Ports Energy and Carbon Savings

Deliverable 1.8.1

Reports about the optimum mix of low carbon options in ports

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Author

NAME [USE TABLE-TITLE]	ORGANISATION [USE TABLE-TITLE]
Dimitar Bozalakov	Ghent University
Lieven Vandevelde	Ghent University

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1. Introduction

In this report, a summary of the adopted low carbon technologies by the port partners of PECS is given. The report is based on the optimisation tool, which is developed in D1.7.3. As input for this optimisation tool, D1.7.1 was used. The tool was distributed to the port partners of PECS and besides their energy results, comments, opinion about the user-friendliness and future improvements are also given.

2. Results from the different project partners

This section gives a partner by partner description of the achieved energy savings and carbon reduction after performing an optimisation with the tool. As input data, the ports use the annual electrical consumption, its cost per kWh and total available surface for renewables.

2.1. Energy and Carbon savings in port of Portsmouth (PP8)

A screenshot of the case of PP8 is presented in Figure 1. The port's total energy consumption is about 5.39GWh, while the cost of electricity is about 0.1376/kWh. This results in a total energy bill of about 740kEuro/a.

1	Input data		Important!!	Before you run a new optimisation, make sure that cells B11 and I11 are equal!!					
2	Total energy consumption	[kWh]	5388053		Annual electricity consumption of the port				
3	Cost of electricity [Euro/kWh]		0.13736		Contracted price of electricity by the port and the distribution system operato				
4	Total Energy cost	[Euro]	740102.9601		The total energy cost does not include connection costs to the distribution sy				
5	Desired decrease of the electricity cost [%]		6%		Enter the desired annyal decrease of electricy on annual basis				
6	Target energy cost [Euro]		695696.7825		Target cost to be reached!				
7	Define maximum surface for renewables [m^2]		1000		Enter the available surface of renewable energy resources				
8	GHG of Enegy mix of	[gCO2/kWh]	Uninted_Kingdom	0.281	Select a country from the drop menu				
9					Solar energy				Middle sized WT
10			Solar PV T1	Solar PV T2	Solar PV T3	Solar PV T	Solar ther	SolarThermal PV	Wind
11	Total available surface		856.1331944	856.13319	856.1331944	856.133	50		1000
12									
13	CAPEX	[Euro/kWp]	1500	1550	1400	1600	3000		2500
14	OPEX	[Euro/year]	30	31	28	32	30		75
15	LCOE		0.067776102	0.0793371	0.046454399	0.05789	#DIV/0!	#DIV/0! #DIV/0!	0.050375
16	Reference annual solar irradiation	[kW/m^2/yr]	1700	1700	2400	2400			
17	Calculated Energy yield	[kW/m^2/yr]	1050	1049	1053	1071			
18	Green house gas emissions	[gCO2/kWh]	22.66666667	22.688275	31.90883191	31.3725	39		10
19	Power density	[kW/m^2]	0.15	0.17	0.11	0.12	0.6		0.1
20	Life span	[years]	25	25	25	25	20		25
21	Annual production of energy per kWhp		960	1070	870	860			2000
22	Social acceptance indices								
23	**Peak power**	**[kWh]**	**128.4199792**	**145.54264**	**94.17465139**	**102.736**	**2900**		**100**
24	**Annual electricity production**	**[kWh]**	**123283.18**	**155730.63**	**81931.94671**	**88352.9**			**200000**
25									
26	RESULT cost (1st yrear)		695696.7825	691239.8	701376.7879	700495			
27	Resulted reduction in %		6	6.602211	5.232538483	5.35171			
28	Investment cost in renewables		442629.9688	475591.1	381844.5119	414378			
29	Return of investement [years]		9.967756574	9.7331222	9.860115014	10.4619			
30									
31									
32	Total emissions without renewables	[kg]	1514042.893						
33	Total emissions of the renewables	[kg]	4794.418747	5533.2592	4614.352715	4771.86			
34	Annual carbon reduction with	[%]	5.683336663	6.2367485	4.927768206	5.03654			
35									

FIGURE 1 DATA OF PORT OF PORTSMOUTH

A decrease of 6% of the energy bill is desired and the available surface for renewables is 1000m^2. After the optimisation to determine the optimal energy mix is ran, the results show that the needed surface to achieve the desired reduction is about 856m^2 of PV and 1000m^2 for wind. The best technology among the considered are PVT2 – which is the monocrystalline PV technology and 100kW peak power of medium sized wind turbine. A

summary of the return of investment and carbon savings is given in **Fout! Verwijzingsbron niet gevonden.** in section 2.5.

2.2. Energy and Carbon savings in port of OD Ijmond (PP3)

Figure 2 shows the obtained results of (PP3). In this particular case, the local energy community focusses only on rooftop photovoltaic technology. The annual energy consumption is 70.5GWh, while the total bill is 8.46ME at 12 eurocents per kWh.

1	Input data		Important!!	Before you run a new optimisation, make sure that cells B11 and I11 are equal!!						
2	Total energy consumption	[kWh]	70500000		Annual electricity consumption of the port					
3	Cost of electricity [Euro/kWh]		0.12		Contracted price of electricity by the port and the distribution system operator					
4	Total Energy cost	[Euro]	8460000		The total energy cost does not include connection costs to the distribution sytem oe					
5	Desired decrease of the electricity cost [%]		122%		Enter the desired annyal decrease of electricy on annual basis					
6	Target energy cost [Euro]		-1861200		Target cost to be reached!					
7	Define maximum surface for renewables [m^2]		600000		Enter the available surface of renewable energy resources					
8	GHG of Enegy mix of	[gCO2/kWh]	The_Netherlands	0.505	Select a country from the drop menu					
9					Solar energy					Middle sized WT
10			Solar PV T1	Solar PV T2	Solar PV T3	Solar PV T4	Solar thermal	SolarThermal PV		Wind
11	Total available surface		597277.7778	597277.78	597277.7778	597277.78	50			10
12										
13	CAPEX	[Euro/kWp]	1500	1550	1400	1600	3000			2500
14	OPEX	[Euro/year]	30	31	28	32	30			75
15	LCOE		0.067513617	0.0790659	0.046209414	0.0576117	#DIV/0!	#DIV/0!	#DIV/0!	0.0875
16	Reference annual solar irradiation	[kW/m^2/yr]	1700	1700	2400	2400				
17	Calculated Energy yield	[kW/m^2/yr]	1050	1049	1053	1071				
18	Green house gas emissions	[gCO2/kWh]	22.66666667	22.688275	31.90883191	31.372549	39			10
19	Power density	[kW/m^2]	0.15	0.17	0.11	0.12	0.6			0.1
20	Life span	[years]	25	25	25	25	20			25
21	Annual production of energy per kWhp		960	1070	870	860				2000
22	Social acceptance indices									
23	**Peak power**	**[kWh]**	**89591.66667**	**101537.22**	**65700.55556**	**71673.333**	**2900**			**1**
24	**Annual electricity production**	**[kWh]**	**86008000**	**108644828**	**57159483.33**	**61639067**				**2000**
25										
26	RESULT cost (1st yrear)		-1861200	-4577619	1600622	1063072				
27	Resulted reduction in %		122	154.10898	81.0801182	87.434137				
28	Investment cost in renewables		134390000	157385194	91983277.78	114679833				
29	Return of investement [years]		13.02077278	12.071621	13.40985695	15.503711				
30										
31										
32	Total emissions without renewables	[kg]	35602500							
33	Total emissions of the renewables	[kg]	1949534.667	2464983.7	1823912.346	1933794.6				
34	Annual carbon reduction with	[%]	116.5241636	147.18535	75.95712868	82.002511				

FIGURE 2 A SCREENSHOT OF THE CASE OF OD IJMOND

The overall rooftop surface of 60000m^2 that is able to support the weight of the PV panels is given. Since no wind is considered, a small (negligible) number is placed in cell I11, thus the weight factor of the wind in the overall optimisation can be neglected. The results show that if the entire surface is fully populated with PV, the energy reduction is more than 122%. This results in 22% surplus of annual energy production. These results are achieved if PVT1 (poli-crystalline technology) is used. If Mono-crystalline PV panels are installed, then the total energy savings are 154%, which is 54% surplus.

2.3. Energy and Carbon savings in the marinas of Hellevoetlsuis (PP2)

The optimisation result of PP2 are shown in Figure 3. Annual energy consumption of 300000kWh is been reported and cost of 0.15E/kWh. This results in 45000 euro annual energy bill.

1	Input data		Important!!	Before you run a new optimisation, make sure that cells B11 and I11 are equal!!						
2	Total energy consumption	[kWh]	300000		Annual electricity consumption of the port					
3	Cost of electricity [Euro/kWh]		0.15		Contracted price of electricity by the port and the distribution system operat					
4	Total Energy cost	[Euro]	45000		The total energy cost does not include connection costs to the distribution s					
5	Desired decrease of the electricity cost [%]		10%		Enter the desired annyal decrease of electricy on annual basis					
6	Target energy cost [Euro]		40500		Target cost to be reached!					
7	Define maximum surface for renewables [m^2]		2000		Enter the available surface of renewable energy resources					
8	GHG of Enegy mix of	[gCO2/kWh]	The_Netherlands	0.505	Select a country from the drop menu					
9				Solar energy					Middle sized WT	
10			Solar PV T1	Solar PV T2	Solar PV T3	Solar PV T	Solar therr	SolarThermal PV	Wind	I
11	Total available surface		228.8	228.8	228.8	228.8	6.4	0	0	
12										
13	CAPEX	[Euro/kWp]	1500	1550	1400	1600	3000		2500	
14	OPEX	[Euro/year]	30	31	28	32	30		75	
15	LCOE		0.068496825	0.0800819	0.047127075	0.05866	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
16	Reference annual solar irradiation	[kW/m^2/yr]	1700	1700	2400	2400				
17	Calculated Energy yield	[kW/m^2/yr]	1050	1049	1053	1071				
18	Green house gas emissions	[gCO2/kWh]	22.66666667	22.688275	31.90883191	31.3725	39		10	
19	Power density	[kW/m^2]	0.15	0.17	0.11	0.12	0.6		0.1	
20	Life span	[years]	25	25	25	25	20		25	
21	Annual production of energy per kWhp		960	1070	870	860			2000	
22	Social acceptance indices									
23	**Peak power**	**[kWh]**	**34.32**	**38.896**	**25.168**	**27.456**	**2900**		**0**	
24	**Annual electricity production**	**[kWh]**	**32947.2**	**41618.72**	**21896.16**	**23612.2**			**0**	
25										
26	RESULT cost (1st yrear)		40057.92	38757.192	41715.576	41458.2				
27	Resulted reduction in %		10.9824	13.872907	7.29872	7.87072				
28	Investment cost in renewables		51480	60288.8	35235.2	43929.6				
29	Return of investement [years]		10.41666667	9.6573209	10.72796935	12.4031				
30										
31										
32	Total emissions without renewables	[kg]	151500							
33	Total emissions of the renewables	[kg]	746.8032	944.25695	698.6808889	740.774				
34	Annual carbon reduction with	[%]	10.48946059	13.249635	6.837544496	7.38176				

FIGURE 3 A SCREENSHOT OF THE CASE OF HELLEVOETLSUIS

In this case, the maximum available surface is 2000m^2 and the desired energy reduction is 10%. After performing the optimisation, it turns out that the needed surface to achieve this reduction is only 229m^2, which gives a headroom for further decrease of the annual energy cost. Usually in marinas, big and medium sized wind turbines are not desired due to noise and aesthetic reasons. Therefore, this section is not used.

2.4. Energy and Carbon reduction in the Port of Ostend (LP)

The port of Ostend has an annual energy consumption of about 1.5GWh and cost of about 225 000 euro. This results in an average price of 0.15e/kWh. The optimisation results of the LP are presented in Figure 4.

1	Input data		Important!!	Before you run a new optimisation, make sure that cells B11 and I11 are equal!!						
2	Total energy consumption	[kWh]	1500000		Annual electricity consumption of the port					
3	Cost of electricity [Euro/kWh]		0.15		Contracted price of electricity by the port and the distribution system operator					
4	Total Energy cost	[Euro]	225000		The total energy cost does not include connection costs to the distribution sytem oerator					
5	Desired decrease of the electricity cost [%]		20%		Enter the desired annyal decrease of electricy on annual basis					
6	Target energy cost [Euro]		180000		Target cost to be reached!					
7	Define maximum surface for renewables [m^2]		5000		Enter the available surface of renewable energy resources					
8	GHG of Enegy mix of	[gCO2/kWh]	Belgium	0.169	Select a country from the drop menu					
9					Solar energy					Middle sized WT
10			Solar PV T1	Solar PV T2	Solar PV T3	Solar PV T	Solar thermal	SolarThermal PV		Wind
11	Total available surface		713.1225896	713.12259	713.1225896	713.123	50			986.5592183
12										
13	CAPEX	[Euro/kWp]	1500	1550	1400	1600	3000			2500
14	OPEX	[Euro/year]	30	31	28	32	30			75
15	LCOE		0.067828816	0.0793916	0.0465036	0.05795	#DIV/0!	#DIV/0!	#DIV/0!	0.050380109
16	Reference annual solar irradiation	[kW/m^2/yr]	1700	1700	2400	2400				
17	Calculated Energy yield	[kW/m^2/yr]	1050	1049	1053	1071				
18	Green house gas emissions	[gCO2/kWh]	22.66666667	22.688275	31.90883191	31.3725	39			10
19	Power density	[kW/m^2]	0.15	0.17	0.11	0.12	0.6			0.1
20	Life span	[years]	25	25	25	25	20			25
21	Annual production of energy per kWhp		960	1070	870	860				2000
22	Social acceptance indices									
23	**Peak power**	**[kW]**	**106.9683884**	**121.23084**	**78.44348485**	**85.5747**	**2900**			**98.65592183**
24	**Annual electricity production**	**[kWh]**	**102689.6529**	**129717**	**68245.83182**	**73594.3**				**197311.8437**
25										
26	RESULT cost (1st yrear)		179999.7755	175945.67	185166.3487	184364				
27	Resulted reduction in %		20.00009977	21.801923	17.70384503	18.0604				
28	Investment cost in renewables		407092.3872	434547.61	356460.6834	383559				
29	Return of investement [years]		9.046452365	8.8584971	8.948732329	9.43892				
30										
31										
32	Total emissions without renewables	[kg]	253500							
33	Total emissions of the renewables	[kg]	4300.750569	4916.1733	4150.763213	4281.96				
34	Annual carbon reduction with	[%]	18.30355122	19.862604	16.06646309	16.3713				

FIGURE 4 A SCREENSHOT OF THE CASE OF PORT OF OSTEND

Total available surface of 5000m^2 is reported. Nevertheless, after running the optimisation, it turned out that only 713m^2 for PV and 1000m^2 for wind are needed to achieve the needed cost reduction. A summary of all partners is given in **Fout! Verwijzingsbron niet gevonden.**. Again, the most performing PV technology is PVT2, which gives 1.8% advantage compared to the other PV technologies.

2.5. Energy and Carbon reduction in the Port of Dunkirk

This port is a classified as a big port and its annual energy consumption is 10.5GW at about 0.15 euro per kWh. In is assumed that the consumed energy satisfies only the needs of the port utility while the consumption of the situated enterprises in the port is not included in this optimisation. In addition to that, No wind turbines are considered in the port. The available surface for PV technology is about 200 hectares.

1	Input data	Important!!	Before you run a new optimisation, make sure that cells B11 and I11 are equal!!						
2	Total energy consumption [kWh]	10500000		Annual electricity consumption of the port					
3	Cost of electricity [Euro/kWh]	0.15		Contracted price of electricity by the port and the distribution system o					
4	Total Energy cost [Euro]	1575000		The total energy cost does not include connection costs to the distribut					
5	Desired decrease of the electricity cost [%]	20%		Enter the desired annyal decrease of electricy on annual basis					
6	Target energy cost [Euro]	1260000		Target cost to be reached!					
7	Define maximum surface for renewables [m^2]	2000000		Enter the available surface of renewable energy resources					
8	GHG of Enegy mix of [gCO2/kWh]	France	0.058	Select a country from the drop menu					
9				Solar energy					Middle size
10		Solar PV T1	Solar PV T2	Solar PV T3	Solar PV T4	Solar therr	SolarThermal PV		Wind
11	Total available surface	14569.44444	14569.444	14569.44444	14569.44	50			10
12									
13	CAPEX [Euro/kWp]	1500	1550	1400	1600	3000			2500
14	OPEX [Euro/year]	30	31	28	32	30			75
15	LCOE	0.067528687	0.0790815	0.046223479	0.057628	#DIV/0!	#DIV/0!	#DIV/0!	0.0875
16	Reference annual solar irradiation [kW/m^2/yr]	1700	1700	2400	2400				
17	Calculated Energy yield [kW/m^2/yr]	1050	1049	1053	1071				
18	Green house gas emissions [gCO2/kWh]	22.66666667	22.688275	31.90883191	31.37255	39			10
19	Power density [kW/m^2]	0.15	0.17	0.11	0.12	0.6			0.1
20	Life span [years]	25	25	25	25	20			25
21	Annual production of energy per kWhp	960	1070	870	860				2000
22	Social acceptance indices								
23	**Peak power [kWh]**	**2185.416667**	**2476.8056**	**1602.638889**	**1748.333**	**2900**			**1**
24	**Annual electricity production [kWh]**	**2098000**	**2650181.9**	**1394295.833**	**1503567**				**2000**
25									
26	RESULT cost (1st yrear)	1260000	1177172.7	1365555.625	1349165				
27	Resulted reduction in %	20	25.258876	13.29805556	14.33873				
28	Investment cost in renewables	3280625	3841548.6	2246194.444	2799833				
29	Return of investement [years]	10.41468254	9.6563225	10.72453936	12.39769				
30									
31									
32	Total emissions without renewables [kg]	609000							
33	Total emissions of the renewables [kg]	47574.66667	60148.056	44510.35138	47190.72				
34	Annual carbon reduction with [%]	12.18806787	15.382348	5.989295067	6.589844				

FIGURE 5 A SCREENSHOT OF THE CASE OF PORT OF DUNKIRK

In this optimisation, total surface of 2000000 m^2 is considered, while the desired cost reduction is 20%. After performing the optimisation, it turned out that only 14600 m^2 are necessary to achieve the 20% cost reduction. PV T2 again shows the highest energy outcome and it is able to achieve the incredible 25% compared to the PV T1 and the other considered technologies. PV T2 is also able to decrease the carbon emissions of the port with almost 15.4%. It is worth pointing out that this reduction is the smallest of all of the considered ports, which is due to the fact that a large portion of the total energy mix of France mainly consists of nuclear power plants.

3. Remarks of the different ports and marinas

The following questions were asked to the port and marina partners:

1. Was it easy to set it up?
2. Is it relatively easy to use?
3. Did you need a lot of assistance from the port's specialised personnel? (Getting data like surface area, cost of electricity and energy consumption, etc.)

The results of which are listed in Table 1.

TABLE 1 USEFULNESS AND USER-FRIENDLINESS OF THE TOOL

Partner	Easy to set-up	Easy to use	Any assistance from Port specialised personnel
Port of Portsmouth (PP8)	Yes	Yes	No
OD Ijmond (PP3)	Yes*	Yes	No data
Hellevoetlsuis (PP2)	Yes	Yes	No data
Port of Ostend	Yes*	Yes	No
Port of Dunkirk	Yes	Yes	No data

* One e-mail is exchanged for further instructions due to technical reasons

Additional remarks are made about the accuracy of the tool from PP2 about the accuracy of the results. The tool was developed based on literature studies and available data from PV and wind generation data in Ghent University. It was compared with reference cases of existing plants and accuracy of 5% is achieved for the solar PV technologies. As of the wind generators, the accuracy varies based on every particular case due to local geographical and human made obstructions.

A remark from LP was made about the energy use of the renewable energy and whether feed in tariffs are considered. Note that the tool is developed to target the annual cost reduction. This means that all renewable energy is locally consumed. If the share of renewables is very high (more than 50% was found in literature), then there will be some injection into the public grid and the prices are then much lower. This will result in a different number of return of investment, energy and carbon savings. Nevertheless, to consider the feed in tariffs and minimise the injection into the grid, the user must feed the tool with more data and the complexity and the interpretation of the result will be more difficult.

4. Conclusion

In this report, a summary of the used carbon saving technologies, that can be adopted by the different ports and marinas in the project consortium of PECS is given. The majority of the ports have selected the solar PV T2 (mono-crystalline photo voltaic) to reach the needed energy reduction and thus cost reduction of their annual bill. The overall opinion is that the tool is easy to use after reading the set-up instructions.