REPORT

Network-DC

Policy, regulatory, and commercial obstacles to the uptake of Direct-Current Circuit Breakers: findings and recommendations

2026

Acknowledgments

The Carbon Trust wrote this report based on an impartial analysis of primary and secondary sources, including expert interviews.

The Carbon Trust would like to thank everyone that has contributed their time and expertise during the preparation and completion of this report.

This report was commissioned by Scottish and Southern Electricity Networks Transmission (SSEN Transmission) and delivered as part of a project funded through the Strategic Innovation Fund (SIF), an initiative led by Ofgem in partnership with UK Research and Innovation (UKRI). For the avoidance of doubt, this report expresses the independent views of the authors.

Who we are

Our mission is to accelerate the move to a decarbonised future.

We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions globally. From strategic planning and target setting to activation and communication - we are your expert guide to turn your climate ambition into impact.

We are one global network of 400 experts with offices in the UK, the Netherlands, South Africa, China, Singapore and Mexico. To date, we have helped set 200+ science-based targets and guided 3,000+ organisations in 70 countries on their route to Net Zero.

Authors

Helen Andrews Tipper

Global Head of Policy

Helen.andrewstipper@carbontrust.com

Karolina Zieba

Senior Associate

Karolina.zieba@carbontrust.com

Fred Stace-Smith

Senior Analyst

Fred.stacesmith@carbontrust.com

Contents

Executive summary

The need for High-Voltage Direct Current (HVDC) offshore networks was universally acknowledged by the stakeholders who contributed to the research behind this report. It was also widely acknowledged that **direct-current circuit breakers (DCCBs) are highly likely to be the most cost-effective solution to provide the fault interruption necessary to enable delivery at scale.** These stakeholders included **government bodies, industry, and academia**, enabling us to explore the challenge from every perspective.

Whilst the need for HVDC networks is clear, their development will entail a significant shift from the status quo and a very significant level of investment from the private sector into what some still perceive to be a risky solution, both in terms of meshed networks and the DCCBs themselves. DCCBs have been demonstrated in China but many still consider them insufficiently tested in Europe. Furthermore, the Clean Power 2030 target is driving both government bodies and the market to deliver at speed, but the coordination required to deliver meshed networks means their build-out takes longer than a point-to-point network. **There is a potential tension between the need to deliver at speed and the need to deliver coordination; if not addressed it could lead to the 'over-deployment' of point-to-point connections at the expense of HVDC offshore networks, resulting in higher costs and community disruption.**

The UK Government has a target of 43-50GW of offshore wind capacity by 2030[1]. This is a significant scale-up compared to installed capacity in 2020 (10.4GW) or 2024 (14.7GW)[2]. **Ensuring that grid infrastructure planning is timely and well-coordinated is critical to meeting this target**, as well as the 2050 target of up to 125GW.[3] Offshore wind projects are capital-intensive and involve long-term commitments, with business plans and stakeholder agreements often locked in after auctions and leases. Once auctions are underway or leases are signed, it becomes difficult to change business plans, stakeholder agreements, and transmission plans. Transmission infrastructure, especially offshore HVDC networks, is characterised by long lead times, delays in planning and stranded asset risks, inefficient connections, and delays in deployment. Late changes can trigger costly renegotiations, legal disputes, and undermine stakeholder confidence. **Planning for HVDC networks now is critical to ensure they can contribute to the future GB energy system.**

A successful energy transition is dependent on achieving buy in from the British public and consumers, whose priorities are affordability and reliability. If the GB offshore grid remains dominated by radial connections without meshed networks, the system will have **reduced flexibility and the full integration and benefits of offshore renewables could be curtailed**. In order for meshed networks to operate effectively, they need to include fast-acting fault interruption technology, such as DCCBs.

[1] UK Government - DESNZ (2024) Clean Power 2030 Action Plan

[2] UK wind and global offshore wind: 2024 in review

[3] Offshore Wind Report 2024 | The Crown Estate

Stakeholder engagement highlighted four key areas where action is needed:

(1) **Current governance structures or their limitations have resulted in market inertia and the mutual deferral of responsibilities**. The energy system is complex and involves a large number of actors and institutions. As DCCBs do not have a natural 'champion' within the system, in the absence of a clear assignment of responsibility, progress has been limited. Stakeholders felt that the current governance limitations have contributed to a lack of clarity over which actions should be undertaken by which party to support DCCB and meshed network development. This was echoed during stakeholder engagement as well as being highlighted in consultation responses, such as the Scottish Renewables CSNP consultation response that stated "a need for clear governance structures to define how various processes interact within the energy sector…"[4] Whilst it is beyond the scope of this report to propose new governance structures, our recommendations focus on the steps to enable their creation.

(2) While regulations in the form of Grid Code and Security and Quality of Supply Standard (SQSS) do not represent a significant barrier, **industry will need to agree on the necessary changes and initiate the request to Ofgem** to make any necessary changes. It is critical that **regulation does not impede innovation by regulating ahead of technology development**.

(3) Industry stakeholders indicated that, due to the significant financial cost and limited options for revenue generation**, a dedicated business model is likely to be required to support the deployment of DCCBs and meshed networks**. We suggest that, alongside engaging with the CSNP development process, industry explore this further and, if deemed necessary, develop a needs case and engage with DESNZ and NESO to ensure mutual understanding of the opportunities and barriers.

(4) **Further reform to network build and procurement models,** continuing Ofgem's consideration of Offshore Transmission Owners (OFTO) build models, was noted by stakeholders as necessary to create a more favourable environment for the deployment of DCCBs and wider HVDC meshed networks.

[4] SR Response: Centralised Strategic Network Plan (CSNP) draft methodology consultation

Introduction

The Network-DC project

Network-DC is a collaborative Strategic Innovation Fund project focusing on the development of high-voltage DCCBs in GB. As part of the Beta Phase of the project, the Carbon Trust is seeking to identify the policy, regulatory, and commercial barriers that might support or hinder their deployment in the GB market. The Alpha Phase concluded in 2022 and produced a list of 37 recommendations to reduce these barriers to DCCBs, including the responsible 'action owners'. This report summarises the Beta Phase findings, including a review of the Alpha Phase recommendations in the context of an evolving landscape and the summarised findings of extensive stakeholder.

Why does the GB system need meshed networks and DCCBs?

The UK Government has set an ambitious target of 43-50GW of offshore wind capacity by 2030[5] as a key part of its Clean Power by 2030 Mission (CP30); this represents a significant increase from the UK's current operational capacity of 14.7GW[6]. Progress on deploying offshore wind farms (OWFs) to date has been good and is expected to continue, with an additional 22.85GW of offshore wind capacity in the planning system[7]. However, this rapid expansion requires a corresponding increase in both on- and offshore network transmission infrastructure, including AC and DC cabling, converter stations, substations, and connection points. The financial and material cost of deploying such networks is huge; European Network of Transmission System Operators for Electricity (ENTSO-E) estimates that, by 2050, approximately €400bn of investment and up to 54,000 km of offshore network 'routes' across Europe[8] will be needed to integrate offshore wind energy[9]. The potential for network infrastructure to act as a bottleneck for wind deployment (in large part due to cost, planning, and construction times) has led to a renewed consideration of how offshore grids can be optimised and made more cost-effective; meshed networks are one possible solution.

Whereas traditional radial networks connect one offshore asset to the shore via a single route, meshed networks allow multiple offshore assets to share transmission routes to and between countries. Crucially, meshed networks also integrate interconnectors, allowing power to flow from an OWF to multiple

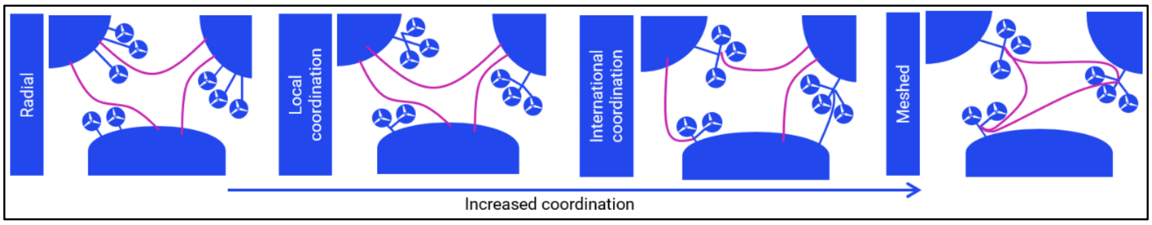


Figure 1: Illustration of different types of grid interconnection. Adapted from [Benelux (2012)](#)

[5] UK Government - DESNZ (2024) Clean Power 2030 Action Plan

[6] RenewableUK (Feb 2025) UK wind and global offshore wind: 2024 in review

[7] RenewableUK (Feb 2025) UK wind and global offshore wind: 2024 in review

[8] EU27 + Norway + GB

[9] ENTSO-E (Jan 2024) TYNDP 2024: Offshore Network Development Plans – Transmission Infrastructure Needs

electricity markets, unlike traditional point-to-point interconnectors. Figure 1 shows different levels of coordination that can be achieved (from the left):

- Radial connections transport energy from one source of generation to one source of demand
- Local coordination allows nearby generation sources to coordinate via a shared landfall
- International coordination allows cross border networks to connect, either directly through interconnectors or indirectly through multi-purpose interconnectors (MPIs), which combine interconnection with offshore wind asset transmission
- Meshed coordination is a complex system where multiple sources of generation are connected to multiple sources of demand and can be national or international.

Methodology

Our approach to the Beta Phase and the production of this report involved:

Literature review and Alpha Phase refresh

This analysis began with a desk-based literature review focused on updates to policy and regulation and technical progress on DCCBs since the Alpha Phase report. This allowed us to establish the overall landscape and any changes in the preceding four years. While there were some changes, primarily arising from the National Energy System Operator (NESO) strategy and forward-looking plans, the overall DCCB regime has not changed or progressed significantly since 2021. Where appropriate we drew on the analysis conducted by Mott MacDonald as part of the Network DC project, in particular the cost benefit analysis. We also drew on the knowledge of experts at Carbon Trust and in the wider Network DC project consortium.

Stakeholder engagement

We conducted semi-structured interviews with ten stakeholders from across industry, government, regulators, academia, and networks. Insights from these interviews were used to develop and test hypotheses on the barriers and enabling factors, and insights on the views around roles and responsibility for actions on DCCBs. Stakeholders were selected for their role or interest in the technological development, manufacturing, deployment, and ownership and operation of DCCBs or meshed networks. A list of organisations consulted is included in Annexe 1.

We also conducted one online stakeholder workshop attended by 9 people from 5 organisations and one facilitated discussion attended by 8 people from 7 organisations, with the goal of achieving consensus over what actions are needed to advance the deployment of DCCBs, an approximate timeline, and who should be responsible for each action. While agreement on who is responsible for each action could not be reached in the time available, there was broad consensus over what needs to be done and the overall timeframe.

1. The role of DCCBs in enabling meshed networks in GB

HVDC meshed networks have the potential to be more cost effective than traditional radial connections and facilitate greater capacity in some cases.

Whilst radial connections will continue to form the majority of the network, in some scenarios a meshed network could offer significant efficiency gains. Through sharing network routes or connecting to pre-existing routes, more offshore wind assets/farms can be deployed and at a faster rate, largely due to the reduced need for transmission cabling and onshore landing points. **Modelling by ENTSO-E indicates that for the same cost (€148bn), an additional 14 GW of transmission capacity could be deployed in the EU27 through the strategic use of meshed networks**[10]. The cost benefits of meshed networks stem primarily from the reduction in required network build-out. There are also environmental and maritime benefits from reduced undersea cabling and onshore landing points. Furthermore, meshed networks have lower CO_2 emissions due to reduced embodied emissions from materials and construction. Results of the cost benefit analysis[11] show a significant financial saving – up to £834m in relative NPV over an assets lifetime (~35 years) – when using meshed networks with DCCBs compared to non-meshed networks, largely resulting from significant material and installation savings, but also gains to be realised from a more efficient system operation and power flows. Nevertheless, there are challenges around anticipatory investment and stranded assets, particularly given the scale of investment, that must be reduced to an acceptable level of residual risk if meshed networks are to be viable.

HVDC meshed networks at scale require effective fault interruption devices in order to operate reliably

The increased connectivity of meshed networks leads to a heightened risk of cascading, network-wide uncontrolled faults because currents can flow from several directions. In a meshed configuration, a major infeed loss can escalate into equipment damage or trigger a widespread outage[12]. Beyond routine fluctuations and technical faults, this scenario has serious national security implications, particularly if a single point of failure could lead to such extensive disruption. To avoid these scenarios, a fault must be isolated quickly and selectively.

Effective fault interruption devices isolate the faulty section, essentially localising the fault while keeping the rest of the network in service. This capability is crucial for both safety (preventing fire, equipment failure, hazards) and reliability (maintaining supply to unaffected areas).

Fault interruption devices are also critical to enabling the deployment of more international interconnection. ENTSO-E found that the availability of DCCBs could triple the level of interconnectivity in

[10] ENTSO-E (Jan 2024) TYNDP 2024: Offshore Network Development Plans – Transmission Infrastructure Needs

[11] Undertaken by Mott MacDonald as part of the Network-DC project.

[12] 141203_gsr015_decision.pdf

Europe by 2050 while costing only 3% more in comparison to an entirely point-to-point system[13]. Interconnection is recognised as supportive of flexibility, security of supply and resilience, emissions reductions, and contributing to cost reduction through competition. Interconnection also enables economies of scale by allowing systems to share reserve capacity, which enhances reliability during periods of domestic stress or renewable intermittency.[14] Moreover, hybrid transmission corridors (MPIs) offer significant advantages in terms of reduced build time and cost, more efficient use of materials, and greater operational flexibility.

High speed DCCBs are emerging as the preferred solution for safely clearing faults in meshed DC networks.

DC networks are harder to interrupt than AC networks. The main technology enabling fault interruption in meshed DC networks are DCCBs. There are three main types of DCCB: mechanical, solid-state, and hybrid. The first DCCBs were mechanical, with the first large-scale deployment in the Nan'ao HVDC project in China (2017). Solid-state DCCBs are theoretically very fast, but incur serious losses so are not used at scale. Hybrid DCCBs are currently seen as the most promising solution as they deliver quick interruption with limited losses. These hybrid solutions have been successfully applied in Zhuhai and Zhangbei, China[15].

While DCCBs have been successfully deployed in China, they have not been demonstrated at scale in Europe. The largest Chinese implementation was within a relatively small DC system embedded in a very large AC network, meaning any malfunction would have limited impact. This differs from a scenario where DC links are integrated into smaller AC networks, as in the Network DC hub case, where a fault or failure could have far more significant consequences for system stability. Between 2016 and 2018 an EU-funded Horizon project, "Progress on Meshed HVDC Offshore Transmission Networks" (PROMOTioN), successfully tested and demonstrated DC fault current interruption in lab conditions with DCCBs. ENTSO-E estimates the DCCB Technology Readiness Level (TRL) as being between 5 (technology basic validation in a relevant environment) and 6 (technology model or prototype demonstration in a relevant environment).[16]

One primary advantage of hybrid DCCBs is their operational efficiency, which means they introduce minimal losses when the system is running smoothly with no faults. Hybrid DCCBs work within a few milliseconds, offering the additional benefits of fast interruption.

Due to their high cost, DCCBs are not the most cost-effective in all cases, but they are often viewed as essential to complex, meshed HVDC networks as they provide fast, selective isolation with minimal disruption.

---

[13] ENTSO-E (Jan 2024) TYNDP 2024: Offshore Network Development Plans – Transmission Infrastructure Needs, webpage

[14] Billinton, R. & Allan, R. N. (1996) Reliability Evaluation of Power Systems, Springer New York

[15] Chen, W. et al. (2021) Development and prospect of direct-current circuit breaker in China, *High Voltage*, 6: 1-15

[16] HVDC Circuit Breakers

2. Policy, regulatory, and commercial barriers to DCCB deployment in GB

Whilst stakeholder discussions and desk research both indicate that there are no inherent technological, commercial, or regulatory barriers to the deployment of DCCBs from the mid-2030s, there are significant challenges to the development and delivery of meshed networks. DCCBs are likely to be necessary for meshed networks and meshed networks represent the largest use case for DCCBs. Many of the barriers that we outline below relate therefore both to meshed networks as a whole, and by extension to DCCBs as a specific component.

Unless something changes to enable buyers to adopt DCCBs, the status quo of favouring point-to-point and radial network connections is unlikely to change. This has led to a lack of confidence in some OEMs that there is a market for DCCBs in the UK. Overcoming this negative feedback loop is particularly challenging for policymakers and developers.

1. Despite agreement on the value of DCCBs, the current lack of clarity around business models and governance responsibilities is holding back investment decisions

All stakeholders agreed that meshed networks would, in principle, benefit GB in terms of cost effectiveness, reduced environmental and onshore community impact, and an optimised energy system. Stakeholders also agreed that DCCBs are a necessary feature of meshed networks and are therefore likely to form an important part of the future GB energy system. However, there are still significant challenges that are hindering the development of meshed networks and therefore the future deployment of DCCBs in GB. There was stakeholder consensus from both government and industry bodies that there is a pressing need to review and possibly revise governance arrangements to give clarity and confidence to all parties, including OEMs and investors.

2. There is a potential tension between build out at speed and build out with coordination and meshed networks

Through stakeholder interviews and facilitated discussions we noted a lack of certainty over the commitment to meshed networks in GB, both by government and industry. Several stakeholders noted the potential tension between the prioritisation of building out offshore wind networks at speed, with the government Clean Power 2030 target and the supporting Clean Power Mission requiring significant time and resources, and the slower process for delivering coordination and meshed grids.

Planning and modelling, likely to be undertaken by NESO and Ofgem with input from DESNZ, would be required to sufficiently 'forward plan' offshore networks and ensure that the potential benefits of meshed networks are realised. Results from the cost-benefit analysis (CBA) modelling show that non-coordinated, radial build out prior to 2030 does not impact the CBA case for DCCBs, provided that this radial build does not detract time, focus, or funding from meshed networks post-2035.

3. Meshed networks pose greater delivery risks than radial connections because they require anticipatory investment and carry a higher likelihood of stranded assets

While support for coordinated networks is not incompatible with a short-term prioritisation of offshore wind deployment at pace using point-to-point connections, there is a risk that by focusing limited resources on short-term build out, the necessary work to bring meshed networks to market may be delayed. Despite recognising the system value of DCCBs, key stakeholders operate in restrictive regulatory and financing regimes which limit their ability to invest. Given the risks around anticipatory investment and stranded assets, it is likely that the government will have to make significant interventions to enable investors to commit. Determining and developing these interventions will require significant government time and resource.

4. The uncertainty around the future role of meshed networks in the GB system is currently a significant obstacle to investment

Stakeholders expressed a lack of clarity over which organisations are or should be driving forward progress on meshed networks and DCCBs. This issue is compounded by the growing complexity of offshore energy infrastructure and the number of actors involved. The scale, costs, and current level of perceived and actual risk are contributing to the general reluctance to be the first mover and industry is looking to government for clear direction.

There was significant debate among stakeholders over whether current policy signals were already clear enough to drive investment by OEMs and potential buyers, such as Transmission Operators (TOs), and a recognition that a policy signal can only be considered effective if the market recognises it as such. The CSNP will underpin future network planning and stakeholders largely felt that little progress can be made until its publication in 2027, since delivery of meshed networks is largely dependent on network design. This gives the CSNP and NESO a significant degree of effective responsibility but concerns have been raised that this responsibility has not been effectively formalised, with the necessary transparency, engagement, and accountability frameworks[17].However, there was consensus that a governance refresh with greater transparency, new structures and channels of communication would significantly contribute to unblocking the current situation.

5. Given the cost of manufacturing DCCBs, uncertainty over the role of meshed grids, and the need for further technology development, DCCBs will not be produced ahead of demand and available for purchase at the time of need

Due to the long procurement, manufacturing, and testing timelines, as well as the need to resolve remaining technical uncertainties, DCCBs are not expected to be deployed until the early 2030s at the earliest. However, to achieve deployment in the mid-2030s the procurement process by DCCB buyers would need to begin imminently (see figure 2 timeline below). While vendors are confident in the current technology levels, the as-yet untested nature means that deployment is likely to take several years.

[17] Scottish Renewables (Aug 2025) Response to the Centralised Strategic Network Plan draft methodology consultation

Organisations such as DESNZ, Ofgem, and NESO typically have publicly stated priorities but these are often relatively high level[18]. For the OEMs who will be required to manufacture DCCBs, this level of commitment may not be enough to give them confidence to invest in developing new technology for sale in the GB market. DESNZ reiterated their commitment to coordinationrepresentati through the engagement process in the project, highlighting the role of National Policy Statements and the Centralised Strategic Network Plan (CSNP) under development by NESO. However, DESNZ and NESO also highlighted that they cannot specify which technology buyers should use to enable meshed networks. Again, improved governance arrangements could open channels of communication between industry and government, allowing them to identify and resolve issues more effectively and create greater confidence on all sides.

[18] For example, see NESO's strategic priorities and commitments Strategic priorities | National Energy System Operator

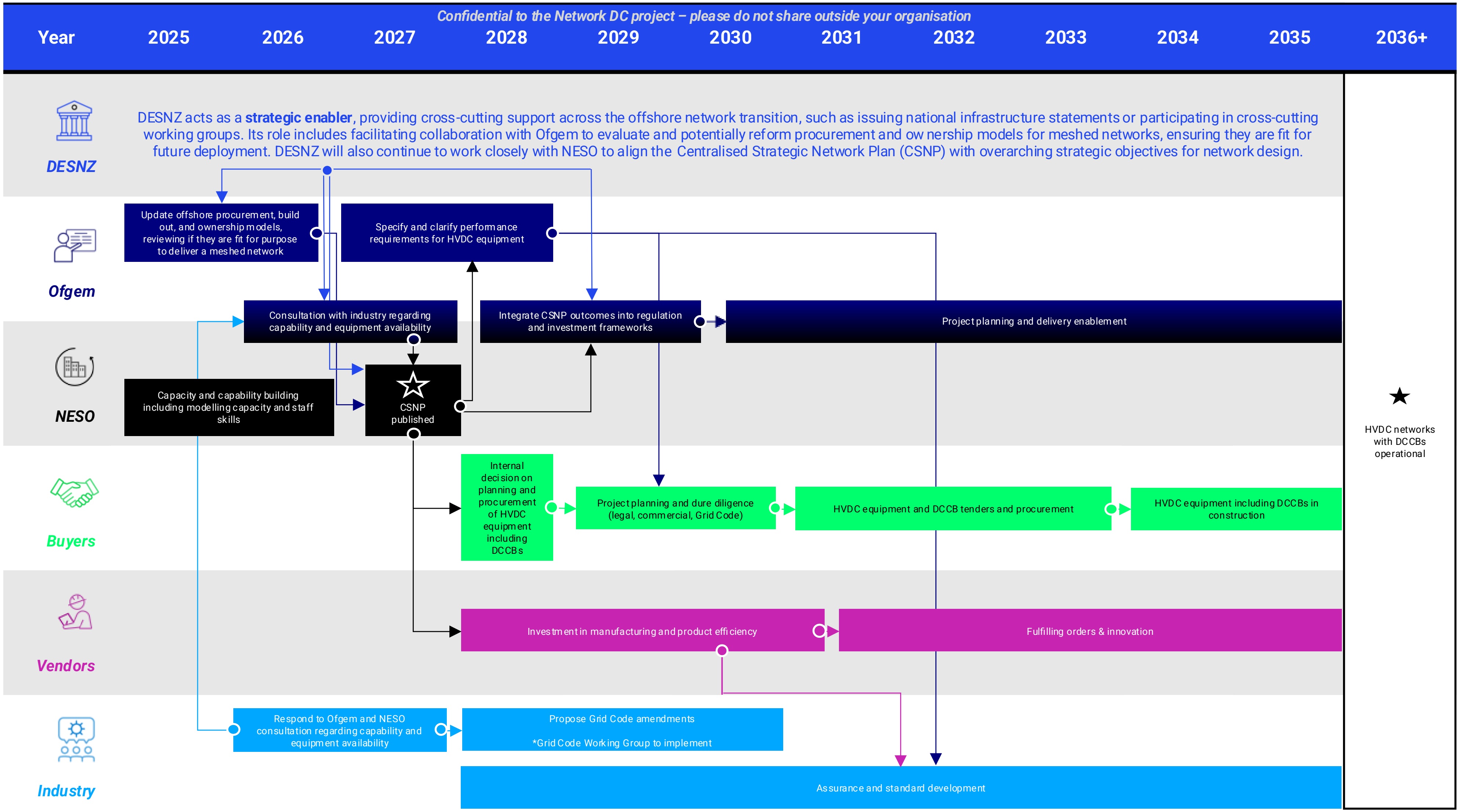
3. Commercial, policy and regulatory recommendations to enable GB DCCB deployment

The following recommendations have been developed using stakeholder interviews, collaborative stakeholder workshops, and the expertise of Carbon Trust and the wider Network DC project team.

Our recommendations have been formulated to comprehensively address the challenges identified above. Those barriers are complex and often mutually reinforcing. The recommendations below seek to identify the key points of leverage to create positive change in the current system.

Given that the need for actions in the short-term to enable long-term outcomes, we co-created an indicative timeline of actions and action owners with relevant stakeholders (figure 2). It should be noted that stakeholder input was representative rather than exhaustive (e.g. one OSW developer engaged in the process) and further iteration of the timeline may be necessary. The timeline illustrates the importance of near-term actions due to the long lead and build out times of meshed networks and DCCBs. It also highlights the importance of collaboration and coordination.

Figure 2: Indicative timeline for DCCB deployment in GB co-created with stakeholders and including action owners



Recommendation 1: Governance arrangements to enable the development and delivery of meshed networks and DCCBs should be revised and adequate resource allocated by all parties

Effective governance supports sound and accountable decision-making, appropriate allocation of resources, clarity on responsibilities and accountability, and good communication and engagement. Good governance is particularly important in complex stakeholder landscapes or where roles and responsibilities and the allocation of risk is challenging. As described above, a stakeholder consensus emerged during this project on the possibility that many of the current commercial challenges could be resolved by improved governance structures and processes. There was both government and industry support for a 'governance reset'.

This could be initiated and led by DESNZ but would require buy-in from across industry and the energy landscape. Meaningful governance reform is also likely to be seen as a strong positive signal of intent towards meshed networks and DCCBs, which was raised by industry stakeholders as key to their commitment to the GB market. Stakeholders noted that the publication of the CSNP was itself a major 'reset moment'; ensuring governance reforms are ready at the same time could increase their impact.

The creation of new governance arrangements to ensure transparency and accountability between government, industry and investors is beyond the scope of this project, but suggested actions to create a new governance structure and high-level principles for governance are outlined below.

Proposed action	Suggested action owner
1.1 A comprehensive assessment of existing governance arrangements, including formal and informal groups, to establish gaps and overlaps	NESO/DESNZ/Ofgem
1.2 Development of proposed new or amended governance arrangements, taking advantage of existing structures but creating new ones where necessary	NESO/DESNZ/Ofgem
1.3 Consultation with implicated stakeholders on the new governance arrangements to ensure both that they are fit for purpose and have buy-in	NESO/DESNZ/Ofgem
1.4 Implementation of new governance arrangements, led by an appropriate stakeholder	TBC depending on the chosen structure

Recommendation 2: Regulatory change is not a major barrier, but industry will need to agree on the necessary changes and request Ofgem make the Grid Code amendments

Current regulation does not include any direct provisions for DCCBs. However, the stakeholders consulted and experts in the Network DC project consortium did not foresee this being a significant barrier to the deployment of DCCBs or HVDC meshed networks. Several stakeholders noted that existing regulations relating to AC circuit breakers and fault interruption devices could be adapted to cover DCCBs. Existing Grid Code includes requirements for installation and operation, as well as technical requirements on performance, fault clearance, and back up protection for AC circuit breakers. Stakeholders felt that regulations and specifications for DCCBs are unlikely to be significantly different to existing provisions, meaning the development of DCCB-specific regulation should be relatively rapid and straightforward. There are also no prohibitive regulations that currently prevent DCCBs from being deployed.

Ofgem highlighted that they can only proactively instigate large-scale reviews and would therefore only be able to action any necessary minor Grid Code changes in response to an external request. This would therefore require industry consensus on the Grid Code change needed, and a specific organisation to raise the request.

The process for regulating meshed networks could resemble the Offshore Hybrid Asset (OHA) pilot scheme[19], where a preliminary regulatory regime was designed for a pilot scheme, the learnings of which will feed into a permanent regulatory framework. This is intended to create speed and flexibility in the development of demonstrator/trial projects, which are important for bringing technologies to market. Ofgem's decision to grant a pilot OHA regulatory regime in principle to the LionLink (1.8 GW to the Netherlands) and Nautilus (1.4 GW to Belgium) projects reflects growing confidence in the consumer value of coordinated offshore transmission.[20]

DESNZ have expressed concerns around regulating HVDC networks and components while the technology is still being developed, fearing that over regulation could rule out possible beneficial technologies or solutions. Taking a facilitative approach of specifying minimum performance requirements and specifications is likely to be more appropriate given the speed of technological development and value of developing new and emerging technologies.

Proposed action	Suggested action owner
1. Industry bodies to begin Grid Code revision request process with NESO	TOs with support from HVDC Centre
2.1 Reach agreement on minimum standards or technology specifications that must be met	TOs with support from HVDC Centre
2.2 Ofgem to decide on initial, indicative regulatory regime to support pilot DCCB/meshed network project	Ofgem

[19] Ofgem (Feb 2024) Decision on the Regulatory Framework for the Non-Standard Interconnectors of the Offshore Hybrid Asset pilot scheme

[20] Ofgem (Nov 2024) Decision on the Initial Project Assessment for the Offshore Hybrid Asset Pilot Projects

Recommendation 3: Consider reform to delivery and procurement models to aid industry decisions.

There was general consensus among stakeholders that reforms to the procurement and delivery model for offshore networks should be considered in order to better deliver complex infrastructure such as meshed and multi-terminal networks.

It was noted that the current 'developer build' model for offshore development, which sees wind asset developers building the transmission network before transferring ownership and operation to an OFTO, is not suited to meshed networks, which require grid-sharing, collaborative planning and interoperability.

Ofgem have recognised this emerging challenge and conducted a consultation on introducing an OFTO-build model[21], concluding that such a build model would be valuable, but shifting from a 'late' to 'early' model to better integrate different actors in the development, procurement, and build process[22].

Evaluating the implications of different ownership and build out arrangements for offshore wind transmission infrastructure is essential. A centralised ownership structure, where a single entity (a public or regulated body) owns and operates the central infrastructure, including the central substation and associated equipment, can offer advantages for market integration and technical standardisation. This model simplifies expansion, reduces legal and regulatory barriers, and provides clear lines of responsibility and accountability.

Alternatively, a distributed ownership model involves individual developers or transmission system operators owning both the offshore terminal and the cable connecting to the central DC substation. This approach can expedite investment and project delivery, as each participant is responsible for their own assets and business case. However, it is likely to require careful coordination to ensure interoperability, reliability, and equitable cost and risk allocation.[23]

We recommend that Ofgem continues to consult on introducing this model and should consider an expanded scope to reduce risks for developers and generate greater commercial viability of projects (see recommendation 4).

Proposed action	Suggested action owner
3.1 Continue considering reforms to build and ownership model, with particular focus on enabling meshed networks and DCCBs.	Ofgem

[21] Ofgem (Dec 2024) OFTO build model: policy update

[22] Under Ofgem's OFTO build model, 'late' and 'early' refers to the point at which OFTOs engage in the design and construction process. Under the early model, OFTOs would be involved in the design, planning, and procurement stage, rather than merely being engaged at the construction stage (late model).

[23] Jovcic, D. (2022). *High Voltage Direct Current electrical systems, as facilitator of largescale offshore wind generation, oil platform electrification, and green hydrogen integration, in the Scottish context*. Report prepared for Net Zero Technology Centre.

Recommendation 4: Exploration of the need and possible form of a government-backed DCCB business model to reduce investment risk to an acceptable level

Stakeholders consistently noted that DCCB or meshed network deployment is likely to be limited without significant change to the current environment, such as the development of a business model that reduces the current level of risk. High capital costs and limited options for revenue generation, alongside anticipatory investment challenges and stranded asset risks, arguably place meshed networks alongside technologies such as nuclear, carbon capture, usage and storage (CCUS), hydrogen, and offshore wind, all of which are being (or will be) supported through business model schemes.

There are several investment challenges specific to deploying and operating a DCCB in a meshed network:

- **High capital costs**: the exact cost of DCCBs is withheld but is expected to be in the region of £40-60 million. With no prospect for payback until installed and operational, this represents a significant upfront capital expense for buyers and/or developers. It is expected that the cost will fall over time, as economies of scale and improvements in manufacturing develop.
- **Limited options for revenue**: as transmission infrastructure, DCCBs are expected to be owned by OFTOs, who would receive fixed revenue payments in line with the OFTO regime. OFTOs noted that, without an additional subsidy or revenue stream, there is a very limited financial case for investing in meshed networks and DCCBs. OFTOs also noted the innovative aspect of DCCBs and the challenge of a highly-regulated regime, which can serve to limit innovation that may add to consumer bills.
- **High insurance premiums**: given the critical importance of DCCBs and scale of potential impact if they go wrong, OFTOs noted the prohibitively high insurance that would be required to hedge against faults. Equally, building duplicates would be expensive although they are expected to be the most likely or realistic option for ensuring fault interruption.

Despite the system wide benefits and economic savings, the investment case for individual developers and/or buyers is therefore currently insufficient. Greater certainty through the CSNP may or may not be sufficient to improve the investment case.

The exact form of a business model for DCCBs was not discussed but it was noted that a Regulated Asset Base (RAB) could be suitable given the high capital cost, limited revenue generation options, and presence of a natural monopoly. RAB models are typically used for large infrastructure projects and are used for nuclear generation; these models provide the license holder with a fixed payment for providing a set service, e.g. fault interruption.

Proposed action	Suggested action owner
4.1 Further exploration of options to overcome the current investment challenges for meshed networks and DCCBs	Industry trade association
4.2 Engage in dialogue with DESNZ and NESO on how to overcome investment challenges	Industry trade association
4.3 If deemed necessary by industry, develop the needs case for a government business model to enable investment	Industry trade association

4. Annexe

The findings reflect perspectives shared during interviews with diverse organisations spanning policy, operations, and industry. Engagement was conducted on a confidential, non-attributable basis to encourage open dialogue. In total, 15 unique stakeholder organisations were engaged. The stakeholder categories engaged include:

- NESO
- DESNZ
- Ofgem
- Offshore wind developer(s)
- DCCB vendor(s)
- Transmission network operator(s), GB and international
- OFTO(s) and OFTO manager(s)
- Academic(s)
- Industry funded simulation and training facility(s)
- Private research and innovation organisation(s)

carbontrust.com

+44 (0) 20 7170 7000

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230 with its Registered Office at: Level 5, Arbor, 255 Blackfriars Road, London SE1 9AX.

Published in the UK: 2026