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Barriers and solutions for UK shore-power

Recipients: - UK Major Ports Group and British Ports Association;

- Project interviewees

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Background

This report on shore-power is based on 40 interviews over May to October 2020 with UK port and ship operators, equipment providers, trade associations, regulators, electricity network operators, classification societies and European ports. It is part of research at the Tyndall Centre for Climate Change Research at the University of Manchester into the potential for maritime electrification, and is part of a project with the UK Major Ports Group (UKMPG) and British Ports Association (BPA) to understand the barriers to implementation of shore-power in the UK, and how these might be overcome. Many thanks to all the interviewees for their time and insights, to three reviewers of a draft of this report, and particularly to the UKMPG, BPA and the UK Chamber of Shipping for their support. All views expressed in the interviews are anonymised.

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Executive Summary

The use of marine fuel oils in shipping contributes to major environmental problems, particularly local air pollution and climate change.

Shore-power can cut local air pollution from ships at berth to zero, and help reduce greenhouse gas emissions, by connecting ships to electricity grids while docked, so they don't use their diesel engines in ports. It is a proven technology which is available now, and growing in use worldwide. But it is relatively uncommon in the UK.

There are major barriers to shore-power. Projects can be complex and expensive. They have long payback periods, and uncertain returns. And there is little policy support, despite widespread acknowledgement of the urgency of air pollution and climate change problems, and the role shore power can play in addressing them. These barriers are however all surmountable.

This report recommends three actions to drive the uptake of shore-power in the UK over the next 5 years:

1) Electricity network capacity will be an increasingly important issue for ports, beyond just shore-power, as ports electrify their operations more generally. **The UKMPG and BPA could convene a working group with DNOs, National Grid, Ofgem, and the Government with the aim of developing a clear, simple framework for enabling the development of Port smart grids.** The most important issues to address are electricity charging mechanisms, and planning for infrastructure development.

2) Some form of intervention is necessary to incentivise demand for zero-emission vessels in ports – such as a Zero Emission Berth Standard. **The Port Associations and the UK Chamber of Shipping could lead a focussed working group aiming to set out the core principles, purpose and detail of a regulatory standard**: its aims and time-frames, and how it could work in practice.

3) To build on the ambition in the Clean Maritime Plan, **the Government could set a clear strategy for developing shore-power and cutting at-berth emissions, with five central components:**

   a. **a capital fund** for projects over the next 5 years sufficient to see 5-10 further shore-power projects in place by 2025;
   b. a consultation on **reductions in electricity taxation for shore-power** to allow it to compete fairly with marine diesel oil, and to ensure a level-playing field for the UK, given EU shore-power tax exemptions for Germany, France, Sweden and Denmark;
   c. a clear remit in MERAS[1] for **information provision**;
   d. a commitment to put in place a **zero-emission regulatory standard** compatible with future EU legislation (link to Recommendation 2); and
   e. a commitment to enabling wider port electrification and smart grids through changes to **electricity network planning and regulation** (Link to Recommendation 1).

Introduction

The overwhelming majority of ships worldwide use oil-based fuels as their main energy source. Use of these fuels contributes to global climate change and local air pollution. Shore-power is a partial solution to these problems. It involves ships connecting to land-side electricity infrastructure while at berth, either to provide power so ships don't need to use their auxiliary engines, or to recharge any on-board battery systems[2]. This can cut local air pollution and noise, lower greenhouse gas emissions, and reduce engine wear.

Shore-power has been a proven global technology for 20 years, however it is almost non-existent in the UK. Beyond the major shore-power facility at the Royal Navy Base at Portsmouth, there are just two major projects: in Orkney, starting before end 2020, and Southampton, starting in 2021[3].

There was consensus among interviewees that shore-power as a business proposition suffers from four main problems:

- Shore-power projects are highly capital-intensive, particularly for ports, competing with many other potential projects in what are now very challenging economic circumstances.
- Uptake of almost all solutions to environmental problems requires some combination of financial or regulatory policy support. Neither are in place in the UK for shore-power.
- In the absence of supportive policy, shore-power's viability stands on a business-case which is perceived to be very weak: returns are seen as being low, long and uncertain for both ports and ships.
- Shore-power projects are viewed as complex and difficult.

Given all this, why bother? Why try to fix these barriers to shore-power? Why not simply wait for low-emission, zero-carbon technologies like hydrogen or ammonia?

There was consensus that there is a place for the growth of UK shore-power. Participants were clear that they see the global and national policy direction for shipping as one-way: there will only be growing pressure for the sector to reach net-zero and to improve air quality. It was also clear that there are many potential alternative fuel and propulsion choices, and multiple solutions will be needed. In this context, although shore-power will not be appropriate for every port or every ship, it is seen to have a clear and useful role to play – and it is well worth finding ways to overcome the barriers it faces.

This report is set out in four sections:

1) Drivers. What are the drivers for solving air pollution and climate change, and how useful is shore-power's potential contribution?
2) Barriers: What are the main barriers for shore-power projects?
3) Solutions: What could overcome these barriers?
4) Recommendations. How progress could be made on these solutions?

1) Drivers

Interviewees identified two main environmental drivers for shore-power. One, it is a technology that can reduce local air pollution in ports. Two, it can reduce greenhouse gas emissions. These two issues are also the main environmental priorities for European ports surveyed in the recent ESPO 2020 Environmental Report[4]. Other cited environmental and social benefits were that it can reduce noise in ports and on ships, and that it improves the working conditions of ship crew and dockworkers. On the economic side, shore power is seen by many ship operators as a means to reduce wear and tear on auxiliary engines, leading to lower maintenance costs. But air quality and climate change were the overwhelming cited reasons for considering shore power.

Shore power is however just one of many potential options for tackling air quality and climate change issues in the shipping sector. This section summarises interviewees' views on how strong a solution it is compared to these alternatives. It then summarises views as to whether the pressures to implement shore power will increase in future.

1.1 Shore power compared with other solutions

1.1.1 Shore power and air pollution

Ports are often in highly populated areas, and as such a ship at berth can be effectively running a very large and highly-polluting diesel engine in the centre of a city. International legislation on emission limits on marine fuel at the IMO has cut the emissions of some pollutants dramatically, but ships' emissions limits are still far higher than those for cars and lorries. Shore-power is a solution which cuts local air pollution from ships at berth[5] to zero.

Shore-power is widely seen as a good solution to air pollution, although the scale of the benefit will vary greatly: exposure to air pollution is less of an issue at a container port miles from urban areas than it is in berths in town centres. Shore-power also does not reduce air pollution in a port while the ship is manoeuvring. These manoeuvring emissions are usually a small percentage of a ship's in-port emissions, but will vary port-to-port and for different ship segments[6].

Historically, shore power has been introduced as a response to political pressures to address local air pollution – for example the Californian regulation to mandate shore power, and the introduction of shore-power in European cities such as Hamburg and Bergen.

Interviewees felt that public and political pressure to improve UK air quality would continue, and that policies to cut air pollution would be strengthened, including in ports and from shipping, via the UK Clean Air Strategy.

1.1.2 Shore power and climate change

Shore power can also reduce greenhouse gas (GHG) emissions. This benefit varies in size. For transoceanic container vessels, the overwhelming majority of GHGs will be emitted at sea, not at berth. But for short-sea shipping, the at-berth emissions will be a higher proportion of the total. In the UK the GHG benefit from shore-power will be high, as the UK's electricity grid carbon intensity has fallen rapidly in recent years, and is forecast to continue doing so.

Climate change has not been seen as a major driver for shore-power in the past, but there was almost total consensus that national and global political and public pressure to act on climate change generally will only increase, and that the UK's net-zero strategy is here to stay. People expressed divergent views about the speed at which IMO climate policy might increase, but there was consensus in the belief that the EU was likely to take greater action, including through inclusion of shipping in the EUETS. Many respondents noted that shipping owners and charterers were increasingly acting on climate change – such as the Getting to Zero Coalition[7] - that an increasing number of port owners were giving climate change higher prominence, and that the finance community are also taking action on shipping and climate change, for example through the Poseidon Principles[8].

1.1.3 Other benefits of shore power

Interviewees mentioned three other practical advantages for shore-power. First, shore-power is a proven technology that can be implemented now. Many of the other highly-touted alternatives in shipping to tackle air pollution or climate change, such as ammonia and hydrogen, are years away at best from commercial deployment at scale. Second, it is one of the few technologies which deliver strongly on both air quality and climate change. For example, ammonia could be net-zero GHG, but has issues with NOx pollution; LNG cuts local air pollution, but as many interviewees pointed out, is still very high carbon. Third, it fits with the general drive in ports and shipping towards greater electrification.

1.1.4 Shore power and other solutions

There are many ways shipping can cuts its contribution to air pollution and climate change. An overview of how shore-power compares with the main alternatives interviewees cited[9] is set out in Table 1; these comparisons are complex and depend upon many assumptions[10].There are also other issues, for example a number of interviewees expressed major concerns around ammonia's toxicity and safety. The relative performance of these options on cost is also a major factor, with large uncertainties.

Table 1 Solutions to address air pollution and climate change

Technology	Availability	Air Quality impact (eg NOx, SOx, particulate emissions)	Climate Change impact (CO_2 emissions)
Shore power	Now	Cuts emissions to zero where they are most problematic: in ports	Lowers emissions, but only addresses at berth emissions, which are a small proportion for non-short-sea shipping
Hybrids/ Batteries	Now	Cuts emissions to zero where they are most problematic: in ports, and also while manoeuvring and near ports	Can do more than at-berth cuts, but needs to be combined with shore-power to cut emissions
Biofuels[11]	Concerns about supply	Emissions eg of particulates still a problem	Emissions benefits very uncertain. Could be worse
Ammonia[12]	5-10 years	NOx emissions can be a problem	Can cut to zero
LNG[13]	Now	Lower emissions, including very low SOx emissions	Some reduction, but still a high carbon fuel, even if methane slip could be addressed
Scrubbers	Now	Meets IMO standards, but emissions still high	Zero or negative impact
Hydrogen[14]	5-10 years	Cuts to zero	Can cut to zero

1.2 Shore power drivers in future

Beyond overarching political pressures to implement solutions to air quality and climate change, interviewees identified two clusters of reasons why shore-power might increase in the UK in future:

- Growth in shore power globally, allied with greater levels of shore-power policy;
- The growth of electrification of ports, shipping and the economy in general.

1.2.1 Growth in shore-power installation and policy

Shore power has had very slow global growth in the last two decades – the exceptions being Norway and California. In the 2010s other environmental issues took precedence in the shipping sector. In the mid-2010s the EU Alternative Fuels Infrastructure Directive focussed on shore-power and LNG, but LNG took priority. Also from the mid-2010s, new IMO regulations on air pollution limits focussed ship-owners' attention on scrubber technology. There has however been some progress and growth - there are currently shore-power installations at over 100 ports worldwide[15] - and interviewees saw increasing signs that shore-power installations are now rising: China has embarked on a major shore-power expansion programme, the German Government has recently put over £100m into shore-power infrastructure, the technology is increasingly fitted as standard on new ships, and there is likely imminent improved EU shore-power legislation, through both the Fuel EU Maritime Initiative and through revisions to the Alternative Fuels Infrastructure Directive. The European Sea Ports Organisation (ESPO) report that 40% of respondents to their 2020 survey plan to install shore power in the next two years[16].

1.2.2 Port and ship electrification

Allied to this, shore-power is increasingly seen as one part of a much wider growth in port and ship electrification. Recent years have seen dramatic and continuing falls in the costs of battery technology, and increases in their efficiency. This, alongside major and continuing falls in the costs of renewable electricity and the growth of smart electricity networks and tools such as Active Network Management are seeing a surge in interest in both port and ship electrification. For ports, shore-power could be integrated with renewable power generation, battery storage and the electrification of port equipment such as gantries, cranes and forklifts to develop a holistic smart grid. For ships, although ocean-bound vessels will likely never be fully-electric, there is major growth in electric shipping in various short-sea segments, and growth of hybrid-vessels of various configurations are seen as likely in almost all vessel types – these hybrids are already justifiable in many cases just for the engine efficiency savings, let alone environmental benefits.

1.2.3 Shore-power drivers summary

Overall, these environmental policy drivers and the growth of shore-power and related electrification worldwide are signs that led the majority of interviewees to believe that the pressure and incentives to install shore-power will increase, and have a sense that shore power's "time has come". Overall, interviewees were very positive about the contribution shore-power could make, if barriers can be overcome. The main benefits cited were that it is deployable now, it makes a contribution to both of the major environmental problems from diesel use, and that it fits with the general drive in ports and shipping towards greater electrification.

However, there was widespread concern expressed that despite the strong political direction being set on climate change and air quality in general terms, there are no actual on-the-ground policies to incentivise shore-power in countries like the UK. It was a consensus view that despite shore-power's potential, without policy support its uptake in the UK will remain very low. Interviewees also expressed the view that the impact of COVID-19 was likely to reduce port and ship operators' ability to act, making Government policy intervention more important. The next section looks at the barriers to shore-power implementation.

2) Barriers

Interviewees set out a wide range of real and perceived barriers to shore-power, split here into six main categories:

- Lack of policy support
- Weak business cases for ports
- Difficulties for ship owners and operators
- Grid capacity issues
- Project complexity
- Low prioritisation

2.1 Lack of policy support

2.1.1 Global policy

In any sector, without intervention, pollution of the environment is a free externality, the use of which lowers costs. Reducing such environmental impacts requires policy action, such as regulatory standards and financial mechanisms. Each sector faces unique challenges in enacting policies. Shipping's global nature means that international policies are preferred, via the IMO. The IMO has enacted regulation on air pollution standards, however although targets have been set on climate change[17], actual policy is lagging and progress continues to be very slow[18]. In particular, there are no carbon pricing mechanisms, marine fuel is exempt from taxation, and as a consequence fossil-fuel use in the maritime sector has an extreme competitive advantage against nascent lower-carbon fuels. This lack of pricing policy is a barrier to the development and implementation of all alternatives to marine fuel oils. This is a similar situation to aviation; but is markedly different to road transport which sees major financial incentives against fossil fuel use and for alternatives. Interviewees did not see that there was likely to be specific policy on global pricing or to promote shore-power at the IMO level. There is no regulatory focus to promote shore-power at IMO level either.

2.1.2 EU policy

On pricing, there is growing likelihood that inaction at IMO level will lead jurisdictions like the EU to take unilateral action – in September the EU parliament voted to enact carbon pricing for shipping via its inclusion in the EUETS from 2022[19]. However, it is unlikely the price impacts will be high, at least in the short term.

There is legislation at the EU level to support shore-power, via the Alternative Fuels Infrastructure Directive, however in practice caveats means there is no requirement for action (see Section 3.3). The EU is considering strengthening shipping emission legislation, including on shore-power, but the form and strength of this is uncertain. Given Brexit, this legislation would not apply to UK ports, and it is uncertain what degree of harmonisation of EU-UK maritime policy there will be post-Brexit.

2.1.3 UK policy

At the UK level, there is prominence for shore power as one of the solutions to decarbonisation in the Clean Maritime Plan[20] and in the follow-up Clusters[21] research, but there is currently no actual policy support for shore-power in the UK. Interviewees were supportive of the framework and ambition set out in the Clean Maritime Plan, however expressed concern that there were insufficient policies to deliver on that ambition. There was a broader concern that maritime was a "Cinderella" sector within the Department for Transport, with far less institutional capacity and funding than road, rail or aviation.

Because shore-power has high capital costs, and little opportunity to recoup those costs given the cheap nature of the fuel it is seeking to replace, no project shore-power globally has gone ahead without Government funding support. This situation is unlikely to change without major changes to carbon pricing globally, or regulation which requires shore-power installation (with costs passed down the supply chain) or action on economic incentives to improve business cases. These specific financial issues are covered in sections 2.2.

2.2 Weak business cases for ports

Interviewees expressed three main concerns around business cases:

- Payback periods in the UK need to be shorter than on the continent because of ownership structures;
- Paybacks are long, because of a combination of low operating margins and high capital costs, and;
- Concerns around the potential for stranded assets.

2.2.1 UK Private port model

Most ports on the continent are part or wholly owned by regional or national Governments. In the UK, private-sector port ownership is predominant. This difference in ownership model means it is harder for UK ports to invest in projects such as shore-power: public ownership on the continent means it is easier (in some but not all countries) to obtain state funding for capital projects. And on the continent, it is also more likely that the air quality or climate change benefits of shore power are formally costed into business cases, and longer payback periods are deemed acceptable.

2.2.2 High capital costs

The costs of shore-power projects vary wildly from port to port, depending on multiple factors, such as the demand and load-profile from ships, the need for outside-port grid reinforcement, and the varying needs for substations, cabling, switch-gear and frequency conversion equipment. Some costs are higher in particular ports – for example new cabling into historic ports. Lack of clear understanding of capital costs is an issue, and the tendency to treat shore-power as individual bespoke projects rather than one where a modular approach could be applied tends to mitigate against projections of future cost reduction. There is some evidence that ports can overestimate potential costs. In addition, the funding environment is currently very poor. Not only is there no specific maritime funding available from Government funding[22], COVID has reduced the sector's capacity to invest, withdrawal from the EU has removed potential EU sources of funding, and the imminent removal of red diesel subsidy for port equipment will increase port costs and reduce the available funds for them to invest in projects such as shore-power.

Table 1: Main components of Shore Power projects:

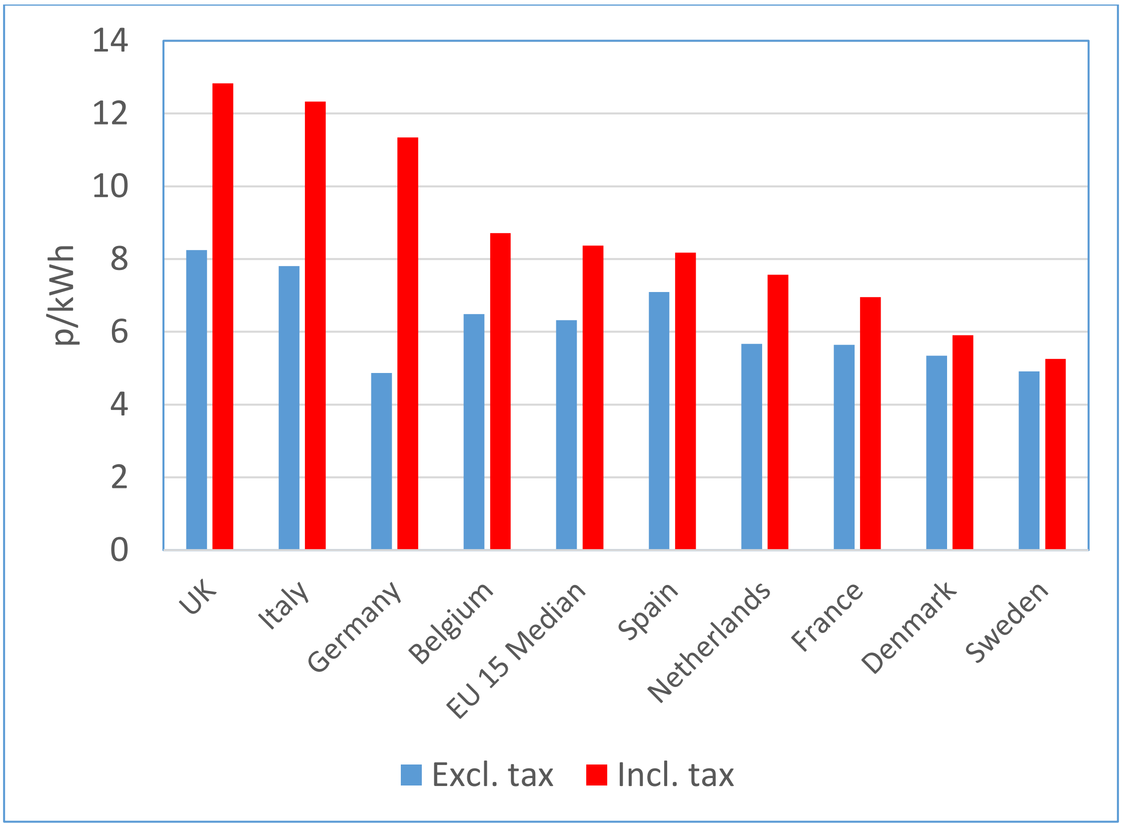
Category	Components	Cost
Grid-to-port	Outside the port, any necessary grid upgrades or reinforcement eg substations	Highly variable, from zero to several millions
In-port	Bringing power from the port-gate to the berth: cabling, transformers etc.	Highly variable, from zero to several millions
Port-to-ship: shore-power voltage/frequency management	More expensive if a frequency convertor is required (if a ship runs at 60Hz rather than grid 50Hz)	For a 2MW connection: £0.3-0.4m without frequency conversion; £0.8-1.0m with frequency conversion
Port-to-ship: cabling systems	Fixed-point cranes or moveable systems. Low voltage systems require more cabling	£10k to £1m, with fixed-point cranes most common at around £100k
On-Ship	Hatch, socket, cable to main switchboard, potentially more switchgear	Negligible % cost for a new-build, more expensive to retrofit, costs highly variable, up to £1 million for largest most complex projects, much lower for average vessels.

2.2.3 Low or uncertain operating returns

Recouping capital costs requires port operators to make a margin between their costs of electricity, and the price they sell to ships. There are five difficulties:

- The ongoing untaxed nature of marine fuel oils, a subsidy worth hundreds of pounds per tonne of fuel, compared with taxation of other transport fuels (see Box 1, p15).
- The high costs of UK grid electricity. The UK's industrial electricity prices are among the highest in Europe, in part due to electricity network charges, environmental taxes and VAT (see Graph 1). In addition, EU legislation allows nations to exempt shore-power from environmental taxes; Germany[23], Denmark[24] and Sweden[25] have done this to help promote shore-power, which lowers the costs for those countries in Graph 1 below by a further 2p/kWh. Most recently, in October 2020 France has also successfully applied to the EU to reduce its electricity taxes on shore-power[26].
- Shipping operators have very small margins and are unlikely to accept paying higher prices for shore-power than for electricity from their on-board diesel engines. This is problematic not just because marine oils are exempt from international and national taxation; eg the price of Rotterdam MGO is also currently very low compared with three years ago.
- Even if the margins per kWh sold were acceptable now, there is no guarantee ships would use a port's shore-power capability in future. Ships could shift routes, or price changes could mean it was cheaper for them to go back to using their diesel engines. It is hard for ports to be sure of future revenues.
- Even if margins per kWh are acceptable, payback periods will be long if small volumes of electricity are sold – if berth occupancies are low, and with low power demand per berth.

Graph 1: EU industrial electricity prices, Medium-sized industrial users[27]



2.2.4 Concern over stranded assets

Many interviewees expressed the concern that shore-power could become a stranded asset, because 10 years from now the maritime sector would be making a wholesale switch to alternative fuel infrastructures such as for ammonia or hydrogen, making shore-power unnecessary. At the least, this represents a major source of uncertainty, with some interviewees expressing the view it was better to wait and see in which ways the alternative fuel debate moves in the coming years before deciding on shore-power.

There was however a stronger and prevailing view that this concern is unfounded. This is due to a belief that it is almost certain that shore-power and fuels such as hydrogen and ammonia would be complementary technologies. There is likely to be a wide range of interlocking solutions to the maritime decarbonisation challenge, and increasingly combinations of options will be deployed together. Broader electrification and use of zero-carbon liquid fuels are complementary, not in conflict[28]. Even if a particular fuel came to predominate in a particular sub-sector, obviating the need for shore-power from an environmental perspective, shore-power would still make economic sense. This is because for these fuels to be zero-carbon it's most likely that these new fuels would be produced using electricity – so it would then be more efficient and cheaper when at berth to use electricity directly, rather than for example a three-step process of the use of electricity, made from ammonia, made from electricity.

A number of interviewees also made the argument that shore-power is likely to be a "no-regrets" move for ports, given that it is extremely likely that investments in grid reinforcement in-port or outside would be needed in any case, given the accelerating drive for electrification of other port operations and increased renewable power generation.

2.3 Difficulties for ship owners and operators

Although the capital costs for shore-power are lower for ships than for ports, there are still substantial hurdles to ships installing and using shore-power technology. The wide variance in different ship types, sizes, routes and modes of operation mean that the following issues vary considerably in their severity for different operators. The main issues are:

- Not enough ports have shore-power capability. If a ship operates regularly between 5 ports, it needs shore-power connectivity at all of them to gain the full benefit of investment. This problem is compounded if ships change routes frequently, or if ships are not guaranteed to be able to dock at the shore-power-enabled berth at a given port.
- Short-times at berth. There are two types of difficulty here. First, if the turn-around time is less than an hour, some operators feel it would not be worth the effort to plug-in. This affects ferries making multiple trips per day, however successful experience with fast turnaround electric ferries in Sweden and Denmark show this technical problem is potentially surmountable. Second, some ship operators are less likely to prioritise shore-power because the vast majority of their vessels' time is spent at sea, so are more likely to prioritise climate change solutions focussed on at-sea emissions reduction, eg efficiency or alternative fuels for propulsion.
- Capital costs. Although smaller than for ports, investment costs are not trivial, and the funding situation for segments which are particularly promising for shore-power is extremely difficult since COVID-19, for example ferries and particularly the cruise sector.
- Uncertain and high electricity costs. Most ships operate in multiple jurisdictions. Fuel oil costs are reasonably consistent between countries, but electricity costs can vary wildly.
- Retrofitting. Most ships do not have shore-power technology fitted. Retrofitting shore-power technology is more expensive than designing into new-builds. It is hard for ship-owners to justify the cost for vessels with short remaining lifespans.

2.4 Grid capacity issues

Interviewees reported two main issues regarding grid capacity. First, because shore-power loads can be high - up to 10MW[29] for a cruise ship – there may not be grid capacity to supply sufficient power. Also, in future, multiple vessels berthing and connecting simultaneously could increase power requirements significantly. Ports are also often at remote parts of the distribution network. This capacity problem is not uniform – some areas have plenty of spare capacity, for example because of reduced industrial electricity demand nearby. But if extra capacity is needed, this can be expensive. This issue is compounded by reported difficulties in working relationships between ports and the District Network Operators, more generally, not just on shore-power. Interviewees reported that both DNOs and ports often did not understand each other's priorities, nor who to talk with in their respective institutions. Many ports expressed frustrations that DNOs were too busy to engage, or that DNOs raised multiple objections to port projects – that there was not sufficient capacity in the network, that demand was already too high in the area, or that shore-power loads were too peaky - and it was very difficult to overcome these objections. From the DNO side, concern was raised that proposals from ports arrived unexpectedly or piecemeal, and expecting unrealistically fast resolution.

2.5 Projects complexity

A major set of barriers to shore power was around the general complexity and difficulty of projects. Interviewees' concerns here can be grouped into three areas:

- Lack of information or expertise

Shore-power projects are complex, requiring negotiation between multiple stakeholders. Many interviewees noted that at present energy management is not part of a port's core business. The UK's electricity charging and regulatory systems are seen as complex and hard to understand. There is lack of information on the costs of critical parts of shore-power projects, or how to obtain the necessary infrastructure, or how to manage more complex electricity buying and selling arrangements. In addition, some respondents felt that a reason why Government has not supported shore-power so far is because officials are not aware of the difficulties and hurdles port and ship operators face.

- Port and ship culture and relations

It is long-understood that there is a "chicken and egg" problem for shore-power – ports will not invest in shore power until they know that ships are equipped and willing to use it; ship owners will not invest until they see that there are ports where they can connect. This is a common problem across many areas of environmental policy, and is overcome by actions on both supply and demand sides, and collaborative working. Interviews showed however that on shore-power there is tendency at present for blame to be attached on both sides for the lack of progress on shore power, and a strong sense from many respondents that the responsibility lies with the other party to resolve the current situation. Often, ports say there is no demand from ships, and ship operators will say there is no interest from ports. There is a sense of stand-off. There was also often a marked difference within both the port and shipping sectors in the cultural attitude towards shore-power, with some interviewees portraying shore-power as having implementation problems which should be resolvable, whereas others presented these same difficulties as insurmountable hurdles.

Interviewees from ports and shipping operators both also stressed the need for greater intra-port collaboration, and intra-shipping operator collaboration. For ports, there were three cited benefits of greater joint working on shore-power. First, the potential for lower components costs if working in consortia. Second, greater likelihood of ship operators investing in shore-power, if they can see multiple ports where they can plug in. Third, ensuring standardisation and compatibility of equipment between ports. These issues among others are being considered by the World Ports Climate Action Program[30].

- Technical issues

Interviewees raised a number of technical concerns around shore-power, such as worries about voltage and frequency compatibility, cross-jurisdiction standardisation, safety concerns, and the variance in charging point locations on ships. These technical concerns are historic, and have been addressed. They mostly date back a number of years, before the recent introduction on international and harmonized standards for shore-power (eg IEEE 80005-1/2/3), and clear class rules from registries. But these concerns linger, and it is the case that there has not been a widespread dissemination of the latest information regarding these technical standards.

2.6 Low prioritisation

The last group of barriers to shore-power projects is that they are often a low priority measure. This is for two distinct reasons:

- External shocks. COVID-19 has made it much harder for ship and port operators to consider shore-power projects, because it has reduced the ability of both entities to finance any project, and because organisational capacity has been diverted towards fire-fighting the pandemic's impacts on their sector. In comparison, fewer interviewees mentioned Brexit as a factor reducing their ability to consider such projects, being mainly raised by some of the ports interviewed.
- Other priorities. Often, although shore-power is considered by a port or shipping company, it is lower down their list of priorities. For example, for ship operators considering action on climate change, measures on efficiency or fuels often take precedence. For both ship and port operators, shore-power's relative complexity and need for negotiation with a wider range of stakeholders mitigates against its prioritisation compared to measures with perceived faster and simpler returns.

3) Solutions

Although there are multiple complex barriers to implementing UK shore-power, interviewees were not short of solutions for overcoming them. Six broad categories predominated.

- Capital grants
- Improving business cases
- Regulatory standards
- Information provision
- Port-ship working relations
- Overall Government Strategy

3.1 Capital grants

First, there is a need for grants or loans to help with high capital costs. No port worldwide has implemented shore-power without such support. It is likely only with a comprehensive global carbon pricing programme that there will be a large enough margin between fuels to justify these investments on a financial case alone. Such a global pricing system is many years away.

Interviewees mostly focussed on the need for direct capital grants, rather than other mechanisms such as tax allowances. Various ranges for Government support were mooted, from 50-100%. It was noted that in Germany, Government support was 90%. A Government support scheme would not be needed indefinitely – future pricing or regulation policy would reduce the need. To accelerate shore-power deployment, a Government capital fund, as part of any wider Clean Maritime Infrastructure Fund, could aim to deliver around 5-10 additional major projects by 2025. The recent Southampton and Orkney projects obtained some UK and Scottish Government funding, however there is no clear source of funding for other future projects.

3.2 Improving business cases

Second, there is action that can be taken now to improve the business case, by improving the margin between grid electricity and power from on-ship diesel. Marine fuel's exemption from taxation will take many years of international negotiation to address, but the UK Government can partially address this anomalous competitive disadvantage for grid electricity by exempting ships from electricity taxes, as has been done in countries like Germany, France, Sweden and Denmark.

BOX 1: UK and EU electricity costs: grid vs diesel

To recoup capital costs, ports will need to make a margin between the price they pay for electricity and the price they charge ships. Without regulation mandating that ships use shore power, the price charged to ships would need to be the same or cheaper than the price from using diesel engines on-board.

The price each UK port pays for electricity varies, and is commercially confidential. BEIS reports that the average electricity price[31] for a medium-sized UK industrial user is 12.8p/kWh, with 4.6p/kWh of that being various environmental taxes. On average a further 5p/kWh of the final cost comes from three electricity network charges – TNUoS, BSUoS, and DUOS: transmission, distribution and balancing services. The remainder is the wholesale cost of electricity.

The price for electricity from on-ship diesel varies. Because diesel is untaxed, swings in global oil prices have a much bigger impact on ship fuel costs than they do in road transport. The price of Rotterdam MGO is currently[32] $340/tonne, a few years ago this price was $500. The rough cost of on-ship diesel electricity is 8p-13p for $340-$500/t fuel costs.

This shows there is currently on average no positive margin for UK shore-power. This may be different in certain locations and times, where power prices are lower: for example ships in the new Orkney shore-power installation will charge at night, when grid electricity is plentiful and cheap. However in general, high UK electricity prices and low, untaxed marine fuel prices mean the economics for shore-power are weak. The high electricity price issue is worse in the UK - our industrial electricity prices are higher than other EU countries: in general and because of higher taxes and network charges (see graph 1). In addition, some countries have successfully applied to the EU to exempt shore-power from electricity – Germany and Sweden's exemptions remove a further 2p/kWh from shore-power costs.

The exemption of marine fuels from taxation is a clear market distortion which unfairly penalises cleaner shore-side power supplies in favour of highly polluting diesel ship engines. In the absence of any likely material change in marine fuel taxation in the short-medium term, the UK could help overcome this by removing taxes and charges from shore-power. The various environmental charges applied in the UK are:

- Feed-in tariff 0.6p/kWh
- Renewables obligation 2.3p/kWh
- Contracts for Difference 0.6p/kWh
- Climate Change Levy 0.8p/kWh
- Capacity Mechanism 0.4p/kWh
- Transmission/Distribution/Balancing 5.1p/kWh

Exemption of all charges related to decarbonising the grid would leave average shore-power electricity costs at around 8p/kWh, able to compete with untaxed diesel. A number of interviewees raised the issue that transmission, distribution and balancing charges have been rising sharply in recent years, with ports receiving disproportionately fewer benefits. But some interviewees felt that reducing such charges for shore-power may be administratively harder to accomplish.

Even with better margins, ports still face an uncertain situation whereby ships might not use these facilities in future. This problem is likely to diminish as more ships in more ship classes become shore-power compatible, and if carbon prices increase. However in the meantime, the problem remains. One solution is for contracts on prices agreed by ports and ships. These could be difficult to negotiate – ship operators in some situations may be reluctant to tie themselves to use of a given port years into the future, given that shore-power is just one of the services negotiated between a port and ship operator.

3.3 Regulatory standards

Third, some form of regulatory standard could be introduced to overcome the "chicken and egg" problem of insufficient demand. This regulation could apply to ships or ports or both, and be specific to shore power or general to achieving zero emissions – either at berth or in the wider port area.

BOX 2: Regulation

US and EU Legislation

The EU has legislation on shore power as part of the 2015 Alternative Fuels Infrastructure Directive (AFID), but it is ineffective. It requires some ports to install shore power by the end of the 2025, but the clause "*unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits*" ensures that in practice any port will have a justifiable reason not to install shore power if they do not wish to. In any case, the UK when transposing this EU legislation into UK law did not include the 2025 requirement. Even if the EU legislation was a driver for port installation, it does not include any requirement on ship operators, risking ports being forced to invest in unused assets. Shore-power related changes to EU legislation are being debated via the EU Green Deal, the Fuel EU Maritime initiative[33] and revisions to the AFID[34].

Californian legislation[35] focuses primarily on vessels, aiming to cut NOx and particulate emissions at berth. Broadly, this 2007 regulation requires container, reefer and passenger vessels at 6 major Californian ports to cut either at-berth auxiliary-engine power consumption or NOx and PM emissions by 50% from 2014, 70% from 2017 and 80% from 2020, allowing for technologies other than shore-power to achieve compliance. It applies to vessels over defined sizes, for visits over defined lengths. The regulation also has requirements on port and terminal operators; the regulation was also backed up by a massive investment programme in installing shore-power facilities in the main state-owned ports. As of September 2020 a new regulation is in the final stages of approval, extending coverage to other ship types and ports: covering full-compliance for containers, reefers and passenger vessels by 2023 and ro-ro by 2025. A port-specific requirement will be put in place for tankers – with vessels visiting Los Angeles and Long Beach compliant by 2025, and at other ports by 2027.

UK possibilities

The British Ports Association[36] has advocated a "Zero-emissions berth standard" (ZEBS) for vessels and the European Sea Ports Organisation (ESPO)[37] also supports setting of targets for ship emission reduction at berths and in ports. This focus on vessels would help ensure that port infrastructure investments were not unused. Also, the focus on "zero emissions", rather than specifying "shore power" allows for other solutions to be adopted. Interviewees from both port and ship operators prefer to have flexibility – "specify the goal, not the means" was a common view. Shore power might not be the best solution for particular vessels or ports, and ships could also meet a ZEBS by using batteries and hybrid engines, or in the medium-term through alternative fuels. Using hybrids to meet a ZEBS would likely be sub-optimal from a climate change perspective, if hybrid batteries were charged at sea using diesel engines. This problem would be removed if the vessel were able to charge by shore-power at one end of a regular route, for power-use in port at the other end.

Also, although a ZEBS is aimed at vessels, in many cases ship owners would still be reliant on shore-power to meet it, meaning they would be reliant on ports also providing the necessary infrastructure. California overcame this by a state investment programme in shore-power, and with requirements on ports also embedded within the regulation. A broad ZEBS in the UK is only likely to be effective if it is in conjunction with other policy - to help ports with capital costs, and on electricity charging to improve business cases.

A ZEBS in the UK is also potentially more complex than in California, because California has fewer nearby jurisdictions with potentially different legislative approaches. A UK ZEBS will need to integrate – or at least ensure no grating incompatibility – with the EU's developing approach. With these qualifiers, the Californian approach appears a reasonable starting point for discussions of a possible UK ZEBS. It requires increasing percentage compliance over time, starting with certain shipping segments first and then expanding coverage, and has differentiated targets for specific ports.

3.4 Information provision

Fourth, there is an expressed need for an information service, helping ports and ships overcome some of the complexities and information gaps which currently make shore power a difficult project to justify. This service could be provided by the Government's proposed MERAS body. An alternative would be a joint port-shipping-electricity network web portal funded jointly by the industries, with regular webinars.

Three areas stood out. First, the electricity market is complex and changing rapidly, charging structures are multi-layered, and the mechanisms by which ports might obtain additional capacity or buy or sell electricity in future are felt to be unclear. Some interviewees expressed interest in understanding the potential for third-party leasing or management of energy and electricity assets in ports. Second, the business cases for shore-power for ports and shipping companies are hard to pull together, because of fragmented and unavailable data on demand and costs. Third, for ports, better understanding of the potential for integrated "smart-grid" electricity infrastructure investments, given the widespread view that much greater electrification and the growth of smart grids is inevitable and could represent major business opportunities.

3.5 Port-ship working relations

Fifth, many interviewees stressed the need for greater collaborative working between ports and shipping operators. In previous years there has been an impasse where the lack of progress on shore power has been assumed to be the responsibility of the other party. In reality, shore-power projects require collaboration – for example a number of European Ports said that the most critical factor in their shore-power deployment was developing a strong working relationship with a committed ship operator, helping give greater certainty for future revenue streams. In the last year, there has been greater co-working in the UK on these issues - cross-sector working groups specifically addressing the detail of potential implementation of tax or regulatory measures would be a strong step forward.

3.6 Government Strategy

Sixth, shore-power will not develop if the above measures are deployed partially or piecemeal. For shore-power to grow in the UK, the Government will need to set out a clear framework for shore-power, to reduce uncertainty, and a package of policies to help ports, ship operators and electricity network operators. The package could also aim to focus on delivery of "quick wins" at the locations where shore-power would lead to the greatest benefits.

This section also looks at how the solutions in 3.1-3.5 might dovetail.

Box 3: Policy packages: integration and timing

Red diesel duty in the UK is charged at 11p per litre, which is equivalent to a carbon price of £48/tCO_2. Normal fuel duty is 58p/l, equivalent to £259tCO_2. Marine diesel is untaxed. Trafigura, one of the world's largest shipping charterers, have recently proposed[38] a global carbon levy of $250-300/t$CO_2$ on carbon-intensive marine fuels, with funds recycled back to the industry to develop alternative fuels, in order to meet the IMO's climate targets. This equates to $747/tonne fuel, which would take the cost of marine fuel from around $340/t now to $1000/t.

This would raise the cost of on-board diesel electricity to around 26p/kWh. In these circumstances, it would be a viable economic proposition for ports to invest in shore-power infrastructure without state-support.

This removal of carbon-subsidies for diesel might be ideal, however given near paralysis at the IMO on carbon pricing it will not happen any time soon. Even an alternative proposal of a $2/t fuel levy from the International Chamber of Shipping has not progressed[39]. In the absence of carbon pricing, even with reductions on environmental charges on shore-power, diesel still has an artificial advantage. A number of interviewees suggested that the simplest way to deal with this would be to remove the option of using on-board at berth fossil-fuelled electricity, for example with a zero-emission berth standard.

Ships would have options to meet this standard – connect to shore-power, use battery packs, or use low-carbon fuels. In a majority of cases shore-power would be the cheapest of these option, but use of a ZEB allows flexibility for when for either port or ship operator there are specific circumstances making shore-power unviable. Again, the removal of the high-polluting option would enable ports to charge higher electricity prices to recoup their capital costs. Some mechanism would be necessary to ensure that ports were not applying excessively high charges. A regulatory standard also gives a strong signal to the sector and the markets about direction of travel; this has been positive in the UK car sector with the Government's announcement of a ban on petrol and diesel new car sales from 2035, and subsequent tightening to 2030.

This last point relates to the wider issue of competitiveness. Regulation and pricing mechanisms will need to work as an integrated package, but because the sector is so heterogeneous, policy design will need to be tailored to circumstance, with potentially different rates of application for different sectors and port, and ensuring compatibility with any EU measures is a critical aspect of any UK policy design, given most UK ships are also operating in EU jurisdictions. Getting this right will be complex and will take time, but tackling these problems is urgent. So, as a parallel track to designing an appropriate regulatory standard, the UK should ensure there is some momentum behind shore-power by supporting their development through capital grants and removal of electricity taxation on shore-power.

The new Royal Navy Portsmouth, Orkney and Southampton projects should help drive further shore-power projects in the UK by showing other ports and ship operators working examples. But these further projects will need Government support. The recent clusters work for the Government suggested certain locations as good candidates for shore power, based on proximity to supplies of renewable electricity, other industrial clusters, and grid connections. There are however a number of further considerations for strong locations for shore-power which need to be included, most importantly around actual rather than theoretical demand. This requires analysis around the type and frequency of vessel traffic, for example ports which have frequent, consistent, long-stay, high-load vessels. A port with a ferry arriving daily might have the same theoretical annual demand for shore-power as a port with 50 container ships visiting 7 times a year, but the former is a better short-term contender as it only requires one vessel to have a shore power connection. Higher demand at night, with cheaper grid-electricity, will also help with project economics. European ports also stressed that an essential element for a successful shore-power project is a strong working relationship between port and ship operator. This suggests that it might not be appropriate or most effective for Government to choose where capital grants should go, but rather that it be open to collaborations of port and ship operators to bid for. One mechanism could be to copy the approach taken by China, which is to reduce the total available funding each year, to encourage early development of projects. Or 90% project funding could be available in Year 1, falling by 10% in each subsequent year.

4) Recommendations

The following are the author's recommendations for actions which could help implement the solutions interviewees proposed.

1) Multiple cultural, economic and technical problems have been identified in obtaining sufficient **network capacity** for shore-power. These issues are wider than shore-power – they will be increasingly important as ports inevitably electrify more and more of their operations in the coming decade. The solutions are not obvious. **UKMPG and BPA could convene a working group with DNOs, National Grid, Ofgem, and the Government with the aim of developing a clear, simple framework for enabling the development of Port smart grids.** The most important issues to address are electricity charging mechanisms, and planning for infrastructure development.

2) There was a broad consensus that some form of intervention is necessary to incentivise demand for zero-emission vessels in ports, where the technologies to do so include shore-power. The overwhelming focus of interviewees was on some form of regulatory standard – such as a Zero Emission Berth Standard. **The Port Associations and the UK Chamber of Shipping could lead a focussed working group aiming to set out the core principles, purpose and detail of a regulatory standard**: its aims and time-frames, and how it could work in practice.

3) For technology, the desire to avoid trying to "pick winners" is understandable, but some technologies are "no regrets". Ports and ships will use more electricity in future, irrespective of the introduction of alternative liquid fuels. Therefore, as part of the implementation of the ambition in the Clean Maritime Plan, **the Government could set a clear strategy for developing shore-power and cutting at-berth emissions, with five central components:**

    a. **a capital fund** for projects over the next 5 years sufficient to see 5-10 further shore-power projects in place by 2025;
    b. a consultation on **reductions in electricity taxation for shore-power** to allow it to compete fairly with marine diesel oil, and to ensure a level-playing field for the UK, given EU shore-power tax exemptions for Germany, France, Sweden and Denmark;
    c. a clear remit in MERAS for **information provision**;
    d. a commitment to put in place a **zero-emission regulatory standard** compatible with future EU legislation (link to Recommendation 2); and
    e. a commitment to enabling wider port electrification and smart grids through changes to **electricity network planning and regulation** (Link to Recommendation 1).

References/notes:

[1] The Maritime Emissions Regulation Advisory Service, whose planned establishment was set out in the Clean Maritime Plan https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/815664/clean-maritime-plan.pdf , p7.
[2] Many smaller vessels can connect to electricity grids when at port, for low loads. When this report talks about "Shore-power" it is referring to higher load demands replacing auxiliary engines' production of electricity at berth, from around 100kW to 20MW, for which specialised equipment both shore and ship side are needed, for example to contend with potential issues of power consistency and need for frequency conversion. These higher loads would place far larger demands on electricity grids compared with the tiny amounts of power used by smaller fishing boats, yachts etc.
[3] Portsmouth: https://www.royalnavy.mod.uk/news-and-latest-activity/news/2019/november/05/191105-portsmouth-is-ready-for-hms-prince-os-wales, Orkney: https://www.orkney.gov.uk/OIC-News/UKs-first-large-ship-to-shore-commercial-connection-to-be-installed-in-Stromness-as-part-of-green-power-project.htm, Southampton: https://www.abports.co.uk/news-and-media/latest-news/2020/port-of-southampton-to-open-new-cruise-terminal-for-2021-season/
[4] ESPO, 2020. ESPO Environmental Report 2020. https://www.espo.be/media/Environmental%20Report-WEB-FINAL.pdf
[5] There may be some residual emissions from use of ships' boilers for heating. Electric boiler retrofits are possible though expensive at present.
[6] Manoeuvring emissions tend to be larger in long estuary ports, eg the Thames and Humber estuaries
[7] https://www.globalmaritimeforum.org/getting-to-zero-coalition/
[8] https://www.poseidonprinciples.org/
[9] There are also non-fuel alternatives to cutting emissions – such as improved engine efficiency, wind-assistance (eg flettner rotors), slower speeds, reduced demand, hull coatings etc. An overview of these issues is set out in Bouman EA, Lindstad E, Rialland AI, and Strømman AH. State-of-the-art technologies, measures, and potential for reducing GHG emissions from shipping–a review. Transportation Research Part D: Transport and Environment. 2017;52: 408-21.
[10] For overviews, see DNV GL, 2019. Comparison of Alternative Marine Fuels. Document No. 11C8I1KZ-1; Lloyd's Register. Zero-emission vessels: transition pathways. 2019; and Gilbert P, Walsh C, Traut M, Kesieme U, Pazouki K, Murphy A, 2018. Assessment of full life-cycle air emissions of alternative shipping fuels. Journal of Cleaner Production.172:855-66.
[11] Life-cycle GHG emissions from biofuels are exceptionally complex to calculate, depending on fuel type, production method and sourcing. See Welfle A, Gilbert P, Thornley P, Stephenson A. Generating low-carbon heat from biomass: life cycle assessment of bioenergy scenarios. Journal of Cleaner Production. 2017; 149:448-60.
[12] Ammonia's potential local air pollution and GHG emissions are complex – see Kobayashi H, Hayakawa A, Somarathne KDKA, Okafor EC. Science and technology of ammonia combustion. Proceedings of the Combustion Institute. 2019; 37(1):109-33.
[13] For some of the complexities re LNG GHG emissions see Pavlenko N, Comer B, Zhou Y, Clark N, Rutherford D. The climate implications of using LNG as a marine fuel. 2020; and Lindstad E, Rialland A. LNG and Cruise Ships, an Easy Way to Fulfil Regulations—Versus the Need for Reducing GHG Emissions. Sustainability. 2020;12(5):2080.
[14] Hydrogen's life-cycle emissions will be much lower if produced via electrolysis than from methane.
[15] https://afi.dnvgl.com/Map, accessed 18/11/2020
[16] ESPO, 2020. ESPO Environmental Report 2020. https://www.espo.be/media/Environmental%20Report-WEB-FINAL.pdf
[17] IMO, 2018. https://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrategy.aspx
[18] Progress on international shipping GHG emissions is rated as "critically insufficient" by independent scientific analysts Climate Action Tracker. https://climateactiontracker.org/sectors/shipping/
[19] https://www.argusmedia.com/en/news/2141385-parliament-votes-eu-ets-ship-inclusion

[20] Frontier Economics for Department of Transport, 2019. REDUCING THE UK MARITIME SECTOR'S CONTRIBUTION TO AIR POLLUTION AND CLIMATE CHANGE. Potential Demands on the UK Energy System from Port and Shipping Electrification. July.
[21] E4Tech and UMAS, 2020. Clean Maritime Clusters Research Study. April 2020
[22] In August 2020, the Government set out a £900m "Getting Building Better" fund for "shovel-ready" infrastructure projects agreed with local mayors and local enterprise partnerships (LEPs). Solent LEP was awarded £15.9m for 6 projects; one of these six projects involved Port of Southampton, with one component of this being shore-power at the cruise terminal. The Orkneys project benefitted from funding from the Scottish Government and the European Regional Development Fund, see https://www.orkney.gov.uk/OIC-News/UKs-first-large-ship-to-shore-commercial-connection-to-be-installed-in-Stromness-as-part-of-green-power-project.htm. On 16th November 2020 as part of the Government's 10 point plan for a Green Industrial Revolution, a £20m Clean Maritime Demonstration Fund was set up, it's likely that shore-power projects would not be eligible for this as they are beyond the demonstrator phase. The November 25th 2020 Spending Review contained no specific funding for shipping.
[23] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52014PC0538. Document 52014PC0538
[24] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015D0993. Document 32015D0993
[25] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014PC0497. Document 52014PC0497
[26] https://data.consilium.europa.eu/doc/document/ST-11192-2020-INIT/en/pdf. Interinstitutional File: 2020/0255 (NLE).
[27] BEIS, 2020. Quarterly Industrial Electricity Prices in the EU. Data for July-December 2019, published June 2020
[28] Eg DNV.GL, 2020. MARITIME FORECAST TO 2050. Energy Transition Outlook 2020.
[29] Previous shore-power analyses have mentioned loads up to 15-20MW for cruise ships, however industry focus on energy efficiency in recent years eg LED lighting have reduced this significantly. 10MW is a likely upper-bound for UK cruise vessels; efficiency gains also affect other shipping segments.
[30] https://sustainableworldports.org/wpcap-ports-aligned-in-series-of-new-climate-change-actions/, Power2Ship Working Group.
[31] June-Dec 2019. Medium = 2-20mkWh/yr. "Small" and "Large" users pay 15.1 p/kWh and 12.1 p/kWh on average. BEIS table 541, June 2020 update. https://www.gov.uk/government/statistical-data-sets/international-industrial-energy-prices
[32] As of 12th November 2020. https://shipandbunker.com/prices/emea/nwe/nl-rtm-rotterdam
[33] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-fuel-eu-maritime
[34] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-revision-of-the-directive-on-deployment-of-alternative-fuels-infrastructure/10-2020
[35] Full details of existing and proposed Californian legislation are available at https://ww2.arb.ca.gov/, including the 2007 regulation: https://ww3.arb.ca.gov/ports/shorepower/finalregulation.pdf and the status of planned revisions: https://ww2.arb.ca.gov/rulemaking/2019/ogvatberth2019
[36] BPA 2020. Reducing emissions from shipping in ports: examining the barriers to shore power. May 2020.
[37] ESPO, 2020. Position of the European Sea Ports Organisation on the Fuel EU Maritime Initiative. 31st August
[38] Trafigura, 2020. A proposal for an IMO-led global shipping industry decarbonisation programme. September.
[39] https://www.maritime-executive.com/article/ics-renews-call-for-bunker-fuel-carbon-levy