Ports Energy and Carbon Savings

Deliverable D.2.1.4.

Energy storage possibilities Hellevoetsluis port area

Project No. 2S03-009

With the financial support of

Author

NAME	ORGANISATION
Ron Bol	BlueTerra Energy Experts

Revision history

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

Table of contents

Table of figures

Table of figures

1. Problem definition and goal

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

Objectives

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

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

Partners

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

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

Energy storage possibilities in the harbour of Hellevoetsluis

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

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

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

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

Abbreviations

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

2. Ceilidh

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

2.1. Project location

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

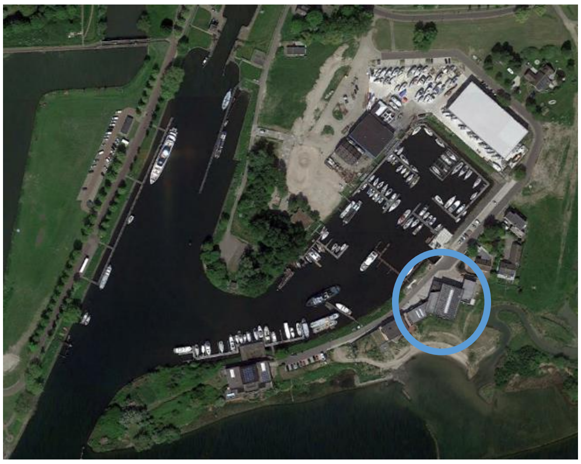


Figure 1 – Port area (the blue circle indicates location of Ceilidh)

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

Figure 2 - Building layout

2.2. Renewable electricity production and local grid setup

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

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

Future PV system expansion plans

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

3. Energy production and consumption

Data availability and conversion

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

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

3.1. Manufacturing process

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

Energy consumption

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

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

[1] *Off-peak hours: weekdays 23:00 – 7:00, entire weekend and holidays.*

[2] *KNMI station Hoek van Holland 2018.*

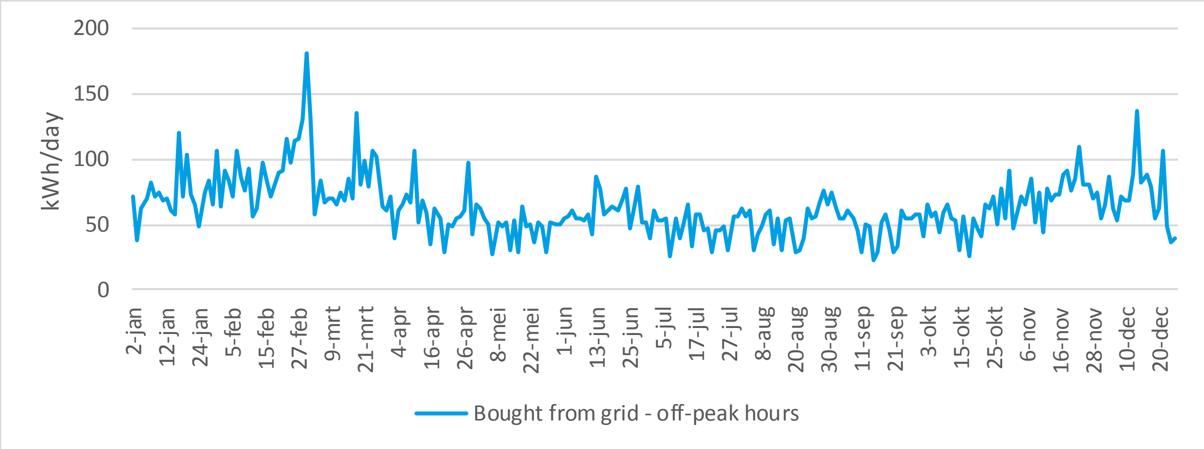


Figure 3 – Manufacturing process energy consumption during off-peak hours

3.2. Energy balance

3.2.1. Current situation

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

Type	kWh/year
Consumption	80.800
Bought - from grid	53.700
Off-peak hours	28.700
On-peak hours	25.000
PV system production	37.000
Excess production – to grid	10.100

TABLE 1 – CURRENT ENERGY BALANCE

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

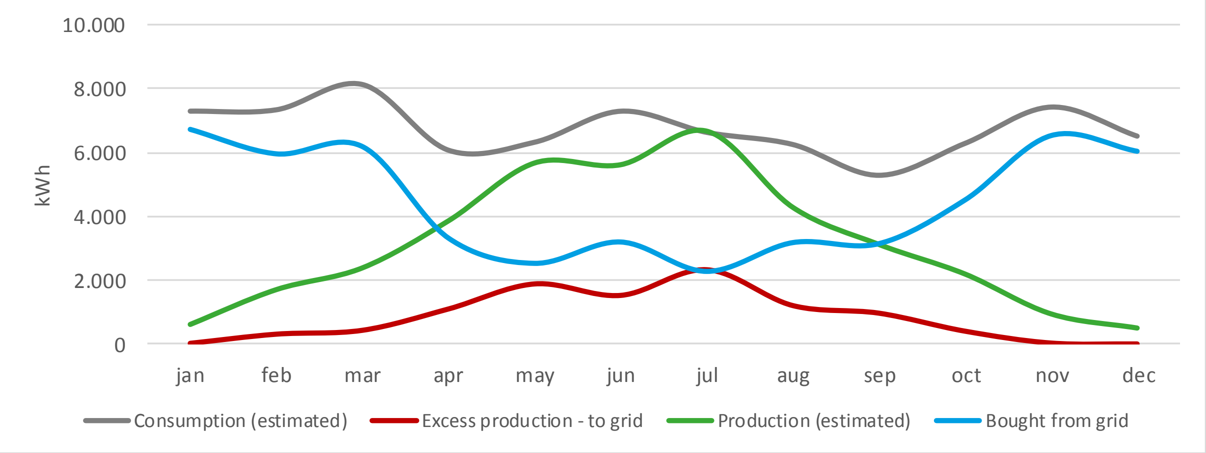


Figure 4 – Energy balance current situation

3.2.1. Situation after PV system expansion

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

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

TABLE 2 –ENERGY BALANCE PV SYSTEM EXPANSION

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

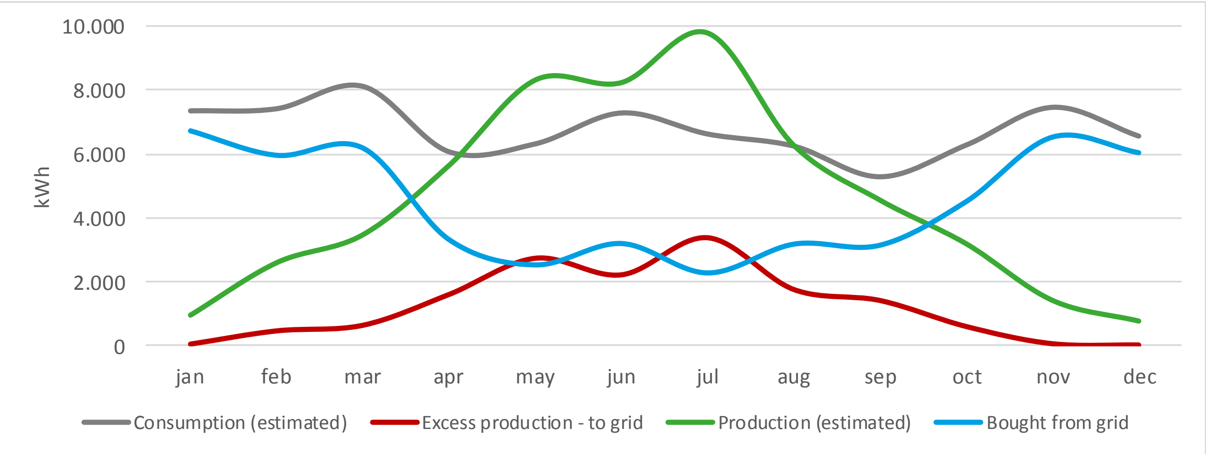


Figure 5 – Energy balance PV system expansion

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

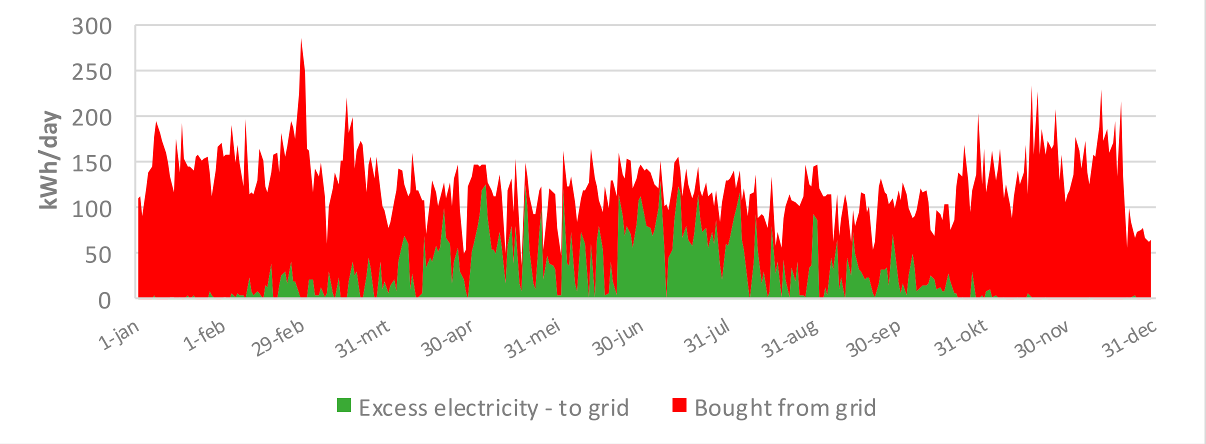


Figure 6 – Energy balance

Energy storage possibilities

3.3. Electric energy storage

3.3.1. Local storage

The easiest option for storage is to choose a commercially available battery system that will be installed at the building itself. A lot of different battery technologies can be used for storage purposes such as; nickel-based, lead-acid and (redox) flow batteries. Nowadays, the largest price developments and technical improvements are seen within the lithium-ion based batteries. These types of batteries are widely used for smaller devices such as laptops and cell phones, for electric mobility and increasingly for energy storage solutions.

Nowadays there are several suppliers (e.g. Tesla [3], LG Chem Resu[4] and Sonnen [5]) available that deliver storage systems that can be used directly after installation. Including installation and additional hardware, battery systems investments start at around 650 €/kWh for smaller systems and will costs around 450 €/kWh for larger systems[6], see Figure 7. On average the roundtrip efficiency of a battery system, as specified by the manufactures described above, is approximately 90%.

[3] https://www.tesla.com/nl_NL/powerwall
[4] https://www.lgchem.com/upload/file/product/LGChem_Catalog_Global_2018.pdf
[5] https://media.sonnen.de/de/media/6/download/inline
[6] *Diminishing costs for additional hardware and installation costs*

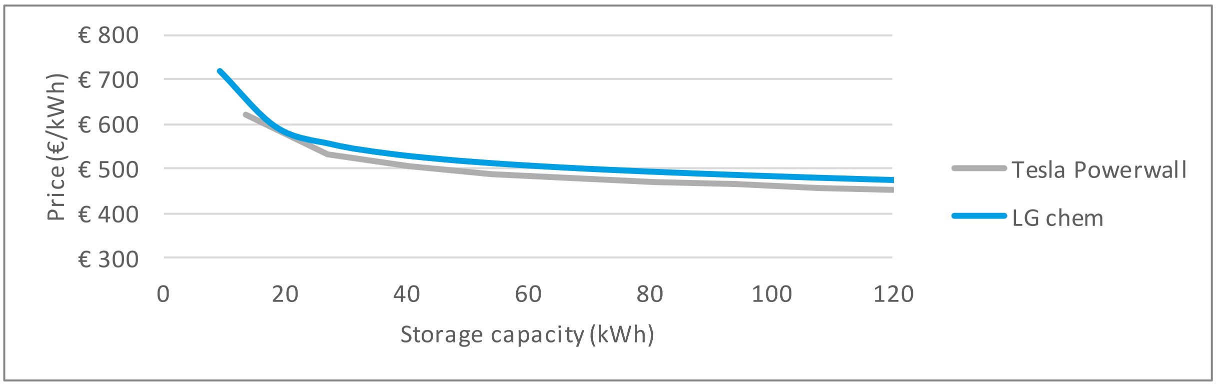


Figure 7 – Battery storage costs (including installation and hardware, excl. VAT)

3.3.2. Port area

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

3.4. Thermal energy storage

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

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

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

[7] *Sarbu, I and Sebarchievici, C (2018). A Comprehensive Review of Thermal Energy Storage*

4. Outlook to future energy pricing and subsidy scheme

4.1. Electricity prices

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

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

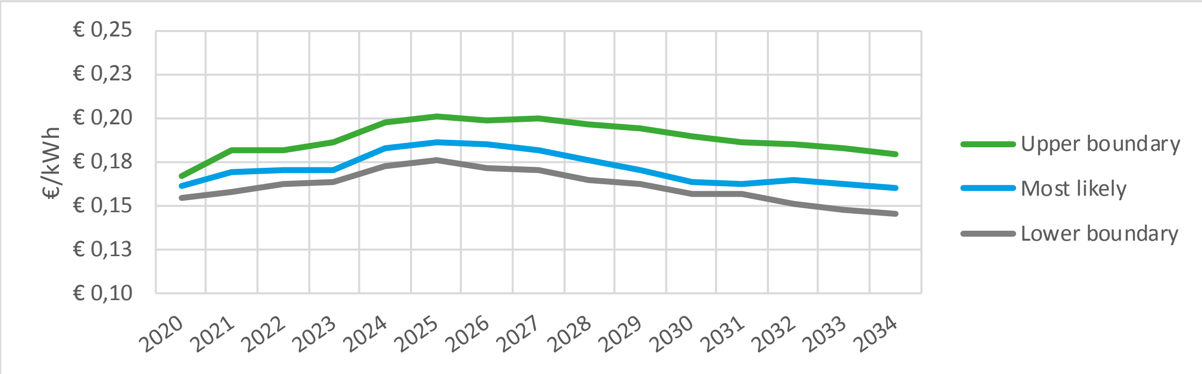


Figure 8 - Electricity price scenarios (excluding VAT and distribution costs, including energy tax)

4.2. Feed-in tariffs

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

5. Energy storage business cases

Local electricity storage

The consumption of electricity for the manufacturing process during night-time is highly variable as is seen in Figure 3. On average, 64 kWh of electricity is required each night. By choosing this storage capacity more than half

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

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

the nights the process can be run on renewable electricity produced during daytime. A larger storage volume would result in more nights that can be run on renewable electricity at a cost of much larger investments.

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

Port area electricity storage

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

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

Thermal energy storage

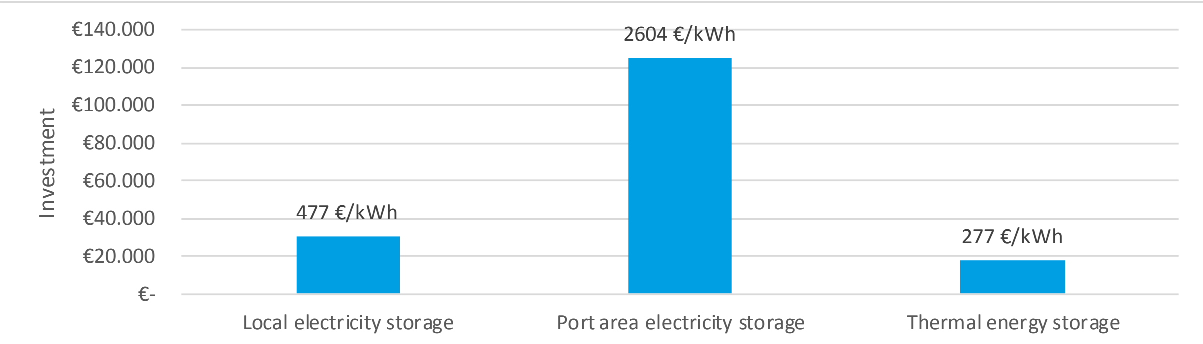
The thermal energy storage developed by Blue Power Synergy has an expected price of €28.000 including installation (excl. VAT) for which 120 kWh of thermal energy can be stored. However, only around 64 kWh is required in which case costs are likely to go down to around €18.000 - €15.000 in total. In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

5.1. Overview of business cases

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

Investments

Figure 9 shows the results for the investments needed. Port electricity storage is the most expensive both for the total investment as in € per kWh. Thermal energy storage still requires a substantial investment but gives a better price for €/kWh compared to local electricity storage.



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

Figure 9 – Energy storage investment costs

Yearly costs

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

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

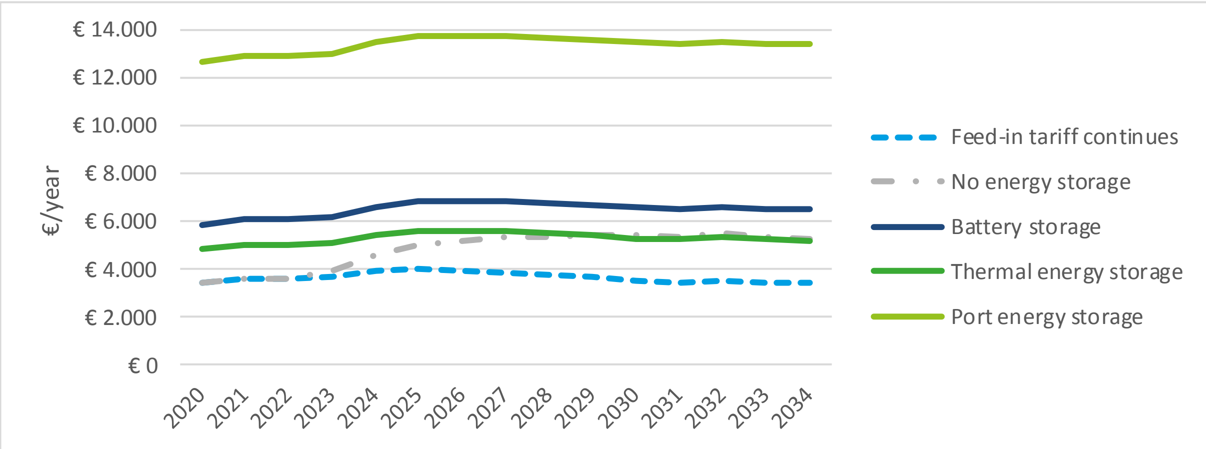


Figure 10 – Total yearly energy costs

Avoided CO_2 emissions

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

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

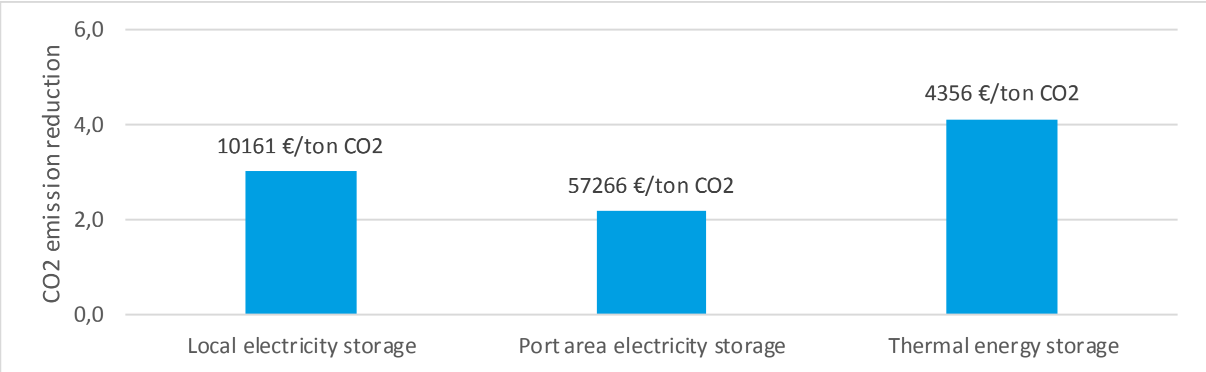


Figure 11 – Yearly CO_2 emission reduction and CO_2 cost effectivity

6. Conclusions and recommendations

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

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

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

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