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Ingenuity for life

Smart Ports; Competitive Cities

Global Center of Competence Cities – Urban Development

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Content

Overall, shipping is one of the most carbon efficient forms of global transport in terms of CO_2 emissions. However, the enormous scale of the industry means that it is estimated to produce around 2.2% of total global CO_2 emissions.

The Vital Link Between Cities and Ports

The global shipping industry is fundamental to world trade, and all governments and businesses rely on its seamless operation to export and import our goods. It must continue to do this despite tightening margins and an increasingly complex fleet. Overall, shipping is one of the most carbon efficient forms of global transport in terms of CO_2 emissions per ton of cargo transported per kilometer. However, shipping is not a standalone industry, it is linked to landside logistics and transport, and even though shipping itself only accounts for 2.2% of total carbon emissions, it does have a wider impact on air quality in port cities.[1]

Cities are at the very forefront of this issue because local government often has to answer concerns about poor air quality and pollution. Within the shipping industry tightening margins, concerns of over capacity, increasing sea and land side congestion, are each significant challenges. How the industry will be able to meet these challenges, while still achieving its expected +2% annual growth rate, is hinging on its ability to use the digital opportunity that is reshaping global industries today. How digitalization is delivered will impact the overall competitiveness of the port and as well as its city.

Yet even with the challenges, many cities together with their respective ports, are taking positive action and investing in cost effective digital electric and automated technology that can often improve performance as well as reduce emissions. This is because cities and their ports are often inextricably linked, particularly in the cases of the world's largest ports of Singapore, Dubai and Rotterdam. Even in cities with much smaller ports, the ports are vital for the success of local industry and job creation.

Job creation is hugely important to cities, and the Port of Rotterdam estimates that it creates 93,000 jobs, of which 73,000 are counted by the city as local jobs – comprising about 23% of total employment.[2] The Port of Los Angeles estimates that it creates 133,000 direct local jobs, 1.5 million jobs across the US, and helps to generate $270 billion in US trade value, and very importantly, that 70% of all the benefits are captured within Los Angeles county.[3] Positive economic impact is not only limited to the largest ports, even the small to mid-sized ports are significant local job creators. The Port of Helsinki is estimated to generate 5% of the city's GDP and employs 7% of its labor force.[4]

Cities can and do work in tandem with ports to drive port improvements and success through their role as both the local governing authority and via their influence within the port authority or managing board, and here are five key ways:

- Grant permissions for the use of new port technologies, for example delivering on-shore power supply for ships to a port could require higher capacity connections to local sub-stations and may require construction works in other parts of the city.
- Incentivize the take-up of lower emissions technologies through subsidy or tax breaks.
- Work with national and regional government to ensure congestion free access to and from the port.
- Support the port and linked industry through workforce training programs.
- Align with other city leaders to ensure a level playing field amongst regional ports and adherence to similar emissions standards.

The technologies that ports are using target both improved efficiency and air quality. The first action that a port can take to positively improve local air quality is to electrify its operations. Full electrification would mean that ports produce zero local emissions and benefit from more efficient electric equipment. Today, about 50% of crane operations are electrified and these tend to be in the largest ports. Very few ports have implemented technologies that supply electricity to docking vessels, and a very select few ports have started to test electric stacking trucks and the electrification of key landside truck routes. Some of these very progressive actions include:

- **Port of Hamburg, Germany:** Targeting a 30% reduction of CO_2 emissions per handled container by 2020.
- **Port of Rotterdam, The Netherlands:** Targeting a 50% CO_2 reduction by 2025.
- **Port of Stockholm, Sweden:** Targeting a 50% reduction of energy use to 2025, and zero fossil fuel CO_2 emissions by 2025.[5]
- **Ports of Los Angeles & Long Beach, USA:** Targeting a 59% reduction of NOx, 93% of SOx and a 77% reduction of Diesel Particulate Matter by 2023.

Policy makers are beginning to realize the role ports and shipping can play in achieving CO_2 emission and air quality targets. With the aim to open dialogue between cities and ports, this report explores the increasing challenges that cities and ports face and highlights how digital technologies can improve the flow of information, how electrification of ports can positively impact local air quality and it provides insights into what a port of the future could look like.

Siemens has estimated that an average European port, with both cargo and cruise terminals, could immediately reduce the CO_2 emissions from docking vessels by 25%, and reduce air pollution by, NOx 90% and PM_{10} 95%. The big air quality win requires vessels to utilize on-shore electric power and terminals to upgrade cranes and electrify as much as possible. If this happens emissions from the total port complex NOx and PM_{10}, would be reduced by 88% and 90% respectively.

Cities and Their Ports: Driving Growth

While many of the port cities owe their very existence to the ports and today benefit from economic growth and jobs, the cities are also confronting the necessity of improving quality of life for city residents, specifically reducing, air pollution, noise and congestion – interests that cities have in common with ports.

According to the International Chamber of Shipping (ICS) about 90% of world trade is carried by the international shipping industry, and seaborne trade has quadrupled since the late 1960s.[6] The world cruise market is also increasing, in 2015 there were 22.2 million cruise passengers a 3.2% increase over just the previous year. Growth within cities and their respective ports has for a very long time been linked.

However, the shipping industry today is facing real economic challenges linked to the purchase and use of the ultra large shipping vessels, the retrofits needed at ports to accommodate the large size and a decrease in container demand growth. Additionally there is a trend showing that more and more goods are moving through fewer, but larger, mega ports. This means that for many cities the port continues to be vital to local industry, but the growth relationship between the port and the city is no longer inextricably linked. This trend has resulted in a shrinking of many city ports and over time logistics constitutes a smaller proportion of local economic value creation.

The word 'port' represents a very complex business, as ports are comprised of multiple terminals where the actual on and offloading takes place. There are numerous types of terminals and the clearest separation of uses is that between the movement of people, cruise terminals, and goods, cargo terminals. Cargo terminals are highly specialized depending upon the types of goods that pass through them. The technologies needed within a container terminal differ from those needed to transfer dry bulk goods or liquid natural gas (LNG).

Port ownership and management structures create yet another layer of complexity across the business. Ports are often nationally or municipally owned and operated through a local Port Authority. Under the jurisdiction of the port authority sit the terminal owners and operators, which are predominantly privately owned and operated by global shipping and logistics companies.

Economic Drivers

The growing cargo and cruise segments of the shipping industry have different economic drivers and these are driving a wedge within port areas as cargo terminals move further and further out into the sea in order to accommodate the ever growing size of container vessels and, cruise terminals are moving towards city centers as passengers want to maximize their time in the city. In many instances these two types of port terminals have already resulted in a geographic split, for example in London the Ports of Tilbury and the Thames Estuary facilitate cargo ships and plans have recently been approved by the city for a cruise terminal in Greenwich, a more inland and central location.

Port of Los Angeles, USA

Mega Ports have, over the last 50 years, been moving further and further out of the city centers and into deeper water in order to manage the ever increasing size of cargo vessels. These ports are also very likely to have extensive linked industrial areas where offloaded goods can immediately be processed. The terminal operations and wider port industry are generally very energy intensive and create significant levels of emissions. These emissions may or may not be accounted for within a city's carbon inventory, but they will still contribute to poor air quality and overall emissions levels.

Cruise Terminals are moving in the opposite direction of the mega ports towards the city centers as passengers wish to disembark in the center and not a faraway port. Cruise ships can be very large, and their arrival within an urban port would create noise, emissions and congestion. Despite these negative impacts, cities and local businesses are keen to attract the linked tourist spend and local jobs.

The Cities that are not home to a mega port or a cruise terminal may still be home to a smaller port that remains vital to local industry. These ports may now be smaller in size, but their continuing operation within the city center means that any negative impacts related to carbon emissions, poor air quality, congestion and noise are very much issues for both the city and the port to manage.

The economic drivers of ports remain the need to operate on ever tighter margins while increasing throughput and TEUs (Twenty-foot equivalent unit), a key performance metric for ports. All of the demands facing cities and ports can largely be distilled into two categories, those that improve local quality of life for city residents, including reducing air pollution, noise and congestion, and those that benefit the port's economic case, including reducing operational costs, the time it takes to transfer goods and increasing overall capacity. Managing these demands requires good leadership coming from both the cities and ports and an understanding of where technology can support their mutual aims.

Siemens has created this brochure with the aim of highlighting to both cities and ports where and to what degree digital and advanced technologies can support these mutual aims. Siemens has vast experience in delivering city and port infrastructure across the world, and Siemens produces specialized port technologies ranging from crane operations, to improved security, energy management and generation and cargo screening. Siemens also offers technologies that can reduce local congestion and noise and improve air quality. An improved local environment could remove a blight on nearby sites and make them again part of the functioning city.

Driving Growth and Change

A significant number of cities today owe their success to the trade facilitated by their ports and harbors. Continued success will rely on ensuring that both cities and their ports can make the digital leap and use technology to remain competitive.

Ports continue to provide jobs and the world's largest ports generate a lot of jobs. For example, the Port of Rotterdam is estimated to create about 93,000 jobs, of which 73,000 are counted by the city as local jobs comprising about 23% of total employment[7]. The local employment base is linked to the actual handling of goods on site as well as any nearby industrial manufacturing where materials are immediately processed or utilized upon arrival.

The world's largest ports support markets that extend well beyond their region, for example nearly 45% of all trade between the US and China moves through Los Angeles and its twin ports.[8] The Port of Rotterdam is as important to European industry and business as it is to the local Dutch market and the Chinese ports of Shanghai and Tianjin are a critical part of China's industrial success. Singapore is the world's largest transhipment hub for goods to any country. Moreover, the most important ports for some countries are in fact not their own ports, but foreign ports well connected to their country, such as the Belgian port of Antwerp for France, heightening the need for regional networks and co-operation.

A report by OECD[9] goes on to suggest that although there are large metropolitan areas without a port, their fate is often strongly dependent on the quality of the connection with ports.

Challenges Facing Ports & Cities

Ports face unique challenges as the companies and people who benefit from them are most likely not local residents. Meanwhile, the local residents are probably very aware of the port's economic importance and they are probably equally – if not more – aware of the negative impacts of the port. In many cases the port is likely to be an inaccessible part of the city because of security concerns and its need for operational space, which can increase the feeling of separation.

'A survey among 1000+ Port Directors, Chief Engineers and Commercial Managers from across Europe shows that beside lack of funding, environmental regulation and planning issues are their biggest challenges in regards to expanding infrastructure.[10]'

The physical challenges facing ports are considerable and include:

Carbon Dioxide (CO_2)

CO_2 emissions from ports and ships are significant and account for 2.2% of global CO_2 emissions.

Air Pollution

The shipping industry is a main contributor of air pollution and it contributes 15% of the world's nitrogen oxides (NOx) emissions and 6% of global sulfur oxides (SOx) emissions, which can be transported very long distances by wind. Shipping also contributes to Particulate Matter, PM_{10} and $PM_{2.5}$ as they are generated by the combustion of fossil fuels in diesel engines from ships and landside trucks.

Noise

Certain types of noise – either too high or too low – may become a health risk for humans. One major source of noise pollution in ports comes from the diesel-powered auxiliary engines used when ships are docked. The noise levels produced by these engines can reach 80-120 dB[11], which far exceeds the industry's standards for allowable noise, namely less than 50dB(A) inside a cabin and less than 65 dB(A) on an open deck. Another aspect of noise pollution is the detrimental impact it has on marine life.

Urban Congestion

Over the past 14 years, the world's container port traffic has more than tripled[12], and the need to transport the containers out of the port into the hinterlands without creating congestion is a huge challenge that is expected to worsen. Congestion within a city negatively impacts the productivity of other business and personal activities. There is a huge variance between the number of trucks entering and exiting a port per day, but numbers for small and mid-sized ports can range from 1,200 to 2,000.[13] The number of trucks entering and exiting a port in one day can reach up to 35,000 in some of the world's busiest ports.

Cruise terminals are linked to crowded harbour areas and city centers. A large cruise vessel has a capacity somewhere between 3,000 and 5,000 passengers and a medium-sized vessel between 1,500 and 2,000 passengers, and the arrival and departure of this many tourists within a short amount of time will create a more congested harbour area and city center.

Vessel Congestion

It is often due to productivity or capacity issues in handling equipment, insufficient planning or tidal dependence. Congested ports usually lead to waiting times for vessels to be offloaded, resulting in congestion within and outside of the port. Local authorities have the task to create resilient hinterland connections that can reduce the likelihood of transit bottlenecks and maintain port access during the busiest of times.

Waste

Although cruise ships represent less than 1% of the global fleet, they account for 25% of all waste that ends up in the sea such as glass, tin, plastic etc. Sewage waste from cruise ships is becoming a focus for Scandinavian ports. A new report from World Economic Forum and the Ellen MacArthur Foundation has found that one refuse truck-worth of plastic is dumped into the sea every minute, and the situation is getting worse.[14]

Economic Challenges

Tightening Margins

The global shipping business is operating under tight margins as ultra large vehicles have created over capacity in supply, which has put downward pressure onto prices and pressure on terminal operators and authorities to reduce shipping charges.

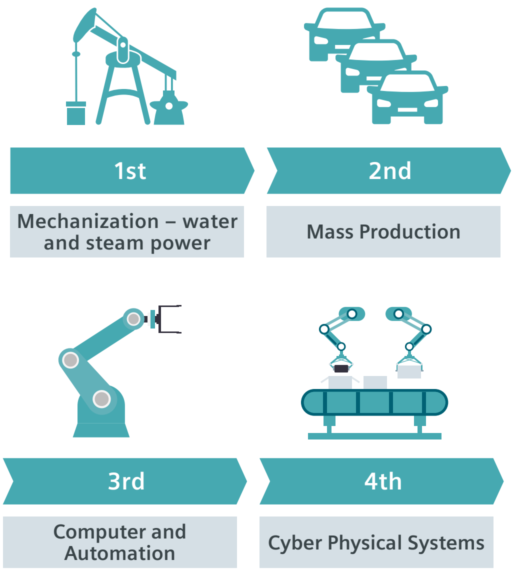
Environmental Regulation

Governments are asking the global shipping industry to reduce emissions and other negative impacts. Actions to date have targeted air quality by reducing the sulfur content of fuel and requiring on-shore power to docking vessels. In most instances, the implementation deadlines have not yet been reached and enforcement of fuel standards appears inconsistent. All in all the benefits of improved port technology have yet to be realized. The European Union is offering some subsidies for private terminal operators to implement on-shore power, but large environmental regulation is linked to increasing operational costs.

Proportion of Global Emissions Generated by Ships:

- 2.2% of all CO_2 emissions
- 15% of all NOx emissions
- 6% of all SOx emissions

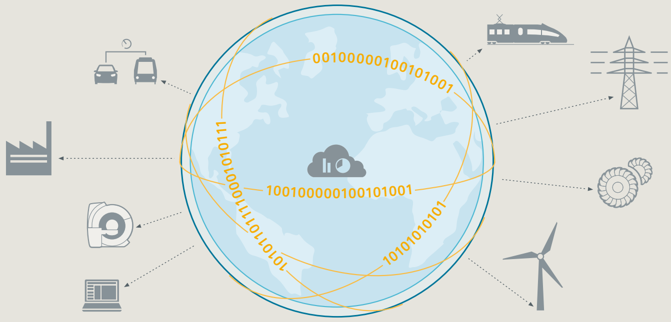
Digitalization



The digital leap – greater efficiency by merging the real and virtual worlds.

The world has never been as connected. From gas turbines to trains, to manufacturing and medical imaging equipment, our physical world is taking on a digital dimension.

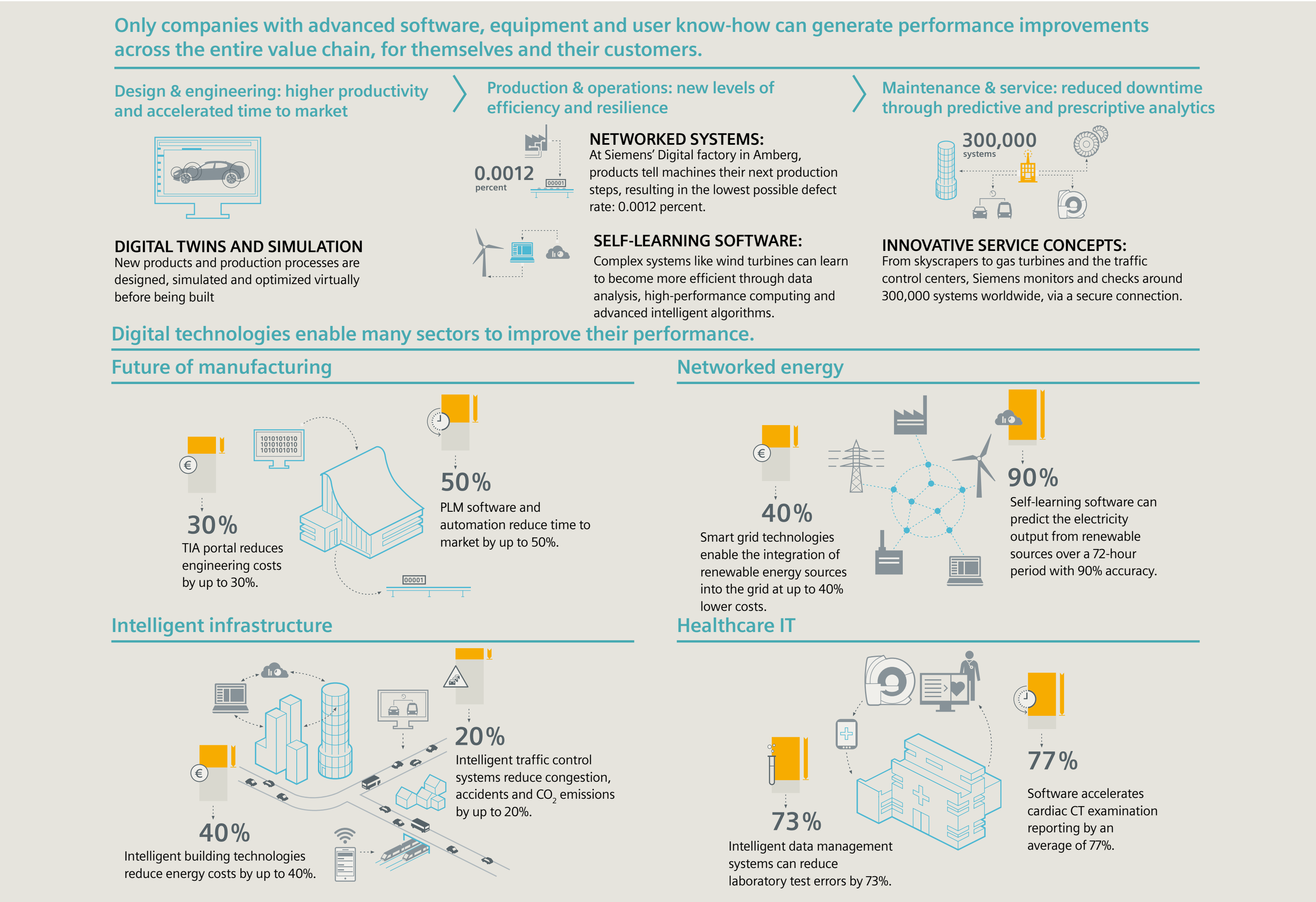
The increasing convergence of the physical and virtual worlds offers boundless opportunities – in almost all areas of society.



Digitalization is the process that turns activities, information and results into data that can be compiled, analyzed and shared. Digitalization is happening across sectors, and it is re-shaping how business and industry works. The ports business, with its numerous players across the value chain, means that there is a huge amount of information that could be digitalized and shared within shipping alliances or between city port authorities and shipping and distribution companies. There are, of course, privacy and competitive reasons, why companies may not wish to share data – this is likely to be the same in all industries. Yet, more data sharing is starting to happen in the ports industry – across supply chains and within terminal operations. Several major ports and shipping companies are engaging new digital technologies to look at the full logistics supply chain and to improve data flow between vessels and terminal operations. For example, the Port of Singapore is using digital technologies to automate container movements and to guide shipping vessels (pages 29 and 35).

In order to manage the complexity of industry today, its need for absolute precision and management, Siemens has expanded on the concept of the Internet of Things (IoT) for industrial applications to create the Web of Systems, meaning systems that are digital, communicate with each other, and can act autonomously. Siemens' vision is that as this ecosystem takes shape its elements will be managed via future Web technologies that use standardized protocols and languages of the kind that are used for the Internet today. Siemens has developed a digital platform, MindSphere, where data from multiple technology sources or partners can be uploaded and apps be created and used to sift out the critical information that can improve business performance.

This linking up of the real world and the virtual world of data offers multiple advantages. It offers infrastructure organizations the ability to capture and analyze the current status of a system and its parts anytime, in detail. This in turn yields immense opportunities for savings through predictive vessel maintenance, as well as major potential for optimizing crane and container handling systems. Using today's technologies from the World Wide Web environment, systems can often be implemented and commissioned faster and more economically. A system's intelligence can be distributed as needed between real components and virtual systems in the Cloud, resulting in enhanced robustness and customer data protection. Finally, as the digital landscape is transformed along these lines, it will become easier to update



systems with new functions, or to update system software on the fly, in much the same way as smartphones and other devices are updated through apps.

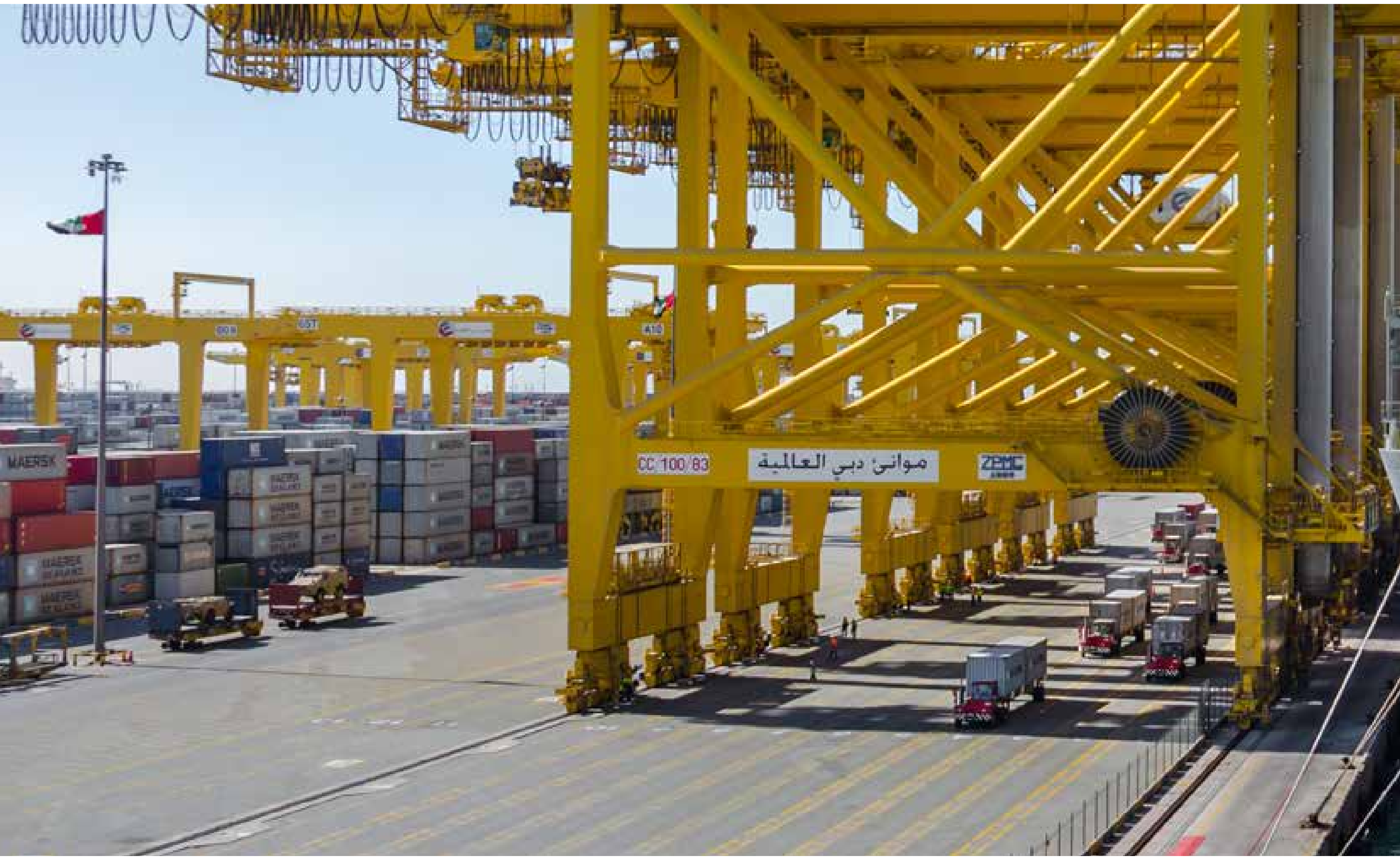
Digitalization is transforming industries across the globe so much so that now digitalization has been coined the 4th industrial revolution or Industry 4.0. Digital ideas coming out of one sector are now having impacts in other sectors, and Siemens Digital Twin is one of these cross-over technologies. The Digital Twin allows systems and machine movements to be virtually planned and tested before any physical on-site movements. In the cases of ports, movements of cranes, vehicles and container handling systems can be planned beforehand to speed throughput and energy systems can be planned and future proofed to ensure constant supply and quality.

Digitalization happens in steps, and these include:

Electrification – The basis of intelligent infrastructure is electrification. Through electrification power systems can be more precisely controlled, which leads the way towards automation. Very importantly, the electrification of infrastructure means that there is now the opportunity to use cleaner grid or renewable power.

Automation – Once automated, processes across infrastructure and industry, will be able to operate without direct control. Automation increases speed, efficiency and often times accuracy across sectors.

Digitalization – Digitalization is the process that turns activities, information and results into data. Smart cities and ports will need to run on smart data, meaning that there is the need to pull the valuable data from the cacophony of data that organizations are generating. The ability to source and compile the right data will be a key differentiator for successful organizations in the future.



MindSphere – A Hosting Platform behind new Digital Business Models

Connecting Port Value Chains Through Digitalization

Cut throughput times, increase flexibility, and optimize energy and resource consumption are some of the demands being asked of ports and terminal operators today. These demands may be perceived as common responses to the tougher competition between ports and tightening environmental legislation, but the number of different entities that are active within ports, ranging from customs authorities, international shipping companies and container handling companies, means that software integration is difficult and practices are not often standardized.

In the port of the future, successful use of data will be a key differentiator between ports and determine success. Digitalization can enable the port to evaluate its entire value chain as a single system. However, digitalization requires an overall operating system that can collect, store and utilize vast amounts of data.

Paving the way to digital services, Siemens has released an open and scalable cloud platform for companies regardless of industry or size to use as foundation for building and integrating digital business models into their own businesses:

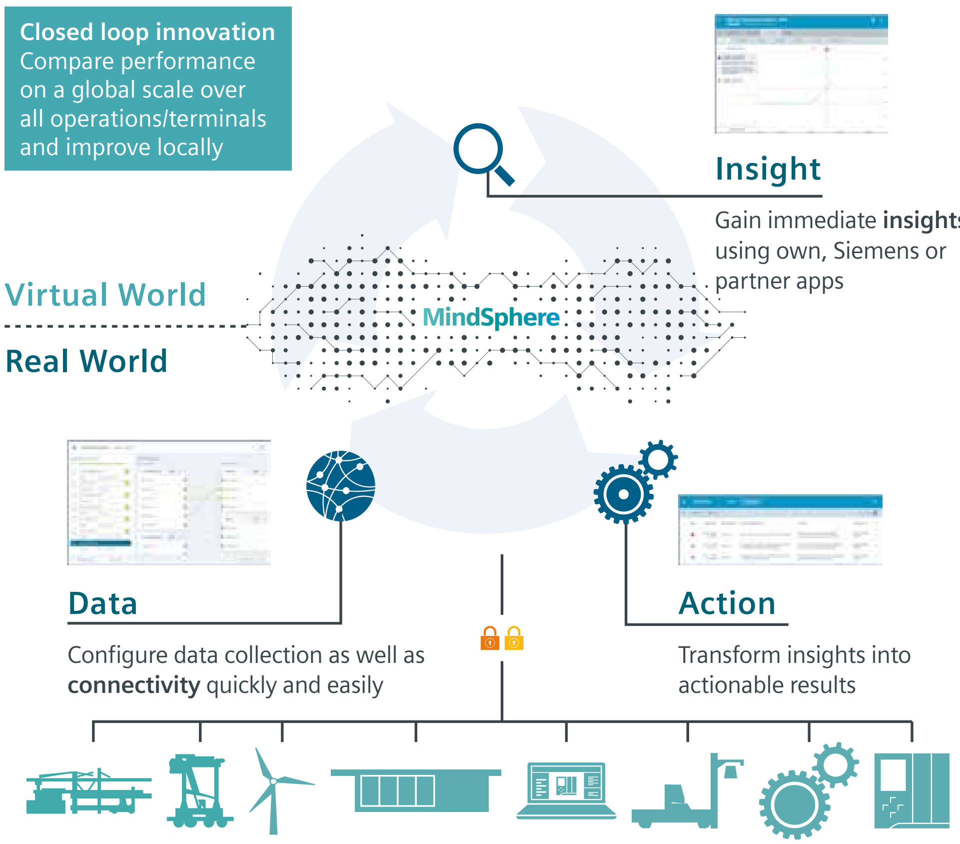
MindSphere – the cloud-based, open operating system for the Internet of Things.

MindSphere provides the capability of developing digital services, applying them and making them available to other partner users. Being a cost-efficient data hosting platform, it combines:

- Encrypted fast data processing across company boundaries
- Safe and global large-scale data storage
- Visualization of analytical results
- Connectivity of assets regardless of manufacturer
- Boundless opportunities for third party application developers to create business specific apps

Using MindSphere in Ports – Turn your Data into Added Value

MindSphere will allow port operators to make data available from connected devices, develop new applications that can optimize port activities, and build entirely new service models. These actions will be possible because of the insights gained through the combination of data sets.



Optimization

Asset performance management: Monitoring and diagnostics, incl. predictive maintenance.

Fault Detection from the cloud: Identify, localize and analyze faults across systems.

E-Car Operation Center: Manage-e-mobility for battery powered AGVs, fork-lifts incl. charging-stations.

New revenue streams

Energy trading and selling: Trading and selling of electricity between port actors, including docking vessels.

Value-add for business models: Transparency and flexibility for billing and pricing (internal and ext. for customers) / e.g. reefer container.

Technology's Role in Reducing Port Emissions

Targeted port technologies can significantly improve local air quality and reduce overall city CO_2 emissions. Estimations show that an average European port could immediately reduce CO_2 emissions from docking vessels by 25%, and reduce NOx 90% and PM_{10} 95%. By requiring the use of on-shore electric power for docking vessels. Should a port terminal utilize more technology they could reduce their total emissions by up to 90%.

Using real city data and Siemens' knowledge of port technologies, the Siemens Global Center of Competence Cities has undertaken research to estimate the potential for reducing harmful emissions from ports and their associated terminals. Siemens is utilizing its in-house City Performance Tool (CyPT), which creates an emissions baseline for cities using energy, transport and buildings data. The emissions baseline is scaled up to a future year and technologies are applied against the future baseline and reductions in the key environmental indicators are calculated. In order to create an emissions baseline for a port, Siemens has modeled an average port. Although an average port does not exist, there are certain characteristics common to several European ports that could be fused to create an average European port.

The modeling utilizes the current and forecasted' national electricity mix of a key European country in 2015 and 2040, and Siemens' knowledge of the impact of technology on energy use and key air quality indicators including: CO_2 emissions, particulate matter (PM_{10}) and nitrogen oxide (NOx) for the following technologies:

- On-shore power supply
- Electric cranes
- Smart grid
- Building Technologies and Lighting

Our modeled average European port will have both container terminals and multi-purpose terminals, including a cruise and dry bulk terminal. We have estimated the likely number of cranes per terminal and sizes of generators required for the different types of vessels as well as the length of time that they would remain in port.

- 2 container terminals
- Multi-purpose terminals with Rubber Tired Gantry Cranes (RTGs) and Ship-to-Shore Cranes (STS)
- 7,500 cargo vessels annually
- 60 cruise ships annually

Siemens has estimated that vessels docking in the average port would generate the following emissions annually:

- CO_2: 397,350 tons
- NOx: 6,883 tons
- PM_{10}: 535 tons

The Siemens City Performance Tool was used to calculate the impacts of several commercially available, emissions reducing, port technologies. Siemens has calculated these results using data from our City Performance Tool and our market knowledge on port technologies. The following tables illustrate the potential today and in 2040 for reducing these specific port related emissions.

Electric and Highly Efficient Cranes

The most progressive terminals already utilize electric cranes. For those that have not already done so, there are significant emissions and energy efficiency benefits through electrification and investment in the most energy efficient crane technologies.

Reductions from electric and efficient cranes:

	2015 electricity mix (Predominantly a mix of gas and coal with some renewables)	2040 electricity mix (higher proportion of renewable energy and gas with some coal remaining)
CO_2	67%	74%
NOx	82%	83%
PM_{10}	84%	84%

Smart Grid

Improving local grid performance through targeted communication based technologies can reduce outages and improve electricity flow. Inclusion of a smart micro gird across the port could produce the following results:

	2015 electricity mix (Predominantly a mix of gas and coal with some renewables)	2040 electricity mix (higher proportion of renewable energy and gas with some coal remaining)
CO_2	9%	41%
NOx	9%	37%
PM_{10}	9%	25%

Port of Rotterdam, The Netherlands

Building Technologies and Lighting

Using existing building and lighting technologies, such as LED lights and sensor technologies, energy savings can be made across the wider port complex.

Reductions from building technologies and lighting:

	2015 electricity mix (Predominantly a mix of gas and coal with some renewables)	2040 electricity mix (higher proportion of renewable energy and gas with some coal remaining)
CO_2	26%	52%
NOx	26%	49%
PM_{10}	26%	39%

On-shore Power Supply

Electrification of docking vessels through the use of on-shore power supply creates the opportunity for them to utilize grid electricity while in port and no longer rely on large diesel generators as has been the industry standard.

Reductions from on-shore power supply:

	2015 electricity mix (Predominantly a mix of gas and coal with some renewables)	2040 electricity mix (higher proportion of renewable energy and gas with some coal remaining)
CO_2	25%	51%
NOx	90%	93%
PM_{10}	95%	96%

Ports and Cities Taking the Lead

Many ports and governments around the world are taking effective actions to reduce port emissions.

Many ports and governments around the world are taking effective actions to reduce port emissions. The following are some of the world's leading examples:

- **Port of Rotterdam, The Netherlands –** 50% CO_2 reduction by 2025 compared to its 1990-level. The Port of Rotterdam has the ambition to be the most sustainable port in the world.

Port of Rotterdam: Environmental Goal:

Port of Rotterdam is the largest port in Europe and also a frontrunner in delivering green port technologies. The Port has a target to deliver a 50% CO_2 reduction by 2025 compared to its 1990-level. The Port Authority has set this goal even though its tenants are facing challenges of a rise in container traffic and the expansion of handling facilities. The port authority's solution is twofold, first reducing the surplus of CO_2 emissions by using alternative energy sources such as wind and solar power, and the second is repurposing emissions through utilization of waste heat and carbon capture pilot projects.

- **Port of Vancouver, Canada –** The Port of Vancouver has implemented numerous measures to reduce emissions including provision of on-shore power for docking cruise vessels and a 47% reduction in docking fees for utilizing this electricity. The port is requiring the retrofit of diesel trucks to reduce emissions, and it is incentivizing the upgrading and electrification of cranes.
- **Port of Stockholm, Sweden –** The port is targeting a 50% reduction of energy use over the period 2005 to 2025, and zero fossil fuel CO_2 emissions by 2025.[15]

Port of Stockholm: Waste Management and Noise Pollution:

The Port of Stockholm is aiming to be fossil fuel-free by 2025, and the Port of Stockholm is taking actions to improve waste management and reduce noise pollution. The port has installed waste management stations along the quays and the port incentivizes their use and the recycling of materials[23]. The port is addressing noise pollution by delivering on-shore electricity technology, its been providing these connections from the 1980s. The port's strategy requires that on-shore power is delivered as part of any quay renovation or new construction.

- **Ports of Los Angeles & Long Beach, USA –** By 2023, the port aims to achieve a reduction of 59% in NOx emissions, 77% reduction of DPM (diesel particulate matter) and 93% for SOx, when compared to 2005 levels. By 2020, 80% of berths in the state of California are expected to have on-shore power capabilities.[16]

- **Ports of Shanghai and Tianjin, China –** The Government of China has amended its air pollution law to require that all new terminals have on-shore power and for existing terminals to be retrofitted with this technology. Vessels that use on-shore power will be given priority and by 2020, 50% of all ports must have on-shore power installed.[17]
- **Port of Helsinki, Finland –** The Port of Helsinki aims to keep its own emissions in check while also supporting environmental improvements across the port operations.[18]
- **Port of Hamburg, Germany –** The port is requiring a 30% reduction in CO_2 emissions per handled container by 2020. The port has already estimated achieving a 29.5% reduction at fiscal year 2015.
- **Port of Antwerp, Belgium –** The port is taking a pro-active approach to emissions reductions including offering discounts to vessels using alternative, cleaner, technologies.
- **Port of Singapore, Singapore –** The port offers a 25% reduction in fees for vessels that use alternative technology to reduce emissions. In 2011, the Maritime and Port Authority of Singapore (MPA) pledged to invest approx. US$70 million over 5 years in the Maritime Singapore Green Initiative targeting greener ships, ports and technology.[19]

Taking Action: at National and Regional Levels

Ensuring that emissions standards are raised across all ports to create a level playing field for doing business is critical. There are several national, regional and even global examples that are setting new standards.

European Union Ports

The EU directive on the deployment of alternative fuels infrastructure mandates a significant reduction in harmful emissions during ship lay days. The EU has also set a deadline for European ports to implement on-shore power by 2025. As a means to incentivizing take-up of the technology the EU is offering subsidies of 20% and 50% to private operators implementing on-shore electricity connections.[20]

Northwest Ports Clean Air Strategy, Canada and the USA

The ports of the Puget Sound-Georgia Basin air shed including the Ports of Vancouver, (Canada), Tacoma and Seattle (USA) have all agreed to target a 75% reduction in Diesel Particulate Matter (DPM) emissions per ton of cargo by 2015 and 80% by 2020. Adhering to similar standards and raising the bar for all ports within the region, that includes two countries, reduces the risk of an operator or shipping company targeting the port with the lowest standards.

Baltic Sea Ports (Sweden, Estonia and Finland)

Recognizing the benefits of on-shore power supply for vessels, the four Baltic Sea Ports have joined together to implement this technology. In September 2016, Sweden's Port of Stockholm, Estonia's Port of Tallinn, and Finland's Ports of Helsinki and Turku signed a Memorandum of Understanding setting a common approach for implementing on-shore power, by agreeing the following:

- The Ports will provide new connections with a voltage of 11 kV and a frequency of 50 Hz.
- All signed ports will encourage other ports and shipping companies to follow and deliver to the same specifications.
- All will continue to find ways to minimize the negative impacts of ports and shipping across the Baltic Sea region.[21]

Indonesia Undertaking Major Marine Development Program

Located in-between the Pacific and Indian Oceans, and consisting of 6,000 inhabited islands, Indonesia holds an important geographic location for global seaborne trade and an internal connectivity challenge. The Indonesian government has the challenge to connect its numerous islands stretching over a total of 5,000 kilometers to each other and to the world.

The government recognizes its unusual geographic challenge, and it is actively trying to transform its level of connectivity through its ambitious Marine Highway Development Program. The program includes an upgrade of six ports into international ports, a development of no less than 24 new commercial sea ports and 1,000 non-commercial ports.

The new ports will be economic powerhouses for Indonesia and those that are already in cities are likely to expand the city or new cities may grow around them. The associated urban development is critical, and Indonesia has the opportunity to utilize leading technologies at the outset to avoid substantial retrofit costs and deliver well functioning ports. Use of technology will also mean that ports will be able to match the transformation happening in cities as they will be an important economic player in those cities.

The comprehensiveness of Indonesia's development program is seldom seen, and the scale of it can potentially benefit the country and deliver quality jobs and extend economic growth to a wider proportion of the population. Indonesia is also pursuing a nationally led Smart Cities initiative and linking port and city development could deliver a higher degree of impact for the money invested.

Port of Jebel Ali, Dubai

Role of International Port Organizations

The sheer number of entities involved in the global shipping industry means that there is no single authority that can implement change across the industry. Any change needs to come from coordinated and consistent global regulation or from within the shipping industry. Global shipping focused organizations such as AIVP (Association Internationale Villes et Ports) are needed to communicate the needs of the industry in a single voice and to disseminate its knowledge amongst its members.

In the case of AIVP, it has been striving to bring public and private development stakeholders together for more than 25 years. AIVP has a unique focus as it engages with the shipping business operators as well as city and local governments. In October 2016, AIVP signed a memorandum of understanding with EFIP (the European Federation of Inland Ports) to carry out joint promotion activities to highlight the importance of port-city relations on the European and international levels.

C40 Cities

C40 member cities recognize that ports have both the responsibility and opportunity to reduce CO_2 emissions, and 55 ports from all over the world came together at the C40 World Ports Climate Conference in 2008. They committed to jointly reduce the threat of global climate change through the signing of a declaration addressing[22]:

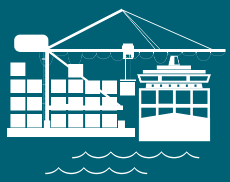
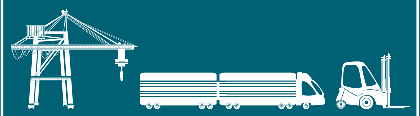
- Reduction of CO_2 emissions from ocean-going shipping, from port operations and development, and of hinterland transport.
- Use of renewable energy generation
- Development and auditing of CO_2 inventories

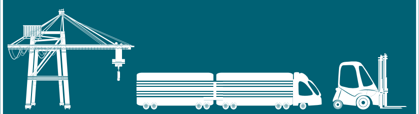
Ports as Technology Accelerators

The Port of Rotterdam's PortXL initiative is a leading example of an accelerator program for port related technologies, open to both start-ups and spin-outs from larger corporations. Creating and supporting an accelerator like PortXL means that port decision-makers stay knowledgeable and connected with some of the latest technology advances, and it gives them a better understanding of how to position their businesses to benefit from them the most. New port related businesses are through the program given access to sector expertise and very importantly a place to test and advertise their products.

Technologies

Shipping companies, terminal operators, port authorities and hinterland transport operators are all facing tightening margins and the pressure to reduce emissions and landside congestion. The following matrix highlights the specific technologies that can address the real challenges facing port cities and where along the landside logistics chain they can be implemented to cost effectively improve performance.

Challenges	 Ship and Quay	 Terminal and Stacking Area	 Transit Connections to the City and Hinterlands
CO_2 Emissions	▪ Ship-to-shore cranes ▪ On-shore power supply ▪ Smart Grid ▪ ECO Crane Drives ▪ Battery Storage ▪ Integration of renewable energies ▪ Electric propulsion systems	▪ ECO Crane Drives ▪ Parking Guidance ▪ Building Automation Systems ▪ Integration of renewable energies ▪ Buildings Energy Efficiency ▪ Electrification of handling vehicles	▪ eHighway ▪ Urban Traffic Control ▪ Rail Electrification ▪ Integration of renewable energies
Air Quality	▪ On-shore power supply ▪ Smart Grid ▪ Battery Storage ▪ Integration of renewable energies ▪ Electric propulsion systems	▪ On-shore power supply ▪ Automated container handling ▪ Parking Guidance ▪ Integration of renewable energies ▪ Totally Integrated Power ▪ Electrification of handling vehicles	▪ eHighway ▪ Urban Traffic Control ▪ Rail Electrification ▪ Integration of renewable energies ▪ Parking guidance ▪ Individual truck guidance
Noise	▪ On-shore power supply ▪ Battery Storage ▪ Integration of renewable energies ▪ Electric propulsion systems	▪ On-shore power supply ▪ Automated container handling ▪ Electrification of all port vehicles	▪ eHighway ▪ Urban Traffic Control ▪ Rail Electrification
Energy Efficiency	▪ On-shore power supply ▪ Ship-to-shore crane optimization ▪ Battery Storage ▪ Smart Grid ▪ Container scanning ▪ Electric propulsion systems	▪ Ship-to-shore cranes ▪ Container scanning ▪ Highly energy efficient Crane Drives ▪ Parking Guidance ▪ Building Automation Systems ▪ Totally Integrated Power ▪ Smart Grid	▪ Urban Traffic Control ▪ eHighway

Challenges	 Ship and Quay	 Terminal and Stacking Area	 Transit Connections to the City and Hinterlands
Throughput	▪ Ship-to-shore cranes ▪ On-shore power supply ▪ Container scanning ▪ Smart Grid	▪ Container scanning ▪ Crane system (rail mounted gantry cranes) ▪ Truck Positioning System ▪ Parking Guidance ▪ Automated container handling ▪ Remote Control Systems. ▪ Rail Resource Management Systems ▪ Rail Control Systems ▪ Rail Infrastructure ▪ Capacity Management	▪ Urban Traffic Control ▪ Parking guidance ▪ Individual truck guidance ▪ Rail Resource Management Systems ▪ Rail Control Systems ▪ Access Control ▪ X-Ray Scanning
Congestion	▪ Ship-to-shore cranes ▪ Crane automation systems to speed handling	▪ Automated container handling ▪ Parking Guidance ▪ Automated horizontal transport	▪ Urban Traffic Control ▪ Individual truck parking guidance ▪ Access Control ▪ X-Ray Scanning
Security / Safety	▪ Fire Monitoring and Detection ▪ Intelligent video management	▪ Perimeter Surveillance ▪ Fire Safety and Danger ▪ Lighting systems ▪ Intelligent video management ▪ Remote Control Systems ▪ Building Automation systems	▪ ANPR cameras ▪ Urban Traffic Control ▪ Access Control ▪ X-Ray Scanning
Job Creation	▪ On-shore power supply construction ▪ R+D – New port tech accelerators ▪ Electrification of port - retrofit jobs		

Port of the Future

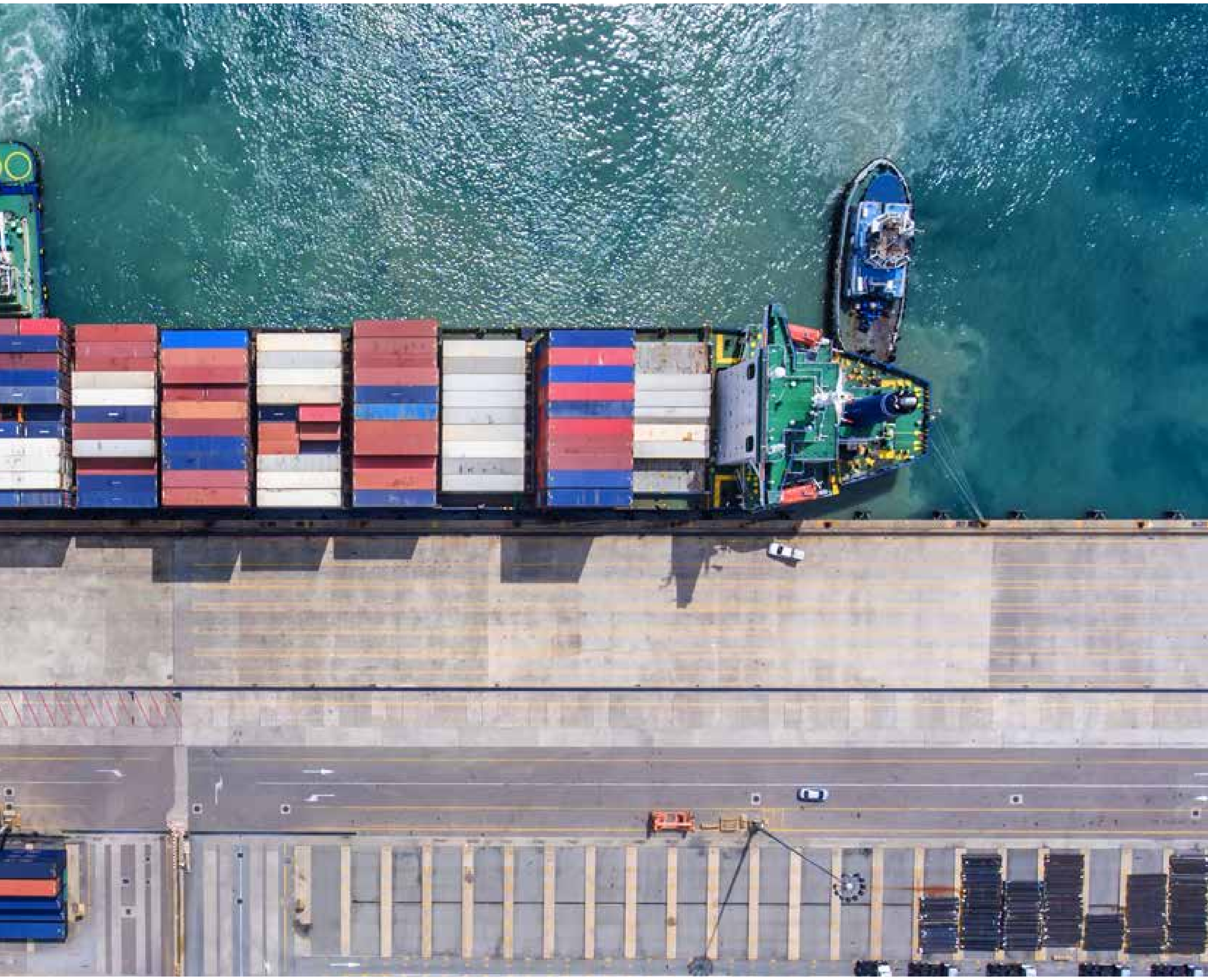
With a quadrupled level of seaborne trade since the late 1960s, there is no doubt that shipping plays a major role for our global economy. Over the years, the industry has embraced new port technologies, but it has to this point not been disrupted by the massive growth in new technologies – possibly until now. Blockchain, 3D printing and smart mobility technologies all have the potential to dramatically impact the shipping industry. This means possible new economic winners and losers, and cities with their respective port authorities need to strategize on how to prepare, change and benefit from these current and future technologies.

Electric, Digital, Efficient and Clean

The port of the future will be 100% electric, local emissions free and able to process more goods in less time. Ports will achieve this future through the use of digital technologies and a shift away from diesel based fuel.

Today, the technologies already exist to significantly reduce the harmful emissions produced in ports. The importance being placed on air quality in many cities today tells us that by 2040 and possibly even sooner, many of the world's ports will be fully electrified. Electricity across the port will be delivered via a decentralized energy system that will optimize generation, manage flows and reduce the number of interactions with the main grid. All docking vessels will run on onshore electricity with an increasing amount of locally produced renewable electricity from wind, solar or wave energy or eventually other resources, depending on availability. Some of the world's leading ports already use electric crane technologies today, and electric stacking trucks are being tested in factories, and these technologies are projected to be commonplace by 2040.

Moving beyond electrification, we expect that the port of the future will be fully connected and digitalized. Integrating software solutions will enable the port to work as a single system; everything from energy generation and energy storage to the operations of buildings and warehouses. Digitally controlled cranes and automated container systems are already being used in some of the world's leading ports. Increasing digitalization could mean that ports are able to automate a virtually limitless range of tasks, thus providing a higher cost effectiveness and peak efficiency. Trucks will be intelligently guided into the port area when they are needed to avoid congestion. Local associated industries will be linked and they will share data to ensure an efficient flow of goods.

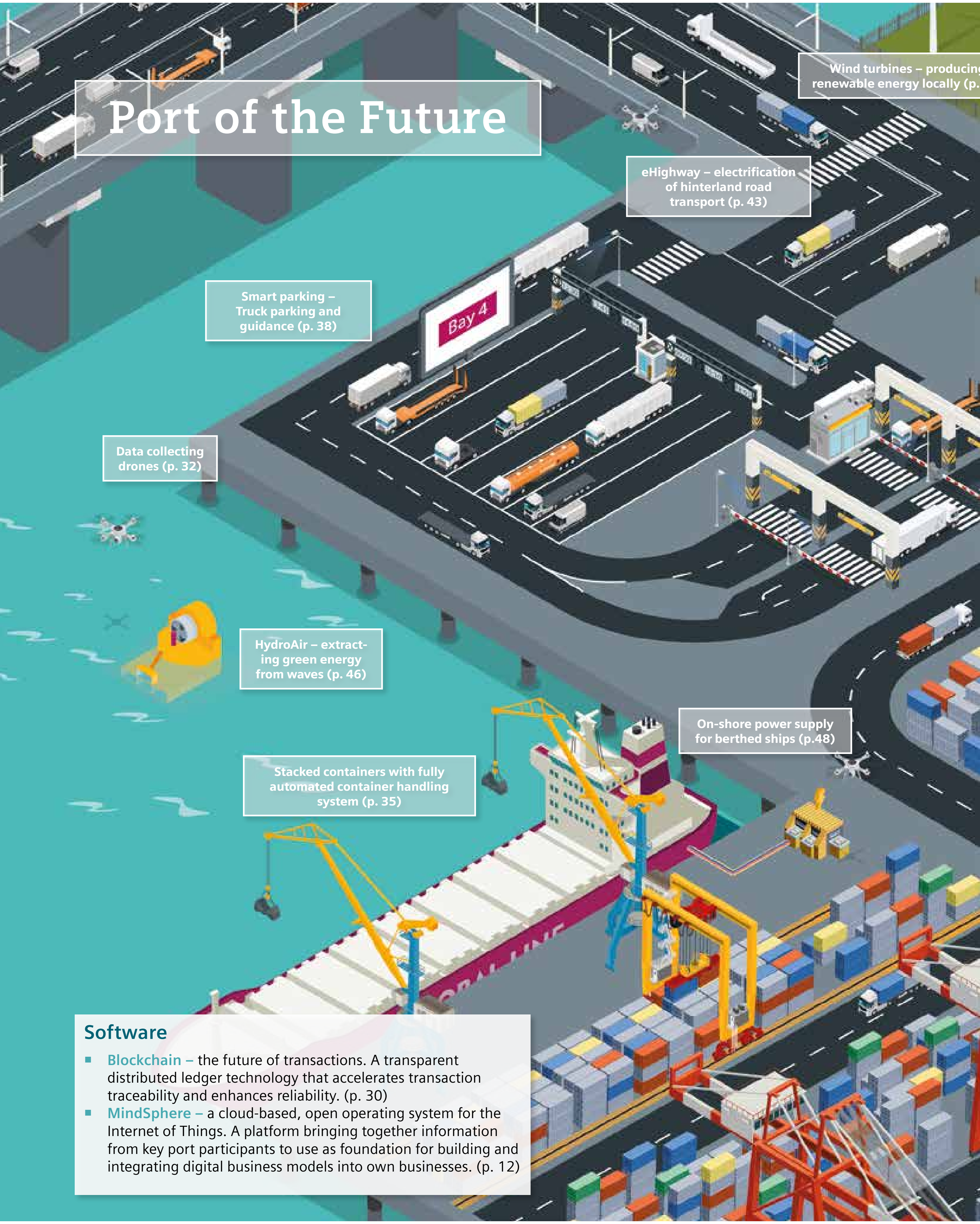


Port of the future will be:

- **Electric –** the port will be powered only by electricity
- **Digital –** the port will be a single system, where all elements are digitally connected
- **Emissions free –** terminal operations and docking vessels will run only on electricity sourced from either the grid or local renewable generation
- **Clean –** the port will be clean and vessel waste will be recycled
- **Highly efficient –** the time it takes for goods to move through the port will be dramatically reduced allowing ports to increase handling capacity through increased automation
- **Secure –** ports will utilize automated container scanning technologies, port perimeters will be digitally monitored and gate entry will be digitally monitored and operated
- **Transparent –** new technologies such as blockchain will improve transparency and reduce costs associated with running local customs operations
- **Employers –** ports will continue to be a source of high-quality, local employment, new technologies will require more highly skilled people

Today, a port's performance is measured by container throughput, recorded in TEUs, gross value added and jobs created. We expect that all of these performance metrics will continue to be measured in the future, but that cities and international bodies will also be paying increased attention to port emissions, noise, waste, recycling and land use. It is likely that throughput will be weighed against these other factors, and ports could be benchmarked on TEUs per square meter of port area or kWh of electricity per 1000 TEUs.

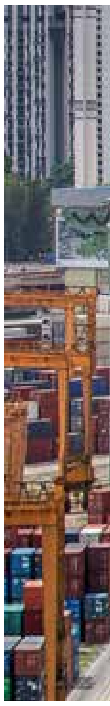
Port of the Future



Software

- **Blockchain –** the future of transactions. A transparent distributed ledger technology that accelerates transaction traceability and enhances reliability. (p. 30)
- **MindSphere –** a cloud-based, open operating system for the Internet of Things. A platform bringing together information from key port participants to use as foundation for building and integrating digital business models into own businesses. (p. 12)


46)
Smart Grid – managing renewable sources and maintaining grid stability (p. 44)
Solar power – installation on rooftops and spare land (p. 46)
Building automation – Zero emission buildings and warehouses (p. 50)
Fully electric and automated cranes (p. 34)
3D printing center (p. 32)
Electric vessels with large battery packs (p. 50)



Managing the Port of the Future

Managing the port of the future and its various complex applications, processes and systems while optimizing safety, security, energy efficiency, cost and environmental care will continue to be an ever increasing challenge. Given the task load, port operations will have to rely more and more on technology.

Other logistics hubs such as airports are already starting to digitally integrate their distributed systems and partners in order to move passengers and freight more smoothly, efficiently and in a cost effective way.

New platforms for ports will allow the sharing of data between shipping companies, terminal operators, customs officials and local transport operators. These technologies will need to integrate the vast amount of information produced by all of the entities operating within a port, and it will give governments more information about who and what is entering and exiting their port, reduce bunker fraud and decrease the time it takes for goods to enter and exit the port area. Digital technology will also help the port authorities to better monitor, predict and prevent port related problems such as congestion.

Managing the Split Incentive – Global Shippers, Local Ports

The shipping industry is comprised of various actors operating either at the global or local level: Some actors, such as shipping companies, are geographically mobile and their vessels travel to ports across the globe, while other actors, such as port authorities or terminal operators, are geographically fixed and they serve a regional or local market. The global market is extremely competitive and ports are often competing against each other for standardized, container based goods. Many shipping companies also own port terminals, and they fund their own operations with port authorities charging some form of a rent and providing shared services across the port. Smaller shipping companies may only own the vessels and have no financial stake in the terminals and are free to move to whichever port charges the least amount in fees. These various entities, their different operating areas and ownership structures means that the costs of implementing emission reducing technologies may fall onto the entities that are least likely to benefit.

The future uptake of emissions targeted technologies will largely depend on environmental regulations. The technologies within this brochure that improve throughput and reduce costs will most likely be implemented naturally. However, those technologies that have a very compelling environmental impact, but not as strong of a business case, will likely need regulation to be implemented. For example in the case of on-shore power, both the port and shipping vessels would need to be adapted. In this case the owner of the vessel would have to fund to the adaptation costs while the benefit goes to the local city in terms of cleaner air. The city and local utility would also have to fund or somehow ensure that there is sufficient electrical power for this technology, which could require the construction of additional sub-stations or new transmission lines. This split incentive could be overcome with legislation or a binding agreement between ports that ensures that all vessels coming into a particular geographic or market area all adhere to the same standards. This is an area where national and supra national governments and international organizations can make a difference.

Port of Singapore harbor, Singapore

Building Next Generation Mega-Port Today: Singapore

Elements of the Port of the Future are already happening at some of the world's leading ports. The Singapore port is not only the world's busiest transhipment hub, but it is also leading in many technology areas. Furthermore, the government has already initiated plans to increase the handling capacity of the seaport by relocating the PSA Corporation terminals, the main port operator in Singapore, from their current location in the city to Tuas in the west of the island. The relocation will enable the better handling of larger vessels and to free prime city land for redevelopment. Key aspects of the government's vision are to increase port efficiency, intensify land-use, improve safety and raise its level of sustainability. In this new port, technologies will have a major role to play in delivering these outcomes.

The first phase of Singapore port's vision has already begun – namely the construction of the new deep-water terminal in Tuas, which will double the seaport's handling capacity. When completed, the new mega-terminal will have a total capacity of up to 65 million Twenty-foot Equivalent Units (TEU) annually, making it the world's largest container port by TEU.

Better Utilization of Spaces

The plan for PSA Corporation to move all its port activities to Tuas by 2027, will support the city's aim to best use its most scarce resource – land. This freed up land in the Keppel and Tanjong Pagar area will be used for the expansion of the current business district as well as for residential and mixed-use. The new mega-terminal at Tuas is not restricted to traditional port layouts. Instead the port will maximize land use by utilizing both above and underground spaces for its operations including storage and a logistics hub.

Forecasting Potential Congestion Hotspots

As the handling volumes will double in the new mega-terminal, potential congestion hotspots have been identified and will need to be mitigated in order to move freight efficiently. PSA intends to use in order to mitigate against possible congestion. PSA is investing in highly automated yard cranes and port equipment to further increase its productivity and reduce labor costs. Furthermore, the new PSA terminal will take advantage of next generation vessel traffic management systems that allows for just-in-time vessel arrival and will enable service providers to accurately plan ahead the deployment of cranes, vehicles, and storage facilities before the vessels arrive in order to minimize waiting time and congestion.

This traffic management system can be integrated with modeling and simulation systems to be able to predict bottlenecks and therefore re-route ships and goods accordingly. This aids in the reduction of congestion and will boost port security and safety.

Blockchain: Chained Data Blocks as a Revolutionizing Solution for Digital Transactions

Blockchain is digital code that is being used to securely record and store valuable information between business partners in the presence of unknown parties. It is based upon Distributed Ledger Technology that came to prominence through the digital currency Bitcoin.

A blockchain consists of a series of data blocks holding one or more transactions, each one referring back to the previous transaction block. New blocks or changes are recorded in real-time. Each transaction is validated, secured and time-stamped and then distributed to all participants over a network. A copy of each block is maintained by a global system that prevents manipulation as information is encrypted and stored in thousands of servers around the world, making it nearly impossible for information to be altered as an alert would be signaled and the discrepancy identified.

Blockchain is simplifying the integration of data streams, particularly in those areas where data forms the basis of a transaction and multiple parties are involved. In the bigger sense, blockchain is shifting where trust lies in a transaction – it is moving away from third parties and into a trust in the technology from a 'shared single source of truth'. The new trust is built on full disclosure as opposed to past history, and the removal of third parties boosts transparency and reduces cost.

Revolutionizing the Way We Trade

The full potential of blockchain is still being discovered, but experts involved in blockchain research agree that it has the potential to disrupt how the shipping industry operates today. Ports are trading hubs and by definition this means that each time a vessel docks a ship owner, shipping company, terminal operator, port authority, customs official and hinterland transport company are somehow involved. The amount of smaller transactions that occur at each step in the process is hugely significant and costly for all parties, and any delay in the system can bring an entire port's logistics to a stop. The time that it takes to move goods from a ship and onto hinterland transport could be significantly reduced in a more transparent and secure way through blockchain.

Fundamental to the system is that information can be added but not removed from a block. This is particularly important when tackling and preventing the issue of bunker fraud; a too common form of corruption within the global shipping industry, where the volume of goods received are smaller than those originally shipped. Historically, it has been difficult to identify where the theft was occurring, however, with blockchain and the required transaction signatures linked to safeguards such as weighing scales and inspections, it will be easier to identify where along the process the discrepancies occur. Blockchain technology can make supply chain and container information more transparent, which means that the parties involved can trace the whole shipping process from raw material to point of purchase.

Blockchain Technology has the Potential to:

- Minimize vessel berthing time
- Accelerate transaction traceability
- Provide real-time information on products and supply chain
- Enhance efficiency through digitalization and automation of processes
- Increase transparency by monitoring product volumes and financial transactions
- Simplify processes of documentation and validation
- Ease measurement and evaluation of performance
- Enhance reliability through higher level of data security and documentation
- Reduce fraud related to imported goods and taxes

The development of blockchain technology is increasing at a rapid pace, and implementation of blockchain in the maritime sector has just started. However, the technology itself will not inhibit full-scale adoption, rather, it will be the challenges associated with adopting and upgrading the technological infrastructure of the ports and the relevant shipping partners.

'A cross-sector approach is needed. Without buy-in from all major actors in the maritime industry, the predicted outcome of blockchain is less likely to be achieved.'

Blockchain – Key Actors and Value Drivers			
	Blockchain Benefits	Key Interest in Blockchain	Potential Role in Blockchain Implementation
Port Authorities	Automated coordination, monitoring and auditing	▪ Clarify which goods are imported and exported. ▪ Simplify custom formalities and paper work. ▪ Address inefficiencies. ▪ Monitor CO_2 emissions and fuel combustion.	▪ As governing and coordinating body, port authorities would set the requirements and standards for implementation. ▪ Raise the opportunity potential amongst terminal operators and shipping companies. ▪ Need for comprehensive training for employees to aid in digitally inputting.
Terminal Operators	Lean and agile terminal operations with automated compliance, verification and settlement procedures	▪ Identify fraud and corruption. ▪ Reduce container transit-time (throughput). ▪ Ensure correct evaluation and transfer of goods. ▪ Minimize vessel berthing time.	▪ Play a key role in the logistics and operations in ports through the implementation of smart contracts to automatically facilitate the interchange of cargo. ▪ Database needs to be build with required storage capacity and planning algorithms.
Shipping Companies	Accurate and reliable reporting and planning data	▪ Reduce liability. ▪ Validate the transfer of cargo. ▪ Guarantee quality control and security of goods.	▪ As primary information holders, they must ensure that the benefits from implementing blockchain increase exponentially with each new shipping company user. ▪ Assets must become digitalized onto blockchain.

A special thanks to BLOC and BSR (Business for Social Responsibility) for contribution.

There is always a risk tied to technologies with disruptive potentials, and research in blockchain is still at its early stage of development. Researchers, companies and organizations are considering whether and how blockchain technology can be used. More real world testing is needed and global standards are required, but one thing is clear; the escalating interest in this technology is very real and the – potential of blockchain is revolutionizing.

Environmental Enforcement Through Drones

Ship emissions can be hard to monitor and existing sampling technologies can be very costly to deploy. Consequently, adherence to environmental regulations in many instances is left to the vessel owners. As cities are more actively trying to enforce air and water quality standards, they are looking for better and more cost effective ways to do it. One solution that is increasingly expected to become a standard procedure in the coming years is data-collecting drones. By using smart, self-guided drones programmed to intelligently seek out the ships at sea, sample the plumes via onboard sensors, and transmit the compliance results back in real-time, drones can collect the data in a safe and low cost manner.

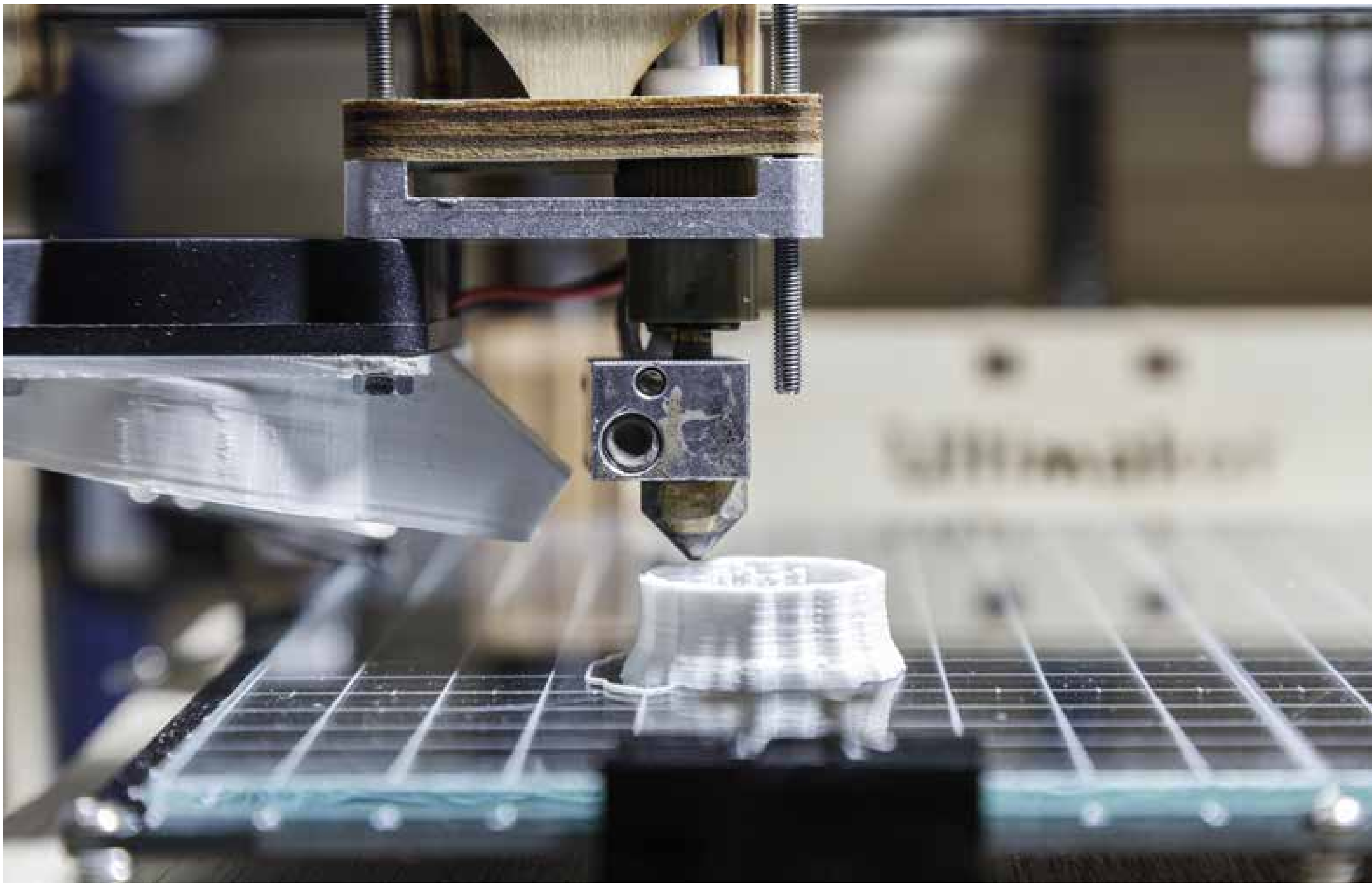
South Africa's busiest commercial port, the Port of Durban, has already embraced the new technology by using drones as a data acquisition tool for several purposes. The port receives real-time information on ship movements, and the port has further plans to use drones' detailed aerial view to improve operations. For instance the port will use drones to decrease the time it takes to manage incident reporting, deliver packages to vessels, monitor road network congestion on the roads leading to the port area and conducting hull inspections. All this can be done quickly, safely and cheaply – and most importantly without interrupting port operations.

3D Printing – Is it a Game Changer for the Shipping Industry?

3D printing – also known as additive manufacturing – is an example of a data-based technology that could re-shape the role ports play in our future economies. 3D printing is booming, and the International Data Corporation, a US based market research company, expects the sector's global sales to increase by 30% annually between 2016 and 2019. It is not difficult to understand why: 3D printing allows you to print what you want, when you want, and most importantly in respect of the port industry, where you want it. In other words, you move production of the items to where they are actually needed, potentially reducing the need for transporting goods, particularly low-value goods, across oceans and through vast logistic chains.

A Changing Role for Ports

If 3D printers do find their way into our industries and offices, and at such a scale that global shipping is affected, then ports and their respective cities may need to reposition themselves as points of advanced manufacturing. Ports will certainly not be starting from scratch, as many port areas are already home to vast amounts of industry and production. Port based manufacturing benefits from being co-located where both raw materials and other finished goods arrive and where they



depart through local transport networks. A leap in 3D printing would require a massive increase in demand of raw printing materials and the volume of such materials could potentially equal or even exceed the potential decrease in shipping of finished goods. The co-location benefits for manufacturing at ports could also mean that port areas become the location for large-scale printing facilities.

Vessels as Mini-factories

Today when a shipping vessel needs a repair en-route, it will most likely dock at a port and new parts will be purchased and repairs made, but time will have been lost and costs incurred. However, should onboard 3D printing become a standard then spare parts could be produced and possibly installed without needing to dock. This could mean lost business for dock-based repair companies, but could reduce transport costs for shipping companies.

This "mini-factory" advantage would likewise be available to terminal operators and port authorities. As terminal vessels often have a long lifespan, 3D printing could make it possible to quickly and economically produce spare parts that are seldom required. A reduction in storage and repairing facilities could free up space in the port for new initiatives or regeneration.

Terminal Operations

Terminal operators today need to off-load ever larger shipping vessels, reduce throughput times and manage landside logistics. Terminal operators are relying on technology to meet these challenges.

Cranes off-loading containers from ships, transporting containers to the appropriate warehouse, scanning the containers, certifying cargo - all of these activities take place within the dock yards and transfer areas. These technologies are of critical importance to terminal operators as they increase throughput, reduce the cost per container handled and reduce the amount of time required for moving goods into and out of the terminal.

From the city and port authorities perspective these technologies can boost transparency of cargo and potentially help to simplify the tasks required for customs clearance.

Larger Throughput with Automated Crane Solutions

How to increase speed and throughput is a key aim for all terminal operators particularly as shipping vessels have become significantly larger, in excess of 20,000 TEU per vessel. The surge in volume means that maintaining a high-speed for port throughput is a challenge. Ship-to-shore (STS) cranes are the type of crane that is used to on and off-load containers from a shipping vessel and are a key element in a terminal operator's ability to maintain fast throughput speed.

There are multiple design options for STS cranes and some of the most important elements include; sway control, truck positioning guidance, remote control systems and remote operations monitoring. The sway control allows for semi-automated movement and it automatically adjusts the sway and skew and can adapt to heavy wind speeds. Truck positioning guidance ensures that the truck driver positions the truck exactly where the hoist system can drop-off or pick-up a container without losing valuable time to re-position. Remote management systems can also monitor crane functions and predict maintenance needs. These options have the additional benefits of reducing energy use as they minimize crane movements, and the remote nature of operations also improves terminal site safety. This fuel-saving technology is also available for STS cranes in ports where the grid supply is not reliable enough and diesel power is required.

Siemens hybrid diesel-electric Rubber Tired Gantry cranes (RTG) have demonstrated in field tests that operators can save more than 50% of fuel use compared to a standard diesel electric RTG. If the terminal decides for the option to integrate ultra-capacitors, savings of up to 70% are possible.

Many, but not all, operational cranes are powered by grid electricity. On an STS crane the hoisting and trolley travel motions are constantly accelerating and decelerating and are energy intensive. It is possible to minimize energy use by eliminating unneeded crane movements, and running at optimum motion paths. The crane auxiliary systems are constantly running and highly energy efficient motors for fans and hydraulic pumps are available to further reduce energy use.

Automation: Moving 19/20 Containers without involving a person

The Port of Singapore is leading the world in automation of its operation. Singapore's Pasir Panjang Terminal 5 has recently installed 56 fully automated rail-mounted gantry cranes. The cranes have the capability to stack containers 6 high and 10 wide, while operators watch from a centralized control room. Each operator is responsible for up to five cranes. These cranes can move more than 30 containers per hour, boosting productivity by more than 10%. The boost in productivity comes with the additional benefit of improved safety.

These cranes are fully automated using chassis alignment, stack profiling, auto landing and container number recognition sub-systems. These technologies manage skew, sway and various ship profiles, and combining all of these capabilities through digital automation means very simply that up to 95% of containers go through the unloading and sorting without involving an actual person.

Automated Container Handling and Scanning

Almost 90% of the total cargo volume today is containerized , and container management is fundamental in the operation of a port – not only in terms of throughput, but also in terms of security. Designed for non-destructive testing and use in scanning devices for cargo and vessels in the security sector, the SILAC® scanner system linear accelerator system has been developed. Allowing maximum efficiency and flexibility, the scanner can be set-up to be stationary or mobile, depending upon the needs of the port and truck configuration.

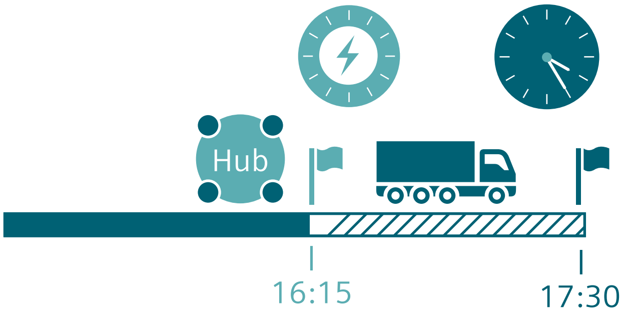
Container Handling Set for Growth in Sines, Portugal

Port of Sines is the largest port for general freight and containers on the Atlantic coast of the Iberian Peninsula. Siemens Integrated Drive Systems have been tailored the port's specific needs and the port has minimized equipment downtime and increased overall productivity. As a result, the Port of Sines ended third quarter of 2014 with a significant increase in the containerized cargo segment, totalling 926,531 TEU, which is a growth rate of 34% for the same period in 2013, and ultimately led to breaking the one million TEU barrier in October 2015. The port is now saving 2,070,600 kWh every year – and 1,200 tons CO_2 – by having invested in the modernization of its automation and drive technology as well as its ship-to-shore cranes.

Integrated Systems – Truck location details are combined with real-time traffic information.

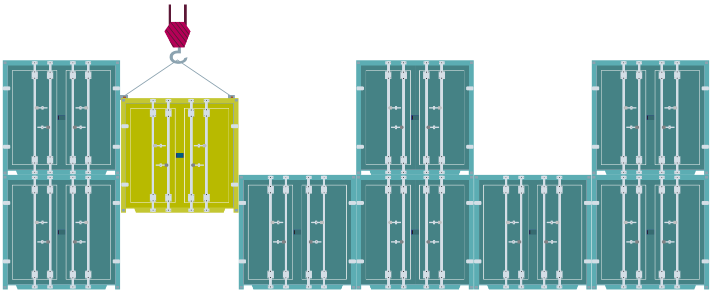
Drivers, logistics providers and terminal operators know at a glance whether the planned times of arrival match up.

If delays occur, the logistics provider and terminal operators are automatically informed, and the truck driver receives information on the app on suitable nearby parking until they are assigned to continue.

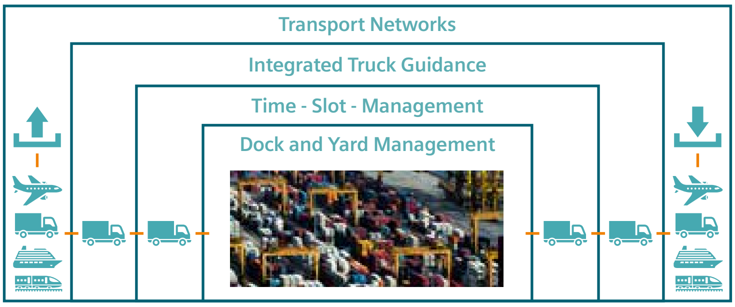


Warehouse IT – Warehouse IT gives operators constantly updated inventories, order and status information that can help them to meet delivery dates and shorten throughput times. Based on efficient processes and a high degree of automation, warehouse operators can reduce capital lock-up, increase order quality and optimize personnel and operating costs.

Block Management System (BMS) – BMS is an automated container management software solution that reduces the standby time of cranes, optimizes crane and vehicle movement sequences, reduces power consumption and provides feedback on operational key performance indicators.



Dock and Yard Management – Intelligent software and IT platforms are changing how port yards and transfer areas are operated. Information about incoming and outgoing freight and tracking the progress of shipments is possible. Dock yard software coupled with increasing automation means that logistics bottlenecks are avoided and processing times reduced. Material flows are mapped and optimized with Cargo Compact controls.



Landside Transport

Landside transport is the most connected area of port operations and city management. Cities must be able to provide congestion free port access and port operators must be ensure that port vehicles are not clogging city roads and worsening air quality – technology is playing a key role in helping both ports and cities manage transport.

Managing landside transport logistics is the responsibility of the terminal operators, freight forwarders, port authority and ultimately the city with oversight over local transport. The number of very different stakeholders could create information bottlenecks as well as real city congestion. Digital technologies are creating the opportunity to share data and ensure the timely arrival and departure of freight landside vehicles.

How these landside vehicles are powered and their route taken are becoming very important to city and port authorities. There are efforts now to reduce the impact on air quality through the electrification of landside transport and through the use of cleaner fuels and vehicles to reduce the Diesel Particulate Matter (DPM).

Minimized Congestion with Intelligent Traffic Control and Guidance

A lack of transparency about real time traffic information on the roads can result in long waiting times for trucks, causing unnecessary pollution in the city. An integrated and intelligent approach to urban traffic management and truck guidance allows optimized process flow for vehicles approaching, leaving and moving within the port.

'A traffic jam caused by trucks on an access road can be enough to bring an entire port's logistics to a stop.'[29]

Handling Growing Traffic Volume in Duisburg, Germany:

With 1400 ha of logistics area, 8 container terminals and annual handling of 3.6 million TEU, Duisport is the world's largest in-land port. More than 120 million metric tons of goods are handled there every year, and this figure is rising. But the growth in port throughput has also resulted in increased traffic volume. With an aim to minimize congestion Duisport and Siemens partnered to optimize the movements of cargo vehicles in and around the port. The result is a comprehensive "Integrated Truck Guidance" system, which shares for instance the estimated time of arrival of the trucks in real-time to all relevant stakeholders and directs heavy vehicles within a range of about 20 km from the highways and main roads to the port as quickly as possible. The truck guidance system is currently installed at Logport I, a logistics area of 265 ha within the port, and if it proves successful it will be expanded to cover the entire port area.

The following highlights the digital transport technologies that are positively impacting landside logistics

Parking Guidance – When the truck arrives in port, parking guidance systems use dynamic signs to guide drivers to available parking slots or designated areas. The guidance system utilizes truck loading and departure times to optimize the timing and reduce waiting time and congestion.

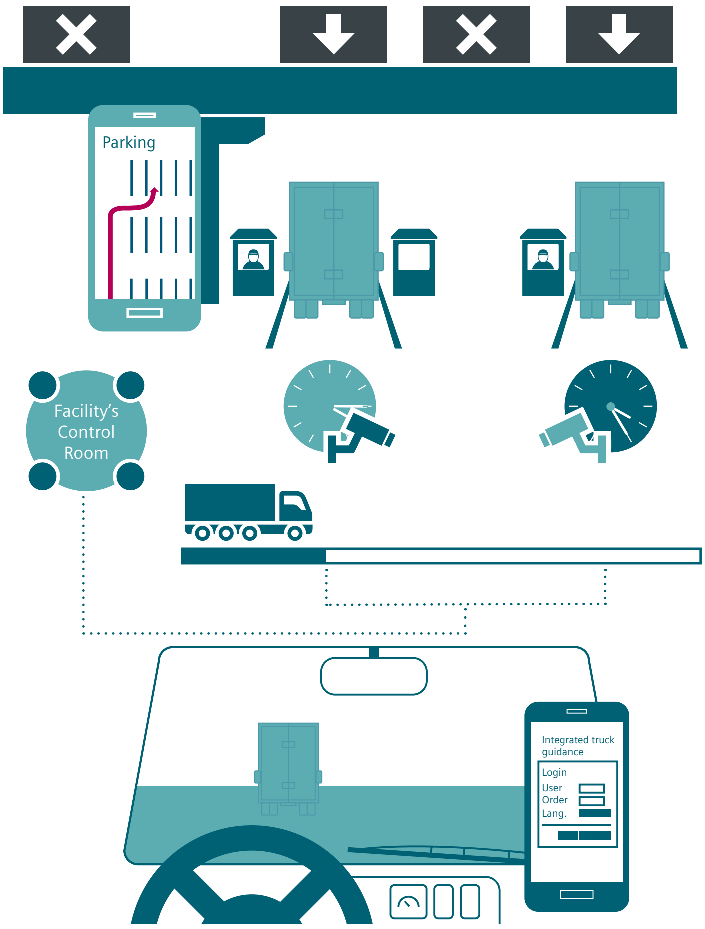
With this intelligent guidance system, less parking space is needed – space that can be used for other port purposes.

Intelligent Traffic Control – Cameras are set up at defined points to detect travel times. All information is collected at the central level. The collected information is anonymized and forwarded to the facility's control room.

Effective and flexible Urban Traffic Control can be programmed to cut trucks and vehicles' waiting times at intersections to zero.

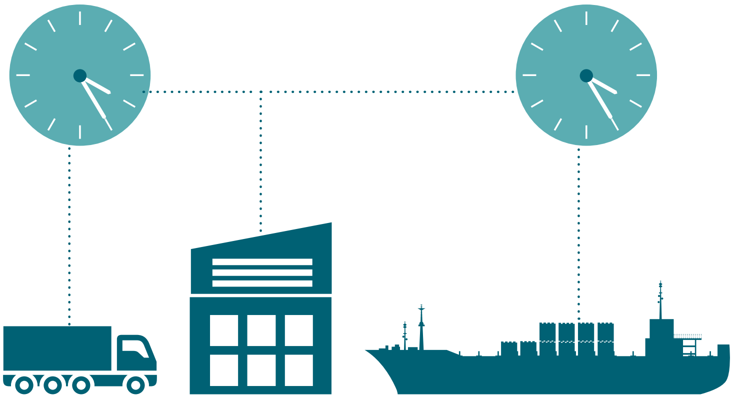
Individual Truck Guidance – Truck drivers are provided with a smart phone app into which they log their crucial trip details and a GPS determines their position on the road network.

LED displays keep the truck drivers informed of travel times via the app. Trucks can be guided around busy areas to prevent congestion and increase road safety in the city.

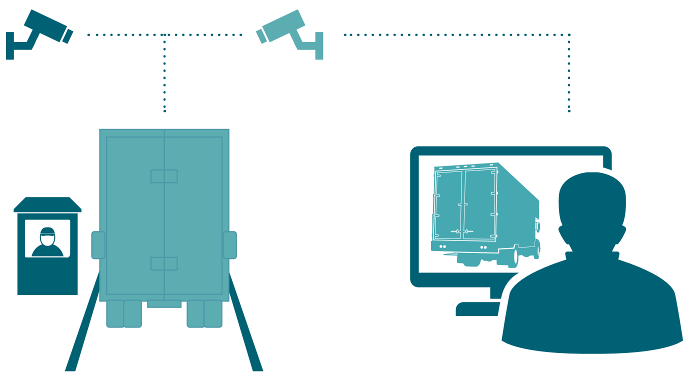


Transport Management – Easy collaboration between all participants involved at big ports for the delivery or pick up of shipments via one central platform.

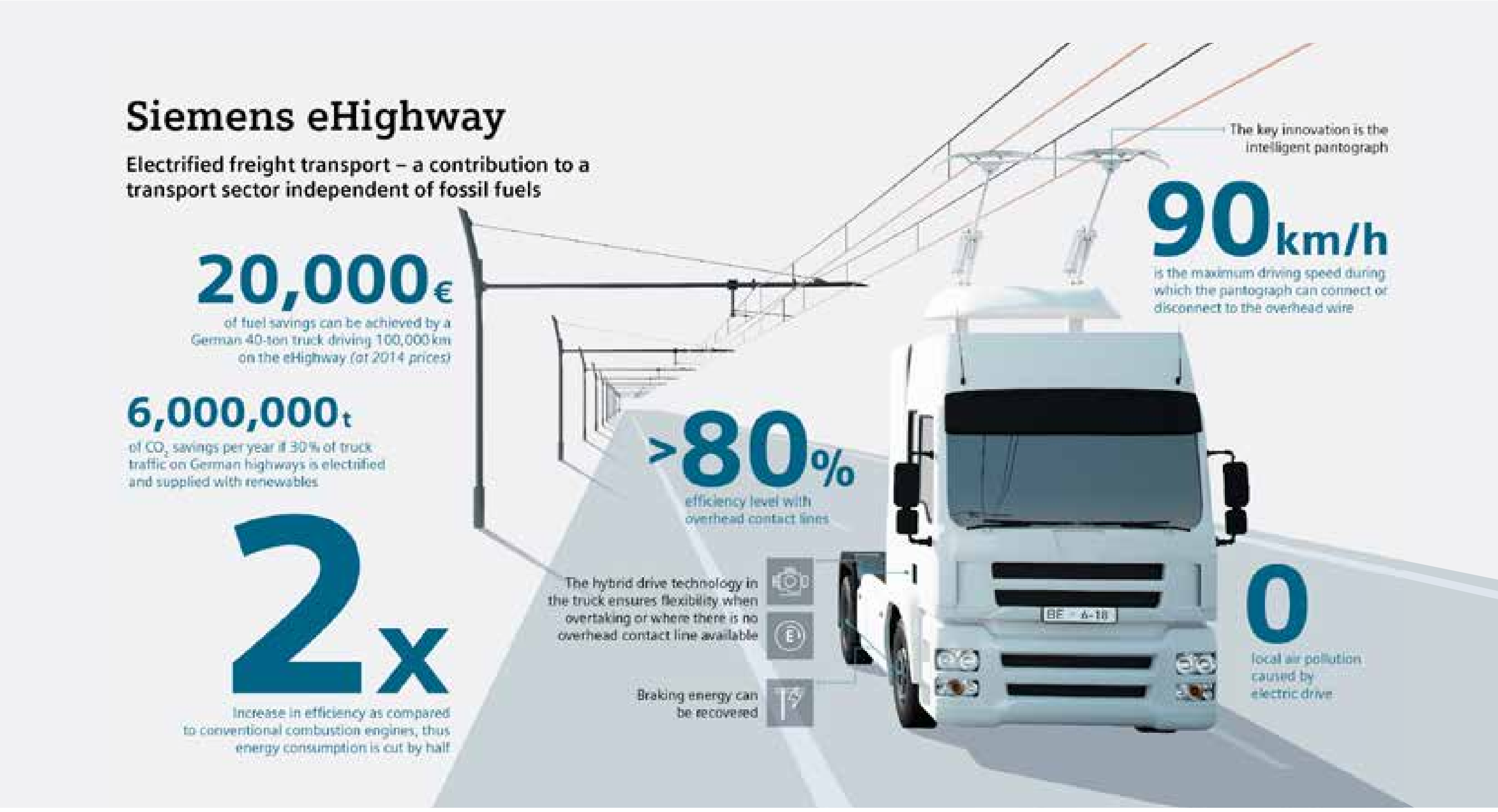
For the port this platform offers a transparent view along the entire supply chain, on all incoming shipments and across forwarders. Status information is available at any time at the push of a button and allows for seamless cooperation and more efficient planning at the port. This ends up in reliable and fast transshipment processes even in case of tightly clocked time slots.



Gate Automation – Integrated gate operation systems consisting of intelligent video detection and either Radio Frequency Identification (RFID) cards or biometry scanners, can speed up gate handling times, improve the certainty of arrival times, improve security and reduce port congestion. Conventional systems today mean that drivers have to leave their trucks and sign-in, with technology both the truck, through license plate recognition, and the driver, through a biometric scanner or RFID card, are identified and compared against an approved 'white list' and given entry without the driver ever leaving the truck.



eHighway reduces air pollution by using overhead lines to deliver electricity directly into the hybrid-drive trucks, enabling the trucks to cut energy consumption in half.



Electrifying Hinterland Connections – eHighway

Electrification of hinterland road transport through an electric highway (eHighway) solution complete with truck guidance technologies allows just in time freight delivery and pick-up through a low emissions system. The eHighway eliminates local air pollution and offers economic benefits in terms of fuel savings, longer life and less required maintenance while keeping the same high performance. Thanks to the high energy efficiency of the solution, it is possible to finance the system investment with the operational savings.

The core of the eHighway solution is an intelligent pantograph – that enables the truck to connect and disconnect to the power cables – combined with a hybrid drive system to keep the truck flexible, for example when overtaking. This means that the trucks can begin their journey in fully electric, battery mode within the port. When the trucks exit the port they can seamlessly join via the contact lines. When the trucks reach the end of the eHighway cable, they can revert back into hybrid mode and complete their journey. The eHighway also makes it possible to regenerate electricity and store it on-board or feed other trucks on the system, thanks to long sections of contact lines. In June 2016, the world's first eHighway opened in Sweden north of Stockholm. Not only is energy consumption now cut by 50%, but also local air pollution is reduced.

eHighway Demonstration Project, California

The eHighway is currently being installed along the roads leading to and from the port of Los Angeles and Long Beach, California, USA. These are two of the busiest ports in the US, and more than 40% of all goods being shipped to the US enter through these two ports. Off-loading this level of goods and transporting them across the US, means that 35,000 trucks enter and leave the port each day. Successful delivery and use of the eHighway could mean a significant reduction in air emissions and noise, both at the port and along the main route into and out of the port.

Port Energy

How and where ports generate their energy affects local air quality and port resilience. The trend today is to electrify port infrastructure, and leading ports are installing electric power for docking vessels.

Ports are large users of energy, including electricity and diesel fuel. There is a growing trend towards electrification across port infrastructure as it creates the path towards higher degrees of automation, improves efficiency, reduces cost and reduces air pollution from diesel fuels.

Energy across ports includes everything from the diesel and electricity required to power shipping vessels at sea and while docked at the port, the power required for cranes and terminal vehicles, terminal buildings and countless other port energy users. The technology advancements linked to the electrification of ports are of particular importance because of their connection to automation and the follow-on benefits of increased throughput.

Electrification of ports means that more electricity is required to fill the gap left from reductions in diesel use. However, this gap is not a 1 to 1 ratio. Electrification of technology usually improves efficiency so in overall terms, electrification is typically an energy reduction measure. The amount of electricity required to power shipping vessels while docking or to re-charge eFerries and other boat transport will result in an increased demand for electricity. This increased electricity demand may or may not be met by the local grid, but chances are that substations would need to be upgraded and more generation would be required.

Generation and increased use of electricity will require energy management systems and an agile power infrastructure. The energy system should be considered in its entirety, resilience can be built through decentralized networks and Totally Integrated Power – systems thinking and technologies should be considered to ensure that data and technology is linked and that the result is cost effective, flexible, resilient and guaranteed.

Distributed Energy Systems in Ports

Ports will be needing more electricity, and in some ports power constraints are limiting growth. Fluctuating and rising electricity prices also make it difficult for port owners to gauge the business case for electrification. Delivering emissions reductions at ports and unlocking further growth potential requires a new understanding of how port power is used and generated. Today, this is likely to mean that ports, with the support of the city, develop a Distributed Energy System (DES) that integrates on-site electricity generation, energy efficiency upgrades, energy storage and grid management technologies.

Distributed Energy Systems (DES) is a term which encompasses a diverse array of generation, storage and energy monitoring and control solutions. The concept is that electricity and heat can be generated and managed within a smaller system, similar to a microgrid, and limit the number of local grid connections. A DES system can be tailored to the very specific needs of a port, and it has the added flexibility of being a modular system that could be used to provide only incremental additional power or to efficiently and economically deliver all of the port's energy needs.

Many ports have grown over a long period of time and DES at a port requires first an understanding of the power demand today, and second, how much more electricity will be needed in the future to meet stricter air quality measures. Within a DES system, electricity can be generated in a modular plan fitting the port's exact energy requirements and energy could be sourced from renewable or fossil based sources. Storage and grid management technologies can be added to manage demand and balance loads, and a microgrid is incrementally built. For the port or terminal owners, fully financed solutions

are available that are repaid either through energy savings with no upfront costs through lifecycle contracts or Power Purchase Agreements.

DES solutions can be applied to all energy users, including ports, and operational cost and carbon emissions reductions can be measured in large fractions, up to 30%, with a return on investment (ROI) between 3-7 years compared to a business as usual. If ports and cities are aiming to boost productivity and reduce local emissions, then rethinking energy at the port is a critical first step.

Your Challenges

Rising Energy costs

Secure and resilient energy supply

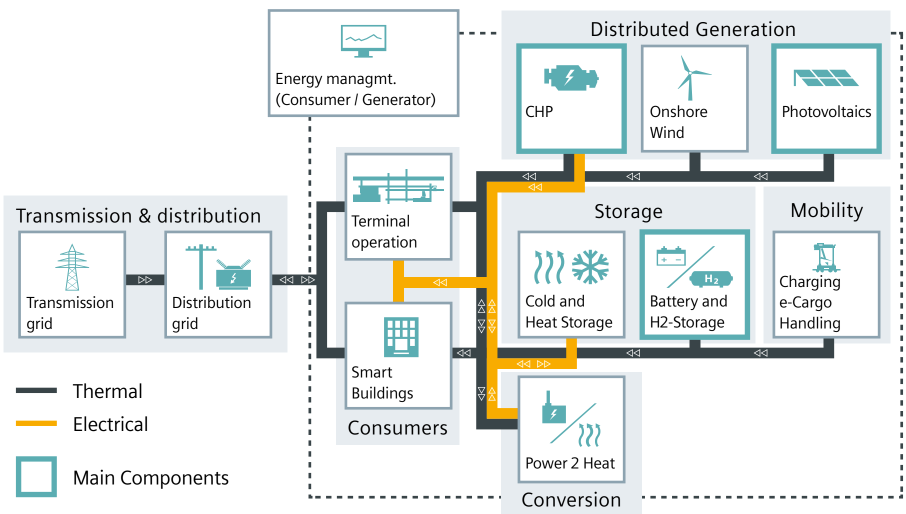
CO_2-saving, environ-mental requirements

Modern communication and innovation

Maintaining/ strengthening of market position

Business models for changing Business environment

Tailored solution for your long-term success



Renewable Energy in Ports: Generating Clean Energy

Ports can integrate renewable generation into its on-site infrastructure.

Wind Power

A good example of renewable integration in a port can be seen in the Port of Antwerp in Belgium. The port has 11 Siemens wind turbines each producing 3 MW of power and all of the generated power is being integrated within the port grid. The Port of Rotterdam has installed wind turbines in the port area with a total capacity of 200 MW. In its Port Vision, the Port Authority has committed itself to 300 MW installed wind energy in the port by 2020.

Solar Power

Large-scale solar power can be integrated within ports in several ways through installation on rooftops, construction of canopies over employee parking spaces or refrigerated container parking stalls and through installation on the surface areas of cranes. In June 2016, 9.5 MW of solar power capacity was successfully installed in Jurong Port, in Singapore, making it the world's largest port-based solar power facility. With an annual generation capability of 12 million kWh, the solar panels will offset more than 60% of Jurong Port's electricity demand, saving 5,200 tonnes CO_2 annually.[26] More recently, the Ministry of Shipping in India has announced its plan to install 82.64 MW solar plants in India's 12 major ports as a part of its Green Port Initiative.[27 28]

Recently, the Port of Los Angeles, announced plans to install a $26.6 million solar Microgrid. The holistic approach will also include energy efficiency upgrades, zero emission cargo handling equipment and vehicles, charging infrastructure, and a dockside vessel emissions treatment system.

Solar power rooftop installations are also possible and effective even in very northern and southern locations. Stockholm's Hamnar has installed solar power on rooftops in three of their ports, not only to cover their own energy needs, but also to demonstrate that they are a progressive and positive contributor to the city development.

Extracting Green Energy from Ocean Waves

Energy generation from waves has great potential to become an important global power source, supporting the transition towards clean, renewable energy. Ports and coastal cities have an opportunity to most directly benefit from this technology by allowing their construction within local waters. This so-called Siemens HydroAir solution is a single floating Power Take Off unit consisting of a turbine, generator and variable frequency drive, and it generates electricity from the breakwater areas where waves are high and powerful enough to push air through a void. The entered air will activate an impulse air

turbine, which then generates the electricity. Such powerful waves can be found in many places and has the potential for global application.

The marine sector's great opportunities arises as Siemens HydroAir can supply onshore power requirements by either drawing a power cable to land from an offshore platform, or by being part of the harbor breakwater, away from the shipping lanes. With a minimum installation time and flexible location either onshore, near-shore or offshore, Siemens HydroAir offers a variety of options for ports and ships to supplement their existing energy mixes, while simultaneously cutting emissions.

Each unit can currently generate up to 1MW, but the potential is not limited as multiple units can be installed in parallel increasing the end MW output. A pilot project in Hawaii is already initiated and a development group in Vietnam is currently looking into installing multiple units into a new breakwater.

Liquefied Natural Gas as Alternative Ship Fuel

Over the long term ports and vessels will run solely on electricity generated from renewable sources. However, before getting there, another alternative to traditional oil and gas has proved itself valuable when it comes to reducing air pollution: Liquefied natural gas (LNG). Natural gas in liquid form has a much lower volume than natural gas itself; an attractive attribute when carried and used at sea. The advantage of using LNG as a propulsion fuel is its reduction of dangerous emissions: Using LNG almost eliminates SOx emissions, and NOx and CO_2 emissions are reduced with up to 85% and 25% retrospectively compared to traditional diesel fuel.

Creating LNG locally in port

While many of the larger European ports have LNG-facilities for trucking and shipping, many smaller or isolated ports do not have the same capability. In more remote areas where they may not have LNG facilities, but they do have a source of natural gas, it is now possible for the port to create LNG itself instead of importing it to the region. By using a Siemens LNGo™ natural gas liquefaction system, local markets can take advantage of local resources and eliminate the need for costly transportation of LNG. Capable of producing up to 48 tons of LNG per day, the compact micro-scale LNG production plant can thus be a very cost effective and cleaner solution than traditional fossil fuels.

On-shore Power Supply for Clean Air

One of the major contributors to local air pollution is the combustion of fossil fuels for generating electricity while vessels are docked at a terminal. The emissions of a berthed cruise liner can be compared to the environmental pollution of a medium-sized city. With the on-shore SIHARBOR solution, berthed ships can draw the needed energy from the on-shore power grid on a fast and flexible connection to the ship via a cable handling system, the SIPLINK converter system. The converter system makes the connection possible by adapting the grid frequency from 50 Hz to the standard on-board frequency of 60 Hz. On-shore power supply can be used for lighting, heating, pumps, refrigeration and unloading.

A standard solution for on-shore power supply is established, and it can be installed at any port and supply all types of vessels, including cruise liners or container ships and ferries.

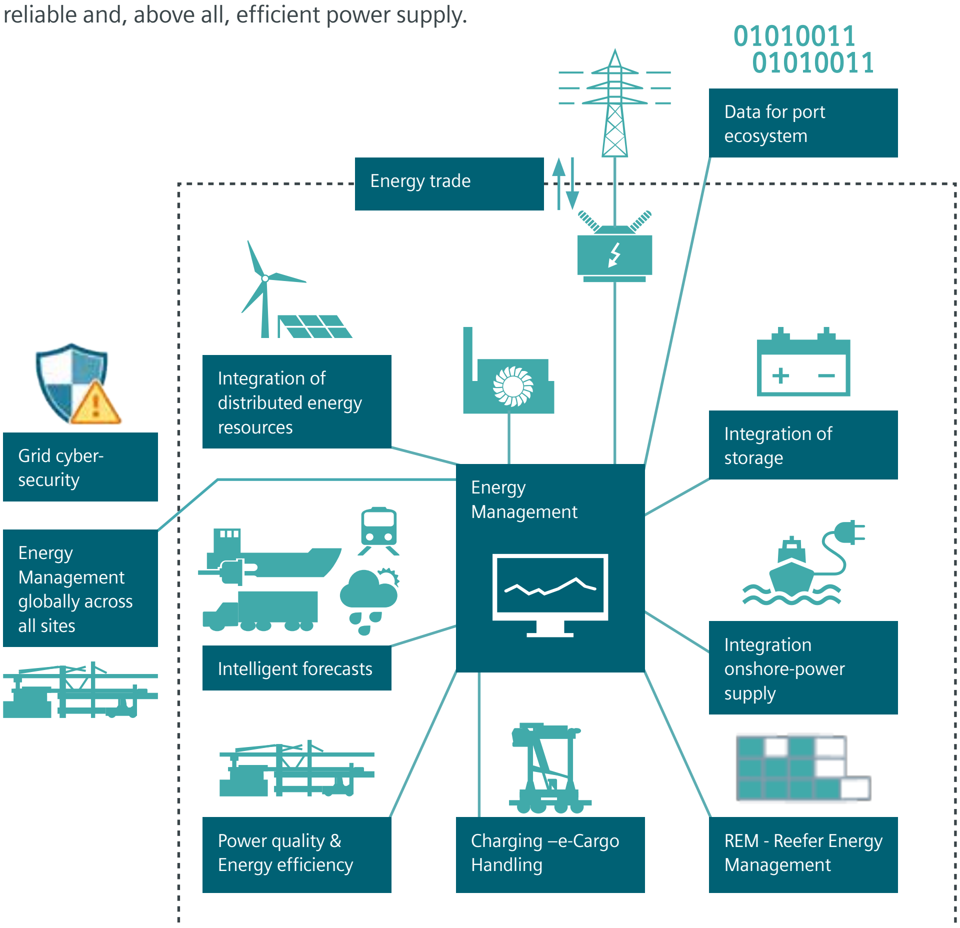
'The emissions of a berthed cruise liner can be compared to the environmental pollution of a medium-sized city'[30]

Totally Integrated Power – Delivering at ports

Energy solutions for ports go beyond just on-shore power supply for ships. Ports can maximize reliability and efficiency of their energy supply for the entire port infrastructure. With an approach of seeing all power distribution components as an integrated entity, Siemens Totally Integrated Power (TIP) concept can provide ports with a secure, intelligently planned, reliable and, above all, efficient power supply.

Reliable and Safe Power Supply – Seaport Nacala, Mozambique

One of the most recent facilities to adopt the Totally Integrated Power concept is the new port of Nacala-a-Velha in Mozambique. The port uses the TIP concept to create a more reliable power supply. Siemens has delivered and installed the seaport's power generation network, inclusive of high-voltage components, and power distribution solutions. It's low and medium voltage systems in prefabricated power distribution units known as e-Houses have also been installed.



Benefits

Transparency

- Internal billing
- Systematic efficiency improvements
- (Predictive) Asset Management

Optimized energy mix

- Integration of own, distributed generation
- In combination with energy purchase strategy and storage

Flexibility for increasing electrification

- Flexible integration of new power demand
- e-mobility of cargo handling
- Intelligent reefer energy management

Optimized Power Quality

- Load Management
- Optimal voltage & frequency conditions for operation

Reduction of CO_2-emissions

- Systematic energy efficiency
- Towards zero emissions operations

On-shore Power Supply for Greener Harbour in Hamburg, Germany:

The Port of Hamburg is situated in the middle of the city with nearby residential areas. The port has an hourly fuel consumption of 1.2 metric tons – even when operating in port. Installed with Siemens' shore connection system SIHARBOR, the Port of Hamburg has been the first in Europe to operate with the land connection system autonomously. Hamburg now benefits from:

- Improved air quality – zero local emissions and overall reductions in CO_2, SOx, NOx, emissions, particulate matter and fine dust.
- Less noise and vibrations in the neighborhood.
- A reliable and secure energy supply for ships.
- Saved fuel and energy costs during generator tests.
- Creates a positive environmental image for the port.

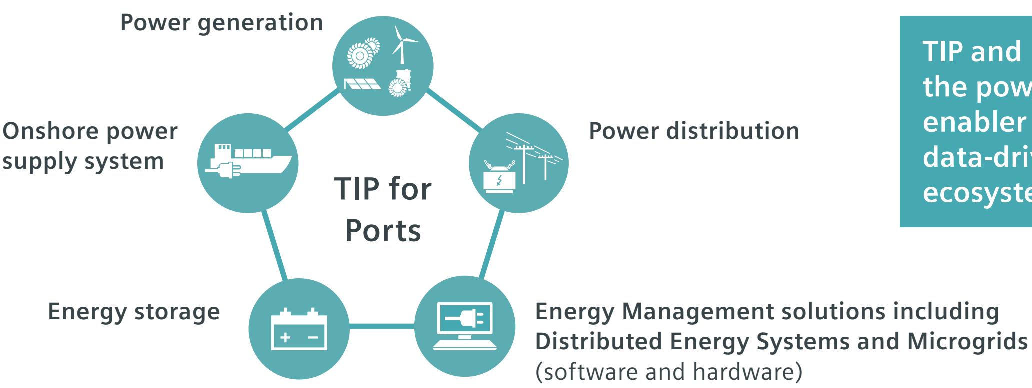
On-shore Power Supply in Norwegian Ports:

In 2016, Siemens conducted a study of the financial and environmental outcomes of connecting ships to on-shore power in the 28 largest cargo ports and 10 largest cruise terminals in Norway. The study found that in Norway:

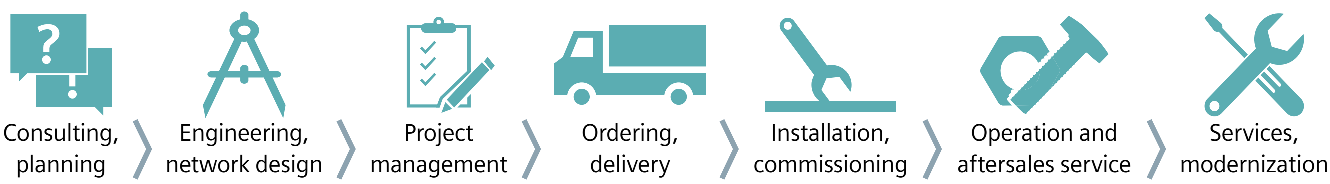
- NOx and SOx emissions can be reduced by 7,000 and 23 tons respectively in a year – equivalent to 58% and 107% of passenger cars emissions respectively.
- CO_2 emissions can be reduced by 365,000 tons in a year – equivalent to 5% of passenger cars emissions.
- Particulate matter can be reduced by 678 tons in a year – equivalent to 98% of passenger cars emissions.

There is a cost to implement on-shore power in terminals; however, this study concluded that the costs saved in energy and maintenance exceeded the investment over the calculation period. Given the high proportion of renewable energy in Norway's electricity mix, this type of technology makes environmental and economic sense.

Totally Integrated Power (TIP)



TIP and Metering are the power supply enabler for a data-driven ecosystem



The world's first electric ferry entered service in Norway in early 2015. With a capacity of 360 passengers and 120 cars, it is free of emissions.

Electrification of Vessels and Ferries

Today's leading technologies are now making it possible for ocean going vessels to go electric. In these ships, the diesel engines are replaced with large battery packs that function as electric propulsion while in motion. The batteries can be recharged directly from the grid when off-loading, thus saving vast amounts of fuel and reducing turnaround times.

The pure battery-powered solution is suited for ferries and smaller vessels travelling relatively short distances. The solution can even be used for fishing vessels. For longer routes, a higher capacity is needed, and a hybrid solution is more suitable. Hybrid solutions use a combination of battery power and a diesel-driven propulsion system and engines can be set to optimal speeds and should the ferry be moving slower than the optimal speed excess energy can be stored within batteries for later use. In a Siemens project in Denmark, the hybrid solution has proved its worth by reducing the ferry's fuel demand, which has lead to a 15% reduction in carbon emissions.

'Transport is the only major sector in the EU where greenhouse gas emissions are still rising[24]. Road transport contributes about one-fifth of the EU's total emissions of CO_2.'

Building Automation

Ports also have numerous buildings and warehouses, buildings within Europe account for 41% of primary energy and there are many options to reduce consumption through building automation, ventilation and lighting technologies. Lighting is vital in all port areas for protecting people and assets in buildings and stacking areas, and it is also a big energy consumer. Fortunately, it is also one of the areas where energy consumption can most easily be reduced. Thanks to automated lighting control, the system can switch luminaries automatically on whenever there is presence detected in the area. It can also optimize the balance between natural and artificial light by always ensuring that there is sufficient lighting using the least amount of energy required.

The World's First Electric Car Ferry

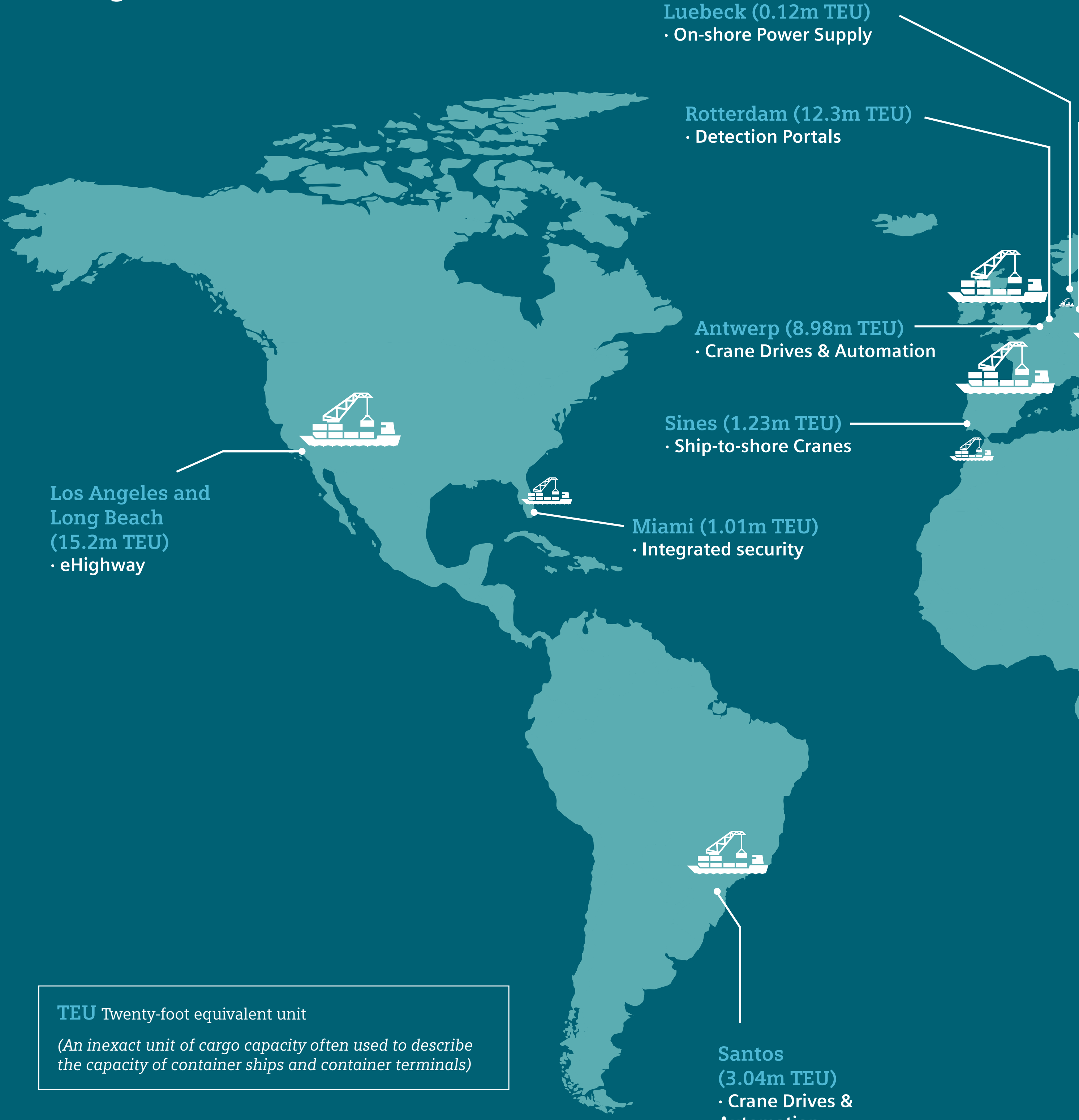
In Norway, the world's first fully electric car ferry has been in operation since May 2015. It has now travelled the equivalent of 1.5 times around equator with batteries instead of traditional diesel propulsion. The batteries are quickly recharged when dropping off passengers in dock, and they are powered by renewable energy, namely hydro power. In this way, the ferry does not emit any CO_2 and around 1 million liters of diesel fuel from the conventional ferry is saved every year. On this route, the Norwegian ship owner has reduced its fuel costs by 60%, and the eFerry has delivered significant savings in CO_2 emissions as well as operational costs.

Self-healing Grid in the Port of Rotterdam, Netherlands

In Rotterdam, the network operator received the concession to supply electricity to the port facilities only under the condition that the operator shoulders all the costs associated with a power failure. The costs involved amount to six-digit figures per hour. For that reason, the supplier automated the harbor electricity network to ensure that any fault is corrected within 20 seconds.

Port of Vancouver, Canada

Selected Siemens References in Major Global Ports



TEU Twenty-foot equivalent unit

(An inexact unit of cargo capacity often used to describe the capacity of container ships and container terminals)


Hamburg (9.73m TEU)
· Ship-to-shore cranes
· Marshalling Yard Technologies
· On-shore Power Supply
Helsinki (0.43m TEU)
· Traffic Management
Dubai (15.25m TEU)
· Ship-to-shore cranes
· Traffic Management
· Integrated Security
Dalian (10.13m TEU)
· Perimeter Surveillance
Shanghai (35.29m TEU)
· Building Management
· Security & Fire Detection
Shenzhen (24.03m TEU)
· Perimeter Surveillance
Nhava Sheva (4.47m TEU)
· Crane Drives & Automation
Pipavav (0.85m TEU)
· ECO Crane Drives & Automation
Chennai (1.47m TEU)
· Crane Drives & Automation
Nacala (0.08m TEU)
· Totally Integrated Power
Singapore (33.87m TEU)
· Automated Gantry Cranes
· Automated Container Handling

Source

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