DELIVERABLES 2.1.2 – 2.1.10 + D2.2.2: PILOT VERIFICATION

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Contributions of all Ports and knowledge Institutes within PECS

Report version
Wednesday, 23 October 2019

Table of Contents

DELIVERABLE 2.1.2: FEASIBILITY OF SMALL WIND TURBINES IN HELLEVOETSLUIS

Hellevoetsluis (support HZ)

Introduction to the three pilots in Hellevoetsluis

To make Hellevoetsluis ports carbon neutral, the potential of using renewable energy is researched. Based on the research unit and quality, this research is exploratory. Thus, it follows with research instruments of survey and interview for later analysis. Knowledge gained from it can be used to conduct a reasonable business case.

With the development of this research, ethical dilemmas like different facilities and the changes of energy are possible to have potential problems like personal benefit (job, salary), environmental dangers. For example, when it is necessary to build solar panels or wind turbine, it is important to protect the old city and nature at the same time.
The goal of this research is to conduct feasible business cases applied in Hellevoetsluis. These business cases are formulated to reduce energy costs, meanwhile to realize carbon savings through renewable energy exploitation in Hellevoetsluis. A way of achieving carbon saving in Hellevoetsluis is to investigate the feasibility of each renewable source. While the carbon footprint of all activities is measured first among the port, then carbon neutral goals can be set. In business cases, environment, technical challenge and financial issues including cost and benefit should be taken into consideration accordingly. While exploiting renewable sources, two harbours and a marina in Hellevoetsluis could achieve carbon neutrality at some extent, and the extent needs to be analysed and calculated during the research.
From searching information about general ports to focus on Hellevoetsluis, environmental trend will be learned during the process of research, there will be new views on renewable sources and it might be helpful in many fields.
At the first stage, the collected data mainly focus on several samples: solar energy, wind power, tidal power and wave energy. Devices of these renewable sources and energy parameters containing tidal range, installation length of wave devices and available area of solar panels installation are within the scope of this research. When these environmental concepts are introduced, desk research on techniques issues including solar plant, small wind turbine and battery storage are being conducted. The population of this research is data of all sub questions in Hellevoetsluis ports. Port officers and wind turbine researchers are selected as our interview object, relevant reports are chosen for our desk research. A comparison among each renewable source is required, and then the best option will be selected from the assessment.

For Hellevoetsluis three business cases/pilots are investigated, concerning application of:

1. Small wind turbines in Helius harbour, project deliverable 2.1.2.
2. Floating solar panels in Marina Cape Helius, project deliverable 2.1.3.

3. A BPS-storage in Veer habour, project deliverable 2.1.4.

The options were selected after a pre-feasibility study and site visit on March, 2018.
Given the very small tidal amplitude, (0,3 m), tidal energy was not considered further.

Small wind turbines Helius harbour

Helius harbour is situated most west in the port of hellevoetsluis.

Figure 2.1 Area of Helius harbor

Figure 2.1 shows the area of Haelius harbour. The main energy consumption is electricity which used to maintain the daily operation of three clubs at here. According to the potential of renewables, the most possible method to reduce carbon emission is to build some small wind turbines on the coast. The option to install solar panels on the roof of the sailing associations was abandoned in an early stage, due to proclaimed insufficient mechanical strength of the roofs. As discussed with port managers and client, solar panels are not allowed to be placed on the roof. In addition, the south shore will be occupied by six wind turbines and not enough space is available for solar panels.
The best option in this harbour is to take advantage of wind energy. Considered with noise factor, it is better to build small wind turbines with smaller blades.

Wind regime

Figure 2.2 describes wind speed in the next few months. Substantial wind power is available here as the highest wind speed will reach over 10kn and most of time it is around 6kn.

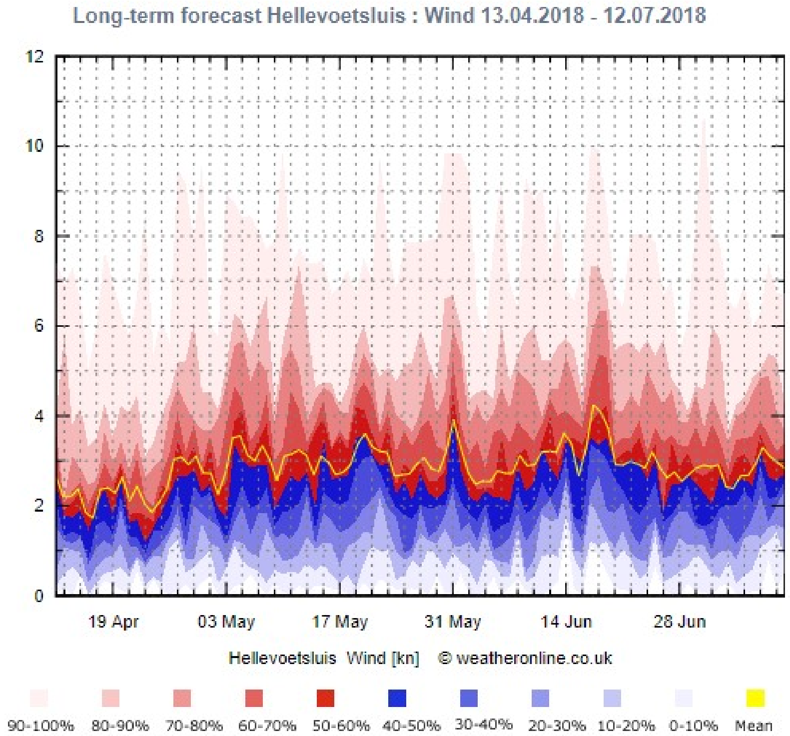

Figure 2.2 Hellevoetsluis Wind (Long-term forecast Hellevoetsluis Temperature 90 days)

Depending on the tendency and annual wind map attached in the appendix, future wind speed will normally range from 8 – 6 knots which is expected to be developed.

Wind turbines

from April in 2008 to December in 2012, 11 types of wind turbine have been tested based on their generated amount of energy, consumption and relevant parameters. Each type has their advantages and disadvantages, see table 10.1

Table 2.1 Available options of small wind turbines (Testveld Kleine WindTurbines Zeeland)

	Opbrengst in kWh								
	WRE 060	Skystream	Airdolphin	Swift	WRE 030	Energy Ball	Passaat	Montana	Turb
Totaal 1ste jaar	485	2109	393	191	404	73	578	2691	24
	WRE 060	Skystream	Airdolphin	Raum	WRE 030	Energy Ball	Passaat	Montana	Turb
Totaal 2de jaar	526	2171	406	633	612	65	660	2315	32
	WRE 060	Skystream	Airdolphin	DonQi	WRE 030	Energy Ball	Passaat	Montana	Turb

As for WRE 060, this Ropatec WindRotor is a vertically driven wind rotor which demonstrates special product characteristics through its unique construction. (Product Information Sheet) Comparing to WRE 060, some types like Skystream can reduce consumption from the grid by up to 400 kWh per month in a 12 mph wind. (skystream 3.7). In addition, other wind turbines have advantages of quiet or stability. Ampair motor is designed to be smooth running, quiet and vibration-free to the severest marine environments and all components are sealed to prevent corrosion. (Ampair Pacific 12Volt 100Watt Marine Wind Generator)

For urban application, small vertical wind turbines have advantaged:

1. Less susceptible for turbulence
2. Low noise production.

Noise production

As a result of 3 clubs in this harbour, noise is a big challenge for building wind turbines. Noise is absolutely undesired and controversial issue. However, it is common weakness of conventional wind turbine. Noise emanated from wind turbines comes from two main sources, the mechanical noise from the turbine's nacelle and the aerodynamic noise from the wind turbines blade. The dominant of these two sources is the blade of wind turbine, especially during the blade's downwards stroke during a rotation. (Casey, 2013)

Figure 2.3 How loud is a wind turbine? (Kellner, 2014)

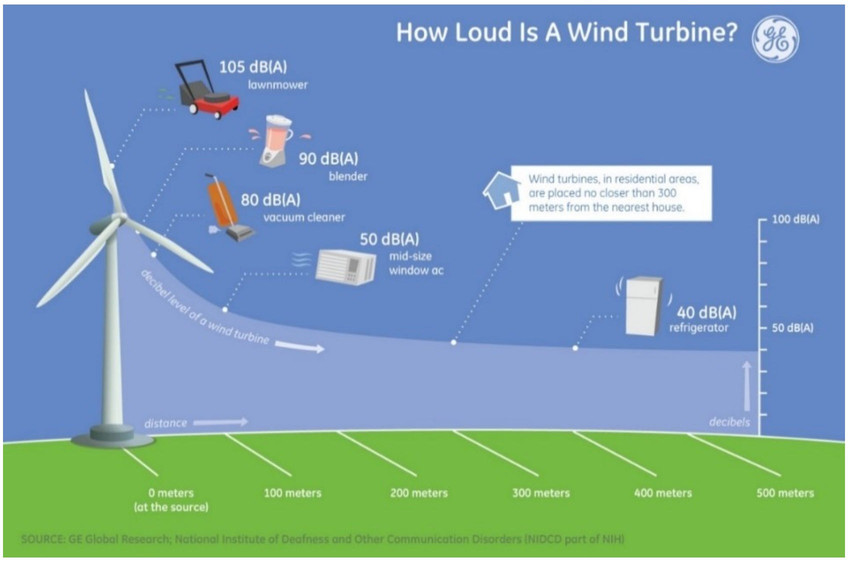

Figure 2.4 describes the relationship between the sound-power level of turbines and the rotor diameter. It turns out that while blades lengths increase, the potential for greater noise goes up. (HAYASHI, 2012)

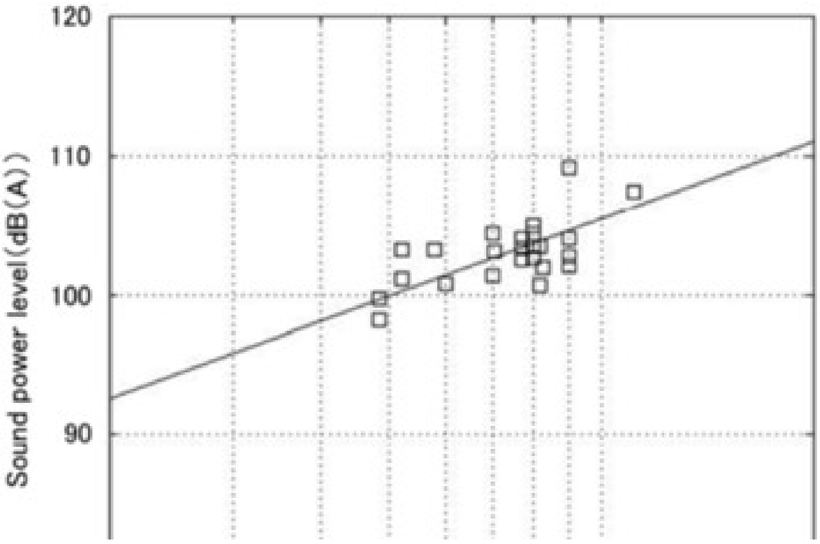

Figure 2.4 The relationship between the sound power level and the rotor diameter. (HAYASHI, 2012)

Based on research, a kind of small wind turbine with small blades that are able to produce less noise is available in recent years. To residents around the marina, it decreases the danger of suffering noise.

Energy consumption

The main energy consumption used to maintain the daily operation that includes supplying electricity for three clubs in Haelius harbour. In 2016, the electricity consumption is about 135882 kWh and gas consumption is about 20212 kWh.

Selection of the wind turbine

Some small wind turbines as follows:

Table 2.2 Test production of period (Testveld Kleine WindTurbines Zeeland)

	Test production of period (kWh)				
	WRE 060	Skystream	WRE 030	Swift	Ampair
Total 1st year	485	2109	404	191	245
Total 2nd year	526	2171	612	633	341
Total 3rd year	562	2271	649	317	358

According to table 2.2, it describes test production vary from the first year to the third year, Skystream generates more wind energy production than others. In addition, within these types, power production of Skystream wind turbines in each year is more stable than others relatively, fluctuating from 2109 kWh to 2217 kWh with maximum gap of 121kWh. Comparing to other type like Swift wind turbines, from 191kWh to 633 kWh with gap of 442 kWh, Skystream wind turbine has more superiorities. After all, steady production efficiency is an essential point to further operation.

Table 2.3 Consumption in kWh & Percentage (Testveld Kleine WindTurbines Zeeland)

	WRE 060		Skystream		Ampair	
	Consumption	Consumption/ Production	Consumption	Consumption/ Production	Consumption	Consumption/ Production
Total 1st year	7	1.40%	24	1.10%	15	6.10%
Total 2rd year	16	3%	27	1.20%	14	4.10%
Total 3rd year	13	2.30%	23	1.00%	10	2.70%

Because of calculation and record, although consumption of Skystream wind turbines to start up is more than other three types, the percentage (consumption/production) is the lowest except in the 2nd and 3rd year comparing to WRE 030. Table 2.4 shows that not only more production can be guaranteed by Skystream but also it consumes less relatively. Therefore, Skystream is regarded as the best choice for this project based on above mentioned.

Table 2.4 The description of skystream 3.7 (Skystream 3.7 windgenerator, 2018)

Weight	77 kg
Rotor diameter	3.72 m
Contour surface	10.87 m²
Type	Windward rotor with sta
Rotation sense	Point of change (looking
Wick material	Fiberglass reinforced cor
Number of blades	3
Tips speed	60 to 325 rpm
Estimated speed	9.7-63 m / s
Alternator	Brushless permanent ma
Yaw steering	Passive
Brake system	Electronic stall control
Start wind speed	3.5 m / s

The price of each small wind turbine is €5069.97. (Skystream 3.7 Wind Turbine 2.6KWp SOUTHWEST Land 230V 50Hz, 2018)

The Skystream 3.7 is the first small-scale wind turbine with the control system and the inverter is already installed as standard in the housing. This small windmill (rated power 1.8 kW) already produced useful energy at low wind speeds. In this way, residents and small businesses (a large part of them) can generate their own energy and reduce their electricity bill thoroughly. Based on analysis above, the Skystream 3.7 can be used for this harbour.

Legal

The wind turbines will be installed in Haelius harbor might cause associated legal issues. Firstly it is essential to ask for permission of the land owner to install these devices and prepare all relevant documents. In addition, the permission of government to implement the project is also necessary.

Business case

As table shows, there will be installed 6 Skystream 3.7 small wind turbines. They can produce 13251 kWh per year in total. Then it can save €1987.65 in electricity cost. The investment cost associated with implementation of 6 wind turbines is €30419.82, (Skystream 3.7 Wind Turbine 2.6KWp SOUTHWEST Land 230V 50Hz, 2018) annual operation cost is €3180.24. Therefore, assuming the pilot lifetime is 20 years, on average it will cost €4701.23 per year. Obviously, although it can save less carbon emission, it will cost a lot to apply these applications.

Table 2.5 Business case for wind turbines (HZ University of Applied Sciences, J. van Berkel., 2018)

Preliminairy viability check PECS pilots
Tool: Jacob van Berkel, HZ University of Applied Sciences
Data provided by: Skystream, Advitek energy systems

Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	Small wind turbines in Haelius harbour
Where is the system boundary (e.g. the perimeter of the harbour).	boundary is small wind turbine system(6 turbines) including connection to the electrical installation
What is the PECS pilot system?	pilot = specifically wind turbines in harbour
Reference electricity price [ct€/kWh]	**15.00**
Reference costs CO2-emission [€/tonne]	**incl**
Current system performance	
Electricity consumption in Kwh	135,882.00
Gas consumption in m3	20,212.00
Future system performance	
Electricity production 6 small wind turbines in Kwh	13251.00
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€]	30419.82
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/year]	3180.24
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	20 years
Annual Energy + CO2 benefit, expressed in €:	**1987.65**
Annual costs (simple), expressed in €:	4701.23
Reduction of CO2-emission of the system, after implementation of the pilot [%]	9.75

It turns out that small wind turbines program is not feasible to be conducted in Helius Harbour from a financial perspective. This project further adds the burden and expense of the port company instead of saving expenditure. Comparatively, the CO_2 reduction rate will reach 9.75%, but the cost of implement will be more expensive than current cost. It clarifies that wind energy is not suitable to be exploited in Haelius Harbour from financial perspective if only the port company will pay these costs.

Based on general situation, the reduction of CO2-emission is 0.36kg/Kwh (Bereken je CO2-uitstoot, 2018). The total energy saved from small wind turbines is 13251 kWh, so it means these small wind turbines can reduce 4770.36kg CO2-emission per year.

Conclusions

1. Depending on the long-term wind speed forecast and wind map, it is assured that wind energy can be exploited in Haelius harbour through small wind turbines while 540 meters length field is available based on on-the-spot investigation. Different types of wind turbines are compared on cost and energy production.
2. The production and stability of Skystream 3.7 is superior to others and thus be the final choice of business case. Taking electricity price and energy production into consideration, annual energy benefits will be €1987.65 while costs containing 6 wind turbines and complete electrical system could reach €4701.23 in the next 20 years. Due to 13251.00 kWh electricity produced by these wind turbines, reduction of carbon emission analyzed in the business case will be 9.75%.
3. This business case help this harbour reduce carbon emission but not feasible from a financial perspective.

recommendations

The SDE+ (in Dutch: Stimulering Duurzame Energieproductie) is an operating grant. Producers receive financial compensation for the renewable energy they generate. Production of renewable energy is not always profitable because the cost price of renewable energy is higher than the market price. (Stimulation of Sustainable Energy Production (SDE+), 2018) It aims to encourage the production of renewable energy in the Netherlands.

Combined with this governmental policy, this research for renewables accords with SDE accurately. It is the best way to meet financial requirement efficiently.

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DELIVERABLE 2.1.3: FEASIBILITY OF SOLAR PANELS IN HELLEVOETSLUIS

Hellevoetsluis (support HZ)

Introduction Marina Cape Helius

Figure 3.1 shows the area of Marina Cape Helius. It is a marina mainly for tourism. The main energy consumption are electricity and gas which is used to maintain the daily operation. There are suitable area to set up solar panels for reducing the carbon emission.

Figure 3.1 Area of Marina Cape Helius

Solar power

As figure 11.2 shows, depending on the forecast of Hellevoetsluis radiation, it turns out that average solar radiation within this period is approximate 1000 W/mm².It is predicted that in the next few years, the radiation will range from 800 – 1200 W/mm².

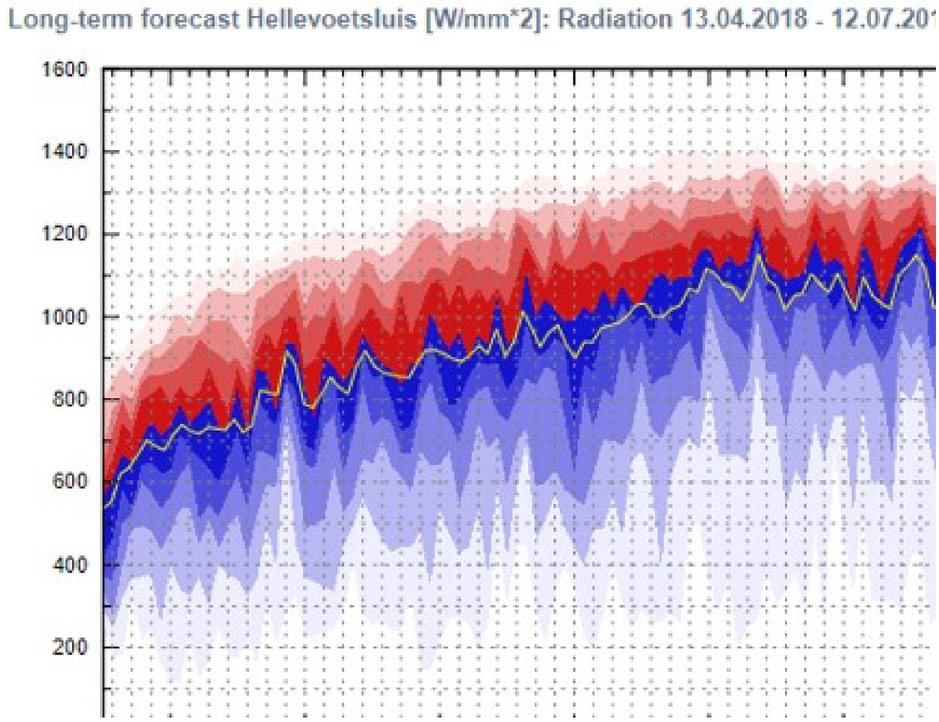

Figure 3.2 Hellevoetsluis Radiation (Long-term forecast Hellevoetsluis Temperature 90 days)

Substantial solar power can be exploited and Veer harbour has installed solar panels these years. These facts justified that it is feasible to develop solar photovoltaic system in Hellevoetsluis ports.

As conventional solar panels are generally placed on the flat ground but most of flat ground has been used for residence houses and business hall in Marina Cape Helius. Therefore, the suitable location that we observed during the on-the-site investigation is not available. Another possible area for solar panels is a water area alongside the shore but conventional solar panels might be damaged as water level changes constantly. In addition, available area for solar panels installation are limited by lots of ships which need to park along the shore.

Compared with conventional Solar panels, there is an innovative model, floating solar panels. According to the present condition which had no available area on the ground, it is the only way to apply solar panels by floating ones.

Through research, there is an innovative floating PV system named Hydrelio that allows standard PV panels to be installed on large water area. (Hydrelio Floating Solar System, n.d.) With the help of floating structure, it can be placed on the surface of water.

There are data analyses to each sub question for Marina Cape Helius. After analysis, it shows the final answers to sub questions.

Energy Consumption

Marina Cape Helius is a marina. The main energy consumption is to maintain the daily operation which includes supplying electricity for WSV buildings and outdoor lighting as well as tourism consumption. In 2016, the electricity consumption is about 135882 kWh and gas consumption is about 20212 kWh.

Floating Solar

Instead of conventional solar panels, it is an innovation to explore the surface of water for saving area on the ground. Firstly it is a new technology, the relevant source and data is not enough to investigate. The manufactures of floating solar panels are less than conventional one. What is more important is the process of comparison, the models and types of floating solar panels are limited.
Through further research about different kinds of solar panels and their functions, a kind of floating solar panel was found out that meets requirements basically. This innovative technology to ground-mounted systems is particularly suitable for water-intensive area. (FLOATING SOLAR PANELS: A VIABLE SOLUTION?, 2018)

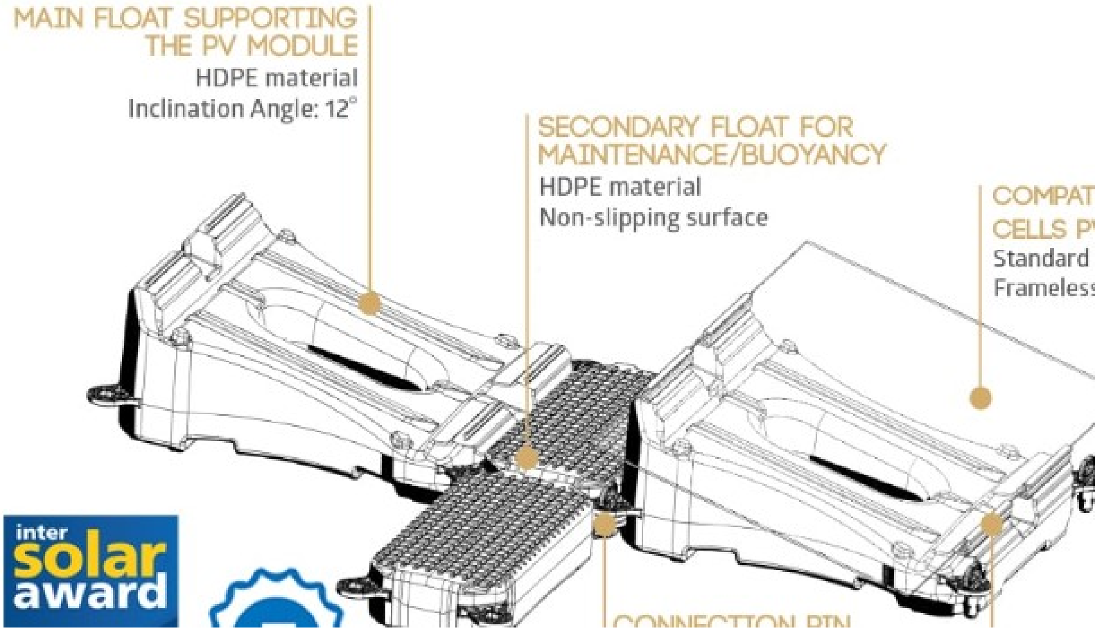

Figure 3.2 floating Solar Panel Hydrelio (Hydrelio Floating Solar System, 2018)

Through research, there is an innovative floating PV system named Hydrelio that allows standard PV panels to be installed on large water area. (Hydrelio Floating Solar System, n.d.) A secondary non-slip HDPE float links the main floats together and provides a platform for maintenance as illustrated in figure above. With these floating solar devices, solar energy can be exploited in Marina Cape Helius without occupying other space.

According to Ciel & Terre, the system is easy to install and dismantle, can be adapted to any electrical configuration, is scalable from low to high power generation, and requires no tools or heavy equipment. It is also ecofriendly, fully recyclable, has low environmental impact and is cost effective. (FLOATING SOLAR PANELS: A VIABLE SOLUTION?, 2018) As the Hydrelio information shows, it is not necessary to assemble and mount with special or heavy tools. The installation work of the Hydrelio technology is quick and simple. Minimal condition for construction work is an area of 5 meters length and a width equivalent to the floating platform row (depending on structure design).

Location

Based on the research, it is expected to use solar energy in Marina Cape Helius. Floating solar panels are determined to be used and placed on the north side and the south side of the port as shows in the Figure1. The north area is approximately 600 m² with 40 meters length and 15 meters width while the south area is also about 600 m² but with 10 meters length and 60 meters width. 100 panels will be installed with complete connection to the electrical system. (blue mark in figure 22)

Figure 3.3 Location to set up floating solar panels

Figure 3.3 Location to set up floating solar panels

Legal

The floating solar panels will be installed in Marina Cape Helius might cause associated legal issues. Firstly it is essential to ask for permission of the land owner to install these devices and prepare all relevant documents. In addition, the permission of government to implement the project is also necessary.

Business case

As table .. shows, there will be installed 100 Hydrelio floating solar panels. They can produce 27930 kWh per year in total. Then it can save €4189.50 in electricity cost. The investment cost associated with implementation of

100 Hydrelio floating solar panels is €51503, annual operation cost is €500. Therefore, assuming the pilot lifetime is 25 years, on average it will cost €2560.12 per year. Obviously, it can save much carbon emission, besides the annual cost after implementing this system is less than annual energy benefit.

Table 3.1 Business case for solar panels (HZ University of Applied Sciences, J. van Berkel., 2018)

Preliminairy viability check PECS pilots Tool: Jacob van Berkel, HZ University of Applied Sciences Data provided by: Wattco, Maasdijk

Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	Floating solar panels in Marina Cape Helius
Where is the system boundary (e.g. the perimeter of the harbour).	boundary is solar panel system(100 panels) including connection to the electrical installation
What is the PECS pilot system?	pilot = specifically solar panels in harbour
Reference electricity price [ct€/kWh]	**15.00**
Reference costs CO2-emission [€/tonne]	**incl**
Current system performance	
Electricity consumption in Kwh	135,882.00
Gas consumption in m3	20,212.00
Future system performance	
Electricity production sloar panels in Kwh	27,930.00
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€] (offer wattco)	41,503.00
What are the investment CAPEX costs associated with implementation of the pilot [€] (estimation connection cost)	10,000.00
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	500.00
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	25-30 years
Annual Energy + CO2 benefit, expressed in €:	**4,189.50**
Annual costs (simple), expressed in €:	2,560.12
Reduction of CO2-emission of the system, after implementation of the pilot [%]	20.55

It turns out that floating solar panel program is feasible to be conducted in Marina Cape Helius from a financial perspective. Comparatively, this project represents a significant improvement in carbon neutrality that the reduction of CO2-emission of the system after implementation of the pilot is 20.55%. Most importantly, energy requirement is able to be satisfied by exploiting solar energy. It clarifies that solar energy is suitable to be exploited in Marina Cape Helius.

Based on general situation, the reduction of CO2-emission is 0.36kg/kWh (Bereken je CO2-uitstoot, 2018). The total energy saved from floating solar panels is 27930kWh, so it means these floating solar panels can reduce 10054.8kg CO2-emission per year.

Conclusions

1. After confirming the energy consumption with enough relevant people, it is clear that in 2016 the electricity consumption and gas consumption is 20212 kWh. Solar potential is rich based on data from long-term radiation forecast.
2. Hydrelio floating PV system can be applied on the surface of water so it is chosen for business case. Annual cost of using solar energy including installation and purchase reaches €2560.12.One hundred floating panels will be installed near shore covering an area of 1200m². Reduction of carbon emission of the system will be 20.55% in the next 25-30 years.
3. Port can be benefited from it with less carbon emission and proper cost. Therefore, it is feasible to apply this project in the future.

recommendations

The SDE+ (in Dutch: Stimulering Duurzame Energieproductie) is an operating grant. Producers receive financial compensation for the renewable energy they generate. Production of renewable energy is not always profitable because the cost price of renewable energy is higher than the market price. (Stimulation of Sustainable Energy Production (SDE+), 2018) It aims to encourage the production of renewable energy in the Netherlands.

Combined with this governmental policy, this research for renewables accords with SDE accurately. It is the best way to meet financial requirement efficiently.

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DELIVERABLE 2.1.4: FEASIBILITY OF BPS ELECTRICITY STORAGE IN HELLEVOETSLUIS

Hellevoetsluis (support BPS & HZ)

Ports Energy and Carbon Savings

Deliverable

Energy storage possibilities Hellevoetsluis port area

Project No. 2S03-009

With the financial support of

NAME	ORGANISATION
Ron Bol	BlueTerra Energy Experts

Revision history

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
Draft	24-05-2019	Ron Bol	BlueTerra Energy Experts	
Final	24-06-2019	Ron Bol	BlueTerra Energy Experts	

Problem definition and goal

Between 01 February 2014 and 31 July 2015, the Hellevoetsluis local authorities took part in the Sustainable Ports (SuPorts) cluster project, which was subsidised by the European Union. The SuPorts cluster project has led to a Strategic sustainability vision for the Hellevoetsluis port area. The Ports Energy and Carbon Savings (PECS)/Sustainability Impulse Hellevoetsluis Port Area project is a follow-up to the SuPorts cluster project and is in line with the objectives of the strategic sustainability vision for the port area, aimed at the continued sustainability of the ports. The project is for 60% financed by the Interreg Two-Seas program of the European Union and for 40% by the province of South-Holland. This report was prepared within the context of the PECS/Sustainability Impulse Hellevoetsluis Port Area project.

Objectives

The overall objective of the project is to develop, test, validate and demonstrate various methods, instruments and concepts of proven and innovative applications for energy-efficient, coast-related renewable energy sources and energy storage. The aim is to reduce the CO2 emissions in small and medium-sized ports.

The long-term (2040) goal is to realise an energy-neutral port. The short-term (2020) goal is for 10% of the energy consumption in the port to be generated sustainably.

Partners

Partners on a local level include water sports associations (Heliushaven and Kanaal door Voorne), commercial ports (Heliushaven and Vestinghaven) and water sports-related businesses (Veerhaven). Other partners include other small and medium-sized ports in Voorne-Putten, the Netherlands and the two-sea area.

Other partners who take part in the project are ports and knowledge partners from the two-sea area: the Port of Ostend (Belgium) also the lead partner, the IJmond environment agency (the Netherlands), Zeeland University of Applied Sciences (the Netherlands), CEREMA (France), Indachlor (France), Solent University (England), the municipal port of Portsmouth (England), Gent University (Belgium) and Blue Power Synergy (Belgium).

Energy storage possibilities in the harbour of Hellevoetsluis

Ambitious climate goals, depleting gas fields with corresponding seismic events and changing global energy prices are expected to diversify the current Dutch energy system within the years to come. As more renewable energy is generated, and cheap coal fired powerplants are being phased-out it is likely that electricity prices will change. It is also expected that subsidy schemes and energy taxation levels will change too.

These changes will affect the total electricity costs and revenues for small enterprises that consume and produce (excess) renewable electricity. Potentially making it less interesting to invest in renewable energy generation.

A company, located in the harbour of Hellevoetsluis, that might be affected by these changes is Ceilidh. This company produces high-tech carbon products in ovens run on electricity, which is partly self-produced by their PV systems.

Energy storage solutions might contribute in minimizing these negative effects whilst also lowering peaks on the local grid and increasing the consumption of self-produced electricity. Three types of energy storage are analysed; thermal energy storage by using PCM's, battery storage at the company and battery storage in moored vessels close to the company. The results are compared on yearly costs for running these systems, total investments and avoided CO_2 emissions.

Abbreviations

- PV Photo-voltaic
- kWp kilowatt peak
- kWh kilowatt-hour
- PCM Phase Change Material

Ceilidh

The company Ceilidh produces a broad range of high-performance carbon products. These products include masts, sail boat components, industry specials and other custom products. These products are baked in ovens that consume a considerable amount of electricity. Ceilidh has set a goal to fabricate their products without any CO_2 emissions in the near future, the 100 PV panels on the rooftop help contribute to this goal.

Project location

Ceilidh is located in one of the port areas of Hellevoetsluis, see Figure 1.

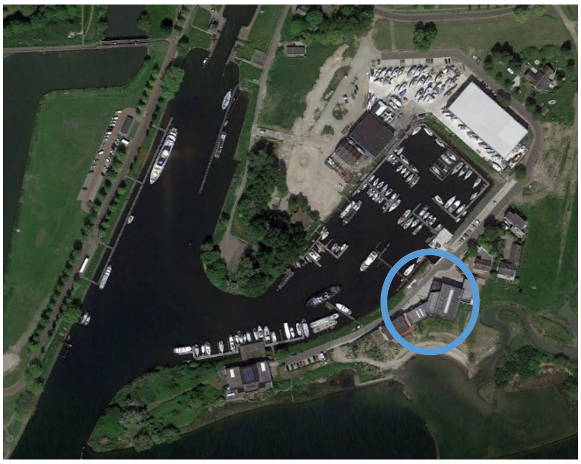

Figure 1 – Port area (the blue circle indicates location of Ceilidh)

When taking a closer look at Ceilidh itself, the building in which the production takes places is clearly visible due to the solar panels installed on the roof.

Figure 2 - Building layout

1.1. Renewable electricity production and local grid setup

Currently the company's rooftop is filled with 152 PV panels facing southwards with a tilt angle of 25-30°, the PV panels are connected to three string inverters. The total capacity of this system is approximately 52 kWp with an annual electricity production of approximately 54.000 kWh/year.

Ceilidh is connected to only 2 inverters so that it has access to electricity produced by 100 PV panels (35 kWp) that account for a production of around 36.000 kWh/year. The entire building complex is equipped with an electricity grid so that PV electricity can be distributed from one building to another and can be used 'behind the meter'. Due to this construction paying double energy taxation is avoided.

Future PV system expansion plans

On the short term an expansion of 48 PV panels (16 kWp) is planned and will probably be operational from 2020 onwards. These panels will be placed on the adjacent rooftops (left and right). Including the slightly higher kWp capacity for this new installation the expected added electricity generation will be 17.000 kWh/year. On a longer term 48 more PV panels might be placed on the remaining rooftops (bottom left area in Figure 2). This might pose a problem regarding as it probably will exceed the maximum connection capacity. In this report, only the first expansion phase is taken into account.

Energy production and consumption

Data availability and conversion

In order to create insights in the production and consumption of electricity several types of data have been used. Electricity bought from the grid (off-peak and on-peak[1]) and electricity delivered to the grid (off-peak and on-peak) were gathered through the portal of the electricity supplier, this data has a time resolution of one-day (hourly data were not available). Production by the PV system is known only on a monthly basis and was gathered trough production totals on the inverters itself.

Monthly PV production was converted to daily production by the use of PV system specifications, (Peak capacity, tilt and orientation) irradiance data[2] and a performance ratio of 0,85. The total energy consumption of Ceilidh has been estimated on a daily basis by using the bought, exported and produced electricity numbers.

Manufacturing process

Carbon products are made by wrapping pre-impregnated fibres around a mould. The mould wrapped in carbon layers is put into the oven which is set at 120°C. The time that the product needs to be in the oven depends on the thickness of the material. Workers prepare large moulds during daytime so that the product can be finished during the evening and night in the ovens, both on workdays as during weekends. This procedure is mainly applied to larger products. Most smaller products are put in the oven during daytime.

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[1] Off-peak hours: weekdays 23:00 – 7:00, entire weekend and holidays.
[2] KNMI station Hoek van Holland 2018.

Energy consumption

Limited information is known on the consumption of electricity for the manufacturing process that takes place in the ovens. The electricity consumption of the ovens is not metered directly, and electricity bought from the grid could not be obtained on an hourly basis. Ceilidh's own estimation is that the process takes up to 8 kW of electric power and can last 10 hours.

To get a better understanding of the electricity demand to run the manufacturing process during the evening and at night, the consumption data during off-peak hours at weekdays has been analysed. The results in Figure 3 show that there is quite some variation throughout the year. By deleting the outliers an average consumption of 64 kWh during off-peak hours with an average capacity of 7,95 kW results.

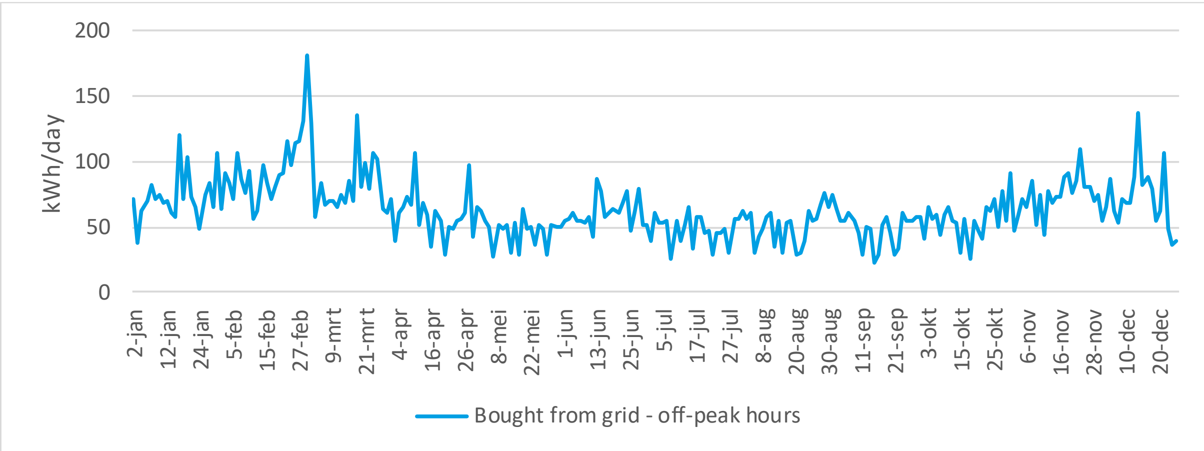

Figure 3 – Manufacturing process energy consumption during off-peak hours

1.2. Energy balance

Current situation

Table 1 shows the consumption and production volumes from 2018, on a yearly basis, around 2/3 of the total consumption is imported from the electricity grid, the remainder is used directly from the solar energy system. The amount of electricity bought during on-peak hours is comparable to the amount bought during off-peak hours. On a volume basis, 75% of the electricity produced by the PV system is directly consumed in the company itself, the remaining 25% is fed back to the electricity grid.

Type	kWh/year
Consumption	80.800
Bought - from grid	53.700
Off-peak hours	28.700
On-peak hours	25.000
PV system	37.000

production	
Excess production – to grid	10.100

Table 1 – Current energy balance

Figure 4 shows that the total consumption is rather constant throughout the year. Due to the electricity generated by the solar panels the total electricity bought from the grid decreases significantly during the summer months. Furthermore, the amount of electricity exported to the grid increases as the production from the solar panels increases during summer months.

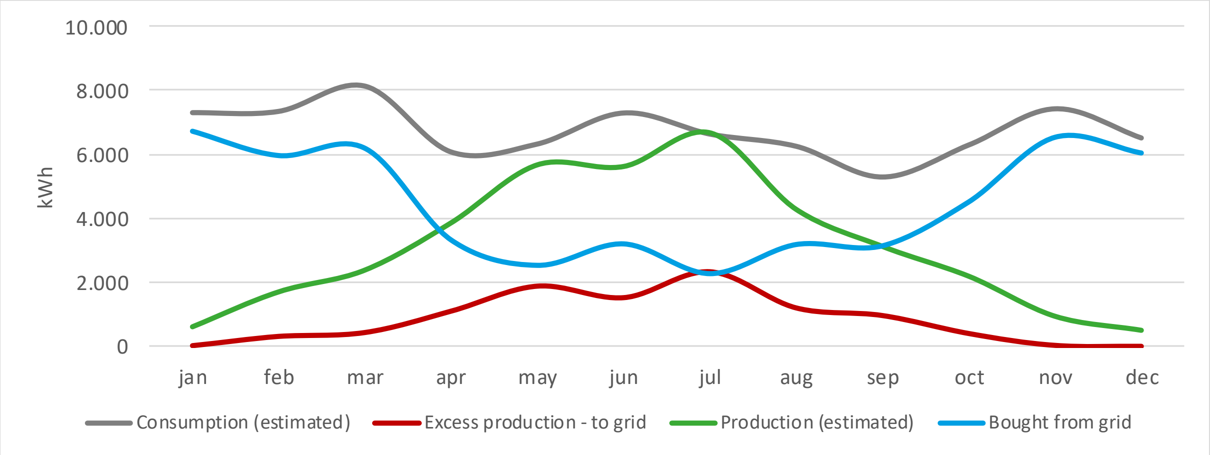

Figure 4 – Energy balance current situation

Situation after PV system expansion

With the addition of the extra PV panels the amount of electricity bought from the grid decreases. However, the amount of electricity delivered to the grid increases as not al electricity can be used directly. This can affect the total yearly costs for electricity when the feed-in tariffs decrease.

Type	**kWh/year**
Consumption	80.800
Bought - from grid	36.500
Off-peak hours	19.500
On-peak hours	17.000
PV system production	55.100
Excess production – to grid	14.900

Table 2 –energy balance PV system expansion

The graph in Figure 5 shows that in July, more electricity is fed to the grid than what is bought from the grid. Overall more electricity is being fed to the grid compared to current situation.

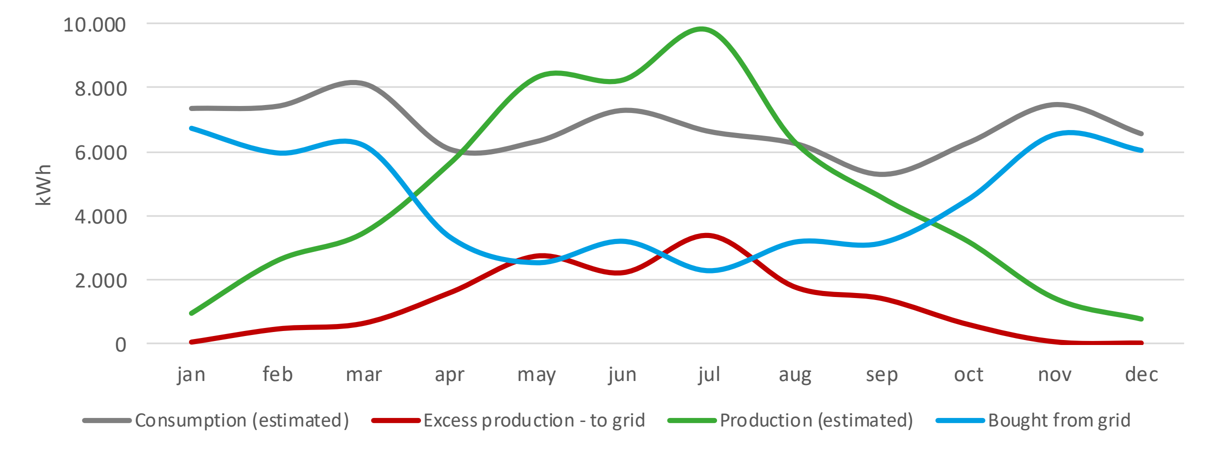

Figure 5 – Energy balance PV system expansion

In Figure 6 the graph shows that on a daily basis most moments of exporting electricity to grid occur during the summer months. Moments of excess electricity production will occur around 260 days per year. This energy could potentially be (partly) stored for later use.

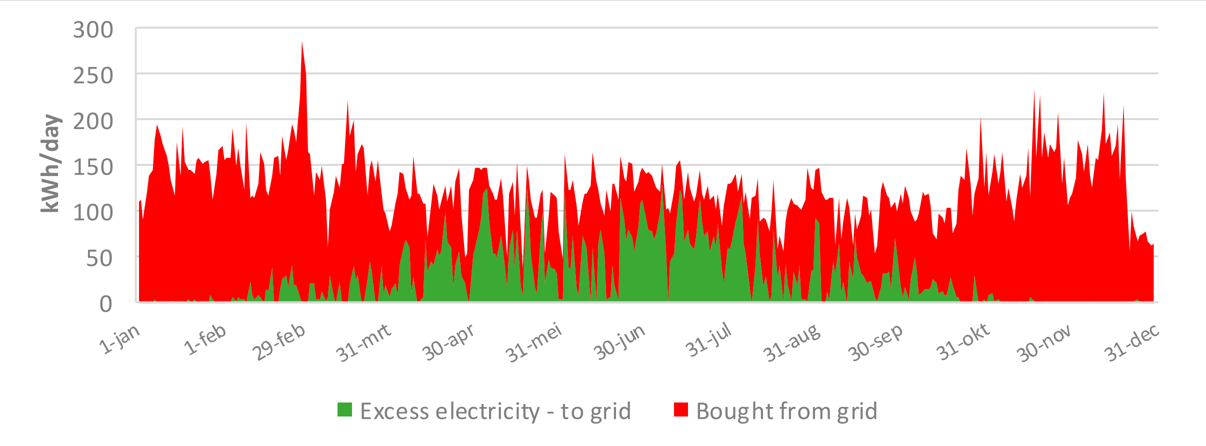

Figure 6 – Energy balance

ENERGY STORAGE POSSIBILITIES

Electric energy storage

Local storage

The easiest option for storage is to choose a commercially available battery system that will be installed at the building itself. A lot of different battery technologies can be used for storage purposes such as; nickel-based, lead-acid and (redox) flow batteries. Nowadays, the largest price developments and technical improvements are seen within the lithium-ion based batteries. These types of batteries are widely used for smaller devices such as laptops and cell phones, for electric mobility and increasingly for energy storage solutions.
Nowadays there are several suppliers (e.g. Tesla [3], LG Chem Resu[4] and Sonnen [5]) available that deliver storage systems that can be used directly after installation.

[3] https://www.tesla.com/nl_NL/powerwall
[4] https://www.lgchem.com/upload/file/product/LGChem_Catalog_Global_2018.pdf
[5] https://media.sonnen.de/de/media/6/download/inline

Including installation and additional hardware, battery systems investments start at around 650 €/kWh for smaller systems and will costs around 450 €/kWh for larger systems[6], see Figure 7. On average the roundtrip efficiency of a battery system, as specified by the manufactures described above, is approximately 90%.

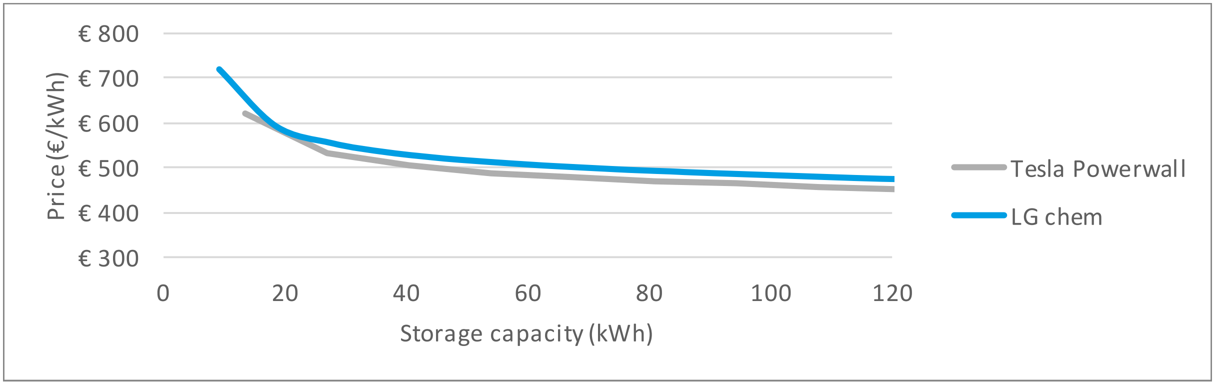

Figure 7 – Battery storage costs (including installation and hardware, excl. VAT)

Port area

Instead of storing electricity at the company, another option would be storing electricity in the port area, specifically in moored vessels. There are around 40 vessels in the port at any time, both during winter and summer. The port area is already prepared with two electrical systems (12V and 230V). For this report it is assumed that most small vessels have an energy consumption of approximately 1-2 kWh/day and are now fed by the electricity grid. Based on an average battery capacity of 100 Ah at 12V, each boat has a storage capacity of 1,2 kWh. The round-trip efficiency for these systems is estimated at 80%.

Thermal energy storage

A phase change material (often based on salts) captures and releases heat by using the energy required to change the material into a solid or a liquid phase. During this phase change, heat is added or released at a fixed temperature. Heat is added by using electricity, heat can be extracted by running a liquid medium (such as oil) through the PCM's heat exchanger. Energy losses during charging, discharging and storage during short periods are usually low. Depending on storage time, temperature and sizing, a roundtrip efficiency up to 90% can be achieved[7].

Project partner Blue Power Synergy has developed a thermal energy storage system with a capacity of 120 kWh. This system turns electricity into heat and stores it in a PCM at 135°C – 140°C to make heat extraction at 120°C possible. Currently, heat is added to the ovens by circulating air in an electrically heated heat exchanger. In the case of heat storage in molten salts the same circuit is used, only a different electrically heated heat exchanger is used: a double one who's body is filled with PCM. During daytime, excess electricity from the PV

[6] *Diminishing costs for additional hardware and installation costs*
[7] *Sarbu, I and Sebarchievici, C (2018). A Comprehensive Review of Thermal Energy Storage*

system is used to charge the PCM, at night-time the air circulates through the heat exchanger, absorbing heat from the PCM.

As the required capacity at 64 kWh is nearly half the amount of energy that can be stored in Blue Power Synergy's system, it will be over dimensioned making it cost inefficient. For Blue Power Synergy it becomes too small for an interesting product, in case the company would be able to make a system this size, costs would probably be around €18.000- to €15.000. In mass production such a system could cost around €12.000,- according to Blue Power Synergy.

Outlook to future energy pricing and subsidy scheme

Electricity prices

The current energy system is likely to change significantly in the forthcoming years due to CO_2 reduction goals set by the Dutch government. Cheap coal fired gas plants will be shut down or be obliged to be fed by sustainably grown biomass. LNG imports are likely to increase and on a longer-term renewable electricity generation is expected to be more price setting in the future. Furthermore, a shift in energy taxation from electricity towards natural gas is expected. In order to determine the market prices BlueTerra's Energy Market Forecast model has been used.

Figure 8 shows three different scenarios for the next 15 years. The upper boundary scenario shows electricity prices that tend to be the most expensive whereas the lower boundary describes the opposite situation. The most likely scenario is based on current policies and market expectations. The most likely scenario is used for further analyses in this report. The costs for electricity are representative for small and medium sized enterprises and includes ODE and EB[8].

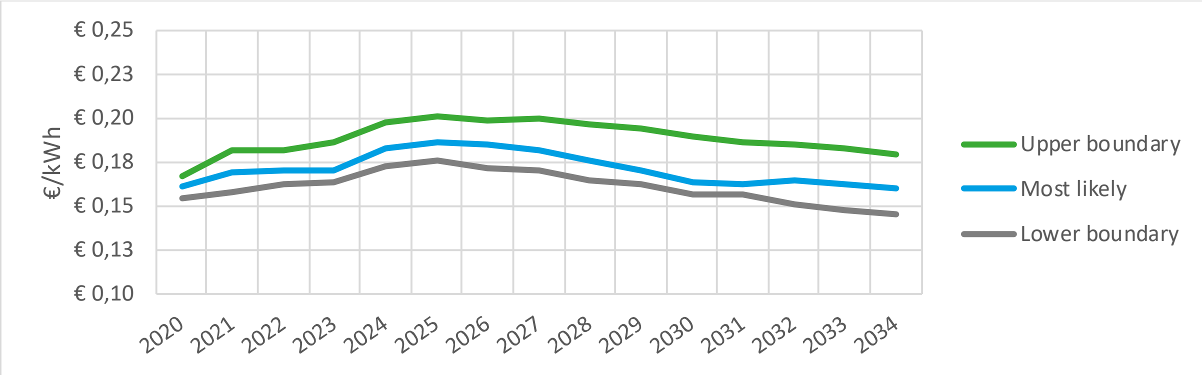

Figure 8 - Electricity price scenarios (excluding VAT and distribution costs, including energy tax)

Feed-in tariffs

Currently the feed-in tariff for electricity generated by small scale PV systems is equal to the electricity price paid by consumers. Recently, the government decided to extend the current feed-inn tariff scheme until 2023. After 2023 the feed-in tariff is expected to be reduced gradually each year. As it is unknown what will happen exactly the following is assumed: until 2023 the feed-in tariff reflects the current price for electricity (0,17 €/kWh). Between 2023 and 2030, the feed-in tariff linearly decreases to the wholesale price (0,035 €/kWh). This is because it is expected that from 2030 onwards the wholesale price will be much more affected at times that there is a lot of renewable energy generation. As a result, electricity delivered to the grid will be worth less in the future[9].

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[8] ODE= taxation used for investing in renewables. EB= energy taxation

[9] However, as storage techniques might become cheaper in the near future, energy storage systems can come up with energy brokerage markets. As a result, wholesale prices will be much less affected.

Energy storage business cases

Local electricity storage

The consumption of electricity for the manufacturing process during night-time is highly variable as is seen in Figure 3. On average, 64 kWh of electricity is required each night. By choosing this storage capacity more than half the nights the process can be run on renewable electricity produced during daytime. A larger storage volume would result in more nights that can be run on renewable electricity at a cost of much larger investments.

This storage capacity needed includes 5% losses while discharging the system. A storage system based on lithium-ion, including installation costs around € 30.000 (excl. VAT). Maintenance should be very limited, and the expected lifetime is over 10 years.

Port area electricity storage

It is assumed that when using the moored vessels as a storage solution, around 48 kWh becomes available for storing excess electricity[10]. As the docks are already prepared for 230V and 12V systems the amount of investments required to realise the charging system are relatively low. The system required for discharging is expected to be more expensive as vessels can use either 24V or 48V systems, which requires conversion back to 230V.

To connect to docks to Ceilidh a physical connection needs to be made. Charging and discharging the vessels requires a dedicated software platform that controls when charging and discharging is possible. Furthermore, to put all the different "feeders" into 1 grid every vessel needs a hybrid invertor and an overall synchroniser. The expected costs for the total system are expected to be around €125.000 up to €150.000.

Thermal energy storage

The thermal energy storage developed by Blue Power Synergy has an expected price of €28.000 including installation (excl. VAT) for which 120 kWh of thermal energy can be stored. However, only around 64 kWh is required in which case costs are likely to go down to around €18.000 - €15.000 in total. In this report an investment of € 18.000, - is used. Regular maintenance is required only once every 5 years and is expected to cost €500, - each time.

Overview of business cases

The business cases described above are compared based on investments, €/kWh, total yearly costs and avoided CO_2 emissions.

Investments

Figure 9 shows the results for the investments needed. Port electricity storage is the most expensive both for the total investment as in € per kWh. Thermal energy

[10] However, in reality the available storage capacity is dependent on the availability of vessels and the storage capacity within each vessel. Furthermore, most battery systems are based on 'lead-acid' which have limited charge/discharge cycles over their lifetimes. This effect is not taken into account in this report.

storage still requires a substantial investment but gives a better price for €/kWh compared to local electricity storage.

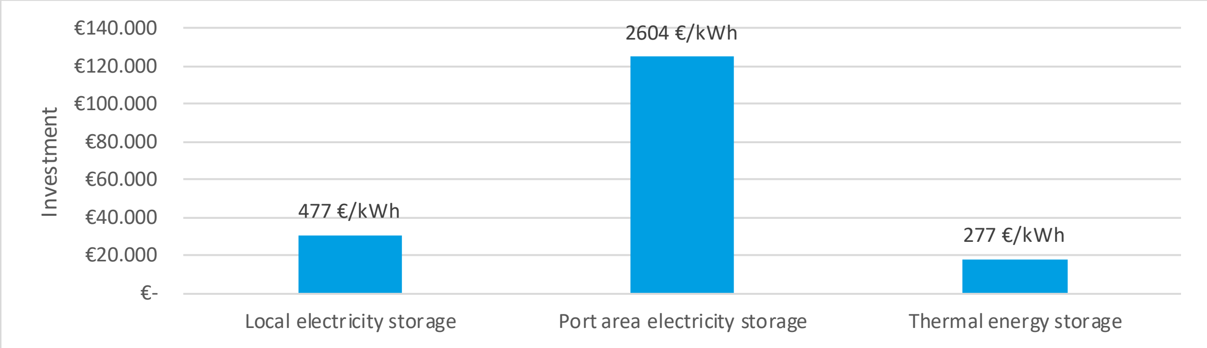

Figure 9 – Energy storage investment costs

Yearly costs

The above business cases have also been analysed in terms of yearly total costs for Ceilidh. The total costs include electricity bought from the grid, revenues from electricity exported to the grid, maintenance and depreciation.

The blue dashed line indicates what happens if the current feed-in subside scheme would be maintained, the dashed grey line shows the costs for when electricity is not stored. Considering current and expected future policies the storage option can best be compared to the 'no energy storage' business case. From the results it becomes clear that all options initially result in higher costs than when no electricity would be stored. From 2027 onwards, thermal energy storage becomes feasible as its costs are equal to the reference scenario.

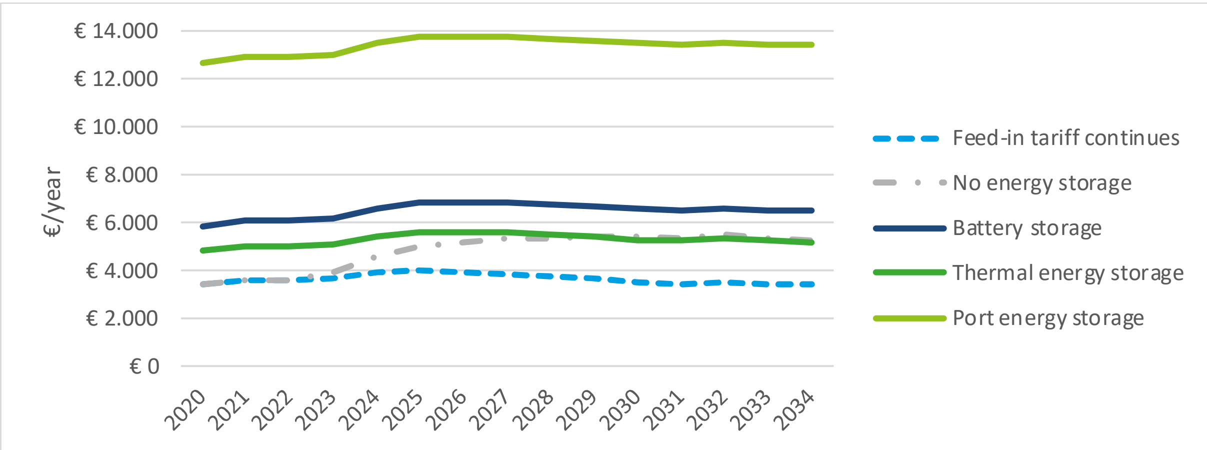

Figure 10 – Total yearly energy costs

Avoided CO_2 emissions

Furthermore, the avoided CO_2 emissions by reducing the use of electricity from the grid have been analysed. This only includes avoided emissions due to electricity generation. Emissions related to the production of storage systems are out of scope. The emission factor used is 0,413 kg CO_2/kWh.

The results indicate that the thermal energy storage system has the largest emission reduction potential. The highest cost effectivity per ton CO_2 avoided is realized by using the PCM storage system.

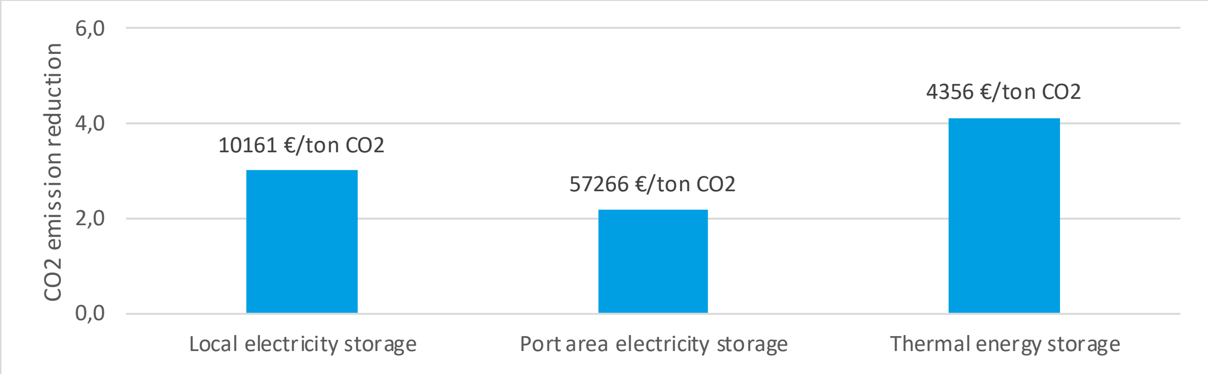

Figure 11 – Yearly CO_2 emission reduction and CO_2 cost effectivity

Conclusions and recommendations

With current investment levels, energy tariffs and the expected subsidy scheme energy storage does not seem feasible. Not only the investment costs negatively affect the business cases for energy storage, also the amount of electricity used behind the meter has it impact. Because of the direct consumption behind the meter, potential lost revenues remain relatively low in the future. In other words, the current daytime electricity consumption of Ceilidh gives little room for large investments.

Storing energy in the port seemed interesting but is probably impractical in reality as the vessels have different storage systems, can be absent when storage is required, lowers the battery lifespan and because the costs for the physical components are high.

Thermal energy storage might be an interesting option as large volumes of energy can be stored at relatively low costs. It is recommended to research the exact applicability of this -and alternative-system to the existing ovens, investigate which manufactures can deliver such a system and check which additional costs may apply. From 2027 onwards, the yearly costs for a thermal storage system become equal to the reference scenario so that this might be a feasible solution for storage.

Considering potential costs down expectations for storage systems, changing subsidy schemes, different energy tariffs and potential investment subsidies, it is recommended to do a comparable study in 3-5 years time to check if the feasibility has changed. Also, large changes in the production process or added PV capacity may result in an overcapacity, in case excess PV electricity reaches over 35 000 kWh/year a re-evaluation seems logical.

DELIVERABLE 2.1.5: FEASIBILITY OF A MEDIUM SIZED WIND TURBINE IN OOSTENDE

Oostende (support UGhent)

Ports Energy and Carbon Savings

Output 10 D 2.1.5
Independent verification report of feasibility of an innovative medium sized wind turbine in Oostende

Project No. 2S03-009

With the financial support of

NAME [USE TABLE-TITLE]	ORGANISATION [USE TABLE-TITLE]
Dimitar Bozalakov	Universiteit Gent

Revision history [This is alinea title – size 9 – bold]

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
1	16.01.2019	Wim Stubbe	AGHO	[Use Table-text – size 9 – row hight is 1 cm]

Introduction

To reduce the carbon footprint of the port of Ostend, the potential of using carbon saving and renewable energy technologies is investigated. According to the Kyoto protocol, all carbon emission must be reduced by 20% by 2020. Carbon saving and renewable technologies seem very promising solution to reach these ambitious targets.

With the development of this research, ethical dilemmas like different facilities, changes of energy are possible to have some potential problems like environmental dangers and also personal benefit. For instance, installing a big wind turbine may put at risk (or in danger) bird specious, so additional measures should be taken to minimise the risk for the nature.

The goal of this report is to perform a basic examination of some possible solution so that the carbon saving is achieved in the port of Ostend. Carbon saving and renewable technologies with a high technology readiness level (TRL) are considered to conduct the feasibility studies. The outcome of these studies will be used to form business cases so that energy cost is reduced and also more effective use of the energy is achieved.

By measuring the carbon footprint of the energy consumption of the port, a carbon saving goal can be set. In the business cases, some technical, economic (including cost and benefit) and environmental challenges will be considered. Within this report, the potential of renewable energy sources such as solar, wind, wave and tidal will be briefly examined. In addition, storage elements such as chemical batteries will be also discussed. Port officers and wind turbine researchers are selected as our interview object, relevant reports are chosen for our desk research.

For port of Ostend, three business cases/pilots are investigated, concerning application of:

1. Medium-sized wind turbine with rated power of 100 kVA - D 2.1.5
2. Smart LED lights pontoon D. 2.1.6.
3. A BPS-energy pontoon - D 2.1.9

The options were selected after a pre-feasibility study and discussion with the port staff in Jan 2019. Given the very small tidal amplitude, (0,5 m), tidal energy was not considered for further investigation.

Energy consumption of the port

A general picture of the Port of Ostend is presented in Figure 12. The electric energy consumption of the port is to maintain its daily operation and also the companies located in the port’s premises. The annual electricity consumption of the port is 1.416 GWh and the goal is to reduce this consumption with at least 20%.

Figure 12 Port of Ostend

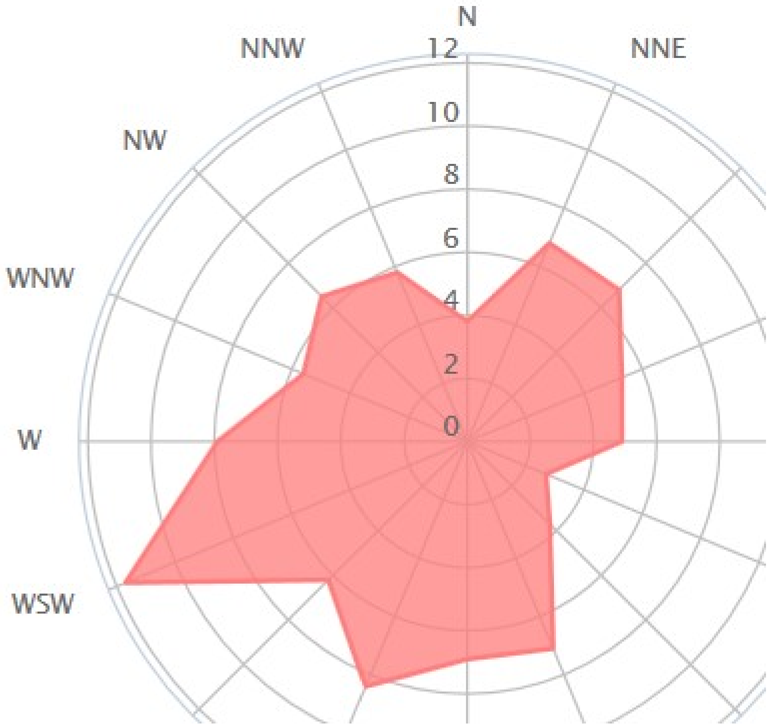

Figure 13 Wind speed and wind direction in the port of Ostend [1]

Wind turbine potential

Wind has an intermittent character, but wind speeds tend to be higher at night and increase significantly with the height above the surface. For Flanders, at 75 m annual averages of 5 m/s inland to about 9 m/s at the coast are attained and the wind direction can be seen in Figure 13. According to [2], large wind turbines achieve 2000 full load hours which makes them very promising solution for decreasing the carbon footprint. A wind turbine converts wind energy into electric energy. The Port of Ostend is not a leisure port and there are some industrial activities. This implies that the environmental noise can be high (but still kept

within regulations) when there are loading, unloading and other activities in the port. Since the noise level is not a critical issue, a wind turbine with a horizontal axis is selected by the port authorities for the purpose of the pilot within PECS. A wind turbine based on the "kiss" principle is chosen and it is produced by Xant.
According to the manufacturer of the wind turbine which is installed in the premises of Port of Ostend, the average wind speed is 6.2 m/s at the height of the rotor. The installed wind turbine has a power rating of 100 kVA nominal power and 150 kVA peak power. Based on the power curves of the wind turbine, the manufacturer has calculated annual energy yield of 256 MWh. Considering the fact that the total energy consumption of the Port of Ostend is 1416.1 MWh, the wind turbine will reduce the total energy consumption of the port from the distribution grid with about 18%. Given the fact that in Belgium one kWh is been produces with almost 550g of CO2, the total annual carbon emission reduction for the port of Ostend will be 141t.

Legal

Port of Ostend and Xant have obtained all necessary permissions for the installation of the wind turbines. Usually in Flanders, Belgium, all permits can be obtained within 4 months but ports are under the jurisdiction of the government and the required time can be considerably longer.

Business case

The total cost (CAPEX) of the installed wind turbine is 300 000 € and the annual maintenance cost (OPEX) is 3 200 €. This wind turbine will produce 256 000 kWh annually and taking into account the cost of the electricity which is 15 €c/kWh it will result in 38 400 € gross. Finally, when the OPEX is deduced the net profit is 35 200 €. As mention above, greenhouse emissions will be also reduced with about 141t/a. Nowadays, the reference price of CO2-emissions per ton is 20€/t which brings additional 2 820 € savings to the port. The life span of the pilot is expected to be 15 years. Considering the CAPEX and OPEX, the wind turbine will pay itself in 10 years ant it will bring profit to the port for another 5 years. In conclusion, this pilot will reduce the carbon emissions of the port with 18.08%. A summary of the business case data are listed in Table 3.

Conclusions

1. The wind power has a great potential to significantly reduce the carbon footprint of the ports. In this particular case, the installed wind turbine has huge impact on the carbon reduction. For the considered pilot, the greenhouse gases are decreased by 18.08%. Thus only additional 1.92% are needed to reach the goal of the total 20% reduction.
2. This business case helps the Port to reduce its carbon emission and it seems feasible from a financial perspective.

Preliminairy viability check PECS pilots Tool: Jacob van Berkel, HZ University of Applied Scieces Data provided by: Wim Stubbe, Port of Oostende	
Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	O&M-site Oostende Offshore Village
Where is the system boundary (e.g. the perimeter of the harbour).	Boundary lies inside the harbour, around the site
What is the PECS pilot system?	Innovative 100 kWe windturbine according to "kiss" principle 
Reference electricity price [ct€/kWh]	**15**
Reference costs CO2-emission [€/tonne]	**20**
Current system performance	
What is the current annual energy consumption of the system [kWh/a]	1416100
What is the current annual CO2 emission [tonne/a]	779
Future system performance	
What is the future annual energy consumption of the system, after implementation of the pilot [kWh/a]	1160100
What is the future annual CO2 emission, after implementation [tonne/a]	638
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€]	300000
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	3200
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	15
Annual Energy + CO2 benefit, expressed in €:	**38.016 €**
Annual costs (simple), expressed in €:	**23.200 €**
Reduction of CO2-emission of the system, after implementation of the pilot [%]	**18.08%**

Table 3 A summary of the associated costs of the wind turbine pilot in the port of Ostend

Literature:

[1]https://www.windfinder.com/windstatistics/oostende_pier

[2]Timmerman J., Deckmyn C., Vandevelde L. and Van Eetvelde G. "Low carbon business park manual : a guide for developing and managing energy efficient and low carbon businesses and business parks," 2014

DELIVERABLE 2.1.6: FEASIBILITY A LED PONTOON IN OOSTENDE

Oostende (support UGhent)

Ports Energy and Carbon Savings

Output 11 D 2.1.6
Independent verification report of the feasibility of a smart LED lights pontoon in port of Oostende

Project No. 2S03-009

With the financial support of

NAME [USE TABLE-TITLE]	ORGANISATION [USE TABLE-TITLE]
Dimitar Bozalakov	UGent

Revision history

REVISION	DATE	AUTHOR	ORGANISATION	DESCRIPTION
V1.0	08.01.2019			

P109 D. 2.1.7 According to the project description:

LP, supported by PP9, will conduct a draft report of the feasibility and the technical qualities and quantities of a smart LED light pontoon in relation to the costs, maintenance and energy-production. Also needs related to smart, smooth and safe handling of crew transfer vessels and workboats will be identified and objectives for installing pontoons in coordination with the ENSOR port management system. The draft study will be verificated by Joint Advisory Panel and afterwards completed.

O11 P65 :

- this investment will lead to a reduction of carbon emissions in the port of Oostende with 5%
- it will lead to ongoing investments and further development of these techniques and thus to reduction of carbon emissions in 2 seas ports with 20-30% in 2030
- this investment will lead to a reduction of the light pollution in the port with 5%
- this investment will increase the port security and realise a better control of the port access
- this investment will increase the collection of data related to port activities with 10% (obligatory check who leaves the quay and goes on board, etc)
- this investment will increase the maritme safety : in case of ship calamities, passengers on board can be immediately identified, as well as the goods on board (risks on oil spill)

Introduction

To reduce the carbon footprint of the port of Ostend, the potential of using carbon saving and renewable energy technologies is investigated. According to the Kyoto protocol, all carbon emission must be reduced by 20% by 2020. Carbon saving and renewable technologies seem very promising solution to reach these ambitious targets.
With the development of this research, ethical dilemmas like different facilities, changes of energy are possible to have some potential problems like environmental dangers and also personal benefit. For instance, installing a big wind turbine may put at risk (or in danger) bird specious, so additional measures should be taken to minimise the risk for the nature.
The goal of this report is to perform a basic examination of some possible solution so that the carbon saving is achieved in the port of Ostend. Carbon saving and renewable technologies with a high technology readiness level (TRL) are considered to conduct the feasibility studies. The outcome of these studies will be used to form business cases so that energy cost is reduced and also more effective use of the energy is achieved.
By measuring the carbon footprint of the energy consumption of the port, a carbon saving goal can be set. In the business cases, some technical, economic (including cost and benefit) and environmental challenges will be considered. Within this report, the potential of renewable energy sources such as solar, wind, wave and tidal will be briefly examined. In addition, storage elements such as chemical batteries will be also discussed. Port officers and wind turbine researchers are selected as our interview object, relevant reports are chosen for our desk research.
For port of Ostend, three business cases/pilots are investigated, concerning application of:

1. Medium-sized wind turbine with rated power of 100 kVA - D 2.1.5
2. Smart LED lights pontoon D. 2.1.6.
3. A BPS-energy pontoon - D 2.1.9

The options were selected after a pre-feasibility study and discussion with the port staff in Jan 2019. Given the very small tidal amplitude, (0,5 m), tidal energy was not considered for further investigation.

Smart Pontoon (MaRiot)

Pontoons are used very widely in ports and marinas. Depending on the application, they are usually constructed by using wood (deck), plastic (floating tubes) for the light duty pontoons and steel for the heavy duty ones. They are used to create massive decks to help with the activities held in a port such as loading, unloading, maintenance bunkering etc. To ensure a safe operation to the users during night, a proper lighting is needed which requires electricity. However, these pontoons may be used in remote areas in the port, where the access to the distribution grid is not available. Diesel generators could be used to supply the pontoons during the activities but this is a costly solution and also not environmentally friendly due to its CO_2 emissions. The prices of chemical energy storage such as batteries are dropping continuously and they start to seem an appropriate solution for supplying the lighting of the pontoons. An efficient way of using the stored energy would be achieved with as less conversions as possible, so amount of the intermediate matching devices to be kept to minimum or none. Therefore, compact fluorescent lights can be replaced with light emitting diodes (LED) which have very high efficiency and also provide sufficient light flux for the needs of the pontoon. The lighting and the battery storage can be combined with motion sensors power up the pontoons in times when only necessary to do so, such that a normal operation is guaranteed to the activities in the port. In addition, solar and wind energy could be used to make the pontoon self-sustainable. Thus, the energy that is consumed by the pontoon will be generated locally which will further reduce the CO_2 emissions of the port. Due to the intermittent nature of the renewable energy sources, a combination between them is usually made so that the times without renewable energy production are as less as possible.

At this current state, only the lights of the pontoon are implemented so the main focus of this report will be about a comparison between the most used light solutions for these applications. The pontoons in port of Ostend are equipped with 12 lighting units. Each unit consists of TL58 fluorescent light with nominal power of 58 W and it is able to deliver 5200 lumen. Within the framework of PECS, reports regarding the lighting is been conducted by CEREMA (Odile Lefrere, 2018) as well as (Dimitar Bozalakov, 2019). These reports suggest that the LED lighting solution is one of the most energy efficient and economically viable solutions when compared to high-pressure sodium lights, halogen lamps, compact fluorescent limp, incandescent lamps, etc.

A comparison between LED light and fluorescent light is presented in Table 4. These results are found in (Stoutchlighting solutions, 2019), and some of the most relevant aspects listed below.

	CFL	Fluorescent lamp
Cycling (Turning On/Off)	LEDs are an ideal light for purposely turning on and off because they respond rather instantaneously (there is no warm up or cool down period). They produce steady light without flicker.	Fluorescent lights exhibit a short delay when turning on. Older fluorescent models actually required a significant warm-up period before the tube would light but this has been significantly improved with newer, rapid-start fluorescent lights. Possible failures or delays in the start-up process are typically due to faulty starters, transformers, or ballast. Fluorescent bulbs may also flicker, display swirling or pink light, light at the ends of the tube only, or cycle on and off as the bulb reaches the end of its useful life.
Dimming	LEDs are very easy to dim and options are available to use anywhere from 100% of the light to 0.5%. LED dimming functions by either lowering the forward current or modulating the pulse duration.	Newer CFL bulbs can be dimmed very effectively (down to about 15% of their normal light) while older fluorescent bulbs are often not suitable for dimming. If looking to dim a fluorescent bulb make sure that you choose a ballast that is rated for dimming
Directionality	LEDs emit light for 180 degrees. This is typically an advantage because light is usually desired over a target area (rather than all 360 degrees around the bulb). You can	Fluorescent light is omnidirectional meaning it emits light for 360 degrees, requiring fixture housings or reflectors to direct the emitted light

	read more about the impact of directional lighting by learning about a measurement called "useful lumens" or "system efficiency."	
Efficiency	LEDs are very efficient relative to every lighting type on the market. Typical source efficiency ranges 37 and 120 lumens/watt. Where LEDs really shine, however, is in their system efficiency (the amount of light that actually reaches the target area after all losses are accounted for). Most values for LED system efficiency fall above 50 lumens/watt.	Fluorescent and CFL lights are very efficient compared to incandescent lights (50-100 lumens/watt source efficiency). They lose out to LEDs principally because their system efficiency is much lower (<30 lumens/watt) due to all of the losses associated with omnidirectional light output and the need to redirect it to a desired area
Efficiency Drop	LED efficiency drops as current increases. Heat output also increases with additional current which decreases the lifetime of the device. The overall performance drop is relatively low, however, when compared to fluorescent lights.	Fluorescent lights also experience efficiency losses as the device ages and additional current is required to achieve the same lighting output. Efficiency losses are greater and the degradation time shorter in the case of fluorescent bulbs.
Failure Characteristics	LEDs fail by dimming gradually over time.	Fluorescent lights can fail in a number of different ways. Generally they exhibit an end-of-life phenomenon known as cycling where the lamp goes on and off without human input prior to eventually failing entirely
Lifespan	LEDs last longer than any light source commercially available on the market. Lifespans are variable but typical values range from 25,000 hours to 200,000 hours or more before a lamp or fixture requires replacement.	Fluorescent lights have good lifespan relative to some bulbs but not compared to LED. Typical lifespan values range from 7,000 hours to 15,000 hours before a bulb requires replacement. Note: sometimes fluorescent lights need to be changed out before the end of their useful life to pre-empt serious degradation effects like flicker or changing light colour (turning pink).
Lifetime Costs	LED lighting has relatively high initial costs and low lifetime costs. The technology pays the investor back over time (the payback period). The major payback comes primarily from reduced	Fluorescent lights are relatively cheap to purchase but relatively expensive to maintain. Fluorescent bulbs will likely need to be purchased several times and the associated labour costs will need to be paid in order to attain the equivalent lifespan of a single LED light.

	maintenance costs over time (dependent on labour costs) and secondarily from energy efficiency improvements (dependent on electricity costs).	
Maintenance Costs	LED has virtually zero maintenance costs and the frequency with which bulbs have to be changed out is by far the best on the market.	Fluorescent bulbs require regular re-lamping and ballast replacement in addition to the labour cost to monitor and replace aging or expired components
Upfront Costs	LED light costs are high but variable depending on the specifications. The typical 100W-equivalent LED light costs somewhere between $10 and $20.	Fluorescent and CFL bulb costs depend on the specific type of light. Generally they are cheap compared to LED ($3-$10 for a 100W incandescent-equivalent CFL bulb). Fluorescent tubes vary widely depending on the specific technology (prices between $2 and $30 are typical for the same rating discussed above)
Shock Resistance	LEDs are solid state lights (SSLs) that are difficult to damage with physical shocks.	Fluorescent bulbs are particularly fragile - especially T5, T8, and T12 tubes. Perhaps more importantly, broken fluorescent bulbs require special handling and disposal due to hazardous materials like mercury inside the lights
Cold Tolerance	Minus 40 Degrees Celsius (and they will turn on instantaneously). In (Jiri Vincenec, 2016) is reported that the temperature affects the LED lights only up to 2% if temperature range of 25 degree is considered.	Fluorescent lights with regular magnetic ballasts (such as the T12 tube) is not generally recommended for temperatures below 50-60 Degrees Fahrenheit. For colder weather choose a fluorescent light with an electronic ballast such as a T8 tube
Heat Tolerance	100 Degrees Celsius. LEDs are fine for all normal operating temperatures both indoors and outdoors. They do, however, show degraded performance at significantly high temperatures and they require significant heat sinking, especially when in proximity to other sensitive components.	In literature it is found out that the fluorescent lamps decrease their illumination at extreme temperatures. They are best suited for 25-45 degree Celsius while lower or higher temepratures decrease the illumination with 30 to 50% (C. S. Moo, 2003).
Warm-Up Time	LEDs have virtually no warm-up time. They reach maximum brightness near instantaneously.	Fluorescent lights (particularly the older technology) requires a noticeable warm-up time that varies depending on the light

Warranty	Often 5 to 10 years.	Typically 1-2 years.
Wintery Weather Conditions	LEDs produce significantly less heat than conventional gas discharge lights. This is typically a positive, however, for the unique case of application with traffic lights, there is a small potential that snow can accumulate on the bulbs. In reality, however, this is generally not an issue due to the use of visors and/or proper orientation of the light within a fixture that shields it from the elements.	Fluorescent bulbs are not generally recommended for outdoor lighting. CFLs will work but as the temperature drops the light quality suffers significantly. This is noticeable slightly below the freezing level and dramatic below about 5 degrees Fahrenheit.

Table 4 Comparison between LED lights and fluorescent lamps (Stoutchlighting solutions, 2019)

One of the major disadvantages of the fluorescent lamps is that the emissivity is temperature dependent. Although there are 12 lamps in the pontoon which in total gives 62400 lumen, which is rather high flux for such applications. Since this is outdoor application, during cold winter nights (temperature below 5 degrees Celsius) this light flux will be decreased by almost half.

The manufacturer of the pontoon has equipped the pontoon with 8 LED fixtures where each fixture has two LED trips of 63 W and each strip is able to deliver 6750 lumen. This gives in total 54000 lumen, but the temperature dependency of the LED lights is lower compared to the fluorescent lamps. In addition, the LED lights are almost not dependable on the temperature differences so even in cold winter nights, the flux will be rather constant. This is also confirmed by the results presented in Figure 14.

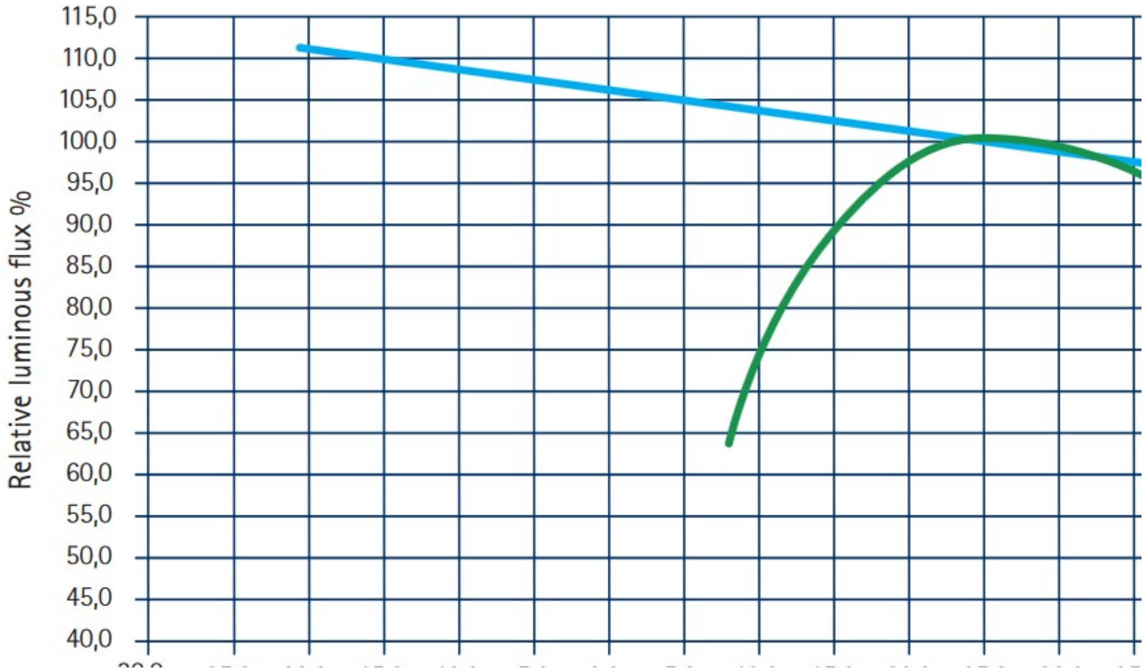

Figure 14 Influence of the ambient temperature on the relative luminous flux (ETAP, 2015)

Despite the higher price of the LED lights over the fluorescent lamps, the better efficiency and longer life span which will pay out the investment. In Figure 15 are presented the typical efficiency ranges for the different lighting solutions and the LED could reach 140 lm/W while the fluorescent lamps can reach top 110 lm/W. In this particular case, the lumen to watt ratios for the used light solutions (LED and fluorescent TL58) is 107 lm/W and 90 lm/W, respectively.

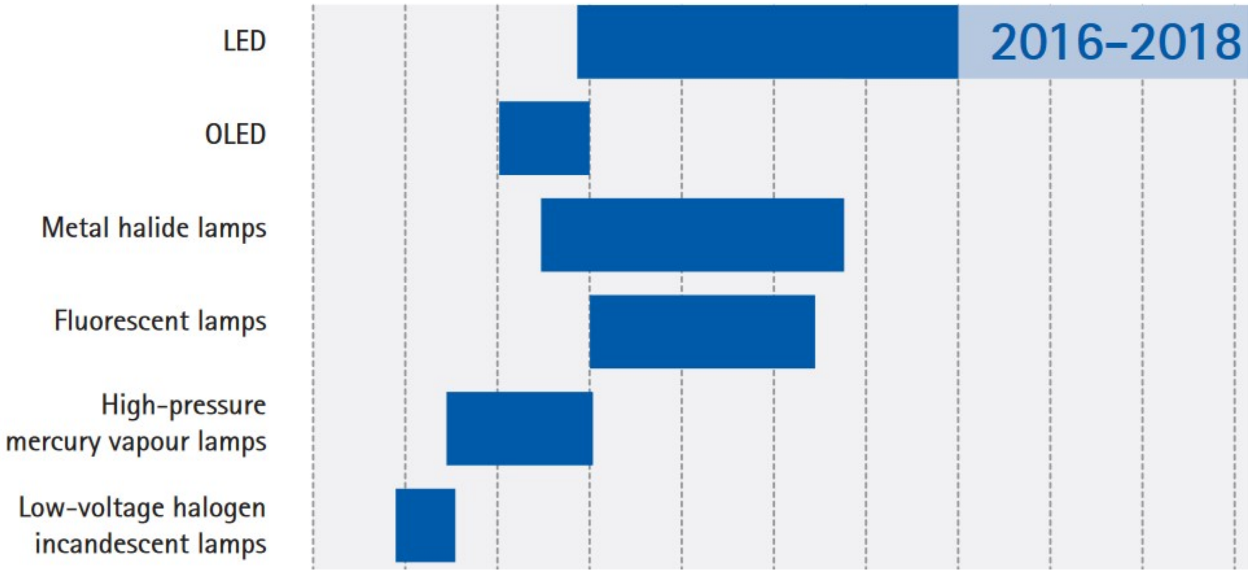

Figure 15 Typical efficiency of different types of lighting solutions (ETAP, 2015)

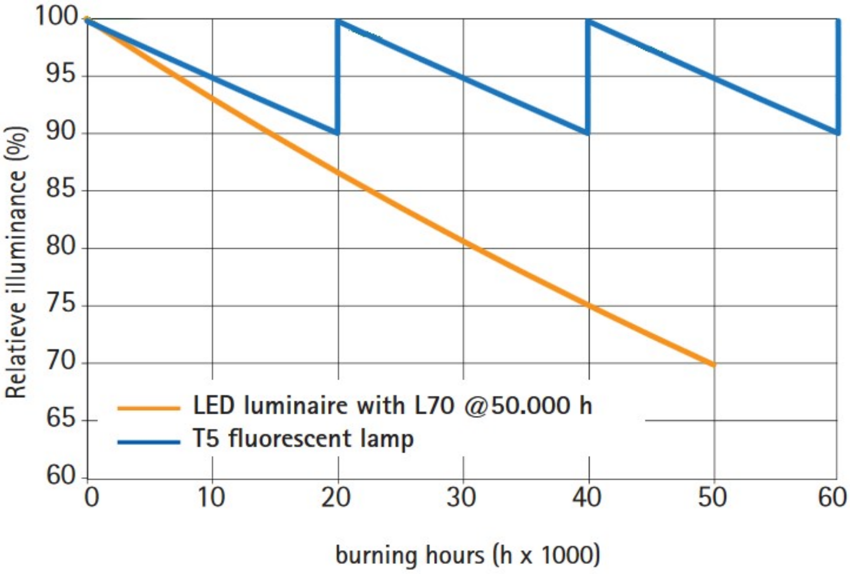

Figure 16 Lifespan comparison between LED and fluorescent lamps (ETAP, 2015)

Figure 16 shows the lifespan comparison between the LED and fluorescent lamps. It can be clearly seen that the life time of one LED lamp is equivalent to 2.5 fluorescent lamps. Therefore, investing in LED lighting solutions will decrease the maintenance cost and electricity consumption. By considering electricity price of 15 €c/kWh and 550 gCO_2/kWh, the annual energy consumption and CO_2 savings as well as lifespan savings are listed in Table 5.

Solution	Energy [kWh] (annual)	Cost [€]	CO_2 [t] annual	Energy [kWh] (lifespan)	Cost [€]	CO_2 [t] lifespan	Number of fixtures
LED	1462	219	20	25200	3780	347	1
TL58	2018	302.7	28	34800	5220	479	2.5
difference	556	83.7	8	9600	1440	132	-

Table 5 Comparison of the energy and CO2 savings per annual and lifespan basis

From the presented comparison results in Table 5 it can be seen that the LED light solution alone (without diming and installing intelligent control) is able to save 556 kWh energy on annual basis which results in 83.7 euro savings of the port and 8 t reduction of the carbon footprint of the port. For the entire life span of the LED light (50 000 h) these numbers are 9500 kWh, 1440 euro and 132 t, respectively.

Conclusions

In conclusion, it is possible to reduce the amount of energy used significantly going from an old to an entirely new situation. From the conducted comparison and feasibility study, it can be concluded that the LED have great potential to bring carbon savings as well as energy saving to the port of Ostend.

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DELIVERABLE 2.1.7: FEASIBILITY OF LEM IJMOND

IJmond (support HZ + UGhent)

Introduction

Basis of the feasibility study for the LEM platform in the port of IJmond is the spreadsheet shown on the next page. This spreadsheet is constructed to weigh the economic benefit, including benefits from prevented CO_2 emissions, against the total costs of the project.
The LEM an abbreviation for Local energy management system. The aim of implementing the platform is to keep as much renewable and locally produced electricity in the area, instead of transporting it to trade it on the wholesale market. This will very likely decrease the grid congestion problems and therefore postpone or prevent grid reinforcement. Therefore this study will only calculate the benefits of the locally produced energy that will stay on the business park specifically due to implementing the LEM platform.

Assumptions

To calculate whether this type of solution is actually feasible, some assumptions are made.

1) *The goal of at least 50 participants by the end of 2020 is achieved.*
2) *The average electricity demand of the 50 participants is 104.000 kWh, which is the equal to the average demand (per business) of the complete business area. (In other words: the mean of the sample is equal to that of the complete population).*
3) The potential for producing electricity, using rooftop solar PV, for the 50 participants is proportional to the potential for the whole business park. (In other words: the mean of the sample is equal to that of the complete population).

Method and results

The table shows us several things. First of all is shows us the current annual energy consumption of the system. This is calculated in the following way:
The average demand for electricity (104.000 kWh) is multiplied by the amount of participants (50), which gives us a total amount of 5.200.000 kWh.
The next step is to decrease the amount of electricity that is produced by rooftop solar PV, which is 4.098.706 kWh. However this doesn't mean that all of this electricity can be locally used. Figure 1 shows why this is the case.
Figure 1 shows that an overproduction of solar PV exists from April to August. This means the excessively produced electricity will not be used locally and therefore needs to be subtracted from the local renewably produced electricity. This leaves us with an renewable energy use of 3.104.163 kWh and a total electricity demand (from outside the business park) of 2.095.837 kWh. This is the amount that is written down in the table. The corresponding CO_2 emission of this electricity use is 1237 tons, based on an emission of 0,59 g/kWh.

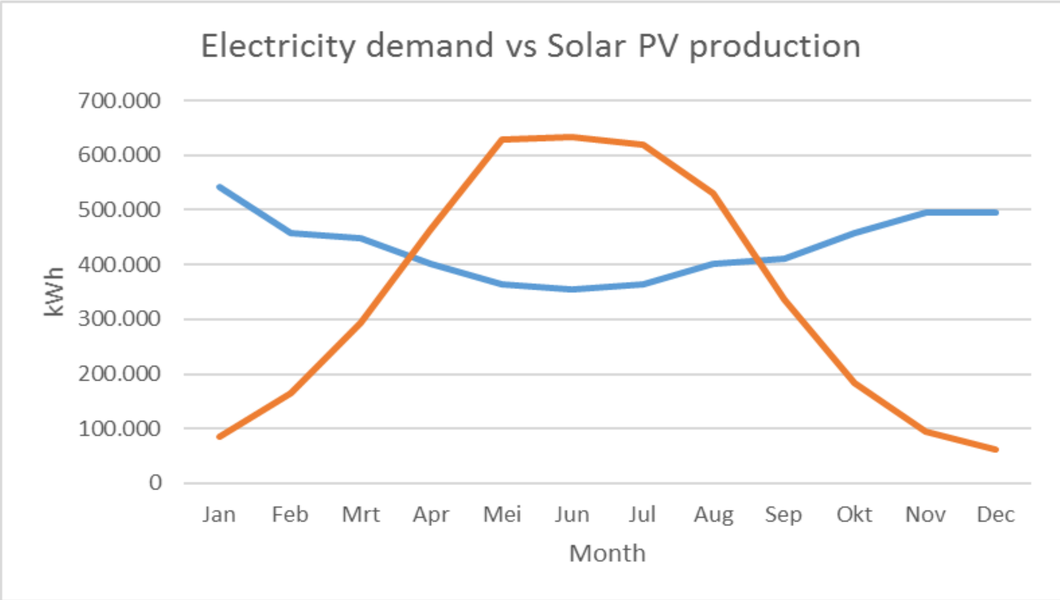

Figure 7.1 Electricity demand vs local production in the PECS IJmond system (Ruiter, 2018).

The next step is to calculate the future energy consumption. The hardest thing in this stage of the analysis is estimating the extra amount of energy that stays on the business park, solely due to the implementation of the LEM platform. This is done by analysing existing literature about demand response programs in smart grid environments. Authors like Albadi and El-Saadany (2008); Kirschen et al., 2000; Edward and Policy (2005); Moghaddam et al. (2011); Lijesen (2007); Roger (2008) estimate that the elasticity of substitution is between -0,065 and -0,14 on peak demand. This means that approximately 6,5%-14% of the peak energy demand can be shifted towards a different time period (when using a demand response program). Because of the indicated uncertainty, we use the more conservative estimation of a 6,5% reduction of peak demand. This would mean 6,5% more energy will stay on the business park, instead of being transported to be sold on the wholesale market.

Now we can calculate the future electric energy consumption of the business park, after implementation of the LEM platform. Before implementation the surplus production, or the amount of electricity being returned to the grid, was 994.544 kWh. This will be reduced by 6,5% after implementation of the LEM platform. Therefore 'only' 929.989 kWh will be returned to the electricity grid. This means the future electricity consumption will be the total electricity use (5.200.000), minus the total rooftop solar production (4.098.706) subtracted by the return to the grid (929.989 kWh). The calculation looks as follows: 5.200.000 – (4.098.706 – 929.989) = 2.031.191 kWh.

This means a total reduction of 2.095.837 – 2.031.191 = 64.645 kWh could be realized.
The future annual CO_2 emission than will be 1152 tons, which means an annual CO_2 reduction of 1237-1152 = 85 tons could be realized. Which is equal to 6,81% CO_2 reduction.

This brings us to an analysis of the costs of the project. This part is a little bit more straight forward. The costs are split up into two parts: the capital expenditures (CAPEX) and the operational expenditures (OPEX).

The CAPEX costs have a summed total of €134.000. This is built up in the following way:

1) Energy Management (sensing and controlling) System (EMS) module: €80.000
2) Smart meters: €4.000
3) Research: €17.000

The costs for the EMS module or the LEM platform software of €80.000 are based on the tender document used by Omgevingsdienst IJmond to select a LEM software provider. This amount has resulted from an extensive market consultation held by Omgevingsdienst IJmond (who was supported by TNO). This market consultation has taken place with the following 7 parties: Energy 21, EnergyZero, SWECO, EXE, Econvert, Scholt energy and Enervalis.

The costs for the smart meters are based on the earlier mentioned 50 participants, which all need to pay €80 for smart meter implementation. 50x80 = €4.000

The research costs were needed to get a good picture of the most important functionalities of the LEM platform. TNO executed this study.

The OPEX costs need to be made for implementation of the ESCo. These are costs for one person, who will be working for two days a week, to establish an ESCo. The total costs are €50.000, which means €25.000 annually.

The minimal pilot lifetime is now estimated at 2 years. After this period the pilot phase should be over and the LEM platform should be running under the control of the ESCo.
All costs are add up (CAPEX+OPEX) and divided by the minimum pilot lifetime.

Table 7.1 Spreadsheet to assess the economic viability of a pilot.

Preliminairy viability check PECS pilots Tool: Jacob van Berkel, HZ University of Applied Scieces Data provided by: Niels Tijhuis, Nick Ruiter, ODIJmond

Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	Business parks in the harbour area of the IJmond, spread across two municipalities, Beverwijk and Velsen.
Where is the system boundary (e.g. the perimeter of the harbour).	
What is the PECS pilot system?	The Local Energy Management-platform will offer flexible distribution (based on demand and generation) of local renewable energy. Local actors (e.g. SME-firms) with high energy demands or supply are connected to this virtual platform by way of an IT-connection and smart meters, and will be enabled to access the market, offer flexible capacity and purchase local reneweble energy when required or when it is economically most beneficial.
Current system performance	
What is the current annual energy consumption of the system [kWh/a]	2.095.837
What is the current annual CO2 emission [tonne/a]	1.237
Future system performance	
What is the future annual energy consumption of the system, after implementation of the pilot [kWh/a]	1.953.069
What is the future annual CO2 emission, after implementation [tonne/a]	1.152
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€]	
Energy Management (sensing and controlling) System (EMS) module	80.000
Smart meters	4.000
Research costs	17.000
Total CAPEX	101.000
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	**€ 25.000**
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	2

Annual Energy + CO2 benefit, expressed in €:	**€**	**120.700**
Annual costs (simple), expressed in €:	**€**	**75.500**

Reduction of CO2-emission of the system, after implementation of the pilot [%]	**6,81%**

Conclusions

Based on the results shown above, a LEM platform in the port of IJmond seems to be economically feasible. The final annual benefits, expressed in euros is €120.700, whereas the annual costs are €75.500. This means the returns are 60% higher than the costs!

Sources

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DELIVERABLE 2.1.8: FEASIBILITY OF A RECUPERATIVE STEAM TURBINE AT INDACHLOR

Indachlor (support Cerema)

Introduction

Background information on the IndaChlor project

The EU has established a hierarchy in waste treatment. The solutions can be to aim at:

1. No more waste generation.
2. Produce waste that is easily and directly recoverable.
3. Treat the waste in such a way as to make it easily recoverable, or extract a valuable fraction (material or energy).
4. Treat the waste to destroy or extract a fraction that makes it harmful, or reduce its volume.
5. Store the waste (with possible prior stabilization).

This hierarchy is currently complemented by an action plan of 2 December 2015 of the European Commission adopting an ambitious package of measures in favour of the circular economy and the adoption of a package of measures relating to the circular economy and guidelines on the energy recovery of waste. The EU Action Plan includes measures covering the entire product life cycle, from design, supply, production and consumption to waste management and the secondary raw materials market.
What are the waste management measures planned?
Europe is currently losing some 600 million tonnes of waste materials every year that could be recycled or reused. Only about 40% of the waste produced by EU households is recycled, with recycling rates ranging from 80% in some areas to less than 5% in others. The transformation of waste into resources is essential to make more efficient use of them and to move towards a more circular economy.
What is the Commission doing to encourage the transformation of waste into resources (secondary raw materials)?
Secondary raw materials still represent only a small proportion of the production materials used in the EU. There are significant barriers to their integration into the economy, for example due to uncertainty about their composition. Standards are needed to build trust.

General presentation of the IndaChlor operation

The schematic diagram of the synergy of the industrial process at the Loon-Plage - IndaChlor site with the neighbouring industrial sites is presented below:

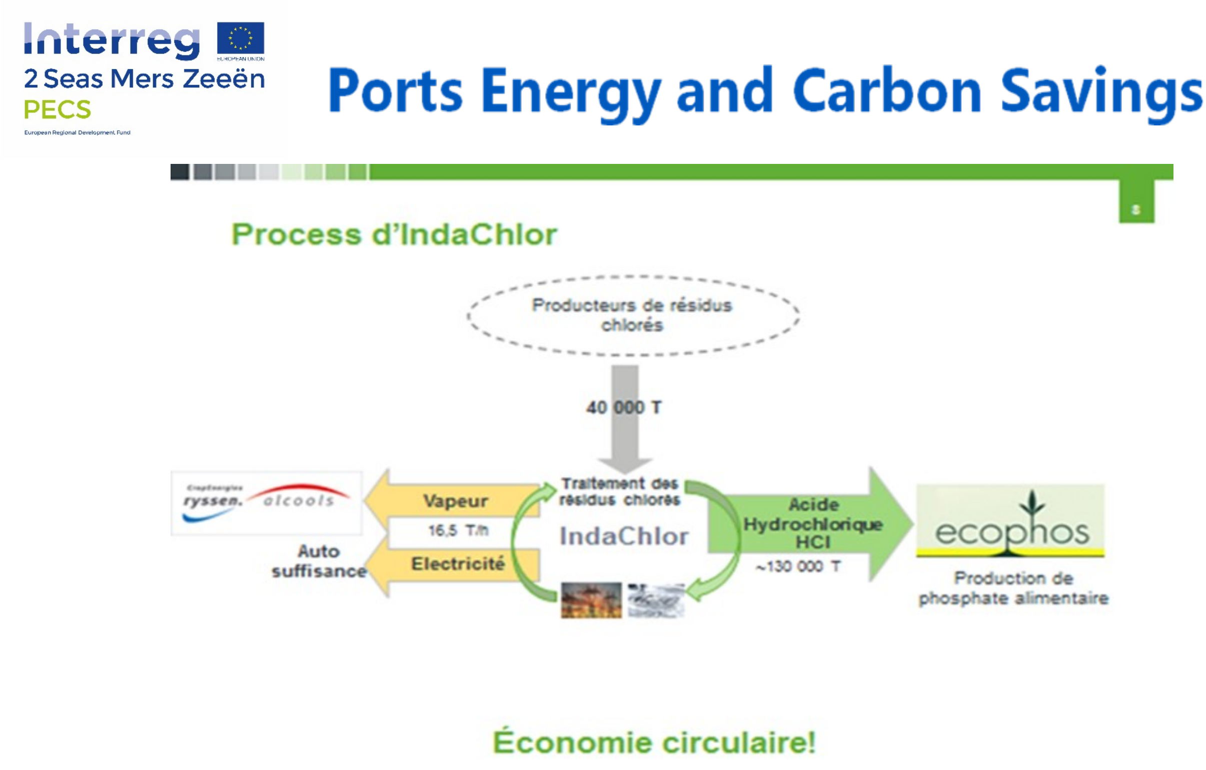


Figure 8.1 The project: Technical content of the investment with flow sheet / description

The following diagram illustrates all the installations of the thermal treatment process for chlorinated liquid hazardous waste at the Loon-Plage operating site.

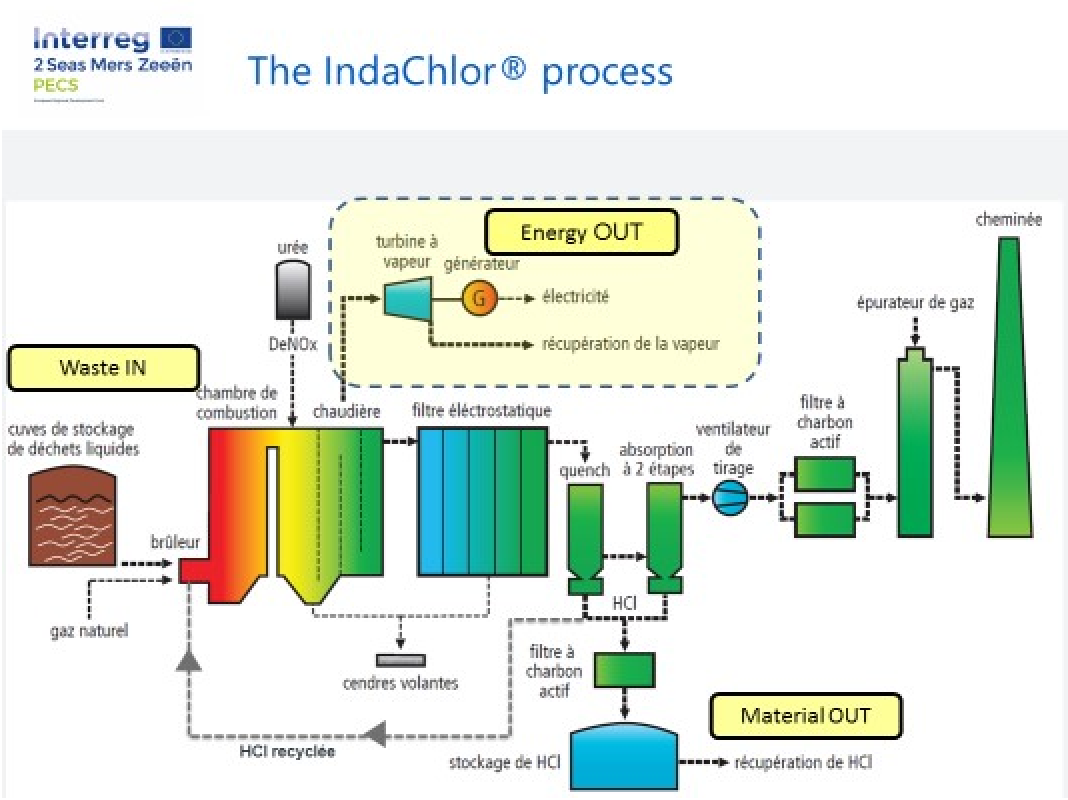


Figure 8.2 The project schematic.

The purpose of the installation is:
- the valorisation of the recovered hydrochloric acid on the neighbouring site of the French branch Aliphos (Ecophos Group) located in the North-East: this branch specialises in the production of phosphates and uses hydrochloric acid for the extraction of phosphates contained in the rock and phosphates contained in sewage sludge incineration ash;
- the energy recovery of the vapours produced to meet the needs of the neighbouring site of the company Ryssen Alcools located in the North, which specialises in the production of alcohols used in the composition of drinks, intended for perfumery and the production of green fuels (bioethanol);

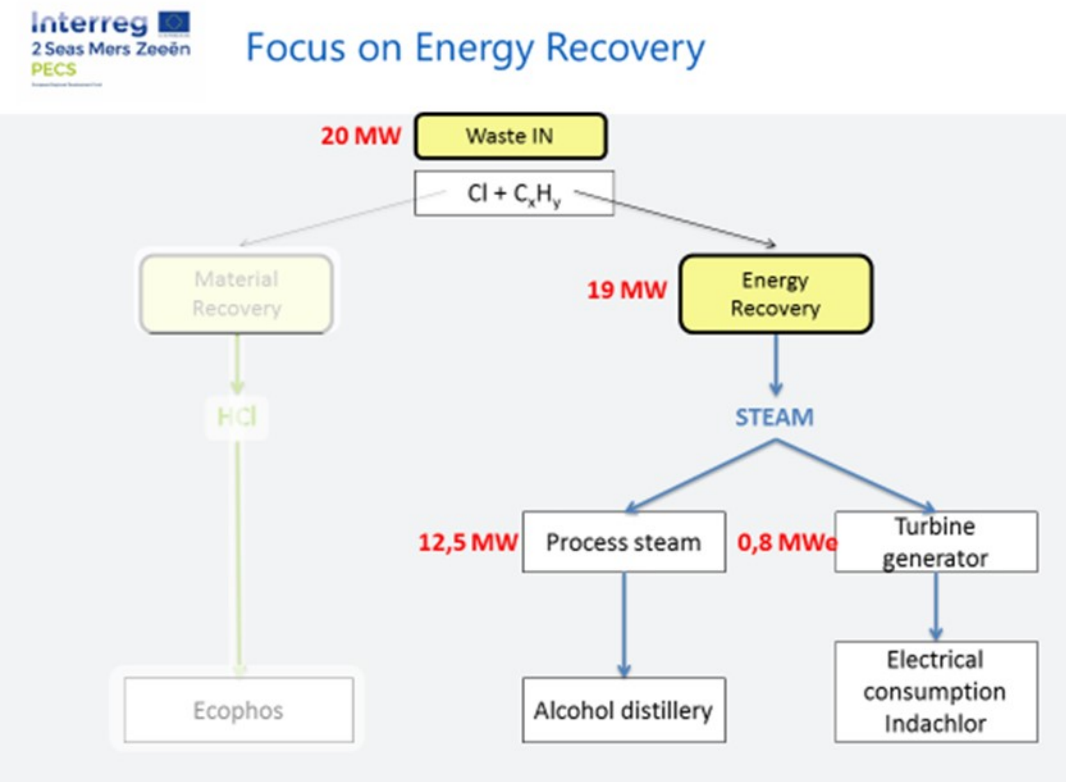


Figure 8.3 Energy recovery outline

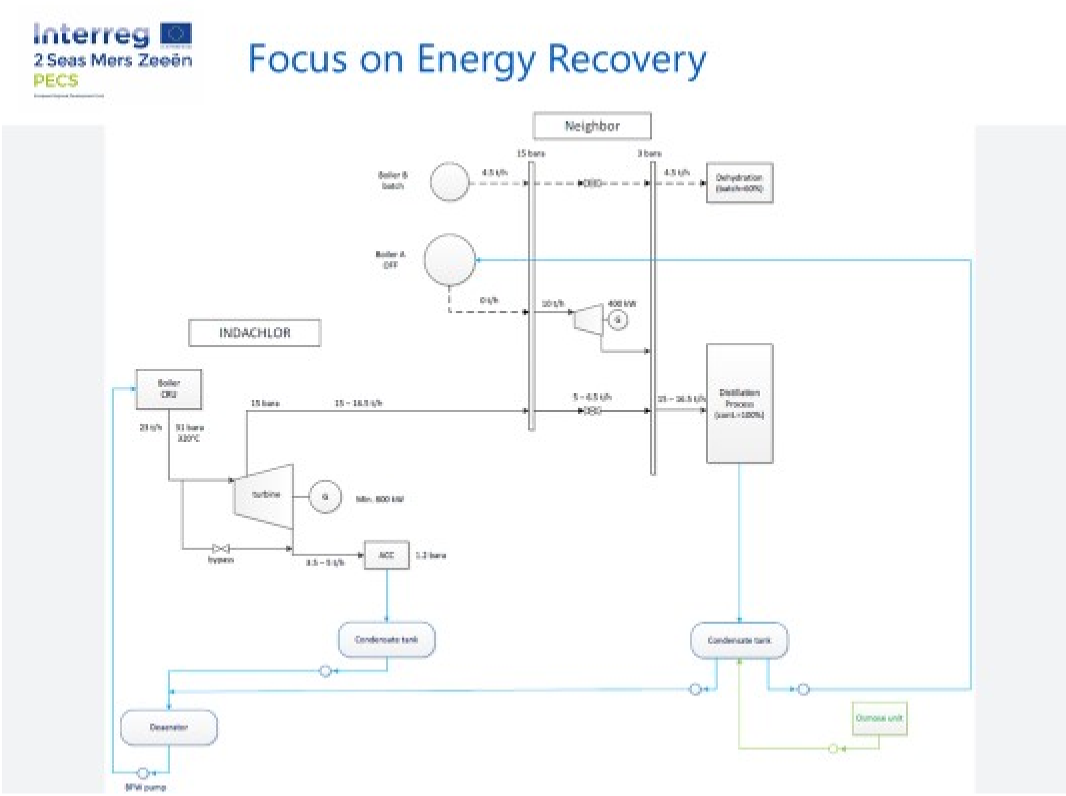


Figure 8.4 Process outine

- the production of electricity from part of the steam released by a turbine. This electricity will be reused as a priority to supply the site's installations and may be fed into the EDF grid in the event of a surplus.

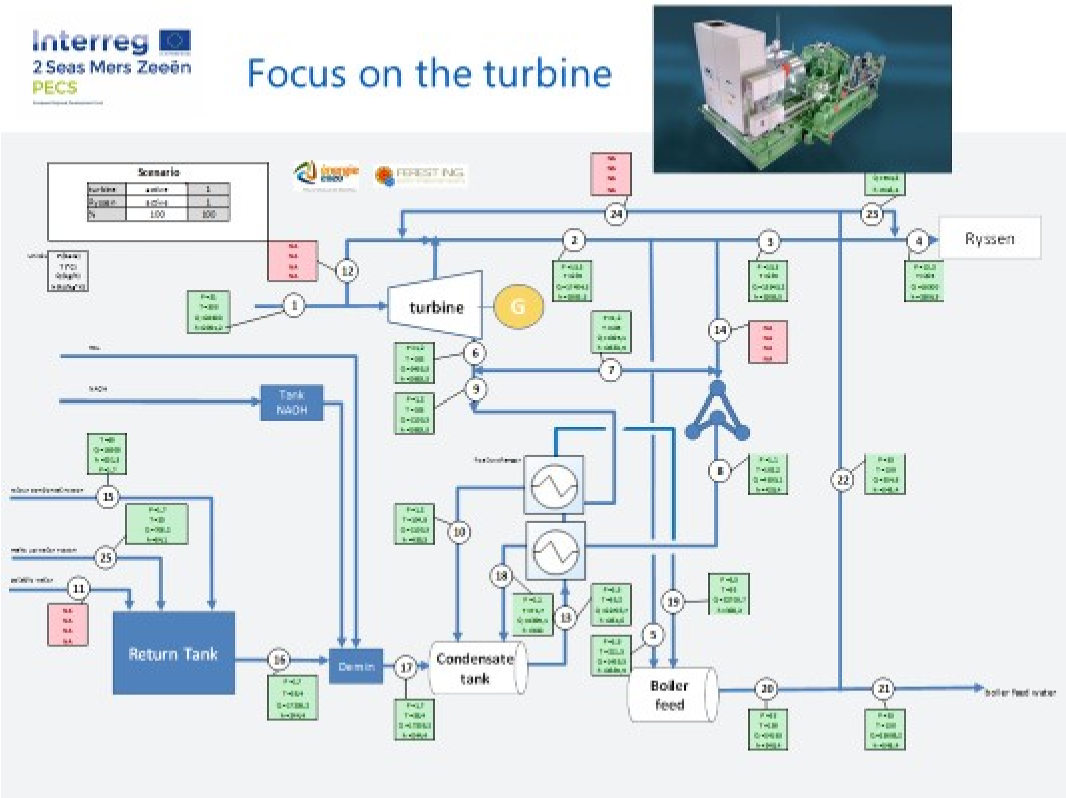


Figure 8.4   Process outine

The IndaChlor pilot within the Interreg project 2 Seas has its focus on the energy recovery and electricity production part of the installation only.

Objectives to be achieved

At the Loon-Plage site, IndaChlor plans to operate a thermal treatment unit for chlorinated solvent waste, called "IndaChlor" for "chlorine recovery unit", with a dual objective of material and energy recovery. Recycling these hazardous wastes will produce hydrochloric acid (HCl) and use the heat from the process to produce water vapour and electricity.
IndaChlor's process will ensure a stable supply of secondary raw materials and renewable energy to neighbouring industry.
The heat treatment process planned by IndaChlor will allow the treatment of pollutants contained in used organic solvents with high chlorine concentrations. On the other hand, this process will offer the opportunity to recover 99.5% of the chlorine contained in these liquid hazardous wastes, in the form of hydrochloric acid (HCl). The recovery of hydrochloric acid (HCl) from organic waste chlorinated solvents will replace the production of hydrochloric acid (synthesis of hydrogen chloride from chlorine (Cl2) and dihydrogen (H2) or co-production during the formation of chlorinated organic compounds) which is an extremely energy-intensive industrial process.
For this reason, Indaver has sought an optimal solution where steam can be valorised directly. This solution was found thanks to the synergy with Ryssen Alcools, which uses steam directly in their process.

IndaChlor through its project will also reduce (traffic impact study) to half the external transport (by truck or rail) that would be necessary for Ecophos in its supply of hydrochloric acid.

Expected results (target...)

IndaChlor through its waste recovery project will produce new secondary raw materials and recover the entire chlorine molecule (40,000 tonnes containing 65% chlorine), and consequently reduce

1. by half the external transport (by truck) that would be necessary for Ecophos in its supply of hydrochloric acid (130,000 tonnes per year)
2. the natural gas requirement (104,000 MWh per year; except during maintenance/repair periods) of Ryssen.

Ecophos: Avoid raw material consumption and transport benefits

Ecophos requires a large volume of HCl in their production. Without IndaChlor, its volumes will be supplied by external 33% HCl suppliers from Germany, France, Belgium and the Netherlands.

The synergy with IndaChlor allows Ecophos to substitute their external raw material HCl with IndaChlor HCl from chlorinated waste.

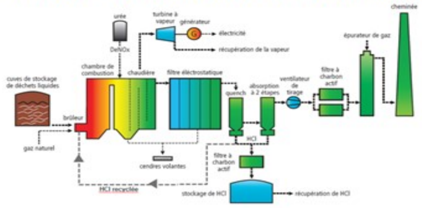
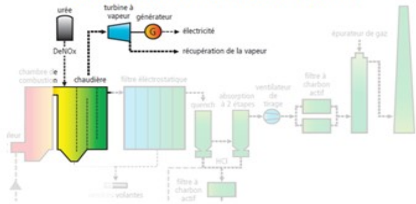
In addition, there is a gain on transport of +/- 50%:

- IndaChlor's capacity (40,000T of waste at 63%) results in a volume of 129,550T HCl 20%. Only the 40,000T of incoming waste will be transported by truck and rail. Transport between IndaChlor and Ecophos will be done through a pipeline connection.
- If Ecophos imported this volume in HCl externally, this is equivalent to a volume of 78,515T (=129,550*0.2/0.33) - because the commercial concentration is 33%.
- The synergy between IndaChlor and Ecophos then results in a transport reduction from 78,515T to 40,000T or almost 50% reduction!

Ryssen Alcohols: Substitution of fossil energy by energy from waste

Today, Ryssen Alcools uses a gas boiler for their energy needs. IndaChlor will make it possible to substitute the majority of their fossil energy consumption with energy from waste. Specifically, the symbiosis will achieve a natural gas reduction of 104,000 MWh/year equivalent to a CO2 reduction of approximately 20,500 T/year.

Preliminairy viability check PECS pilots
Tool: Jacob van Berkel, HZ University of Applied Scieces
Data provided by: Jan Geroms, Indachlor

Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	(part of) a 40k tonnes/year highly chlorinated waste treatment facility. It will recovers all Cl in form of HCl for re-use and recovers all energy through steam (19MW thermal power). 
Where is the system boundary (e.g. the perimeter of the harbour).	Arond the new sustainable energy plant
What is the PECS pilot system?	The pilot concerns the engineering, supply and construction of a turbogenerator and its anciillary equipment (electricity & instrumentation and automation). 
Reference electricity price [ct€/kWh]	**5**
Reference costs CO2-emission [€/tonne]	**20**
Current system performance	
What is the current annual energy consumption of the system [kWh/a]	6560000
What is the current annual CO2 emission [tonne/a]	3608
Future system performance	
What is the future annual energy consumption of the system, after implementation of the pilot [kWh/a]	
What is the future annual CO2 emission, after implementation [tonne/a]	
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€]	3050000
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	61000
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	20

Annual Energy + CO2 benefit, expressed in €:	**€**	**400.160**
Annual costs (simple), expressed in €:	**€**	**213.500**

Reduction of CO2-emission of the system, after implementation of the pilot [%]	**100,00%**

DELIVERABLE 2.1.9: FEASIBILITY OF BPS PONTOON

To be written by UGhent

2. INTRODUCTION

To reduce the carbon footprint of the port of Ostend, the potential of using carbon saving and renewable energy technologies is investigated. According to the Kyoto protocol, all carbon emission must be reduced by 20% by 2020. Carbon saving and renewable technologies seem very promising solution to reach these ambitious targets.
With the development of this research, ethical dilemmas like different facilities, changes of energy are possible to have some potential problems like environmental dangers and also personal benefit. For instance, installing a big wind turbine may put at risk (or in danger) bird specious, so additional measures should be taken to minimise the risk for the nature.
The goal of this report is to perform a basic examination of some possible solution so that the carbon saving is achieved in the port of Ostend. Carbon saving and renewable technologies with a high technology readiness level (TRL) are considered to conduct the feasibility studies. The outcome of these studies will be used to form business cases so that energy cost is reduced, and also more effective use of the energy is achieved.
By measuring the carbon footprint of the energy consumption of the port, a carbon saving goal can be set. In the business cases, some technical, economic (including cost and benefit) and environmental challenges will be considered. Within this report, the potential of renewable energy sources such as solar, wind, wave and tidal will be briefly examined. In addition, storage elements such as chemical batteries will be also discussed. Port officers and wind turbine researchers are selected as our interview object, relevant reports are chosen for our desk research.
For port of Ostend, three business cases/pilots are investigated, concerning application of:

1. Medium-sized wind turbine with rated power of 100 kVA - D 2.1.5
2. Smart LED lights pontoon D. 2.1.6.
3. A BPS (Blue power synergy)-energy pontoon - D 2.1.9

The options were selected after a pre-feasibility study and discussion with the port staff in Jan 2019. Given the very small tidal amplitude, (0,5 m), tidal energy was not considered for further investigation.

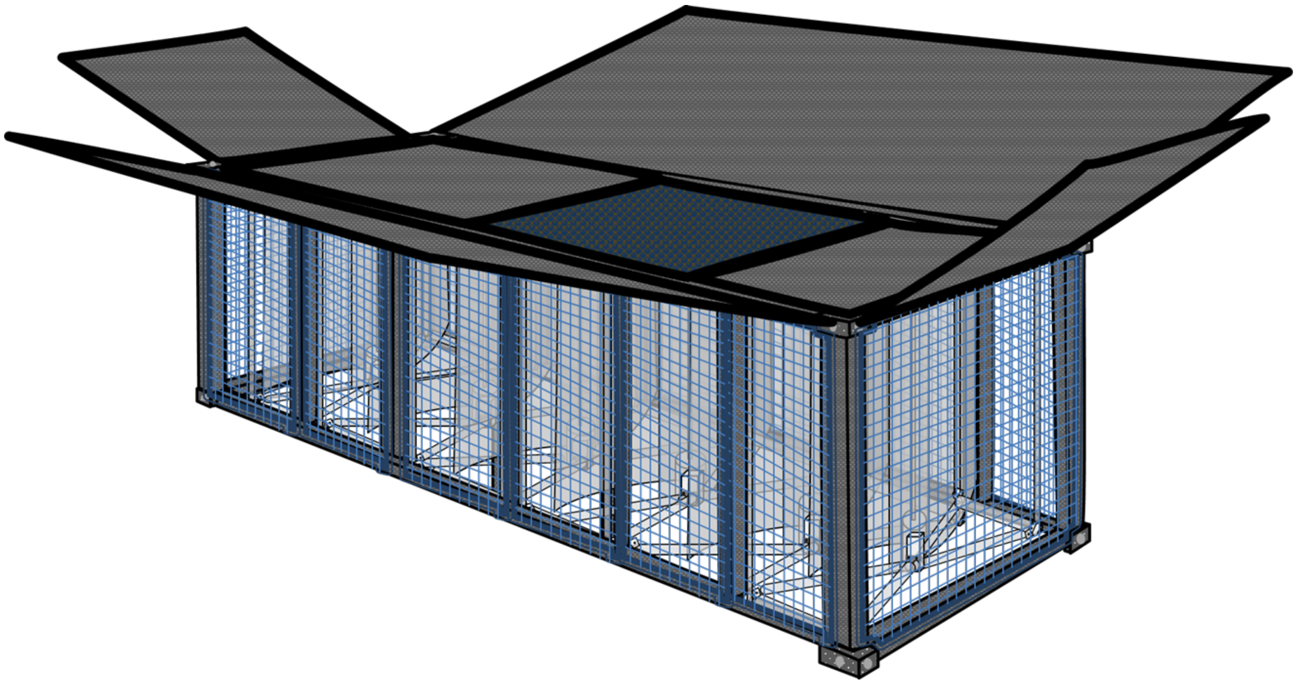
ENERGY PONTOON BPS

Usually, in remote areas of the port where the distribution grid is not present and to maintain activities that need electricity a diesel generator is used. However, these generators suffer from very low efficiency, the CO2 emissions are very high and the ratio €/kWh is very high. The purpose of the developed pontoon by BPS, in the framework of PECS, is to provide electrical energy (or heat) in remote places of the port where the access to the distribution grid is not available or to operate in grid connected mode and inject energy into the grid. The energy pontoon is equipped with renewable energy technologies which provide this electrical energy. However, due to the intermittent behavior of the renewables, a combination of two or more renewable sources is made in order to ensure continues supply of energy to the load. Solar irradiation is available only during day hours and when clear sky is available. Therefore, at night the renewable source does not produce any power. Wind can be present during both, day and night, and it can be harvested with wind turbines and electrical generators to convert the wind flow into electrical energy. Thus the combination of solar and wind energy decreases the intermittency and it increases the reliability of the supply. Nevertheless, there will be periods when any of both will be present. Therefore, a battery storage system is foreseen to cover the load demand when no energy is provided by the renewable energy sources.

SOLAR IRRADIATION POTENTIAL

The energy pontoon has the size of a cargo container (40x8x8 ft) and all sides plus the top are covered by solar panels. A preliminary drawing of the energy pontoon is presented in Figure 17. The total installed peak power is 14 kW.

Figure 17 Sketch of the energy pontoon developed by BPS

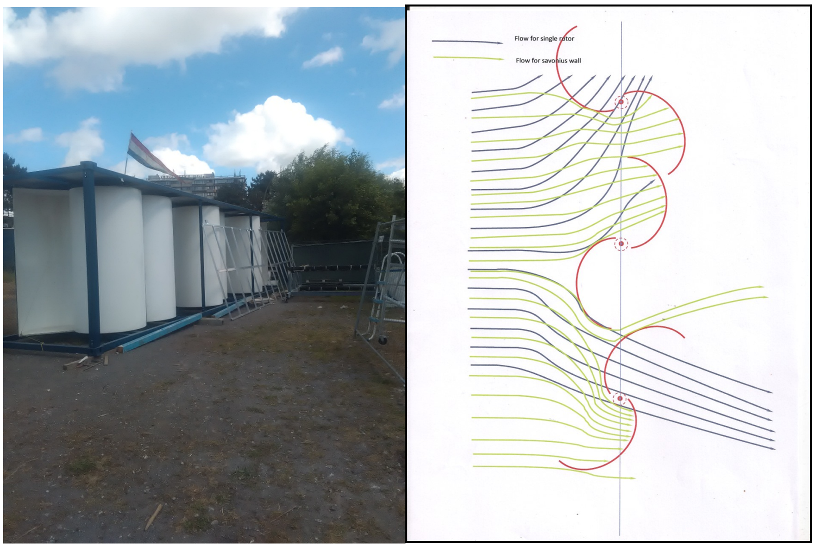


According to [1] the average solar irradiation given for the latitude and longitude of the port of Ostend is 950W/m^2. Therefore, a rough estimate of the total annual production of the solar energy of the pontoon will be 15.2 MWh. The pontoon can operate also in grid connected mode and taking into account the price of 15 €c/kWh it will return 2 280 €/a. Note that this is a preliminary calculation. Measurements on the field of the pilot will be performed and the final annual energy yield will be then assessed more accurately.

WIND POTENTIAL

As mention above, wind energy can be also harnessed to decrease the intermittency of the renewables. In this pontoon 6 Savonius' vertical axis wind turbines are used as shown in Figure 18 a). The rotors are arranged in an innovative configuration that allows each of the rotors to harvest the redirected wind form the neighbor rotors. Thus, the harvesting of the wind energy is improved. To achieve this, the rotors must be synchronized in order to avoid mechanical contact and thus failure in the rotor blades. Hence, all rotors of the wind turbines are mechanically connected and thus synchronized.

According to [2], the average wind speed for an entire year in Ostend is 5m/s. In order to ensure smoot mechanical power the wind turbines are paired in two and their mechanical output is passed to a water hydraulic system. Then the hydraulic system transfers the smooth mechanical power into electrical power. To do so, three hydraulic systems with peak power of 7.5 kW are used. The manufacturer has installed two (optional 3) 7.5 kVA generators in the energy pontoon. According to [4], large wind turbines achieve 2000 full load hours which makes them very promising solution for decreasing the carbon footprint. By making the same assumption, the proposed set of wind turbines has the potential to achieve 45 000 kWh annual energy yield which will bring a gross profit of 6 750 €. Nevertheless, because of the innovative topology, some final tests and measurements will be performed in the pilot installation to access more accurately the annual energy yield of the wind turbines.



a) b)

Figure 18 Advanced wind turbine topology used in the energy pontoon of BPS

The choice of a Savonius type wind turbine guarantees low noise level which makes them very suitable for leisure ports and marinas.

WAVE POTENTIAL

Wave energy is another renewable source that could be harvested and converter into usable energy. Mechanical and hydraulic actuators are used to convert the mechanical energy into rotational moment which turns the shaft of an electrical generator. According to the manufacturer of the pontoon, the wave energy potential should have wave height of at least 0.5m and period smaller than 6s in order for the wave converter to be economically viable. Unfortunately, the Belgian harbors do not have this wave potential so the wave converter will not be implemented and investigated further for the moment. A test could be performed at a test position at sea once the test location will be disponible.

ENERGY STORAGE

The combination of different type of renewable energy sources results in a reduced intermittency of the energy supply but there will be some periods when no power will be delivered by the renewable sources. Therefore, some storage elements could be used to contain the excess of energy and contain it for a later use. Battery storage systems are promising solution for energy storage and in the recent years they became an economically viable solution because of the decreasing prices of the storage. Reference [5] reports prices of about 500-700 €/kWh and a life span of 10 years which also includes the power electronic inverter. The total amount of cycles is about 3000 to 5000 cycles but it is also dependent of the depth of charge. Therefore, end-user prices of about 0.15 to 0.24 €/kWh can be expected.

The energy pontoon will have a battery storage system with a capacity of 37 kWh with the possibility for expansion up to 75 kWh. This stored energy will be used to satisfy the energy demand which is needed to maintain the activities in the remote areas in the port when the solar and wind are not available.

Finally, by using the pilot verification tool developed by PP4 (HZ University of Applied Sciences), a summary of the feasibility study is listed in **Fout! Verwijzingsbron niet gevonden.** where the CAPEX and OPEX are also given.

CONCLUSION

The combination of solar and wind power has a great potential to significantly reduce the carbon footprint of the ports. In this particular pilot, the energy pontoon has the potential to produce 60.2 MWh of electrical energy annually which can result in a total reduction of carbon emissions with about 33.1 t/annually.

Literature:

[3]https://globalsolaratlas.info/?c=51.230314,2.942263,11&s=51.235647,2.935222&e=1

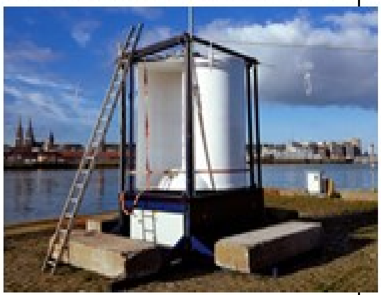
[4]https://weather-and-climate.com/average-monthly-Wind-speed,Ostend,Belgium

[5]https://www.windfinder.com/windstatistics/oostende_pier

[6]Timmerman J., Deckmyn C., Vandevelde L. and Van Eetvelde G. "Low carbon business park manual : a guide for developing and managing energy efficient and low carbon businesses and business parks," 2014

[7]Global trends in renewable energy investments in 2018, Frankfurt School-UNEP Centre/BNEF. 2018.

Table Spreadsheet to assess the economic viability of a pilot.

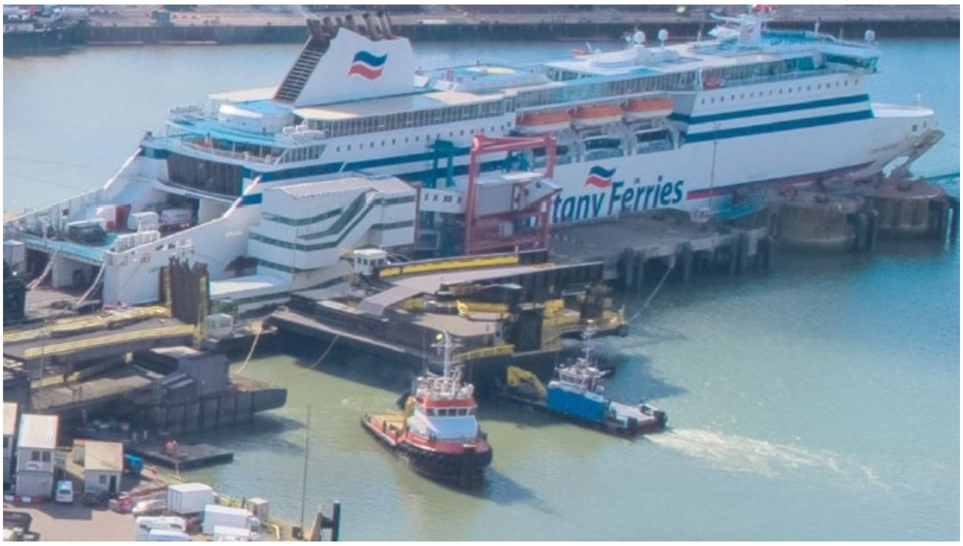
Preliminary viability check PECS pilots **Tool: Jacob van Berkel, HZ University of Applied Sciences** **Data provided by: Yvon Timmerman, BPS**	
Brief description of the system and the pilot	Character
Brief description of the system in which the pilot is implemented (e.g. a part of the harbor)	Pontoon, with wind turbine and 
Where is the system boundary (e.g. the perimeter of the harbor).	boundary is perimeter of pontoon
What is the PECS pilot system?	pilot = pontoon, with turbine, panels and optionally storage
Reference electricity price [ct€/kWh]	**15**
Reference costs CO2-emission [€/tonne]	**20**
Current system performance	
What is the current annual energy consumption of the system [kWh/a]	60200
What is the annual potential of saving CO2 emission [tonne/a]	33.11
Future system performance	
What is the future annual energy consumption of the system, after implementation of the pilot [kWh/a]	0
What is the future annual CO2 emission, after implementation [tonne/a]	0
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€]	170000
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	340
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	25
Annual Energy + CO2 benefit, expressed in €:	**9,692 €**
Annual costs (simple), expressed in €:	**7,140 €**
Reduction of CO2-emission of the system, after implementation of the pilot [%]	**100.00%**

DELIVERABLE 2.1.10: FEASIBILITY STUDY OF LINKSPAN

Portsmouth (support Solent)

Introduction

Ports Energy Carbon Savings (PECS) addresses the challenge of achieving carbon reductions through the introduction of low carbon technologies in maritime operations in small to medium sized ports. The main focus is on demonstrations of low carbon technologies and solutions in real life and different circumstances using the best mix of low carbon options. This post –feasibility is written in the realisation of the construction, delivery, installation, acceptance and operation of the Link-span having already taken place but in deep and grateful acknowledgement of the contribution of Interreg 2 Seas and the requirements of their Letter of Notification dated 24/07/2018.



Portsmouth International Port

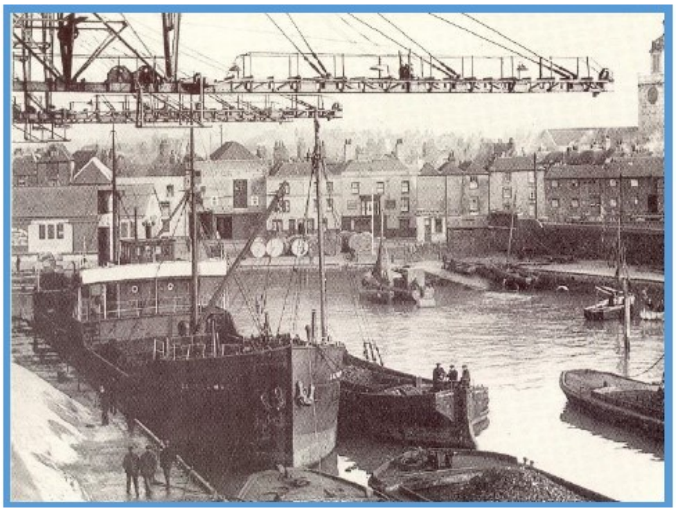
Portsmouth International Port is owned by the people of Portsmouth (Portsmouth City Council) and is in that regard rather unusual in the UK as being one of the few successful ports within the UK that is not in private business hands.

The main business of the Port (unloading and loading ships) takes place on five R0-Ro berths (Roll-On/Roll-Off) and two 'standard' berths that take ships with a more normal discharge and loading method usually involving cranes, fork lift trucks and Lorries.

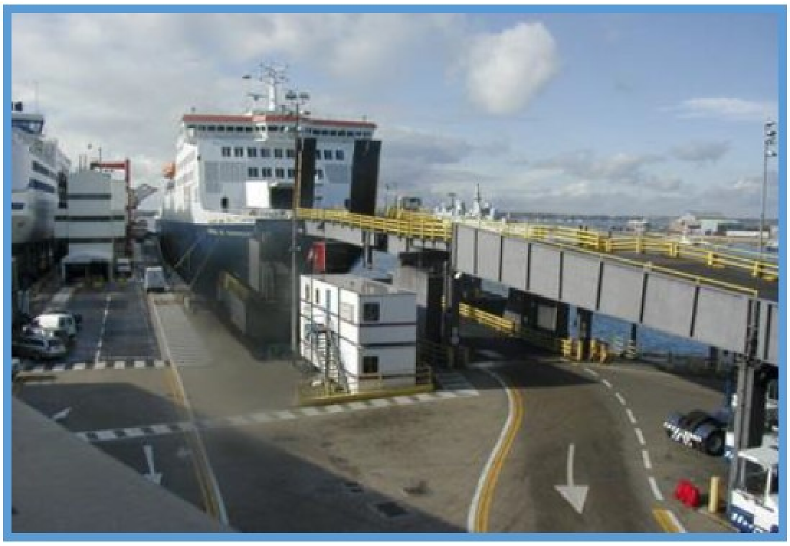
Portsmouth Port has the advantage of Geography in that its position to the West of Dover makes it the natural port for traffic wishing to access France to the West rather than travelling East to Dover and then having to 'back-track' once landed in Calais from Dover. In measures of traffic Portsmouth does however have some distance to go in catching up with Dover who at 19M passengers a year

In the small map above you can see that those wishing to travel into France and Spain benefit from travelling through Portsmouth rather than through Dover where a large amount of additional mieleage needs to be undertaken simply to recoup miles added by choice of route. The opening of the Channel Tunnel caused a small dip in numbers but generally the routes served by Portsmouth reflect the choices of passengers who wish to minimise road distance. St Malo, Le Havre, Cherbourg, Caan, Bilbao, Santander.

Development of the Port and Development of Linkspans



Ports develop. They do not choose how to develop (beyond perhaps deciding which trade that they wish to be in and this will usually be based upon whichever trade will bring them most money). In the two photographs above you have the merchant trade of Portsmouth as it would have been seen from the start of WWI into the 1930's. The principal trade seen here was coal. The modern port as we know it does not yet exist it has not been dug out of the weeds and mud of the upper harbour and the chalk cliffs of Portsdown hill have not yet been scarred to provide the in-fill. The main trade was coal because Portsmouth as the home of the Royal Navy needed coal for her new steam ships that had replaced the 'Man of War' sailing ships. This is the Camber Docks, once the heart of the commercial port of Portsmouth it is now home to the Isle of Wight ferry, a few fishing vessels and a yachting marina. It is to some extent an example of the challenges that face any port (not just SMS) ports in having to deal with the challenge of changing trade routes, changing trade types and (in the case of the Camber Docks above) changing fuel choices. Just a few years after these photographs would have been taken the choice was made to convert the Royal Navy from coal to Oil, principally because it would take a large Battleship 24hours to 'raise steam' within her boilers sufficient to proceed out to sea. Changing to oil gave the Navy the ability to sail immediately. Thus the trade for the small port above changed virtually overnight.



Generally speaking, until the advent of WWII, having doors in the front of ships was considered if not unwise then at least perhaps a little risky. The Herald of Free Enterprise and Estonia disasters have done nothing to suggest that this was wrong. However, having a door at each end of the ship allows cars and lorries to literally treat the ship as a simple stretch of road, driving in at one end and off at the other. Turning vehicles around within the vessel loses space and takes a great amount of time. The first serious use of Ro-Ro vessels was in the D Day landings in 1944. All that has changed is that the beach is now a linkspan connected to the port. The linkspan needs to go up and down at the ship at one end and stay connected to the port at the other. A direct route from the port to the National road system also helps.

The picture above shows the port being reclaimed from the shallows at the upper part of the Harbour in 1976. Note the three vessels on the traditional berth to the right (centre) of the picture. This berth is still in use although ships of the length shown no longer have a commercial life in UK waters. The current Maersk vessel that uses Albert Johnson Quay is three times the length of the vessels that you see above.

In 1978 we see the completion of two berths with single lane/single decked link-spans.
Each investment in the port requires a business plan to validate the expense of expansion. The success and take-up of the two berths built in 1976 and 1978 resulted in investment in two further berths which required that new port land needed to be reclaimed. In the picture below you can see a large dredger engaged in pumping sand and gravel behind the piled perimeter to create berths number 3 and 4. As you can already see from the photograph the port is running out of room, there is little room to advance to the North where Whale Island (now the home of RN Fleet HQ) and to the South the Naval Dockyard itself. Time to start making better use of infrastructure in 1982.

Fast forward to 2010 and you see the modern port of Portsmouth below. Already we have started to develop double-decked link-spans (berth No.4) in order to make better use of space and you will see the two fast craft at the bottom of the photograph 'hot berthing' as one waits off the berth for the other to leave.

The International Port of Portsmouth is a very constrained port in terms of land, it makes its business on 14 hectares of land and is constrained on all sides by either water, the Royal Navy or unalterable roadway. It is these constraints that have caused Portsmouth to seek alternatives to simple expansion by joining other SMS ports in finding smart ways of growing. Most recently this has involved looking at more sustainable transport, for instance, alternatives of using road for freight (IMPACTE bid Interreg IIIB 2005 – 2010), making better use of existing infrastructure (C2C 'Connect to Compete' Interreg IVA), port strategic planning (PATCH 'Ports Adapting to Change' Interreg IVA 2007-2013) and the use of innovation to reduce dwell times for HGV's awaiting cargoes WEASTFLOWS (Interreg IVB NEW).

It is no coincidence that these actions have a common theme of improvement and improvement that either creates a more sustainable environment or improves the efficiency of existing infrastructure without jeopardising our futures. The aims of a small, struggling port to improve its efficiency can sometimes lead us to be blind to improvements that may cost more initially but prove a great saving ultimately in terms that cannot be measured in terms of finance. The ability to harness the aspirations of the ERDF and Interreg funding has allowed the author to unlock improvements that might otherwise have gone unsought.

Business Case for a New Linkspan

The following information is commercially sensitive and Portsmouth City Council would ask that the information in the section of the report is not shared with those outside of Interreg 2 Seas and the PECS partners. A linkspan has a rough life. Whilst (like most large pieces of infrastructure) the design life will be stated as 25years, often it does not last that long. This is particularly the case with one of the perennial problems associated with ships and shipping (and one that has cause casualties throughout the world), the wrong declaration of shipping weights. A double decked linkspan designed to take a maximum of 160tonnes at any one time with a safety factor of only 110% might well find herself being ridden over by 240 tonnes of illegally loaded HGV's.

In considering the replacement linkspan for berth number 4 the option of 'doing nothing' was considered as a pre-cursor to the business plan itself, the following was determined:

☐ The do nothing option will result in the berth 4 linkspan becoming un-operational in 2017/18.
☐ This will reduce the number of ships the port can accept. It is highly likely that this would adversely impact on Brittany Ferries sailings. It is uncertain how Brittany Ferries would change their timetable.
☐ The income loss associated with the do nothing option assumes Brittany Ferries will no longer run a Spanish Service from Portsmouth.
☐ It also assumes the port will no longer be able to accept the majority of cruise ship calls.
☐ The annual net reduction in income if we did not have a berth 4 linkspan was £1.3m

Having determined that the 'do nothing' option was not a viable alternative to either refurbishing the existing link-span or purchasing a new one, the options shown in the table below were considered.
It should be stated at this point that where the commercial survival of a port is concerned, the idea of including in a business plan measures to reduce carbon footprint or improve sustainability are not first concerns – they should be but they are not. Where carbon reduction measures result in energy savings however, this is where you can get those involved in the procedure to sit up and take notice. This is also where having like-minded partners in other SMS ports is an advantage, where knowledge can be shared and where mutual aspirations can take 'solid' form as a bid for funds to ensure that Carbon Reduction measures can be incorporated in new designs.
All of the five options shown in the table below are given in detail on the following pages with each option being given its own page. HZ Draft report on HZ-PECS deliverables 54

It should be noted that these Business Plans are for the full piece of infrastructure itself and not for the Carbon Reduction improvements to the initial design which are the result of the PECS bid and subsequent grant funding from Interreg 2 Seas.

BERTH 4 LINKSPAN REPLACEMENT OPTIONS APPRAISAL SUMMARY

Option	Rank	NPV £	Initial Capital Expenditure £	Life of Linkspan Years	Linkspan Downtime Weeks
Option 1: £9m new linkspan in 2017/18	1	11,841,743	9,000,000	25	2
Option 2a: £6m refurbishment offsite. No reduction in income. New linkspan 15 years thereafter	2	12,518,997	6,000,000	15	30
Option 2b: £6m refurbishment offsite. Reduction in income). New linkspan 15 years thereafter	4	13,810,264	6,000,000	15	30
Option 3: £5.6m refurbishment in situ M&E refurb. New linkspan 4 years thereafter	5	16,067,578	5,600,000	4	30
Option 4: £3.1m refurbishment in situ M&E refurb. New linkspan 4 years thereafter	3	13,361,213	3,100,000	4	27
Option 5: Do nothing (do not replace linkspan)	6	25,838,103	0	n/a	n/a

Key Notes and Assumptions Option 1 is the least risky option because: 1) Linkspan downtime is far lower than refurbishment options. 2) During refurbishment unforeseen problems may be identified with the linkspan, which increases the cost refurbishment. With the exception of option 2b) and option 5, the options do not result in a reduction in income. For refurbishment options this assumes: 1) Ferries that would have used berth 4 move to berth 2 or 3. This would mean Brittany Ferries may have to reschedule some of their ships. This could result in a reduction in services running from Portsmouth thus a loss of income (not built into appraisal excepting option 2b). 2) Works are undertaken over the October to March period, and there will be very few cruise calls during this period. 3) If there are cruise calls over the October to March period, they can still be handled by the Port, such as on berth 4. However, this may not always be possible which would result in less cruise calls and a loss of income (not built into appraisal excepting option 2b). Option 2b) assumes Brittany Ferries would move the Baie de Seine ship from Portsmouth (sailing to France and Spain) for a period of 12 months. It also assumes the port could not accept any cruise line calls over the October to March period. Those cruise liners affected will not return to Portsmouth for 5 years. The do nothing option will result in the berth 4 linkspan becoming un-operational in 2017/18. This will reduce the number of ships the port can accept. It is highly likely that this would adversely impact on Brittany Ferries sailings. It is uncertain how Brittany Ferries would change their timetable. The income loss associated with the do nothing option assumes Brittany Ferries will no longer run a Spanish Service from Portsmouth. It also assumes the port will no longer be able to accept the majority of cruise ship calls. Refurbishing the linkspan outside the October to March period is not a viable option. This is because of increased throughput during the summer period, including circa 40 cruise calls. Initial capital expenditure assumes elements of the old linkspan can be salvaged, e.g. components, steel.

Option 1 - £9M New Linkspan in 2017/2018

Option 1: £9m New Linkspan in 2017/18	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
New Linkspan	9,000,000						
Loan	(9,000,000)						
Principle	360,000	360,000	360,000	360,000	360,000	360,000	
Capital Costs Sub Total	**360,000**	**360,000**	**360,000**	**360,000**	**360,000**	**360,000**	
Revenue Costs / (Income)							
Maintenance	-	50,000	50,000	50,000	50,000	20,000	
Interest	372,600	298,080	223,560	149,040	74,520	14,904	
Revenue Costs / (Income) Sub Total	**372,600**	**348,080**	**273,560**	**199,040**	**124,520**	**34,904**	
Net Relevant Cost / (Income)	**732,600**	**708,080**	**633,560**	**559,040**	**484,520**	**394,904**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**732,600**	**641,330**	**519,740**	**415,375**	**326,068**	**245,520**	**11,841,743**

Option 2a - £6M Refurbishment off site, no reduction in Income. New Link-span 15yrs thereafter.

Option 2a: £6m Refurbishment Offsite. No reduction in income. New Linkspan 15 Years Thereafter	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
New Linkspan							
Refurbishment	6,000,000						
Loan	(6,000,000)						
Principle	400,000	400,000	400,000	360,000	360,000	360,000	
Capital Costs Sub Total	**400,000**	**400,000**	**400,000**	**360,000**	**360,000**	**360,000**	
Revenue Costs / (Income)							
Maintenance	-	50,000	50,000	5,000	20,000	50,000	
Interest	248,400	165,600	82,800	357,696	283,176	223,560	
Revenue Costs / (Income) Sub Total	**248,400**	**215,600**	**132,800**	**362,696**	**303,176**	**273,560**	
Net Relevant Cost / (Income)	**648,400**	**615,600**	**532,800**	**722,696**	**663,176**	**633,560**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**648,400**	**557,568**	**437,082**	**536,974**	**446,298**	**393,898**	**12,518,997**

Option 2b - £6M Refurbishment off site. Reduction in income. New Linkspan 15yrs thereafter.

Option 2b: £6m Refurbishment Offsite. Reduction in income. New Linkspan 15 Years Thereafter	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
New Linkspan	-	-	-	-	-	-	
Refurbishment	6,000,000	-	-	-	-	-	
Loan	(6,000,000)	-	-	-	-	-	
Principle	400,000	400,000	400,000	360,000	360,000	360,000	
Capital Costs Sub Total	**400,000**	**400,000**	**400,000**	**360,000**	**360,000**	**360,000**	
Revenue Costs / (Income)							
Maintenance	-	50,000	50,000	5,000	20,000	50,000	
Interest	248,400	165,600	82,800	357,696	283,176	223,560	
Loss of Ferry Income	471,620						
Loss of Cruise Income	107,800						
Revenue Costs / (Income) Sub Total	**827,820**	**215,600**	**132,800**	**362,696**	**303,176**	**273,560**	
Net Relevant Cost / (Income)	**1,227,820**	**615,600**	**532,800**	**722,696**	**663,176**	**633,560**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**1,227,820**	**557,568**	**437,082**	**536,974**	**446,298**	**393,898**	**13,810,264**

Option 3 - £5.6M Refurbishment in Situ M&E Refurb. New Linkspan 4 years later

Option 3: £5.6m Refurbishment In Situ M&E Refurb. New Linkspan 4 Years Thereafter	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
New Linkspan							
Refurbishment	5,600,000						
Loan	(5,600,000)						
Principle	1,120,000	360,000	360,000	360,000	360,000	360,000	
Capital Costs Sub Total	**1,120,000**	**360,000**	**360,000**	**360,000**	**360,000**	**360,000**	
Revenue Costs / (Income)							
Maintenance	20,000	5,000	20,000	120,000	20,000	12,000	
Interest	231,840	357,696	283,176	208,656	134,136	74,520	
Revenue Costs / (Income) Sub Total	**251,840**	**362,696**	**303,176**	**328,656**	**154,136**	**86,520**	
Net Relevant Cost / (Income)	**1,371,840**	**722,696**	**663,176**	**688,656**	**514,136**	**446,520**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**1,371,840**	**654,568**	**544,035**	**511,682**	**345,999**	**277,611**	**16,067,578**

Option 4 - £3.1M Refurbishment in situ M&E refurb. New Linkspan in 4 years

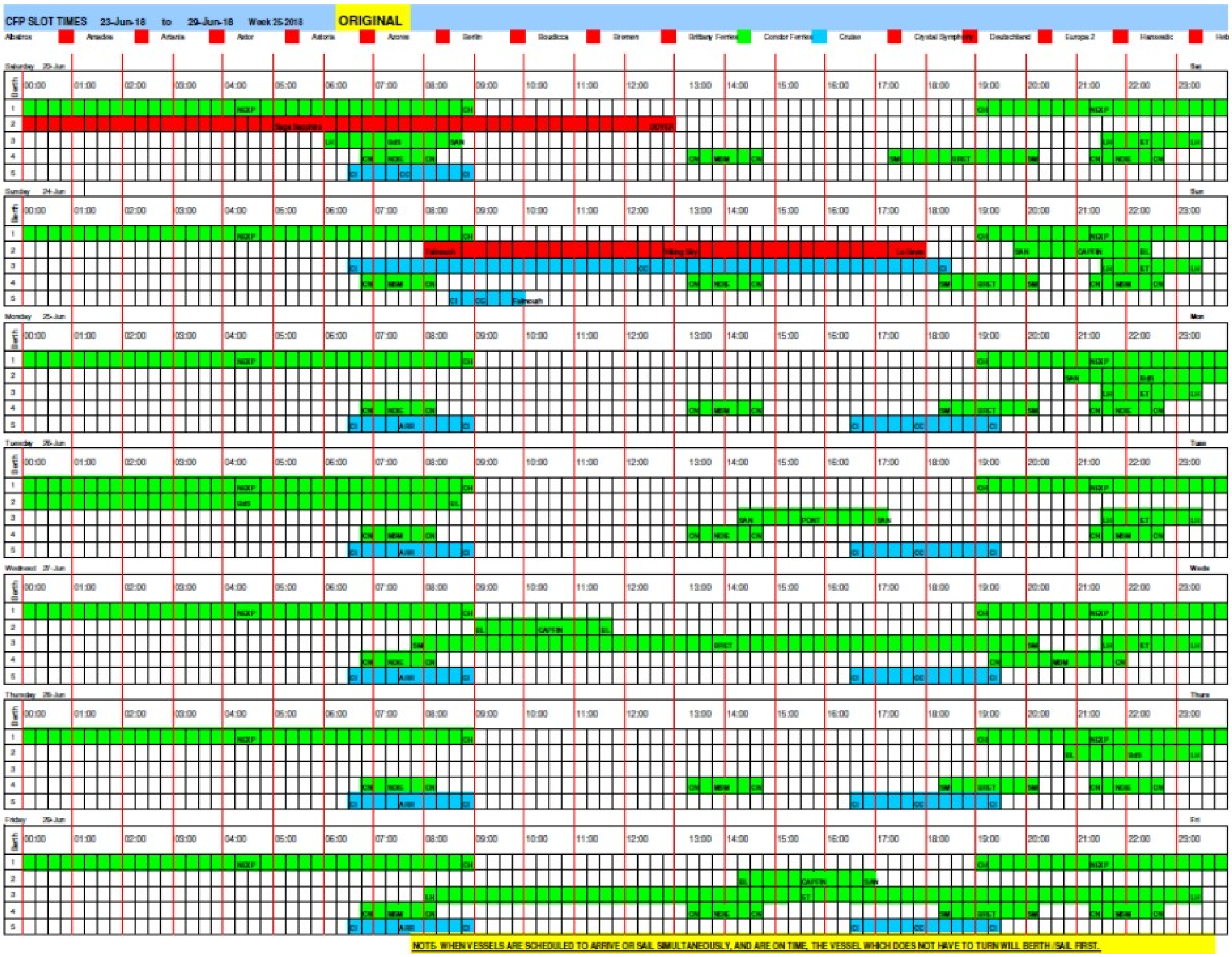
Option 4: £3.1m Refurbishment In Situ M&E Refurb. New Linkspan 4 Years Thereafter	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
New Linkspan						-	
Refurbishment	3,100,000						
Loan	(3,100,000)						
Principle	620,000	360,000	360,000	360,000	360,000	360,000	
Capital Costs Sub Total	**620,000**	**360,000**	**360,000**	**360,000**	**360,000**	**360,000**	
Revenue Costs / (Income)							
Maintenance	20,000	5,000	20,000	120,000	20,000	12,000	
Interest	128,340	357,696	283,176	208,656	134,136	74,520	
Revenue Costs / (Income) Sub Total	**148,340**	**362,696**	**303,176**	**328,656**	**154,136**	**86,520**	
Net Relevant Cost / (Income)	**768,340**	**722,696**	**663,176**	**688,656**	**514,136**	**446,520**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**768,340**	**654,568**	**544,035**	**511,682**	**345,999**	**277,611**	**13,361,213**

Option 5 – Do Nothing

Option 5: Do Nothing (do not replace linkspan)	Year 0 2017/18 (£)	Year 5 2022/23 (£)	Year 10 2027/28 (£)	Year 15 2032/33 (£)	Year 20 2037/38 (£)	Year 24 2041/42 (£)	NPV (£)
Capital Costs							
Capital Costs Sub Total	-	-	-	-	-	-	
Revenue Costs / (Income)							
Maintenance							
Loss of Net Income	1,250,000	1,300,000	1,300,000	1,300,000	1,300,000	1,300,000	
Revenue Costs / (Income) Sub Total	**1,250,000**	**1,300,000**	**1,300,000**	**1,300,000**	**1,300,000**	**1,300,000**	
Net Relevant Cost / (Income)	**1,250,000**	**1,300,000**	**1,300,000**	**1,300,000**	**1,300,000**	**1,300,000**	
DCF @ 2.0%	1.0000	0.9057	0.8203	0.7430	0.6730	0.6217	
Net Present Value	**1,250,000**	**1,177,450**	**1,066,453**	**965,919**	**874,863**	**808,238**	**25,838,103**

Customer Requirements of a New Linkspan

Portsmouth International Port can be described in a number of ways. The first would be to describe it as a Municipal port insofar as it is owned by the people of Portsmouth through Portsmouth City Council (PCC). The second descriptor would be that it is a 'Landlord' port, that is to say that it does not run most of the services that operate within the port itself but encourages private enterprises to compete for this work on PCC land.
Thus the stevedoring in the Port Ro-Ro part of the port is undertaken by Portsmouth Handling Services a private company. Security around the port is similarly undertake by private contractors. The port reserves for itself the roles of administration of the port as well as engineering and the provision of mooring gangs for the vessels.
For the companies that wish to use the port there is a period of negotiation for what are known as 'slots' on the available linkspan berths (rather like an airport). These slots are for four hours although most of the ferries that use the port tend to wish to 'turnaround' in 2 hours or less. Staying alongside for greater than 4 hours results in a further 4 hour charge period being levied. A typical week of 'slot times' is shown in the reproduced spreadsheet below.



It can be seen from the above that the ship operators are interested in effective infrastructure that allows them to load and discharge their vessels as efficiently as possible with the least delay and without breakdowns. It also follows that when a major customer spends many millions of Euro's on a 'state of the art' LNG powered ferry that will reduce Carbon Emissions significantly over any chosen route that customer will expect the Carbon savings to not end abruptly at the port but for the infrastructure to complement their own investment.

Type of Linkspan

Lifespan

A link span is very simply the floating link between the ship and the port itself. It is unusual for any two ships to have exactly the same freeboard (height above sea level) and therefor the linkspan must be fully adjustable for height. Whilst the link span and ship will both be prone to the same tides, the linkspan itself must be built such as to be afloat at all times but also have sufficient buoyancy to support the discharging cargo of freight and passenger vehicles.
The linkspan was designed for a life of 30 years.
The lifespans first major maintenance will be 10 years.

Design Standards

The linkspan was designed and constructed in accordance with, and classified as, a Lloyd's Register classification ✠AT Passenger and Vehicle Linkspan and also, where applicable, to the latest British Standards, in particular BS5400 and BS6349.

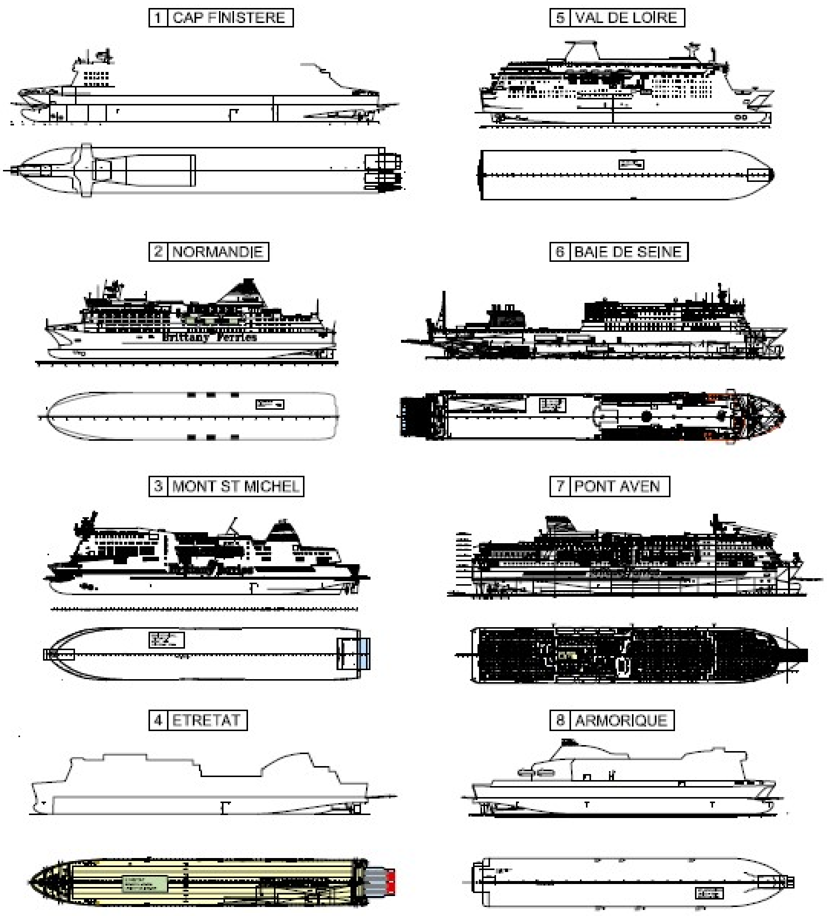
Existing Facility

The shore end of the linkspan was supported on the existing bank-seat. The contractor had to determine that the existing structure was capable of taking the loads to be applied to it.
The existing guide pile was retained for the new linkspan. The Contractor had to determine its adequacy for the loads to be applied to it.
The upper deck connects to the existing viaduct structure. The contractor determined that the existing structure was capable of taking the loads to be applied to it.

Berthing and mooring loads
Horizontal structural capacity was determined from berthing impact, mooring and vehicle braking loads.

Sinkage
The sinkage of the linkspan under live loading was not to exceed 350mm.

Vessels to be considered
All vessels in the existing Brittany Ferries fleet were considered**.** These vessels are indicated on drawing MAR539/08. The requirement for freeboard of the linkspan measured at 1.5m from the face was 1.0m to 4.5m achievable at all states of the tide.
The upper deck was to be retractable to provide clearance for overhanging bow structures/visors.



	VESSEL NAME	LENGTH (m)	BREADTH (m)	GT	DRAUGHT (m)
1.	CAP FINISTERE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
2.	NORMANDIE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
3.	MONT ST MICHEL	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
4.	ETRETAT	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
5.	VAL DE LOIRE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
6.	BAIE DE SEINE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
7.	PONT AVEN	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
8.	ARMORIQUE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT
9.	BRETAGNE	[illegible]	[illegible]	[illegible]	[illegible] LOADED [illegible] LIGHT

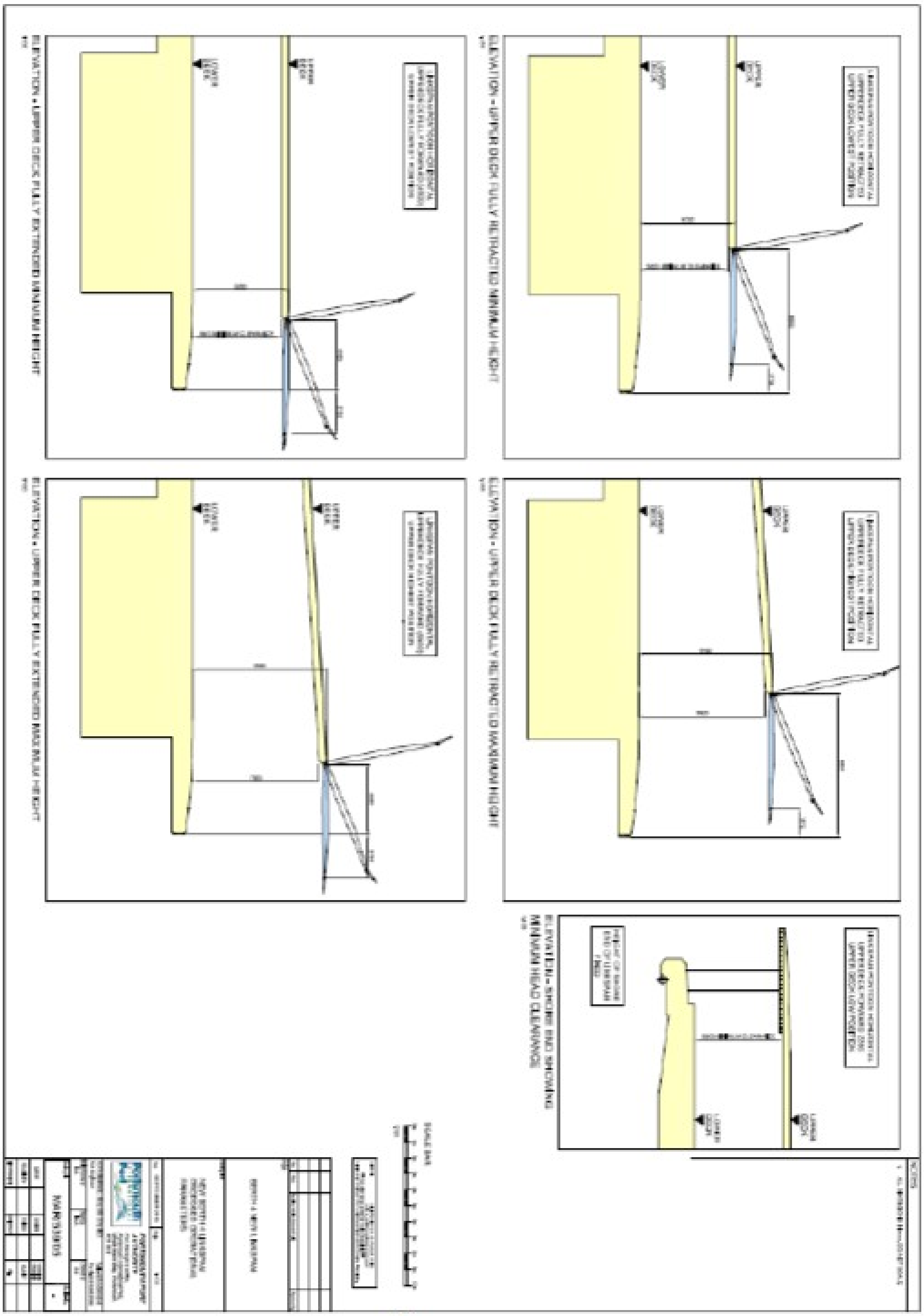
VESSEL DETAILS

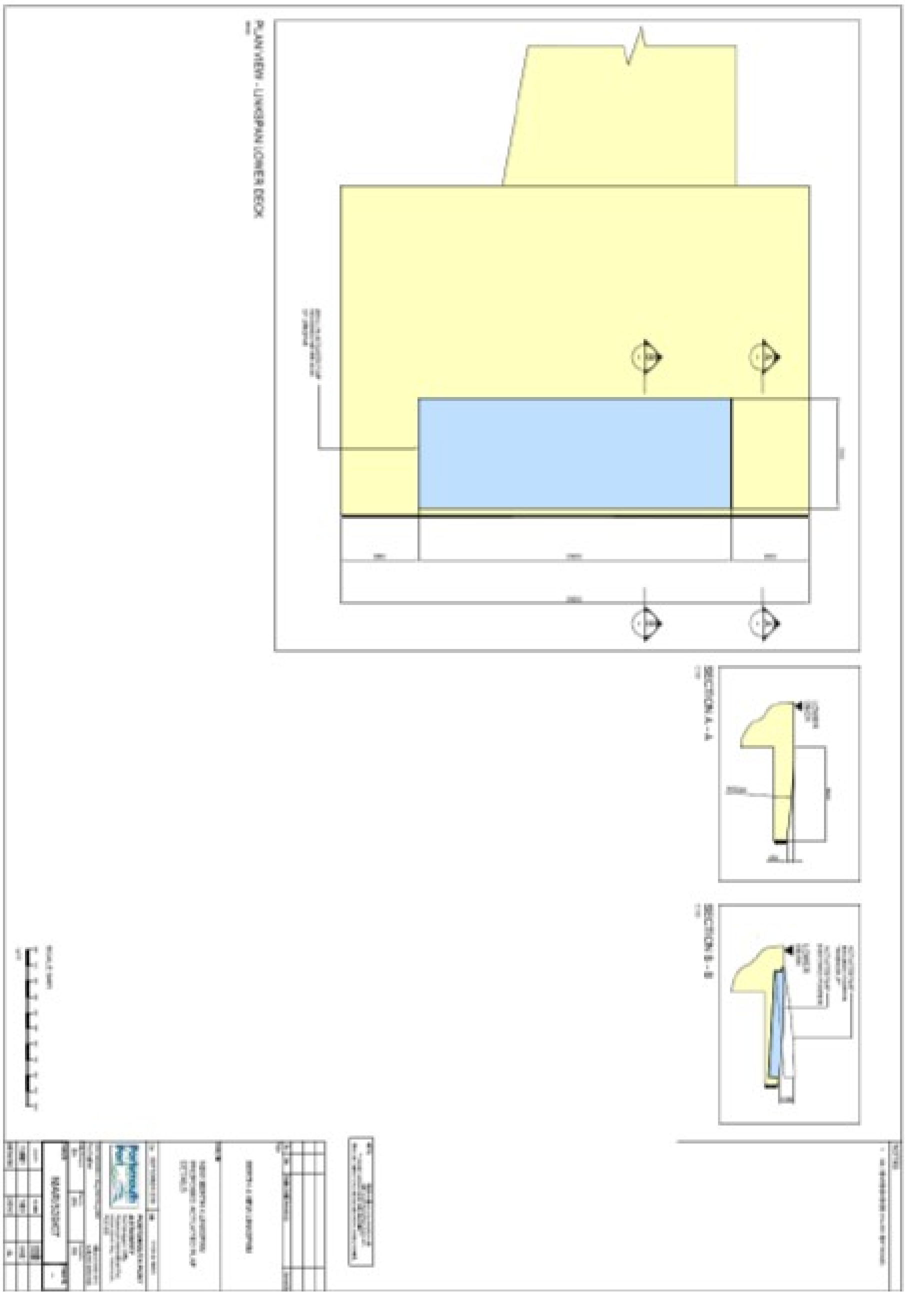
Vehicles/Loading to be considered
For normal operations, the seaward end of the linkspan is supported on a buoyancy tank capable of supporting the dead load of the bridge, upper deck and tank structure and the additional live load of any one of the following vehicular loadings.
(i) 2 lanes of HGV Vehicles on the top and bottom decks simultaneously.

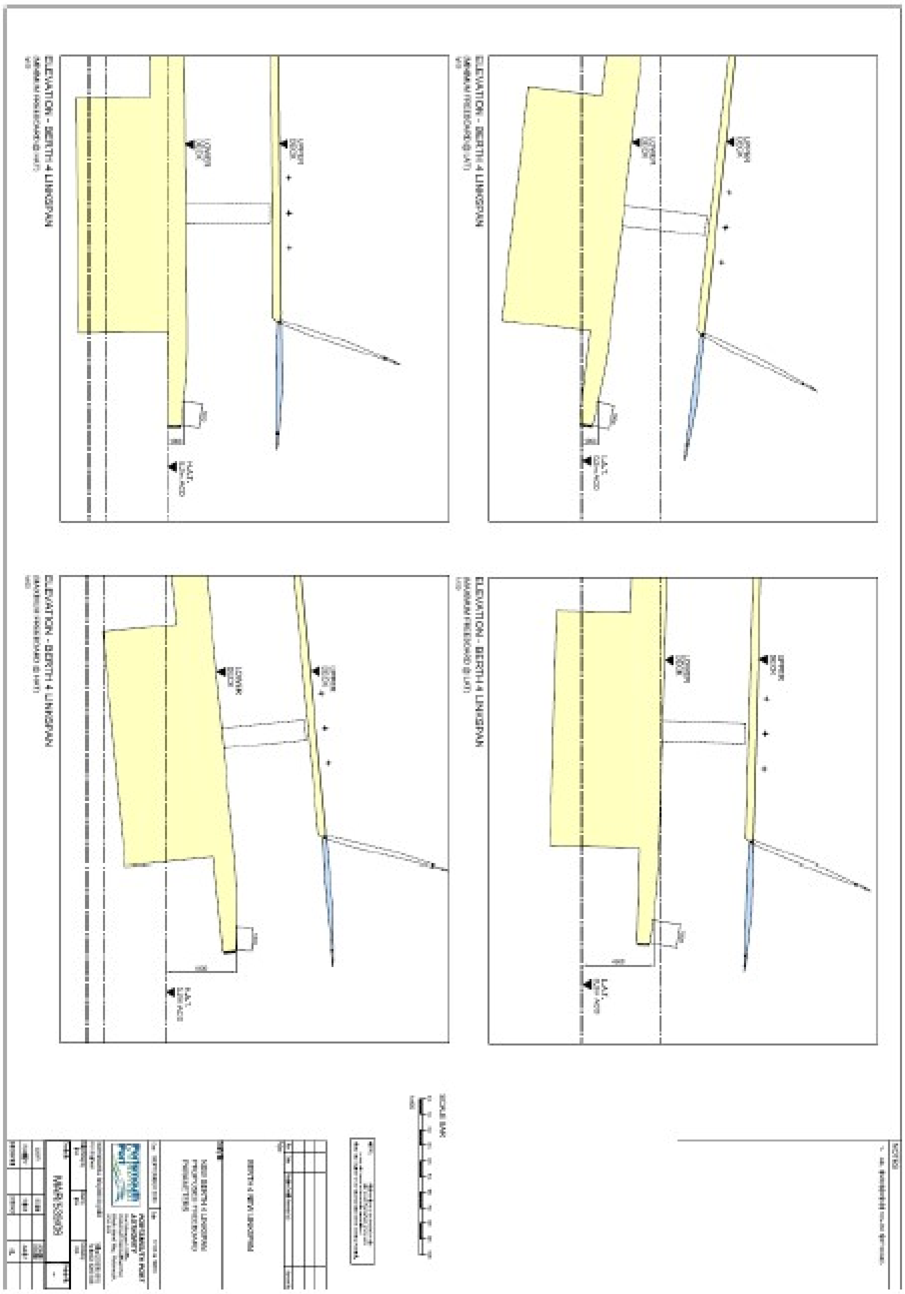
(ii) 1 lane of loaded, 85t MAAFI units/Cassettes plus one lane of tugs returning empty on the lower deck only.
(iii) 1 vehicle of 45 units HB loading (180t) on the lower deck only.

Geometry

The outer end of the lower deck of the linkspan was to be the same as existing to maintain the position of vessels in relation to mooring and passenger access systems.
The operational requirements for the range of adjustment required for the linkspan decks and fingers are shown on drawing MAR539/05.
Minimum headroom for the lower deck was 5500mm under normal operating conditions. Maintenance stops were provided at the seaward end of the upper deck such that this headroom may be maintained if the upper deck adjustable supports are removed.
The lower deck ship's ramp landing area were to have a vertical curved profile similar to that of the existing berth 3 linkspan ref. drg. MAR539/07. Wear strips shall be 100mm wide at 500mm spacing provided over the seaward 12m of this area.
There is an adjustable flap approx. 20m wide at the seaward end of the lower deck capable of being raised by 1.0m. Drg.MAR539/07 refers Hydraulic systems actuating this flap are accessible for maintenance/replacement without the requirement for the flap to be removed or for floating plant.


ELEVATION - UPPER DECK FULLY RETRACTED MINIMUM HEIGHT
ELEVATION - UPPER DECK FULLY EXTENDED MINIMUM HEIGHT
ELEVATION - UPPER DECK FULLY RETRACTED MAXIMUM HEIGHT
ELEVATION - UPPER DECK FULLY EXTENDED MAXIMUM HEIGHT
ELEVATION - SHORE END SHOWING MINIMUM HEAD CLEARANCE


PLAN VIEW - LINKSPAN LOWER DECK
SECTION A - A
SECTION B - B



Tank Size and Arrangement

The width of the tank is 30m at the outer face. The outer face of the buoyancy tank over a distance of at least 5 to 25 metres from the projected line of the berthing face is set back by 3m from the nose of the linkspan to provide room for bulbous bows.

The depth of the tank is limited by the draft available.

Additional bulkheads are provided within any permanent buoyancy tanks to reduce sinkage in the event of damage.

The tank and its internal bulkheads are designed to resist water pressures equivalent to it being sunk at high tide level.

There is be safe access to all permanent and adjustable buoyancy tank compartments, in accordance with confined spaces regulations, for operatives carrying out maintenance works.

Pumping System

The nose level of the linkspan is adjusted by changing the ballast water in the buoyancy tank using a system of pumps and valves.
A pumping system shall is arranged to ballast and de-ballast the tank. The pump set must be arranged such that pump(s) may be isolated and removed for maintenance whilst maintaining the capability of the linkspan to operate at no less than 75% of its design speed.
Pumps are capable of raising or lowering the linkspan at not less than 200mm per minute and are contained in a fully accessible plantroom. Electric pump motors are of the 'soft-start' type to reduce energy consumption.
Valves are to be electric motor actuated. Electric motors to be of 'soft-start' type.

Pump Plantroom
The plantroom is accessed from the deck of the linkspan via a staircase. It contains adequate lighting and a ventilation system. Lifting beams are provided over heavy items of equipment and adequate hatchways to enable such equipment to be easily lifted in and out.
Flooring is non-slip finish and walls and the ceilings are painted white.

Hydraulic Power System
The Hydraulic Power Unit is located within the pump plantroom. It contains three pump/motor units. It normally operates with two pumps running and one standby.

Hydraulic Fluid
Hydraulic fluid is biodegradable, fully compatible with Fuchs Plantohyd 40N (datasheet at Appendix A). All components and seals are compatible with the use of this fluid.
6.14 Operator's Cabins
a. The control stations are housed in enclosures which afford the necessary environmental conditions for the control equipment they contain. They also provide all weather protection for the linkspan operator and are fitted with internal lights, a suitable heater and provision for data connections including ducting to the bankseat.
b. The position and layout of all controls and the arrangement of all control panel switches, lamps, visual and audible displays etc. have been subject to the approval of the Employer's Representative.
c. Each cabin contains 4 no.13A power sockets

Lower deck operator's cabin
The cabin is situated on the lower deck with a good view of the ship's ramp landing area.
The lower deck operator's cabin contains controls for the following:-
Main on/off switch/Swipe card reader
Ballast/deballast
Adjustable flap
External Lighting
Berth availability lights
Lower deck traffic barriers & lights
It shall also contain two CCTV monitor screens both fully capable of being switched between any of the CCTV cameras.
Audible/visual Alarm with its Accept button, and fault annunciator lamp panel, or MMI with capability to display all fault conditions of the pump system, HPU and mechanical and control equipment. HZ Draft report on HZ-PECS deliverables 66

Freeboard (set and actual) is displayed together with indicators for all other functions.
It also contains 2 no. CCTV monitor screens both fully capable of being switched between all and any of the CCTV cameras.

Upper Deck
The upper deck is supported from the lower deck and has the range of adjustment detailed on drawing MAR539/05.
Speed of operation of the upper deck is:-
Extend/retract 50mm/sec
Up/down 50mm/sec
There is a self-levelling tread access stair to the upper deck from the lower.

Upper deck fingers
Fingers are individually selectable to cater for different vessel access widths and beams. The total width of flaps is 10m (5m each side of the linkspan centreline). Fingers are 500mm wide.

Upper deck operator's cabin
The upper deck operator's cabin is sited with a good view of the fingers and the landing area on the vessel. It contains controls for:-
Vertical adjustment of upper deck
Horizontal adjustment of upper deck
Upper deck fingers
Viaduct automatic barriers & lights
Vertical and horizontal positions of the upper deck are displayed, together with indicators for all other functions.
It also contains 2 no. CCTV monitor screens both fully capable of being switched between all and any of the CCTV cameras.
6.19 Berth Availability Signal
The linkspan includes LED berth availability lights in a position clearly visible from the bridge of vessels. These lights are controlled by the linkspan operative from the lower deck control station. The controls are:
i) Red - berth not available, stand off; HZ Draft report on HZ-PECS deliverables 67

ii) Green - berth available, commence approach;
iii) Off - no signal visible.

External lighting
Lighting to both decks are LED and provide an average of 50 Lux minimum, evenly spread.
B6.21 Internal Lighting
a. Internal lighting is installed in all the linkspan internal compartments for which access is required for operational purposes and regular maintenance at monthly or more frequent intervals.
b. Internal lighting required for operational purposes is designed in accordance with the current CIBSE Lighting Guide to give a minimum illumination of 150 lux. Isolation is by means of a manual

switch in the switch panel
c. Lighting levels for maintenance purposes are sufficient to permit the maintenance function without further portable lighting.
6.22 Emergency Lighting
a. Emergency lighting is installed in all linkspan internal spaces for which access is required for operational purposes and also in any enclosed control station.
b. Emergency lighting is in accordance with BS 5266:1988 Part 1. All fittings are of twin tube self-contained and maintained type, with a 3 hour duration.
6.23 Cyclamen
a. The Cyclamen units mounted at the shore end of the linkspan were removed.
b. Mounting brackets and ducts for Cyclamen units were provided in a similar position on the new linkspan so that the units could be re-fitted.
6.24 Water Supplies HZ Draft report on HZ-PECS deliverables 68

A water supply for vessels was provided at the jetty side of the ship end of the linkspan with local operating valve and provision for connection of a water meter by others. The shore end connection is a 3" BSP female hose connection to connect with the existing supply and the ship end is a 3" 8-bolt flange to BS 4504/8 PN16 to accept a meter by others.
6.25 Automatic barriers
The linkspan control system links in to the existing automatic traffic barriers and lights situated on the bank-seat for the lower deck and at the bottom of the viaduct for the upper deck.
6.26 Audible & visual warning systems
All movement of the upper deck and upper deck fingers sound an audible warning and a visual warning to all potential areas of danger.
6.27 CCTV System
4 No. CCTV cameras compatible with Dedicated Micros operating system are provided to monitor the upper and lower decks of the linkspan.
The cameras are linked to screens in both operator's cabins. These are capable of displaying the current view from all or any of the cameras.
The cameras are also connected to a sprite compatible with Dedicated Micros and capable of real-time recording, which will retain 30 days of records. This is connected to the Port CCTV network.

Vessel Approach Speed Monitoring
A speed monitoring device is fitted to the linkspan to monitor the approach speed of vessels. This is displayed digitally on the appropriate CCTV monitor screen and linked into the CCTV data retention system.

CCTV Monitors
CCTV monitors are 19" TFT screens

Control System
The linkspan is activated by a key operated switch. Provision is made for alternative activation by proximity card. Space is available in the control cabinet for the necessary equipment to enable this.
HZ Draft report on HZ-PECS deliverables 69

The Ballast system is programmable to automatically achieve and then maintain an adjustable pre-

set freeboard height. There is also a facility for manual up/down operation. The freeboard pre-set and actual levels are monitored and displayed in the lower deck operator's cabin.
The adjustable flap controls are up/down buttons.
All valves and pumps are capable of being locally manually operated in case of control system failure.
The upper deck controls are up/down and extend/retract buttons, both manually operated. The position of the upper deck is monitored and displayed in the upper deck operator's cabin.
The upper deck fingers are individually selectable with an up/down button to operate all selected fingers.

Carbon Reduction

The Contractor included carbon reduction technology into the design:

1. Higher Quality (longer lasting) steel to S355.
2. Softy starters on the ballast pumps to reduce electrical consumption.
3. LED lighting.
4. Environmentally friendly hydraulic Oil.
5. Paint system to have approximately 20-25 year life-span. Warranted for at least 10 years.

Disposal of Existing Linkspan

The existing linkspan was re-used (in part), recycled (in part) and disposed of (the remainder) in accordance with environmental best practice.

Bird Deterrence

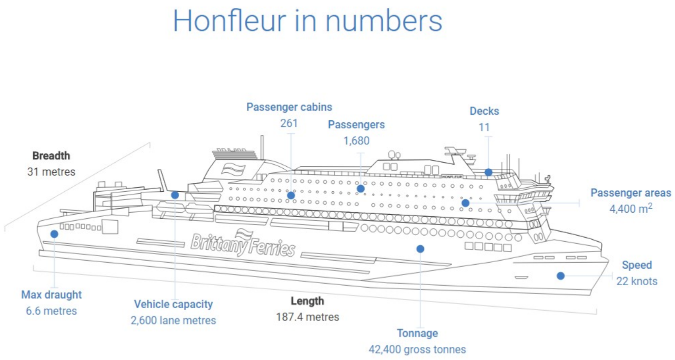
a) Where practical, measures were to be taken to prevent birds roosting in the structure and on services.
b) External hydraulic valves and hydraulic/electric control equipment were contained in enclosures to protect them from bird fouling, with access for maintenance.

Maintenance Access

All regular maintenance shall be possible without the requirement for additional access equipment.

Rationale

- The existing linkspan on No. 4 berth was coming to the end of its working life with increasing failures and maintenance costs and a 'bespoke' software controlling system that could not be upgraded to match necessary refurbishments.
- The Business Case looking at the options for the berth 4 linkspan indicated that the purchase of a new linkspan was the 'least cost' option when one took into account losses incurred by keeping a failing linkspan in operation.
- The possibility of financial support through ERDF in order to incorporate the improvements necessary to try and match the Carbon Reductions incorporated into the new LNG drive technology of the 'Hornfleur' could become possible.



Energy Saving Capability

Energy Saving features possible given higher specification of Linkspan

The customer required a larger linkspan of greater capacity. This did not mean that the new linkspan could not be made more energy efficient but it did mean that the absolute measurements of energy used may be higher than the original link-span's albeit for greater load and greater performance. The features that were considered (and either implemented or not were as follows):

i. Solar Panels. These were considered for use on the linkspan but were dismissed as being impossible for two reasons, the first that the linkspan has no roof onto which attach such solar panels and no side that could be similarly used, being an 'open' structure and because the linkspan moves up and down and would not be able to be kept at the optimal angle for solar reception.

ii. 'Soft Start' Electric motors. These were considered and implemented in the design and build of the new linkspan as providing not just an energy saving in the operation of the link-span but also extending the life of the motors and auxiliaries in use. Across the line starting of induction motors is accompanied by inrush currents up to 7-10 times higher than running current, and starting torque up to 3 times higher than running torque. The increased torque results in sudden mechanical stress on the machine which leads to a reduced service life. Moreover, the high inrush current stresses the power supply, which may lead to voltage dips. As a result, lifespan of sensitive equipment may be reduced. A soft starter eliminates the undesired side effects.

iii. Low Loss Electrical Transformer and Switchboard unit. The new Linkspan being of greater size and performance than the original needed a new larger transformer and switchboard that could take advantage of the new technology available since the time of the original linkspan at berth 4. By the nature of the operation of a transformer there is a heat loss created, due to current-low in conductors and a magnetic flux circulating around the magnetic core. Whilst transformers are inherently efficient (around 99% plus), transformer losses are thought to represent around 25% of all the UK distribution network losses. The new low-loss Transformer and distribution boxes have been fitted as part of the new linkspan in order to take advantage of these energy savings.

iv. LED Lighting. The new Linkspan incorporates latest generation LED lighting throughout.

v. Sustainability Measures. The new linkspan incorporates higher quality steel that should give this structure an operating life of 30 years rather than the 25 years of its predecessor.

vi. Expected Carbon Savings. The new linkspan is of greater capacity (can suspend more tonnes of vehicles moving across it at any one time) and of higher performance (it will raise and lower more quickly than the one it replaces). In absolute terms it is difficult to state what carbon savings will be made by the new linkspan (being 400 tonnes heavier than its predecessor). However with a baseline figure of 243,000KWh consumption over 1 year of operation and 176 tonnes of carbon produced as a result of its operation we hope to reduce this figure to 206,550KWh and 150tonnes respectively. The linkspan is still undergoing 'snagging' as minor issues are addressed following its installation, but as this probably includes re-designed hydraulic rams and new stainless steel bearing surfaces for the upper deck, correct electricity consumption readings have not yet commenced.

Conclusion

The intervention by PECS in the development of the new linkspan for Portsmouth Commercial Port was crucial. It is very easy in the commercial atmosphere of a busy port to lose sight of what 'can' be done in the fog and fight of what 'needs' to be done. The new linkspan was the perfect small pilot for proving that low energy/high efficiency starter motors can be fitted and used even on the busiest structure. The lights can be LED even though the specification has not changed with each new linkspan over the last 40 years. The challenge now is to prove the energy savings on a piece of infrastructure that is larger, heavier and more operationally efficient (it raises and lowers more quickly and carries more traffic) than the one it replaced.

Table Spreadsheet to assess the economic viability of a pilot.

Preliminairy viability check PECS pilots
Tool: Jacob van Berkel, HZ University of Applied Scieces
Data provided by: Mark Webb, Port of Portsmouth, Company Ravestein

Brief description of the system and the pilot	**Character**
Brief description of the system in which the pilot is implemented (e.g. a part of the harbour)	Linkspan 
Where is the system boundary (e.g. the perimeter of the harbour).	System boundary is the linkspan perimeter
What is the PECS pilot system?	pilot = system = linkspan
Current system performance	
What is the current annual energy consumption of the system [kWh/a]	161983
What is the current annual CO2 emission [tonne/a]	168,81
Future system performance	
What is the future annual energy consumption of the system, after implementation of the pilot [kWh/a]	**unknown**
What is the future annual CO2 emission, after implementation [tonne/a]	
Costs	
What are the investment CAPEX costs associated with implementation of the pilot [€] (direct claimable, ref. Revestein)	
Soft starter on the ballast pumps to reduce the E-supply	30000
Hydraulic system environmentally friendly oil	5000
Total CAPEX [€]	**35000**
What are the annual operation costs (OPEX) associated with implementation of the pilot [€/a]	
Pilot lifetime	
Pilot lifetime (minimum of technical or economical) [year]	20

Annual Energy + CO2 benefit, expressed in €:	**unknown**
Annual costs (simple), expressed in €:	**€ 1.750**

Reduction of CO2-emission of the system, after implementation of the pilot [%]	**unknown**

D2.2.2. FINAL REPORT VERIFICATION STUDIES:

Using a straightforward calculation tool, the potential for application of Pilots-systems for conversion of renewable energy in Ports has been assessed indicatively. On the basis of this, the following conclusions can be derived:

1. Most of the techniques (6 out of 9), provide a positive business case. The annual benefits (in terms of energy- and CO_2- savings) are expected to be higher than the annual costs. The data of 3 pilots (Linkspan, LED-pontoon and Hellevoetsluis-storage) is inconclusive and open for further improvement.

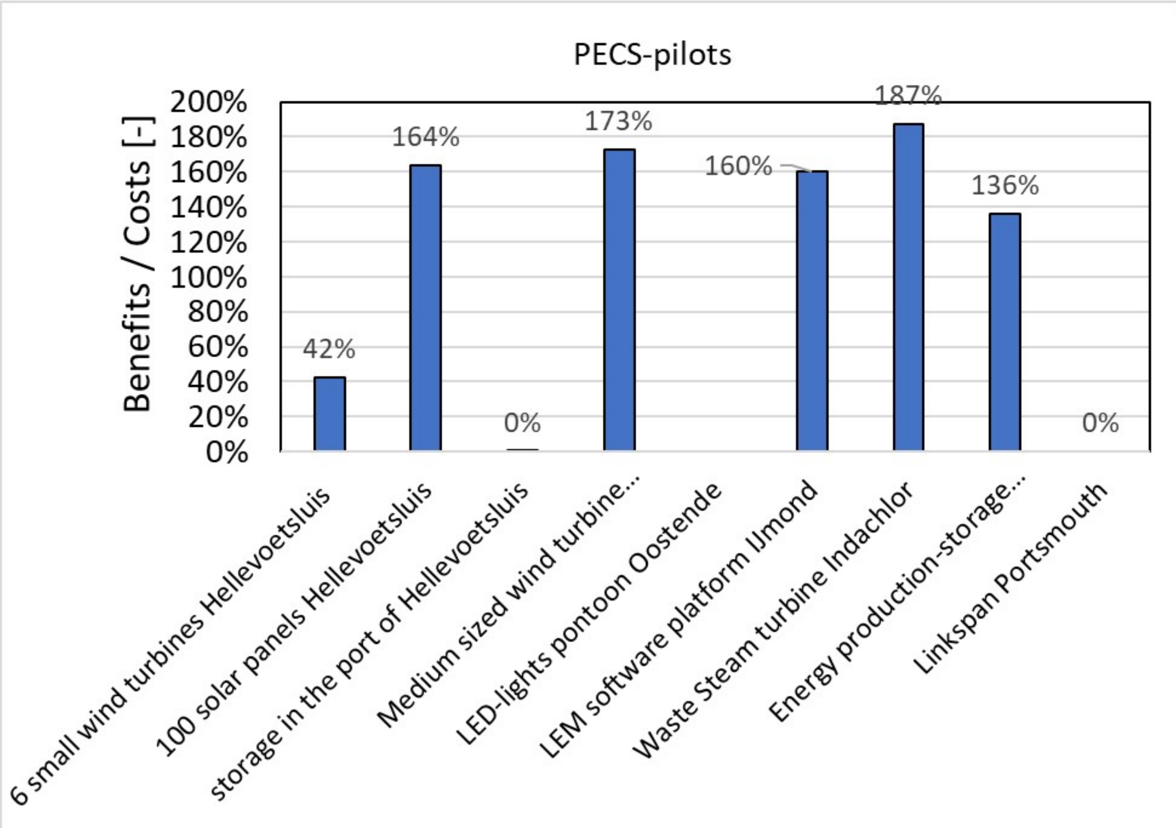


Figure 11.1 Annual benefits/costs for the pilots in the PECS-project.

The graph indicates the benefits, in term of annual savings [€] of Energy and CO-2, compared to annual costs. A factor of 100% implies that the benefits are higher than the costs.