Interreg North-West Europe
H2SHIPS

System-Based Solutions for H2-Fuelled Water Transport in North-West Europe

Design note on the equipment and infrastructure for the H2 bunkering station

Document Control Sheet

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1 Introduction

This document addresses Deliverable I3.1.1, "Design note on the equipment and infrastructure for the H2 bunkering station", part of the WP, "Installation of a High Voltage station to power an H2 refuelling station in the Port of Oostende". This work package represents the new version of the WP "Development and testing of an H2 bunkering system for ships in the Port of Oostende" approved by the Joint Secretariat.

Port Oostende had to investigate several scenarios during the development of the hydrogen bunkering infrastructure. The new WP seeks to materialize the synergy of the two Interreg H2SHIPS and ISHY projects in a combined objective. This means that a hydrogen bunkering station will be realized as planned initially, and in addition, a crew transfer vessel (CTV) will be converted to a hydrogen diesel dual-fuel engine. Both these projects are done in close cooperation with the industrial partner Parkwind. Parkwind will lead the implementation of the activities in close cooperation with Port Oostende. In the meantime, more and more companies active in the crew transfer vessel (CTV)- business are building CTVs on hydrogen.

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2 About Port Oostende

In the last 10 years, Port Oostende has become a major hub for the offshore wind business, especially concerning the installation and maintenance of windmills. In the Belgian North Sea, 2.2 GW has been installed, and another 3.6 GW has been decided by the Belgian government to be installed by 2030.

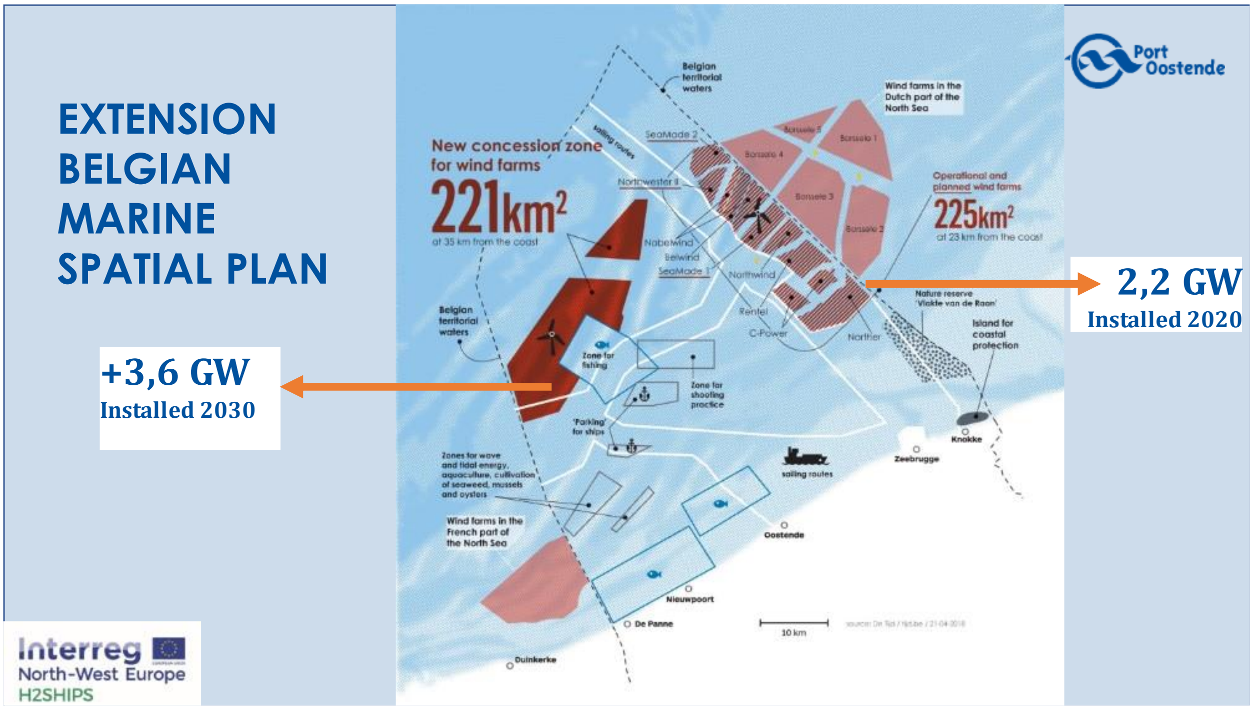

Figure 1, Offshore Wind farms off the coast of Belgium

The maintenance (O&M) of those Belgian parks, as well as some Dutch parks located just behind the border between Belgium and the Netherlands (called Borssele), is done from the port of Oostende. This maintenance is done with crew transfer vessels (CTVs) and service operating vessels (SOVs).

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Figure 2, Crew transfer Vessels

Figure 3, Service Operating Vessel

With more than 800 people currently working in the O&M business out of the port of Oostende, this sector has become of major importance for Port Oostende.

2.1 Reducing the carbon footprint of the offshore wind

The O&M activities in the offshore wind industry have today a considerable carbon footprint.

The vast majority of specialized vessels for offshore wind installation, operation and maintenance are driven by internal combustion engines, mainly using fossil fuel for propulsion. This is still the case for most of the recently built crew transfer vessels (during the last five years), which will be in use for at least another 10 to 15 years. For CTVs, the priorities are speed, reliability and safety of transfer.

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Incentives for CO2 emission reduction are low, and so far, little or no requirements have been imposed as permit requirements or as award criteria.

If we have a closer look at the existing wind farms in front of the Belgian coast, we estimate that the O&M (operations and maintenance) logistics for the existing Belgian windfarms consume 7.5 to 9 million litres of diesel fuel per year, generating 20 000 to 24 000 tons of CO2 (which is approximately the equivalent of 3000 cars). In other words, this means an average of 3500 to 4000 litres diesel /year per MW of installed wind power!

2.2 Incentives and corporate sustainability

Many studies and initiatives have already been initiated targeting the sustainability of the installation and maintenance of offshore wind parks. The main initiatives which are expected to play a role in the context of wind farm operations can be summarized as follows:

- IMO (International Marine Organisation) has committed to reducing GHG emissions of the whole marine sector by at least 50% by 2050 from the 2008 baseline.
- Carbon Price is expected to reach more than 100€/ton by 2030 (source: Bloomberg NEF).
- Aside from tangible targets, Corporate Sustainability Reporting (CSR) is becoming an important consideration for many companies to report on their own impact on people and the environment.
    - RE100 (a climate group) brings together hundreds of large and ambitious businesses committed to 100% renewable energy
    - SME Climate Hub members aim to reduce their emissions by 50% in 2030, and reach zero emissions by 2050
- It is expected that permit requirements for potential **lifetime extensions of the current wind farms** will increasingly focus on LCSA (Life Cycle Sustainability Assessment) considerations and impose qualitative and quantitative criteria.
- The offshore wind industry leaders (Siemens Gamesa, Vestas, Orsted, Vattenfall…) have also started to impose **sustainability targets** on their vessel providers.
- The first “green” CTV concepts are under development: hybrid-electric, hybrid with H2 fuel cells…, some of which are being implemented by front-runners (e.g. Orsted in Borssele 1&2)

The overall conclusion is that there will soon be a demand for alternatives to grey fuels for vessels employed in offshore wind O&M operations.

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3 Choice of the location

Port Oostende sees a large increasing interest in hydrogen as a clean alternative for shipping. Especially the stakeholders working on the offshore wind farms seem very interested in realizing zero emissions with their shipping activities.

3.1 Hydrogen Interest

To highlight the increased interest of hydrogen in the port of Oostende ecosystem, a list of other ongoing hydrogen related projects is presented:

- Port Oostende is participating in the Interreg program ISHY, where a hydrogen bunkering station is built, and a CTV is converted for running on hydrogen.
- Hyport project was initiated on December 2019 with the target of installing a 70MW hydrogen production facility in the port area of Oostende. For the time being, the preliminary feasibility study showed that it is not economically viable to build such a facility (high (green) electricity prices + no certified contracts with off-takers). However, this does not mean that local production of hydrogen is off the table; Hyport is now evaluating a minor installation using electricity produced on site.
- On November 19th 2021, a dissemination event with the Benelux Parliament took place in Oostende concerning hydrogen.
- Hydroville–the first vessel running on hydrogen (designed by the company CMB Tech), was already in the port during the summer of 2019. A delegation from the Benelux visited that vessel on November 19th 2021. A whole explanation was given to them by CMB Tech.
- As Parkwind owns and monitors some wind parks in front of the Belgian coast, they are also looking to have a small hydrogen station in those wind parks. CTVs would be able then to fuel over there.

3.2 The exact location of the hydrogen bunkering station

The pilot in Oostende has been slightly altered given some unexpected developments within the port authority structure. However, with some creative thinking and good project management the port has managed to combine the ongoing ISHY project and the H2SHIPs project into a development that exploits the synergy between these two Interreg projects.

The bunkering station at Oostende needs to consider many factors to identify an appropriate location where everybody is satisfied. The CTV operators do not prefer a location behind the locks as they would lose too much time by passing over the lock.

But the most critical issue was to preserve safety. The public opinion regarding the safety risks of installing a hydrogen bunkering facility is essential. In the automotive domain, it

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was observed that initial enthusiasm from the public could turn easily when a bunkering infrastructure is placed in proximity to local communities because of perceived safety risks. Port Oostende does not recognize this problem since the bunkering infrastructure is installed inside the port area and sufficiently far from the urban centre. However, no offices or large groups of people can be allowed in the vicinity of the hydrogen bunkering station.

Finally, the location was chosen as indicated in the photo underneath, where the circle corresponds to the zone of maximum effect on the neighbourhood in case of an accident.

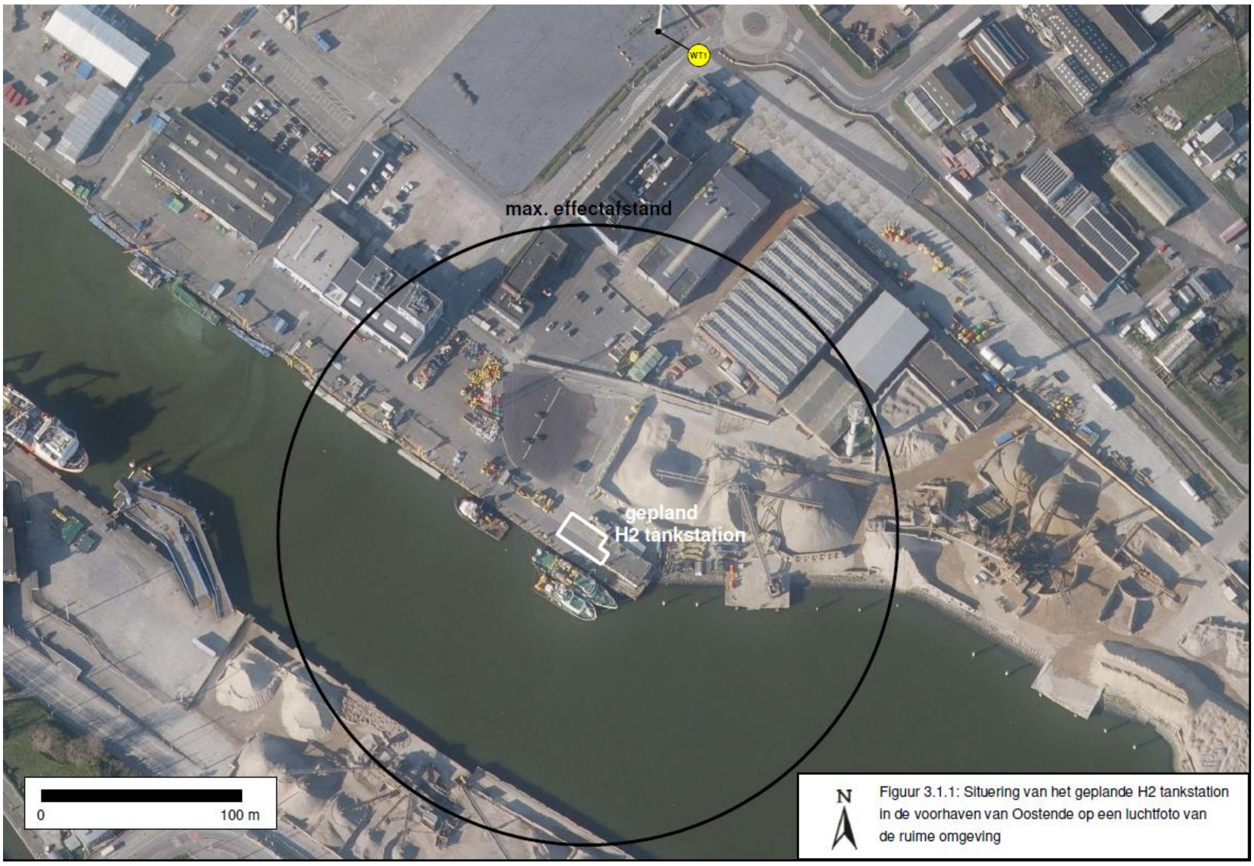

Figure 4, Zone of maximum effect of the Refuelling Station

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4 H2 Refuelling Station

This chapter gives an overview of the activities finished and planned as part of the delivery plan of the Hydrogen refuelling station in the port of Oostende.

4.1 Status of the project

Before the construction phase, a feasibility study was done by:

- Exploring the potential future demand and related business model for hydrogen in the port of Oostende.
- Conceptual design, safety screening for suitable locations, and identification of the preferred location.

In this process, stakeholders were engaged through HAZID and HAZOP studies; local authorities, designers and safety experts were involved in assessing potential safety risks and mitigating these risks accordingly.

The following phase is constructing the bunkering station, which consists of different steps. Among them, the followings have already been realized:

- Detailed engineering
- Permit application, safety and implementation study
- Procurement

After the detailed engineering had been concluded, the permit for the construction was submitted in April 2022. On August 25th 2022, the permit was obtained and the procurement phase initiated. However, due to the geopolitical situation, the delivery of the equipment for the installation of the bunkering station in Oostende was delayed to 8 or even 10 months. This means that the expected time of delivery of the equipment in Oostende is now foreseen for March 2023.

The next steps will be:

- Construction
- Commissioning
- Testing

As soon as the equipment is delivered, the construction of the bunkering station can start. The installation can be done in 1.5 months, followed by the commissioning (which means the checking of the bunkering station by the supplier and the hand-over of the installation to the new operator). This means that the bunkering station will be operative no earlier than May 2023.During the Summer of 2023, the testing phase can be executed.

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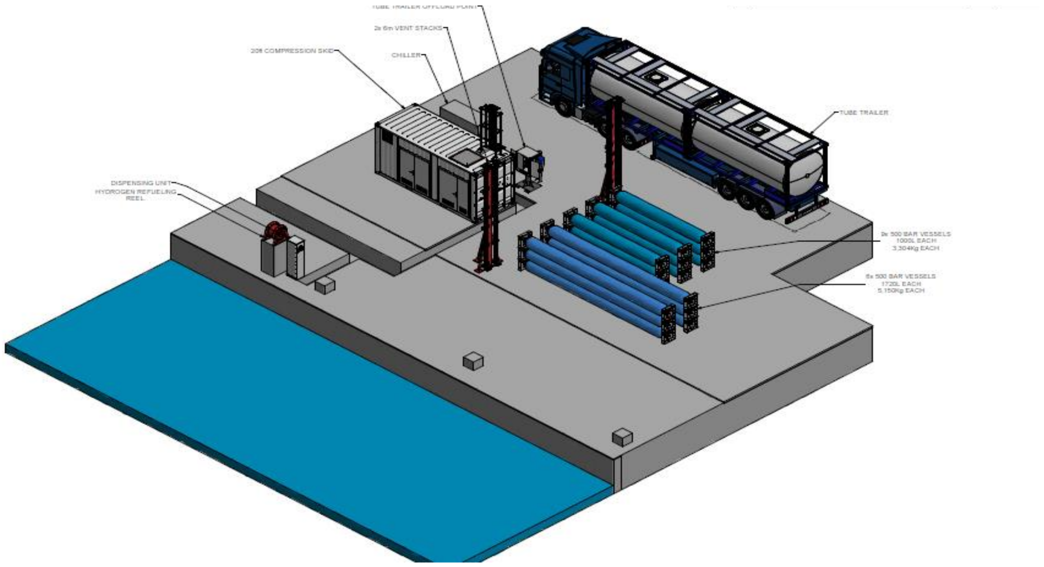

Figure 5, Artist Impression of the hydrogen bunkering station

4.2 Planned capacity and phasing

The artistic impression shows the design of phase one of the project.

Phase one is counting on 4 vessels per day that will bunker each 150 kg of hydrogen per day, resulting in an overall demand of 600 kg per day. In phase two, the overall demand is expected to increase by up to 1600 kg, and in phase three, 3000 kg of hydrogen will be required per day.

In summary:

- Phase 1: 600 kgH2/day, 4 vessels @150kg H2/day
- Phase 2: 1600 kgH2/day, expected within x years
- Phase 3: 3000 KgH2/day, expected within y years

The growth of the station capacity will result in an incremental expansion of the station and, consequently, the land used. By choosing the location, this aspect has been taken into account, and the final site allows for extending the existing surface of the installation.

4.3 Use of bunkering station

The bunkering station will be used to bunker CTVs. A first crew transfer vessel running on dual fuel (diesel and hydrogen) is already operational in the port of Oostende, namely the Hydrocat 48 of the company CMB-tech. The second dual-fuel ship operating in the port will be a pilot vessel developed by the company GeoAqua (part of the company GEOxyz), and plans are being developed for more hydrogen vessels. The CTV that Geo Aqua will

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develop has the capability to operate with a mixture of hydrogen and diesel fuel which is injected into an internal combustion engine.

The bunkering station will be supplied with tube trailers transporting hydrogen at 300 bar. The hydrogen is further compressed and stored at the station at 500 bar in high-pressure accumulator tanks. The bunkering occurs by filling the tanks on the boat up to a pressure of 350 bar; the difference in pressure between onshore and onboard tanks allows for optimizing the bunkering time.

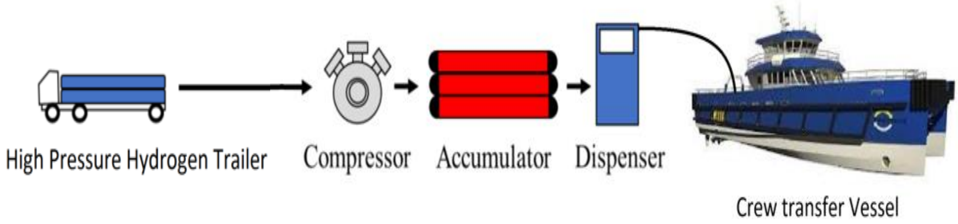

Figure 6, Bunkering Station components

4.4 Power

It is good to build such a bunkering station, but this means also an increase of use of electricity. The hydrogen compression will require electrical energy; therefore, the port of Oostende will need to invest in the electrical grid in the port.

H2 Mass Flow	1544.648649 kg/day

H-Drive Parameters	Inlet Pressure (Bar)	Interstage (Bar)	Outlet Pressure (Bar)	Flowrate (Nm3/hr)	Flowrate (kg/hr)	Running Time (Hours)	Hyd Pressure (Bar)	Hyd Power (kW)	No. of Boosters	Hyd Power (kW)	Hyd Flow (l/min)	Process Cooling Required Per Booster (kW)	Total Process Cooling Required Per System (kW)
	99	308	500	357.2	32.18018018	24	248	73	2	146	140	37.8	60.48
	99	308	500	357.2	32.18018018	24	248	73	2	146	140	37.8	60.48
Average				357.2	32.18018018	24	248	73	2	146	140	37.8	60.48

	Maximum	Average Running	
Total Hydraulic Power (kW) / Running (kW)	146	97.3236	
Total Process HPU Cooling Required (Per HPU / Total)	20	40	
Total Process Cooling (kW)	100.48		
Total Process Electrical Power Installed (kW) / Running (kW)	49.53004953	25.4	ICE 116
Total Dispense Cooling Electrical Power (kW) / Running (kW)	0	0	

HPU Installed Power
150 kW

HPU T0 Cooling:- 8 kW for 30 kW for 55 kW motor. 12/55 For 75 kW 16/75

Chiller Installed
42 kW
0 kW

CO2 Chiller Running
65

	Maximum Installed	Average Running	Maximum Running	
Total Electrical Power Required (Installed / Running)	193.285	122.7236	195.5300495	kW
Safety Factor (10%)	212.6135	134.99596	215.0830545	kW
Total + Safety Factor (Installed / Running)	**212.6135**	**134.99596**	**215.0830545**	**kW**

150 kW Installed

Hydraulic Power	1.512166797	
Process Power	0.394652856	
Dispense Power	0	
Ancillaries	0.019965705	
Total kWh/kg	**1.926785358**	**kWh/kg Total (Running)**

Ancillaries	kW
Extractor Fan (x2)	0.75
Fire System	0.25
Lights (x2)	0.03
PLC	0.025
HMI (x2)	0.05
Solenoids (x10)	0.06
TT (x10)	0.06
PT (x10)	0.06
Total	**1.285**

Process Chillers

Model ICE		003	005	007	010	015	022	029	039	046	057	076	090	116	150	183	230	310	360
air-cooled Cooling capacity	kW	2,5	5,1	7,0	9,5	14,3	21,8	28,1	38,2	45,2	56,4	76,0	90,2	115,5	149,2	182,3	227,9	309,1	359,7
air-cooled Compr. abs. power	kW	0,70	1,40	2,0	2,27	3,43	5,19	5,66	7,69	10,1	12,3	15,4	20,3	24,9	30,8	40,1	51,4	46,4	81,5
air-cooled Cooling capacity	kW	1,8	3,8	5,2	7,0	10,6	16,2	20,8	28,4	33,8	42,1	56,5	67,1	86,4	110,9	135,4	165,3	223,7	259,1
air-cooled Compr. abs. power	kW	0,62	1,31	1,67	2,16	3,24	4,46	5,93	8,26	10,6	13,1	16,4	21,2	25,8	33,5	42,1	54,3	66,4	83,7
water-cooled Cooling capacity	kW	N.A.				on request		29,6	39,5	47,6	59,0	79,8	97,5	120,1	156,7	195,0	on request	N.A.	
water-cooled Compr. abs. power	kW							5,16	7,13	9,04	11,0	13,8	17,3	22,6	27,6	34,8			
water-cooled Cooling capacity	kW							21,9	29,3	35,3	43,9	59,1	72,3	89,4	116,1	144,6			
water-cooled Compr. abs. power	kW							5,17	7,17	8,93	11,1	13,9	17,0	22,8	27,8	34,4			
Compressors																			
Compr./circuits		1/1										2/2			4/2				
Max abs. power - 1 compr.	kW	0,7	1,5	2,0	3,0	4,3	6,9	7,8	11,1	13,7	16,8	11,1	13,7	16,8	11,1	13,7	16,8	23,3	28,7
Axial fans																			
Quantity	n°	1							2		3				2		3	4	
Max abs. power - 1 fan	kW	0,12	0,12	0,14	0,14	0,61	0,61	0,78	0,61	0,61	0,61	0,78	0,78	0,78	2,0	2,0	2,0	2,0	2,0
Air flow	m³/h	2300	2300	4400	4100	7100	6800	9200	12400	12000	17400	25500	25000	26400	47000	46000	66000	88000	86000
Centrifugal fans																			
Quantity	n°	N.A.				on request		2	2	2	3	3	3	3	3	3	on request	N.A.	
Max abs. power - 1 fan	kW							1,1	1,1	1,1	1,1	1,5	1,5	1,5	3	3			
Air flow	m³/h							9200	12400	12000	17400	25500	25000	26400	47000	46000			
Head pressure	kPa							200	180	160	200	100	100	100	180	180			
Water-cooled version																			
Condenser water flow	m³/h	N.A.				on request		2,57	3,94	5,36	7,79	10,84	10,96	16,16	18,88	29,17	on request	N.A.	
Connections (in/out)	"							1 ¼"	1 ¼"	1 ¼"	1 ¼"	1 ¼"	1 ¼"	1 ¼"	1 ¼"	1 ¼"			

Figure 7, Calculation sheet for additional power capacity

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A calculation was done to know how much extra electricity was needed. To summarize the above table, we can conclude that 210 kW installed capacity is needed for the first phase. However, Port Oostende already wants to be ready for the second phase and beyond.

A public tender was issued in May 2022, and the order for a new high-voltage station with extra low-tension electrical cables was commissioned to the winner of the tender in June 2022. However, even in this case, the geopolitical situation did not favour Port Oostende. The expected arrival of the different components has been delayed to March 2023.

5 Conclusions

Port Oostende sees a growing interest in hydrogen as fuel in the maritime industry. A hydrogen bunkering station will be an important milestone for serving the industry appropriately. However, the current geopolitical situation is not helping us. Port Oostende is doing its utmost to put in operation the bunkering station in Spring 2023.

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