With input from

Ports: Green gateways to Europe

10 transitions to turn ports into decarbonization hubs

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About this report

In this report, we use DNV GL's Energy Transition Outlook to predict the expected impact of the Ten Green Transitions on ports. The DNV GL *Energy Transition Outlook* is a forecast based on our best knowledge of the current energy system and expected developments towards 2050. We forecast a rapid energy transition, but this transition is not fast enough to bring global warming well below 2°C by 2050. Globally, the share of fossil fuels in the primary energy consumption will decrease from 85% today to 56% by 2050 and fossil fuel use will reach its peak around 2025. In Europe, the share of fossil fuels is forecasted to be less than 50% but still significant. In this light, a fully decarbonized port in 2050 is a challenge and thus we assume that ports in 2050 will not be fully decarbonized, despite their potential in terms of direct and indirect electrification.

DNV GL's *Energy Transition Outlook* is a forecast that differs in methodology and results from *Eurelectric's Decarbonisation Pathways*, which is based on a series of enablers to ensure that electricity is carbon free well before 2050. In the first phase of the study, Eurelectric developed three EU electrification scenarios towards 2050 that achieve 80%, 90% and 95% decarbonization of the main energy-using sectors: transport, buildings, and industry. In the second phase of the study, decarbonization pathways to drive the power sector towards carbon-neutrality well before 2050 at the lowest possible were analysed. Compared to DNV GL's Outlook, Eurelectric's Pathways include a higher share of renewables in the power mix by 2045 (around 80%) and a more limited role of fossil fuels.

FOREWORD

The race to reduce greenhouse gas emissions to limit global warming is on. The energy transition towards a clean energy future is essential in winning this race. But the global challenge of climate change and environmental degradation requires decarbonization of all industry sectors. Existing technology can already curb emissions enough to hit the climate target. Unfortunately, technology is not the only aspect to consider. Economic feasibility and social acceptance as well as political viability, resulting in an efficient regulatory framework, are other important factors.

Progress is being made, for example in Europe, the Green Deal is going to be one of the main enablers to transform the EU's economy so that it is fit for a sustainable future. It requires a rethinking of policies for clean energy supply across the economy, industry, production and consumption, large-scale infrastructure, transport and many other sectors. Ports can play a key role in this context.

Today transport accounts for one-third of the overall EU CO_2 emissions. Road transport is responsible for 72% of the overall transport CO_2 emissions, water transport for 14%, and air transport for 13%. It is estimated that due to CO_2 targets imposed on vehicles the relative contribution of water transport will increase significantly if emissions from water navigation are not tackled in time.

At the intersection of land and sea, ports can play a pivotal role in Europe's decarbonization agenda and the much-needed energy transition. Ports are a natural hotspot for sector coupling and energy system integration as they host many industry sectors including maritime, oil and gas, cruise-tourism, heavy transport, bulk transfer, manufacturing industries, power generation, electricity grid operators and offshore wind.

To unleash the potential for decarbonization in and around European ports, DNV GL and Eurelectric have joined forces to develop this report. By bringing together DNV GL's global expertise from the power, renewables, maritime and oil and gas industries and Eurelectric's network and knowledge of Europe's electricity industry and EU policies, this report uncovers the opportunities and provides policy advice and recommendations to EU policymakers, port authorities, the power, renewables, oil and gas and maritime industry, industrial energy users and many other industry stakeholders.
It gives new insights and inspiration for all parties working in and around ports to help them create strategies for business development to ensure we all act quickly to secure a more sustainable future.

Drastic additional measures are needed to change the forecast and speed up the energy transition to meet the Paris climate goals. Together DNV GL and Eurelectric are committed to tackling the challenge of a faster energy transition through our daily work in all industry sectors and by providing fact-based information to all interested parties. This report provides vital new insights that have the potential to make ports front runners in the energy transition, supporting a greener Europe. To turn this into reality, clear policies are needed and strong cooperation between regulators, authorities and a variety of industries. Only together can we transition faster and now it is all about taking concrete measurable actions.

Ditlev Engel
CEO DNV GL - Energy

Kristian Ruby
Secretary General Eurelectric

Ports: the front runners of the energy transition

Ports can be front runners of the energy transition. Ports provide a variety of avenues for decarbonization, from the ports themselves, the vessels that use them, heavy trucks that transports goods to and from the ports, and the surrounding industrial sites, which are often co-located with ports to benefit from easy access to bulk transportation.

All stakeholders connected to a port have their own key drivers for reducing CO_2 emissions. Port Authorities want to decarbonize operations, reduce energy cost and to provide a competitive gateway for attracting the maritime industry as customers. For the maritime sector it is the need for emissions reductions, in response to national and international regulations, based on for instance the IMO CO_2 reduction target, and the access to compliant fuels and technologies at a competitive cost. For utilities it is providing reliable energy and heat and responding to increasing energy demand through electrification of transportation, port-related activities and industrial activities in the vicinity and increasing the value of the energy they provide to their customers.

This report uses DNV GL's *Energy Transition Outlook* as a basis for exploring the expected impact of Ten Key Green transitions on ports, and reveals:

- The decarbonization potential in European ports including a variety of industries and water transport
- How stakeholders can transform and decarbonize ports and co-located industries
- The barriers and the necessary measures, including regulatory, economic and technical to unleash this potential
- The policies that we recommend for accelerating the decarbonization of ports using electrification.

A closer look at ports in Europe

Ports are essential for different types of transport across Europe, from moving cargo to providing transport for people, hosting industrial and commercial activities and being the hub where different sectors connect and come together.

European seaports are also an essential part of the Trans European transport network (TEN-T), a planned network of roads, railways, airports and water infrastructure in the European Union. There are currently 331 seaports in the TEN-T core and comprehensive network. In 2016, these seaports processed 3.5 billion tons of throughput. European seaports are often home and key partners of industrial clusters. A 2016 survey of 86 port authorities from 19 EU Member States, found that 66% of the respondent ports are host to industrial plants.

However, the different demands placed on ports vary enormously. European seaports differ substantially in the cargo they handle, their access to the sea and the time that ships spend in port.

The energy transition and COVID-19

In the next few years, ports will also need to overcome big challenges, such as adapting to new requirements including the increased size and complexity of the fleet and requirements on environmental performance and alternative fuels. It's important to note that the impact of lockdowns in many countries worldwide, as we see today caused by the spread of the Coronavirus, will be significant on several industries including, on ports. Today we do not yet know the full implications of the COVID-19 global shutdown on emission levels. It may be a temporary dip and not a structural change, in which case industry cannot afford to decrease decarbonization ambitions to address climate change.
It may also be a structural change, which may alter the way we live, work and travel, and therefore, will have a huge impact on the energy transition and the ports of the future.

The Ten Green Transitions towards decarbonization

Understanding the decarbonization potential of ports starts with understanding the transitions that will take place in and around ports. We assessed Ten Green Transitions towards decarbonization that directly or indirectly affect port sites. Some transitions are specific for ports such as the fuel switch for maritime and electrification of port-related activities.

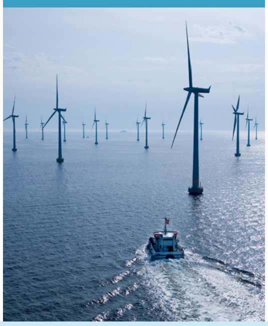
Others are more general, such as electrification of industry and the phase-out of fossil fuels, for power generation. The transitions create opportunities for decarbonization strategies if coordinated well and with the right policies in place.

1
Electrification of port-connected activities

2
Fuel switch for maritime transport

3
Electrification of industry

4
Integration of offshore wind



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Energy system integration

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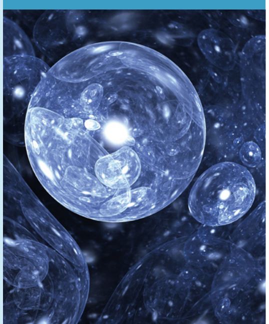
Hydrogen as feedstock and energy vector



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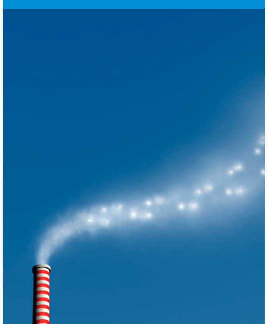
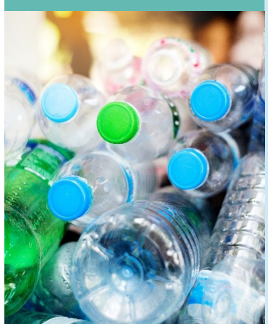
Phase-out of fossil fuelled power plants

8
Carbon capture and storage



9
New regulations

10
Circular and bio-based economy



1

ELECTRIFICATION OF PORT-CONNECTED ACTIVITIES

With the increased penetration of renewable energy sources such as solar PV and wind power, the carbon intensity of electricity generation will decrease significantly. Switching from fossil fuels to renewable electricity will therefore reduce carbon emissions on a global scale.

There are other benefits to electrifying processes and activities. Such as, reducing local emissions and higher reliability and lower maintenance costs when using electromotors instead of internal combustion engines. Activities in ports provide ample opportunities for decarbonisation through electrification. These activities include, bunkering; logistics and freight handling with cranes and logistical vehicles; (cold) storage; service vessels, such as pilot boats and tugboats; and offices and buildings.

A specific topic for ports is cold ironing, also called shore-to-ship power (SSP). The term cold ironing means that a ship docked at the port is supplied with electricity from shore and so can avoid running its engines or diesel generators to power on-board activities. Cold ironing has the benefit that local air pollution, noise and carbon emissions are reduced.

Ports are also greatly affected by electrification of other sectors, such as nearby industry and electric road, river, and short distance sea transport. The electric infrastructure does not only need to facilitate the electrification of processes within the port itself, but also needs to facilitate the electrification of transport. This means that a huge capacity upgrade is required for the local electric distribution infrastructure. This requires major investments as well as sufficient space to deploy the necessary infrastructure.

2

FUEL SWITCH FOR MARITIME TRANSPORT

The International Maritime Organization (IMO) has set a target to reduce greenhouse gas emissions by 50% in 2050 compared to 2008. Multiple actions can be taken to reduce greenhouse gas emissions of which fuel switch is one. The impact of fuel switch on ports will be mainly in changes to bunkering facilities, bunkering is the supply of fuel for use by ships.

Regular facilities for heavy and medium fuel oil will be complemented with bunkering and charging facilities for liquefied gasses (LNG, LPG) or hydrogen-based fuels (such as ammonia) and electricity. This will require additional investments in storage facilities and infrastructure. The lower energy density of the alternative fuels may also require a much finer granularity of bunkering facilities as ships will have to bunker more often. This poses a challenge to ports as they have to decide in which fuel infrastructures to invest. An electricity charging infrastructure seems a no-regret option as electricity is a common denominator in decarbonizing ports.

3

ELECTRIFICATION OF INDUSTRY

In several ports industry is a significant part of the ports-related activities. Electrification is an important enabler of emission reduction in industry as mandated by the amending Directive on Energy Efficiency (2018/2012). A key element of this directive is an overall EU energy efficiency target for 2030 of at least 32.5%.

Part of the industrial energy efficiency increase will be in more energy efficient technologies and processes. EU industries have a target to reduce greenhouse gas emission by 45-55% by 2030 and 80-100% in 2050. Refineries, production of iron and steel, chemical industries and non-metallic minerals industries are responsible for almost 75% of the emissions.

Electrification of industry will be enabled by a massive deployment of additional renewable energy source capacity, the associated grid and storage infrastructure, green hydrogen production, electric boilers and heat pumps. Electrification of industries could mean up to 50% decrease of ‘fossil cargo’ (oil, gas, LNG). This would have a significant impact on the surrounding industry as well as improving the local electricity grid and support utility services and other electricity production facilities.

4

INTEGRATION OF OFFSHORE WIND

Another development that will have a major impact on the port's energy system is the connection of offshore wind to the grid. According to DNV GL's Energy Transition Outlook, offshore wind will grow in Europe from 16 GW in 2017 to 56 GW in 2030 and 168 GW in 2050. One of the biggest challenges with integration of offshore wind is the connection to the onshore electricity grid. For Northern European countries, where offshore wind is feasible because of relatively shallow water depths, the wind capacity will exceed hosting capacity of the substations at the shore, and the grid behind these substations. A large part of this power cannot be transported inland and will need to be absorbed by industry (electric boilers, electric furnaces, heat pumps) in and near ports as a cost-efficient alternative to battery storage to avoid curtailment.

Around the North and Baltic Seas, ports are the natural landing point for the huge planned capacity of offshore wind. These ports can play a major role in the development of offshore wind activities as they often have strong industrial clusters, which have the potential to offer flexibility that can be used to have a better match with offshore wind electricity production profiles. In addition, many industrial processes make use of hydrogen, which is currently in most cases produced using natural gas. By locating an electrolyser close to large ports, industry would get access to large quantities of green hydrogen, directly produced from wind power.

Increasing the electricity consumption within the port area during peak production of offshore wind will decrease the required inland grid capacity. These developments point towards a heavy electricity grid in impacted ports to accommodate offshore wind connection, industries and hydrogen production. This grid might be privately owned because of its specific use.

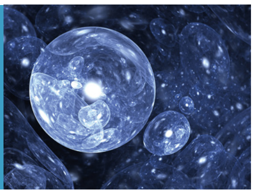
Finally, the uptake of offshore wind will increase the need for wind turbine installation and service activities. Ports located near large offshore wind parks are natural locations for such an emerging installation and service industry.

5

ENERGY SYSTEM INTEGRATION

Energy system integration (or sector coupling) describes the trend that the value chains of different sectors are becoming more interconnected. Typically, this originates from coupling of energy vectors between sectors that previously were characterized by one dominant energy carrier e.g. electricity for power application, natural gas for (industrial) heating and feedstock and oil for transport and off-grid electricity generation. Energy system integration is driven by renewable penetration, the increased need for flexibility in energy demand and supply, efficiency gains and optimization – it is also the object of upcoming EU legislation. The trend is beginning to gain traction because of the increasing pressure to decarbonize; to optimize energy infrastructure, to become more efficient and sustainable.

Ports are logistical hubs connecting many different sectors through transportation and logistics. They are now emerging as energy hubs where many trends driving energy system integration are coming together. Challenges regarding energy infrastructures are already manifesting themselves, both regarding necessary investments in operating and managing them. Energy system integration does not only couple sectors, but also energy infrastructures and their regulation frameworks. Regulation for managing and operating these infrastructures, are not optimal for such a specific and interactive infrastructure system as the energy supply for an industrial or logistics port.



6 HYDROGEN AS FEEDSTOCK AND ENERGY VECTOR

As mentioned in the European Green Deal, electrification is an efficient and sustainable way to decarbonize the economy. However, with current technology, it cannot reach all sectors. The so called hard-to-abate sectors are not currently possible to electrify, and hence to decarbonise. Hydrogen is a potential energy carrier that can complement electricity in these areas. Hydrogen can also be used as feedstock to produce carbon neutral fuels for difficult to decarbonize sectors, such as aviation and intercontinental shipping. When produced from electricity these fuels are called electro or e-fuels and include ammonia, methanol, formic acid, synthetic methane (SNG) or higher hydrocarbons so-called synthetic fuels (syn-fuel).

Hydrogen is currently predominantly used as feedstock for the chemical and petro-chemical industry and produced from natural gas through steam reforming or partial oxidation (blue hydrogen if combined with carbon capture and storage). Hydrogen has great potential to decarbonize industrial processes and facilitate the energy transition as it can also be produced from renewable electricity, usually being referred as green hydrogen. Some ports are natural hubs for connecting offshore wind, having therefore privileged access to abundant renewable electricity which can be converted to green hydrogen through electrolysis. The economic competitiveness of green hydrogen can become a reality in ports sooner than any other location, assuming industry can benefit from the products hydrogen and from oxygen and heat as by-product from electrolysis.

7 PHASE-OUT OF FOSSIL-FUELLED POWER PLANTS

Co-location of large fossil fuel- or biomass-fired power plants in large ports is common because it has several advantages such as the abundance of cooling water for power plants and large-scale bulk transportation infrastructure available for coal and biomass.

Fossil fuel fired power plants are a large contributor to carbon emissions in Europe. In 2017, the total fossil CO_2 emission in Europe was approximately 3.7 Gt of which 1.4 Gt (approximately 40%) related to the power industry. Phasing out of fossil-fired power plants and especially coal-fired plants is a fast way of decreasing carbon emissions.

The phase out of fossil fuel fired power plants will have other impacts that are specifically important for ports. Depending on the type and age of the power plant, it will be retrofitted or preliminary amortized, leaving valuable land space to use for other purpose. Several options are viable to retrofit a relatively new coal fired plant, such as converting the power plant to a natural gas fired plant, a hydrogen fired plant, or a biomass fired plant. This is mostly a fuel supply side change as coal is replaced by biomass, hydrogen or natural gas, in the short to medium term.

Dispatchable generation will become increasingly important to accommodate intermittent generation and provide reliable electricity to the port industrial sector. Moreover, storage technologies, providing flexibility as well as essential system services, can and will compete on the market with other flexibility providers such as dispatchable generation assets as well as demand side management.

8

CARBON CAPTURE AND STORAGE

Capturing carbon dioxide and sequentially storing it is called CCS. CCS involves three major steps; capturing CO_2 from the emitted gas at the source, transporting it to the storage site and then injecting it deep into carefully selected underground reservoirs, where it is permanently stored.

Often, CCS is referred to capture systems applied at coal and gas fired power stations, however, the range of application is larger and includes major industries like cement, steel, hydrogen and ammonia - namely to all processes that release CO_2 in the atmosphere as a result of a combustion or an industrial process.

Ports can play an important role in the development of CCS. The North Sea offers a huge potential storage volume for carbon dioxide. By applying carbon dioxide storage offshore in depleted gas fields far from population centres, public support for CCS can be enhanced.

Ports around the North Sea might play an important role as hubs within the carbon dioxide infrastructure. If CCS takes off, they can provide the necessary infrastructure for shipping captured carbon dioxide to empty offshore oil and gas fields. The Port of Rotterdam in the Netherlands, and the Northern Light consortium involving the port of Oslo and Bergen in Norway are already actively involved in CCS.

9

DEVELOPMENT OF NEW REGULATION

Regulation is considered an important enabler for change in general and more specifically for meeting the UN Sustainable Development and the green transitions discussed in this document. For the European Union, the policies driving change are shaped by the EU climate policy goals for 2030 and beyond, notably the carbon emission reduction target, the renewable energy target, the energy efficiency target, the IMO requirements and the EU Alternative Fuels Directive.

For ports, border tax adjustments and new fuel taxes are likely to increase cost and could reduce international freight transport. Taxes are expected to change due to energy system integration as the need for a level playing field for previously uncoupled energy vectors arises.

Port Authorities could stimulate and facilitate greenhouse gas emission reduction with specific fees and taxes, onshore power supply, mobile power-to-ship services and improved efficiency of port operations.

10

CIRCULAR AND BIO-BASED ECONOMIES

Circular and bio-based economies are both part of the new European Green Deal. A circular economy (CE) works within ecological constraints and will deal efficiently and in a socially responsible manner with products, materials and resources. A circular economy will use a decreasing amount of raw materials. In a circular economy the life span of products will be extended, with an emphasis on repair, reuse and recycling. For ports, there will be a growing demand for biomass to produce bio-based products. A substantial share of biomass or bio-based raw materials are expected to be imported from other continents. Ports could become circular hubs transforming waste material produced in ships and maritime-related processes into valuable products for other sectors like fertilizers in agriculture or raw materials for the cement industry.

Ports of the future

The impact of the Green Transitions will differ depending on the type of port. To quantify and illustrate the effect of the green transitions we have defined two "typical" European seaports:

- **A large European Industrial Port** - this port is based on the average size of the 20 largest ports in Europe. It is mainly focused on bulk goods and containers. It has a large crude-oil and chemical industry cluster, co-location of power plants and a large potential for connecting offshore wind
- **A smaller European Transport Port** – This port is one tenth of the size of the large or average industrial port and represents the average size of a seaport in Europe. It has a limited industrial cluster, mixed container and passenger transport and no offshore wind connection potential.

For both seaports we have envisioned the impact of the ten green transitions in terms of energy consumption and CO_2 emissions. For both ports we have defined the current situation as Port 1.0 and the future situation in 2050, as Port 2.0.

Each port is characterized by five building blocks, representing the main clusters of activities that impact the energy consumption and the CO_2 emissions of ports and together represent the whole port area. These building blocks are identical for all typical ports but will vary in significance and final energy use depending on the individual port.

The five main building blocks, describing Port 1.0 and Port 2.0 are:

PORT OPERATION
Port connected activities require fuelling, e.g. for service vehicles and vessels, freight handling.

FUELLING OF TRANSPORT
Fuelling of transport includes conventional oils, emerging fuels like LNG and LPG and potential new fuels like hydrogen, ammonia and electricity for hybrid or full electric ships, service vessels. It includes electrification of inland transport (e.g. heavy trucks).

ELECTRICITY GENERATION
This includes generation by fossil fuelled power plants, by on-site solar PV and wind turbines and connection of offshore wind parks to the public grid.

INDUSTRIAL CLUSTER
These include ship building and construction; chemical, metal, food and automotive industries.

HYDROGEN PRODUCTION
Currently this is mainly done by steam methane reforming (SMR) to serve co-located chemical industries (grey hydrogen). Future production methods include SMR and partial oxidation (POX) of natural gas combined with carbon capture and storage (CCS) resulting in blue hydrogen and electrolysis based on renewable electricity (green hydrogen).

		PORT 1.0	PORT 2.0
		Current situation	Future situation (2050), reflecting the effects of the 10 green transitions
INDUSTRIAL PORT	Typical large industrial port, mainly bulk goods and containers, co-location of power plants and a large potential for connecting offshore wind	INDUSTRIAL PORT 1.0	INDUSTRIAL PORT 2.0
TRANSPORT PORT	Typical mid-sized transport port, mainly passengers and containers, no significant industry, no power generation and no potential for connecting offshore wind	TRANSPORT PORT 1.0	TRANSPORT PORT 2.0

Industrial Port 1.0

This large industrial port is a net exporter of electricity. Most of the electricity is produced based on fossil fuels, including coal and natural gas. Renewable electricity generation is less than 5% of the total electricity generation. Less than 10% of the electricity generated is used on port site, the remaining part is exported outside the port area. The industrial cluster is the largest consumer of energy and of electricity in the port. Other sectors are comparable in energy consumption.
The CO_2 emissions mirror this distribution. The electricity consumption for fuelling of transport is almost negligible.
The main energy carriers for Industrial Port 1.0 are natural gas, coal and light fuel oil.

Industrial Port 2.0

The figure on page 12 shows the energy consumption and CO_2 emissions for Industrial Port 1.0 and Industrial Port 2.0. To validate the effects of the 10 Green Transitionsm, the effect of the growth in port size and transport volume, without Green Transitions, is also shown as an intermediate state. The final energy consumption, including exported energy consumed outside the port area, almost doubles and the CO_2 emissions decrease less than 10%. This graph illustrates that Industrial Port 2.0 becomes an energy hub and a major net exporter of renewable electricity and hydrogen. This is due to the connection of offshore wind, requiring a strong electricity grid. Both the availability of offshore wind electricity and the strong electricity grid make Industrial Port 2.0 an advantageous location for power generation and hydrogen production.

The port final energy consumption reduces by approximately 50%. The CO_2-emissions decrease by almost 70%. Industrial Port 2.0 is therefore not emission free, although the actual reduction of final energy consumption and CO_2 emissions is larger than it appears because the effects of the 30% growth in port activities and the approximate 50% growth in industrial activities are also compensated.

The main conclusions from the Industrial Port 2.0 analysis are:

- Industrial Port 2.0 becomes more of a net exporter of renewable electricity and additionally a net exporter of hydrogen. The expected connection of offshore wind and the required grid enforcements to realize this connection lead to an advantageous position as location for electricity generation and hydrogen production.
  The total electricity generating capacity increases more than tenfold in the coming 30 years. Renewable electricity generation accounts for approximately 75% of the total electricity generation. Approximately 10% of the electricity generated is used on port site, the remaining part is exported outside the port area. The industrial cluster profits from the available grid facilities and the onsite hydrogen production. The position as an energy hub will become more pronounced.

- Despite the increase in export volume and the growth of port activities, CO_2-emission decreases. Excluding the emissions related to exported electricity and hydrogen the emission decrease is more than 60%. Industrial Port 2.0, however, is not totally carbon free. The main reasons are:
  - Natural gas is still used for e.g. industry, buildings and electricity generation. Only part of the related CO_2 emissions is mitigated with CCS.
  - Despite its electrification potential, cold ironing is not fully introduced for all ships, meaning that light fuel oil (LFO) is still used for ship power at berth.
  - The electrification of transportation is limited to an estimated 50% (ships) to 80% (road transport), according to DNV GL's ETO. Electrification potential in 2050 for Eurelectric, in a 95% decarbonization scenario, is 94% for passenger cars.
  - Generally, electrification can be pushed to its full potential and yet a part of the energy demand will still need to be met by other less decarbonized solutions.

- Electricity becomes the main carrier of final energy use for port services, fuelling of transport and the industrial cluster. Natural gas takes the second largest share but just as fuel oil, it decreases in significance by more than 40%. Hydrogen accounts for almost 7% of the onsite energy consumption. Hydrogen is used for feed stock and/or decarbonizing high temperature heat demand in industry.

Transport Port 1.0

This smaller, mid-size port is a net importer of electricity. The onsite electricity generation is negligible. The industrial cluster remains the largest consumer of electricity, but in final energy use it is the smallest consumer. The main energy carriers for this port are natural gas and light fuel oil.

Transport Port 2.0

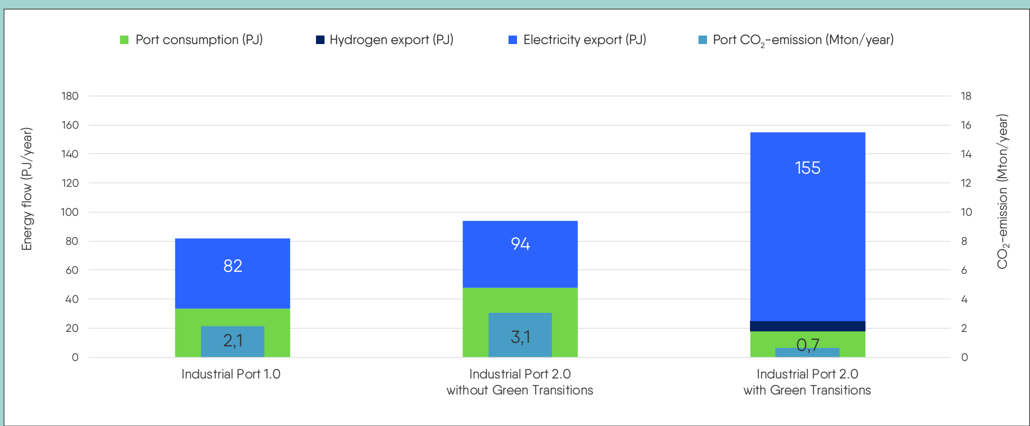
As for the other ports, we use the same building blocks to define Transport Port 2.0. The building blocks differ in size and type of fuel used.

The graph shows the energy consumption and CO_2 emissions for Transport Port 1.0 and Transport Port 2.0. The intermediate state shows the effect of growth in volume, without the 10 Green Transitions. The final energy consumption decreases with approximately 35%, the carbon emission with approximately 60%. Not only does Transport Port 2.0 consume less energy, the carbon intensity of the consumed energy is lower also. This is due to the switch towards electricity that can be used more efficiently and is assumed to decrease in carbon intensity because of the increased penetration of solar PV and wind generation.

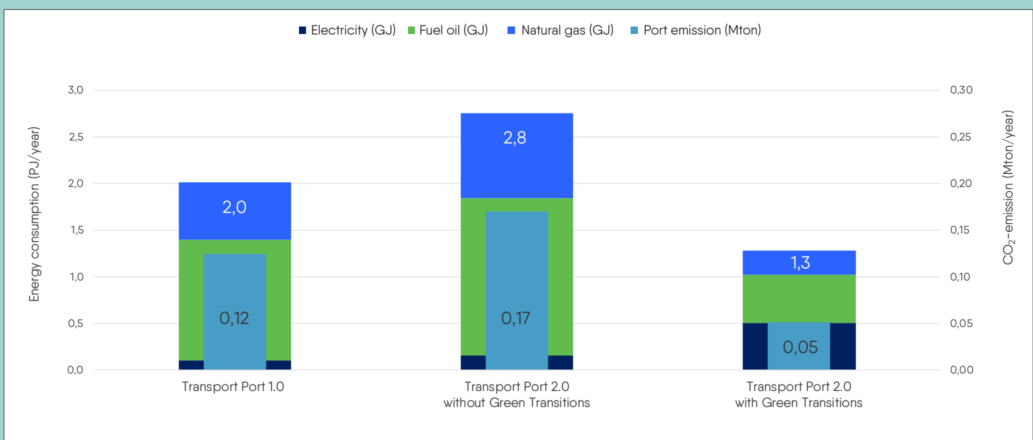
The main conclusions from the Transport Port 2.0 analysis are:

- Transport Port 2.0 has a smaller industrial sector and no significant electricity generation or hydrogen production. It does not export electricity or hydrogen but relies on the public electricity grid and onsite production of hydrogen for industrial use. The effect of development of the industrial sector and core port activities (port operations and fuelling of transport) are more pronounced.
- As industrial Port 2.0, Transport Port 2.0 is not fully decarbonized for reasons discussed before (remaining natural gas and LFO consumption and not fully decarbonized electricity from the pubic grid, according to DNV GL's ETO).
- Electricity is on its way to becoming the main energy carrier.

INDUSTRIAL PORT: Comparison of energy consumption and CO_2-emission



TRANSPORT PORT: Comparison of energy consumption and CO_2-emission



Impact of Green Transitions on the power sector

The electricity sector is facing major challenges in becoming carbon neutral. Decarbonization of transport will have an above average impact on electricity demand, but with the decrease in conventional power plant capacity, the need for renewable energy generation becomes more urgent.

The fact that large amounts of energy from offshore wind will become available, especially near ports in the North Sea and the Baltic Sea, could make it more cost effective to use this energy near the port than to transport it inland. If the industry can benefit from cost savings in the electricity infrastructure, this will be a major driver for energy system integration in and near ports. This does however require close cooperation between the electricity sector, especially grid operators; the local industries; port authorities and terminal operators; and regulatory and permitting agencies.

However, offshore wind energy will not always be fully available. To utilize this energy will require very flexible applications. As most industrial processes and applications need to run continuously, they will require an alternative energy source to switch to, such as natural gas. The most obvious applications are electric heating/steam generation and electrolysis of water to hydrogen. Both applications use natural gas as alternative fuel to switch back to during times of low variable electricity generation.

Most hydrogen applications demand a continuous supply, requiring that hydrogen is buffered, or that production alternates between electrolysis and production from natural gas. This last option can benefit greatly from carbon capture and storage (CCS) infrastructure and carbon dioxide storage in depleted offshore gas fields, making continuous hydrogen production near carbon free.

Hydrogen might eventually be used to produce high value fuels for sectors that are difficult to decarbonize such as aviation and shipping. With the transition to a carbon neutral energy system, there will still be a need for carbon neutral fuels that can be transported around the world to meet demand and the role ports play in supplying society with energy (whether electricity or alternative fuels) remains.

Electricity infrastructure and operation

Within the port itself, electrification of port-connected activities through cold ironing and electrifying ferries and short-range shipping will have a major impact on the required electricity infrastructure. For example, charge poles must be installed and connected in crowded port areas. Inland transport will have a similar impact on the required infrastructure, depending to what extent road transportation will be decarbonized by electrification or by other means, like hydrogen. Most of this additional electricity demand in ports will likely have little flexibility by itself. Benefits often allocated to electrification of road transport, such as peak shaving to avoid extra cabling for which there might be little space, will need to come from additional measures, such as batteries.

The landing of immense quantities of energy from offshore wind farms in the North Sea and the Baltic Sea to shore will also require huge investments. This applies not only for establishing the needed offshore grid and connections but also for the transmission of this energy to the main electricity system.

It may be possible to avoid or reduce costs for investments in the transmission system through flexible solutions that use part of this energy at or near the port. The most obvious applications are electric opportunity heating and hydrogen production by electrolysis. A prerequisite however is that this industry can share in the cost savings in the transmission system, making the business case for these flexible solutions viable in ports first. This requires a clearer regulatory framework at EU and national level coupled with the right incentives to allow local demand and generation to support the networks for a representative reward, such as a local flex market where grid operators can buy flexibility to avoid congestion.

This means a significant strengthening of local infrastructure. It will need to be able to facilitate huge swings in load, and special control and coordination is required as industry switches between electricity and (bio-)gas or previously stored green hydrogen, depending on the availability of electricity from offshore wind. It will require close cooperation between industry and the operation of the different infrastructures for electricity, natural gas, heat, hydrogen and possibly carbon dioxide, as all will be affected. The different infrastructures need to support each other, which leads to implications for the design as well as for operation of the energy system in and around ports.

Concerns over grid reliability are often expressed due to the switch to variable renewable energy ensuring the security of electricity supply. As the system is undergoing a major change and complexity and interaction are increasing, the effect on grid reliability is uncertain. While the redundancy in the greater electricity system potentially will decrease with decarbonization, the redundancy of the energy system for industry around the port potentially will increase. The risks and consequences of these changes could be mitigated by a smart design of the whole system and intelligent operation and control.

Policy recommendations

Ports look set to play a big role for EU goals on sustainability and decarbonization. However, these sustainability goals interact with other goals, such as security of energy supply and affordability of energy. This makes policy development a complex balancing act that affects all aspects of society. The nature of the ten green transitions, including their consequences, makes this even more complex. The different energy carriers and different uses of energy are increasingly interacting with each other. Successful policy will facilitate energy carriers to complement each other's weaknesses and will offer guidance to stakeholders to establish and adapt infrastructures to changing circumstances. It's only if we use the full potential of the ten green transitions that we can realize ports as decarbonization hubs for many industries. Without the active support of all involved stakeholders, the sustainability goals and paths towards them cannot be realized.

1. Standardization of shore power should be stimulated and barriers to adhere to the standards should be removed

Some standards for shore power have been established, while more are in process for new technologies. Still these standards are not yet fully accepted. Some suppliers of charging equipment—especially for ferries—do not adhere to it, and instead opt for more automated and tailored solutions to reduce connection time and to save on handling cost. When their facilities are specifically designed for specific individual ferries, this can prevent other ships from using these facilities, possibly limiting the potential of these facilities later. The use of the existing standards and evolution of new standards should be further promoted. Ports belonging to the Trans European Transport Network (TEN-T) already have to implement shore power facilities by 2025 according to the existing standard for High Voltage. It is recommended to expand this to standards in other domains and promote the use of the standards in other ports.

2. Stimulate further electrification of port-connected activities for early movers

The general conclusion of most innovative electrification projects designing, developing and testing installations and vehicles powered by electricity, seems to be that these alternatives are well suited for the assigned tasks. Follow-up investments are rarely made because of the high investments in charging infrastructure, initial lack of customers that will use it, and the current limited number of suppliers for equipment (comparable to the EV market 5 to 10 years ago). Interventions like funds for the unprofitable top, buy-back arrangements and accelerated depreciation should be considered to compensate first movers to implement existing, or soon to be available standards. Notice that electrification of port connected activities should be aligned with the extension of the electricity infrastructure.

3. Funding research, development and innovation

There is no progress without R&D and innovation. They are the guarantee of development. Direct funding to business R&D is therefore essential. Research and innovation in power and fuels as well as business models for cooperation between industry and infrastructure and between energy carriers should be regarded a high priority.

4. Facilitate environmentally friendly investments

The necessary actions for transformations of ports and port areas can consist of costly and lengthy procedures. To boost investors' willingness to intensify their green business decision, a friendly and simple financial regulatory ecosystem should be guaranteed. As ports are meeting points of a variety of players, ranging from private to public sectors, design of efficient regulatory environment to ensure sustainable provision of Public Private Partnerships (PPPs) will accelerate the green transition.

5. European coordination to establish environmental-friendly incentives and fees for maritime through ports

Pricing signals prove to be beneficial by rewarding maritime operators opting for more environmental-friendly technologies, preventing maritime pollution. Such port incentives could reward vessel owners who operate high performing fleets and apply more stringent environmental requirements and show lower emissions and pollution, while at the same time acting as an incentive stimulating other vessel owners to follow.

6. Facilitate and support stakeholders' dialogue

To develop a view of the future transition, the port authorities and involved stakeholders should develop integrated roadmaps which include future infrastructures, transition pathways, ways of working between the involved parties, governance structures and business models showing how stakeholders will be awarded for supporting and using the energy ecosystem.

7. Enable ports to continue to facilitate the interaction between dispatchable and renewable power generation

The power mix will change fundamentally towards 2050. The new energy system will be defined by renewable sources of energy which will partner with dispatchable power generation, flexibility and infrastructure (incl. hydrogen). The current mix of dispatchable base, mid and peak power will adapt to high percentage of variable renewable power capable of handling the volatility in generation and demand. Rules for ancillary services may need to evolve to accommodate this change. Ports should be allowed to play an important role in this context as they offer many opportunities for power generation, infrastructure and flexibility to interact in the same location.

8. Support the initial investments in hydrogen production through electrolysis at ports

Hydrogen production using renewable electricity from wind and solar will be an important aspect of the future energy ecosystem. Electric opportunity heating requires much lower investments and can outcompete green hydrogen production on the short term. To avoid electric opportunity heating creating a financial lock-in in the long term, green hydrogen production needs to be initially supported.

9. Implement a fair way to share benefits of avoiding unnecessary grid investments with stakeholders to which this can be attributed

To stimulate electric opportunity heating and green hydrogen in and near seaports, as well as other flexibility options that can prevent unnecessary investments in the transmission system, stakeholders offering this flexibility should be able to share fairly in the avoided grid investments, for example through a market based congestion management solution, provided this is the most cost-efficient and optimal solution.

10. Mandate port authorities, in coordination with DSOs, to facilitate the development of a port energy infrastructure across multiple energy carriers

Energy infrastructures and use of various energy carriers are interacting with each other. This requires cooperation between all involved stakeholders, including DSOs. Port authorities, in coordination with DSOs should be mandated to facilitate the realization of a port (energy) infrastructure including multiple energy carriers and taking into account flexible demand as mentioned in recommendation. For example, by investigating the possibility of central heat generation, including electric opportunity heating and heat infrastructure, thus preventing excessive investments in the electric distribution for electric opportunity heating at industry premises.

11. Develop and implement a structured way of solving inconsistencies in legislation and tax-regulation

Inconsistencies in legislation and between legislation and decarbonization goals are gradually becoming clear. Current examples are taxing electricity use at times of overproduction which can lead to curtailment of renewable energy instead of use of excess electricity in for opportunity heating; double taxation on electricity storage; and different taxation for energy carriers. These discrepancies in tax regimes and rules and regulations, should be identified, debated openly and solved in a structured and consistent way. A concerted action to identify inconsistencies is recommended.

With input from

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