Bornholm Energy Island

Powering

Maritime Electrification

A whitepaper made by Port of Roenne,
Baltic Energy Island and Stillstrom by Maersk,
June 2026

PORT OF ROENNE Together we create | BALTIC ENERGY ISLAND | STILLSTROM by Maersk

Executive Summary

Decarbonising global shipping is a central challenge in the maritime sector's transition toward climate neutrality. Initial efforts have mainly focused on finding new low-carbon e-fuels to replace current use of fossil fuels. However, these e-fuels are challenged in both cost and scalability, inhibiting wide-scale adoption.

At the same time, maritime electrification is moving forward in replacing all or parts of current use of fossil fuels within two broad categories – shore power solutions and battery-electric vessels. Shore power solutions have developed significantly over the last years and enables vessels at berth and idling to use electricity instead of running their auxiliary engines on fossil fuels. Recently, direct electrification solutions for battery-electric vessels have emerged as a reliable solution due to significant improvements in battery technology and cost reductions. Globally, vessel owners are now investing in battery-electric tugs and ferries, with projects for battery-electric short sea shipping[1] - like container vessels and bulk carriers – in development.

Vessel electrification requires a distributed power supply with the necessary capacity for power supply. Implementing the needed power supply is often challenged by long lead times and high capital requirements for for upgrading land-based transmission. Power availability in key ports like TEN-T ports[2], is both the central challenge and a critical enabler of maritime electrification—for shore power at berth and, even more so, for the higher-capacity demands of charging large battery-electric ferries.

In parallel with delivering sufficient power in the ports, another key enabler for maritime electrification is being developed – Offshore Power Zones (OPZ). Offshore Power Zones will make it possible for vessels to get power supply at sea while idling or charging onboard vessel batteries. Offshore Power Zones will therefore expand the use of electrified solutions onboard vessels by increasing the operational flexibility with more zones to access power supply outside ports. Offshore Power Zones also help bypass onshore grid expansion challenges, as they can be connected directly to offshore wind farms located near shipping lanes. This creates the potential for a cost-effective and fast-tracked power supply for vessels at sea.

The EU has already implemented and is further developing policy measures for maritime electrification through the Alternative Fuel Infrastructure Regulation (AFIR) and FuelEU Maritime. AFIR sets shore power requirements for the TEN-T ports, while FuelEU Maritime sets requirements for shore power readiness for ferries, roll-on/roll-off passenger vessels (RoPax), cruise ships and container vessels. EU ETS and FuelEU Maritime also provide economic incentives of reducing GHG-emissions from larger vessels, which also create further incentives for vessel owners to pursue GHG-reductions.

Scaling-up maritime electrification has the potential to be the next crucial step on Europe's electrification journey. Moving electrification at large scale into the maritime sector will be fully aligned with the policy goals of reducing fossil fuel dependencies and imports as well as GHG-emissions. Unlocking this potential strengthens resilience by leveraging domestic energy resources and improving efficiency.

> **Battery-electric vessel propulsion is up to four times more energy efficient than using e-methanol, as fuel for vessel propulsion.**

This whitepaper outlines how leveraging planned transmission infrastructure and offshore wind farms from projects like Bornholm Energy Island (BEI) can enable cost-efficient and rapid uptake of maritime electrification. BEI simply serves as a blueprint for how offshore wind farms and associated transmission grid infrastructure can play a crucial and cost-effective role in unlocking the potential for maritime electrification both in ports and at sea. Delivering sufficient power at cost-competitive prices are two key drivers for vessel owners considering investing in onboard electrification solutions from shore power capabilities to fully battery-electric propulsion for various types of vessels incl. short sea shipping cargo vessels, ferries and RoPaX.

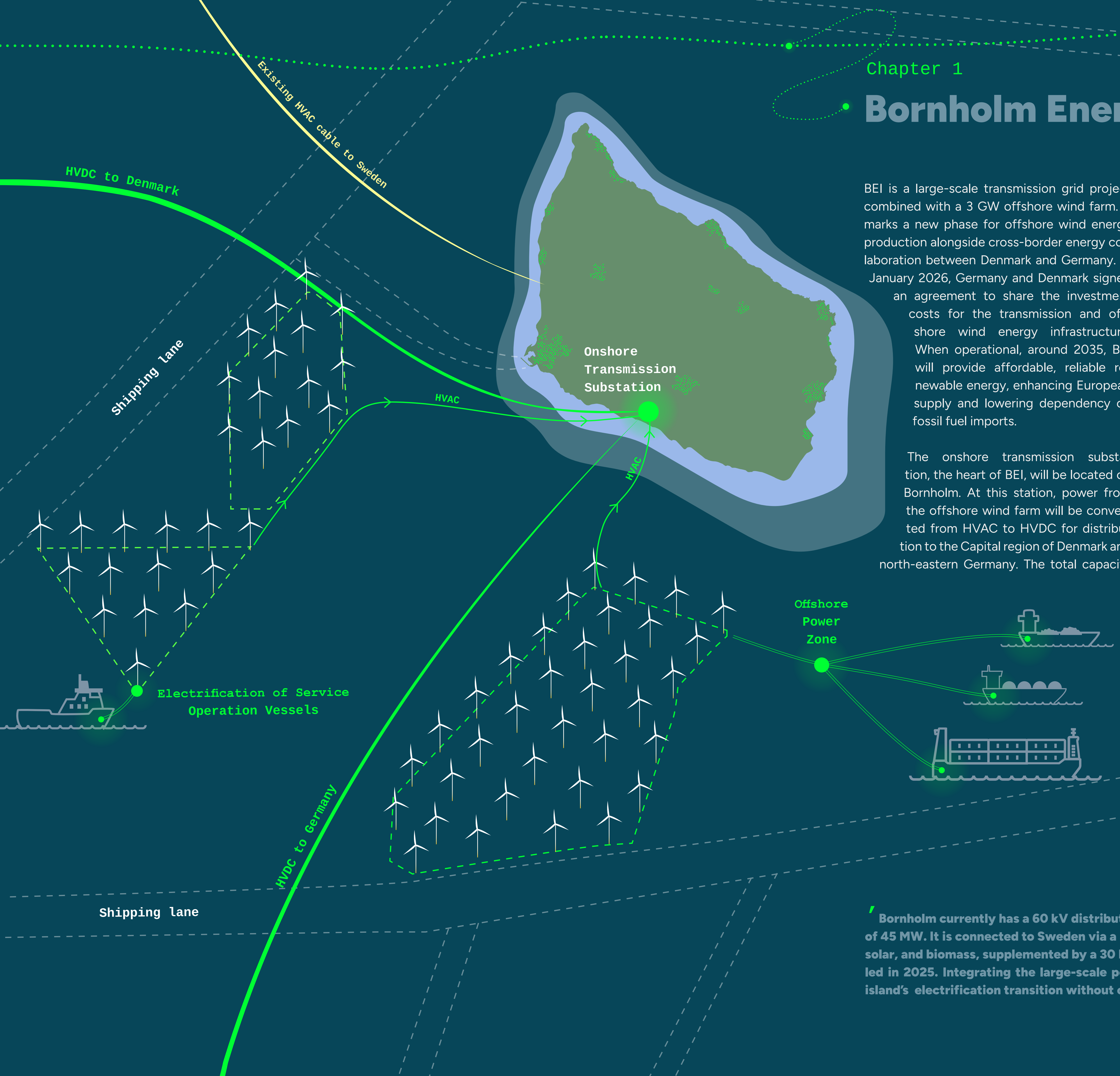
BEI is an obvious case-study for how maritime electrification can be fast-tracked, taking advantage of offshore wind farms and energy island solutions. The Port of Roenne on Bornholm is currently challenged to meet even the shore power requirements under AFIR for cruise vessels calling at the port. The existing transmission capacity cannot service shore power demands from the visiting cruise vessels, let alone electrification of the ferry services to and from Bornholm. The lack of power – both in terms of supply and transmission infrastructure – can be solved cost-effectively by BEI. BEI's planned 3 GW offshore wind farm will not only provide a solution for Port of Roenne, but will also enable large-scale electricity supply at sea in Offshore Power Zones, where idling vessels can access power to cover their hotel load and battery-electric vessels can do "highway"- fast-charging.

[1] Short sea shipping is the maritime transport of goods over relatively short distances, as opposed to the intercontinental cross-ocean deep sea shipping. Source: Eurostat

[2] TEN-T: Trans-Europe Transport Network

Chapter 1

Bornholm Energy Island



BEI is a large-scale transmission grid project combined with a 3 GW offshore wind farm. It marks a new phase for offshore wind energy production alongside cross-border energy collaboration between Denmark and Germany. In January 2026, Germany and Denmark signed an agreement to share the investment costs for the transmission and offshore wind energy infrastructure. When operational, around 2035, BEI will provide affordable, reliable renewable energy, enhancing European supply and lowering dependency on fossil fuel imports.

The onshore transmission substation, the heart of BEI, will be located on Bornholm. At this station, power from the offshore wind farm will be converted from HVAC to HVDC for distribution to the Capital region of Denmark and north-eastern Germany. The total capacity will cover the equivalent electricity consumption of 3.3 million households. The existing distribution grid on Bornholm will also be connected to BEI, allowing the island to attract new business opportunities with high electricity consumption needs such as e-fuel production, data centres and similar power consuming industries.

Bornholm is located in the western Baltic Sea and approximately 60,000 vessels pass by the island annually. making the sea around Bornholm one of the busiest waterways globally. It is therefore ideally positioned to benefit from the new business opportunities presented by new maritime electrification opportunities in Port of Roenne and at sea in vicinity of the offshore wind farm.

The location of Bornholm and BEI also creates the opportunity for the island to become a beacon, showcasing how maritime electrification can ramp-up through aligned use of the transmission infrastructure alongside BEI and the offshore wind farm.

’ Bornholm currently has a 60 kV distribution transmission system and a peak consumption of 45 MW. It is connected to Sweden via a 50 MW sea cable. Local production includes wind, solar, and biomass, supplemented by a 30 MW battery energy storage system (BESS) installed in 2025. Integrating the large-scale power supply from BEI is essential to support the island’s electrification transition without compromising the energy stability.

Chapter 2

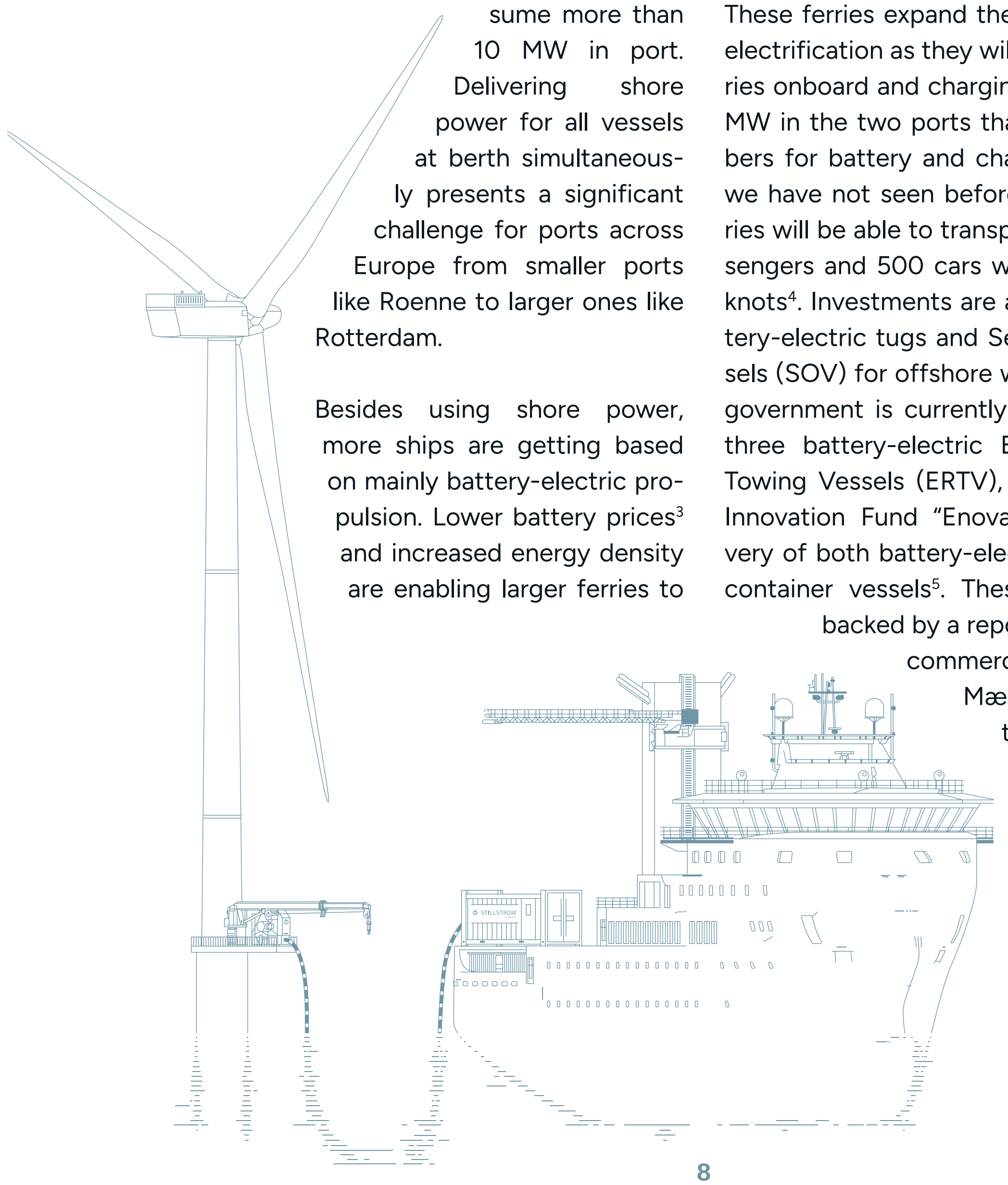
Direct Vessel Electrification

The International Energy Agency states in its report "Electricity 2025" that the world is entering the "Age of Electrification". In Europe, electrification has focused on road transport, heating, and manufacturing. Maritime electrification is the next phase. Shore power solutions allow ships, such as cruise and container ships, to plug into the power supply in ports and thereby switch off fossil-fuelled engines while in port. These solutions are becoming increasingly more common globally.

In EU, FuelEU Maritime and AFIR require use and provision of shore power at key TEN-T ports. For example, a single cruise vessel can consume more than 10 MW in port. Delivering shore power for all vessels at berth simultaneously presents a significant challenge for ports across Europe from smaller ports like Roenne to larger ones like Rotterdam.

Besides using shore power, more ships are getting based on mainly battery-electric propulsion. Lower battery prices[3] and increased energy density are enabling larger ferries to operate on longer routes using battery-electric propulsion. With the necessary charging infrastructure in place, battery-electric solutions become applicable for the short sea commercial cargo fleet as well. In fact, the lack of charging infrastructure and sufficient transmission capacity in ports are rapidly becoming a key barrier for widespread maritime electrification.

The rapid development of investments in battery-electric vessels is further strengthened by higher GHG-emission costs if continuing burning fossil fuels. Nordic Ferry Infrastructure recently ordered three large battery-electric catamaran ferries for one of its routes in Denmark. These ferries expand the boundaries of direct electrification as they will have 45 MWh batteries onboard and charging capacity around 55 MW in the two ports that they service. Numbers for battery and charging capacities that we have not seen before. The catamaran ferries will be able to transport almost 1,500 passengers and 500 cars with a speed up to 40 knots[4]. Investments are also increasing in battery-electric tugs and Service Operation Vessels (SOV) for offshore wind farms. The Dutch government is currently running a tender for three battery-electric Emergency Response Towing Vessels (ERTV), while the Norwegian Innovation Fund "Enova" is supporting delivery of both battery-electric bulk carriers and container vessels[5]. These developments are backed by a report on battery-electric commercial vessels from the Mærsk Mc-Kinney Center for Zero Carbon Shipping[6], where battery-electric short-sea commercial vessels are analysed to be technological feasible. Based on the assumptions in 2024 container vessels were also analysed to be economically competitive as well when compared to using e-methanol as energy input. Given the continued development in battery technology and reduced prices the business case for battery-electric cargo vessels have further improved.



These developments show that direct vessel electrification is possible, despite the shipping industry being widely regarded as hard-to-electrify. Decarbonising the maritime sector has until now almost exclusively focused on production and supply solutions for e-fuels like e-methanol and e-ammonia or a drop-in biofuel like hydrotreated vegetable oil (HVO). However, maritime electrification is now gaining attention as it offers improved business cases compared to other decarbonised solutions. With the right incentives and power supply, maritime electrification can play an important part of fulfilling EU electrification and decarbonisation goals. The benefits include reduced fuel costs and imports, lower geopolitical risks, and increased energy efficiency. Direct electrification also contributes to significant reductions in GHG and various particle emissions such as NOx, SOx and PM2.5 from the maritime sector.

[3] IEA Global EV Outlook 2025 and BNEF, New Record Lows for Battery Prices, 2025

[4] Nordic Ferry Infrastructure, 2025

[5] Enova 2024 and 2025

[6] The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, 2024: Understanding the potential of battery-electric propulsion for cargo vessels

Chapter 3

Potential Demand for Cargo Vessels passing by Bornholm Energy Island

Most tonnages entering the Baltic Sea pass Bornholm via the main shipping lanes. In total around 60,000 vessels navigate past the island each year. This whitepaper has examined the energy needs of 37,000 cargo vessels out of the 60,000 vessels passing by Bornholm. The 37,000 cargo vessels are bulk carriers, tankers, and container ships, which are mainly on routes between EU countries, Norway and United Kingdom. The remaining vessels are mainly ferries, offshore vessels, roll-on/roll-off, and ships to/from non-EU ports in the Baltic Sea.

’ These 37,000 cargo vessels are estimated to consume some 3 million metric tons of marine gas oil (MGO) annually emitting 10 million tons of CO_2. The fuel used in these vessels represents an annual import value of approximately €2 billion on routes, where the vessels pass by Bornholm.

Full electrification of these cargo vessels would require approximately 17 TWh for charging of the vessel batteries annually in the case of battery-electric propulsion. This demand could be met by the production from 4 GW offshore wind capacity in the Baltic and North Seas. Since most analysed voyages pass numerous offshore wind farms, power supply for charging in ports or at sea could be accessible allowing for a larger part of the fleet to be electrified.

BEI provides opportunities to supply electricity to vessels using Bornholm’s ports, such as local ferries, cargo and service vessels. Port of Roenne estimates that combined, cruise and ferry electrification could increase its annual demand by 55–60 GWh – a level of consumption that cannot be met by the current transmission grid to Bornholm.

Electrification is expected to develop rapidly from the early 2030s, provided economic and regulatory incentives are in place for vessel owners and infrastructure providers. Maritime electrification will initially continue to focus on ferries, roll-on/roll-off vessels, tugs, and short sea cargo vessels. These vessels operate on fixed routes, making it possible to establish the necessary charging infrastructure in ports where power supply is available.

In the short term, the electrification potential for short sea vessels passing by Bornholm is about one-third of the total 17 TWh identified covering smaller short sea cargo vessels operating in the North Sea and Baltic Sea. These smaller short sea cargo vessels are, from a technology perspective capable of operating on battery-electric propulsion[7]. Over time, the size of battery-electric cargo vessels is expected to increase, making it possible to electrify a larger part of the fleet. Additionally, new demand will arise from shore power requirements in ports under FuelEU Maritime, in compliance with AFIR, as well as from the electrification of other vessel types such as ferries, RoPax vessels, and tugs.

Offshore wind farms are obvious power suppliers, able to meet the new demand from maritime electrification. According to Aegir Insights around 37 GW of offshore wind farms are today in operation from France to Finland. Aegir Insights also expects that by 2040, an additional 143 GW will come online in the Northern European Seas. The forecasted accumulated capacity around 180 GW will translate into 789 TWh/yr. If realised, it will cover at least 40 times the full battery-electric propulsion demand from cargo vessels passing by Bornholm. This development will ensure that the power supply for maritime electrification is well-covered, provided that power supply infrastructure is available in ports and offshore power zones.

’ Frontloading power supply and charging infrastructure is essential to accelerate maritime transport electrification. The experience from road transport shows why. Early electric vehicles (EV) adoption was limited to first movers who accepted range anxiety, short driving ranges, and sparse charging. As public charging expanded along major highways — supported by initiatives like AFIR requiring Member States to provide sufficient highway charging capacity — EV adoption scaled. This scaling of charging infrastructure and lower prices for EVs created a flywheel effect: more infrastructure enabled more EVs, which in turn justified more infrastructure investments.

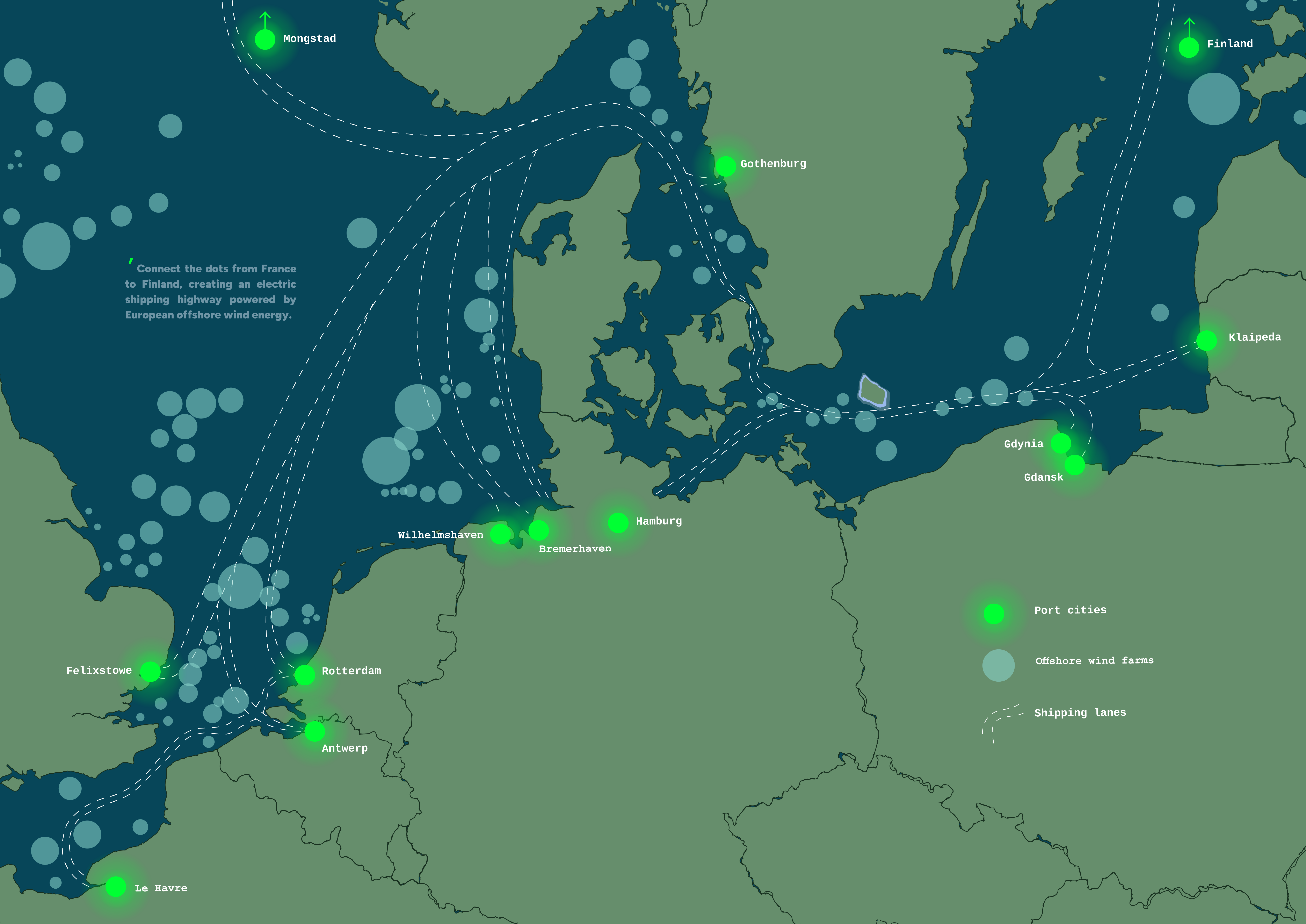
Electric trucks are now following the same pattern. Initial deployment focuses on point-to-point routes with dedicated chargers at logistics hubs, while AFIR also requires public highpower charging suitable for trucks along main highways. As “on-the-go” fast charging rolls out, e-trucks gain route flexibility and are no longer limited to a few short routes or operator owned chargers.

Short sea cargo vessels are expected to follow a similar trajectory. Early electrified operations will rely on port-to-port routes where charging is available. As more ports and the first ”on-the-go” Offshore Power Zones come online, vessel owners gain greater flexibility, improved access to low-cost energy, and reduced operational risks through a more redundant and robust charging network. Frontloaded charging investments will start the same flywheel effect seen in EVs and e-trucks, unlocking a rapid rampup of maritime electrification.

What seemed impossible only a few years ago is now underway — but progress depends on adequate power supply access. Combined with the ongoing cost reductions in maritime batteries and increasing GHG-emission costs, the business case for electric vessels is becoming financially viable for an increasing range of vessel types and sizes. This presents a major opportunity to releasing private investments in cost-effectively decarbonising maritime transport given societies continues to support the critical frontloading of charging infrastructure.


iStock. Credit: sbedaux

[7] Container ships up to 1,999 TEU, Tankers 10-54.9 kwt and bulk carriers up to 39.9 kdwt



' Connect the dots from France to Finland, creating an electric shipping highway powered by European offshore wind energy.

Chapter 4

Technological Feasibility

Onshore Power Supply (OPS), or "cold ironing," allows large vessels to access high-voltage power in certain ports to cover their hotel loads, which consists of the energy used while at berth in the port. OPS has been in place for many years demonstrating the industrial readiness and solid platform for further development of new maritime power supply solutions. Furthermore, regulatory mandates, like AFIR requirement for OPS at TEN-T ports by 2030, ensure continued focus on development of OPS solutions. Efficient use of OPS requires improved interoperability, and the industry is committed to supporting the development by defining standards for different vessel types, see table 1 below.

Providing power in Offshore Power Zones in addition to ports increases the number of reachable vessels and reduces the burden on port infrastructure. Offshore Power Zones will also reduce the need for grid investments, as the Offshore Power Zones can be connected directly to a power source in the form of offshore wind farms.

Shore-based options include container vessels, cruise ships and ferries for both hotel loads and charging of battery-electric vessels. Offshore Power Zones can serve idling vessels, like container vessels, bulk carriers and tankers as well as charging capabilities for battery-electric vessels. An SOV can even access power within the offshore wind farm, where it is operating. The technological standards for the various cases and solutions are mostly already in place. Those solutions that are not yet implemented are under development and will, to a large extent, build upon the standards already established.

The set of maritime electrification solutions covered in this study are depicted in table 1 below. The table also shows that, besides high-capacity charging for ferries and other larger battery-electric vessels, the standards for the required technological solutions are already in place. Current investments in battery-electric ferries will drive the development of high-capacity charging technology, which can be deployed in future Offshore Power Zones. Over time, this progress will create the basis for establishing future standards for high-capacity charging in ports and at sea.

Grid (50 Hz)			Port/Offshore Platform	Plug			Onboard vessel		Use Case Example	
Source	**Vessel Type**	**Required MW**	**Power Conversion**	**Plug Type IEC/IEEE**	**Voltage kV**	**Frequency Hz**	**Power Conversion**	**Frequency Hz**	**Power Coverage**	**Potential Routes**
Shore Power	Cruise ship	5-15	Transformer and frequency converter (AC->AC)	80005-1 Annex C	6.6 or 11	60	Transformer	60	Hotel Loads Only	Visiting cruise ship
	Ferry - Charging	2-50+	Transformer	Future Standard	22 to 66	50	Transformer and rectifier (AC->DC)	DC	Battery Charging	Roenne-Ystad Roenne-Koege
Offshore power	Commercial - Idling (Container, tanker, bulker)	1-8	Transformer and frequency converter (AC->AC)	80005-1 Annex D, F, H	6.6 or 11*	60	Transformer	60	Hotel Loads Only	Idling at anchorage
	SOV - Charging	6-8	Transformer	80005-1 Annex B	11	50	Transformer and rectifier (AC->DC)	DC	Battery Charging	Service operations in offshore wind farms
	Commercial - Charging (Container, tanker, bulker)	50+	Transformer	Future Standard	22 to 66	50	Transformer and rectifier (AC->DC)	DC	Battery Charging	Transit within and between North and Baltic Seas

Table 1:
Shore and offshore power solutions

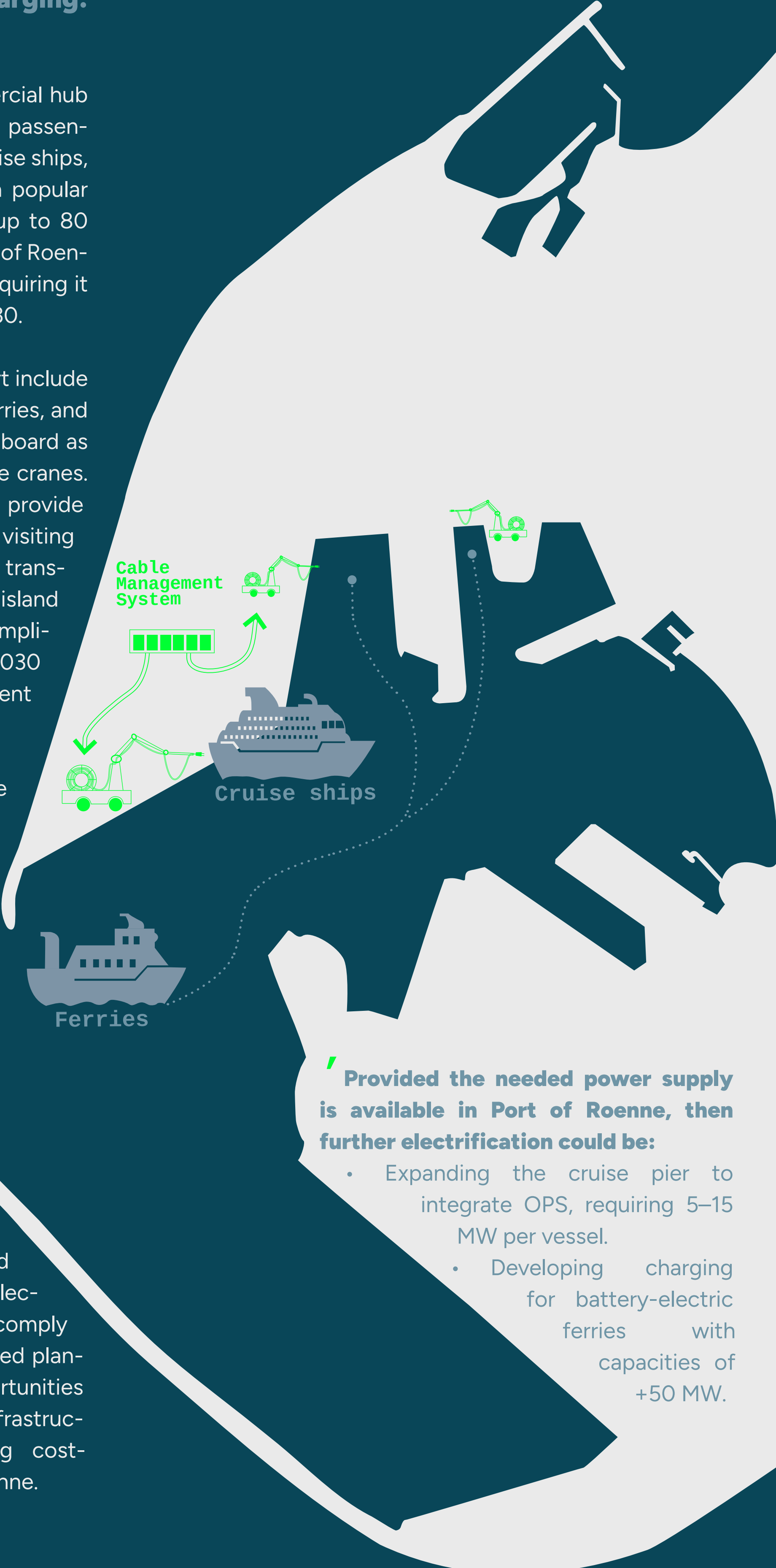
* 11 kV only for bulk carrier

Onshore Power and Charging: Port of Roenne

Port of Roenne is the primary commercial hub for Bornholm, handling all goods and passengers. It serves ferries, bulk carriers, cruise ships, and the offshore wind industry. As a popular tourist destination, the island hosts up to 80 cruise ships annually. Under AFIR, Port of Roenne is a TEN-T Comprehensive Port, requiring it to provide OPS for cruise ships by 2030.

Electrification opportunities in the port include as mentioned OPS for cruise ships, ferries, and other vessels with OPS equipment onboard as well as electrifying port machinery like cranes. Going forward, the port could also provide power for charging ferries and other visiting battery-electric vessels. The existing transmission grid capacity to and on the island is currently a key challenge. Being compliant with AFIR in Port of Roenne by 2030 is simply not possible with the current transmission grid.

Combined, a charging setup for the Roenne-Ystad ferry service and shore power for cruise vessels could increase the yearly power consumption in the port with 55-60 GWh. Exploiting the full maritime electrification potential in Port of Roenne could see peak electrical demand exceed 65 MW – more than 40% higher than the current peak demand for the entire island. This potential increase highlights how BEI can serve as showcase for how the upcoming 3 GW offshore wind energy capacity can unlock maritime electrification beyond the need just to comply with AFIR OPS requirements. Integrated planning, flexibility of connection opportunities and co-use of the associated grid infrastructure provides options for enabling cost-effective electrification in Port of Roenne.



Provided the needed power supply is available in Port of Roenne, then further electrification could be:

- Expanding the cruise pier to integrate OPS, requiring 5–15 MW per vessel.
- Developing charging for battery-electric ferries with capacities of +50 MW.

Offshore Power Zones

For vessel electrification, power supply infrastructure is as vital offshore as it is in ports. Offshore environments offer fewer space constraints and easier access to power supply for vessels when the Offshore Power Zone is located relatively close to an offshore wind farm's transmission infrastructure or an offshore transmission hub. Establishing distributed offshore charging points are complementing charging in ports of battery-electric vessels. Offshore charging opportunities increase the vessel's operational range, and consequently the number of ships that can be electrified. Like charging networks for cars, a series of Offshore Power Zones create opportunities for vessel owners to charge "on-the-go" and thereby optimise the onboard battery-size taking business case-drivers into account, such as CAPEX, the balance between onboard battery capacity and storage space, and the vessel's potential for flexible future use.

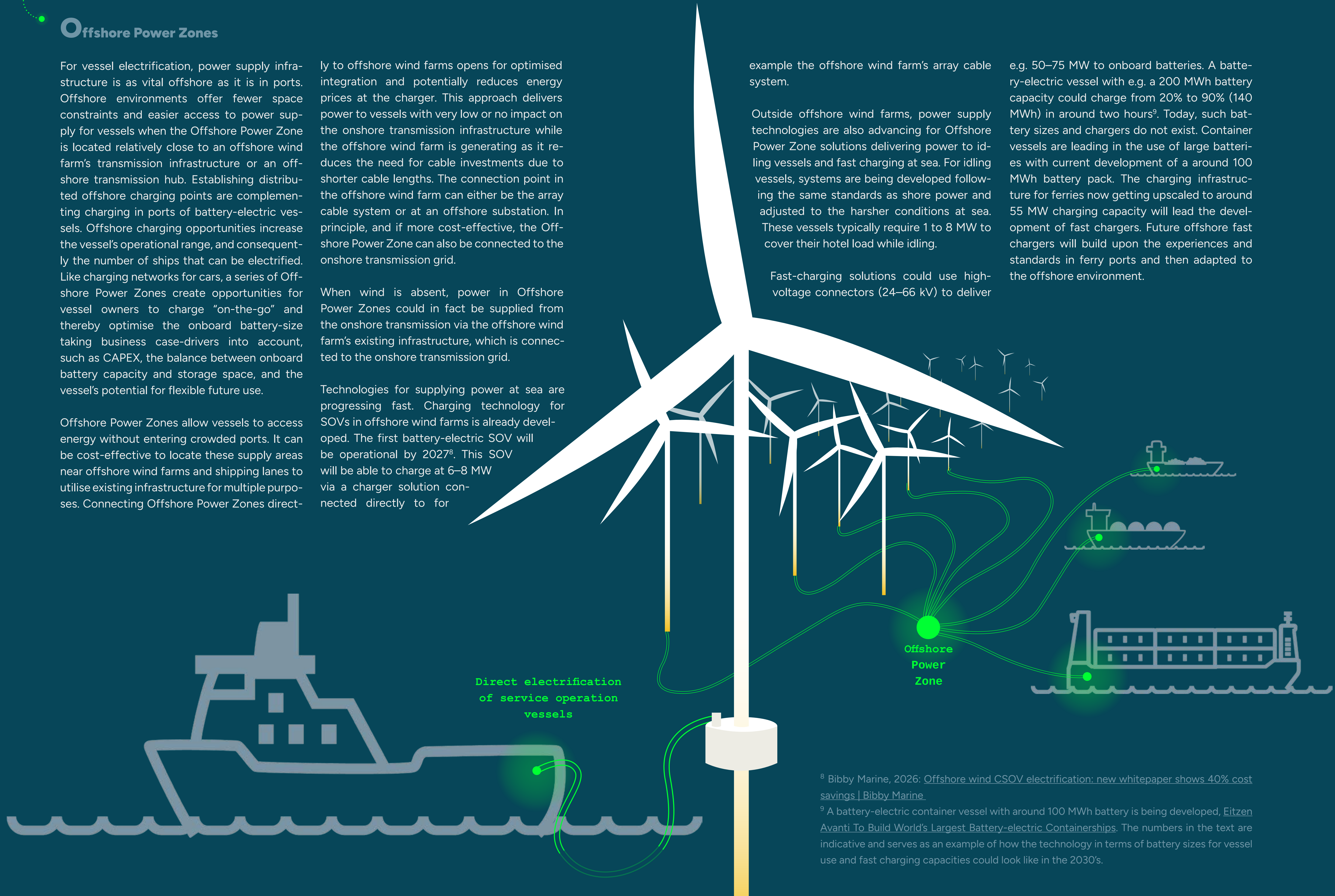
Offshore Power Zones allow vessels to access energy without entering crowded ports. It can be cost-effective to locate these supply areas near offshore wind farms and shipping lanes to utilise existing infrastructure for multiple purposes. Connecting Offshore Power Zones directly to offshore wind farms opens for optimised integration and potentially reduces energy prices at the charger. This approach delivers power to vessels with very low or no impact on the onshore transmission infrastructure while the offshore wind farm is generating as it reduces the need for cable investments due to shorter cable lengths. The connection point in the offshore wind farm can either be the array cable system or at an offshore substation. In principle, and if more cost-effective, the Offshore Power Zone can also be connected to the onshore transmission grid.

When wind is absent, power in Offshore Power Zones could in fact be supplied from the onshore transmission via the offshore wind farm's existing infrastructure, which is connected to the onshore transmission grid.

Technologies for supplying power at sea are progressing fast. Charging technology for SOVs in offshore wind farms is already developed. The first battery-electric SOV will be operational by 2027[8]. This SOV will be able to charge at 6–8 MW via a charger solution connected directly to for example the offshore wind farm's array cable system.

Outside offshore wind farms, power supply technologies are also advancing for Offshore Power Zone solutions delivering power to idling vessels and fast charging at sea. For idling vessels, systems are being developed following the same standards as shore power and adjusted to the harsher conditions at sea. These vessels typically require 1 to 8 MW to cover their hotel load while idling.

Fast-charging solutions could use high-voltage connectors (24–66 kV) to deliver e.g. 50–75 MW to onboard batteries. A battery-electric vessel with e.g. a 200 MWh battery capacity could charge from 20% to 90% (140 MWh) in around two hours[9]. Today, such battery sizes and chargers do not exist. Container vessels are leading in the use of large batteries with current development of a around 100 MWh battery pack. The charging infrastructure for ferries now getting upscaled to around 55 MW charging capacity will lead the development of fast chargers. Future offshore fast chargers will build upon the experiences and standards in ferry ports and then adapted to the offshore environment.



[8] Bibby Marine, 2026: Offshore wind CSOV electrification: new whitepaper shows 40% cost savings | Bibby Marine

[9] A battery-electric container vessel with around 100 MWh battery is being developed, Eitzen Avanti To Build World's Largest Battery-electric Containerships. The numbers in the text are indicative and serves as an example of how the technology in terms of battery sizes for vessel use and fast charging capacities could look like in the 2030's.

Chapter 5

Operational Feasibility

In addition to available technology, delivering power including high charging capacities for vessels in ports and at sea requires safe and efficient operational procedures. Shore power supply and charging operations of for example ferries are already showcasing how to handle these operational procedures.

The operational procedures at sea will build upon the current process for using for example mooring buoys or similar methods to keep the vessel in position during power transfer. The new procedures that need to be developed are those involving receiving, connecting, disconnecting, and returning the power cables.

For the SOVs in offshore wind farms, the procedures for connecting and disconnecting are already fully developed. SOVs are all equipped with a dynamic positioning (DP) system. The DP system use thrusters to maintain the SOV's position at sea instead of mooring or anchoring. During the power transfer, the SOV can therefore remain in a fixed position at safe distance from the offshore wind farm's assets.

In an Offshore Power Zone vessels could go through the following steps:

1. Manoeuvre into position near the power supply point, where for example an integrated mooring system ensures the vessel remains securely fixed during the entire power transfer operation to prevent the vessel drifting.

2. Connecting the vessel's charging interface to the power supply/charging unit via a power cable:

    - The interface will, to the greatest possible extent, follow shore power standards to ease the usability across power supply points in ports and at sea.

    - The exact method of cable delivery will depend on vessel specifications and environmental conditions.

3. When the power transfer is completed, the cable is disconnected and retracted, and the vessel is released, ready to continue its operations.

Illustration by Stillstrom
Offshore Power Zone

Chapter 6

Socio-Economic Perspectives

Maritime electrification aligns with the broader EU policy to use domestic supplied renewable electricity to lower:

- GHG-emissions
- Geopolitical risks
- Energy imports
- Overall energy demand due to energy efficient electrification solutions

Offshore wind farms are well-suited to unlock the potential of maritime electrification. Using parts of the power generated in offshore wind farms for maritime use can reduce the need for new, expensive land-based transmission infrastructure if planned across the energy and maritime sectors. Planning should include optimisation of the grid infrastructure investments taking into account the location of ports with a need for additional capacity to support maritime electrification as well as the onshore grid connection point. Such an optimisation could potentially move the onshore connection point closer to key ports where this would reduce overall grid investments across the offshore wind farm and specific ports with high maritime electrification potential.

The vessel traffic passing by Bornholm currently depends on fossil fuels. This dependency can be lowered as vessel electrification can follow the path of electric road transport. Rapid uptake requires front-loaded investment in charging infrastructure. Vessel owners will invest in electrification when battery-electric ships are competitive with fossil-fuelled vessels, and they have clarity regarding power availability at competitive price levels in ports and at sea in Offshore Power Zones. Availability of power in multiple ports and at sea will reduce both the operational risk (similar to the range anxiety of early electric vehicle adopters) as well as risk of stranded assets as battery-electric ships can service more routes.

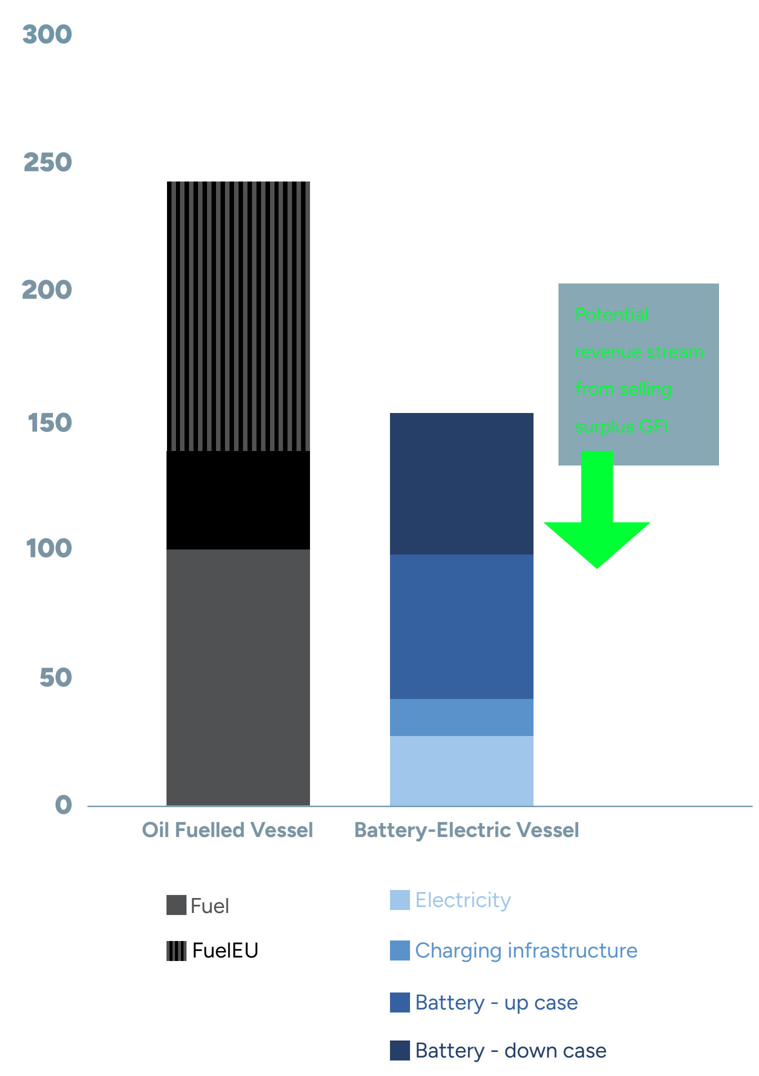
BEI will transform Bornholm's limited power capacity into a potential abundance of available power for use on the island and in Offshore Power Zones in the Baltic Sea, close to the planned offshore wind farm. This allows BEI to showcase how maritime electrification and offshore wind can contribute positively to the socio-economic value by:

- Enabling maritime electrification across Europe and globally
- Sharing transmission infrastructure lowering grid investments and costs for servicing maritime electrification
- Reducing port congestion and lowering the need for costly quayside expansion
- Implementing direct connections to e.g offshore wind farms reducing integration challenges

Decarbonising ships via battery-electric propulsion is contributing positively to the socio-economic case as well. Battery-electric vessels offer high energy efficiency, approximately 75% from well-to-wake, compared to around 15% for e-methanol. Production of e-methanol has a high energy loss due to the conversion process from renewable electricity via hydrogen to, e-methanol and then used for propulsion.

Battery electric short sea vessels are becoming financially viable, lowering transport costs and boosting Europe's competitiveness. Despite higher upfront costs, vessel electrification becomes cheaper over the lifecycle when EU ETS costs are included, which from 2026 cover all large commercial vessels (>5,000 GT) and from 2028 also offshore vessels such as large SOVs.

In addition to EU ETS, FuelEU Maritime applies to large cargo and passenger vessels (>5,000 GT), requiring progressively lower GHG intensity measured by the GHG Fuel Intensity (GFI). This raises costs for non compliance, while over compliance generates tradable credits, surplus compliance units, particularly for zero GFI solutions like battery-electric vessels.



The TCO compares energy, carbon costs (EU ETS & FuelEU), and additional vessel capital expenditures (CAPEX) for batteries and charging. Vessels enter service in 2035 and operate for 25 years with a 100 MWh battery.

Battery cost and utilisation are the key drivers, shown through two scenarios:

Up case: Battery price ~$130/kWh (2035) and ~150 charging cycles/year (~3/week)

Down case: Battery price ~$170/kWh (2035) and ~100 charging cycles/year (~2/week)

Operational costs include fuel, electricity, EU ETS, and FuelEU impacts. FuelEU adds indicative costs for non compliant vessels or revenues from selling surplus credits, shown as shaded in Figure 1.

Figure 1:
Comparison of the total cost of ownership (TCO) of conventional fossil oil-fuelled short-sea cargo vessels and battery-electric short-sea cargo vessels. Numbers are shown as index 100 with fuel costs as the baseline.

Sources: Stillstrom calculations. Fuel price $900/ton (2025), EU ETS price: Danish Ministry of Finance, Electricity price: Danish Energy Agency, Engine efficiency: IMO. Comparison is based on new-build vessels. Prices are nominal & inflation 2%.

Figure 1 shows that by 2035, battery electric cargo vessels are likely to be cost competitive with fossil oil fuelled vessels, driven by advances in battery technology (lower prices) and optimised utilisation (more charging cycles), which reduce CAPEX per MWh of propulsion.

Up case: With ~150 charging cycles/year and battery costs of ~$130/kWh battery electric vessels are cost competitive with fossil vessels, with EU ETS further strengthening the business case.

Down case: At ~100 cycles/year and ~$170/kWh, competitiveness depends more on EU ETS, FuelEU costs, and revenues from selling surplus GFI credits.

The business case for battery electric short sea vessels is approaching viability where technically feasible, driving investment interest and increasing electricity demand in ports and along key shipping lanes. Unlocking this requires clear signals on power prices, grid charges, and availability. As adoption grows and charging infrastructure is shared, unit costs will fall with higher utilisation, though early infrastructure investment remains critical.

Establishing an "electric shipping highway" from the North Sea to the Baltic Sea could ensure power availability in specific key ports and Offshore Power Zones along the main shipping lanes. By tapping offshore wind, energy islands, and hubs along major corridors, it would enable large scale vessel electrification. In the Baltic Sea BEI could act as a central hub, supplying power in ports and at sea. With strong electrification potential across ferries, RoPax, and short sea cargo as well as of offshore wind farms, the English Channel–North Sea–Baltic corridor is well suited, with BEI positioned as a beacon showcasing a cost efficient power supply hub supporting maritime electrification.

Illustration by Stillstrom
Direct Service Vessel electrification

Chapter 7

Regulatory Focus

Realising the benefits of maritime electrification requires a combined focus on energy and maritime regulations. Offshore wind farms and transmission assets are typically regulated by energy ministries, while transport ministries handle the shipping sector, and decarbonisation can be handled in a third ministry depending on the national set-up of ministries. Because shipping is a cross-border activity, EU-wide or global regulation is necessary to incentivise investment in maritime electrification solutions such as shore power, battery-electric vessels and charging infrastructure. For the energy sector BEI and the partnership between Germany and Denmark stands out as an example of cross-border collaboration aiming to harvest the full socio-economic value of electrification across sectors.

The EU focused regulatory framework to reduce GHG-emissions from the maritime sector is evolving:

- **EU ETS:** Now includes large cargo and passenger vessels, with offshore vessels included from 2028.
- **FuelEU Maritime:** Requires a reduction in the ship's GHG fuel intensity (GFI) and mandates the use of shore power for container and passenger vessels in TEN-T ports.
- **AFIR:** Requires TEN-T ports to supply shore power for container and passenger vessels above 5000 GT from 1st of January 2030.

Port of Roenne showcases the core challenge in maritime electrification; securing access to power, with BEI providing a viable solution by supplying power from newly built offshore wind farms. Through BEI, Port of Roenne can comply with AFIR and offer additional power for charging ferries and other maritime electrification opportunities – making it equally possible for vessels like e.g. cruise ships complying with FuelEU Maritimes requirement of using shore power at berth.

National regulations should provide the flexibility needed for the port, the transmission service operator (TSO), and offshore wind farm owners to seek the most cost-efficient connections servicing maritime electrification. At sea, the framework needs to be flexible enough to enable direct connections from offshore wind farms for charging service vessels, idling ships, and "on-the-go" vessel fast-charging in defined Offshore Power Zones. Deploying such infrastructures will also occupy part of the sea area and impact maritime spatial plans (MSP). These MSPs should therefore include the option of Offshore Power Zones alongside other economic uses of the respective national sea zones.

Actions for National Regulators:

- **Integrated Infrastructure Planning**: Energy, Transport, and other relevant ministries to align on how offshore wind farm developers and/or TSOs can support the needed power supply in relevant ports and Offshore Power Zones.
- **Regulatory Flexibility:** Enable flexible frameworks for cost-efficient direct connections between offshore wind farms and maritime users, bypassing onshore bottlenecks and reducing costs and integration challenges.
- **Spatial Planning Integration**: Include and prioritise Offshore Power Zones in the National Maritime Spatial Plans to streamline the consenting process for offshore power infrastructure.
- **Economic Incentives:** Maintain strong GHG pricing (EU ETS) and FuelEU incentives, including lowering the GT threshold to capture smaller vessels sustaining financial incentives for vessel electrification, from shore power to fully battery-electric ships.
- **FuelEU Maritime:** Include requirements to use electricity onboard vessels such as requirements to use power supply while idling at sea in territorial waters relatively close to shore.
- **AFIR:** Support investments in power and charging infrastructure in ports and Offshore Power Zones ensuring frontloading of the necessary infrastructure by expanding the AFIR financial support and requirements for shore power and e-fuels infrastructure to also cover investments in power supply infrastructure at sea like Offshore Power Zones.
- **AFIR:** Extend to require offshore charging hubs along key European shipping lanes, mirroring existing EV and truck charging mandates. For example, AFIR requires truck charging pools every ~60 km with high-capacity chargers (≥3.6 MW). A maritime equivalent could mandate, for example two ≥75 MW chargers within 75 NM along major shipping lanes.

Chapter 8

Conclusion

The push for maritime electrification is accelerating rapidly due to lowering battery prices and regulatory measures such as rising GHG-emission costs and shore power requirements. Shipowners are also facing external risks from fluctuating fossil-fuel prices, which can be significantly affected by geopolitical events, as we have seen in recent times.

Ports are key areas for providing power supply options to meet the need of shipowners, terminal operators and the ports themselves. The first steps in enabling maritime electrification have already been taken in the form of shore power in some ports for ferries, cruise ships and container vessels as well as in specific ports where battery-electric ferries have access to charging infrastructure while off- and onloading passengers and vehicles.

This development, along with ongoing projects is already frequently facing significant challenges in accessing sufficient power capacity. These challenges are mainly due to limited grid capacity reaching the port, as the existing infrastructure is – naturally – designed for known power usage rather than new demands from maritime electrification. Increasing grid infrastructure capacity to meet these new loads may require reinforcement of the current grid. It can, however, take a long time to obtain the necessary consents, if new infrastructure needs to be built.

Port of Roenne is a prime example of this challenge, as it currently has very limited power capacity to the port. It is therefore not able to deliver on the 2030 requirement of supplying "just" shore power for the cruise vessels. However, when BEI with 3 GW of offshore wind capacity is realised around 2035, Port of Roenne will be able to service all types of maritime electrification needs in the port, including high-capacity charging for example for ferries servicing Bornholm.

In the sea around Bornholm the offshore wind farm can also act as a direct connection point to an Offshore Power Zone where vessels can access power while idling and/or carry out fast charging on-the-go, similar to electric vehicle fast charging along main highways. Power in Offshore Power Zones can lower costs versus port-based electrification by:

- Less cabling is needed as Offshore Power Zones can be located close to offshore wind farms
- Direct connection from offshore wind farms to Offshore Power Zones lowers impact on the onshore grid, which will reduce the potential integration challenges
- Reduce quayside expansion and power needs by enabling charging in Offshore Power Zones.
- Flexibility for battery-electric cargo vessels increases as the vessels can service more routes, as they can charge during voyages and not only in ports

The offshore wind farm development from The English Channel through the North Sea and into the Baltic Sea provides a reliable guaranteed power supply for vessels. Careful planning and co-ordination between the energy and shipping sector – and relevant policy areas – can then unlock socio-economic benefits.

A first step could be implementing an electric shipping highway from France to Finland. Power is available, electric vessels are coming and, with regulatory flexibility and financial incentives the needed infrastructure "dots" from offshore wind farms and energy islands/hubs to battery-electric ships can be connected. Frontloading the implementation of power supply at sea will unlock further investments in battery-electric short sea shipping vessels making large scale maritime electrification a reality.

Illustration by Stillstrom

PORT OF ROENNE
Together we create

BALTIC ENERGY ISLAND

STILLSTROM
by Maersk