Kompetenz Zentrum Wasser Berlin

# LCA study for water supply options for a Power-to-X project in Bornholm

WaterMan project

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## LCA study for water supply options for a Power-to-X project in Bornholm

Within the WaterMan project, Kompetenz Zentrum Wasser Berlin (KWB) has conducted a Life Cycle Assessment (LCA) study for water supply options for a Power-to-X project in Bornholm.

WaterMan promotes a region-specific approach to water recycling, which intends to use the occurrence of both too much and too little water that has become typical in the Baltic Sea Region, to make the local water supply more resilient, and supports municipalities and water companies in adapting their strategies. The project is co-financed by the European Union (European Regional Development Fund) and implemented within the Interreg Baltic Sea Region Programme.

- eurobalt.org/WaterRecyclingToolbox
- interreg-baltic.eu/project/waterman

The goal of this study is to analyse the environmental impacts of water supply for a Power-to-X (PtX) project in Bornholm. The results feed into the feasibility study done in the Waterman project, conducted by Bornholms Energi & Forsyning. The study is based on the method of Life Cycle Assessment (LCA) as described in ISO 14040 (ISO 14040, 2006).

### Goal and scope definition

The goal of this LCA is to compare two options for water supply for a Power-to-X project in their environmental impacts. The study focusses on two major aspects of environmental concern: 1) the impact on climate change (“carbon footprint”) and 2) the emissions of nutrients into the aquatic environment, leading to eutrophication.

The function of the systems under study is the supply of feed water for an electrolyser unit. In terms of water quality, the feed water should be suitable to be fed to the electrolyser water treatment, where the water is polished and fully demineralized into ultrapure water. Relevant parameters for feed water quality are low conductivity (< 20 µS/cm), low organic content (TOC < 5 mg/L) and low hardness and ionic content. In terms of required water quantity, two different setups are analysed: water supply for a 25 MW PtX plant and b) water supply for an 800 MW PtX plant. Assuming a demand for ultrapure water of 200 L/h per MW at full load, the required feed water would amount to 210 L/h and MW with 95% recovery in the electrolyzer water treatment. Finally, this amounts to 126 $m^3$/d of feed water needs for 25 MW PtX and 4,032 $m^3$/d for the 800 MW PtX plant.

The functional unit of the LCA is defined as “per $m^3$ of feed water supplied at a sufficient quality”.

The system boundaries include the water source, the treatment of water to the required quality, and the disposal of any brine that is produced in the treatment (Figure 1). Delivery of water from the point of treatment to the PtX location is not included.

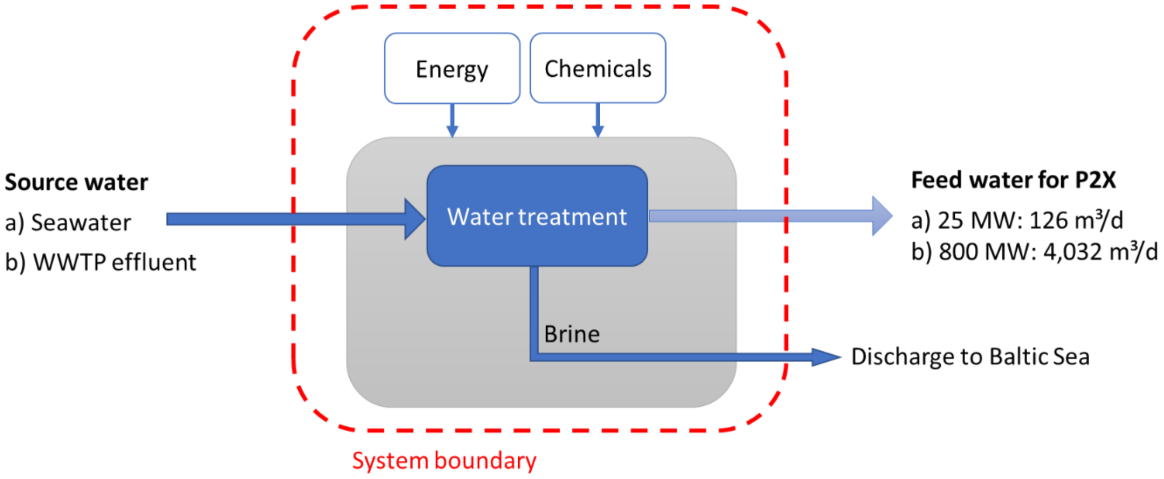

*Figure 1: System boundaries of the LCA study at Bornholm*

Two different water sources are considered: 1) seawater from around Bornholm ("SW") and 2) effluent of the wastewater treatment plant Rönne ("WW"). Both water sources will be treated by a double-membrane process including ultrafiltration (UF) and reverse osmosis (RO). For the water treatment, only electricity and chemical demand are considered, whereas infrastructure (e.g. materials) and any other processes (e.g. water transport) are excluded in this LCA.

### Input data for Life Cycle Inventory

Data for electricity and chemical demand of the water treatment processes (Table 1) is estimated based on comparable data from a similar LCA study (Jährig et al., 2025). This study conducted an LCA for water treatment for cooling water in Kalundborg from different water sources. As source water quality at Kalundborg is differing from conditions in Bornholm, data has been adjusted to reflect these differences adequately. However, quality data for source water in Bornholm is only limited to some basic parameters (e.g. conductivity, COD, nutrients), which made the transfer more challenging. To validate the assumptions and data for Bornholm, it would be helpful to have more detailed water quality data for both seawater and WWTP effluent.

*Table 1: Electricity and chemicals demand for water treatment in the different scenarios*

| **Parameter** | **Unit** | **SW-25** | **SW-800** | **WW-25** | **WW-800** |
|---|---|---|---|---|---|
| Process | | Pre-treatment + double membrane (UF/RO) | | Pre-treatment + double membrane (UF/RO) | |
| Water recovery | % | 45 | 45 | 65 | 65 |
| Source water | m³/d | 280 | 8,960 | 194 | 6,200 |
| Electricity | kWh/m³ | 1* | 1* | 0.5 | 0.5 |
| Chemicals | | | | | |
| NaOH (35%) | g/m³ | 25 | 25 | 20 | 20 |
| NaOCl (12%) | g/m³ | - | - | 2 | 2 |
| Citric Acid (40%) | g/m³ | 7 | 7 | 10 | 10 |
| HCl (25%) | g/m³ | | | 30 | 30 |
| NaHSO3 (18%) | g/m³ | 23 | 23 | - | - |
| FeCl (40%) | g/m³ | 0.7 | 0.7 | 5 | 5 |

** estimated for salt content of Baltic Sea (0.8%)*

Background data for production of electricity and chemicals comes from the LCA database ecoinvent v3.10 ((Ecoinvent, 2023)). For electricity, the Danish grid mix was assumed (179 g $CO_2e$/kWh). For sensitivity, the use of wind power (DK, off-shore: 16 g $CO_2e$/kWh) was also analysed. Chemicals production was modelled with datasets for average European production.

Brine quantity and quality was modelled based on water recovery rates of the treatment trains (Table 2). It has to be noted that the brine from seawater desalination can most probably be discharged back into the ocean, while the brine from wastewater reclamation may not get a permission to be discharged to sea due to elevated concentrations of regulated substances (COD, N, P). Therefore, brine from wastewater reclamation needs a different handling. For the smaller amount of brine in scenario WW-25 (68 m³/d), a direct recycling back to the inlet of the WWTP seems to be the best solution. This small flow accounts for only <1% of the total WWTP inlet, so that the WWTP is not overloaded with brine recycling and no negative effects of this brine on WWTP performance is expected. For the larger scenario WW-800, brine volume is at 2,168 m³/d, which amount up to 25% of the WWTP inlet. Recycling this brine may exceed the hydraulic capacity of the WWTP, and also could have negative effects on WWTP performance. A separate brine treatment could be needed, but this is not included in the present LCA study. It has to be noted that brine management in the WW-800 scenario is a critical issue for the entire concept and should be addressed in future studies.

*Table 2: Brine quantity and quality data for different scenarios*

| **Parameter** | **Unit** | **SW-25** | **SW-800** | **WW-25** | **WW-800** |
|---|---|---|---|---|---|
| Process | | Pre-treatment + double membrane (UF/RO) | | Pre-treatment + double membrane (UF/RO) | |
| Water recovery | % | 45 | 45 | 65 | 65 |
| Source water | m³/d | 280 | 8,960 | 194 | 6,200 |
| Product water | m³/d | 126 | 4,032 | 126 | 4,032 |
| Brine | m³/d | 154 | 4,982 | 68 | 2,168 |
| Relative to WWTP inlet (8,637 m³/d) | | | | <1% | 25% |
| Disposal | | Sea | Sea | WWTP inlet | Sea (permission?) or treatment |
| COD in brine | g/m³ | | | ~ 75 | ~ 75 |
| TN in brine | g/m³ | | | ~ 8 | ~ 8 |
| TP in brine | g/m³ | | | ~ 0.8 | ~ 0.8 |

**Results of the LCA**

Global warming potential of feed water supply amounts to 0.12 kg $CO_2e$ per m³ of feed water for reclaimed wastewater and 0,22 kg $CO_2e$/m³ for seawater (Figure 2). The main contribution to both footprints is the electricity needed for water treatment. Wastewater reclamation has a lower specific electricity demand and a higher water recovery than seawater desalination, which leads to a lower carbon footprint of this scenario (-44%). For the smaller and higher capacity (25 and 800 MW), specific carbon footprints are identical for each water source, as no “economies of scale” are included in the process data. The carbon footprint of chemical demand is comparable between wastewater and seawater scenarios and amounts to 19-27% of the total impact.

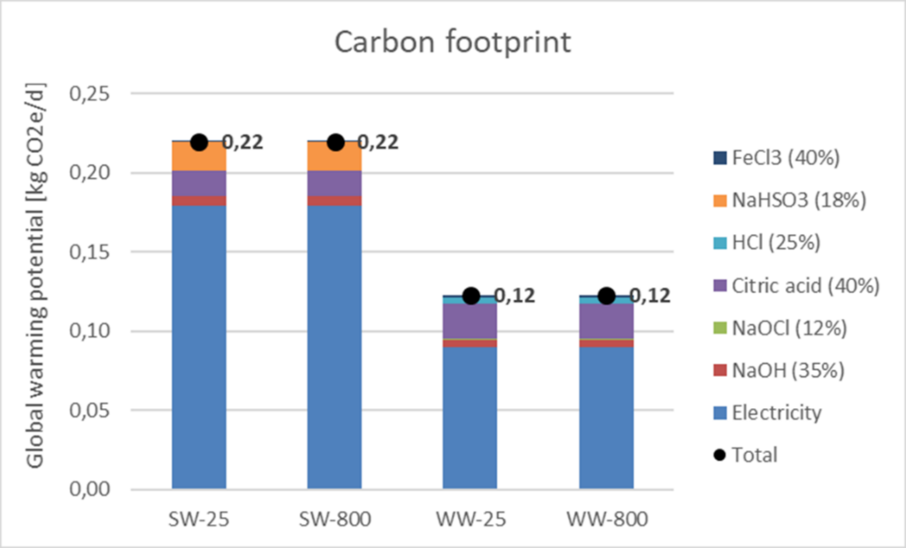

*Figure 2: Carbon footprint of feed water supply in the different scenarios (electricity as DK grid mix)*

If electricity would be supplied by renewable sources only (DK wind power), the total carbon footprint of all scenarios is drastically reduced to 0.04-0.06 kg $CO_2e$ per $m^3$ feed water (Figure 3). Still, seawater desalination has a higher carbon footprint that wastewater reclamation, but the absolute difference is relatively small. With using wind power only, chemicals demand is now the major contributor to the total carbon footprint with 72-81%.

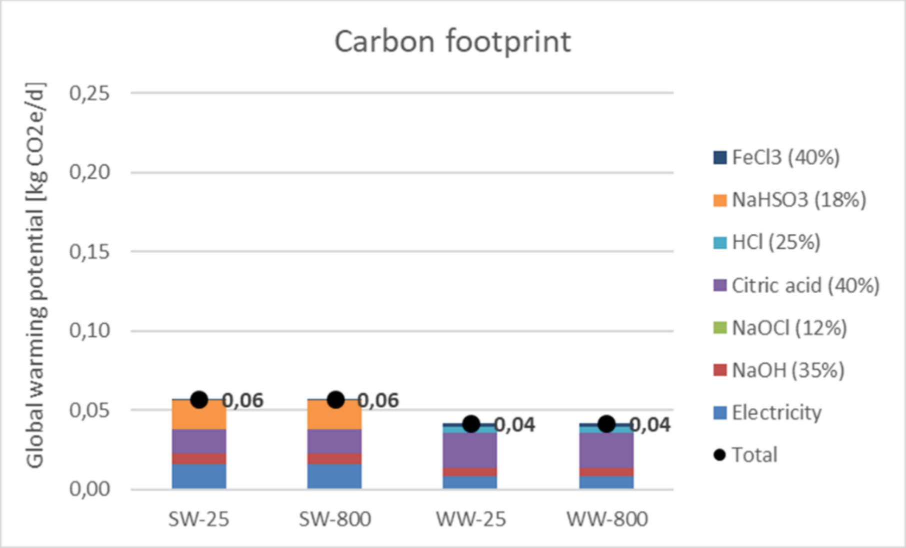

*Figure 3: Carbon footprint of feed water supply in the different scenarios (electricity as DK wind power mix)*

For eutrophication, this LCA only considers direct emission of nitrogen and phosphorus into the aquatic environment for the scenarios with wastewater reclamation, neglecting any contributions from background processes such as electricity and chemicals production. The results only show the total nitrogen and phosphorus load per day for the scenarios with wastewater reclamation (Figure 4), as seawater desalination will not lead to any “extra” emissions as brine is just returned to where it came from. The results show that the scenario WW-25 leads to a small (2%) reduction in N and P loads, as the brine is recycled back to the WWTP inlet. Scenario WW-800 results in no change in N and P emissions if brine is discharged to the sea (logically). However, if brine from WW-800 is separately treated and not discharged (e.g. by following a zero-liquid-discharge (ZLD) concept), nutrient loads could be substantially reduced (-65%). It has to be noted though that a ZLD concept for brine treatment is associated with high energy demand and related carbon footprint, which has been shown in the Kalundborg study (Jährig et al., 2025).

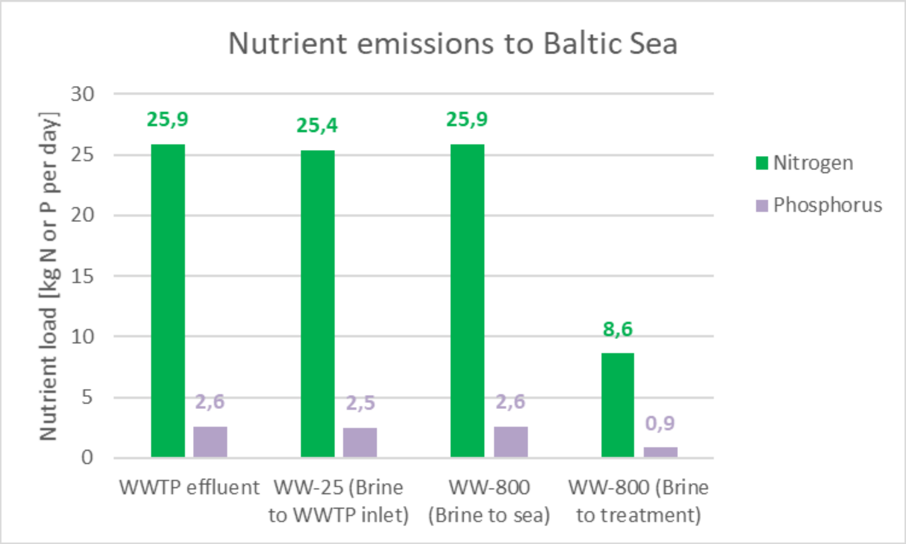

*Figure 4: Nutrient emission loads to Baltic sea in the scenarios with wastewater reclamation compared to the total nutrient loads in WWTP effluent*

## Conclusions

From the LCA study of feed water supply options for a PtX unit in Bornholm, the following conclusions can be drawn:

- WWTP effluent volume is sufficient to produce feed water volumes for 25 MW and 800 MW PtX unit
- Brine disposal from wastewater reclamation is a critical problem for the 800 MW scenario (brine ~ 25% of WWTP inlet), as discharge to Baltic sea may not be permitted due to higher concentrations of pollutants
- Feed water from WWTP effluent has lower energy demand and carbon footprint (-44%) than desalinated sea water (to be confirmed with more water quality data for source waters)
- Benefits in carbon footprint are less important if wind power is used for water treatment
- Nitrogen and phosphorus loads to Baltic sea could only be substantially reduced if brine from 800 MW is treated separately (but this would increase energy demand and carbon footprint drastically)

In general, this LCA study builds on the transfer of process data from another study to the Bornholm conditions. For validating the results, more water quality data is needed to determine specific process performance and important parameters (e.g. water recovery, electricity demand) for the different options on a more solid basis.

## References

Ecoinvent 2023 Ecoinvent data v3.10, ecoinvent reports No. 1-26, Swiss Center for Life Cycle Inventories, www.ecoinvent.org, Dübendorf, Switzerland.

ISO 14040 2006 Environmental management - Life Cycle Assessment - Principles and framework, International Standardisation Organisation, Geneva, Switzerland.

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