

4.2 Planning, consenting and communities

Where are we now?

Most of the energy infrastructure required to deliver clean power by 2030 is already in the development cycle. However, an independent report³ commissioned for ESO in spring 2024 suggested that only 6 GW of onshore wind, 15 GW of offshore wind, 10 GW of solar and 10 GW of battery storage had obtained the relevant planning consent as of April 2024. Engagement with the TOs has shown that of the network projects required, 16 projects are currently awaiting planning and consenting decisions and 28 projects are at an earlier stage of development, prior to planning and consenting.



The research also suggests it currently takes, on average, 21 months to issue a planning decision for offshore wind in England and 15 months in Scotland. For onshore wind, it takes 15 months to receive a decision after applying to local planners and 35 months at the national level.

Communities will be at the heart of the delivery of net zero in Great Britain and the planning process is a key route through which they can have their say on plans for energy infrastructure in their area and raise concerns about the impact on their local environment.

Where do we need to get to?

Unprecedented volumes of clean energy infrastructure projects are needed to meet the Government's energy ambitions. Construction for many of these projects needs to begin in the next 6–24 months. Considering the time it has taken for significant energy projects to get planning consent in recent years, those timelines look challenging. Engaging and bringing along local communities that host energy infrastructure will remain key, both in enabling delivery and maintaining widespread public support for the clean power mission.

What are the challenges and opportunities?

We established a Societal Delivery Forum to understand the views of organisations representing local communities, the natural environment, land use specialists and the planning sector to inform our advice to the Government.

Participants highlighted several consistent challenges around societal and consumer acceptance, engaging local communities, resourcing of local planning authorities and statutory consultees, ensuring the right data is available to make decisions and the experience of consenting major energy projects. Opportunities for improvement through greater coordination between developers in the building and development of infrastructure, better engagement with statutory consultees and the Government's upcoming planning reforms were put forward.

The government has begun to take steps in the planning system to enable clean power – including the removal of the moratorium on onshore wind in England, and the recently announced joint UK and Scottish Government consultation on changes to the planning regime to support energy infrastructure.

Actions needed to drive change

The planning and consenting processes for energy infrastructure needs to be shorter to ensure delivery by 2030. The current approach which can take in excess of two years for approval on some types of projects, and longer in some cases, poses a significant delivery risk. To have a good chance of being built in time. The next 6–24 months are critical for projects to clear planning and move into construction. Expediting the planning process, while maintaining community consent will be vital to delivering on the clean power mission, and maintaining momentum for projects needed after 2030.

³ Research commissioned by ESO and carried out by Regen in July and August 2024. This is based on connection queue and planning information from April 2024 and so figures may have changed since then. It should also be noted that, due to data availability this does not reflect all projects in the planning cycle. Research results are presented for illustrative purposes only.

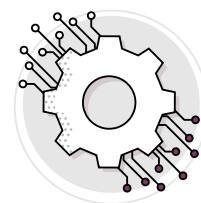
Improved coordination and transparency between developers and statutory consultees and ensuring there is sufficient capacity in the system will help enable acceleration. As will cooperation between all levels of government: national, devolved and local.

Community consent and maintaining public support is vital to the delivery of net zero in Great Britain. Those asked to host energy infrastructure should continue to be effectively engaged throughout the development process, even as it accelerates, and should feel tangible benefit from the critical role their areas play in building a clean, secure and low-cost electricity system.

4.3 Connections reform

Where are we now?

The connections queue currently comprises a greater volume of projects than required for 2030 across our pathways. However: a) not all of those projects may be 'ready' or committed to progressing; and b) there may be projects with connection dates after 2030 that could usefully contribute to the 2030 system, for example with lower delivery barriers or lower costs. Some progress has been made over the last 12 months in addressing connections issues at both transmission and distribution levels. In addition, plans have been set out by NESO to move away from the concept of a 'first come, first served' approach to connections queue management, to one which will see us connect demand and the required generation in a timely and more strategic process.



Building on the plans set out by ESO earlier this year, further work is in train across NESO, DESNZ, Ofgem and industry to ensure that, in support of a clean power system, connections queue processes bring forward the right technology in the right location and when it is needed.

Further actions beyond queue reform have been set out in the joint Government and Ofgem [Connections Action Plan](#) and the previous [Government's Transmission Acceleration Action Plan](#), with a focus on ensuring that projects with a connection offer can then be connected and energised in a timely and efficient manner.

Where do we need to get to?

To get to a clean power system by 2030, the generation and technology mix that is set out across our pathways needs to connect to the electricity system in the next six years. We need a reformed connections process that reflects the needs of the clean power mission.

What are the challenges and opportunities?

Delivering net zero will require connecting new capacity and new types of customers more quickly than at any time since the current process was established. In addition to a 'fit for purpose' process for issuing connection offers and managing the connections queue, consideration must be given to the implications of the volume of connections, as well as significant shifts in the nature of connecting customers and their needs.

The high number of connections and the associated enabling network and substation works will require a coordinated and whole system approach to considering the network planning and delivery implications at both transmission and distribution levels. More collaboration, coordination and understanding of the interactions across the whole network are required.

Given the dynamic nature of the path to clean power in 2030, action is also required to ensure that the codes and methodologies governing the approach to managing connections provide clarity and certainty for developers, while being appropriately flexible to the changing needs of the system and future strategic plans for the period beyond 2030.

Consideration should also be given to whether the open codes governance process is, in itself, sufficiently flexible and adaptable to be effective in enabling the required pace and scale of reform.

Actions to drive change

Delivering a clean power system by 2030 requires a connections process which is aligned to government's plan for clean power by 2030.

As such we have also published, for consultation, details on how we propose to align the reformed connections process with strategic energy plans (initially government's plan for clean power by 2030, and then the first Strategic Spatial Energy Plan, SSEP). The scope of our connections reform proposals includes all projects connecting at transmission level, and any generation and storage projects connecting to the distribution networks that impact upon the transmission system. Consideration will also be given to the treatment of demand connections with regards to the queue and the interaction with the generation connections.

We set out in that consultation our view that the connections process and reformed connections queue should align with the technology, capacity and regional requirements for clean power as set out within Government's clean power plan (at both a transmission and distribution level), and then with subsequent strategic plans like the SSEP. The Government's clean power plan can help ensure the efficiency of the new connections queue and that 'ready'⁴ and strategically aligned projects are connected efficiently to achieve clean power. This could be achieved through including capacity requirements for different technologies connecting at transmission and distribution networks, and that the pathways within the clean power plan clearly separate the proposed mix of transmission and distribution technologies, by capacity and location.

However, the transition to net zero emissions across the economy by 2050 does not stop with achieving clean power in 2030. Projects needed beyond 2030 are in development now and require clarity on their connection agreements too. This could be achieved through the government's clean power plan providing clarity on the pathway upon which connection offers can be based for the period 2031-35.⁵ Including this 2031-35 pathway in the clean power plan will provide a 10-year time planning horizon for the reformed connections queue, thereby providing longer-term investment clarity that will help ensure an efficient transition towards net zero targets beyond 2030 (including the Sixth Carbon Budget targets), while also facilitating an efficient transition to the first SSEP.

We set out more detail on the connections reform enablers in Annex 2.

Looking beyond 2030, we will publish our first SSEP by the end of 2026. It will build on the government's action plan for clean power by 2030 to support the energy transition efficiently and securely, provide greater clarity on the nation's future energy requirements, and achieve net zero ambitions in line with government targets. Once the first SSEP is in place we will then use the SSEP to prioritise future connection offers aligned to the SSEP.

⁴ By 'ready' we mean projects that meet the new criteria we propose to apply to the current connections queue and future applications, that would require projects to demonstrate that they have secured appropriate land rights in order to receive a confirmed connection offer and a place in the reformed connections queue.

⁵ We are proposing that the 2031 to 2035 pathway for connection offers should be based on the Holistic Transition scenario within our Future Energy Scenarios 2024 (FES24) to 2035.

4.4 Supply chain and workforce

Where are we now?

The global race to decarbonise is straining international supply chains and compounding skills shortages. Notably, the offshore wind sector, as well as the broader electrical component supply chain, face pronounced challenges. Shortages of construction workers and engineers across Great Britain further exacerbate project construction delays and increasing costs.



Where do we need to get to?

The Government has recognised the transition to a decarbonised energy system as an opportunity to create jobs and grow the economy, delivering wider benefits to Great Britain. However, those benefits can only be fully realised if action is taken to unblock the differing supply chain and workforce challenges for projects on the critical path to 2030.

What are the challenges and opportunities?

The supply chain and workforce challenges associated with the transition to a net zero energy system are already well described and understood.⁶

Our analysis has identified supply chain and workforce challenges across almost all technologies required to reach clean power by 2030. For example, delays in sourcing electrical components such as cabling, transformers and switchgear are hampering the delivery of network infrastructure, while the Offshore Wind Industry Council suggests more than 100,000 skilled roles are required to deliver 50 GW of offshore wind (up from 32,000).⁷

Stakeholders engaged as part of our Clean Power 2030 activity have reinforced that there are significant obstacles to accessing Original Equipment Manufacturer (OEM) supply chains, parts and materials coupled with limited domestic manufacturing and ports capacity. Securing engineers, digital specialists and construction workers is increasingly difficult due to the high demand for these skills across the economy, both domestically and globally.

Long-term policy certainty and greater collaboration were recognised as having potential to alleviate these challenges. Stakeholders also acknowledged the need to balance delivery at pace, which may depend on “buying in” parts and skills in the near term and developing local capacity which may deliver longer-term benefits to the British economy.

Actions to drive change

Our analysis and engagement with industry have identified three areas where action could help to alleviate supply chain and workforce pressures:

- Providing consistent, long-term policy certainty and line of sight to funding to unlock investment.** In the near term, making swift investment decisions (e.g. on networks, the cap and floor or FOAK funding) can enable developers to sign supply chain contracts. Over the longer term, government’s plan for clean power by 2030, SSEP and future carbon budget strategies can send the long-term signals for supply chain companies and workers to invest or train in Great Britain.
- Exploring the opportunities for a more strategic approach to procurement and manufacturing.** This includes considering how the supply chain needs from the whole sector could be articulated centrally to investors and exploring further opportunities for central purchasing where this provides greater value for money and assurance over delivery. Finally, there may be opportunities to build strategic domestic supply chains where conditions in Great Britain mean this makes sense.

⁶ [Green Jobs Taskforce \(2021\); Mission Zero – Independent Review of Net Zero \(2023\)](#)

⁷ [Crown Estate \(April 2024\)](#)

- **Exploring a broad range of options to address specific skills gaps.** In the short term, this could include targeted options to address domestic workforce shortages in key sectors, such as offshore wind. A sector skills plan could help provide the trained workers the sector needs.

4.5 Digitalisation and innovation

Where are we now?

In recent years, advancement in technology and innovative practices have enabled progress towards digitalisation of the industry. Some industry participants have introduced a digital-native approach to traditional methods and the market has been adopting digitalisation at an increasing pace, although it remains nascent compared other industries. NESO too has enhanced its interaction with the wider industry through digitalisation, such as the modernised balancing mechanism, better open data practices and greater transparency via connections platforms. However, most if not all these efforts remain siloed within organisational or sector-specific priorities rather than whole system objectives.



The Energy Digitalisation Taskforce's call for a unified digital ecosystem has resulted in further progress; for example, DESNZ's Automatic Asset Registration Programme and the NESO-led pilot of data-sharing infrastructure (DSI), both of which are expected to enable rapid digitalisation opportunities by providing foundational digital capabilities.

Broader, sector wide innovation initiatives such as SGN's Intelligent Gas Grid and NESO's Crowdflex (demand flexibility) highlight some of the great work that is being done that can support a better understanding of a future digital grid, a fundamental step towards a clean power system.

Where do we need to get to?

To deliver clean power, we need a sector-wide strategic digitalisation plan that is actionable and delivered. This needs clarity of required outcomes, prioritisation of digital solutions and an aggressive delivery programme backed by policy and regulation to drive adoption and investment where it's most urgently needed.

While robust, safe and prompt data sharing is crucial, we must also focus on platforms and technologies that accelerate progress. One essential technology area is a strategic shift towards responsible AI for better decision making in energy planning, supply chain optimisation, market and domestic flexibility and forecasting. At NESO, we are launching a portfolio of transformative AI initiatives under two programmes (Volta and Vanguard) that focus on strategic energy planning, connections, control room operations and forecasting accuracy.

Our policy and regulatory systems must be able to realise the benefits of digitalisation by defining and revising rules and regulations where appropriate. For example, initiatives like the market-wide half-hourly settlement (MHHS) must be realised promptly to support the flexibility the system needs.

Further, innovation must target transformative change that the sector can mobilise behind, such as grid enhancing technologies and demand side signals. This should be supported by a unified approach to scale innovation through conducive policies, regulations and targeted support.

What are the challenges and opportunities?

The rapid global introduction of new technologies, both in the hardware cleantech space as well as in the digital realm (i.e. AI Large Language Models (LLMs)) presents both challenges and opportunities. Timely action is critical.

Current digitalisation and innovation efforts are often siloed and lack supportive adoption policies and pathways to operational use, making it difficult to scale ideas. Additionally, the sector faces challenges with data quality, availability and sharing, which restrict opportunities to develop and test new solutions.

To meet the clean power target, our analysis raised four key outcomes innovation is required to realise. These include better utilising existing grid capacity (for example, with super conductors), new flexibility sources and reducing overall demand through energy efficiency, as well as using AI to enable the above. It is vital that industry comes together and identifies, then prioritises the key outcomes in a coordinated way that enables market-driven innovative solutions to emerge.

Maximising commercial opportunities for digital products and services could further support wider industry digitalisation, as well as foster shared capabilities and products from innovative incumbents and start-ups.

Actions to drive change

Our engagement with industry experts and leaders has led us to identify five core actions that are crucial for transformative change:

- **Unified digitalisation plan:** The sector develops and delivers on a system-wide digitalisation strategy aligned with government's plan for clean power by 2030, ensuring cohesive progress and prioritisation.
- **Enhanced data sharing:** Focus on robust and scalable data-sharing infrastructure, supported by policies and investments that encourage widespread adoption across the sector.
- **Responsible AI integration:** Develop and implement responsible AI to revolutionise decision making in energy planning, supply chain optimisation, market flexibility, grid management and forecasting. This requires the support of clear policies, technology partnerships and investments.
- **Transformative innovation initiatives:** Prioritise transformational and scalable innovation projects that can significantly accelerate progress to clean power and beyond 2030. Support these initiatives with heightened financial, policy, regulatory and industry backing to ensure broad adoption.
- **Maximise commercial opportunities for digital products and innovation:** Identify and remove barriers to create a dynamic marketplace for digital products and services, leveraging open data sharing and transparency to foster innovation from all. For example, sharing of data on open data portals by NESO and other organisations has already led to AI and technology-based products to be available in the market to solve industry challenges.

These actions are imperative steps towards creating a resilient, innovative and digitally advanced energy sector.

4.6 NESO as a partner in delivering clean power

Where are we now?

NESO was established on 1 October 2024 as a publicly owned system operator, with new responsibilities in strategically planning the whole energy system and giving advice to government and Ofgem. The Government has also committed to establishing Great British Energy as a publicly owned clean energy company and the Clean Power 2030 Unit, tasked with delivering clean power by 2030.



Where do we need to get to?

Delivering clean power will require clarity on roles and responsibilities across key organisations in the energy sector. We need to ensure that our strategy and operations are aligned with government's plan for clean power by 2030 and work effectively with new institutions within the industry to drive forward delivery to 2030.

Where are the challenges and opportunities?

The whole energy system is interested in understanding the implications of a clean power plan and what this means for consumers, communities, networks and industry codes. Stakeholders are also seeking certainty on what organisations will need to do and how they will interact in delivering clean power. Many stakeholders want to see a coordinated delivery approach and governance arrangements that clarify the different roles and responsibilities for clean power.

NESO can act as an enabler for this greater collaboration and coordination and support the Government, Ofgem and the wider industry in providing clarity and establishing the frameworks for success.

Actions to drive change

To deliver on the clean power plan effectively and in a coordinated manner, we as NESO will:

- Work with the Clean Power 2030 Unit and Ofgem to agree NESO's role in delivering the clean power mission and how progress will be monitored, ensuring this is communicated to industry.
- Following the publication of government's plan for clean power by 2030, rapidly develop our implementation plan, setting out how we will play our part in delivering the clean power mission, including reviewing our own operations, processes, systems and investment plans across all areas to reflect on the impacts to ensure alignment with government's plan.
- Put in place an ongoing plan of engagement with industry and key stakeholders to ensure an ongoing conversation about NESO's role in the delivery of the clean power mission, in line with our broader remit as the strategic planner for the energy sector and provide advice to the Government.
- Work with Ofgem to continue to push forward energy code reform and help to identify the direction of future code changes for clean power provided through the Strategic Direction Statement (SDS) and assess how code change can be more effective and responsive to changing system or market needs.

Chapter 5. Costs and benefits of a clean power system



Delivering a clean power system by 2030 will support wider and longer-term efforts to reduce greenhouse gas emissions on the path to net zero and can bring multiple benefits without increasing costs to consumers.

Carbon: Our pathways reduce emissions of carbon dioxide to below the level in the Climate Change Committee's net zero pathway. The CCC's pathway is what is needed for the UK's Nationally Determined Contribution to the global Paris Agreement. Clean power can enable full decarbonisation of other sectors, such as transport and heat, through the adoption of electric vehicles and heat pumps, sending a clear and encouraging message to consumers that the technology they are adopting is clean.

Preparing for the 2030s: Our pathways make a step change in the deployment rates for renewables. This will ensure the system is able to keep pace with accelerated electrification through the 2030s, which is expected to add approximately 19 TWh per year to demand (equivalent to the output of around 5 GW of offshore wind). Progress on new technologies, such as carbon capture and hydrogen, is also essential for decarbonising the wider economy.

Investment: Clean power can support wider economic objectives. It will involve an annual investment programme of £40 billion plus that can support economic opportunities and new jobs across the UK. New networks and an abundant supply of clean power can enable growth in other sectors, including the growing digital and data economy.

Electricity costs: A crucial determinant of overall costs will be the impact of the Government's new approach to clean power. If it can provide greater visibility and greater confidence while unblocking barriers and easing delivery, there may be opportunities for costs to fall. Conversely, if supply chains become excessively stretched, costs could escalate. Taking a neutral view over these effects, our analysis shows that overall cost to consumers would not increase as a result of the move to a clean power system. Other factors will also impact electricity bills to 2030, including a reduction in legacy policy costs (as contracts expire) and energy efficiency improvements.

Wider benefits: A clean power system reduces Britain's reliance on energy imports, as well as bringing about environmental benefits, such as cleaner air and the potential to reduce pressures on water systems. More broadly, delivering clean power by 2030 would send a strong signal internationally, given the importance of clean power in global efforts to tackle climate change.

5.1 Climate, carbon and electrification

Carbon budgets

Clean power 2030 will significantly reduce carbon emissions in the British power sector. Power sector emissions in our pathways are 5 MtCO_{2e} in 2030,¹ less than a third of those in a counterfactual case with no increased decarbonisation efforts² and reduced by more than 90% against 1990 emissions. Power sector emissions in 2030 are below the level in the CCC's pathways to net zero,³ as required for the Nationally Determined Contribution (NDC) under the Paris Agreement and the Sixth Carbon Budget.

Achieving these emissions reductions in the British power sector would help close the current policy gap to meeting carbon budgets and the NDC, as identified by the CCC.⁴ The CCC's latest progress report highlights the need to increase installation rates of renewables and for 'a credible overall strategy' for decarbonising the power sector. Action is also needed to address policy gaps in other sectors beyond power.

There is a corresponding drop in the carbon intensity of power generation, from over 140 gCO₂/kWh in 2023 to around 15 gCO₂/kWh in 2030 in our pathways. With carbon dioxide removal from biomass with carbon capture and storage (BECCS) netted off, net carbon intensity in 2030 would be around 5 gCO₂/kWh in the Further Flex and Renewables pathway (with one unit converted to BECCS) and below zero in the New Dispatch pathway (with two BECCS units).

Our clean power metrics are about meeting demand and reducing unabated gas to very low levels, so do not themselves require removal from BECCS. Removal from BECCS would help with wider efforts to reach the UK's NDC and carbon budgets. Decisions over the timing and scale with which to pursue BECCS should reflect the wider carbon strategy for meeting those targets, rather than be driven by the clean power goal for 2030.

Electrification

More broadly, clean power is the foundation for wider electrification and achieving net zero. Throughout our analysis for this report, we assume progress in the electrification of heat, transport and industry, including the use of clean power to produce green hydrogen and to support carbon removal. This aligns with the carbon budgets and path to net zero, as set out by the CCC. As a result, increasing amounts of energy demand are being met by a clean power system rather than carbon-intensive fuels such as gas, petrol or diesel, driving further emissions reductions beyond the power sector. The displaced emission in residential heating and road transport by 2030 could reach 17 MtCO₂/yr based on our clean power pathways.

Accelerating build rates now for renewables is crucial to enabling the continued growth of demand due to electrification, which is expected to add approximately 19 TWh per year, in the 2030s, to the demand, the equivalent of the output of around 5 GW of offshore wind.

¹ Excluding emissions from combined heat and power and from waste to energy and before removal of emissions from BECCS. This aligns to the CCC's emissions accounting, which attributes these emissions to the industry and waste sectors respectively and identifies removals separately.

² Carbon emissions in the Counterfactual reported here are slightly lower than carbon emissions in the Counterfactual in FES 2024. This is due to the higher carbon price assumption in the economic analysis for Clean Power 2030. The same carbon price was assumed for all pathways, so clearer conclusions can be drawn on how such pathways differ from the Counterfactual in terms of cost.

³ As reported in [Progress in reducing UK emissions - 2023 Report to Parliament](#).

⁴ As reported in [2024 Report to Parliament](#)



Climate leadership

The UK has a strong track record of climate leadership, including being the first country to pass comprehensive climate legislation and legally binding emissions targets through the Climate Change Act (2008). The UK was also the first G20 country to set a net zero target and hosted the COP26 climate talks in Glasgow in 2021, which were a focal point for global adoption of net zero targets.

A commitment to clean power by 2030 would solidify the UK's position as a global leader. Having been the first G20 country to phase out coal-fired electricity generation, aiming for clean power by 2030 would place the UK at the forefront among economies decarbonising from historically fossil fuel-based systems. This leadership is particularly significant given the crucial role of electricity generation in global net zero pathways.

5.2 Wider environmental and local community impacts

Impacts of building clean power infrastructure

Power projects have significant impacts on the wider environment and local communities, making it crucial to consider these factors in their development. Conducting thorough environmental impact assessments, engaging with stakeholders and affected local communities and implementing mitigation measures can help minimise negative impacts and enhance projects' sustainability. The planning and consenting process for new generating sites and infrastructure development covers local environmental factors such as noise, vibration, visual impact, flood risk, heritage, ecology and waste management.

In a clean power system, more power needs to be transported over greater distances from generation sites to areas of demand. This requires various technologies, such as overhead lines, underground lines and subsea cables. Each technology has distinct technical characteristics and environmental impacts:

- Overhead lines are usually the cheapest to build but have a visual impact through pylons and wires.
- Undergrounding is more expensive and involves environmental disturbance and potential damage during installation.
- Subsea cables are also costly and require connections to the onshore network, while posing challenges in the marine environment.
- Furthermore, long-term energy infrastructure may occupy valuable sites that could be used for other purposes.

However, it is possible to minimise and mitigate these impacts. Having a clear plan for clean power allows for considering the environment holistically across the programme, making choices that collectively minimise potential negative impacts to the environment and communities and can support solutions that are positive for nature overall.

The proposed plans in this report minimise new onshore infrastructure. We are prioritising reinforcement of existing infrastructure and have identified some marine cabling by 2030. This was a core part of the network plans that form the basis for proposals in this report: those plans consider ways to maximise and upgrade the existing network first and only once this reaches a limit are new lines considered. Strengthened engagement between developers, local authorities and communities is vital for building trust, addressing community concerns and incorporating them into network plans to minimise overall impact on local people.

Air quality, water and land and seabed use

Fossil fuel-based and biomass power plants emit air pollutants, such as particulate matter (PM), SO_x and NO_x from their combustion processes. These have damaging effects on human health and the environment. Shifting to renewable energy sources reduces pollution and improves air quality, leading to better public health and environmental outcomes. Electrification of heat and transport further reduces air pollution from boilers and vehicles, particularly in urban areas.

Water is a valuable resource that is expected to be under increasing stress as the effects of climate change progress. A shift to clean power brings benefits for water since thermal generation technologies, such as gas-fired generation, can have higher water requirements for cooling compared to wind and solar. On the other hand, power CCS and CCS-enabled hydrogen production consume significant amounts of water.

Overall, a clean power system can reduce pressure on water supplies. The CCC anticipates that shifting to low carbon electricity generation could lead to a 10% decrease in water use in power generation by 2050 (including electrolysis). This is contingent on new nuclear capacity using sea water over fresh water, while different areas of the country will face different challenges, including availability of salt and fresh water and water quality. Accelerated construction timelines for new generation and network build may also place pressure on water systems. Consideration and planning for water availability, quality and efficient use will be important as Great Britain progresses towards a clean power system. Designing plants to maximise water efficiency, such as using seawater for cooling, can also help minimise water-related challenges.

The use of land and the seabed need to be considered for new generation and network assets. A 25 GW increase in offshore wind could occupy approximately 8,600 km² of sea space.⁵⁶ Offshore wind farms may cause seabed disturbance and noise pollution during installation, while floating wind farms reduce these impacts but may pose risks to marine habitats due to anchoring systems.⁷ However, potential positive environmental impacts have been identified as well, such as the creation of artificial reefs that attract more marine life than natural reefs.⁸ Onshore wind with a capacity of 27 GW would require around 3,000 km² of land, representing 1% of the total Great Britain land area. Approximately 99% of this land area would remain available for other uses between the turbines, allowing for shared land use, such as agriculture and pasture. Only a small portion, approximately 30 km², would be occupied by the turbines.⁹

In the longer term, the Strategic Spatial Energy Plan (SSEP) will provide an understanding of the spatial requirements of Great Britain's future energy system by mapping the quantities and location of energy infrastructure, while taking into account cross-sectoral demands on land and sea. This includes considering requirements for agricultural production, transport, water availability and nature recovery to help inform decision making.

5 [AURES II case study seabed auctions.pdf](#)

6 [Scotland awards seabed rights for massive amounts of offshore wind, most of it floating | WindEurope](#)

7 [670791d6196cc689841fc02e_ODI_Offshore Wind Energy Industry Review WEB_compressed.pdf](#)

8 [Reviewing the ecological impacts of offshore wind farms | npj Ocean Sustainability](#)

9 [How can landowners harness onshore wind power opportunities -Trowers & Hamlins](#)

5.3 Investment

Gas-fired power generation costs are primarily driven by fuel and carbon emissions, with some capital investment, while renewable costs are dominated by upfront capital investments. A clean power system therefore involves a shift from operating costs, largely from imports of gas to capital cost, requiring significantly increased investment.

Our pathways for a clean power system in 2030 envision considerable levels of investment, some of which is already underway, driven by current contracts, commitments and expansion plans for generation, storage assets and network infrastructure. In the clean power pathways, offshore wind represents the largest component of investment, with average annual investment of around £15 billion from now to 2030. Networks, onshore wind, solar and storage are other large investment items, though each less than half the scale of offshore wind.

Average annual investment of over £40 billion to 2030 represents a material increase on investment levels in recent years, with average annual investment around £30–35 billion higher over 2025–2030 than over 2020–2024. This is an increase in investment of over 1% of GDP for the entire economy. Wider electrification efforts will further drive national investment.

The main differences in investment between pathways reflect differences in capacity assumptions, as set out in Chapter 3, with similar onshore network investment assumed across scenarios. There are significant uncertainties around the precise level of investment, given wider uncertainties over project costs, as illustrated by significant variations in contracted strike prices over recent renewables auctions. We present relatively cautious (high) estimates reflective of the higher prices in the most recent auction.

Most of the investment is expected to come from the private sector, highlighting significant local economic and job opportunities. Furthermore, this investment also leads to substantial savings in operating costs, as explored in the next section.

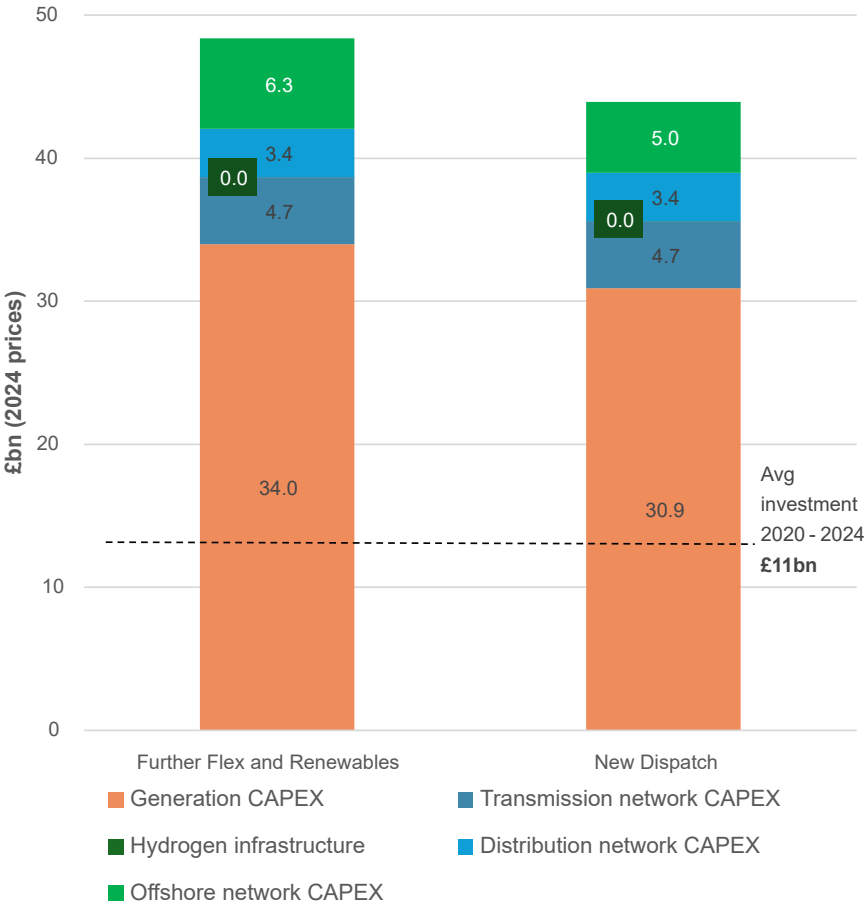


Figure 19: Average annual investment system costs in clean power pathways 2025-2030

5.4 Costs

While at the macroeconomic level, the shift to clean power will be seen as an increase in investment, for consumers it will be felt through its effect on electricity prices and bills. These will reflect the underlying costs of the electricity system, just one part of which is investment (or 'capital') costs, which will be recovered through sales of electricity per unit (for example, per kWh, which is roughly the amount of electricity needed to run a dishwasher cycle or a laptop all day, or per MWh, which would power a household for around four months).

Approach to our cost analysis

In our cost analysis, we focus on how electricity costs per unit can be expected to change in a clean power system. We compare how costs will change compared to the current system, how they may differ between our pathways and relative to the Counterfactual with no acceleration in delivery. We break down our cost estimates between their component parts, which include:

- **Generation costs.** The combined capital and running costs of the power plants providing generation to the system, which we break down into three components:
 - **Capacity costs.** These include the annualised investment cost of building new generating and storage capacity and the costs of operating and maintaining it, but not the fuel or emissions costs attached to use of fuels such as gas or biomass.
 - **Fuel costs.** The cost of buying and burning fuel in the plant to generate electricity.
 - **Carbon costs.** The cost of buying emissions permits under the UK's Emissions Trading Scheme.
- **Net import costs.** The cost of imports and income from exports of electricity bought from and sold to neighbouring markets over interconnectors.
- **Network costs.** The annualised capital costs and operating costs of Great Britain's transmission network,¹⁰ distribution network, offshore network, hydrogen infrastructure for power generation and CO₂ transport and storage, which are utilised by the power generation technologies under consideration.
- **Constraint costs.** Thermal and voltage/stability costs, which make up the majority of the balancing costs and the ones most likely to change as the system develops.

Our pathways to clean power involve increased electrification, which leads to a higher share of British energy demand being met by power, displacing costs in other parts of the energy system. For electric vehicles, this is likely to reduce energy costs, as it could for heat pumps depending on prevailing gas prices. However, we do not attempt to estimate these effects in this work, which focuses on the costs of electricity.

How costs flow through to prices, and ultimately bills, will depend on policy design. Under current policy arrangements, there will tend to be an increase in the cost of support mechanisms such as contracts for difference (CfD), with offsetting falls in wholesale power costs. This reflects the change in underlying costs, with renewables having lower running costs and higher upfront costs. While we can identify some expected changes that will affect prices (not just costs), we do not attempt to estimate an actual electricity bill given the heavy dependence on policy choices.

¹⁰ Onshore enablers were not included in the analysis due to challenges in obtaining the relevant data.

Overall system costs in a clean power system

In estimating how costs will change compared to today's system, there are multiple effects to take account of. Power will be generated from different means with different underlying costs. More will be generated, not just to service growing demand, but because some will be curtailed, exported or lost during storage cycling. Also, there are costs to be covered in expanding the networks and storage infrastructure.

Looking across these effects in 2030, our analysis suggests a slight increase in total system costs for our New Dispatch pathway, equivalent to around £10 /MWh. This overall cost can be broken down between the different elements:

- **Cost of generation.** Contract prices for wind and solar in recent auctions (£71-83/MWh) are an indicator of the underlying per MWh costs of these new plants and of what consumers will pay for them. These are lower than the cost of generating from existing gas-fired power stations (£123/MWh at current projected 2030 gas prices and carbon prices)¹¹. Combined with higher costs assumed for dispatchable power and recognising that not all the displaced generation is from gas, this shift implies a system-wide reduction in the average costs of generation of around £15 /MWh.
- **Curtailement.** The clean power pathways involve higher levels of curtailment when variable and firm generation combined is greater than needed to match demand. This means that, although each unit of generation is lower cost, more of it is needed, pushing up the average cost of meeting demand. We assign no value to this curtailed generation but note there may be opportunities for new flexible demand sources to put this unused clean electricity to positive use. Curtailment adds around £5 /MWh.
- **Net Exports.** Our pathways to clean power see Great Britain become a net exporter of electricity. Exports will be greatest at times of high renewable output, which under current arrangements imply relatively lower prices. So, while exporting will recoup some costs compared to curtailment, it will still involve some net cost to the British system overall. This effect adds around £5 /MWh.
- **Storage.** Our pathways to clean power build a large amount of new storage and use it regularly, which involves round-trip efficiency losses. These are important in reducing the overall cost of the system, for example reducing curtailment and the need for high-cost dispatchable and gas-fired generation. However, the investment and round-trip losses involve new costs, which together increase system costs by around £10 /MWh.
- **Network and constraint costs.** The major expansion in the network in our clean power pathways involves a large investment that will be paid back through increased charges per MWh. Also by 2030, some existing costs will be paid off and others will be spread over a larger demand base. Constraint costs will also change, although provided the full planned network expansion is delivered these need not increase to 2030. Together, these imply rising costs of around £5 /MWh.

Our cost estimates are anchored on the latest auction and DESNZ's published generation cost estimates, with more details set out in Annex 4. We also consider the possibility that costs could differ from these, including using high and low sensitivities for capital costs. The latest renewable auction saw higher prices than the previous one. Should costs fall back towards earlier contracted levels then system costs for a clean power system would be lower than our estimates.

¹¹ All the cost and price estimates in this report are in a 2024 price base, stripping out the effects of inflation. Our 2030 gas price projection is around 100 pence/therm, as used in the Future Energy Scenarios. Our carbon price projection of £147/tCO₂ is based on independent forecasts, as used in the Future Energy Scenarios, plus a UK carbon price underpin of £25/tCO₂.

A particular risk we consider is that the need to contract and then build a large amount of generating capacity in a short period, especially for offshore wind, could lead to an escalation in CfD strike prices. Our analysis is based on an assessment of the pipeline of potential offshore wind projects and the potential for inframarginal rents from the CfD auction.¹² In an extreme case where all offshore wind projects are paid in line with the costs of the most expensive project and costs are further pushed up 25% due to supply chain pressures, average costs of the electricity system could increase by a further £15 /MWh. To keep overall costs down, it is therefore vital that an element of competitive pressure is maintained and that high inframarginal rents are avoided.

Impact of clean power on consumer energy bills

While our system cost analysis points to a slight increase from a move to a clean power sector, there will be direct benefits offsetting these, suggesting that overall costs to consumers would not increase from the shift to a clean power system (as summarised in Table 4 below). Specifically, in our clean power pathways, gas sets the price less frequently. The resulting reduction in wholesale prices would lower payments and infra-marginal rents for generation with low marginal costs, such as existing nuclear plants and those receiving Renewable Obligation Certificates (under current market arrangements). Our analysis points to this reducing average electricity prices by around £10 /MWh under a clean power system. This reduction would not happen without the shift to clean power.

Further bill reductions can be expected as levies for older renewable support schemes, such as the Renewables Obligation and Feed-in Tariffs, reach the end of their contractual periods. Some of the plants with these contracts may need new support for repowering, but this would be at much lower levels than in the legacy contracts and could come with an opportunity to increase output relatively cheaply. This effect would happen even without a shift to clean power and would reduce average prices by around £10 /MWh by 2030, with continuing falls through the 2030s.

There are also additional opportunities to reduce bills through energy efficiency. For example, our clean power pathways involve an efficiency improvement in lights and appliances for households that sees typical electricity usage drop by c. 5-10%.

More generally, bills will be affected by gas and carbon prices, though the move away from gas as the predominant price setter for electricity would greatly reduce the risk of major price spikes. Price spikes are passed on to consumers, as seen during the gas price crisis of 2022, when energy bills increased dramatically due to high gas prices. While gas prices fell into 2023, prices remained very high as forward hedging locked in higher costs. As a result, the electricity price cap for 2023 was between £150 -200 /MWh higher than implied by a system cost analysis akin to those in this chapter (consumers were protected from much of this cost through the Energy Price Guarantee, with the cost falling on the public finances instead).

While these sorts of very high price spikes are hard to predict, the shift to clean power would greatly reduce the exposure for consumers and the public purse.

The translation of clean power costs into bill impacts depends on policy choices, including how and when costs are reflected in prices and how they are distributed among different consumers. These choices will affect both current and future consumers, as well as the allocation of costs between gas and electricity consumers. The impact on bills may vary among consumers, such as those with electric vehicles or electric heating and those who have more flexibility in their electricity usage. Potential distributional impacts across residential and business users should be carefully considered when designing policies in this area.

¹² Our analysis was developed with Baringa using their proprietary offshore wind CfD auction model. Infra-marginal rent refers to the extra payment (above costs) received by lower cost projects that get paid the same strike price as the more expensive projects that set the clearing price in the CfD auction.

Table 4: Costs in 2030 in the New Dispatch pathway compared to today's system (figures rounded to the nearest £5/MWh)

Cost component	Direction of impact	New Dispatch v today's system
Average cost of generation, per MWh produced	↓	- £15 / MWh
Higher curtailment (at times of 'excess' wind/solar)	↑	+ £5 / MWh
Exporting at low cost (at times of 'excess' wind/solar)	↑	+ £5 / MWh
Building storage and round-trip losses	↑	+ £10 / MWh
Grid expansion and constraint costs	↑	+ £5 / MWh
Total = + £10 / MWh		
Bill components resulting from clean power pathways		
Merit order effect reducing infra-marginal rents	↓	- £10 / MWh
Other bill changes to 2030		
Falling legacy policy costs	↓	- £10 / MW
Energy efficiency improvement in typical households	↓	c. 5-10% consumption

Cost comparisons between clean power pathways

As well as exploring how costs change compared to today's system for our clean power pathways, we also explore the differences between pathways and against the Counterfactual that falls short against national carbon targets. We find similar costs across all options, within the bounds of uncertainty, as set out in Figure 20 on the following page.

If gas prices remain similar to those of mid-October 2024 (around 100 pence/therm) and carbon prices rise in line with our projection, costs would be slightly lower in the Counterfactual. However, this would be mostly offset by the merit order effect described above, implying that there is no material cost advantage for the Counterfactual unless gas and/or carbon prices are at materially lower levels.

Between the clean power pathways, New Dispatch is expected to be slightly lower cost. This reflects the reduced investment in renewables and storage and lower curtailment and exports, as it has a greater ability to match dispatchable generation to demand. However, there are other factors to consider (as set out in Chapter 3), such as higher continuing exposure to gas prices (albeit still much lower than today).

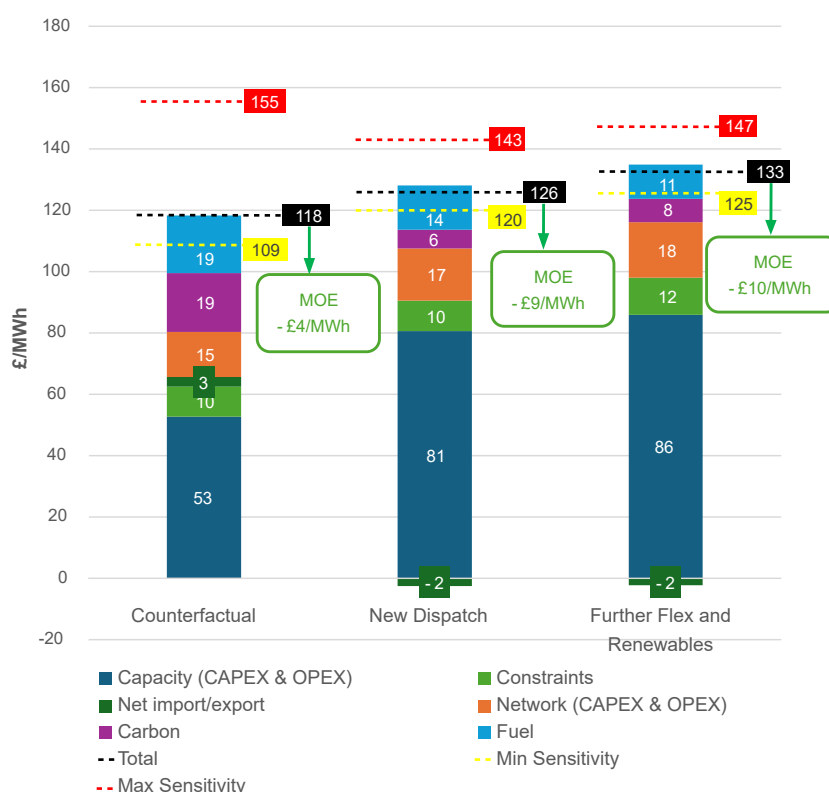


Figure 20: 2030 Annuitised system costs per useful unit of electricity with sensitivities

MOE = Merit order effect, reducing payments to some older plants

Our sensitivity analysis assesses the impact of key assumptions, including gas price projections, investment costs and CO₂ transport and storage costs. The uncertainty bars demonstrate the range of uncertainty, with the Counterfactual being particularly sensitive to gas price assumptions. For the clean power pathways, the range between the lower and upper bounds is smaller, given less sensitivity to gas prices, which outweighs greater sensitivity to capital cost assumptions.

There may be scope to further optimise the pathways to reach clean power at lower cost. For example, more demand side response could cut costs associated with curtailment, exports or storage losses, as could a further rebalancing from renewables to dispatchable generation. It may be also possible to have less, or more efficient, storage without compromising the high value it brings to the system.

We also note that there are wider opportunities and risks attached to the clean power mission to the extent that the mission can unblock barriers to delivery. There may be opportunities to reduce costs, to access cheaper capital and/or to increase competition. However, there are also risks that the accelerated pace reduces competitive pressure, increases supply chain tightness or otherwise increases costs. Managing these risks and opportunities will be a key challenge for the Clean Power 2030 Unit.

Protection from gas price volatility

The unit system costs projections above are based around our central gas price case, assuming gas prices in 2030 remain at similar levels to those in 2023.

If gas use for power generation remained at the levels of 2023 and gas prices were raised to the peak levels in 2022 (300 p/therm on average), this would add around £12 billion to annual electricity system costs in Great Britain. In the partly decarbonised Counterfactual, we estimate this gas price shock would add around £10 billion, while in the clean power pathways it would only add around £5 billion. The flow-through to electricity bills is likely to be more exaggerated given the dominant role of gas-fired generation in price setting in the Counterfactual, compared to in our clean power pathways for 2030 (Figure 21).¹³

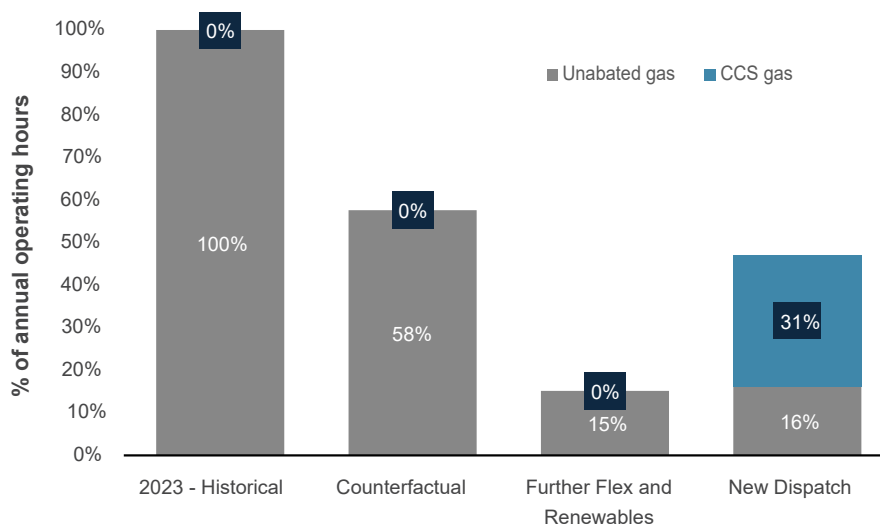


Figure 21: Percentage of annual operating hours where gas-fired generation is used

Gas market impact

The gas volume required to supply the gas-fired generation fleet in our clean power pathways is relatively small, compared to typical historical or current gas flows both within the British gas network and in a global market. It is not anticipated that clean power activity would lead to any significant impact on the day-to-day functioning of the gas market. Situations involving a significant national-scale increase in gas-fired generation can be anticipated in advance, based on weather conditions, allowing the gas market to price in the expected rise in gas demand.

In addition to the gas demand from gas-fired generation, there will also be a level of gas demand for hydrogen production and, more widely, for heating. Therefore, gas assets will remain a vital part of national infrastructure for some time, even in a clean power world.

¹³ Figure 21 shows the share of hours in which gas-fired generation operates at all. It will still be only a fraction of total generation even in these hours.

5.5 Reducing Great Britain's reliance on energy imports

Shifting to a clean power system by 2030 will significantly reduce Great Britain's reliance on energy imports for electricity generation, through several means:

- Great Britain is expected to transition from being a net importer of electricity in 2023 to becoming a net exporter by 2030.
- The amount of gas-fired and biomass generation is reduced in our clean power pathways, reducing the need for imported gas and biomass as fuel sources.
- The use of clean power for electrifying heating and transportation will further displace imports of gas and oil, reducing overall reliance on imported energy in the British energy system. However, the heating and transport sectors will still require significant amounts of gas and oil, with continued reliance on imported energy supplies.

As a result, even though Great Britain's production of oil and gas is expected to fall from now to 2030, reliance on imported fuel for power generation will reduce significantly by 2030 compared to today (see Figure 22), returning to levels last experienced in the mid-2000s.

How imports and exports are affected more broadly will depend in part on how far expansion of supply chains takes place within the country or overseas.

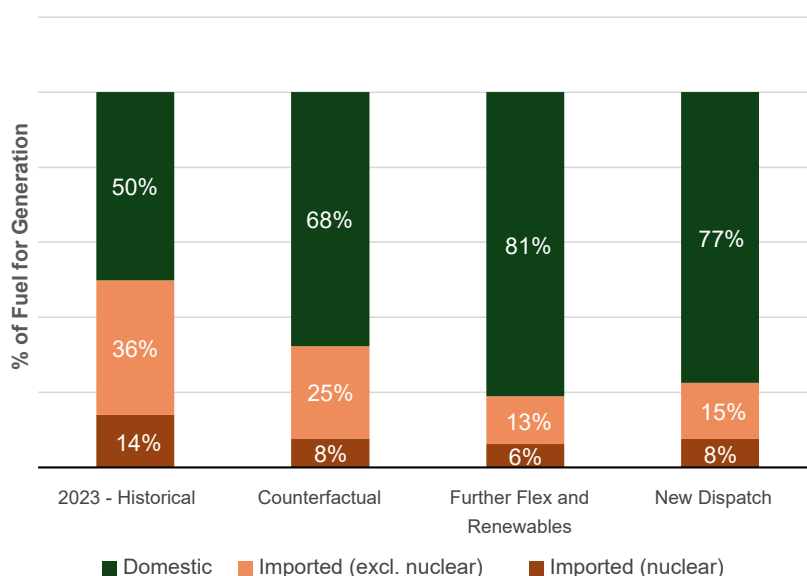


Figure 22: Split of imported and domestic fuel for generation

Wind, solar and hydro are considered British energy resources. Generation from fossil fuels and biomass are split between British and imports in line with the economy-wide shares for these fuels. Nuclear is separately identified, as its fuel is imported, but is a very small percentage of overall nuclear generation costs.

5.6 Impact on the wider British economy

The power system is a key enabler of sustainable economic growth. Households and businesses rely on access to electricity for their day-to-day needs, while increasingly demanding clean power. The transition to a clean power system by 2030 will have significant impacts on the wider national economy. While quantifying these impacts can be challenging due to the importance of wider factors, we have considered some of the key macroeconomic effects:

- The **large increase in capital investment** for clean power could potentially boost GDP and employment rates either locally or across Great Britain, but this is dependent on wider macroeconomic policy and supply side capabilities to respond to this scale-up in demand.
- The transition to a decarbonised power sector by 2030 presents a significant economic opportunity for creating and expanding **green jobs**. The low carbon energy and renewables sector in the UK has already witnessed significant growth, with employment reaching 74,000 in 2022, an over 20,000 increase from previous estimates in 2015.¹⁴ This upward trend is expected to continue at pace. The Climate Change Committee's Net Zero Workforce (2023)¹⁵ report presents a wide range of employment opportunities, projecting between 4,000–192,000 jobs in low carbon energy, CCS and hydrogen.
- Transitioning to a clean power system is likely to lead to a shift in the UK's **trade position**, as the country changes from a net importer to an exporter of power and reduces natural gas imports. However, this may be offset by higher imports, for example of parts and materials, influenced by the increase in capital investment.
- **UK competitiveness** will be impacted by the changing difference between British and overseas electricity prices. If consumer and industrial electricity bills reduce under the clean power pathways, it can provide economic benefits, particularly for large industrial power users, making them more competitive internationally. This of course depends on wider policies and how European power prices evolve.
- The transition to a clean power system presents **industrial opportunities**, including direct investment, a stable market for supply chains and opportunities for major power users seeking clean energy.
- **Public finances** will see some changes due to investment in clean power, but the majority will be delivered from the private sector, backed by contracts that are paid for from energy bills. Some of the potential public spending requirements, for example for CCS, have already been identified and funded by the Treasury. Reduced emissions from a clean power system decrease permit demand in the power sector's Emissions Trading Scheme, but these permits are available for sale to other sectors. Given expected price increases by 2030, the power sector is projected to raise £1.5–2 billion in 2030 (compared to £5.8 billion in 2023) even in a clean power pathway. At the same time, revenues from the Crown Estate will continue to grow due to offshore wind leasing.

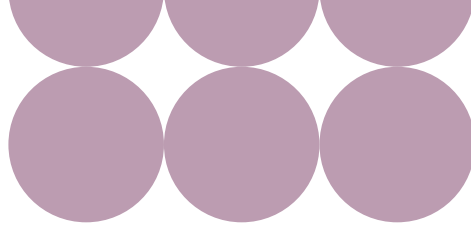
5.7 Conclusion

Our analysis describes pathways to a clean power system for Great Britain by 2030 that involve a major investment programme without increasing costs to consumers, while largely breaking the link with volatile international gas prices. As well as being a major direct contributor to UK carbon targets, it would enable accelerated progress in other sectors. And it would involve development of the tools, policies and momentum to drive through 2030 to meet the ongoing challenges ahead.

This report has set out potential pathways for clean power. The Government will now reflect on those pathways and put forward its own plan. Then the hard work will begin to deliver against that plan while ensuring good value for consumers, developing opportunities across the country and building public trust and support for the clean power mission.

¹⁴ [ONS Low Carbon and Renewable Energy Economy \(LCREE\)](#)

¹⁵ [CCC \(2023\) – A Net Zero Workforce](#)



Glossary

AGR	Advanced Gas-cooled	GETS	Grid-enhancing Technologies
AI	Artificial Intelligence	GW	Gigawatt
ASTI	Accelerating Strategic Transmission Investment	GWh	Gigawatt Hour
BECCS	Bioenergy with Carbon Capture and Storage	HT	Holistic Transition (Future Energy Scenarios pathway)
BM	Balancing Mechanism	HVDC	High Voltage Direct Current
CAPEX	Capital Expenditure	IBR	Inverter-based Resources
CCC	Climate Change Committee	IDNO	Independent Distribution Network Operator
CCS	Carbon Capture and Storage	LAES	Liquid Air Energy Storage
CfD	Contract for Difference	LDES	Long Duration Energy Storage
CHP	Combined Heat and Power	LLM	Large Language Models
CO₂	Carbon Dioxide	MHHS	Market-wide Half-hourly Settlement
CSNP	Centralised Strategic Network Plan	MWh	Mega Watt Hour
DACCS	Direct Air Carbon Capture and Storage	NDC	Nationally Determined Contribution
DESNZ	Department for Energy Security and Net Zero	NESO	National Energy System Operator
DNO	Distribution Network Operator	NTS	National Transmission System
DSI	Data Sharing Infrastructure	OEM	Original Equipment Manufacturer
DSR	Demand Side Response	OPEX	Operating Expenditure
ENCC	Electricity National Control Centre	PHES	Pumped Hydro Energy Storage
EPR	European Pressurised Reactors	PP	Percentage Points
ESO	Electricity System Operator	REMA	Review of Electricity Market Arrangements
ESRS	Electricity System Restoration Standard	SMR	Small Modular Reactors
EV	Electric Vehicle	SPS	Strategy and Policy Statement
FES	Future Energy Scenarios	SSEP	Strategic Spatial Energy Plan
FOAK	First of a Kind	TO	Transmission Owner
		TWh	Terawatt Hours
		V2G	Vehicle-to-Grid
		VirtualESZ	Virtual Energy System

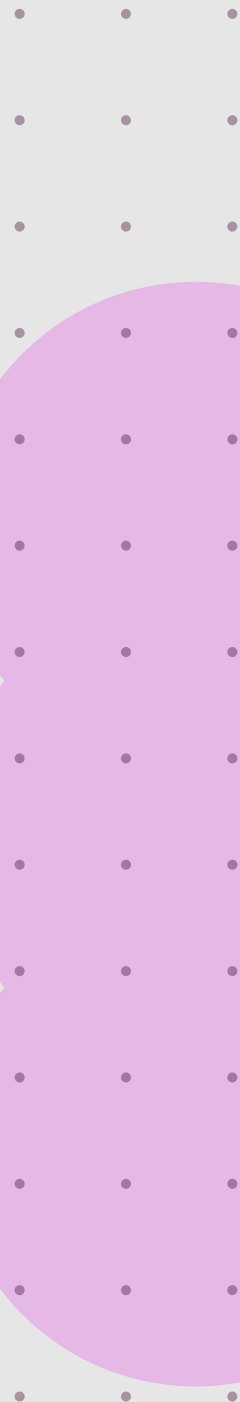


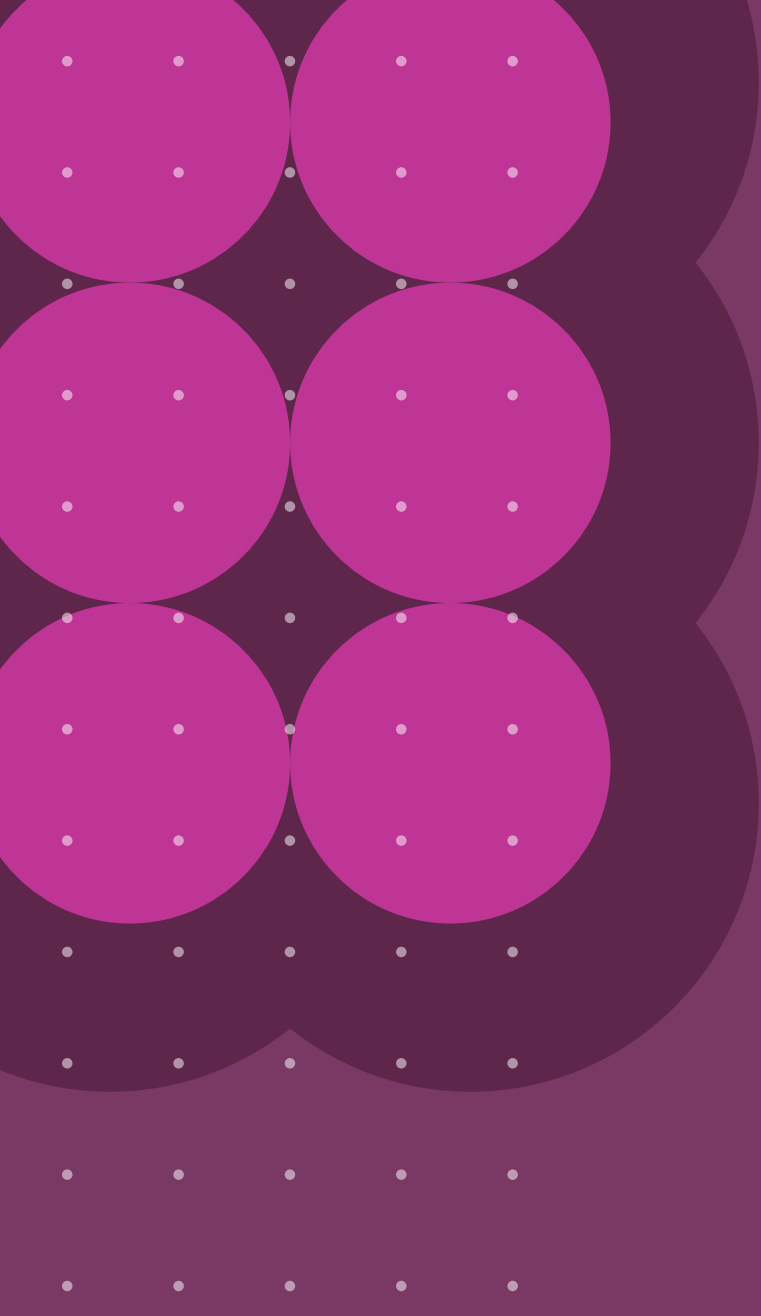


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