for their higher voltage assets and are working on a suite of innovation projects and trials to operationalise flexibility.

Unlocking the potential of consumer flexibility will involve reinforcing the local networks to ensure millions of EVs and heat pumps can connect without delay.

Domestic heating and EV charging will provide over 40 GW of flexibility by 2050



Note: Source - National Grid Future Energy Scenarios, Consumer Transformation scenario. Chart shows peak reduction (measured in GW) of different sources of flexibility in 2050. DSR stands for demand side response, V2G stands for vehicle-to-grid. Y-axis starts at 70 GW. 40 GW flexibility includes domestic heat and all EV charging including V2G.

There is spare capacity but we need to scale-up reinforcement

Based on data from the networks the Government estimates that there is on average 60% spare thermal capacity (known as headroom) across all distribution network assets in Great Britain. Headroom is the difference between the amount of power the network is designed to deliver and the actual demand on the network.

Without upgrades, as electricity demand increases this headroom will be used up. The Government's central model forecasts that on average the networks will run out of headroom around 2035.

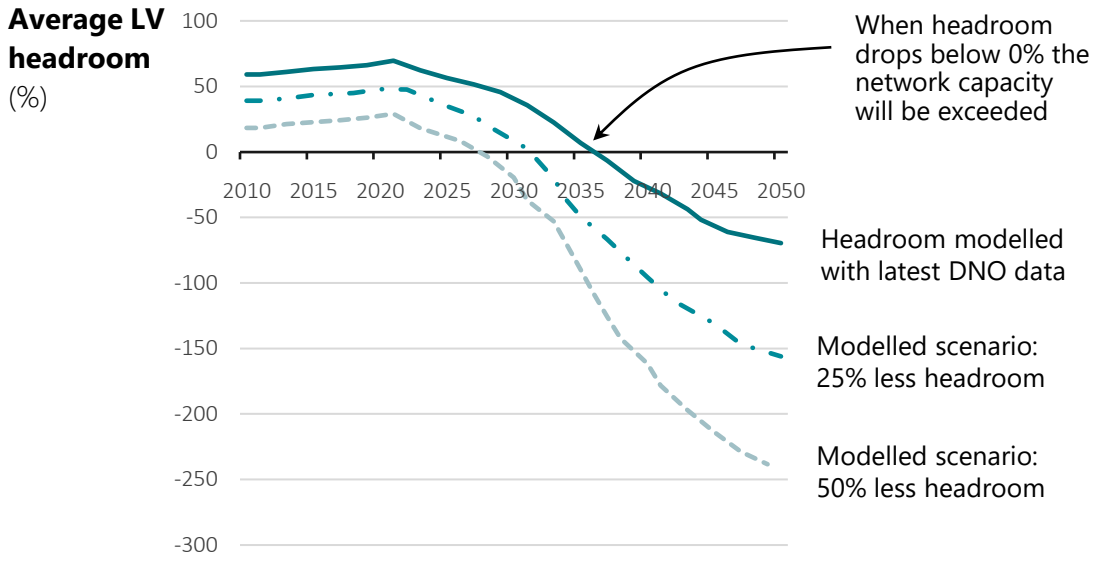
The low voltage part of the network is made up of hundreds of thousands of transformers and cables, some of which were designed over 50 years ago, mainly operating without load monitoring or data collection.

There are two issues:

1) **Due to limited network monitoring, it is possible that average headroom may be lower than 60% across the country**
2) **There is significant regional and local variation in headroom so certain areas will require upgrades before 2035 - potentially in the next few years**

Upgrading individual low voltage cables and transformers can be achieved relatively quickly and inexpensively compared to higher voltage assets but en masse upgrading the low voltage network is a major undertaking that will take years to deliver. The networks must be enabled to make the required network upgrades in advance to avoid a delivery crunch and restrictions for customers wanting to charge their car or install a heat pump.

Low voltage network reinforcement will be required before 2035 on average



Note: In scenarios modelled with less headroom reinforcement is required years earlier. Source: Ofgem/BEIS, Electricity Networks Strategic Framework Appendix I. Net Zero high demand scenario with three levels of distribution network thermal capacity.

> "A large section of the existing networks were designed for 1950s, 1960s and 1970s where the electricity usage assumptions at the time of installation were lower than the current standards."
>
> Heat Pump Strategy
> **National Grid ED**

The distribution networks are confident in their plans

Network business plan commitments

nationalgrid

"Core commitment 2: Ensure customers are able to connect low carbon technologies quickly and easily, with the network being ready to support at least an additional 1.5 million electric vehicles and 600,000 heat pumps by 2028."

SP ENERGY NETWORKS

"What our RIIO-ED2 plan means for customers: Customers will have the capacity they need to decarbonise – they will be able to use EV chargers and heat pumps immediately and at full capacity."

Scottish & Southern Electricity Networks

"We should support the substantial growth in electric vehicles and heat pumps with no delays and simple connections processes"

UK Power Networks

"Our Commitments:

We are continually striving to improve, and we have set ourselves ambitious targets.. to support the uptake of low carbon technologies in the most cost-effective manner."

Network initiatives

Future energy scenario modelling and asset monitoring:

The DNOs all develop annual Distribution Future Energy Scenarios (DFES) which model future consumer energy demand down to the postcode level. They are also installing sensors across the low voltage network to provide data on how much capacity remains on key assets.

Data and connection process digitalisation:

A massive digitalisation programme is underway across the industry to process analogue records using image recognition technology so that there is complete database of all network assets. They have also developed a standardised, self-service connections process for heat pumps and EVs using a shared database of verified devices (more info in Appendix).

Planning and reinforcement:

Tactical reinforcement has begun, informed by energy demand and network utilisation modelling. As well as increasing network capacity (traditional reinforcement) networks can manage some constraints with other solutions – including procuring flexibility and implementing "smart" interventions that get more capacity out of existing assets. Where properties share a single cable (known as looped services) these are being replaced with separate cables.

Ofgem has taken a gamble by delaying investment

> This investment will help deliver the local electricity distribution networks we need to connect up those new sources of energy to our homes and businesses and meet expected increases in electricity demand, such as from heat pumps and electric vehicles.
>
> RIIO-ED2 Final Determinations
> **Ofgem**

In 2022 the networks published business and investment plans for 2023 to 2028 to ensure they have the capacity ready ahead of need.

However, final budget allowances for network reinforcement were reduced by 17%, compared to what the networks submitted in their plans, by Ofgem.

The regulator believes the amount of investment and their contingency mechanisms to release further budgets if required will be sufficient to enable the networks to reinforce their networks in time.

However, knocking 17% of the investment networks proposed is a big gamble. Will networks be able to scale up their capacity and supply chains quickly if faster investment is required? If Ofgem's gamble backfires they will have put net zero at risk.

Distribution network budgets for reinforcement until 2028 will be 17% lower than operators proposed

Source: ED2 business plans, Ofgem draft determinations, Ofgem final determinations.

> If the networks are not sufficiently developed, there will be no net zero. If they are slightly over-invested, the costs across the whole customer base are small, and in any event the assets will in due course probably be needed.
>
> **Dieter Helm**
>
> Professor of Economic Policy at the University of Oxford

Recommendations

1. Low voltage distribution:
preparing for a wave of consumer electrification

Meeting the huge increase in consumer electricity demand will be a challenge for networks. Networks are preparing. However, a sustained approach from the government, Ofgem and networks will be required ensure that consumers up and down the country will be able to connect quickly and easily. In particular:

1.1 Networks must invest ahead of increasing demand

Networks operators have developed plans and initiatives to ensure people can connect heat pumps and EV chargers without delays and at full capacity. They now need to ensure these plans are implemented and step up the pace of change in key areas:

- Carrying out strategic planning of the low voltage network.
- Accelerating digitalisation of their asset data and improving their data quality
- Proactively developing the supply chain for both equipment and outsourced contracts
- Accelerating their reinforcement programmes

1.2 Ofgem should provide strategic leadership to enable net zero

The regulator has taken a gamble with net zero by cutting distribution network investment plans against their draft budgets. They must now:

- Ensure that networks can access budgets tied behind 'Uncertainty Mechanisms' before customers start seeing problems with connections.
- Ensure networks can invest strategically, ahead of need in this price control period.
- Put reinforcement at the heart of the next price control process – ensuring investment is made in so the network has the capacity for net zero.

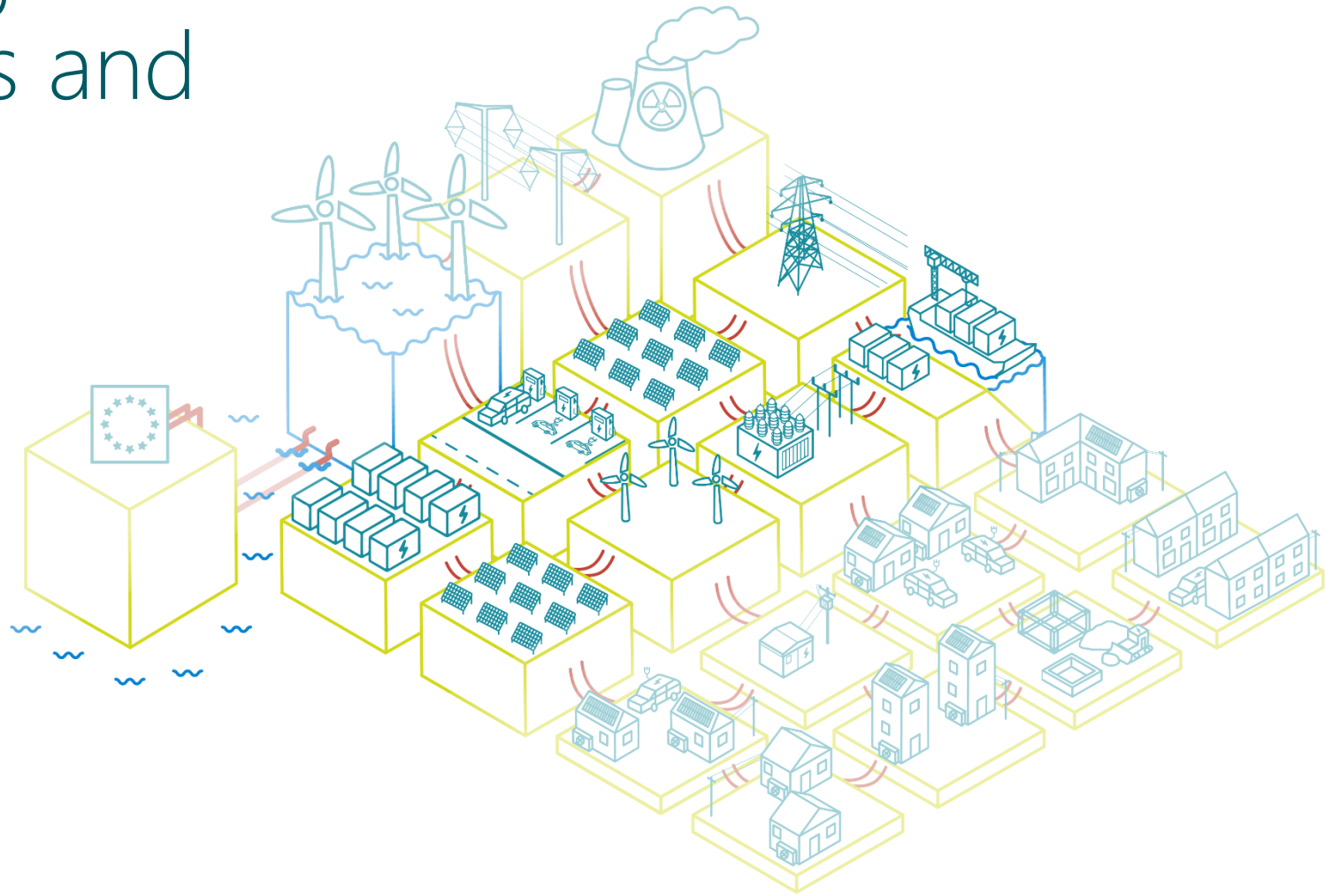
1.3 Government should commit to electrify heat and transport

It is increasingly clear from the evidence that hydrogen will have either a very limited role or no role at all in heating our homes.

However, until the government makes a clear decision on hydrogen heating it is difficult for networks to plan and invest for the electrification of heating through heat pumps.

2. Transmission-distribution interface:

connecting onshore renewables and storage



Long connection lead times are severely delaying renewable generation and storage projects

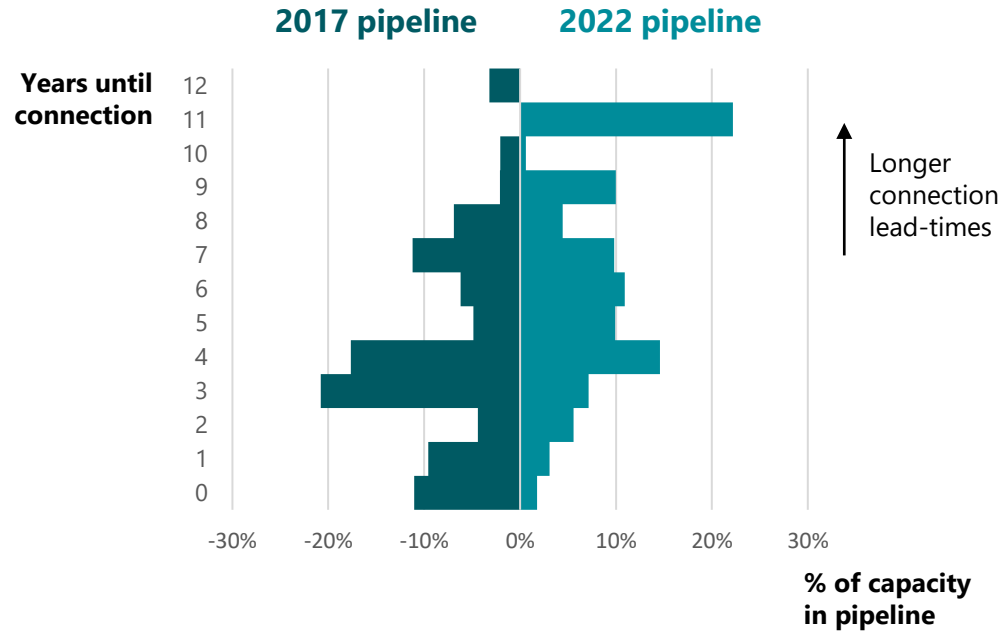
Ask anyone involved in sustainable energy what the biggest challenge they face is, and chances are that they'll cite the grid.

Connecting a large volume of renewable generation and storage projects is critical to decarbonising the power system by 2035.

There is a pipeline of projects in development with connection dates in the next few years wishing to connect into both the transmission network and the distribution networks. However, new projects critical to new zero are stuck in the transmission queue and now face delays of over 15 years to connect. This is becoming a major barrier to net zero.

> The Review heard from hundreds of innovative companies eager to bring new technologies to market but **being hampered by slow, ponderous bureaucracy and an antiquated approach to grid connections** not suitable for a modern 21st century electrified economy
>
> **Chris Skidmore**, Mission Zero – Independent Review of Net Zero

Connection lead-times on the transmission network have increased



Note: Regen analysis of ESO Transmission Entry Capacity (TEC) Register. Data accessed Nov 2017 and Nov 2022. Over the same period the pipeline has increased from 87 GW to 243 GW.

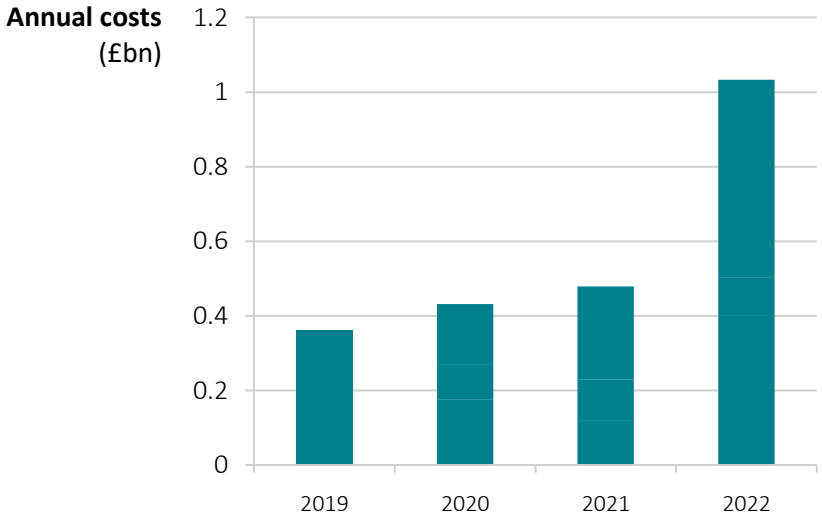
Delays to grid development are costing consumers

Ofgem's policy of delaying grid development and allowing new generation to connect to the grid before full reinforcement works have been completed has led to acute grid bottlenecks.

The ESO manages constraints by turning down generation in one area, usually renewable generation, and paying generators in another to turn up. The turn-up actions are largely provided by gas generation and so the cost of managing constraints has ballooned as gas prices have rocketed. These costs are passed onto consumers through their electricity bills.

> "The "Connect and Manage" regime… has led to high **constraint costs for consumers** and lengthening delays in connecting new generation."
>
> Frameworks for future systems and network regulation
> **Ofgem**

The costs of managing grid constraints exceeded £1bn in 2022 as gas prices soared



Source: ESO – balancing services summary

The legacy process for managing new connections is not fit for purpose

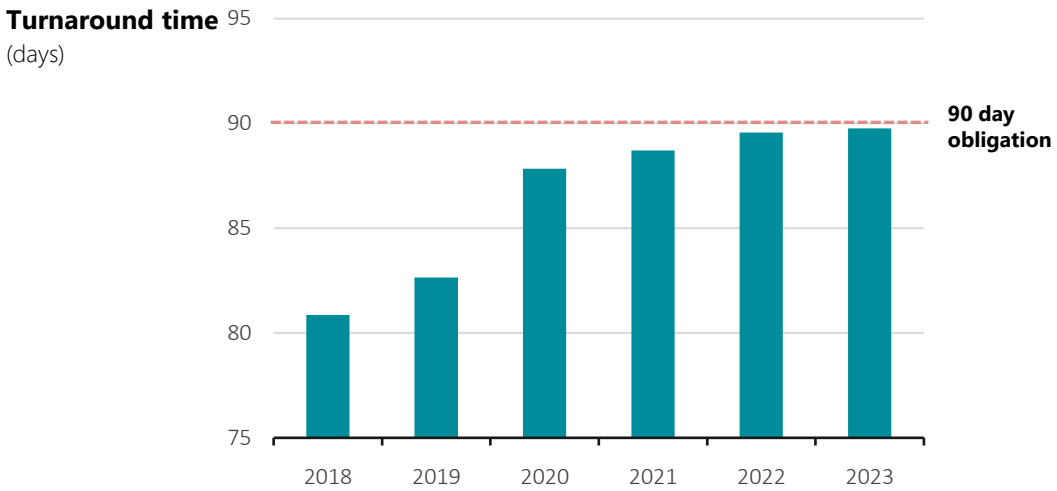
Connections are provided on a first-come-first-served technology neutral basis, allowing customers to reserve network capacity by accepting a connection agreement. This has created a queue of connections which is itself now a significant blocker for new projects as grid capacity has already been reserved for speculative projects that are not progressing.

How new connections are managed is critical to ensuring that viable projects receive the earliest connection date possible. This includes:

1. **Queue management:** ensuring all projects have clear progress milestones so that speculative projects that are not progressing towards delivery do not block projects that are able to progress
2. **Flexible connection agreements:** the use of a wider range of connection agreements so ESO can be less risk averse in its assumptions, freeing up capacity
3. **Planning assumptions:** re-modelling how storage projects are assumed to operate, as storage should help rather than hinder the grid

> The current connections process, which was originally focused on connecting a small number of large fossil fuel plants every year, has not kept pace with the rapid changes occurring in the energy sector.
>
> Case for Change, GB Connections Reform
>
> **Electricity System Operator**

ESO is increasingly struggling to turnaround connection applications in 90 days



Source: GB Connections Reform, Case for Change (ESO).

Connection of renewable generation is outpacing expansion of grid capacity

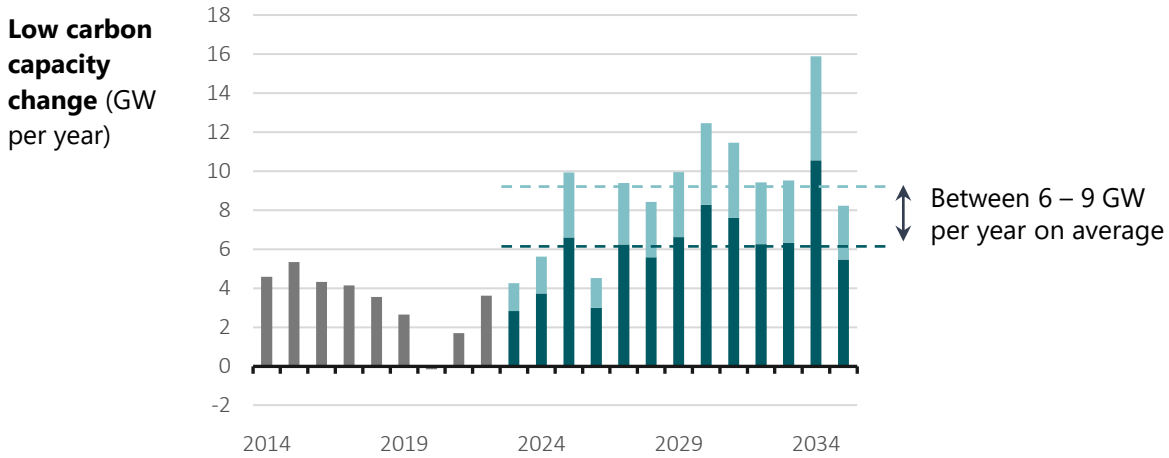
> …under the **Connect and Manage** regime market-led increments to transmission grid capacity perpetually lagged accelerating renewable generation.
>
> Frameworks for future systems and network regulation - **Ofgem**

Improving the way that new connections to the grid are managed is critical. However, increases in grid capacity will be required to enable the renewable generation we need to connect.

To decarbonise the power system and put us on track for net zero 180 - 220 GW of grid connected power generation capacity will be needed by 2035. **This will involve a net capacity addition of between 6 and 9 GW per year – a huge jump above the average of 3.3 GW achieved over the last decade**.

In order to enable new generation to connect to the network earlier the Government in 2010 implemented a grid access regime called Connect and Manage. This allowed generation projects to connect to the transmission system in advance of the completion of wider transmission reinforcement works.

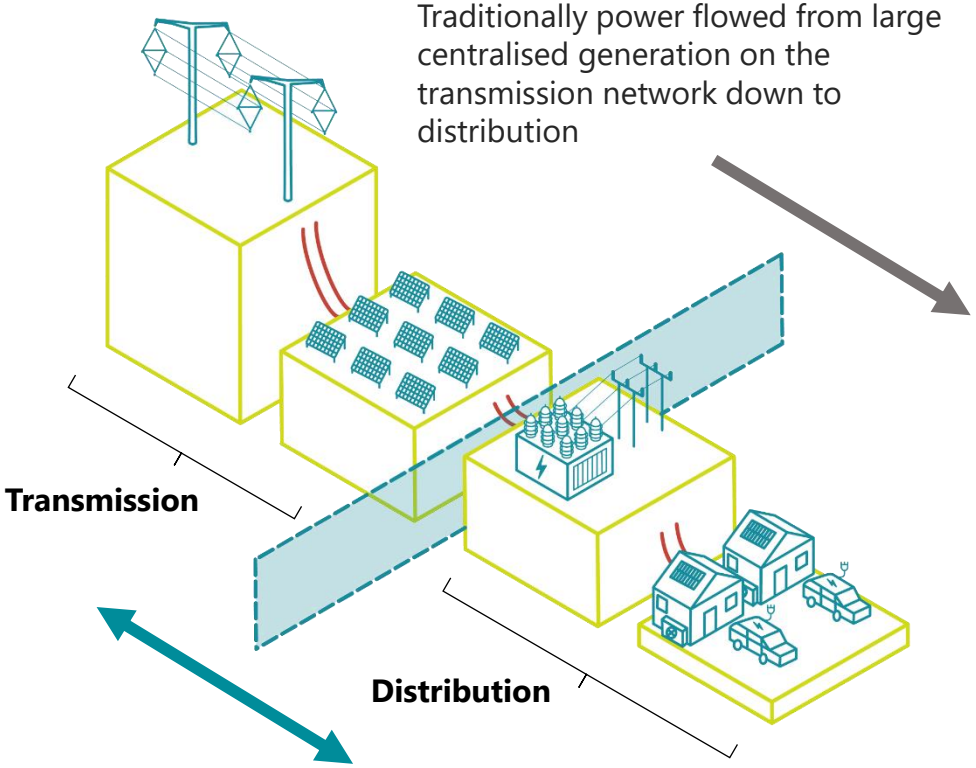
The increase in low-carbon generation required for net zero is significant but achievable



Note: graphic shows net capacity change. Low carbon refers to renewables and nuclear. Capacity has reduced in some years when decommissioning nuclear plants. Source: historic capacity from DUKES 5.12, future capacity from Regen analysis assuming required capacity of 180 to 220 GW from Day in the Life 2035 and using FES 2022 Consumer Transformation scenario.

> We have to shift to a system that does not lag behind, but that anticipates the renewable generation and builds the grid capacity out in advance so that when the renewable generators are ready to connect, the grid capacity is already there.
>
> Akshay Kaul, Director of Infrastructure and Security of Supply, Ofgem (BEIS select committee, inquiry: Decarbonisation of the power sector)

Distributed power generation now flows up to transmission network - leading to long connection delays



New system

There is now 34 GW of generation connected to the distribution networks (and some 58 GW in the pipeline) so power often flows up as well as down.

The ESO now needs to consider the impact on the transmission system of the generators connected to the distribution network. This network impact assessment process, known as a Statement of Works, has affected the connection of renewable and storage projects in several ways:

- **Delays:** Relatively simple connection requests into the distribution network can be delayed as they are wrapped into lengthy assessments of transmission impact.
- **Higher connection costs:** The transmission reinforcement costs, which can be high, are shared between connecting projects.
- **Unworkable areas:** The risk that others may pull out, leaving the reinforcement bill to be shared among fewer projects, is causing many areas to be unworkable for new generation projects.

There are two broad approaches to creating a better system:

1. A single queue across both transmission and distribution
2. DNOs have an agreed headroom at each grid supply point that they manage connections to stay within.

The ESO and DNOs need to agree on the best approach and move on to implementation.

Addressing the connections challenge

Government, Ofgem and the network operators have action plans to address connection challenges:

- The Government has accepted there is a problem and announced in "Powering Up Britain" that a review of connections would be held by the summer.
- Ofgem has launched a consultation on frameworks for future network regulation, proposing to move from "Connect and Manage" to "Invest and Connect" – where grid expansion occurs in anticipation of generation.
- Ofgem has also stated it will take a central role in driving connections reform in its open letter
- The networks are working together and some solutions have already been announced. See table.

> **Grid capacity is one of the things which really concerns me.** If you want to ask why there is a Department for Energy Security and Net Zero now… it is so that we get some real focus on solving this problem.
>
> **Grant Shapps MP,**
> Secretary of State for Energy Security and Net Zero

Initiative	Scope
ESO **5 point plan**	1. Allowing developers to surrender connection agreements without penalty to free-up capacity 2. Updated project progression assumptions 3. More realistic assumptions for storage projects 4. Contracts that allow more robust queue management 5. Earlier connection for battery projects that accept flexible connection agreements
ESO **GB Connections Reform** (input from Transmission Operators, ENA, Ofgem, Government)	"The GB Connections Reform project has been launched to address the fundamental need for reform. This reform project forms part of our longer-term vision for change in the GB ESO Connections space." The objective is to deliver a reformed connections process that: 1. Delivers value to consumers 2. Supports Net Zero and Energy Security 3. Delivers improvements to customer experience and engagement 4. Delivers a whole system approach – i.e. factors in Distribution 5. Efficiently advances projects that are ready to connect 6. Embraces connection complexity in an evolving energy system 7. Is future proof and adaptable
ena energy networks association **Strategic Connections Group** (input from ESO, DNOs, Transmission Operators)	1. Reforming the distribution network connections queue, promoting mature projects that are closer to delivery above those that may be 'blocking' the queue. 2. Changing how transmission and distribution networks coordinate connections, improving their interactivity. 3. Greater flexibility for energy storage through new contractual options. The ENA is the industry funded body that represents the energy networks in the UK.

Recommendations

2. Transmission-distribution interface: connecting onshore renewables and storage

Government, Ofgem, ESO and networks have been slow to properly plan and invest for the scale of renewable generation and storage that will need to connect to the grid.

They have, however, now accepted the problem and set out short term action plans and longer term reviews to address the problem. The focus now needs to be on delivery to achieve significant improvements in connection timelines. Three key areas require laser focus:

2.1 Deliver on strategic investment

Moving to a grid investment regime that delivers grid developments in coordination with and ahead of new generation connections is critical. The government and Ofgem must deliver on their proposal for "Invest and Connect" and ensure the new Future System Operator in up and running to lead a clear plan for grid investment.

2.2 Reform the connections process

The ESO and network operators need to implement a smarter connections process to get gigawatts of generation flowing onto the grid including:

- Prioritise low carbon projects for connection over fossil fuel generation.
- Enable shovel ready projects to connect rather than being stuck in the queue behind projects that aren't progressing.
- Offer flexible connection agreements where the ESO or DNO can turn them projects of for a brief period if needed to protect the transmission system.

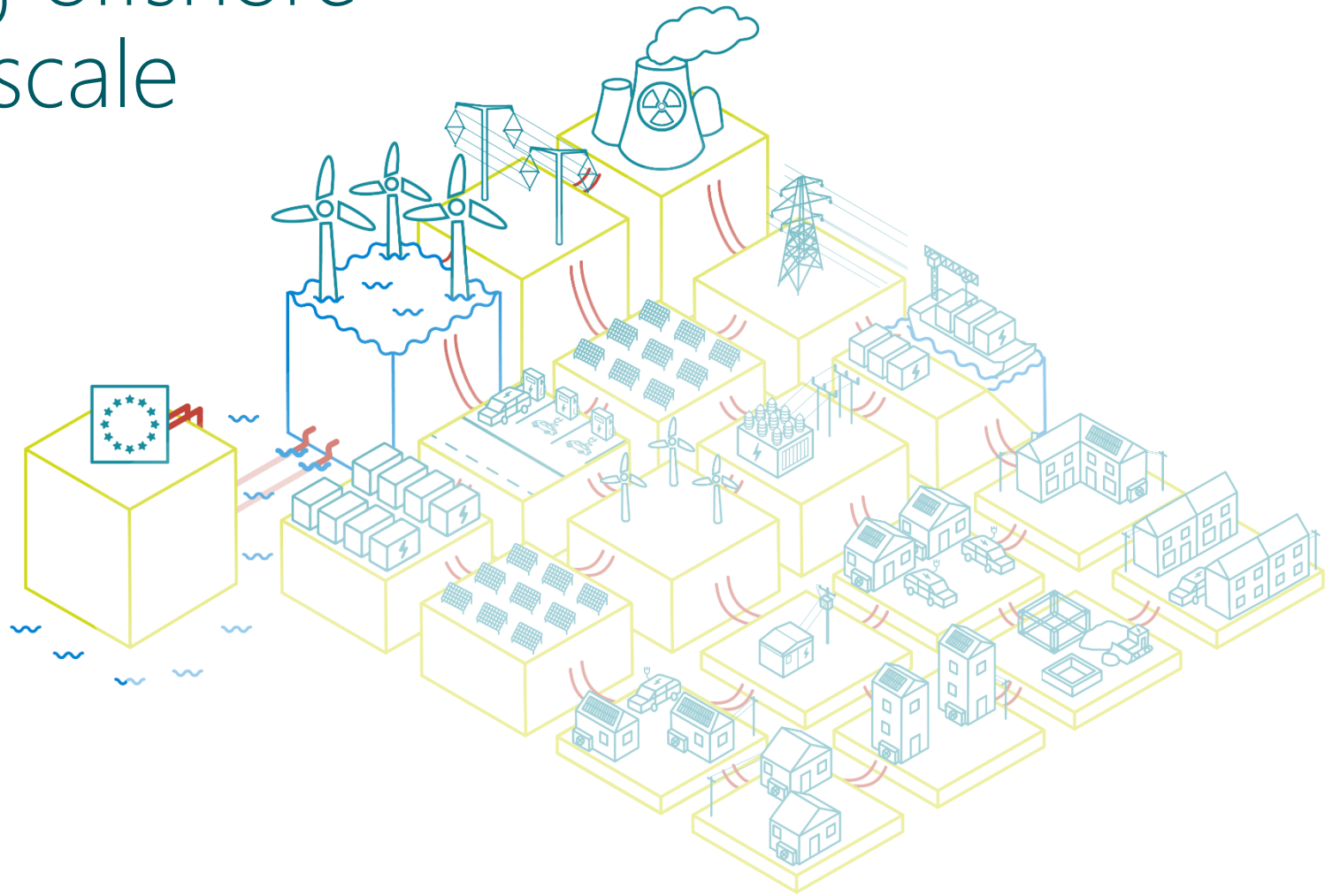
2.3 Reform the approach for interaction between transmission and distribution networks

The process for assessing how projects connecting at distribution will affect the transmission network is a critical barrier for connecting new generation.

The ESO and DNOs need a process to resolve transmission barriers to distribution connections resulting in long queues to connect for relatively small projects.

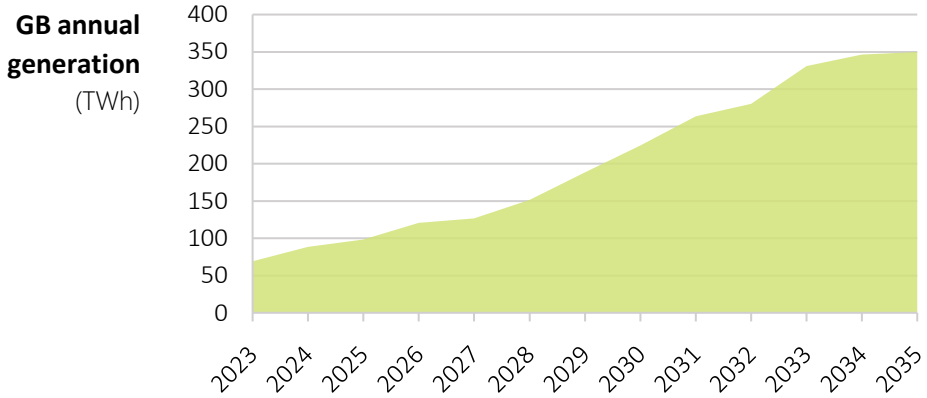
3. Transmission:

connecting offshore and large-scale generation



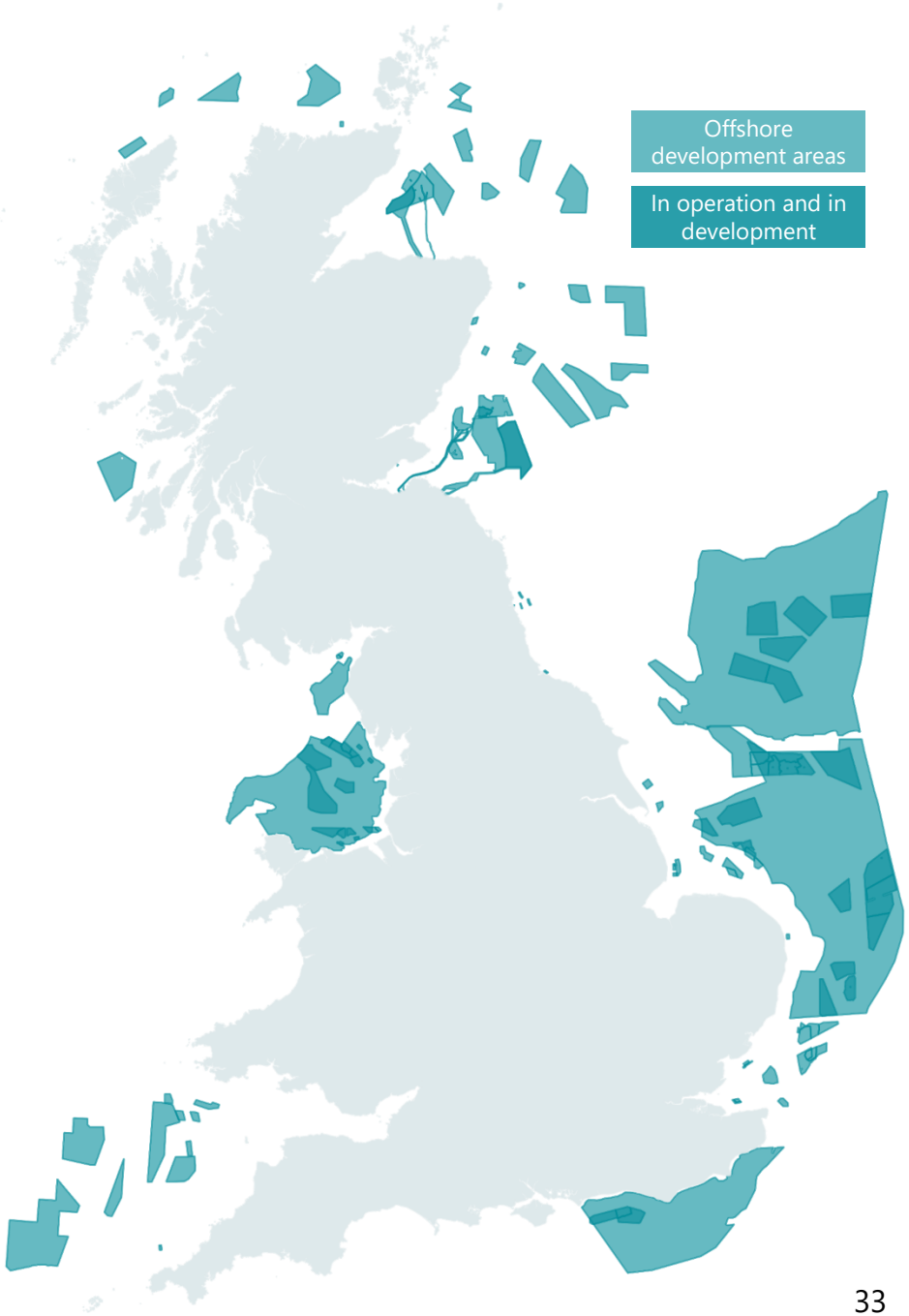
The grid could make or break the UK's ambitious offshore wind target

Annual generation from offshore wind will almost quadruple by 2030



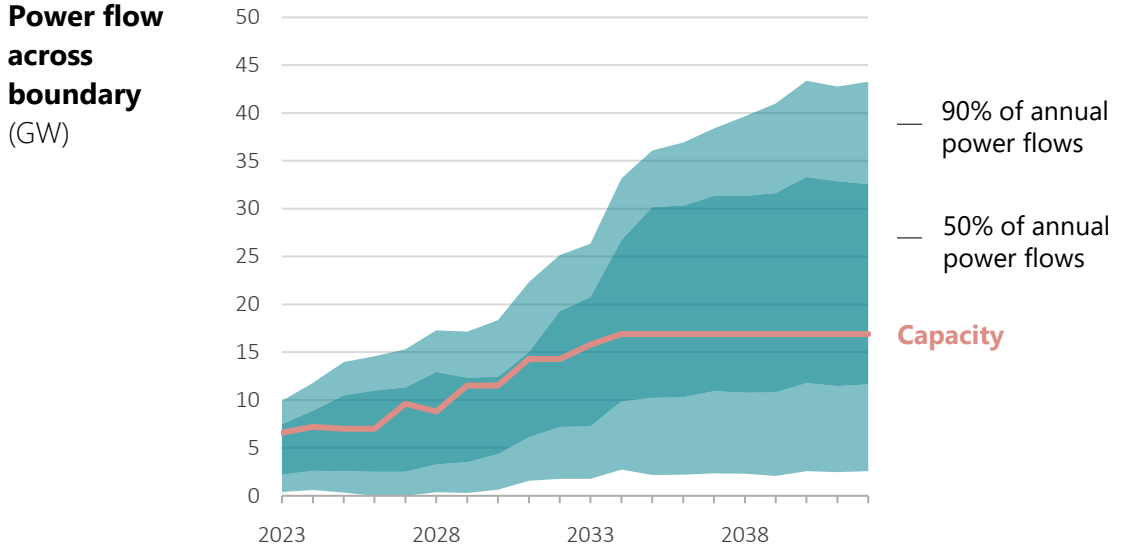
Source: Electricity System Operator future energy scenarios. This scenario is most aligned to the Government's 50GW by 2030 target.

> The British Energy Security Strategy set out the Government's ambition to connect up to 50GW of offshore generation to the electricity network by 2030.
>
> Facilitating this ambition will require **significant reinforcements to the onshore electricity transmission network** and a change to the current regulatory framework in order to accelerate delivery of large projects.
>
> Accelerating Strategic Transmission Investment (ASTI) - **Ofgem**



Investment in network capacity has fallen behind generation deployment

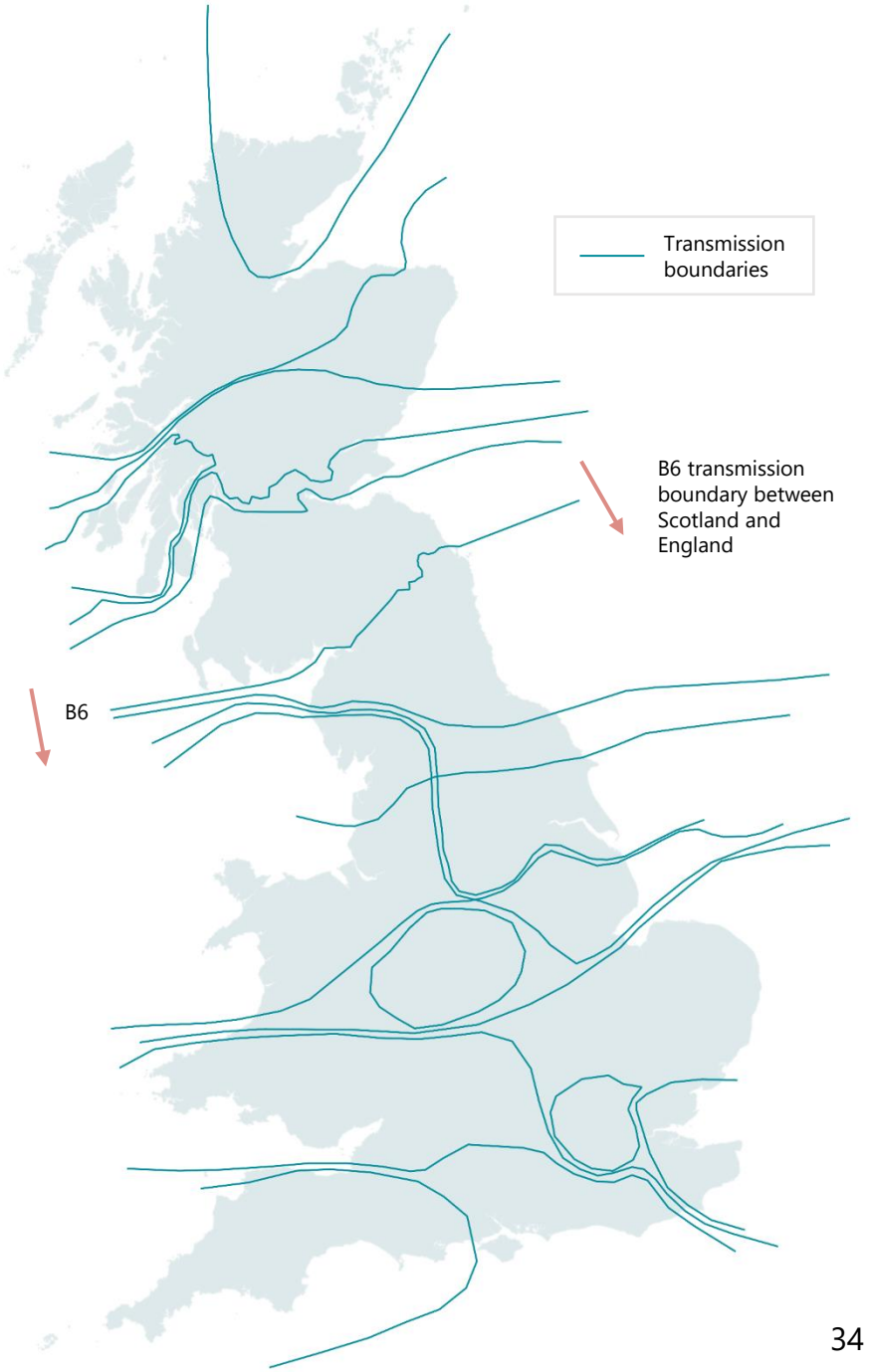
Without further reinforcement, power flows from Scotland will exceed transmission capacity for much of the year



Source: B6 boundary flow from Electricity Ten Year Statement (ETYS), ESO.

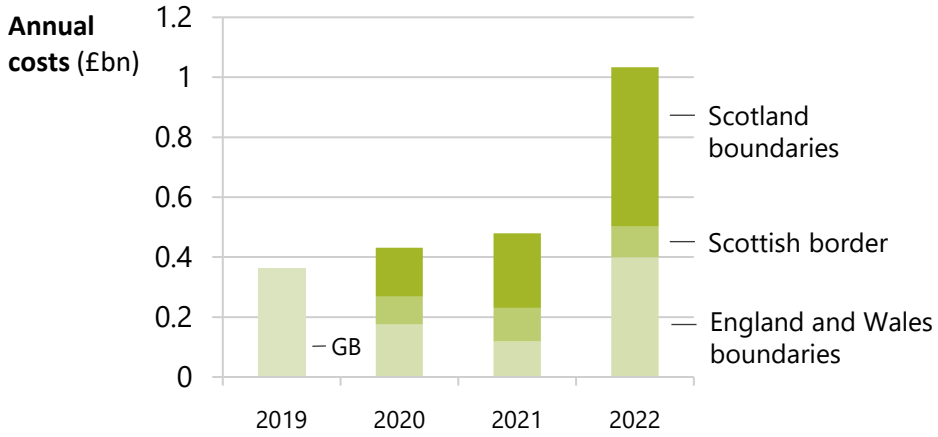
Investment in GB network capacity has fallen behind the rate needed to keep up with generation deployment:

1. Ofgem has been slow to approve new investment under its "Connect and Manage" regime
2. Transmission operators have underspent: National Grid ET underspent its capex budget by 23% (£1bn) in RIIO-ET1 (2013 – 2020).
3. Large transmission projects are inherently challenging with lead times of up to 15 years



Delayed grid upgrades are already generating significant costs

Constraint costs exceeded £1bn in 2022



Source: ESO – balancing services summary

Grid bottlenecks result in constraint management costs, mainly made up of payments for turn-up instructions to gas generators when wind generation is turned down.

Constraints are the result of a policy to delay the costs associated with infrastructure investment and instead manage constraints as they arise. The problem with this approach is that the delays in grid investment have become acute and wholesale gas price rises have increased the costs of relying on gas-fired generation for turn-up actions.

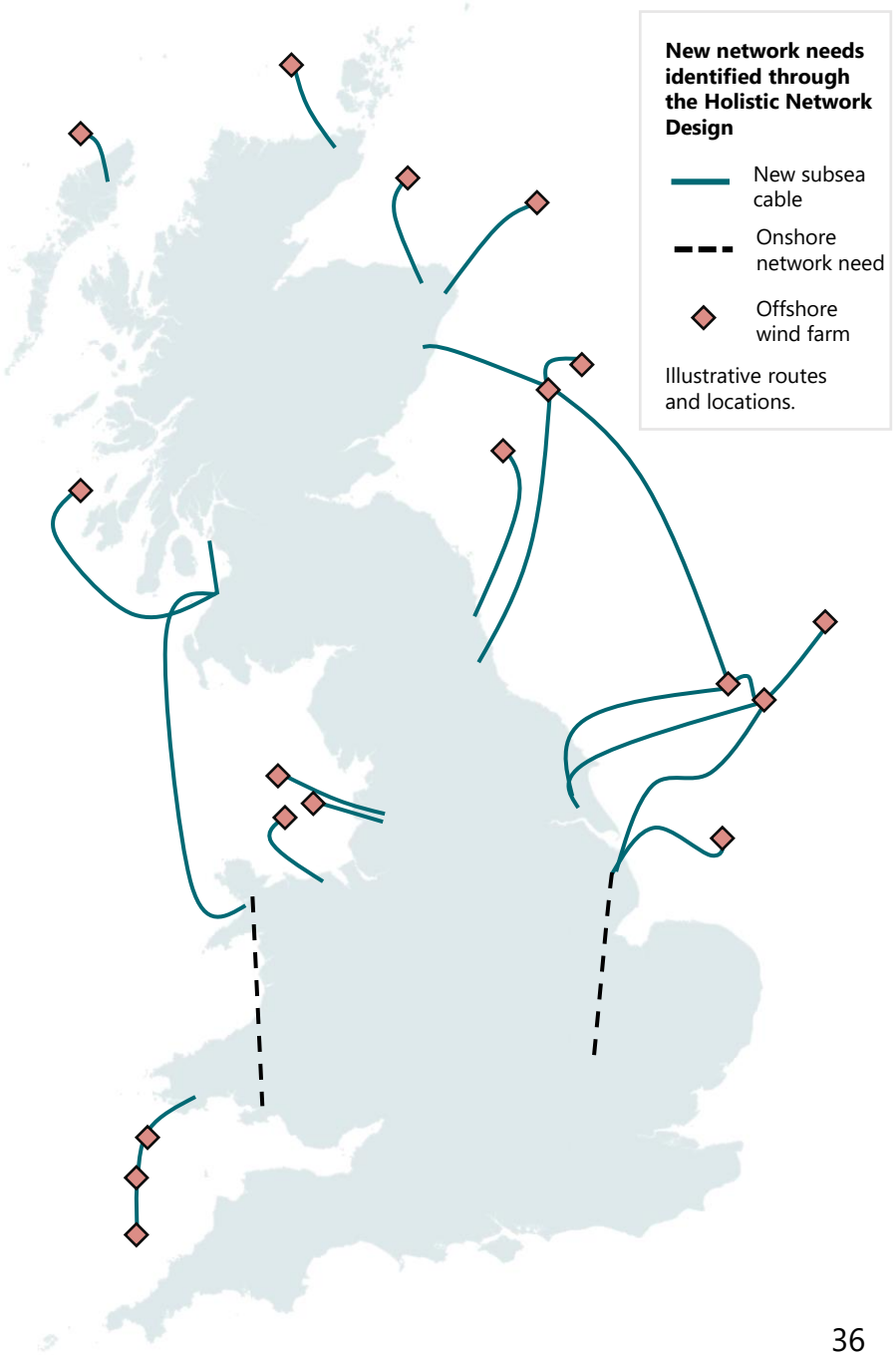
Regen's report found accelerating planning and delivery of transmission network investment as the top solution to rising constraint management costs.

2022/23 saw a major shift in approach to anticipatory investment

Where previously the mantra from Ofgem of achieving "net zero at the lowest cost to consumers" had resulted in delaying investments in transmission to avoid regret costs, it is now acknowledged that the lowest cost route involves accelerating transmission project development.

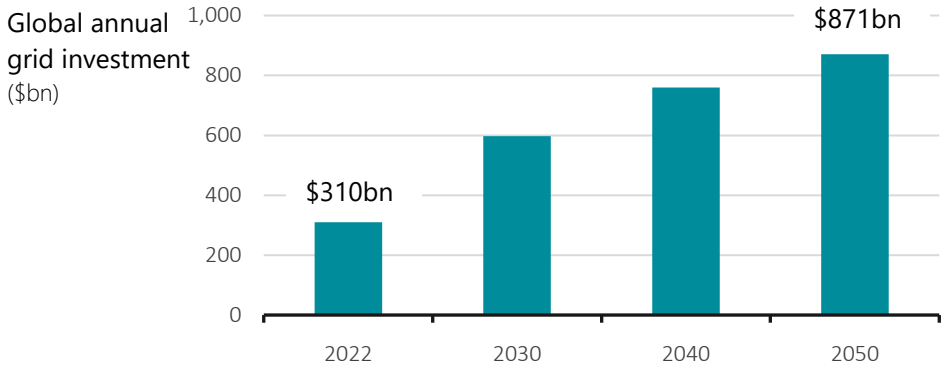
This shift in thinking has resulted in three significant developments towards a more strategic and proactive approach to network planning:

1. The outcome of the Offshore Transmission Network Review – a single, integrated **Holistic Network Design** that supports the large-scale delivery of electricity generated from offshore wind
2. The introduction of a new **Accelerated Strategic Transmission Investment** framework for large onshore electricity network projects (including measures designed to streamline the regulatory approval process and introduce stronger incentives/penalties for timely project delivery).
3. The replacement of the existing network development process with a **Centralised Strategic Network Plan** (CSNP)**,** to be developed by the **Future System Operator** (FSO, a new public corporation).



Supply chain capacity and consenting could stall projects

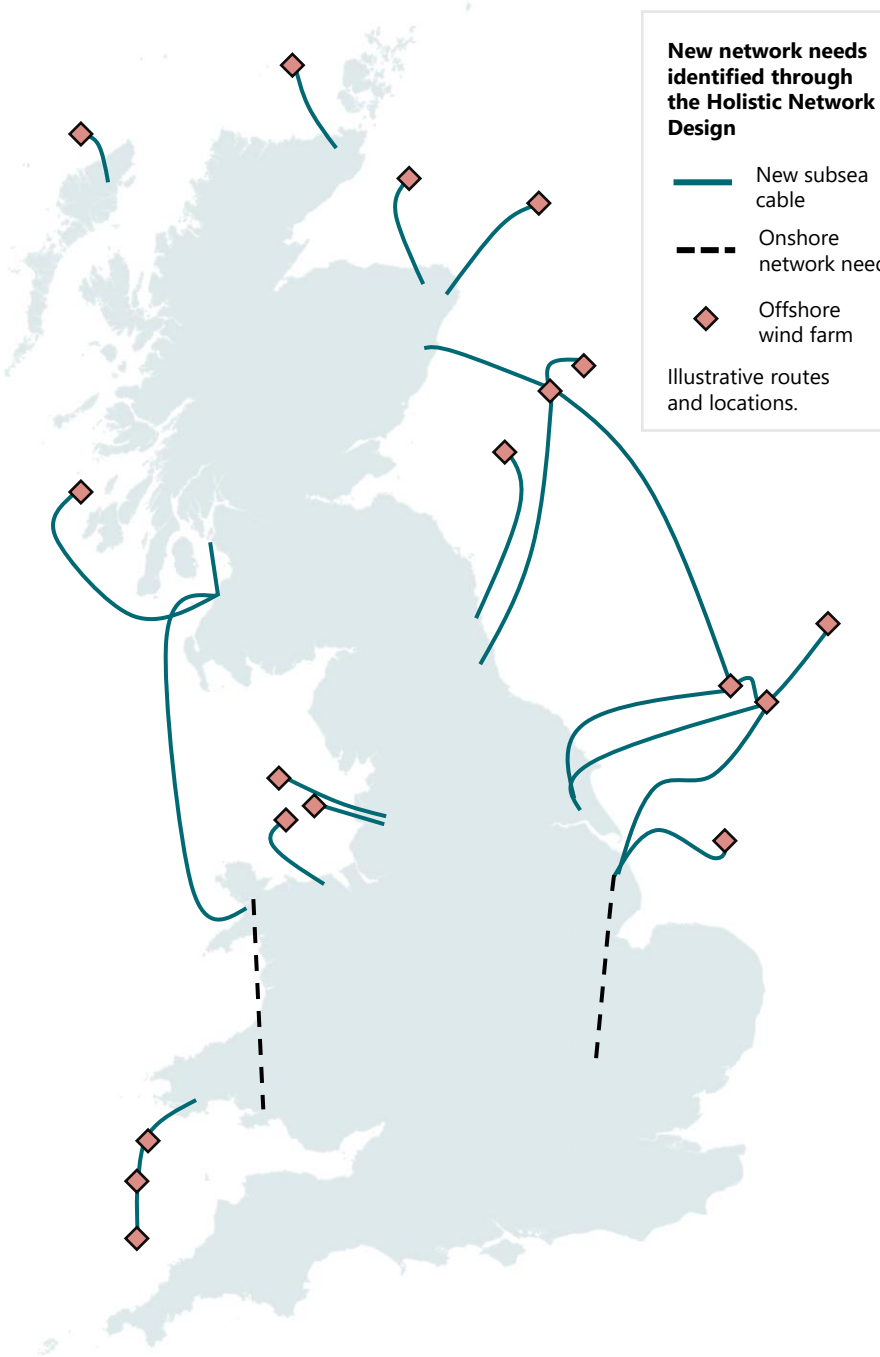
The UK will need to compete to attract manufacturing capacity as grid investment surges globally



Source: Bloomberg NEF.

Competition for investment: Readying the transmission network will involve increasing cable length by 30% and an increase in the number of grid and bulk supply substations by 50% according to analysis by BEAMA (the trade association for energy infrastructure manufacturers). A significant risk is that the UK does not secure investment in manufacturing capacity for the critical components when across the globe grids are being upgraded.

Consenting for 9 GW per year: In the Government's own words, the Nationally Significant Infrastructure Projects (NSIP) consenting regime "is increasingly difficult to navigate". The risk is that, despite recent decisions to accelerate investment, without rapid changes to the consenting regime these critical projects will not be delivered on time due to concerns about community and environmental impacts.



Recommendations

3. Transmission:
connecting offshore and large-scale generation

Net zero will not be possible without the rapid build of transmission projects that have already been approved for delivery by Ofgem. It is critical that these projects can now progress at the fast pace needed of between 6 - 9 GW per year by 2035.

3.1 The Future System Operator needs a clear timeline and remit

The establishment of the FSO as a public body with a remit to oversee a clear strategic plan for the transmission network is a key step. However, the timeline for its creation is not clear (the Government's energy security factsheet gave a rough timeline of "by, or in, 2024") and this could jeopardise delivery of the Centralised Strategic Network Plan in 2024/25 regulatory period.

The Government should:

- Publish the strategy and policy statement
- Minimise uncertainty by putting the FSO in place as soon as possible
- Ensure that the FSO has a clear strategic direction to deliver net zero and the independence and capacity to deliver.

3.2 Ensure the supply chain has sufficient capacity to deliver projects

Investment in transmission networks is growing rapidly across the globe. To date, electricity network infrastructure supply chains have received less focus than those for generation (particularly offshore wind and nuclear). Transmission operators and the Government should:

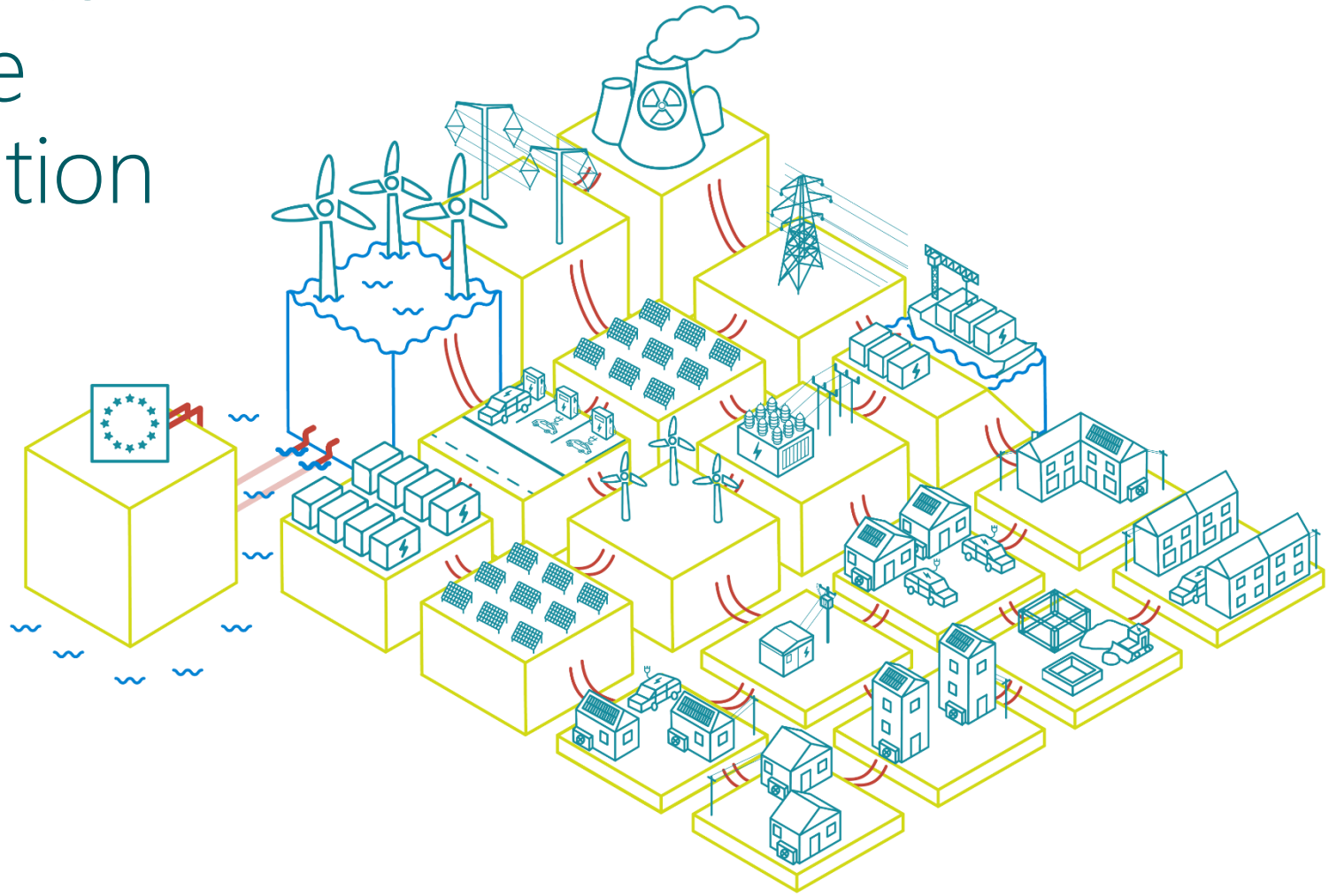
- Prevent the supply of critical components from delaying transmission projects
- Secure investment in UK-based manufacturing capacity where appropriate
- Ensure that delivery partners have the capacity, with the necessary skills and workforce, to deliver

3.3 Speed up the planning and consenting process

The Government has already committed to reforming the planning process to ensure large transmission infrastructure can be built on time. It should ensure that:

- A clear national planning policy statement is made on the importance of electricity network infrastructure
- Net zero is given proper weight in the planning framework
- Community benefits are delivered to areas hosting infrastructure that is critical to achieving the UK's strategic objectives

Whole grid: investment to achieve the transformation

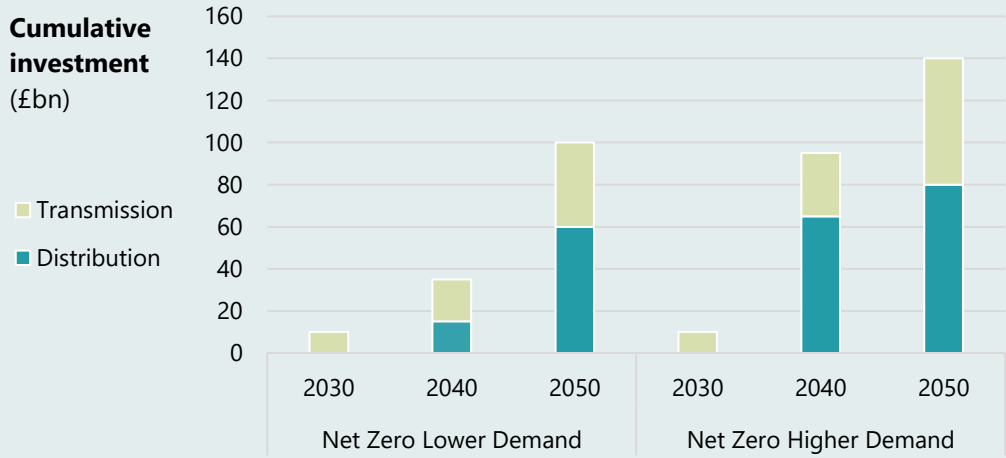


Significant grid investment is required, but consumer unit costs could fall

£100 – 140bn to prepare the grid for net zero by 2050

Per-unit network costs for consumers could fall

Preparing the grid for net zero will require between £100-140bn of additional investment



Source: Electricity networks strategic framework Appendix I, Department for Energy Security and Net Zero.

In its central scenario, the Government estimates that if net zero policies are not adopted then £70bn of "baseline investment" in onshore electricity networks will be required by 2050. To enable all the net zero and energy security benefits an additional £100-140bn investment is required.

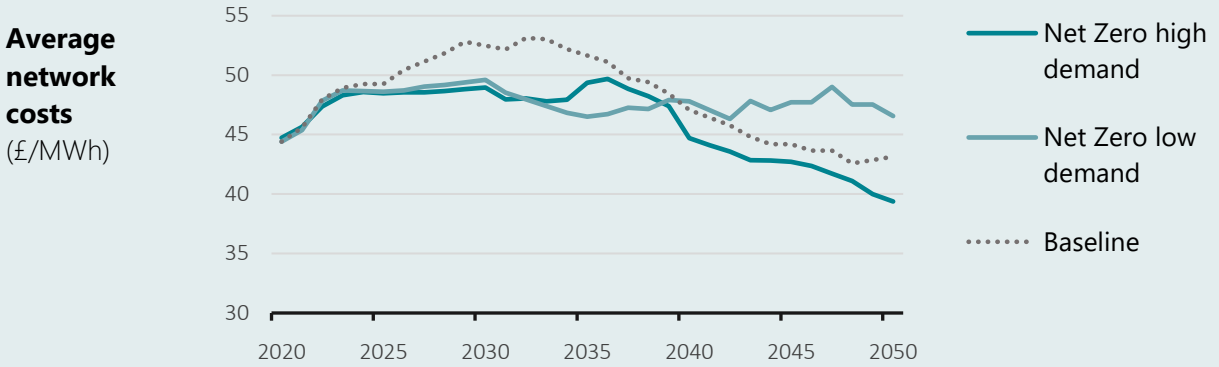
However, there is significant uncertainty in the requirement to reinforce low voltage distribution networks. In a scenario where the entire LV network has 50% less spare capacity than currently understood the additional investment would be up to £240bn.

Significant grid investment is required, but network unit costs could fall

£100 – 140bn to prepare the grid for net zero by 2050

Per-unit network costs for consumers could fall

Network costs per unit could fall in the long term



Source: Electricity networks strategic framework Appendix I, figure 13.

The electricity demand under net zero will increase from 275 TWh to around 800 TWh in 2050.

Whilst increases in network investment will involve higher total network charges, as the grid delivers more electricity the **network costs per unit could fall from around £48/MWh to under £40/MWh** in a high demand scenario. If demand is lower, network costs per unit will stay broadly flat.

Investment in the grid will unlock the benefits of net zero

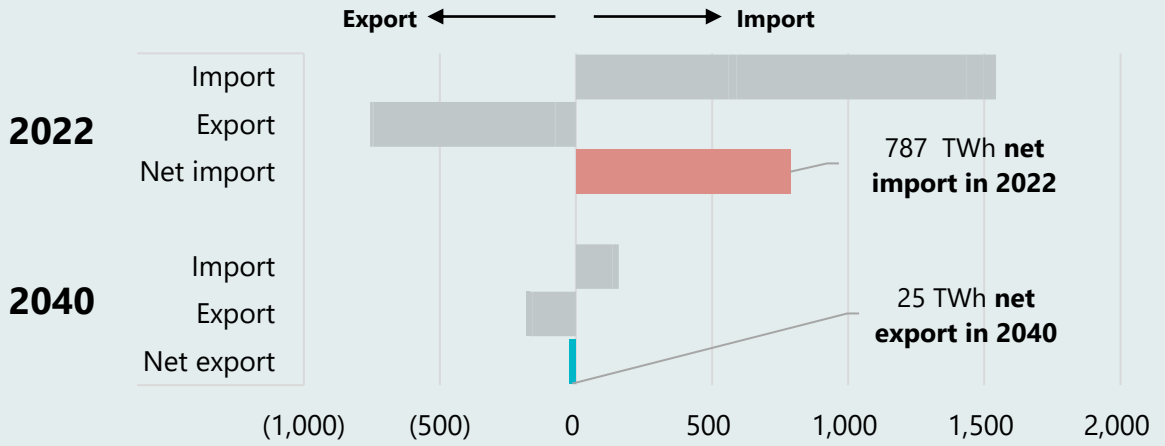
A net exporter of energy by 2040

Access to low cost energy

Doing more with less energy

The economic opportunity of the 21st century

Great Britain could become a net energy exporter by 2040



Source: Regen Analysis – a net energy exporter by 2040.

Aiming to become a net energy exporter during an energy crisis may seem ambitious. However, analysis by Regen has shown that it is achievable by 2040 – enabled by accelerating the transition to net zero and rapidly reducing dependency on imported fossil fuels. Greater energy independence would:

- Reduce vulnerability to energy price fluctuations and shortages
- Improve the UK's trade deficit
- Reduce exposure to geopolitical risks

Investment in the grid will unlock the benefits of net zero

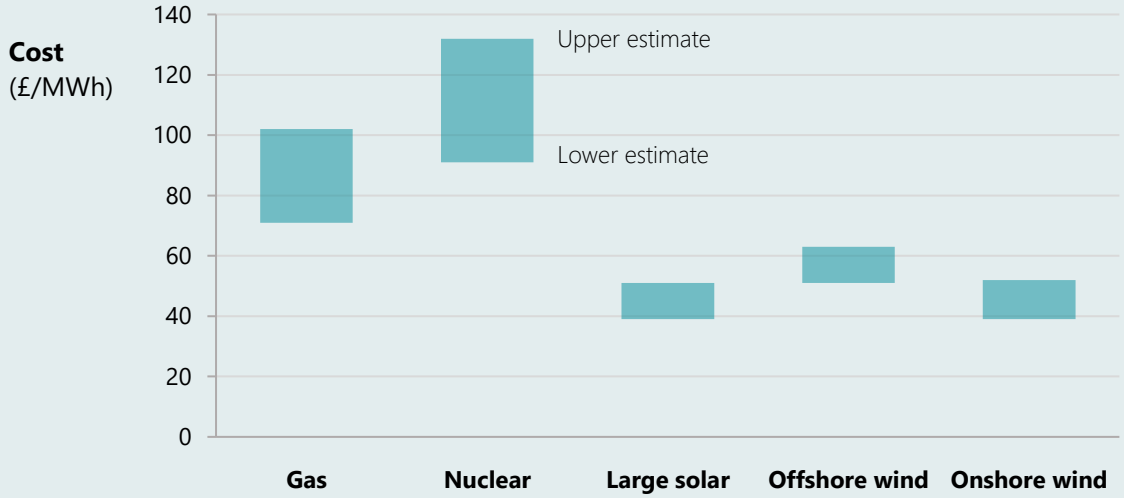
A net exporter of energy by 2040

Access to low-cost energy

Doing more with less energy

The economic opportunity of the 21st century

The lowest cost generation technologies are all renewable



Source: BEIS Electricity Generation Costs 2020 and 2016 – before the energy crisis.

The energy crisis of 2021 and 2022 has shown the economic importance of access to a reliable low-cost source of energy. Even before the recent price spike, renewables were significantly cheaper than fossil alternatives. By 2035, 70-80% of power generation will be from wind and solar at a significantly lower levelised cost of energy than natural gas or other fossil fuels.

Investment in the grid will unlock the benefits of net zero

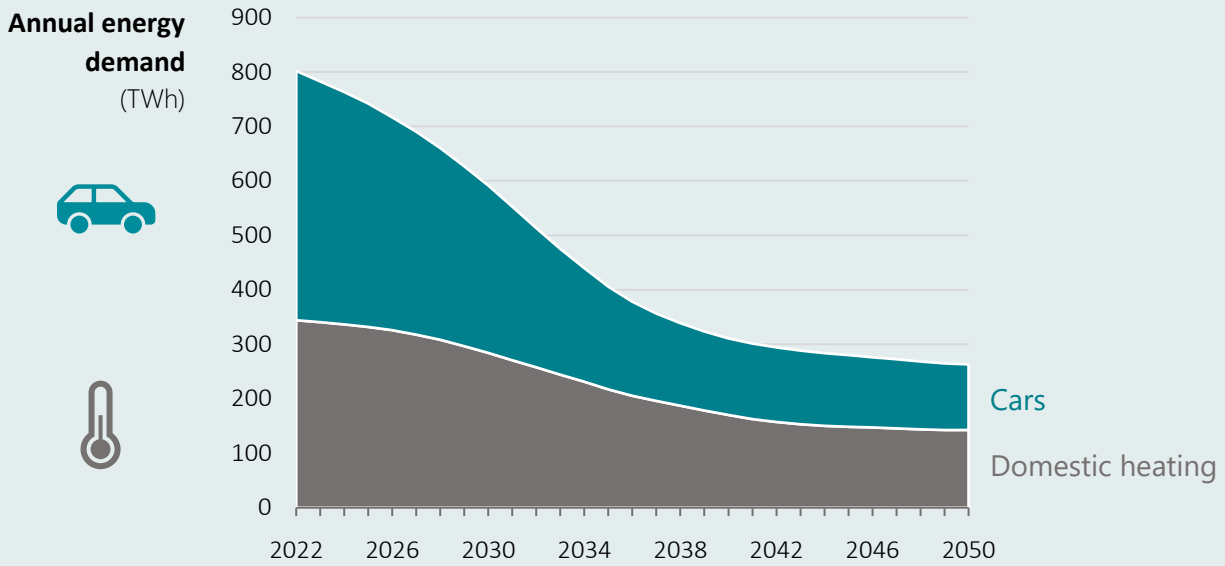
A net exporter of energy by 2040

Access to low cost energy

Doing more with less energy

The economic opportunity of the 21st century

Doing more with less energy



Notes: Source - Regen Analysis of ESO Future Energy Scenarios, Consumer Transformation. Y-axis refers to energy from all fuels at point of use.

Electric vehicle powertrains and heat pumps are more efficient than the combustion engines and boilers that they replace. This superior efficiency will allow consumers to travel and have warm homes for less energy.

Investment in the grid will unlock the benefits of net zero

A net exporter of energy by 2040

Access to low cost energy

Doing more with less energy

The economic opportunity of the 21st century

In Chris Skidmore's review, net zero was framed as **the economic opportunity of the 21st century.** As the global transition to clean energy has entered a new accelerated phase, with the USA announcing $400bn of funding for clean energy and the EU planning a €600bn European Green Deal, the global market opportunity for UK businesses could be worth more than £1tn by 2030. Capturing a share of the economic benefits will be critical to establishing the UK's long-term economic future.

As this report has shown, transitioning the GB energy system to clean power will not be possible without the necessary electricity infrastructure. As well as the wider opportunities that net zero will bring, investments in infrastructure will create a range of economic opportunities:

- **The economic opportunities created from investment in electricity supply will be embedded in the UK as it is inherently a domestic industry.** For every £1 million of spending on electricity, 8 full-time equivalent jobs are supported throughout the UK. This compares to less than 3 in the case of more import dependent petrol and diesel supply.
- Reinforcing Great Britain's onshore electricity network to meet net zero could directly support an additional **50,000–130,000 FTE jobs by 2050**, contributing an estimated £4-11bn of GVA for the UK.
- Upgrading our electricity network to handle the electrification of heat will allow the creation of up to **50,000 jobs by 2030 in heat pump installations alone**.
- Flexibility from technologies such as electricity storage, smart charging of electric vehicles, flexible heating systems and interconnection could create up **to 24,000 jobs by 2050**.

Sources: Mission Zero – Independent Review of Net Zero (page 22), Analysis of refuelling supply chain activity (page 1), Electricity Networks Strategic Framework (page 20), Heat and Buildings Strategy (page 53), Energy Innovation Needs Assessments (page 29)

Glossary

Term	Description
CCC	Climate Change Committee
Consumer Transformation	One of the future energy scenarios developed by ESO. This scenario is most aligned with the CCC's balanced pathway.
DNO	Distribution Network Operator
ESO	Electricity System Operator, owned by National Grid but operationally independent from the transmission operator.
ENA	Energy Networks Association, the industry body for the energy networks.
FES	Future Energy Scenarios developed by the electricity system operator.
Headroom	Spare capacity. The gap between the rating of the electricity network to supply electrical demand and the actual demand in that part of the network.
Interconnectors	Connection to neighbouring electricity systems in Ireland and mainland Europe.
Ofgem	Energy regulator (office for gas and electricity markets).
Price control	A method of setting the amount of money (allowed revenue) that can be earned by the network companies over a period of time (currently 5 years).
RIIO	Revenue = Innovation + Incentives + Outputs. This is the current monopoly regulatory regime for electricity transmission and distribution.
RIIO-ED2	Current price control period for Distribution
RIIO-ET2	Current price control period for Transmission
TO	Transmission Owner
Transformer	A device used to change the voltage of electricity.

Appendix

1. Electrification of heat

The distribution networks have developed heat strategies to consider how the shift away from fossil heating will impact their networks and to ensure the grid is not a barrier to uptake of electric heating. Their main focus has been ensuring that the grid is ready for a wave of heat pump installations.

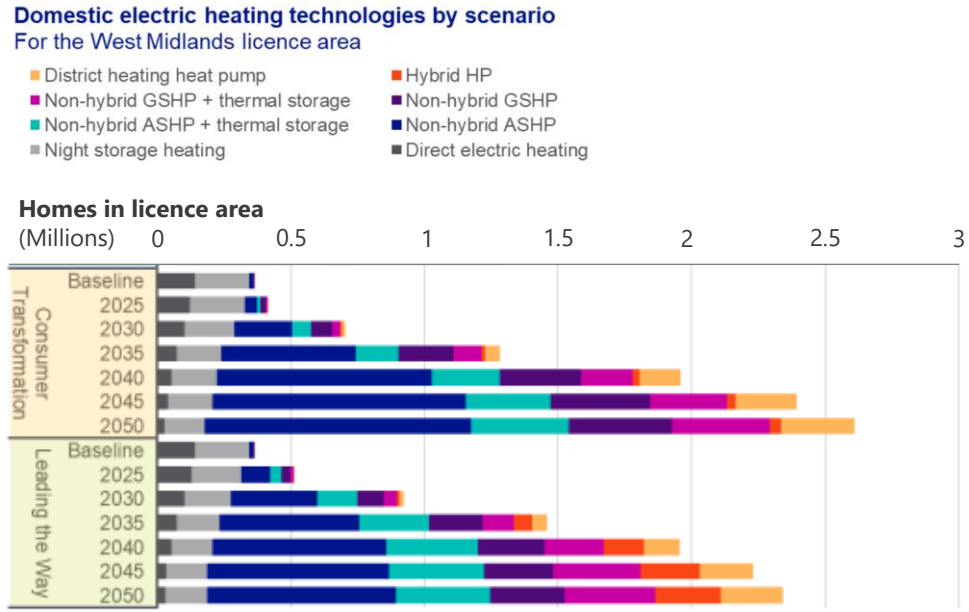
In new developments, the cables and electrical equipment are designed to cater for the electrical load of the heat pump like any other new grid connection. However, most heat pumps will be retrofitted into properties currently heated with gas, so the demand on the electricity network will increase. In some cases, demand will be higher than the original network design assumptions – so mains cables and transformers will need to be replaced and uprated.

The Energy Networks Association (ENA) has developed a connections process that is standardised across all distribution networks, using a shared database of verified heat pump models. Most installations are straightforward –the device is connected and then the DNO is notified. Larger heat pumps rated to over 8kW and those not in the database require an application to the network in advance of connection. This could become a bottleneck as requests to connect ramp up.

The DNOs carry out annual Distribution Future Energy Scenario modelling which forms the foundation of their strategic investment process. Uptake of different heating technologies are modelled down to the granularity of individual postcodes or streets. Whilst the rate of uptake varies across scenarios, all scenarios forecast widespread deployment of heat pumps.

Heat pump size	Approx. connection lead-time	Network considerations	Approx. connection cost
HP up to 16A (3.4kW)	Immediate	None	None
HP up to 32A (7.6kW)	Immediate in most cases	Usually none	Usually none
HP over 32A (over 8kW)	4 to 8 weeks	Likely upgrade to service cable and local mains	£1000 to £3000

Note: Heat pump power requirements and associated reinforcement costs for typical domestic retrofit installations, from National Grid heat pump strategy.

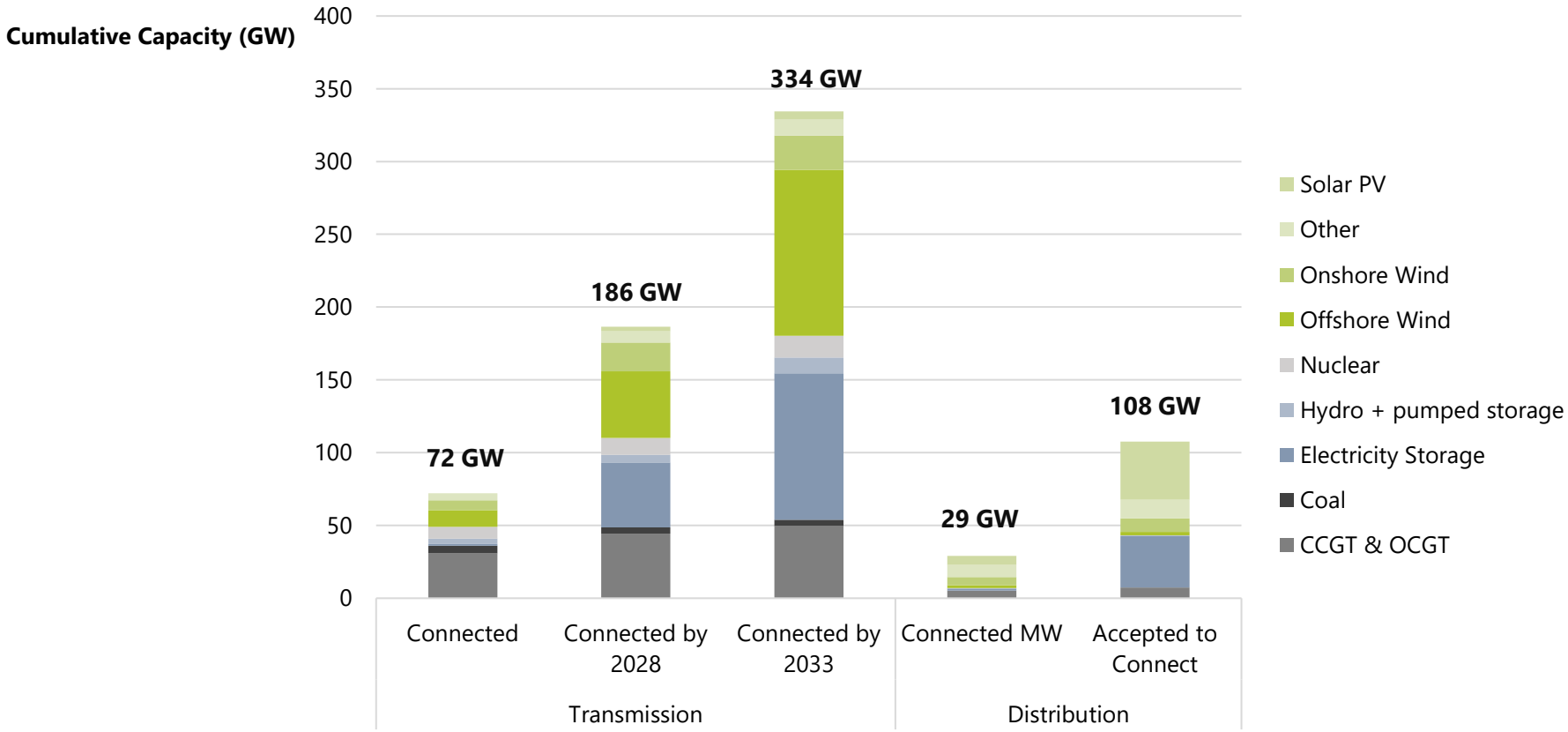


Note: example heat pump uptake from National Grid's Distribution Future Energy Scenarios (West Midlands DFES Technology Summary 2022).

Appendix

2. Transmission and distribution pipeline analysis

Renewables and storage projects will drive a huge increase in connections over the next decade

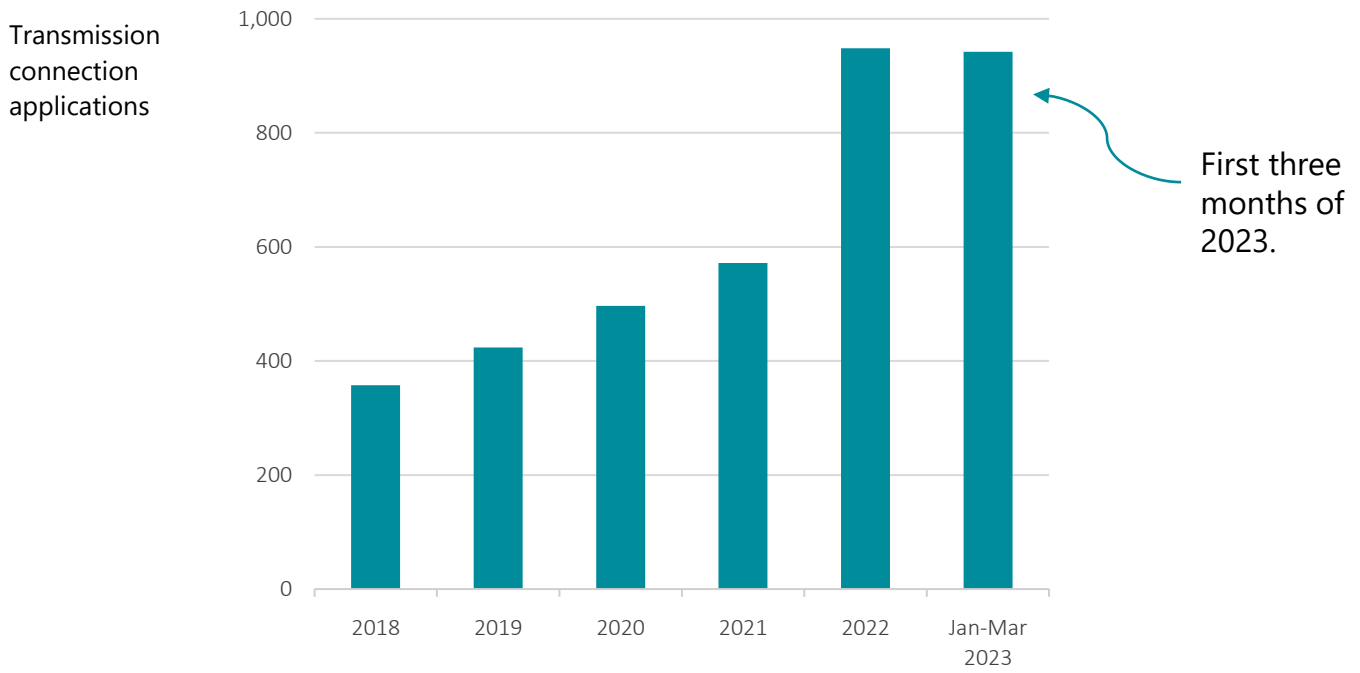


Note: Regen Analysis of the Transmission Entry Capacity Register and the DNOs' Embedded Capacity Registers (data accessed May 2023).

Appendix

3. Transmission connections

Connection applications have surged



Source: GB Connections Reform, Case for Change (ESO).

The number of connection applications into the transmission network in the first three months of 2023 is more 2.5x the annual total five years ago.

Regen is an independent not for profit centre of energy expertise and market insight whose mission is to transform the world's energy systems for a zero carbon future.

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