OPERATIONS AND MAINTENANCE CENTRE OF EXCELLENCE

ELECTRIC VESSEL CHARGING AVAILABILITY STUDY AT OFFSHORE WIND PORTS

COMMISSION BY TIDAL TRANSIT

Contents

1 INTRODUCTION

With the UK seeking to reach net zero by 2050 and renewable energy constituting an ever-growing share of the energy mix, the renewable energy industry continues to innovate in finding new ways to reduce carbon emissions embodied within energy production. In Offshore Wind (OSW), one way to reduce emissions is to use alternative fuels on frequently used CTVs and SOVs. In particular, the electrification of vessels used for O&M could significantly reduce embodied emissions. However, in order for alternatively fuelled vessels to be adopted in the near future, both offshore wind ports and electrical network operators need to be ready for their uptake.

There is yet to be a clear preferred fuel type and indeed most the maritime and OSW industry sees a strong likelihood of multiple fuel types being required for different operational requirements. There is however a particular synergy with OSW and electric power. The need to move away from fossil derived fuels, rapid expansion of renewables and limited capacity for biomass production in the UK means that it is desirable to fuel vessels with electricity and those fuels that can derived from electric power such as Hydrogen and Ammonia. Direct electrification offers the most efficient (and potentially cheapest) use of this energy, either through shore power covering hotel load whilst in port or batteries providing power to the vessel during its journey. Unfortunately however batteries require a high CAPEX investment and are limited in their range compared to more energy dense fuels. In the future however this could be partially offset within OSW O&M by vessels charging in the field directly from the in-field infrastructure and utilising vessels with novel hull types to reduce drag.

Tidal Transit Ltd are a vessel operator providing access, transport and crew transfer services to the industries of the North Sea. The company has been at the forefront of technology development in the OSW electric crew transfer vessel sector, investing in R&D to support development of offshore charging solutions and electric foiling vessels, and currently has designs for its own battery electric CTVs. For electric vessels to become a commercial reality, access to charging infrastructure will be essential, and in order for a the market to develop without barriers to entry, this must be widespread across ports in the OSW O&M sector otherwise vessels will be locked in to particular ports. Tidal Transit have commissioned The Offshore Renewable Energy Catapult to carry out this study in order to understand the readiness of ports in this sector to offer charging to crew transfer vessels.

This report is broken into two parts. Firstly an information gathering exercise from relevant stakeholders to understand the current state of play with regards to in port charging options. Secondly an in depth analysis is carried out to understand the grid connections of relevant ports and their capacity to offer charging in the future.

2 METHODOLOGY

For this project the team has set out to answer the question of future ports charging availability through desk based research and industry engagement, this was carried out in three ways:

The first was an initial engagement of stakeholders likely to be involved in the delivery of electric vessel charging. This was completed in order to better understand the requirements of electrical charging from the perspective of; the electrical infrastructure required; the requirements of vessels; and an understanding of the underlying position of distributed network operators with regards to substation upgrade plans. This was done on an opportunity basis with companies and organisations found through internet searches and industry connections. This part of the study was intended to inform user requirements, and highlight current initiatives. All information received has been anonymised.

The second was engagement with port owners. In conjunction with Tidal Transit a list of priority ports was drawn up. This was based on the current and future interest of Tidal Transit, an analysis of the current offshore wind O&M ports based on current capacity served and CTV operations, and a future forecast of ports usage, based on results of offshore wind bidding rounds. Due to the timescales available for the project, the ports were approached in priority order so that the major ports of interest would be covered first, they were given a short questionnaire about their electrical charging provision and future plans and invited for a follow-up interview. Although many ports had a willingness to engage, many of the ports were unable to respond to specific queries about offshore charging plans, either because the data was not available or it was commercially confidential. Follow up conversation provided significant insight however and so the results of these conversations have been summarised with the relevant quantifiers used to indicate however prevalent an opinion was.

Lastly, capacity at local substations that would be required to enable provision of charging was investigated by interrogating publicly available databases of DNOs. The 6 DNOs in Great Britain provide electrical information regarding substations across the country in varying formats. Initially locations of substations of interest were identified by locating current or likely berths of CTVs requiring charging. Then details of voltage at the substation and (in some cases) headroom for power upgrades was drawn from the data. This raw data was then built upon by contacting innovation managers from DNOs to sense check predictions as to what power would be available within the ports.

In addition to current capacity, the forecasted demand headroom for each location was extracted from the DNO’s network capacity report. This is defined as:

Demand Headroom (MVA) = Substation Firm Capacity – Forecasted Maximum Demand

These forecasts are based on National Grid’s DFE scenarios, meaning that there are 4 forecasts for each substation. SP Energy Networks choose not to follow these exact scenarios, citing that they assume only the minimum necessary change will be made to meet net zero. For the purpose of comparability, we therefore list a best and a worst case forecast for 2030, 2040 and 2050 for each port out of the 3 net zero scenarios listed above.

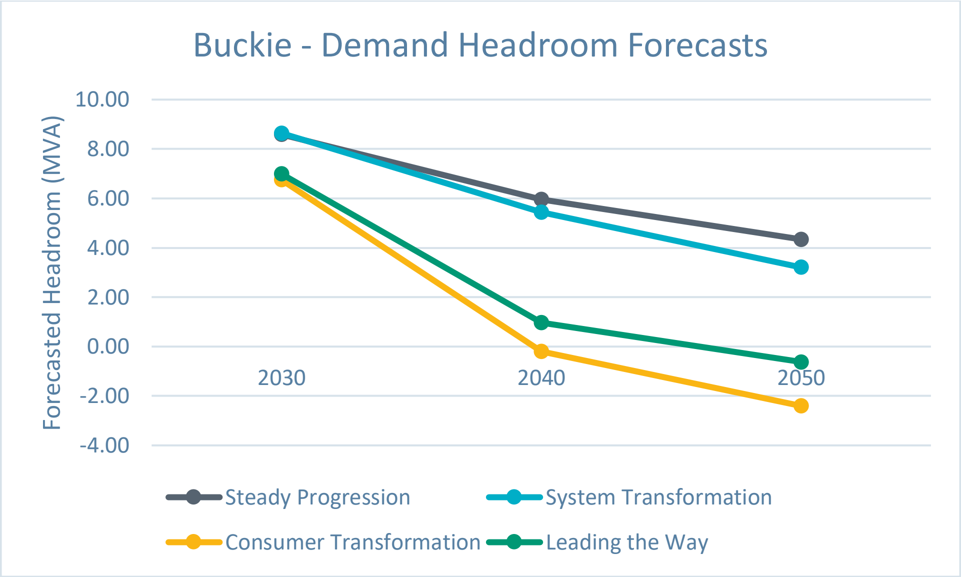

Figure 1: Example of demand headroom forecasts for the four scenarios using the Buckie substation operated by SSEN.

ORE Catapult then identified the maximum and minimum forecasted demand headroom in 2050 for each port and classify the ports based on the following criteria.

Table 1: Classification of ports based on min and max forecasted headroom in 2050

Green	Minimum and Maximum Headroom Forecasts are both >2MVA
Amber	Minimum is <2MVA but Maximum is >2MVA or both 0-2MVA
Red	Minimum is < 0MVA and Maximum is <2MVA

These classifications, along with supplementary information were gathered about the port and its capacity. An analysis of this information is undertaken in Section 5.2 to better understand the extent of forecasted disparities between demand and capacity and any correlations with other variables in the set.

3 STAKEHOLDER ENGAGEMENT

3.1 Technology and electrical infrastructure engagement.

Crew transfer vessels (CTVs) are fast vessels designed to ferry technicians from the port to the wind farm in order for them to carry out maintenance jobs during the day before returning to port. When wind turbines first started to be deployed offshore they consisted of adapted fishing vessels and workboats, before the industry grew and vessels started to be built specifically for role. As wind farms have grown and their distance to shore has increased so has the size of CTVs. Vessels currently in operation are predominantly (though not exclusively) aluminium catamarans.

CTVs operate almost exclusively during the day time, meaning that they would have the opportunity to charge overnight whilst in port. The number of factors would effect the power delivery required to deliver this charge, but predominantly the size of battery that would be required and the length of time at berth. Faster chargers would be preferable but this has to be weighed up against the cost of installation both for the physical charging infrastructure and. In consultation with vessel operators and installers of charging stations there was no clear answer to the optimum installed power of chargers, though the rough consensus was that a power delivery of 1MW would be preferable, with an absolute minimum of 250kW (DC).

Projects are currently underway to assess the possibility of grid services to be provided to ports by vessels connected to charging stations. The operating profile of CTVs (moored up overnight) was seen as ideal for this sort of project. Utilising any power in the battery to feed back into the grid during the evening peak in electricity demand and then charging the battery during the night when demand is low could not only mean that the vessels act as a net benefit to the local grid, but could achieve a low overall cost of electricity. The implications of this for battery warranties however had not been explored.

In general, installations of this type do not exist in the UK. A small but growing network of chargers is starting to be built for smaller vessels such as leisure craft. For larger vessels, some charging points exist for vessels such as point to point ferries with this technology being rare, but more common in European ports. Shore power connections are a separate but connected technology. Delivery of power to (generally) larger vessels whilst in port can allow the switch off of on-board generators. Although power delivery (both in terms of connection type and current type: AC rather than DC) differs from charging solutions, shore power units are likely to pose similar challenges to portside electrical infrastructure.

In the UK ports are supplied electrical power through their distribution network operator, details of these organisations and the capacities available to ports through their local substation are covered in the section ‘Ports Capacity and Demand’. Changes to the way we both generate and use electricity in the UK (with a general movement across all sectors to an increase in electrification) means that DNOs are increasingly under pressure to upgrade local energy infrastructure. Uncertainties in future demand for electricity however means that making investment decisions can be difficult. The challenge of electrical charging in ports however is not entirely novel. Road borne transportation is ahead of maritime in terms of deployment, and significant infrastructure investment has already been made in order to provide charge points for the growing number of electrical vehicles. Projects such as upgrading motorway service stations have required electrical upgrades to local substations that can service todays demand whilst allowing headroom for future electric vehicle deployment. In order to do so DNOs had to liase with multiple stakeholders to try to forecast future demand, and were keen to apply a similar approach to ports electrical usage.

3.2 Ports engagement

Initial ports engagement was centred around the current planning the ports had completed around electrical infrastructure and charging/shore power. IT quickly became clear however that although almost unanimously ports were aware of the need for further electrification to reduce their operational carbon footprint and provide a service to vessel operators, the stage of development was very varied. Most ports were engaging with DNOs to some degree and had carried out some coping work to understand potential demand. Those that were in a more advanced position with regards to specifying equipment, were often doing so in conjunction with a third party and specifics were at this stage confidential.

All respondents had had some for of engagement with vessel operators about electricity usage in port. As multi-user ports, for the most part this had been enquiries about shore-power for larger vessels. Although contractual obligations were not discussed, those with most progressed plans were confident of offtake, with O&G vessels such as PSVs being mentioned as potential customers. With regards to fast charging within the port, although many had had enquiries, they were less confident of future off takers as they knew that Zero-Emission fuels would be used but were less sure that it would be battery electric. This was not unanimous however as some ports mentioned that they thought that even vessels utilising combustion engines would have an increased battery capacity.

Some ports had investigated microgrids, within the port. Utilising in-port renewables such as rooftop solar or nearby renewable installations to provide cheap electricity for decarbonising port operations. These studies had again considered shore power usage but not fast charging, though it was considered that there would be similar effects. When it was raised that CTVs were likely to be charged overnight potentially having a beneficial effect on the grid, one port was very interested in this but would need to understand the implications more.

Ports response to the ownership structure of any infrastructure was very mixed. Traditionally most ports had supported but not delivered bunkering within the port, leaving that to a third party. When it came to electrical charging this could potentially change. Some ports considered that tis would happen in the same way as fuelling where they just provided the land and facilitated an electrical connection, however others considered that they more become more involved as the electricity supply could potentially could from their own assets (such as renewable generation) so it might provide a revenue stream for them.

Although the request for direct government financial support towards charging/infrastructure was by far the most common, it was also pointed out – though less frequently – that capital available for infrastructure was not necessarily limited if the risk profile was reduced. The main reason that it was difficult to raise capital was that returns were not guaranteed. With uncertainty as to future fuel use, there is significant risk of infrastructure being underutilised. One port raised the particular case of shore power, where they were concerned that even if vessels were capable of receiving shore power they might continue to use their generators in port if MGO prices were below the cost of electricity.

4 PORTS CAPACITY AND DEMAND

4.1 BACKGROUND

For investigating the possibilities of electric charging in ports an understanding of capacity and demand at each site is crucial. All DNOs in the UK publish information on capacity and estimates of demand at their substations. While they are not all published in the same format and with the same detail, it is generally possible to establish the nameplate capacity rating the demand headroom of UK substations with voltage 11kV or higher (and in many cases lower).

Network operators also provide forecasts up to 2050 on the expected demand headroom at many of their substations through a 'network capacity report'. These forecasts are based on the Distribution Future Energy Scenarios set out by National Grid to identify how customers use the network and establish how future constraints can be addressed.

In their report, National Grid (2022) outlines 4 scenarios for the future energy system which have varying assumptions about systemic change and consumer choice:

- **Steady Progression/Falling Short**: this scenario is business-as-usual and is not compliant with the UK net zero emissions target, with low levels of decarbonisation and societal change.

- **Consumer Transformation**: this scenario has high levels of decarbonisation and societal change, where consumers adopt new technologies rapidly, and more decentralised solutions are developed – it also has significant electrification of domestic heat.

- **System Transformation**: this scenario has a high level of decarbonisation but with lower societal change, where larger, more centralised solutions are developed including high levels of hydrogen deployment.

- **Leading the Way**: this scenario contains consumer *and* system transformation and is supposed to reflect the "fastest credible" path to decarbonisation.

Naturally, all of these scenarios have major implications for the demand of electricity and the stress placed on the current network. It may be expected that the consumer transformation scenario would put the most stress on the electricity system due to the high electrification and lack of more centralised solutions - this is mostly confirmed in forecasts but it is not always the case, particularly in Scotland. (SSEN, Network Capacity Map, 2023)

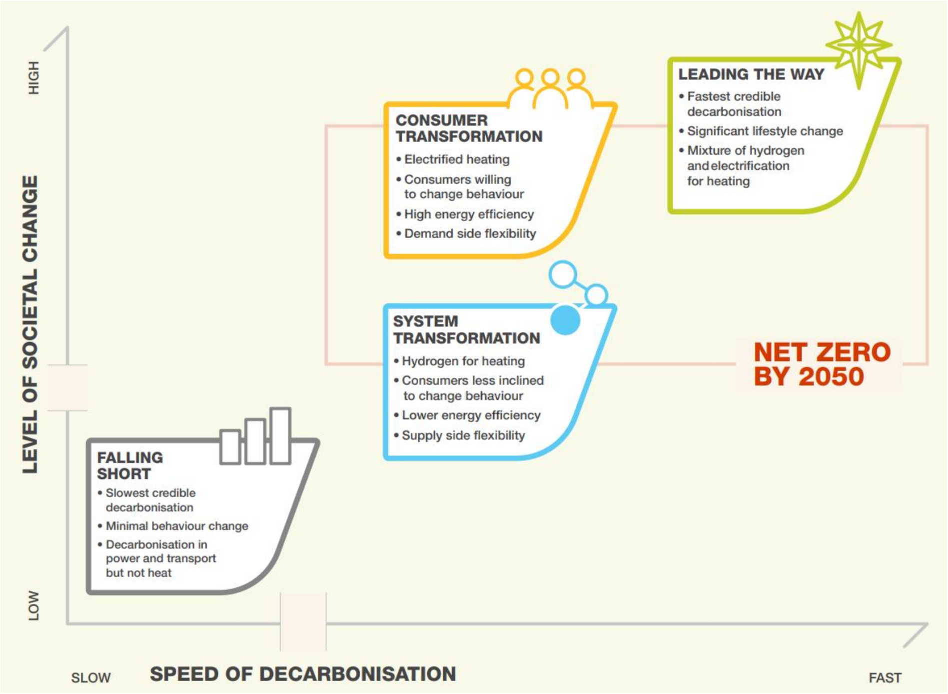

Figure 2: An illustration of the 4 decarbonisation pathways from National Grid's Future Energy Scenarios report (2022).

4.2 PORTS

Ports were highlighted based on current and expected activity in the offshore wind industry, with many in the vicinity on the current regional clusters of offshore wind. A large number of ports were identified in the North of Scotland, as shown by the high representation of SSEN as a DNO in the set.

Table 2: Numbers of ports identified by DNO

DNO	Count of Port
ENWL	2
SP Energy Networks	7
SSEN	15
UK Power Networks	5
Northern Power Grid	4
National Grid (WPD)	2
Grand Total	**35**

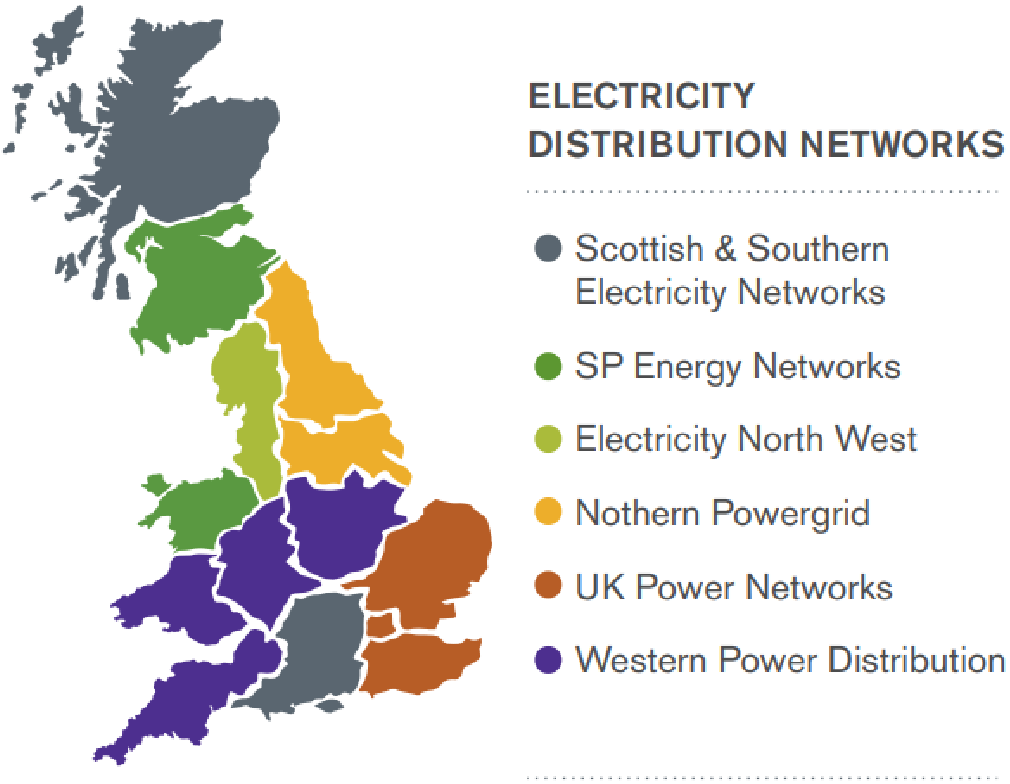

Figure 3: Regions controlled by each DNO. Image from Ofgem.

In addition to these UK ports, a number of other European ports were identified as notable candidates for electric vessel charging and offshore wind activity. In particular, Denmark, Germany and the Netherlands hosted 24 of the 33 international ports identified as potential survey recipients.

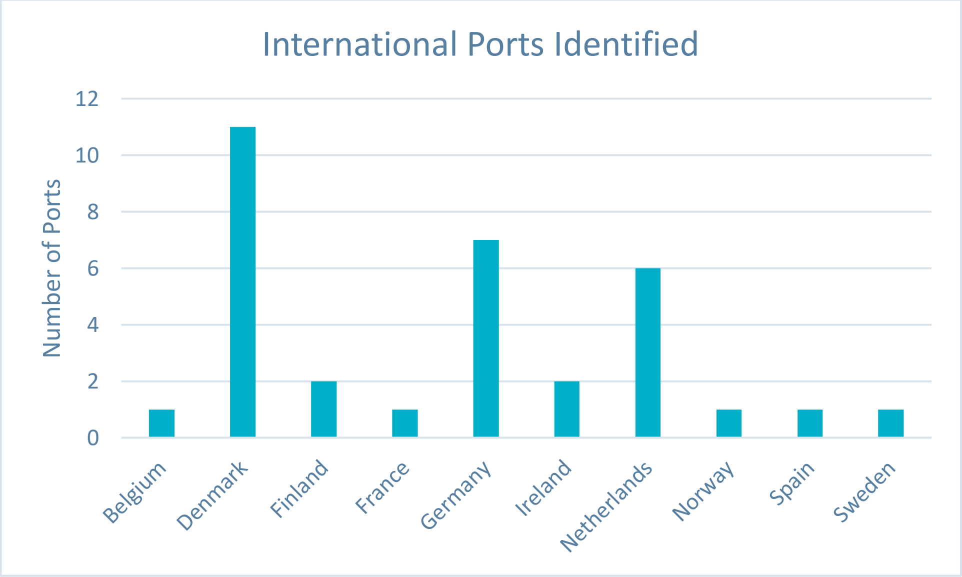

Figure 4: Number of non-UK ports identified by country.

International ports are excluded from the analysis in Section 5.2 due to a lack of data available for these sites.

4.3 SUBSTATION CAPACITY

In their current state, substations at each of the ports generally have a sizeable amount of headroom for extra demand, should charging ports be installed in the near future. Only 4 out of 35 of the substations have less than 2MVA headroom, one of which is exactly 2 and another only has a nameplate rating of 2MVA. The other 2 red flags are Ramsgate, with 0.4MVA headroom and Milford Haven with 0.1. The maximum headroom available is 27 and the average is 8.5.

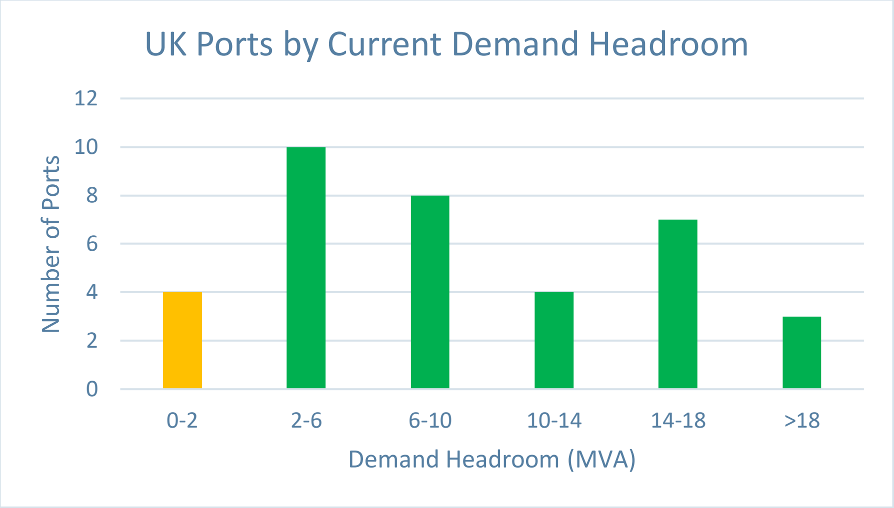

Figure 5: Count of ports grouped by demand headroom in current state.

Splitting by DNO, we can see that most operators have substations on the lower end of the headroom spectrum, with National Grid and UK Power Networks having some of the most in-demand substations.

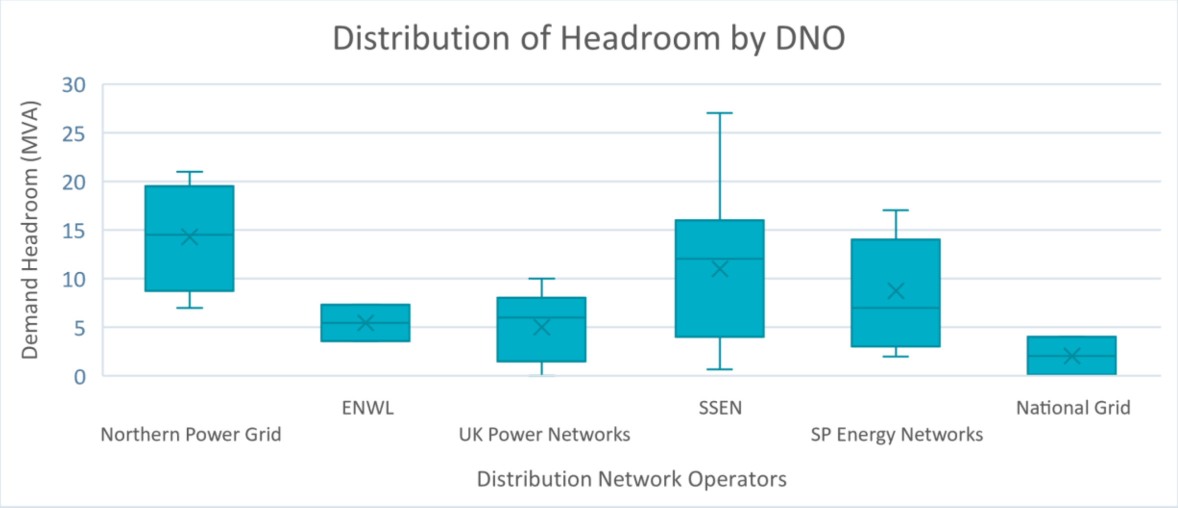

Figure 6: Boxplot of demand headroom by DNO, with mean (X), median (centre line), min and max.

Looking at the forecasted demand headroom shows us a different story as we look at the impact of future changes of our energy system. Many of the substations quickly become insufficient to handle expected increases in electricity demand. Looking to 2050, the substations can be classified by the following expected states.

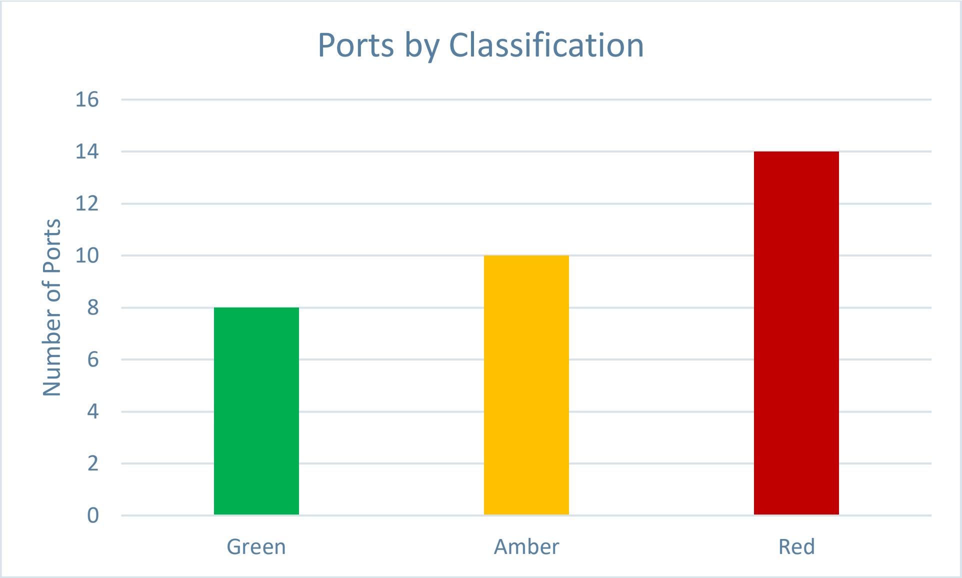

Figure 7: Ports classified by expected demand headroom of substations in 2050.

Only 8 out of 32 ports are expected to still be classified as having green availability (over 2MVA demand headroom). The amber represents 10 ports that may have availability but some forecasts place it below 2MVA. In the red, 14 out of 32 farms (44%) are forecasted in all scenarios of change to not have reasonable headroom in 2050. In 13 of these 14 red scenarios, the maximum expected headroom is less than 0MVA.

Splitting by DNO, we begin to see a regional feature to the set and get a sense of the operators that need to make the most changes. All of the green substations belong to the DNOs handling the North of the country (although 1 exception of these substations is based in Liverpool). These substations all currently have a high headroom and 5 out of 8 are in more remote locations close to renewable energy sources and in areas of low population density (i.e. the North of Scotland). Meanwhile, both of the substations operated by ENWL and National Grid are in the red and 4 out of 5 from UK Power Networks. It should be noted however that *all* DNOs have work to do to make sure all substations are ready for vessel electrification and more generally for the sweeping system changes necessary for net zero.

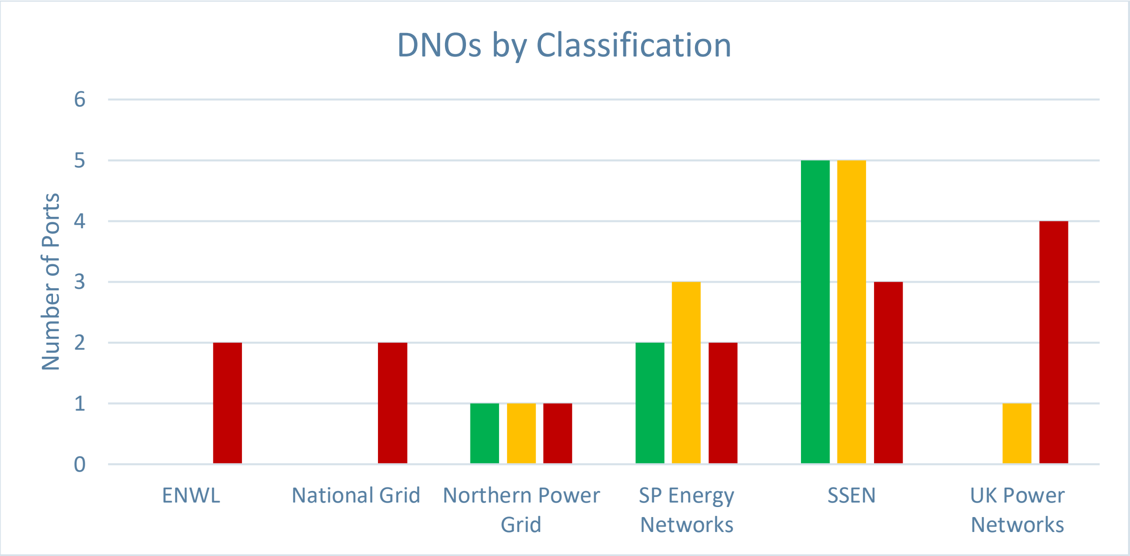

Figure 8: Forecasted classification of demand headroom in 2050 grouped by DNO.

Looking at a more granular level, we can illustrate the distribution of each of these substation groups using box plots. Examining first the worst case scenario for DNOs where demand is at its highest, there are a number of substations which require very significant capacity additions. The highest of these – located near Sutton Bridge - misses out on demand by almost 60MVA, and the second highest -Annie Pit in Workington – is forecasted to have a debt of 28.4MVA. The highest on the other hand has 11.32 MVA (Wick) and the second 7.7 (in the Port of Tyne).

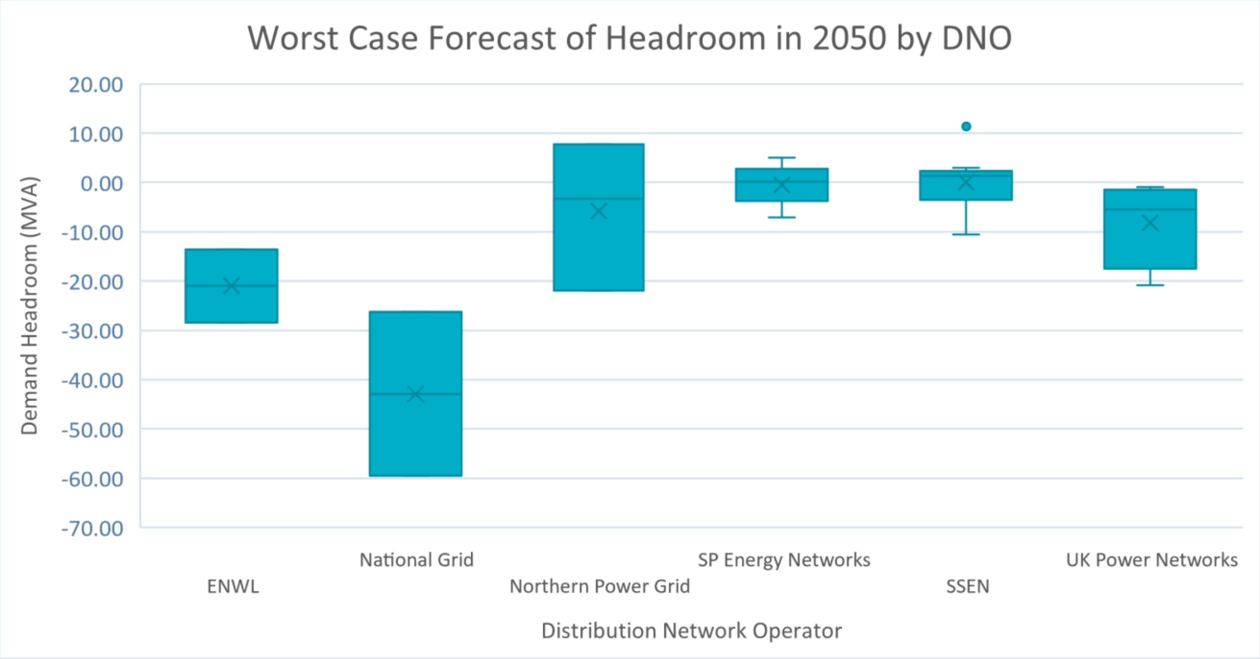

Figure 9: Worst case forecasted distribution of demand headroom in 2050, by DNO, with mean (X), median (centre line), min and max.

This can be contrasted with the best case, in which system change results in higher use of alternative fuel sources such as hydrogen and increases in electricity demand from each of the ports is kept to a minimum. While the substations with the most room gain a few MVA of extra capacity, some of the most significant disparities in capacity are reduced.

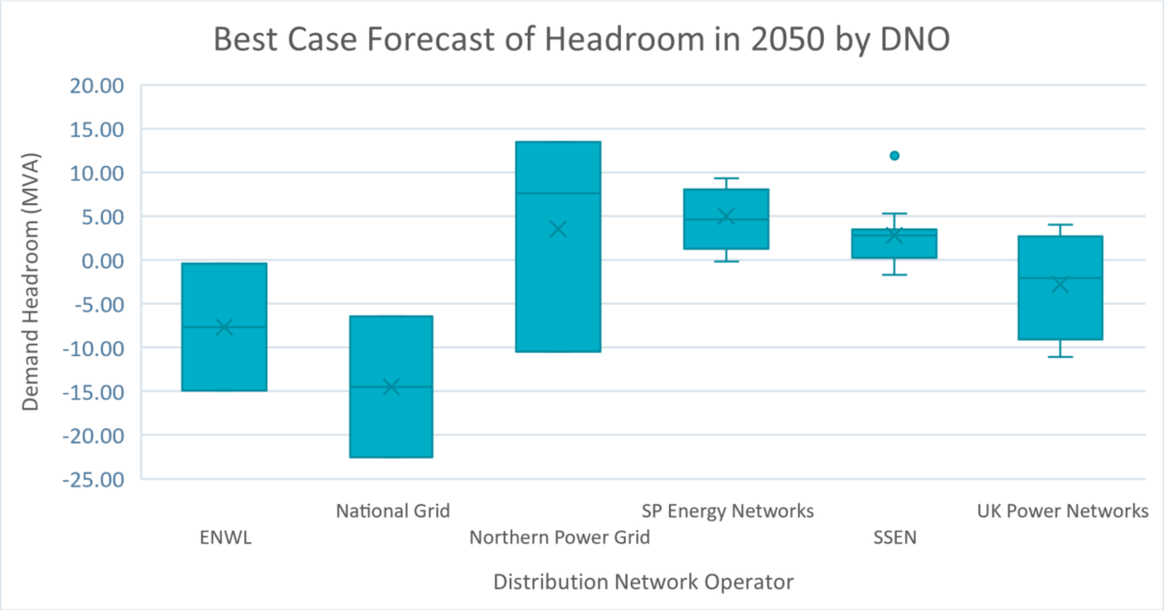

Figure 10: Best case forecasted distribution of demand headroom in 2050, by DNO, with mean (X), median (centre line), min and max.

While capacity for demand is lowest in 2050, it is forecasted to be on average below zero even in 2040, meaning that additional capacity will need to be added well before then, in order to enable electric vessel charging.

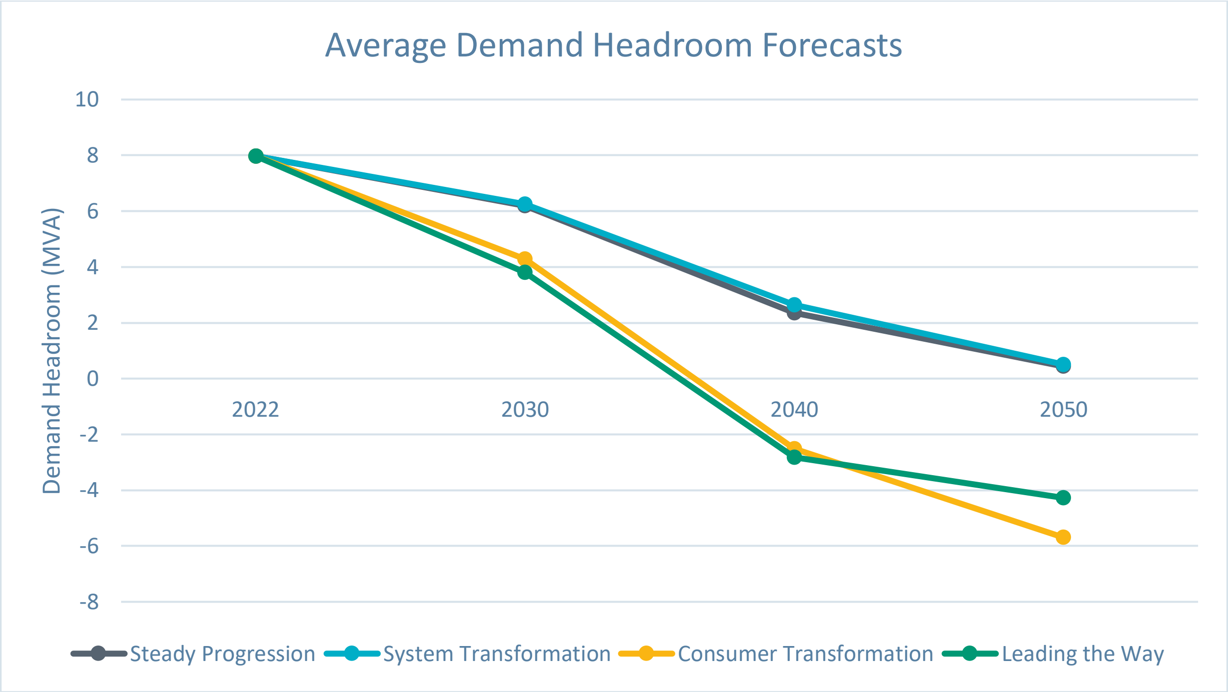

Figure 11: Trend of average demand headroom forecasted up to 2050 for the 4 DFE scenarios.

Over time, the percentage of substations that are eligible for electric charging – defined here as simply having any forecasted available demand headroom – falls through the next decade until it drops to as low as 80% in the worst-case scenario. In the best case, it stays at 93.5% and decreases to 64.5% in 2050.

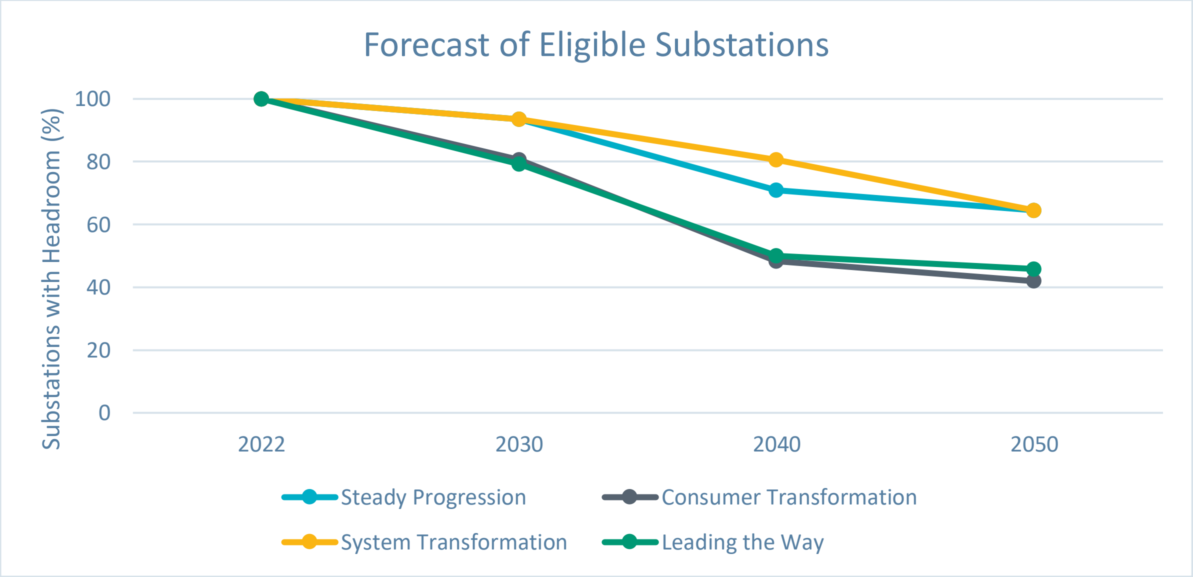

Figure 12: Percentage of substations that have positive forecasted demand headroom under the 4 DFE scenarios.

4.4 NETWORK DEVELOPMENT

The result of such capacity and demand forecasts is that each DNO constructs a Network Development Plan to address any future constraints that might emerge. In order to get a better understanding of the potential to install charging stations in ports, it is pertinent to investigate the measures being taken to increase the headroom in these areas.

In their development plan, SSEN (2022) propose 3 methods where the challenges raised in forecasts can be addressed:

Table 3: Actions proposed by SSEN in their network development report

Symbol	Definition	Description
⏱	Flexible Solutions	Where “flexibility services” are utilised to manage and/or alleviate a forecasted constraint on the network
🔋	Reinforcement (Asset Reinforcement)	Reinforcing existing assets with assets with greater thermal capability to ensure that the network can support the forecasted growth in demand & generation
🚧	Reinforcement (New Assets)	Installing additional assets to increase thermal capacity to ensure that the network can support the forecasted growth in demand & generation

Of the substations identified in our study, the following network developments have been suggested or planned:

Table 4: Plans for relevant substations outlined in network development plans for next 10 years.

Port	DNO	Substation	Intervention	Planned Intervention
Grimsby	Northern Power Grid	Grimsby Docks	🚧	6.6kV transformers to be replaced by 11kV transformers and will be uprated to accommodate demand
Sutton Bridge	National Grid	Long Sutton	🚧	Additional primary substation suggested in area along with an expansion of the South Holland BSP. Other flexibility services to be considered including

				temporary 11kV transfers and an Active Network Management scheme.
Milford Haven	National Grid	Milford Haven	🔋	Additions made to ease load on other circuits downstream from Milford Haven Grid but none on Milford Haven Primary.
Blyth	Northern Power Grid	Maddison Street	⏱	Flexible service to be employed in 29/30
Port of Tyne	Northern Power Grid	Garwood St	🚧	Replacement of 11kV switchboard for fault level reinforcement
Workington	ENWL	Annie Pit	🚧	Significantly high fault level identified on Stainburn & Siddick BSP - preferred solution to install second GT at Siddick.

The substations that are included here are sensible as 2 out of 6 (Long Sutton and Maddison St) are predicted to be amber by 2030 in the steady progression and another 2 (Annie Pit and Milford Haven) are predicted to be red– in fact they are the only substations predicted to be red by 2030 in the business-as-usual scenario.

Plans from other DNOs did not include the substations in our study or, generally, their bulk supply points.

While some action might be encouraging, it is clear that DNOs are only planning for the near future and not yet addressing the long term challenges identified in their forecasts. Thus, the majority of port substations predicted to be red by 2050 (and even 2040) do not yet have any contingency in place for future network constraints.

4.5 FINDINGS

In summary of the research undertaken, an analysis of the available information on substations yielded the following findings:

- Current demand headroom is sufficient to host charging ports for electric vessels in the majority of ports across the UK, but long term this could be in doubt.
- Only 8 out of 35 substations are predicted to have available demand headroom in 2050 without significant upgrades.
- Out of these substations, the biggest constraints exist in the regions of South Wales and the East Midlands (those operated by National Grid), though all DNOs host at least 1 substation in need of upgrade.
- Depending on the nature of the transition to net zero, the percentage of eligible ports could decrease to 80-95% by 2030 and 50-80% in 2040.
- Though network developments are planned on *some* of the substations needing the most immediate capacity, the development is a small fraction of what is necessary to enable the system to host vessel charging across the UK through the next 3 decades.

Any strategy to implement electrical vessel charging across UK Offshore Wind ports may want to focus on the 8 ports that are *least* in danger of losing headroom in the future: Ardersier, Birkenhead, Cromarty, Newhaven, Montrose, Peterhead, Port of Tyne and Wick. Those that have been shortlisted for future development – Blyth, Grimsby, Milford Haven, Port of Tyne, Sutton Bridge and Workington – may also be good candidates for vessel charging. Additionally, it may be prudent to focus any lobbying efforts to get additional capacity on the many ‘red’ ports that are not currently being examined for future development.

5 CONCLUSIONS

Electrification of Crew Transfer Vessels capable of carrying out operations under battery power presents a clear and potentially cost-effective route to decarbonisation and the technology to do so is at a High TRL.

Charging points for crew charging vessels are in their infancy and although there is a lot of interest, most ports do not appear to be investing in this without funding support.

Plenty of ports substations have headroom for significant (100s kWs) extra connections that are capable of charging CTVs and smaller vessels over long time periods. Ports looking to put in this small infrastructure could do so now with an anchor contract. Ownership models are unclear though, and it is likely that more than one party will need to be financially committed in order for a business case to be made.

Government funding through competitions such as ZEVI or Clean Maritime Demonstration Competition or an ongoing financial support mechanism will be required in the short term to support the role-out of Vessel charging.

Regulation to ensure that vessels in the offshore wind sector are incentivised or mandated to reduce their carbon emissions could be transformative in the medium to long term, and reduce or eliminate the need for subsidy towards charging infrastructure.

Although traditionally many ports considered the engagement process and costs to be a blocker to port electrification, engagement with DNOs was positive and there seemed to be a desire to better understand the ports needs to help enable upgrades.

Although ports may wish to continue to engage with DNOs on a one to one basis, it could be beneficial to bring together port users, port owners and DNOs to map out future energy requirements and ensure that upgrades are made in a timely and cost effective manner.

Early trials of charging of CTVs should share and/or analyse data about time of use and battery levels. Demand side management and potential provision of grid services has the potential to make overnight charging of CTVs low cost and beneficial to the ports electrical grid. Practicalities of doing this however need to be better understood.

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