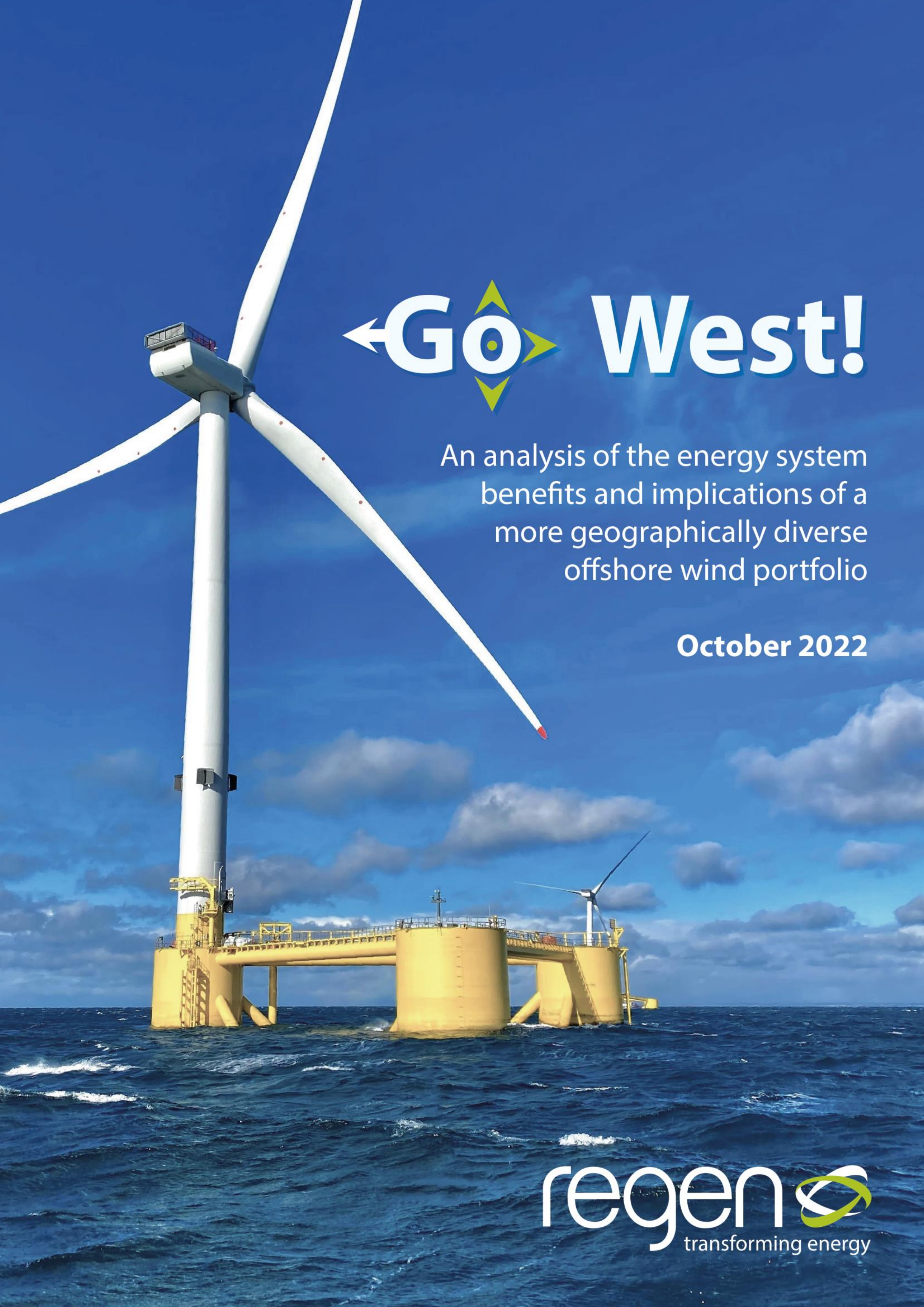

Go West!

An analysis of the energy system benefits and implications of a more geographically diverse offshore wind portfolio

October 2022

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transforming energy

Preface

As of October 2022, the UK is facing the climate crisis alongside one of the greatest economic crises of this generation, driven largely by volatile fossil fuel markets. This ongoing market volatility is being exacerbated by the geopolitical insecurity resulting from Russia's invasion of Ukraine. The current wholesale price of gas is putting huge pressure on the already stretched incomes of millions of people across the UK through rising prices and bills. With vital net zero targets to be achieved and energy prices spiralling, the need for energy independence and innovation at pace and scale in the UK energy system has never felt so urgent.

In response to fundamental changes in the UK economic landscape since the Net Zero Strategy was published, the UK government has commissioned the Net Zero Review (due to report at the end of 2022). The review will assess the government's approach to delivering its net zero target to ensure it is delivered in a way that is 'pro-business and pro-growth', including how net zero can 'support UK energy security and affordability for consumers and business and the need to rapidly increase and strengthen UK energy production and supply'. Controlling energy costs and strengthening UK energy production and supply requires investment in enduring long-term solutions, including seizing the opportunity of cheap, clean, homegrown renewables.

The UK is a world leader in offshore wind and is aiming to deliver 50 GW of offshore wind by 2030. To date, almost three-quarters of the UK's 13 GW offshore wind capacity has been installed along the east coast of Great Britain. Similar momentum is yet to be established on the west coast, with 8 GW of planned projects cancelled or withdrawn. However, recent innovations in floating offshore wind have enabled the development of projects in deeper water off the west coast. This presents an opportunity for west coast offshore wind projects to address the lack of geographical diversity of the UK's offshore wind fleet and to play a vital role in energy system balancing, energy security and price stability.

Using 20 years of weather data, the *Go West!* study explores and identifies the benefits that pursuing a more geographically diverse offshore wind fleet could bring to both the UK energy system and energy consumers, and recommends the policy innovations required to deliver such a balanced fleet.

About Regen

Regen is a not-for-profit centre of energy expertise and market insight whose mission is to transform the UK energy system for a zero carbon future.

Acknowledgements

Regen would like to thank the *Go West!* project sponsors and contributors.

Magnora Offshore Wind (MOW) is owned by Magnora ASA, a Norwegian renewable energy developer, and TechnipFMC, a global energy services company. MOW develops floating offshore wind projects around the world using the joint expertise and capabilities of both Magnora ASA and TechnipFMC. In the UK, MOW has been awarded an option to lease for a 495 MW floating wind project off the coast of the Isle of Lewis as part of the ScotWind leasing round and is also working on the Celtic Sea leasing round with local partner Hiraeth.

Morwind Ltd, a specialist wind developer based in South West England, is partnered with Corio Generation to compete for floating offshore wind rights in the Celtic Sea. The partnership combines Corio's international industrial expertise and access to capital with Morwind's specialist regional knowledge and strong local stakeholder relationships to identify and invest in new floating wind opportunities in the region. Morwind is committed to working and collaborating with local, regional and national partners, engaging the local supply chain, stakeholders and communities and adding value through innovation, efficiency and social impact. Corio, a portfolio company of Macquarie's Green Investment Group, operates on a standalone basis and has one of the world's largest offshore wind development portfolios at over 20 GW, including projects in England and Scotland.

Northland Power is a global power producer dedicated to helping the clean energy transition by producing electricity from clean renewable resources. Founded in 1987, Northland has a long history of developing, building, owning and operating clean and green power infrastructure assets and is a global leader in offshore wind. We were delighted earlier this year to win the rights to develop 2 offshore wind farms off the Western Isles as part of the Crown Estate Scotland's 'Scotwind' tender.

Simply Blue Group is a leading early-stage blue economy developer. Headquartered in Cork, Ireland, the company has an impressive global pipeline of over 10 GW of floating offshore wind projects, including project Erebus, a 100 MW Test and Demonstration project in the Celtic Sea. Erebus is part of Blue Gem Wind, a joint venture between Simply Blue Group and TotalEnergies, which takes a steppingstone approach to floating offshore wind projects in the Celtic Sea. Simply Blue Group is committed to creating new economic opportunities for coastal communities and developing projects that co-exist with sustainable fisheries and marine conservation.

Regen would also like to thank those organisations that participated in the interim roundtable discussion that informed this report: **BEIS, Burges Salmon, BVG Associates, Celtic Sea Power, Climate Change Committee, National Grid (Electricity Transmission and Electricity System Operator), Offshore Wind Acceleration Taskforce, Ofgem, renewableUK, SP Energy Networks, SSE, The Crown Estate, and Welsh Government**.

Image courtesy of Simply Blue Group

Executive summary

Offshore wind energy forms an important part of the UK's energy mix and is expected to be crucial to meeting net zero emissions targets. The UK government's British Energy Security Strategy (April 2022) set an ambition to deliver up to 50 GW of offshore wind by 2030, including 5 GW of floating offshore wind (FLOW). With current offshore wind capacity (as of Q2 2022) at 13 GW and accounting for 12.6% of the UK's total domestic generation[1], National Grid ESO's Future Energy Scenarios 2022 'Consumer Transformation' scenario projects the installed generation capacity of offshore wind to increase by almost nine times to 110 GW by 2050, providing 56% of total domestic generation[2].

To date, almost three-quarters of the UK's offshore wind capacity has been installed along the east coasts of England and Scotland. 8 GW of projects along the west coast of Great Britain have been cancelled or withdrawn, including several Crown Estate Offshore Wind Leasing Round 3 projects, highlighting that even those west coast projects successfully awarded a lease still face significant challenges to reaching full operation. Whilst innovations in FLOW have begun to mitigate some of the challenges posed by harsh marine environments, simplifying and accelerating the planning and development process would maximise the rate of success and pace of development.

The concentration of offshore wind capacity on the east coast has helped the offshore wind sector reduce costs by focusing investment and development in shallower waters near major construction and manufacturing ports. However, as the UK energy market grows increasingly reliant upon offshore wind as a cheap and emissions-free energy source, the lack of geographical diversity of the burgeoning offshore wind fleet is not optimal for energy system balancing and price volatility. The energy system benefits of a more geographically diverse wind portfolio have become increasingly apparent due to current wholesale price volatility and high system balancing costs.

The *Go West!* study seeks to explore, and quantify where possible, the benefits that pursuing a more geographically diverse offshore wind fleet will bring to the UK energy system and consumers.

[1] Energy Trends – UK April to June 2022. BEIS, 2022 (12 months to Q2 2022)
[2] National Grid ESO's Future Energy Scenarios. National Grid ESO, 2022.

Study approach

The UK's offshore waters were split into a number of discrete zones to provide a basis for the analysis (see Figure 1).

Three primary scenarios and several sensitivity studies were defined to explore the impact of geographical diversity of the UK offshore wind fleet on power generation. Each scenario comprises a 70 GW offshore wind fleet[3], but with varying geographical distribution of that power capacity across the zones. All scenarios include UK offshore wind farm capacity that is operational or under construction as of June 2022, to which additional capacity has been added based on current leases and areas of development activity (such as the Celtic Sea and ScotWind leasing areas).

The primary scenarios – 'Stay East', 'Lean West' and 'Go West' – are illustrated in Figure 2.

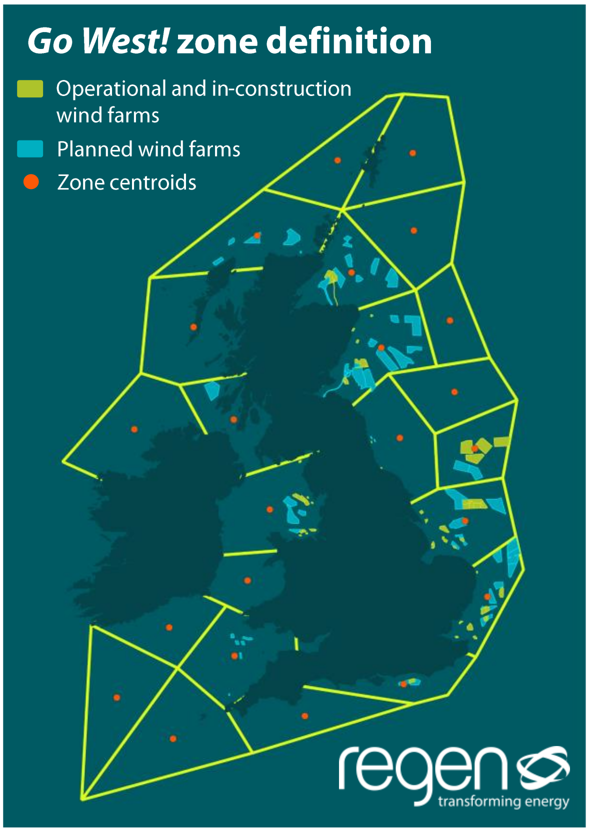


Figure 1: Zones used to model a variety of distributions of a 70 GW offshore wind fleet.

These offshore wind portfolios were combined with 20 years of wind resource and wind farm power output data from the Renewables.ninja[4] website, a tool designed by Stefan Pfenninger and Iain Staffell to help make scientific-quality weather and energy data easily accessible. The resulting offshore wind fleet power generation time history was analysed for each scenario to assess the energy generation potential of a variety of wind farm portfolios across the zones.

[3] 70 GW was selected as an intermediate target on the trajectory to the UK's 2050 Net Zero ambitions - in line with National Grid's Future Energy Scenarios 2022 offshore wind projections for 2034 (Consumer Transformation scenario) and CCC's 6th Carbon Budget projections for 2040-2048.

[4] See www.renewables.ninja and the related paper *Staffell, Iain and Pfenninger, Stefan (2016). Using Bias-Corrected Reanalysis to Simulate Current and Future Wind Power Output. Energy 114, pp. 1224-1239. doi: 10.1016/j.energy.2016.08.068*

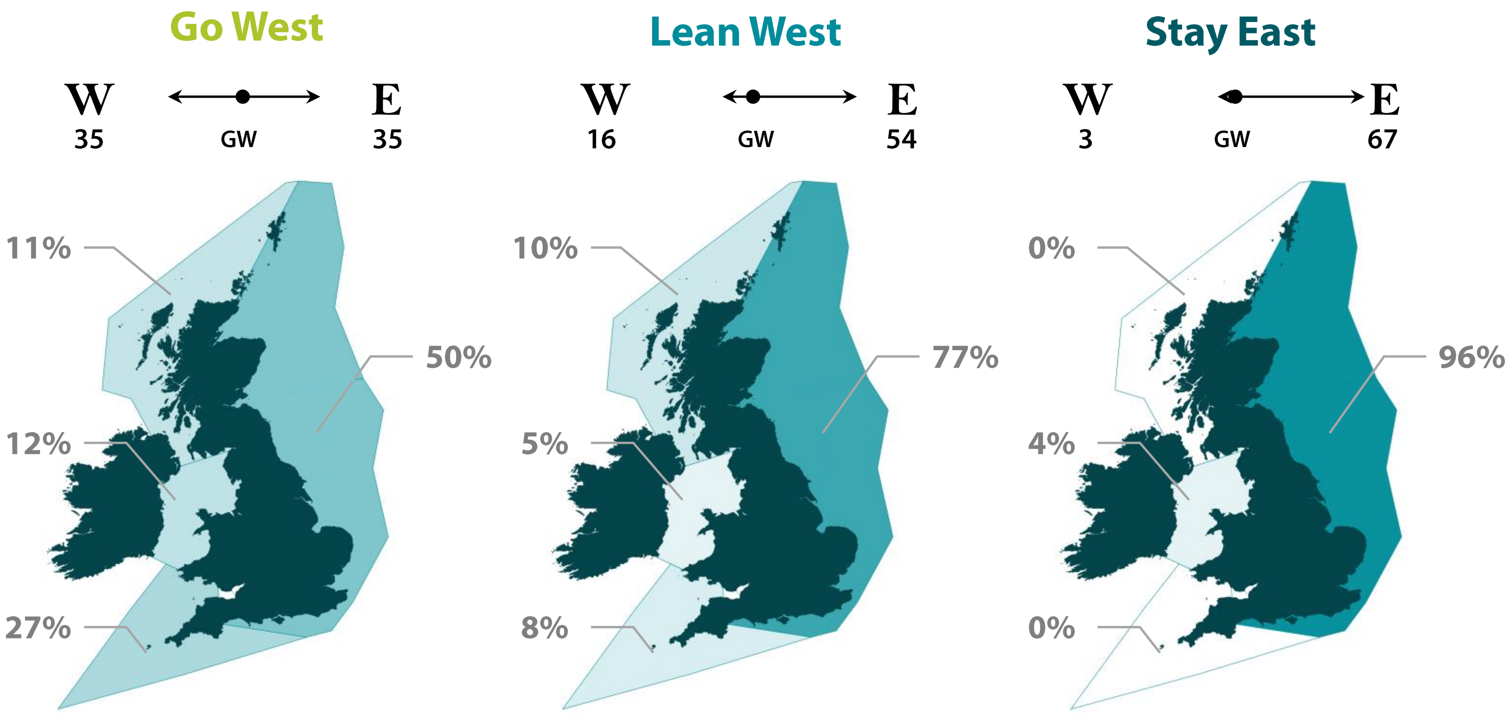


Figure 2: The three primary scenarios used in the *Go West!* study and their associated regional[5] distributions of offshore wind capacity.

Results

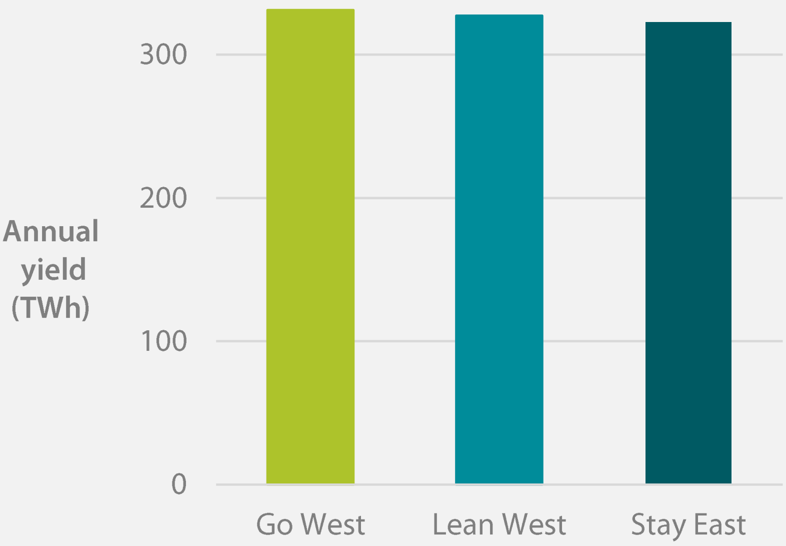
The primary focus of the analysis was to consider differences between the scenarios in:

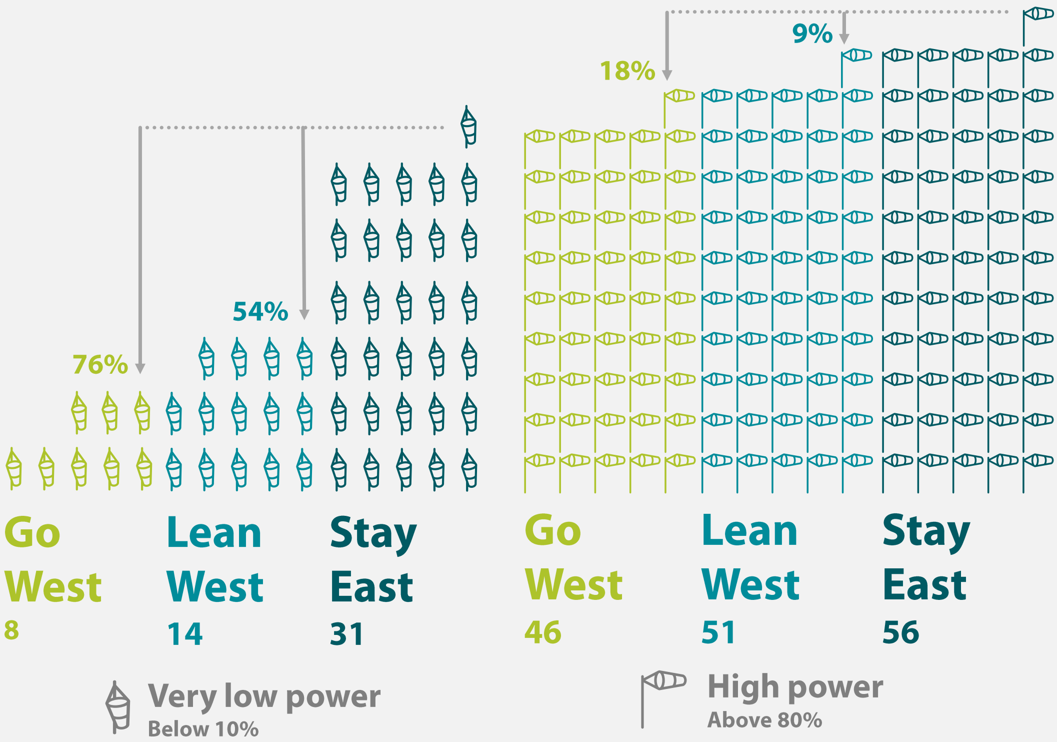
- Total time spent at very high/low power
- The number of occurrences of very high/low power
- The variability of power generation from one hour to the next
- Total annual yield.

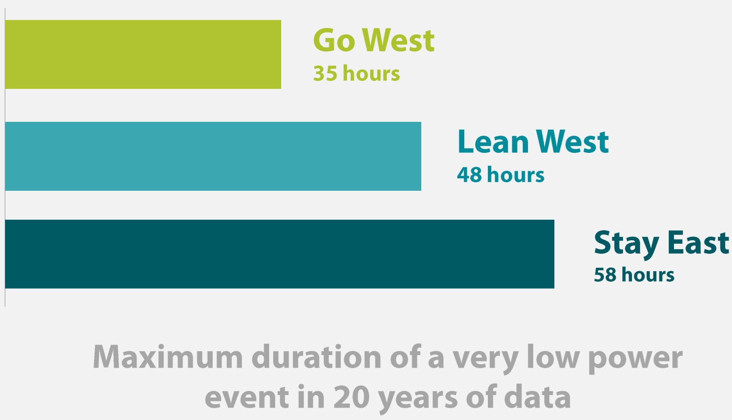
The main findings are illustrated in the below infographics (Figure 3 - Figure 7).

[5] A 'region' in this context is defined as a grouping of a number of adjacent zones. Figure 2 shows that four regions have been used to simplify the comparison of offshore wind capacity distribution around the UK and Ireland per scenario.

Compared to the Stay East scenario, Go West…







1

…does not reduce average annual yield

Figure 3: Annual energy generation per scenario
Units: TWh. 'Yield' represents the average annual total of energy generated by the offshore wind fleet in each scenario, calculated as the mean of 20 years of data

2

…reduces the number of 'events' of troughs and peaks in generation

Figure 4: Average number of discrete occurrences (i.e. 'events') per year where the offshore wind fleet is generating at a high/low power level
Units: average number of events per year.
Power level defined by capacity factor.

3

…almost halves the maximum 'event' duration of very low fleet power

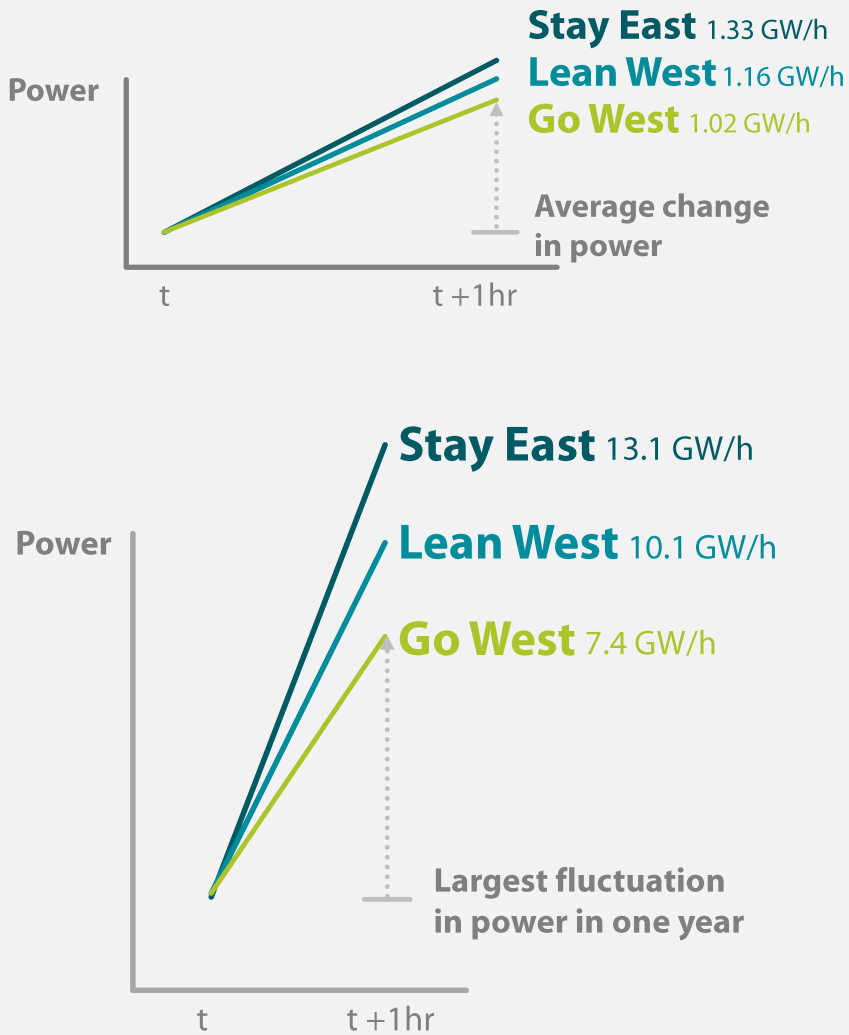
Figure 5: Maximum 'event' duration where offshore wind generation is below 10% capacity factor (20 years of data)
Units: hours

4

…reduces offshore wind generation variability

Figure 6: Ramp rates – the magnitude of hourly fluctuation in total offshore wind power generation

Units: GW/h. Peak change in power per year is the average of the highest ramp rate per year for 20 years of data. Note that these values consider magnitude only and not whether the ramp rate is increasing (positive) or decreasing (negative)

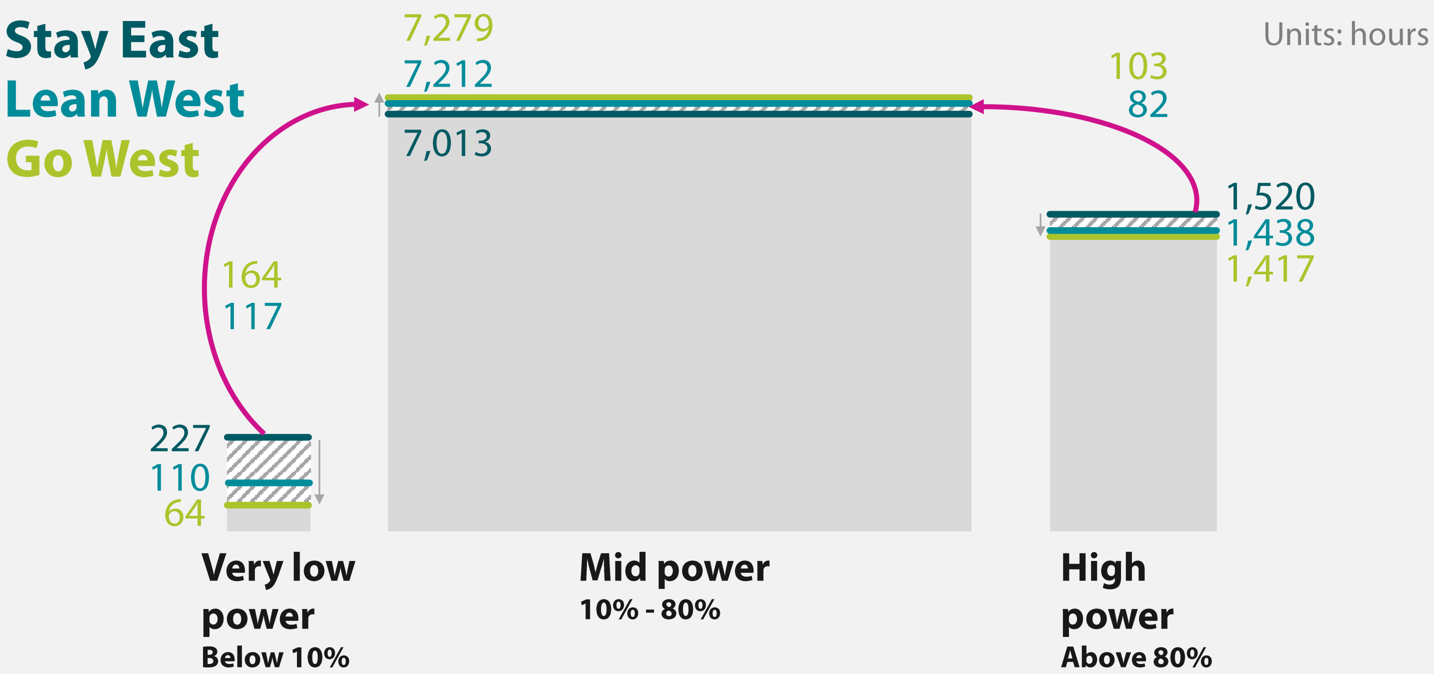


5

…significantly reduces time at very low power ('troughs') and reduces time at high power ('peaks')

Figure 7: Average time per year where the offshore wind fleet is generating at each power level

Units: hours per year. Power level percentages are capacity factors



These results highlight the benefits of a more geographically diverse 'Go West' offshore wind fleet, namely:

- More consistent generation, with reduced duration and occurrences ('events') of high power 'peaks' and low power 'troughs'
- A significant reduction in the longest annual 'event' of very low power[6] (below 10% fleet capacity factor)
- Reduced variability of generation, both hour-to-hour and average annual maximum variability[7]
- No reduction in total energy generation (yield) per year.

The offshore wind power time histories were input into Regen's high-level energy dispatch model, calibrated to reflect National Grid ESO's 2022 Future Energy Scenarios 'Consumer Transformation' scenario for the year 2034. The results highlighted the following benefits of a 'Go West' scenario compared to 'Stay East':

- Increased offshore wind generation
- 17% reduction in the marginal cost of generation[8], as well as reducing price variability by a quarter
- 24% reduction in generation carbon intensity, which almost reaches a level that satisfies the CCC's recommended target of 10 gCO_2e/kWh in 2035
- 6% reduction in renewable curtailment.

There are a number of energy system benefits that can also be achieved with a more diversified offshore wind fleet, as illustrated in Figure 8. These benefits can be grouped into three broad categories (although, in reality, most energy system impacts are interrelated):

1. **Benefits related to the reduction in periods of very low generation, including commodity costs of electricity**, which are driven by increased utilisation of renewable energy and 'merit-order' effects.
2. **Benefits related to the inherent value of geographical diversity of generation,** which improves system resilience and reduces capacity margins and capacity factors. This results in reduced network investment and flexibility costs.
3. **Benefits of lower generation volatility,** including reduced 'ramp rates', which leads to reduced system balancing and operability costs. It also reduces market risk and wholesale price volatility.

[6] Where a 'very low power event' is defined as below 10% capacity factor of the whole offshore wind fleet

[7] Average annual maximum is the mean of the annual maximum value for each of 20 years of data

[8] Marginal cost of generation is the incremental cost incurred when producing additional units of energy

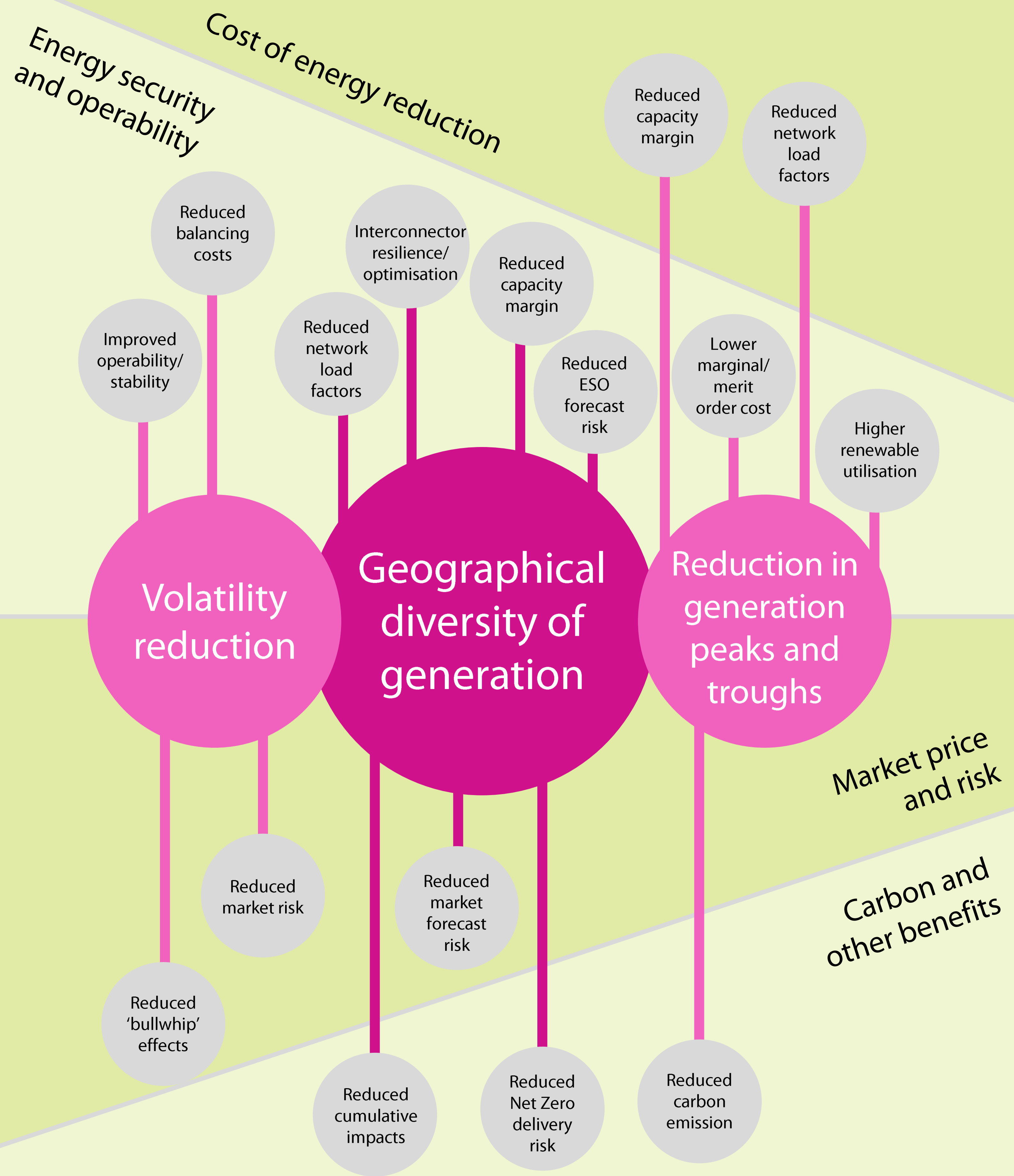


Figure 8: Energy system impacts that can be achieved with a more diversified offshore wind fleet

Benefits related to the reduction in periods of very low generation, including commodity costs of electricity

The *Go West!* analysis highlights a significant reduction in the depth, duration and number of very low wind generation periods resulting from a more diversified offshore wind fleet. Using Regen's high-level dispatch model, this contributed to a reduction in the marginal cost of electricity of 22% (this would be higher if using the current very high cost of gas generation) and higher utilisation of available renewable generation, compared with higher cost and higher carbon fossil fuels, resulting in a 30% reduction in grid carbon intensity, i.e. emissions per kWh generated.

Benefits related to the inherent value of geographical diversity of generation

The more diverse the supply of energy in terms of technology, number of assets, fuel type and geography, the lower the proportional impact of any single failure and, therefore, **the lower the capacity margin needed to maintain a given Loss of Load Expectation**. An increase in the derated capacity of wind generation, and consequently reduced capacity margin requirement, could significantly reduce costs by £75 million per GW of increased offshore wind derated capacity per year[9].

Similarly, diversity of generation can **reduce the overall impact of forecast error**. A concentration of wind turbines in a single weather window means that the impact of forecasting error in that window is amplified, potentially leading to much higher system costs and market price volatility. Diversity of generation across multiple weather windows reduces that risk as an incorrect forecast becomes one of several individual forecasts, thereby reducing its impact overall.

If planned holistically, a more diversified wind portfolio could result in **lower network infrastructure costs** by:

- Spreading variable generation across the network topology and aligning offshore wind with the location of interconnectors and other forms of generation.
- Integrating offshore generation with areas of demand, reducing Transmission Network Use of System (TNUoS) charges for demand customers in areas that regularly require power to be transmitted from other regions.

[9] The 2021 Capacity Market T1 auction clearing price for year-ahead capacity was £75/kW, which suggests a potential annual cost saving of £75 million per GW of increased offshore wind derated capacity.

- Aligning offshore wind generation with new forms of demand and the manufacture and distribution of fuel sources, such as hydrogen.

Conversely, diversity of generation could lead to increased network infrastructure costs if offshore generation is not well integrated with areas of demand, storage and interconnectors.

Diversity of geography and technology are **key components of a smart and flexible future energy system**. As well as balancing national supply and demand, diversity could create more opportunities to increase and optimise energy storage, allow greater use of hydrogen electrolysis at the point of offshore connection, and allow better alignment with interconnectors and Multi-Purpose Interconnectors.

Continuing to deploy offshore wind farms in the same areas has a **cumulative impact** on marine users, the environment, communities hosting infrastructure and other wind farms. At a certain point, these cumulative risks and the absolute reduction of available sea area to develop begin to outweigh the advantage of continuity. Geographical diversity could then become a positive advantage, reducing cumulative development impacts and therefore planning risk, and opening up new areas of resource.

Benefits of lower generation volatility

Go West! shows that a more geographically diverse offshore wind fleet **reduces generation ramp rates** (i.e. reduced generation volatility) from hour to hour. Higher generation volatility increases overall system costs by:

- Increasing the need for balancing market[10] intervention
- Increasing the market price risk for energy traders and supply companies
- Increasing the propagation and severity of ‘bullwhip’ effects (see Explainer: Bullwhip Effects in the main report).

In the 12-month period to June 2022, National Grid ESO measured the **system cost of balancing actions** to be around £2.4 billion. Generation volatility can increase forecast errors and the required level and speed of system intervention. The resource and operational pressure to respond to system imbalances within a one-hour window[11] can lead to suboptimal system

[10] The balancing mechanism is a very short-term spot market, used to balance supply and demand in each half hour trading period of every day. This is done by accepting ‘bids’ and ‘offers’ from individual generators and demand customer to increase or decrease generation or consumption.

[11] The one-hour period between ‘gate closure’ and the settlement period in which energy is delivered

solutions, such as the inappropriate use of large-scale CCGT[12] plants to provide balancing services due to their ease of dispatch relative to more flexible and targeted solutions. With the phenomenal increase in the price of gas in the last year, such actions are becoming a critical driver of increased balancing costs. Generation volatility adds to this time pressure and increases the required level of intervention. So, although the ESO Control Room is investing in automation and digitalisation, volatility is likely to increase balancing costs.

System operability is also an important consideration. Four of the five core elements of operability, as defined by National Grid ESO, are directly impacted by the volatility of generation. Two of these – frequency and stability – would benefit from lower generation ramp rates at a national level.

Generation volatility is a key driver of **overall market price** and a balancing risk for energy supply companies and other energy off-takers/consumers. Volatility in renewable generation can cause significant price changes in the wholesale market and the balancing mechanism. These price changes are partly due to the underlying supply/demand balance and the cost of energy (merit order effects). Still, price swings can be amplified by market factors related to sentiment and speculation, particularly due to a perceived undersupply or oversupply of energy that can cause upward or downward price volatility, respectively. Such price swings result in increased risk for generators and consumers and potential excess profits and rents for energy traders, both of which add to overall energy system costs. It is hard to calculate the degree to which market price volatility constitutes an additional system cost (as opposed to a valid price signal), but it is clear that there has been a significant amount of speculative pricing and uneconomic 'bullwhip' effects during the current energy crisis.

Market price volatility and the risk of price cannibalisation increase **investment risk for renewable generators**. This means that investors in new generation have to secure either higher cost capital or additional mitigation measures, such as revenue support or stability and/or a fixed price guarantee, such as a Contract for Difference (CfD). From a whole system perspective, increases in the cost of capital and investment risk increase the overall economic cost of achieving a given level of decarbonisation and energy security.

Potential energy system costs

Additional project costs to build and operate wind farms in new locations are expected, particularly in deeper waters off the west coast. The extent of this cost increase will depend

[12] Combined Cycle Gas Turbine

on the cost-effectiveness of floating wind and the potential higher energy yield that could be captured from larger turbines further from shore. For this study, we have not considered these to be additional energy system costs, but, of course, this is the fundamental question in the trade-off between building projects with the lowest cost of energy versus building projects that optimise overall system costs.

Primary energy system costs include:

- **Energy generation potential** – system costs could be increased if a more geographically diverse offshore wind fleet had a lower total energy yield. However, *Go West!* wind resource modelling suggests that there is little difference between the east coast-biased 'Stay East' and the more balanced 'Go West' scenarios – in fact, Go West has a slightly higher yield.
- **Grid infrastructure and distance to demand** – a key question is whether the diversification of wind generation to the west increases (or potentially reduces) the overall requirement for both offshore and onshore network infrastructure. The current Holistic Network Design (HND) and Offshore Transmission Network Review (OTNR) initiatives consider the overall grid investment and cost of operation associated with different offshore and onshore network topologies. The holistic approach of the HND methodology could be used to conduct a scenario analysis to ascertain the comparative infrastructure costs of a more 'West-leaning' or 'Go West' portfolio. As previously highlighted, based on current TNUoS charges, there is a good argument in favour of more generation in the Celtic Sea area. The case for the North and West of Scotland will depend on the design and cost of the necessary transmission links to demand centres in North West England and ongoing interconnection to Ireland and Western Europe.
- **Potential loss of economies of scale in infrastructure capital and operational expenditure** – this would affect the upfront capital cost and subsequent operation of supporting system infrastructure. Economies of scale could be maximised by building multiple wind farms in the same area from a small number of super-ports, then connected to a handful of super-sized offshore transmission networks and onshore sub-stations. A key question to be addressed is whether the costs of diversifying generation, which may require new ports and network infrastructure, are offset by regional economic benefits and the reduction of cumulative impacts, as mentioned previously.

Delivering a more geographically diverse offshore wind fleet to capture these system benefits will require policy innovation. The following pages detail Regen's policy recommendations.

Recommendations

An integrated, strategic approach to offshore development, leasing and planning:

1. Central and devolved governments, The Crown Estate, Crown Estate Scotland, system operators, networks and regulators need to work together with the offshore wind industry to develop an overarching delivery plan.
2. This delivery plan should include a high-level geographic plan that recognises the energy system, energy security and regional economic benefits of a more geographically diverse wind portfolio.
3. Further research is recommended to fully quantify the energy system benefits and regional growth opportunities of different offshore wind portfolios.
4. Seabed leasing and an accelerated consenting process should be aligned with the long-term delivery plan. They should give transparency and confidence as early as possible to wind farm developers and investors in port infrastructure, manufacturing and supply chain capability and capacity.
5. The Crown Estate's increased ambition for 4 GW of floating wind in the Celtic Sea by 2035 is welcome. However, there is an urgent need to set out the long-term plan for the Celtic Sea area, including the Western Approaches to the English Channel.
6. Offshore wind development needs to be aligned and integrated with the use of conventional and Multi-Purpose Interconnectors (MPIs) to neighbouring energy markets, including Ireland and Western Europe.

Financial mechanisms that support increased diversity of supply:

1. The Contracts for Difference (CfD) mechanism should continue to provide revenue stability for less-established innovative technologies until they reach competitive scale. For floating wind, this means allocating a sufficient strike price and retaining a separate allocation pot and/or a 'minima' budget allocation provision through Allocation Rounds 5, 6 and 7, at least.
2. The government should consider a means to providing a geographic locational signal (distinct from Locational Marginal Pricing) within the CfD scheme that supports diversity of supply. This could be achieved in several ways, such as:
   a. Running a specific Allocation Round for floating wind projects to support their deployment on the west coast.
   b. Running bespoke regional CfD rounds or rounds with regional minima.
   c. Focusing support for floating wind, tidal and other technologies that offer more geographic diversity.

3. The government could consider an energy system value strike price differential within the CfD allocation round. However, this approach may be difficult to calculate and administer.

Infrastructure investment, innovation and supply chain development:

1. Continue, extend and accelerate the process of Holistic Network Design to ensure that offshore and onshore network investment is in place to support offshore wind and interconnector development.
2. Building on the current Offshore Transmission Network Review[13], implement changes to the regulatory framework that will allow both greater collaboration in the development of offshore transmission networks and strategic investment in shared network infrastructure, including MPIs.
3. Extend, increase and accelerate support for port infrastructure development, building on schemes such as the Floating Wind Manufacturing Investment Scheme (FLOWMIS)[14].
4. Establish a coordinated approach to developing regional supply chains in England, Wales and Scotland, extending across to Northern Ireland and the Republic of Ireland. This should build on existing capabilities, such as those that Regen has identified in South West England[15] and by the Offshore Renewable Energy Catapult in Wales[16] and across the UK[17].
5. Expand levelling-up schemes, such as Offshore Wind Growth Partnership[18] and Fit 4 Offshore Renewables[19], to grow a western supply chain basis capable of deploying at scale.

[13] Offshore Transmission Network Review

[14] See Regen's response to the FLOWMIS consultation

[15] Floating Offshore Wind Opportunity Study, Regen, 2022

[16] Benefits of Floating Offshore Wind to Wales and the South West: Supply Chain Report, ORE Catapult, 2020

[17] Strategic Infrastructure and Supply Chain Development, Floating Offshore Wind Centre of Excellent - ORE Catapult, 2022

[18] Offshore Wind Growth Partnership

[19] Fit 4 Offshore Renewables, ORE Catapult

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