Interreg
2 Seas Mers Zeeën
PECS
European Regional Development Fund

Ports Energy and Carbon Savings

DELIVERABLES 1.4.1, 1.4.2 AND 1.4.3

RENEWABLE ENERGY POTENTIAL OF PORTS

Prof. dr. J. van Berkel (coordinator),
HZ University of Applied Sciences
Vlissingen (NL)

With contributions of all Ports and knowledge Institutes within PECS

Report version
Saturday, 06 July 2019

TABLE OF CONTENTS

INTRODUCTION

In this report the method and tool for the assessment of the potential of renewable energy will be tested against the five ports represented in PECS.
In every chapter, first the port is characterised on a higher detail level than was done in D1.3.2. Also the availability of renewable energy is explored at a higher level of detail.

1. PORTSMOUTH

Portsmouth port is a ‘niche’ port on the UK’s south coast. It is a ‘landlord’ port insofar as the majority of its income comes simply from leasing out ‘slots’ or berths alongside its five Ro-Ro berths and allowing private enterprise to compete serially for the servicing of those vessels with regard to stevedoring, agency, tugs, cleaning, bunkering etc. The only jobs which the port keeps for itself are those of a statutory nature and those which would suffer from parallel competition i.e. security, mooring and pilotage.

Figure 2.1 Portsmouth port layout – total area.

The port layout above shows the entirety of the port land which amounts to approximately 28ha. Whilst there have traditionally been two commercial berths in this area of the port, the first Ro-Ro berth was developed in 1976 to the North of these. By reclaiming land from the sea the Ferry Port now has five berths as can be seen in the photograph above. The two traditional commercial berths can still be seen to the south of the Ferry Port, a refrigerated cargo vessel can be seen to be discharging on Albert Johnson Quay, the largest of the two berths. Albert Johnson Quay and Flathouse Quay whilst operating on land owned by the city of Portsmouth have always been operated by private companies (until 2008 when PCC stepped in to prevent a fire sale). The area of the port which could be most accurately described as a municipal port is the ferry port itself whilst the two traditional berths (primarily utilised in the fruit trade) are operated by Mainland Market Deliveries (MMD). The ferry port comprises 18.6ha and the MMD area around 9.3ha.

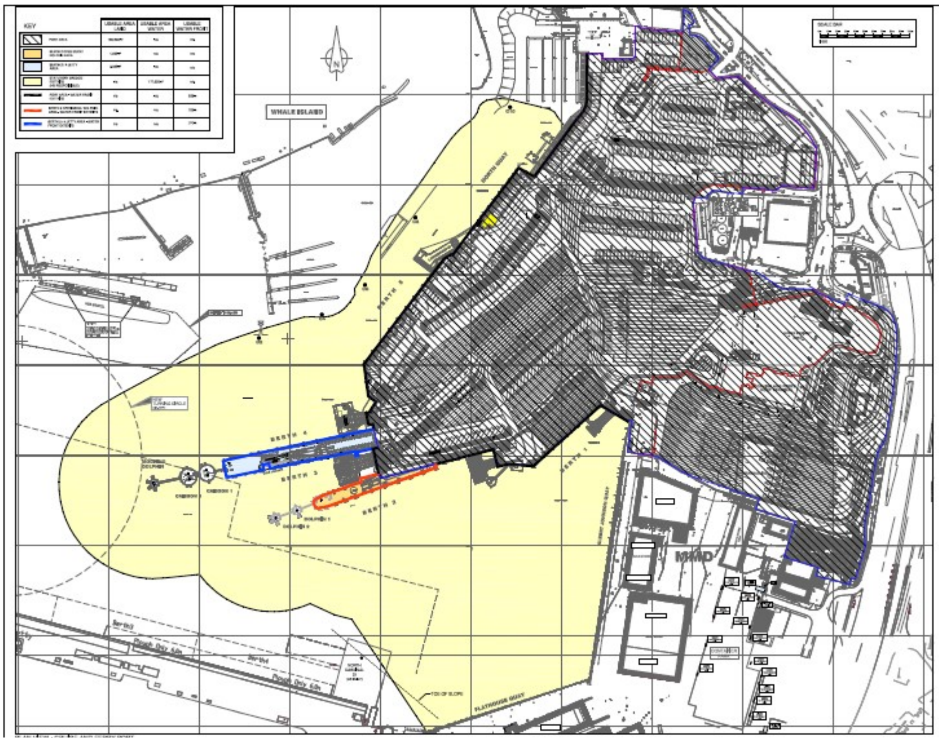


Figure 2.2 Portsmouth Port Layout – Ferry Port Area 18.653ha

The latest figures shows that Portsmouth's carbon emissions stand at 1.2 million tons per year. This is made up of 543,000 tons from the Industrial sector. (Portsmouth Climate Change Strategy, 2018)

Diesel is typically used to fuel mobile equipment and average values show a yearly fuel consumption of almost 10 million fuel litres (in form of diesel oil). Total electricity per year of Portsmouth is about 3,618 kWh/m² and electricity density is 413 W/m². (Gregory, 2012).

Table 4.1 Portsmouth renewable energy potential calculation too

	Quantity	remark
Current port energy consumption		
Port electricity consumption [kWh/a]	2672122	From Energy audit (Workpackage 1),
Port gas consumption [kWh/a]	419519	From Energy audit (Workpackage 1)
Port heat consumption [kWh/a]	0	From Energy audit (Workpackage 1)
Total energy consumption [kWh/a]	**3091641**	Assuming that electricity and heat are equivalent
Port characteristics		
Water area of the port: Floating solar thermal [m2]	1.300.000	Portsmouth International Port is a strange type of port even by UK standards. This is because the commercial 'ownership' of the port extends out to only 50m off the commercial berths which it controls. In commercial terms this is a Net benefit in that the Royal Navy pay for the normal dregging, conservancy and buoyage duties. It does however mean that the commercial port has no control and no rights over those areas of the port that would normally come under its jurisdiction for development and/or in this case energy production from renewable sources. The Filling Factor is also affected by the fact that the majority of the Port area laays within a RAMSAR site, and AONB and also comes under an area denoted and protected under the 'Birds' Directive.
Filling factor [-]	5%	
Nett area FLOATING SOLAR THERMAL [m2]	65000	
Water area of the port: Floating Solar PV [m2]	1.300.000	
Filling factor [-]	5%	
Nett area SOLAR PV [m2]	65000	
Water area of the port: Floating wind [m2]	1.300.000	
Filling factor [-]	5%	
Nett area floating wind [m2]	65000	
Land area of the port: land based and rooftop Solar Thermal [m2]	28.000	
Filling factor [-]	20%	
Nett area land and roof SOLAR Thermal [m2]	5600	
Land area of the port: land based and rooftop Solar PV [m2]	28.000	
Filling factor [-]	20%	
Nett area land and roof SOLAR PV [m2]	5600	
Land area of the port WIND [m2]	28.000	
Filling factor [-]	60%	
Nett area WIND [m2]	16800	
Usable area TIDAL [m2]	0	N.A. due to unfafourable wave climate
Filling factor [-]	0%	
Nett area TIDAL [m2]	0	
Usable water front length (wave) [m]	0	N.A. due to unfafourable wave climate
Filling factor [-]	0%	
Nett area WAVE [m]	0	
Port Renewable potential		
Solar Thermal [kWh/a]	37107360	D x power density of 60 W/m2
Solar PV [kWh/a]	10513752	E x power density of 17 W/m2
Wind [kWh/a]	1433136	F x power density of 2 W/m2
Tidal [kWh/a]	0	G x 2 power density of 2 W/m2. Tidal Range is good but availability of water area to incorporate tidal generation so limited as to be prohibitve of this technology in Portsmouth Harbour. A tidal 'Archimedes' screw could work.
Wave [kWh/a]	0	H x 10 kW/m. N.A. due to unfafourable wave climate
Total renewable potential [kWh/a]	**49054248**	
Reduction of energy consumption [%]	**1587%**	

2. OOSTENDE

The port of Oostende is an SME Port, directly situated at the North Sea coast.

Figure 3.1 Port of Oostende

The port of Oostende focusses on the following maritime and industrial activities :

- **Blue industry, blue growth and offshore renewable energy (outer port)**: a major industrial cluster has been developed, specializing in the technology of the installation and the maintenance of offshore energy installations. This cluster is supported by the **research facilities** at the Greenbridge business incubator, set up by the University of Gent in cooperation with the port of Oostende and major University colleges. Today, a new wave and towing tank is built in the inner port for further research. Within the incubator, projects in the field of aquaculture are set up between the university and the fisheries at sea. A science park has been set up recently.

- **Roll-on, roll off (outer port):** the port of Oostende disposes of one RoRo terminal, as well as several RoRo pontoons. One of the pontoons has been fortified to handle cargo up till 650 tons and is used within the offshore logistics operations.

- **Circular economy (inner port)** : several companies in the port of Oostende have developed new technologies for the reconversion of non-ferro metals, asphalt, construction materials into new materials, ready for the industry and the construction-sector. Different kinds of biomass are used for the production of renewable energy.

- **Project cargo and bulk logistics** (outer and inner port) : the port of Oostende has the only Belgian heavy load-quay, able to carry up to 20 tons/m². This enables the port to handle major logistic operations involving very heavy cargo.

- **SME chemical industry (SEVESO-area in the inner port)**: alongside the canal Oostende-Gent, chemistry-related industries have been developed: on the left bank of the canal, there is the site of Proviron NV, investing in sustainable chemical production; and on the right bank there is the site of GFS NV, specializing in the storage of gasoline (3 tanks of 34 000 m³) and the handling, repacking and warehousing of gasses and chemical products.

- **Fishing port :** up till today, Belgian fishing-ships are landing their fish in Oostende and selling their fish at the fish auction. Considering the decline of the Belgian fishing fleet, this activity has become less and less important. Moreover, more than the half of the ships are in the hands of the Urker families. On the other hand, the fish production industry is still well organized within the port of Oostende.

- **Cruises:** every year, several cruise ships are calling at the port of Oostende. Due to the limited swing circle, only cruise ships up till 200 meter are able to enter the port. On the other hand, the cruise guests have direct access to the city of Oostende and the railway station, contrary to other ports where the guests are stuck in between containers or port traffic.

- **Marina’s (outer port):** within the port of Oostende, several marina’s are operating, hosting several sailing clubs.

Figure 3.2 Port of Oostende

- **The port of Oostende is multimodal connected :**

- the outer port has a direct and efficient access to the North sea,
- the outer and the inner road are directly connected to the A10 and the European motorway system (close links to France and Germany)
- The inner port is directly connected to the European railway system and a railway platform has been developed on the right bank of the port
- Inland navigation and the installed quay infrastructure at the inner port allows the operators to handle inland barges and coasters, up till 4000 tons.

- The airport of Oostende gives the chance for attracting more cargo operations and gives added value in offshore operations.

Characteristics of the port.

- Total surface of the port is 658 ha of which ca. 199 ha water surface (including drainage basin Spuikom).
- The surface of the drainage bassin ('spuikom') is about 80 ha. The drainage bassin is used for different purposes such as fishing, swimming, surfing and diving.
- total length of road network is 55 KM.
- Total length of railway network is 20 KM.
- Total length quay walls is 8.2 KM
- Tidal difference in the port: 4,5 M.
- Length of the breakwaters: 300 M each
- Depth of port : 8 m LOA

Points of attention

- due to the proximity of an airport, there are restrictions for placing (high) windmills
- there are no possibilities to use the coastline of Oostende (6 km) for the installation of renewable energy sources
- there is a plan to build test-infrastructure for wave and tidal energy, close to the Eastern breakwater
- the tidal climate is not the best for operation tidal energy but good for testing
- difference between high tide and low tide is 4,5 meters
- a lock is in between the outer port and the inner port
- Several installations in biofuel and biomass are operational in the inner port. Due to the disappearance of financial support, the business models and the operations have been changed and are in need for further adaptation.
- contrary to the Netherlands, the park managers in Belgian need to build the subsea facilities themselves, including the organisation of the surveying. There are no indirect subsidies in Belgium.
- the first wind park is connected by cable to the high-voltage substation, situated at the port of Oostende.

On the basis of the information under section "Port Characteristics", table gives the renewable energy potential of the port of Oostende.

	Quantity	remark
Current port energy consumption		
Port electricity consumption [kWh/a]	3130000	From Energy audit (Workpackage 1),
Port gas consumption [kWh/a]		From Energy audit (Workpackage 1)
Port heat consumption [kWh/a]		From Energy audit (Workpackage 1)
Total energy consumption [kWh/a]	**3130000**	Assuming that electricity and heat are equivalent
Port characteristics		
Water area of the port: Floating solar thermal [m2]	1.990.000	
Filling factor [-]	0%	N.A. due to insufficient space available
Nett area FLOATING SOLAR THERMAL [m2]	0	
Water area of the port: Floating Solar PV [m2]	1.990.000	
Filling factor [-]	0%	N.A. due to insufficient space available
Nett area SOLAR PV [m2]	0	
Water area of the port: Floating wind [m2]	1.990.000	
Filling factor [-]	0%	N.A. due to insufficient space available
Nett area floating wind [m2]	0	
Land area of the port: land based and rooftop Solar Thermal [m2]	4.590.000	
Filling factor [-]	0%	N.A. due to insufficient space available
Nett area land and roof SOLAR Thermal [m2]	0	
Land area of the port: land based and rooftop Solar PV [m2]	4.590.000	
Filling factor [-]	0%	N.A. due to insufficient space available
Nett area land and roof SOLAR PV [m2]	0	
Land area of the port WIND [m2]	4.590.000	
Filling factor [-]	0%	N.A. due to insufficient space available ???
Nett area WIND [m2]	0	
Usable area TIDAL [m2]	800000	N.A. due to unfafourable wave climate
Filling factor [-]	100%	
Nett area TIDAL [m2]	800000	
Usable water front length (wave) [m]	0	N.A. due to unfafourable wave climate
Filling factor [-]	0%	
Nett area WAVE [m]	0	
Port Renewable potential		
Solar Thermal [kWh/a]	0	D x power density of 60 W/m2
Solar PV [kWh/a]	0	E x power density of 17 W/m2
Wind [kWh/a]	0	F x power density of 2 W/m2
Tidal [kWh/a]	14016000	G x 2 power density of 2 W/m2. Tidal Range is good but availability of water area to incorporate tidal generation so limited as to be prohibitve of this technology in Portsmouth Harbour. A tidal 'Archimedes' screw could work.
Wave [kWh/a]	0	H x 10 kW/m. N.A. due to unfafourable wave climate
Total renewable potential [kWh/a]	**14016000**	
Reduction of energy consumption [%]	**448**	

More information:

http://www.vlaamsehavencommissie.be/vhc/pagina/fysische-kenmerken-haven-oostende
https://www.portofoostende.be/maritime-info
https://www.portofoostende.be/sites/default/files/about/Vision_PortofOostende_2018-04-18_lr.pdf
https://nl.wikipedia.org/wiki/Spuikom
http://www.vliz.be/spuikom/monitoring.php

3. DUNKERQUE

Introduction

Work Package O2-A.1.3 focuses on the assessment of renewable energies to small and medium-sized ports, developing a potential determination method. Special attention is paid to solar and wind. The calculations necessary for the determination of the potential are integrated in a spreadsheet usable by the ports. To go further in this analysis, the renewable energy potential is studied in a very detailed way for the port of Dunkirk.

Purpose of the work

To know the potential of renewable energies, it is necessary to take into account the intermittency of the resulting production. Several complementary technologies can be exploited. To determine the optimal energy mix, a detailed study of temporal variations of production of each technology must be carried out.
Data used describe wind and solar resource over several years. This report doesn’t deal prospectively with the evolution of solar and wind resources that require complex models.
The results delivered are data matrices and graphs showing resource and production averaged by hour, month and year.
The port of Dunkirk can serve as a basis for obtaining the first results. Then the method could be user for other ports.
Beyond the strictly energetic aspect, the legal, social and environmental dimensions could be studied. These results could be valid only at the national level because the jurisdiction varies between countries.

The port of Dunkirk

Dunkirk is the fifth most populated city of Hauts-de-France, with more than 88 000 inhabitants in 2015. In the North Sea, Dunkirk is the third seaport in France in terms of traffic. The port is also the first energy platform in the Hauts-de-France via the Gravelines nuclear power plant, the DK6 power station and the LNG terminal.

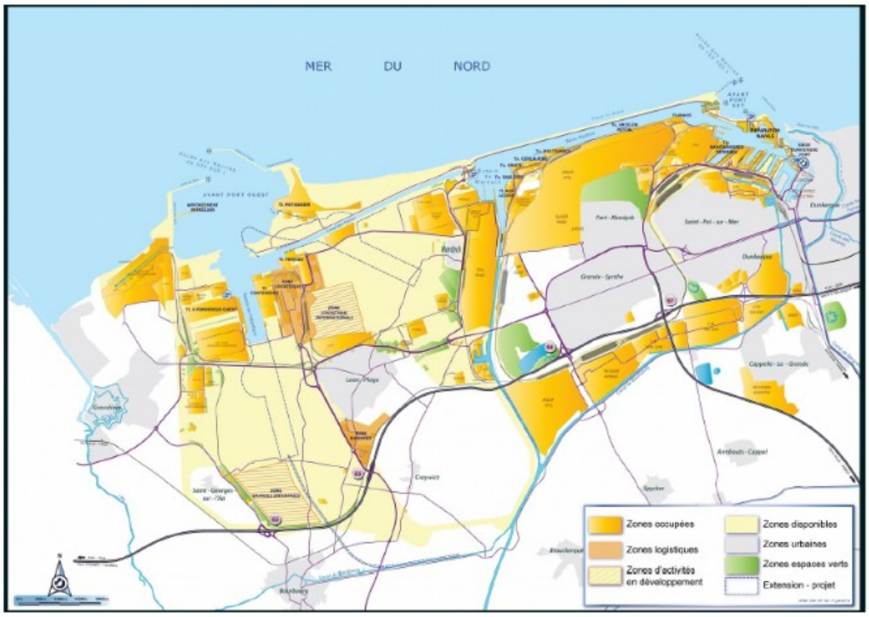


Figure 4.1 Distribution of spaces in Dunkerque

The sunshine of the city is slightly lower than the national average. Wind speeds in the region are relatively high and stable. The region Hauts-de-France has an ambitious wind energy target of almost 4000 MW by 2020. It also aims to install 700 MWp of photovoltaic by 2020.

Photovoltaic potential

Data & method

Photovoltaic Geographical Information System (PVGIS) is a project developed for 10 years by the European Joint Research Center. It involves evaluating solar resources, studying photovoltaic performance, and sharing knowledge and data around these topics.

PVGIS database is free of charge : http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#HR. The PVGIS platform is extremely complete (it provides directly the production values for different technologies) and totally transparent on its calculation methods which cross several models. Initial data is provided by the geostationary satellites of MeteoSat (second generation, MSG). PVGIS 5 data were reanalyzed by CM-SAF (Satellite Application Facility on Climate Monitoring).

Characteristics of PVGIS :

- Type of data : satellite and models
- Time : 2007 – 2016
- Spatial resolution : 3 km
- Time resolution : hour
- Orientations of solar panels : horizontal fixed surface, fixed surface bent at 30 ° south orientation, moving surface with a vertical axis tilted at 55 ° (optimal angle), moving surface with two axes.
- Data : irradiance and photovoltaic production.
- The coordinates of the studied point are: 51,044 and 2,379.

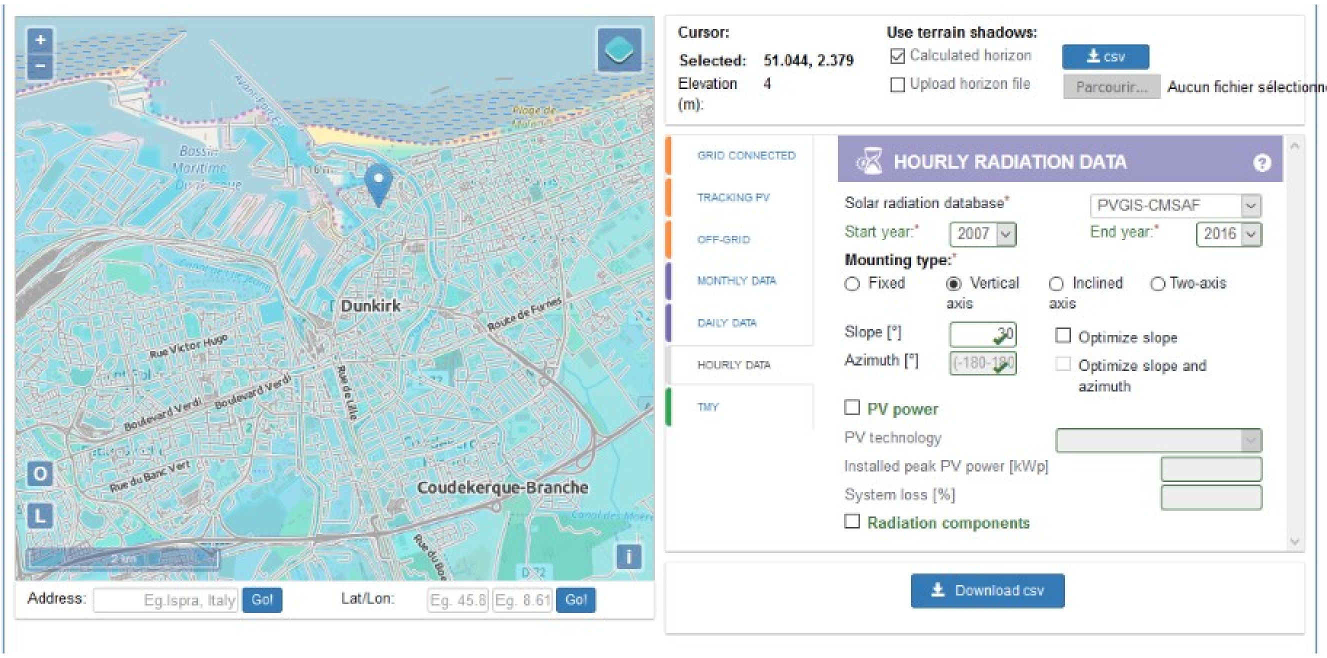


Figure 4.2 Visual of the PVGIS interface

1. In this study, two technologies of solar panel are considered:
   silicon technology : the yield is fixed at 15%. The peak power for 10 m² of solar panel is 1.5 kWp.
2. thin-film-based technology : the yield is fixed at of 10%. The peak power for 10 m² of solar panel is 1 kWp.

Thus, 8 scenarios are established. The scenarios are described in the table below.

Orientation of solar pannel	Silicon technology	Thin-film-based technology
Horizontal fixed surface	Scenario 1	Scenario 2
Fixed surface bent at 30 ° south orientation	Scenario 3	Scenario 4
Moving surface with a vertical axis tilted at 55 ° (optimal angle)	Scenario 5	Scenario 6
Moving surface with two axes.	Scenario 7	Scenario 8

Data is processed by Python. Irradiance and photovoltaic production are studied. The results are established for 10 m² of photovoltaic panels.

	Silicium cristallin	Couche mince
Base 1	Scénario 1	Scénario 2
Base 2	Scénario 3	Scénario 4
Base 3	Scénario 5	Scénario 6
Base 4	Scénario 7	Scénario 8

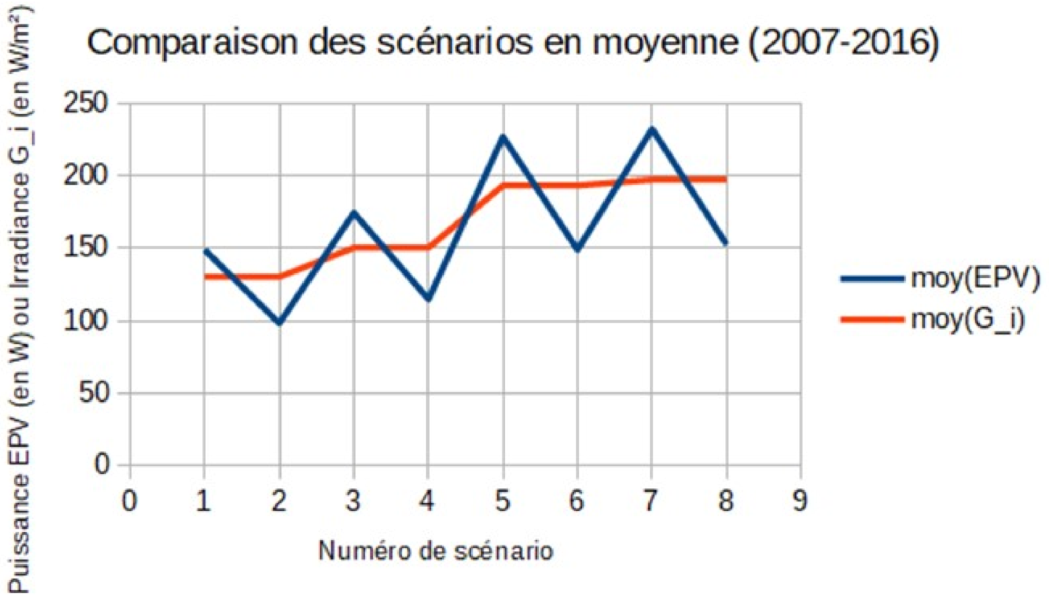
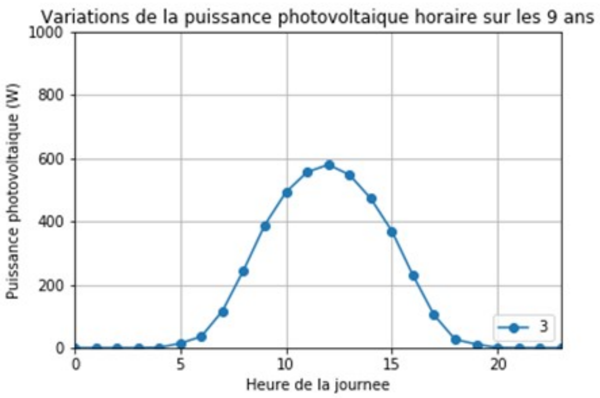


Figure 4.3. Average irradiance (W/m²) and average production of 10m² solar panels (Wh) for each scenario

The choice of technology has a strong impact on average recoverable production, increasing it by around 35%.
From the PVGIS data, it is possible to calculate:

1. annual averages to evaluate the variability of irradiance and photovoltaic power between several years
2. the typical day (UTC) and the typical year over the entire 10 years (below the power curves for scenario 3 : Fixed surface bent at 30 ° south orientation and silicon technology)



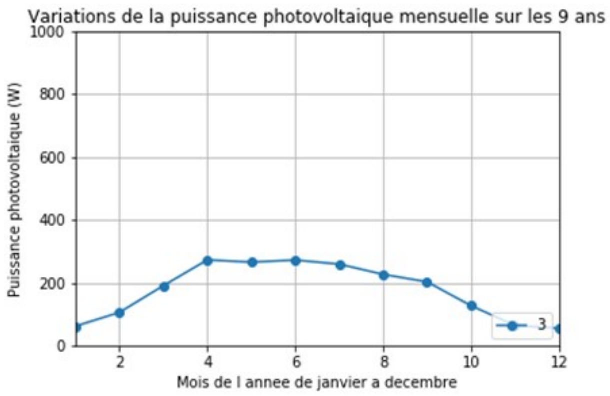


Figure 4.5 Variations of average production of 10m² solar panels (Wh) for each hour of the day and per month

- the typical day for each month (UTC time) (below the production curves for scenario 3).

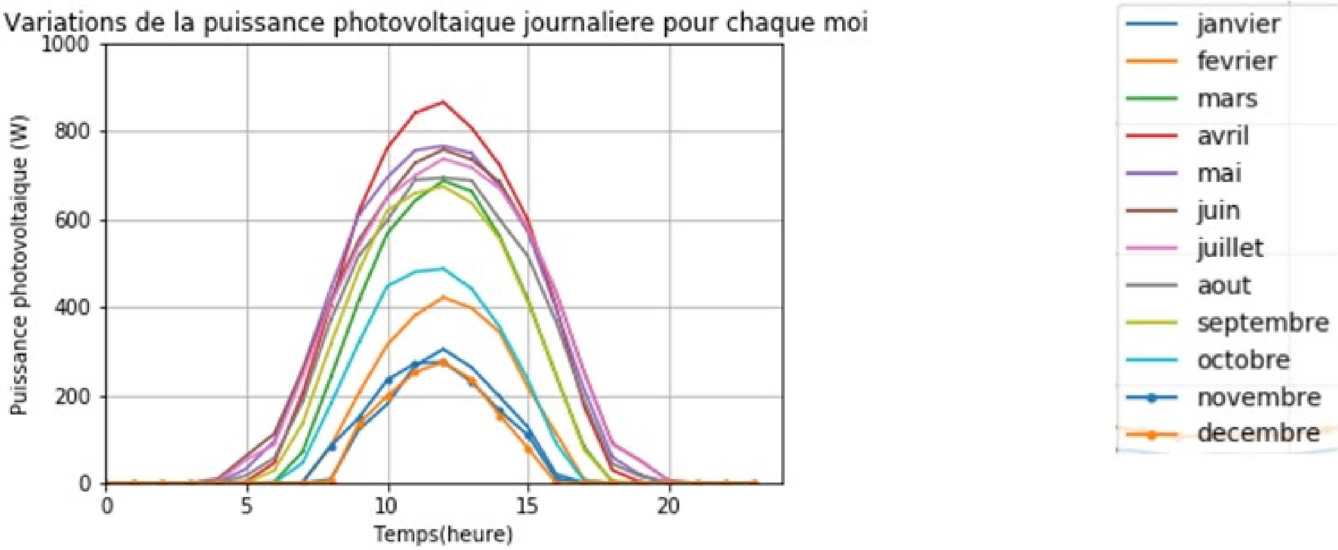


Figure 4.6 Variations of average production (Wh) of 10m² solar panels for each hour of the day and per month

Photovoltaic power varies during the day. There is a peak around 12h. Solar energy is more importantefrom March to September with a power greater than 600 W from 10h to 13h in the case of scenario 3.

Whatever the month of the year, the photovoltaic can not ensure a consistent production at night, between 20h and 4h. This interval extends from 17h to 7h in winter.

Wind potential

Data & method

In order to quantify the wind potential, it is necessary to obtain local wind data. Unlike irradiance, the wind shows very important local variability. Several database exist: the RETScreen model, the CFSR model, the HOMER model, WindFinder, InfoClimat, Météo France (in situ observations, models or climatology)….

In this study, Météo France weather data are used. They are acquired at the Dunkerque semaphore located in the port area, using a Deolia 92 anemometer. The data are available from January 1, 2008 to December 31, 2017. The coordinates of the point are:

- latitude: 51 ° 03'18 "N
- longitude: 2 ° 20'18" E
- altitude: 11m.

Figure 4.7 Location of the wind measurement point

The wind speed is averaged over the 10 minutes before the round time. There is a data for every hour.

A first analysis of the data gives the following information:
- the average speed is 5.42 m/s ;
- the maximum speed is 20.4 m/s (reached 02/01/17 at 2am) ;
- the wind rose describes the origin of the winds at the measuring point (see following illustration).

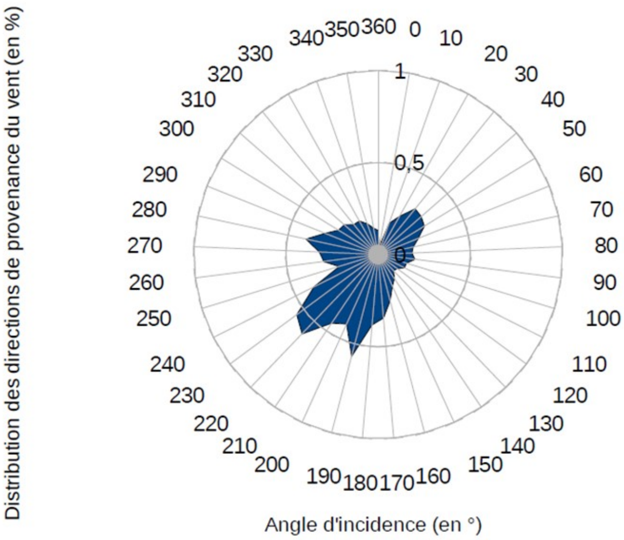


Figure 4.8 Wind rose at the Dunkirk semaphore

Calculation of the wind production is done in several stages. Python software is used for calculation.

- **Step 1: Average wind speed on the surface swept by the blades of the wind turbine**

Wind production is calculated using the following formula:

$(A=\pi.R^2)$,

Pe the wind power, ρ the density of the air, the swept surface and v the wind speed.

Wind turbines sweep a large area through their pale. Depending on the roughness of the ground, the wind speed can vary a lot on this surface. Only wind data at 10m are available. It is necessary to extrapolate the wind at the heights traveled by the blades of the wind turbine.

- **Step 2: Taking into account the yield of wind turbine**

The efficiency of the wind turbine depends on the wind speed coming to the wind turbine. The power curve of the wind turbine identify the variations of the yield with wind speed. The instantaneous efficiency is the ratio between the electrical power delivered by the wind turbine and the instantaneous wind power.

Results

The results are calculated for the operation of a single wind turbine. The technology studied is a Bonus Wind Turbine B41 / 600 (rotor diameter: 41 m, mast height: 50 m, power : 600 kW).

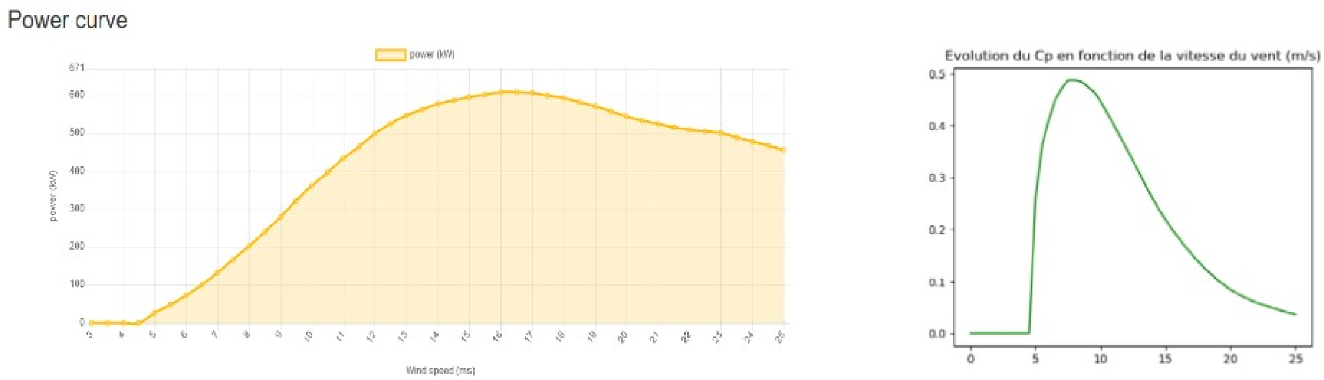


Figure 4.9 Production curve of the wind turbine and variations of its yield according to wind speed (https://en.wind-turbine-models.com)

Several graphics are realized :
- annual averages to evaluate the variability of power between two years ;

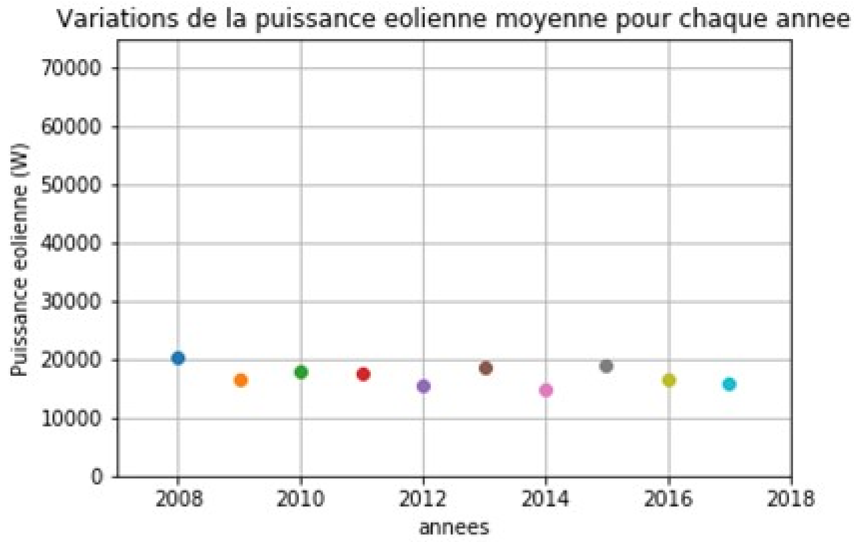


Figure 4.10

- the typical day and the typical year ;

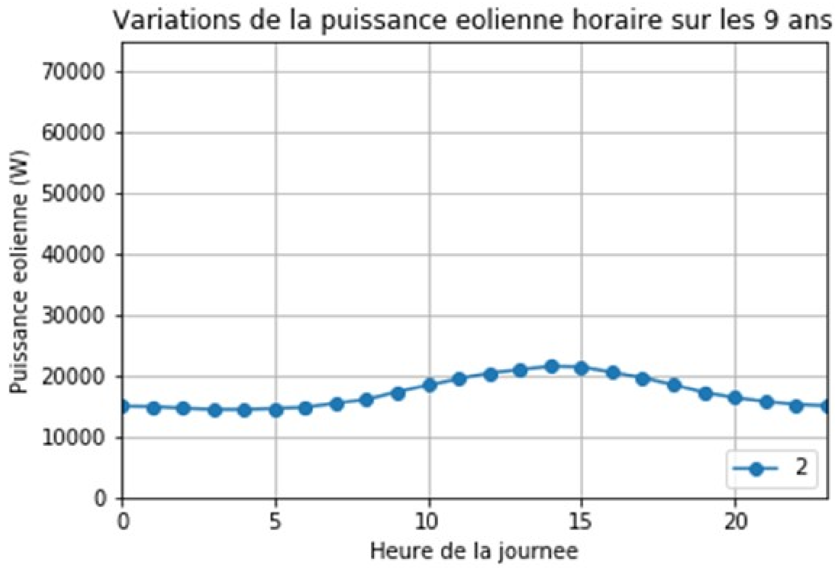


Figure 4.11 Variations of average production for each hour of the day

- the typical day for each month ;

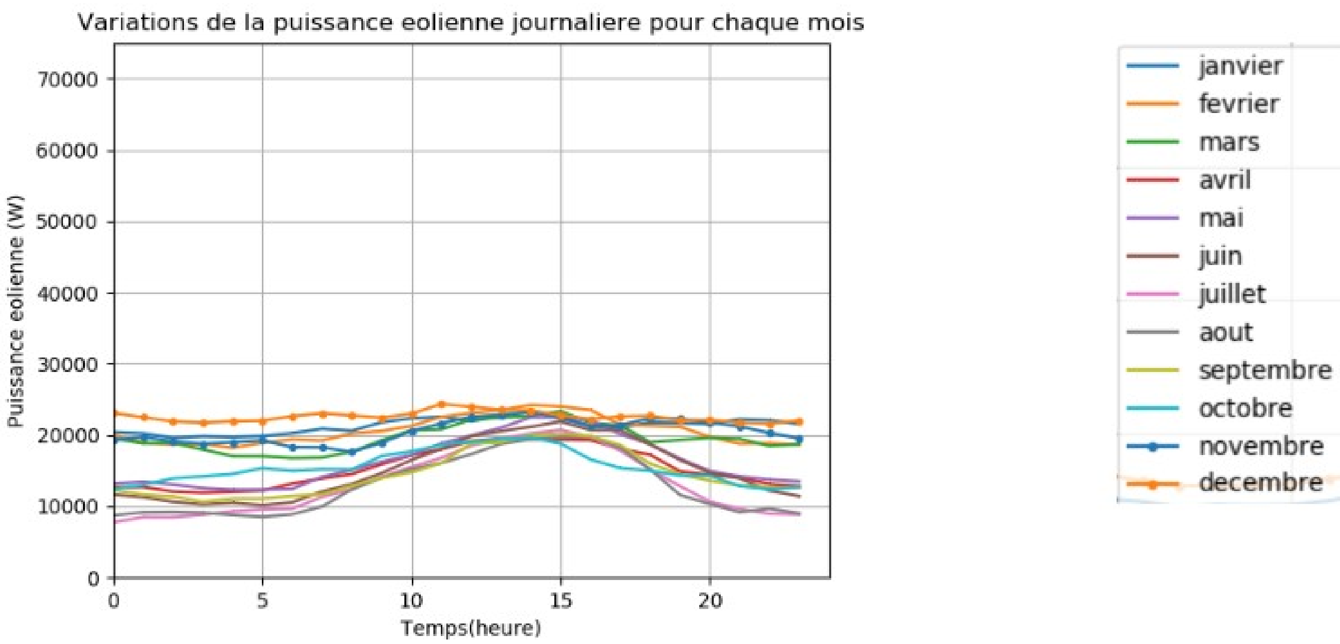


Figure 4.12 Variations of average production for each hour of the day and per month

The wind doesn't show significant variations on the day from November to March, but we can see an increase in the recoverable power from 7am to 20h for the other months. Moreover, unlike photovoltaics, the annual variability is high : increase of the power of 30 % from 2014 to 2015 for example.

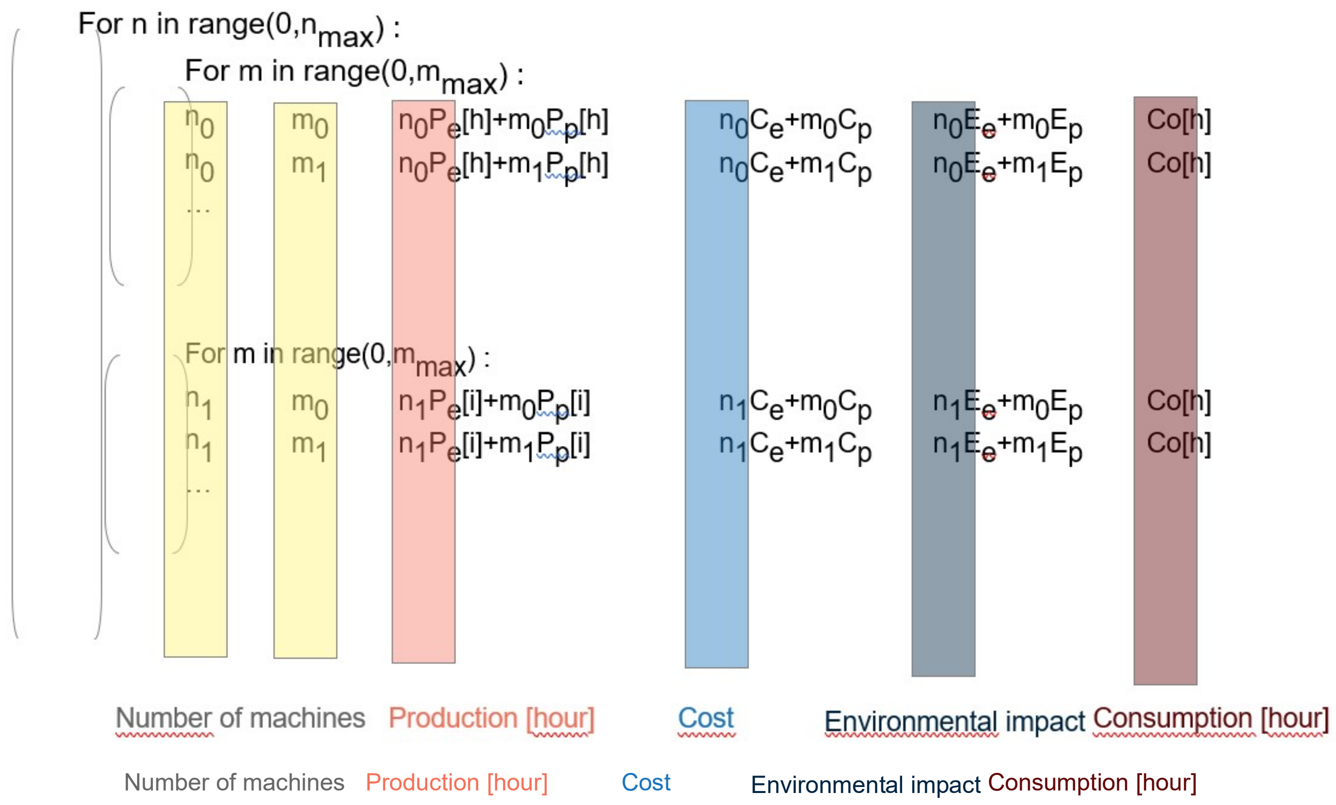
Energy mix

Thanks to the previous results, different energy mix scenarios can be studied. Scenarios can be indicated in a single matrix. Input data are :

- Production :
  → Average photovoltaic production per hour of the day ;
  → Average wind production per hour of the day.
- Average consumption per hour of the day ;
- Average cost of a wind turbine over 20 years of operation ;
- Cost of a photovoltaic installation of 10m² over 20 years of operation ;
- Estimation of the impact of wind turbines on the environment ;
- Estimation of the impact of photovoltaic panels on the environment ;
- Available area for the installation of wind turbines ;
- Distance between wind turbines ;
- Available area for the installation of photovoltaic panels.

Variable parameters are :

- n: number of wind turbines ;
- m: number of photovoltaic installations of 10m².



From this matrix different elements can be searched:

- respond to consumption ($nP_e[h]+mP_p[h] > x(\%) * Co\ [h]$) ;
- minimize costs (min Cost)

....

Generalization of results

The results obtained for the port of Dunkirk could be calculated for the other ports. PVGIS provides informations oh photovoltaic potential.

Port	***Dunkirk***	***Medemblik***	***Porthleven***	***Wells-next-the-Sea***
Average irradinace (W)	192,88	204,14	212,71	192,69
Avrage power (W)	226,95	242,73	254,95	228,66

To estimate the wind potential, reanalysis (CFRS, Era Interim, …) data are available all over Europe. However, these data are less precise than in situ measurements.

	Quantity	remark
Current port energy consumption		
Port electricity consumption [kWh/a]	0	From Energy audit (Workpackage 1),
Port gas consumption [kWh/a]	0	From Energy audit (Workpackage 1)
Port heat consumption [kWh/a]	0	From Energy audit (Workpackage 1)
Total energy consumption [kWh/a]	**0**	Assuming that elektricity and heat are
Port characteristics		
Water area of the port: Floating solar thermal [m2]	0	Due to existing activities
Filling factor [-]	0 %	
Nett area FLOATING SOLAR THERMAL [m2]	0	
Water area of the port: Floating Solar PV [m2]	0	Due to existing activities
Filling factor [-]	50 %	
Nett area SOLAR PV [m2]	0	
Water area of the port: Floating wind [m2]	0	Due to existing activities
Filling factor [-]	50 %	
Nett area floating wind [m2]	0	
Land area of the port: land based and rooftop Solar	120000	
Filling factor [-]	50 %	
Nett area land and roof SOLAR Thermal [m2]	60000	
Land area of the port: land based and rooftop Solar PV	120000	
Filling factor [-]	50 %	
Nett area land and roof SOLAR PV [m2]	60000	
Land area of the port WIND [m2]	0	Due to existing servitudes
Filling factor [-]	0 %	
Nett area WIND [m2]	0	
Usable area TIDAL [m2]	0	About 5 kilometres of seafront/dikes
Filling factor [-]	50 %	
Nett area TIDAL [m2]	0	
Usable water front length (wave) [m]	0	About 5 kilometres of seafront/dikes
Filling factor [-]	50 %	
Nett area WAVE [m]	0	
Port Renewable potential		
Solar Thermal [kWh/a]	31536000	D x power density of 60 W/m2
Solar PV [kWh/a]	8935200	E x power density of 17 W/m2
Wind [kWh/a]	0	F x power density of 2 W/m2
Tidal [kWh/a]	0	G x 2 power density of 2 W/m2. N.A. due to unfafourable tidal rage
Wave [kWh/a]	0	H x 10 kW/m. N.A. due to unfafourable wave
Total renewable potential [kWh/a]	**40471200**	
Reduction of energy consumption [%]	**?**	

For technologies installed at sea (Floating solar thermal, Floating Solar PV, Usable area TIDAL, Usable water front length) the port of Dunkirk doesn't know the surfaces that could be used and like I have indicated in my previous email, it is not possible to install wind turbines on land.

References:

[1] - https://www.interreg2seas.eu/fr

[2] - http://www.enr.fr/energies-renouvelables-dans-le-monde

[3] - https://www.dunkerquepromotion.org/

[4] - https://www.infoclimat.fr/climatologie/annee/2017/dunkerque/valeurs/07010.html

[5] - http://jmj41.com/meteo/climat_vent_moyen.php

[6] - http://homeenergy.free.fr/Photo%20Voltaique-Clement.pdf

[7] - https://www.legifrance.gouv.fr/affichTexte.docidTexte=JORFTEXT000021291950&categorieLien=id

[8] - http://re.jrc.ec.europa.eu/pvgis.html

[9] - http://re.jrc.ec.europa.eu/pvg_static/methods.html

[10] - https://www.ecologique-solidaire.gouv.fr/eolien-terrestre

[11] - https://eolienne.f4jr.org/eolienne_etude_theorique

[12] - https://www.communaute-urbaine-dunkerque.fr/fileadmin/documents/

enquetes_publiques/PLU_INITIAL/plu_initial_-_plans_de_zonage/

2017_02_13_Modifications_DUNKERQUE_Planche_nord.pdf

[13] - http://donnees.bretagne.developpement-durable.gouv.fr/documents/2015/PM_EOLIEN/#37/z

[14] - https://aida.ineris.fr/consultation_document/10789

[15] - https://en.wind-turbine-models.com/turbines/501-bergey-bwc-excel-10

[15'] - https://en.wind-turbine-models.com/turbines/1378-aerodan-75-15

[15''] - https://en.wind-turbine-models.com/turbines/221-danwin-danwin-23

[15'''] - http://www.vergnet.com/wp-content/uploads/2016/04/dc-11-00-01-fr_gev_mp-c_275_kw.pdf

[15''''] - https://en.wind-turbine-models.com/turbines/192-bonus-b41-600

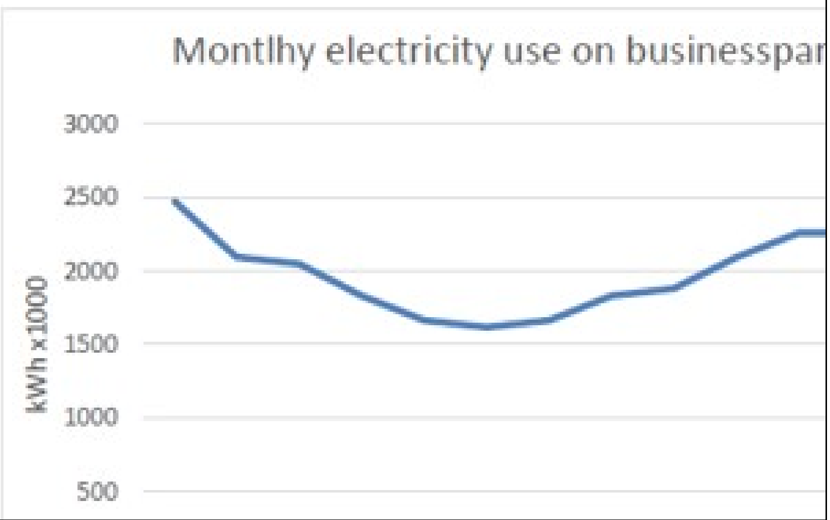
[16] - https://wind-data.ch/tools/weibull.php

[17] - https://www.hauts-de-france.developpement-durable.gouv.fr/IMG/pdf/synthese_evaluation_des_srcae_hdf.pdf

4. PORT OF IJMOND

Figure 5.1 PECS project area in Ijmuiden (blue +yellow) (Nick Ruiter, 2018)

The port of IJmond is characterized by the presence of mainly small and medium sized companies. In total there are approximately 700 businesses in the PECS project area (blue + yellow area). The electrical energy consumption of the total area (blue +yellow) is approximately 70.541.326 kWh and the corresponding CO2 emission is 41.619 tons (based on 0,59 kg/kWh). The electrical energy consumption of the yellow area alone is approximately 23.797.000 kWh and is spread over the time of the year as follows:



Jan	10,4%
Feb	8,8%
Mrt	8,6%
Apr	7,7%
Mei	7,0%
Jun	6,8%
Jul	7,0%
Aug	7,7%
Sep	7,9%
Okt	8,8%

Figure 5.2 Monthly electricity use on business park Kagerweg (Nick Ruiter, 2018)

The gas consumption of the IJmond port area is approximately 5.841.210 m³ per year. If this number is translated into kWh, it would be 57.062.780 kWh per year (1m³ of gas is equal to 9,769 kWh). This means the annual energy consumption of the port area is 70.541.326 + 57.062.780 = 127.562.780 kWh (See table 4.4). The corresponding CO_2 emission then should be 75.262 tons (based on 0,59 kg/kWh).

Table 4.4 indicates the potential for renewable energy production in the port of IJmond. This table shows results based on a model constructed by van Berkel (2018). The last row of the table indicates that there is a renewable energy potential of 147% in this port area. This means there is a surplus of energy available, if all sources for renewable energy production are used. The total energy production (heat + electricity) then would be 187.734.541 kWh. The table shows the underlying assumptions made to compute this potential for renewable energy production.

Figure 1 and 2 show the total land and water surfaces of the port. The size of the land surface area is 2.010.908m² (left map), the total water surface area is 1.056.658 m². To compute the potential for renewable energy production in this port area, the assumption is made that the future demand for electricity and heat has the same ratio as it has today. To determine this ratio, it is assumed that the today's total gas demand is used for heating. This means 44,7% of the available water area could be used for solar thermal energy production and 55,3% could be used for solar PV. This same division is made for the rooftop solar area.

Figure 5.3 Marked in green, the total land surface of the PECS project area (l) and the total water surface area (r).

The total amount of available water area is shown in figure 5.3. This area has a size of 86.251m², which is 1% of the total water area. Again this area is split up, to be used for both solar thermal (44,7%) and solar PV (55,3%). Floating wind energy is left out of the equation, as the available water surface can only be used once. Therefore the choice is made to use solar, which has a higher power density. The same ratio is used for the division of the roof area, which has a total size of 600.000m² of the whole port area.

Table 4.4 IJmond renewable energy potential calculation tool

	Quantity	remark
Current port energy consumption		
Port electricity consumption [kWh/a]	70.500.000	From Energie in Beeld (2018)
Port gas consumption [kWh/a]	57.062.780	From Energie in Beeld (2018) (5841210 m3 of gas) **1 m3 of gas = 9,769 kWh**
Port heat consumption [kWh/a]	0	
Total energy consumption [kWh/a]	**127.562.780**	Assuming that elektricity and heat are equivalent
Port characteristics		
Water area of the port: Floating solar thermal [m2](1)	472.326,13	(1)44,7% of the total water area (times the filling factor) could be used for solar thermal, the other 55,3% (times the filling factor) could be used for solar PV. This number is used due to the ratio between the energy needed for gas(heat) and electricity. The underlying assumption is that all gas consumption is linked to heat consumption, and not to the production of goods.
Filling factor [-]	1%	
Nett area FLOATING SOLAR THERMAL [m2]	4723	
Water area of the port: Floating Solar PV [m2](1)	584331,874	
Filling factor [-]	1%	
Nett area SOLAR PV [m2]	5843	
Water area of the port: Floating wind [m2](1)	0	
Filling factor [-]	50%	
Nett area floating wind [m2]	0	
Land area of the port: land based and rooftop Solar Thermal [m2](2)	268.200	(2)The land area is, after subtraction of the water area in the middle, 2.010.908m2. The area is shaded in the figure between H17-M17 and H26-M26. 44,7% of the roof area (times the filling factor) could be used for solar thermal, the other 55,3% (times the filling factor) could be used for solar PV. This number is used due to the ratio between the energy needed for gas(heat) and electricity
Filling factor [-]	95%	
Nett area land and roof SOLAR Thermal [m2]	254790	
Land area of the port: land based and rooftop Solar PV [m2]	331.800	
Filling factor [-]	95%	
Nett area land and roof SOLAR PV [m2]	315210	
Land area of the port WIND [m2] (3)	2010908	(3)Not all off the surface can be used for the production of wind energy. Roads and rooftops can for example not be used. The area that is left in the port area is for example
Filling factor [-]	10%	
Nett area WIND [m2]	201091	
Usable area TIDAL [m2]	0	The port of Ijmond is not directly located at the sea, therefore there are no tides and also no potential for tidal energy
Filling factor [-]	50%	
Nett area TIDAL [m2]	0	
Usable water front length (wave) [m]	0	The port of Ijmond is not directly located at the sea, therefore there are no tides and also no potential for tidal energy
Filling factor [-]	50%	
Nett area WAVE [m]	0	
Port Renewable potential		
Solar Thermal [kWh/a]	136400170	D x power density of 60 W/m2
Solar PV [kWh/a]	47811260	E x power density of 17 W/m2
Wind [kWh/a]	3523111	F x power density of 2 W/m2
Tidal [kWh/a]	0	G x 2 power density of 2 W/m2. N.A. due to unfafourable tidal rage
Wave [kWh/a]	0	H x 10 kW/m. N.A. due to unfafourable wave climate
Total renewable potential [kWh/a]	**187734541**	
Reduction of energy consumption [%]	**147%**	

5. HELLEVOETSLUIS

Hellevoetsluis is a city on Voorne-Putten Island in the west of The Netherlands in the province of South Holland, a former strategically situated port that has become an important centre for water sports. The ports in the area of Hellevoetsluis considered in this report are Heliushaven, De Kanaalhaven, Vestinghaven and Veerhaven. All together those harbours contain a capacity of over 2000 pleasure boats. A service centre, yacht clubs and the historic city centre make Hellevoetsluis a boating destination.

Figure 6.1 Hellevoetsluis

Numerous museums in the fortress tell the story of the city as a proud home port to the Dutch naval fleet. From the 17th century to the present time, the history of Hellevoetsluis has merged with the water. The fortified port at Hellevoetsluis became a fortress and exit port for naval heroes such as Tromp, De Ruyter and Piet Heyn.
In the historic fortress, you will find an attractive and operational national monument: the first and only double stone dry dock in the Netherlands. The dry dock was built by the first Inspector-General of Rijkswaterstaat, Jan Blanken Jansz.
Prominent fortification sites such as the Prinsehuis, the lighthouse, the former 'Machinistenschool' (Engineers' school), the 'Grootmagazijn' warehouse and the 'Kuiperij' (Cooperage) still show evidence of its sea-related past. But old and new go hand in hand in this fortified city. A brand-new port façade has arisen out of the western strongholds that were damaged as the result of war. Corn mill 'De Hoop' rotates its vanes in the western wind. The fortifications, including Haerlem Barracks, were restored in 2012. The entire area was turned back into a 'state of defence'. Sample the atmosphere whilst taking a stroll along the 'kruithuizen' (gunpowder houses) and bunkers.

Table 4.6 Hellevoetsluis renewable energy potential calculation tool

	Quantity	remark
Current port energy consumption		
Port electricity consumption [kWh/a]		From Energy audit (Workpackage 1)
Port gas consumption [kWh/a]		From Energy audit (Workpackage 1)
Port heat consumption [kWh/a]		From Energy audit (Workpackage 1)
Total energy consumption [kWh/a]	**572638**	Assuming that elektricity and heat are equivalent
Port characteristics		Commercial recreation harbour
Water area of the port: Floating solar thermal [m2]		
Filling factor [-]		
Nett area FLOATING SOLAR THERMAL [m2]	0	
Water area of the port: Floating Solar PV [m2]		
Filling factor [-]		
Nett area SOLAR PV [m2]	250	
Water area of the port: Floating wind [m2]		
Filling factor [-]		
Nett area floating wind [m2]	0	
Land area of the port: land based and rooftop Solar Thermal [m2]		Note that a surface [m2] for hybrid system can be for a combination of solar thermal or PV, or win
Filling factor [-]		
Nett area land and roof SOLAR Thermal [m2]	700	
Land area of the port: land based and rooftop Solar PV [m2]		
Filling factor [-]		
Nett area land and roof SOLAR PV [m2]	4100	
Land area of the port WIND [m2]		
Filling factor [-]		
Nett area WIND [m2]	3901	
Usable area TIDAL [m2]		N.A. due to unfafourable wave climate
Filling factor [-]		Assuming 0 % for Marina Cape Helius
Nett area TIDAL [m2]	0	
Usable water front length (wave) [m]		N.A. due to unfafourable wave climate
Filling factor [-]		Assuming 0% for Marina Cape helius
Nett area WAVE [m]	0	
Port Renewable potential		
Solar Thermal [kWh/a]	367920	D x power density of 60 W/m2
Solar PV [kWh/a]	647802	E x power density of 17 W/m2
Wind [kWh/a]	68339	F x power density of 2 W/m2
Tidal [kWh/a]	0	G x 2 power density of 2 W/m2. N.A. due to unfafou tidal rage
Wave [kWh/a]	0	H x 10 kW/m. N.A. due to unfafourable wave climat
Total renewable potential [kWh/a]	**1084061**	
Reduction of energy consumption [%]	**189%**	

6. D.1.4.2, COMPARISON D.1.4.1 REPORTS:

On the basis of the analysis describes in this report, the following conclusions can be derived:

1. Hard data regarding current consumption is not easy to assess. In one case current consumption could not be derived from port authorities.
2. Ports are very diverse, also regarding their potential for renewable energy sources.
3. Ports are densely used locations, focussed at efficient handling of material and people. Energy density (consumption) in general is high and available space for harnessing of renewable energy scarce.
4. Notwithstanding (3), the potential for renewable energy -even in ports- can be very high, see figure 7.1.
5. High potential techniques are solar (thermal and PV, and thermal energy from surface water).

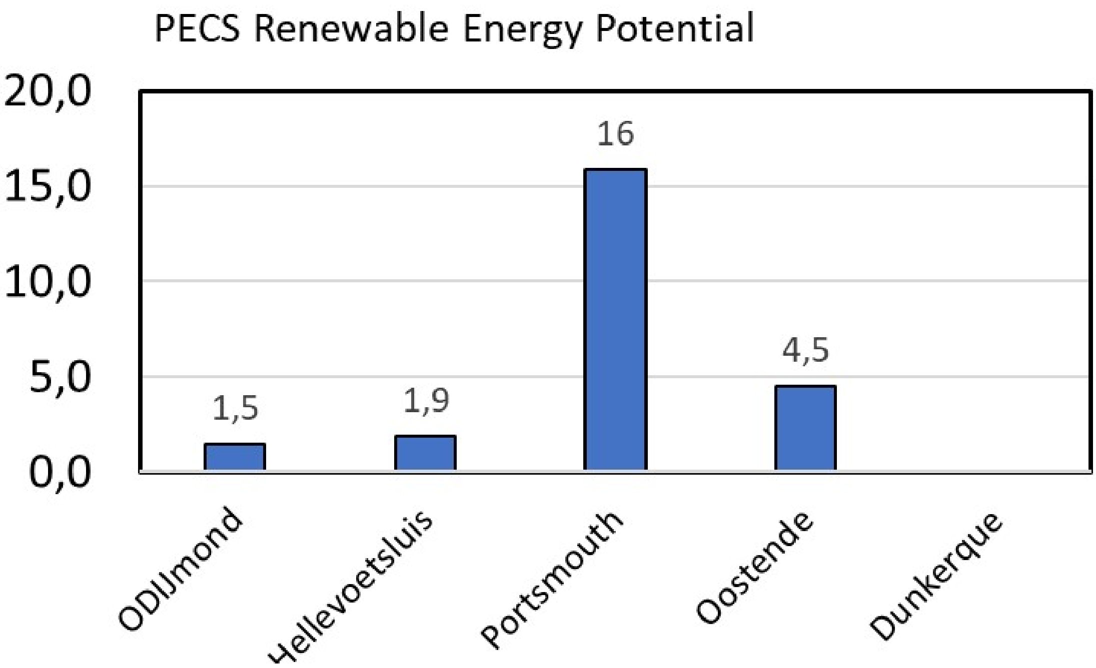


Figure 7.1 Potential for Renewable Energy in PECS-Ports. A factor of 1 implies that the potential generation is (on an annual basis) equal to consumption.

The graph indicates the potential of renewable energy production, compared to the know current consumption. Energy saving measures are not taken into account (yet). A factor of 1 implies that the potential generation is (on an annual basis) equal to consumption.

7. D.1.4.3, VALIDATED METHOD AND CALCULATION TOOL

Using a straightforward calculation tool, the potential for application of Renewable Energy in PECS-ports has been assessed. The method and tool have been developed and described in deliverables D1.3.2 and D1.3.3, and applied by the individual PECS-ports. The tool was adjusted on minor details after the first round comments (in the Dunkirk-meeting), and adopted by the ports.
The port -representatives were able to use the tool independently, without assistance. Results of their output is given in this D1.4.1. report. As such, this validates the method and tool for assessment of the Renewable energy Potential in ports. The tool and method is now ready for usage by other ports.