Output 7

Overall report testing and monitoring

With contributions of all Ports and Knowledge Institutes within PECS

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INTRODUCTION

The heart of the PECS-project is the demonstration of installed systems in ports that save energy or generate renewable energy, thereby reducing CO_2-emissions.
Pilot systems demonstrated within PECS are:

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The systems are monitored in order to check, prove and demonstrate that a pilot system, once installed, operates according to expectations (better or worse).
Monitoring is done according to a protocol; a predefined set of rules according to which the performance of a system is assessed, see Output 7 report "Deliverable 2.3.1: Monitoring and testing procedure and Deliverable 2.3.2 Installed monitoring and testing equipment". The monitoring procedure and outputs cover technical, economical en ecological aspects.

This report summarises the aggregated results of the individual pilot-systems. In addition to a brief description of the pilots, results are presented with a specific focus to parameters that are generally inter-comparable between the pilots. Given the prime focus of PECS (savings on Carbon emissions and fossil energy consumption) the attention is directed at :

1. Reduction of carbon emissions [CO_2-tonnes/year]
2. Fossil fuel energy savings [kWh/year]
3. Financials: Simple pay-back time [years].

For further details (pilot specific data), the reader is referred to the individual pilot-port reports, which are issued under the shared responsibility of the port and associated national knowledge partner, see reference section of this report.

1. SUMMARY OF (SELECTED) MONITORING RESULTS

In total 9 pilot-systems have been installed in the PECS-project. To the extent that information was available, the monitoring data concerning the savings of CO_2, energy and the system payback-time was derived from the individual pilot reports, issued by the pilot-port partner and the associated knowledge institute.

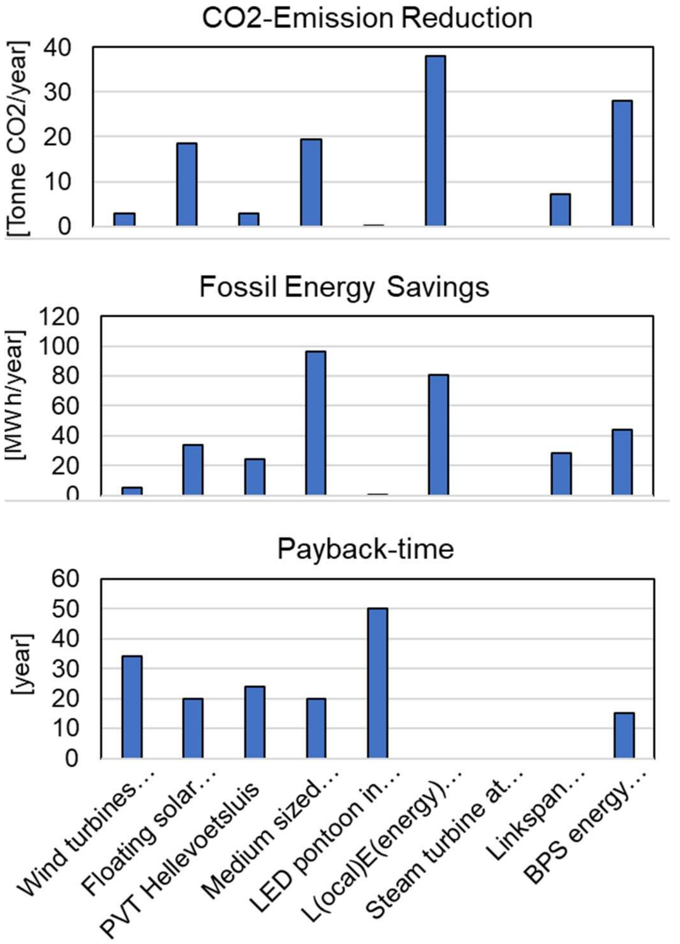

Figure 1.1 Pilot- comparison of CO2- Energy and payback-time

Figure 1.1 gives all aggregated data on CO_2-, energy and payback-time in one visualisation.

The figure clearly illustrates the diversity of the PECS-pilots, especially regarding the size and impact on CO_2-emission and Energy Savings. The smallest system being the LED-pontoon (60 kg CO_2-savings/year, 300 kWh/year) and the biggest system in terms of energy savings: the wind-turbine at Ostend (20 tonnes kg CO2-savings/year, 96 MWh/year).

Despite the diversity, except perhaps for the Indachlor Steam turbine, all systems fall in the category small, compared to the energy consumption of local reference system (harbour), which is in the order of magnitude of GWh/year, see PECS report D.1.4.1.). The highest fraction realised is in the Marina Cape Helius were the floating PV-panels annually produce about 5 % of the local consumption. The mean fraction of energy savings for all PECS pilots amounts to 2 %.

Regarding the payback-time the diversity in pilot outputs is smaller. All pilot payback-times are in the range between 15- and 50 years.

It is fair to say that the pilots are in a juvenile state of development and indeed future costs reduction can be expected (and are realised already) for the options that use Solar PV technology and to a lesser extent Wind energy. Also within the PECS project (D141) it has been established that the potential for carbon- and energy savings in ports and marina's is indeed substantial.

2. D.2.4.1 SMALL WIND TURBINES IN HELLEVOETSLUIS

Within the PECS project three pilot projects have been realized and consequently monitored in the municipality of Hellevoetsluis (Troelstra et al., 2021). Project D.2.4.1 relates to the application of small wind turbines in a marina-environment.

After a tender-procedure in 2019, the “Flower” turbines were selected because of good price-quality ration, bird friendliness, self-starting features and the “cluster effect”, meaning that multiple turbines placed close to each other, amplify the yield.

Different locations were considered for the Flower Turbines, and one location was found suitable: placed behind a dyke, on top of a container at Water sport association (WSV) Haringvliet. The elevated position eliminates the wind obstruction of the dyke and also increases the visibility of the turbines, which contributes to promoting environmental awareness. A permit was requested for the WSV-location in 2020.

Because of turbine supply problems and the Corona pandemic, smaller turbines were placed in November 2020: 3 meter (0,5-1 kW) instead of 6 meter (3-5 kW)[1].

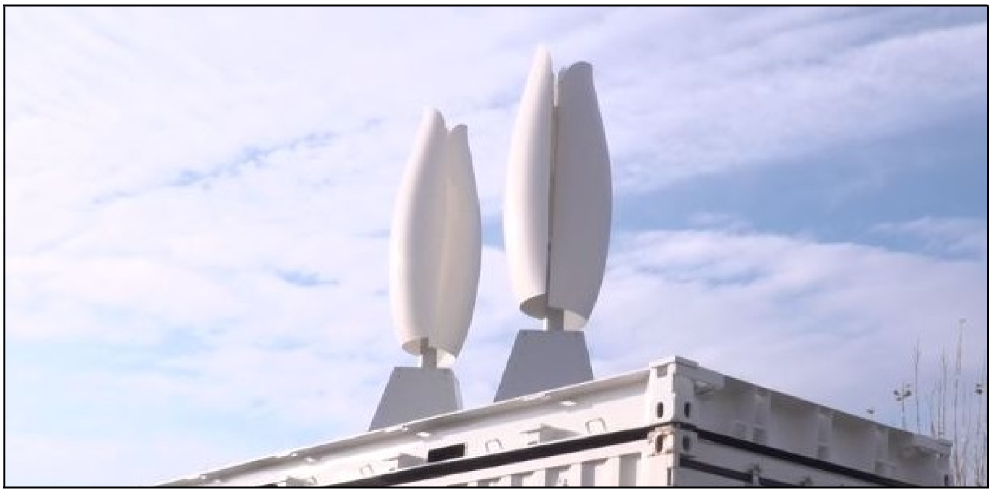

Figure 2.1 Two small wind turbines placed on a sea container at WSV Haringvliet (Hellevoetsluis), (Troelstra,2021)

It is estimated that the two turbines together can generate 2.000–8.000 kWh per year, which would correspond with 5% of the electricity use of the yacht port.

Regarding monitoring, electricity meters were installed (later than expected). Unfortunately wind-meters were not installed. The monitoring period started on 2nd February 2021 and with an intermediate replacement of a battery-control system and the replacement of one turbine, lasted until 11th March, 2021, when the system had to be taken out of operation because of major repairs. Due to technical malfunctioning, in total 4,8 kWh electricity is delivered, corresponding with 2,5 kg CO_2 emission-reduction. It is clear that the turbines had technical problems and need replacement (now underway).

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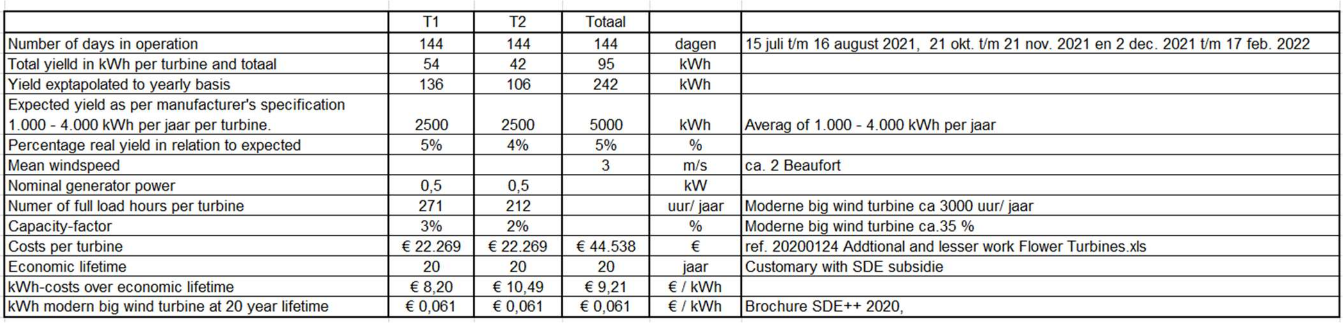
[1] See also the online brochures: https://flowerturbines.com/wp-content/uploads/2020/03/FT_TP-brochure-V5-1.pdf.

The monitoring output-data is based on expected figures based on suppliers information, with proper functioning of the turbines.

Table 1 gives a summary of the measured results in the time-span July 2021 February 2022.

Table 1 Measured performance of small wind turbines in Hellevoetsluis



	T1	T2	Totaal		
Number of days in operation	144	144	144	dagen	15 juli t/m 16 august 2021, 21 okt. t/m 21 nov. 2021 en 2 dec. 2021 t/m 17 feb. 2022
Total yielld in kWh per turbine and totaal	54	42	95	kWh	
Yield exptapolated to yearly basis	136	106	242	kWh	
Expected yield as per manufacturer's specification 1.000 - 4.000 kWh per jaar per turbine.	2500	2500	5000	kWh	Averag of 1.000 - 4.000 kWh per jaar
Percentage real yield in relation to expected	5%	4%	5%	%	
Mean windspeed			3	m/s	ca. 2 Beaufort
Nominal generator power	0,5	0,5		kW	
Numer of full load hours per turbine	271	212		uur/ jaar	Moderne big wind turbine ca 3000 uur/ jaar
Capacity-factor	3%	2%		%	Moderne big wind turbine ca.35 %
Costs per turbine	€ 22.269	€ 22.269	€ 44.538	€	ref. 20200124 Addtional and lesser work Flower Turbines.xls
Economic lifetime	20	20	20	jaar	Customary with SDE subsidie
kWh-costs over economic lifetime	€ 8,20	€ 10,49	€ 9,21	€ / kWh	
kWh modern big wind turbine at 20 year lifetime	€ 0,061	€ 0,061	€ 0,061	€ / kWh	Brochure SDE++ 2020,

3. D.2.4.2 FLOATING SOLAR PANELS HELLEVOETSLUIS

As the locally available roof-area is limited, it was decided to apply floating solar panels in the Marina Cape Helius (Hellevoetsluis).

In total 80 floating panels were installed, each with an electricity production capacity of 345 Wp. A special feature is that the solar panels are bifacial, meaning the (reflected) solar irradiation that is absorbed at the back-side of the panels is also converted into electricity. Figure 3.1 given an impression of the floating structure.

Figure 3.1 Floating Solar Panels at Marina Cape Helius (Hellevoetsluis) (Berg, 2021)

The floating panels were installed in November 2019 and started production in March 2020. The monitoring period lasted until February 2021 (10,5 months). The system was equipped with and electricity production meter, as well as with a solar (pyrano) input meter.

On the basis of the monitored data, it is expected that over an entire year the electricity production would be 33,5 MWh/year, and the corresponding CO_2-emission reduction 18,6 tonnes/year. Given the almost € 50.000,- investment costs (including installation) and ~ € 2500,- annual revenues (direct usage of electricity, feed-in and maintenance), the payback-time would be around 20 years.

Comparison with roof-based panels indicates that the floating panels deliver roughly 20% more electricity, due to the bi-facial effect and also increased cooling of the solar panels (wind/water effect).

Since the system has been purchased, costs of solar panels have gone down and performance has improved. If the system would be bought today, the payback-time would be around 7 years; despite the added costs of the floating structure in comparison to roof-mounted systems.

4. D.2.4.2 PVT-SYSTEM HELLEVOETSLUIS

A PVT-system is a combination of Solar P(hoto) V(oltaic) panels and Solar T(hermal) collectors in one system. The advantage of the system is that one surface is used for both production of electrical and thermal energy. A heat pump is used to lift the temperature of the thermal energy to a comfortable level for heating.
In July 2020 a 1200 Wp_e PVT system (6,5 m^2) was installed at the Water Sport Association "Haringvliet" in the harbour of Hellevoetsluis. The solar PVT-panels were delivered by from Triple Solar (NL) and the heat pump by the Swedish firm (NIBE). The system contributes to the demand of the association members for heat whilst taking a shower.

Figure 4.1 PVT-collectors placed at WSV Haringvliet (Hellevoetsluis), (Romijn, 2021)

For cost-reasons the system was not equipped with heat metering. The performance of the system is derived from the reading of the (overall) natural gas meter (used for heating) and the power capacity of the PV-panels. Measured data indicates that over the monitoring period the annual savings of natural gas is 2112 m^3 and 325 kWh, which indicates an annual savings of 2500 m^3 natural gas and 1080 kWh, summing up to a total of 24 MWh/year. This would correspond with a CO_2-emission reduction of 3 tonnes of CO_2 per year.
System yield, relative to the needed investment, would result in a simple pay-back time of 24 years.

5. D.2.4.3 MEDIUM SIZED WIND TURBINE IN OSTEND

A wind turbine converts wind energy into electric energy. The Port of Ostend is not a leisure port and there are some industrial activities, which implies that the environmental noise-level can be significant when loading, unloading and other activities take place 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, 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 kW nominal power and 150 kW peak power.

Figure 5.1 Medium sized wind turbine in the port of Ostend, (Anon, 2021)

The wind turbine was monitored between 1st January 2018 till 20 January 2021 (~3 years). According to the monitoring report (Anon, 2021) the energy savings were measured at 288 MWh (96 MWh/year), which corresponds to savings of 18000 €/year and a reduction of CO_2-emissions of 19 tonnes/year.

On the basis of € 300.000,- investment costs, € 3000,- annual maintenance costs and an annual savings of € 18.000,- on energy costs, a simple payback time of 20 years is calculated.

6. D.2.4.4 LED PONTOON IN OSTEND

Pontoons are used very frequently in ports and marinas. 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 core economic activities performed 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 needed in remote areas in the port, where the access to the distribution grid is not available. To cut on electricity demands, 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.

At the 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 (226700 lm in total). The fluorescent lights were replaced by two LED lamps in parallel to provide redundancy, producing in total 269520 lm. The costs for replacement were € 1000.

During the monitoring period, no failures in the pontoon’s LED lights were observed.

MaRioT

Figure 6.1 LED-pontoon in the habour of Oostend (Troelstra,2021), no picture available?

During the monitoring period 1st July 2020 till 11 March 2021, the energy savings were calculated at 200 kWh, which corresponds to 300 kWh/year (40 €/year).

On the basis of investment costs and annual savings of energy costs, a simple payback time of 50 years is calculated.

Update June 2022:

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a. LED-lighting

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Figure 6.1 Smart LED-pontoon in the harbour of Oostende

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7. D.2.4.5 LEM ODIJMOND

The task of Omgevingsdienst IJmond within the PECS project is to set up a so called LEM (Local Energy Market) platform, which aims to offer smart grid services, monitor energy use and improve the incentive for firms to invest in renewable energy sources. The LEM platform does not produce or consume electricity by itself. It is an IT platform that makes it possible to connect local electricity producers to local electricity consumers.

The aim is to create such a platform in the port area of the IJmond which contains approximately 350-400 SMEs.

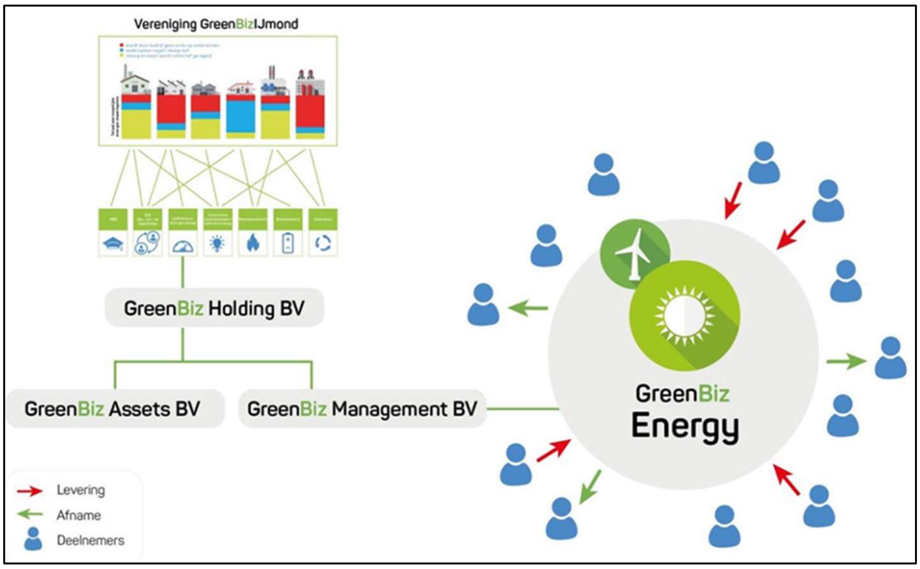

Figure 7.1 Local Energy Market Greenbiz (Ruiter, 2021)

From 01-07-2020 onward a PV installation has been installed with a capacity of 81 kW. Expected production is 81.000 kWh per year.

The transportation of electricity via the platform is measured by reading out (gross) electricity production meters. During the measurement period between 1-1-2020 and 31-07-2020, the measured volume was 42.272 kWh (over 7 months). The annually expected amount of carbon saved, equivalent to 81000 kWh of produced renewable electricity, corresponds to 39 tons of CO_2.

The financial benefit of the LEM platform is hard to determine, because it is largely dependent on the amount of firms and volumes of renewable electricity that will be connected to the platform over time. What can be said is that the average trading price on the platform was € 0,035 per kWh. According to the Dutch Consumentenbond (2020) the average price per kWh was €0,08 including VAT, which means €0,06 excluding VAT. A difference of €0,025 per kWh. The reduced market electricity price is however a disadvantage for the producers; on a community level there is -as yet-no financial positive or negative effect.

When the production costs of PV-electricity in future falls below the 3,5 ct/kWh market price, there could be financial advantage.

8. D.2.4.6 STEAM TURBINE AT INDACHLOR (DUNKIRK)

Energy recuperation plant at IndaChlor

In the Port Of Dunkerque Indaver has built a new installation for the recuperation of energy and hydrogen chloride (HCl) out of highly chlorinated organic waste streams. The HCl is delivered to other industrial plants as raw material, which leads to a reduction of carbon emissions normally emitted during production of HCl by the conventional production process. This recovery is not considered further in this article.

Figure 1 Aerial picture with in front the IndaChlor site and at the back Ryssen, with the direct steam connection between both sites visible.

The recuperation process (CRU) of the highly chlorinated organic waste streams starts with an incinerator of 20 MW. The combustion process is self-sustaining so no fossil fuels need to be added. The produced energy is recuperated in a 19 MW steam boiler. The valorization of the steam is accomplished by a steam turbine of 0,9 MWe and steam delivery of 12,5 MW to a neighboring company thanks to a direct connection.

Figure 2 IndaChlor’s steam turbine of 0,9MWe

This 2 ways of recuperation makes from IndaChlor an example of the circular economy.

The commissioning of the CRU has started in February 2021. From of September 2021 the steam connection with Ryssen has been activated. In the period between September 2021 and Mai 2022 nearly 20.000 MW of energy has been valorized thanks to the steam connection. During the same period, the steam turbine produced 360 MW of electrical power. The nominal valorization rate has not been achieved, due to technical problems during commissioning and first months of start-up which led to a reduced hourly throughput and a lower overall availability of the IndaChlor process plant. Thanks to thorough investigation and troubleshooting, both the availability and the hourly throughput have been increasing since Mai 2022. In the month Mai 2022, 70% of the input energy by the waste has been valorized as steam by the steam turbine or used in the production process of the neighboring Plant of Ryssen.
Table 1 gives a summary of the current and future results.

Table 1 IndaChlor's steam turbine of 0,9MWe

			2022-OL	2023	2024	2025	2026
IN	Liquid Waste	ton/year	30.000	34.500	38.500	41.000	41.000
Out	Ashes and filtercakes	ton/year	1.576	156	163	183	183
	HCl as waste product	ton/year	600	0	0	0	0
	HCl as product to customers	ton/year	35.000	99.000	104.000	116.000	116.000
Energie	Energy in waste	MW	77.500	95.210	108.000	115.040	115.040
	Energy Recoverd	MW total	48.238	83.107	94.291	102.184	102.184
		MW steam delivered	35.000	48.540	56.120	60.100	60.100
		MW electricity	977	3.300	3.600	4.000	4.000
CO2	Avoided	ton/year	42.199	107.336	114.015	126.567	126.567

9. D.2.4.7 LINKSPAN PORTSMOUTH HARBOUR

Installed in the port of Southampton in 2018, the linkspan was the first pilot system in operation in PECS. The linkspan is a simple construction intended to join the port to the ship when the ship is alongside. To accommodate various ship-positions the ship end of the linkspan must rise and fall with the ship on the tide and must also accommodate different sizes of ships with different widths of door and be able to service at all states of the tide.

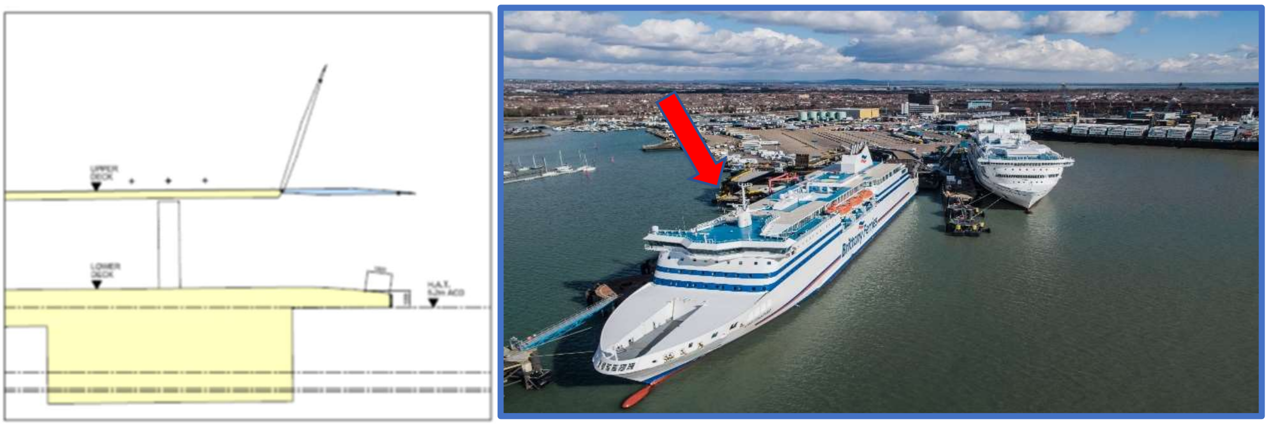

Figure 9.1 Left: schematic of the Linkspan, right: Indicated by the arrow: Linkspan forming a bridge between the quay and the ship (Troelstra,2020)

The Contractor included carbon reduction technology into the linkspan’s 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.

The predominant innovation of the new linkspan lies in the trimming-principle. Whereas the old Linkspan used pneumatic ventilators to force water out of the ballast tanks (thereby raising the linkspan), the new linkspan uses hydraulic pumps to control the water content of the ballast tanks. The pumps are capable of raising or lowering the linkspan at not less than 200 mm per minute and are contained in a fully accessible space. Electric pump motors are of the ‘soft-start’ type to reduce energy consumption.

Due to the energy savings principles applied, the new linkspan uses approximately 15 % less energy: 16,680 kWh/year, corresponding with carbon savings of 4,263 kg/year and an annual revenue of 3216 £/year. As the costs of the pumping equipment relative to the pneumatic equipment is not known, a full financial comparison cannot be made.

10. D.2.4.8 BPS ENERGY PONTOON

The energy pontoon developed within the PECS project comprises a floating structure with 6 Savonius wind turbines mounted on top. Installed capacity: 18Kwh PV and 18Kwh Wind. It also features an integrated battery storage system (74Kwh). Two separate energy pontoons have been developed, built and monitored.

Pontoon1 was placed in the Ostend harbour exposed to the West wind. The system was in operation until it was severely damaged in a storm and unknown external large impact at the end of 2020.

Pontoon2 was intended to be located in Hellevoetsluis, but stayed due to covid at the builder's site (location 2) between the buildings throughout 2020, after which is it was transported to a new location on the water (location 3) in January of 2021. As throughout the monitoring period 2020 pontoon2 was positioned between buildings, no data on electricity production from wind power could be gathered, only from electricity production from solar panels, to the extent that it could be used locally (no energy dump was in use).

Figure 10.1 Energy Pontoons; Top figure Pontoon 1 in Ostend (April 2019 till September 2020) and bottom figure Pontoon 2 at the location3 (January 2021 till to date) (Troelstra,2021)

Due to technical- and organisational (Corona pandemic) problems mentioned before, the system yield is not completely monitored. However, from the installed electricity meters it is clear that overall (throughout the entire monitoring period 2019-2021), in total 6,5 MWh electricity is produced: 1,9 MWh (pontoon 1, 2019) and 4,6 MWh (pontoon 2, 2020). The monitoring data used here is based on the claimed output of 125 kWh/day (46 MWh/year) in this region with solar and wind losses, corresponding with saving roughly 28 tonnes CO_2/year (@0,6 kg/kWh_e). For remote and tropical locations with average windspeed above 6m/s the estimated outputs are 250-375Kwh/day.

Based on the claimed energy output, a total costs of 230.000 (with floating option and integrated battery storage),- and energy costs of 24ct/kWh, the economical payback time is estimated at 15 years and below 10 years for remote & tropical locations.

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