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water mining
value for society

Deliverable 3.4

Demo systems used in CS1 and CS2

Date: February 2022

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Disclaimer

The information included herein is legal and true to the best possible knowledge of the authors, as it is the product of the utilization and synthesis of the referenced sources, for which the authors cannot be held accountable.

Keywords

▪ Brines ▪ Seawater Desalination ▪ Resource Recovery ▪ Demonstration ▪ Installation

The WATER-MINING project has received funding from the European Commission under the Horizon 2020 programme, Grant Agreement No 869474. The opinions expressed in this document reflect only the author's view and do not reflect the European Commission's opinions. The European Commission is not responsible for any use that may be made of the information it contains.

Deliverable information

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Deliverable lead	TU Delft
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Reviewer	Philipp Wilfert (TU Delft)
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History of changes

Version	Date	Description	Author(s)
0.1	18/10/2021	Structure of the report	Dimitris Xevgenos
0.2	December 2021	Addition of information on EFC (template for collection of other demo information)	Dimitris Xevgenos, Marcos Rodriguez
0.3	24/01/2022	Draft version of integrated report	Dimitris Xevgenos
0.4	18/02/2022	Review	Philipp Wilfert (TUDELFT)
0.5	23/02/2022	Final review by coordination team	Project Management Team (TUDELFT)
1.0	28/02/2022	Final version of the deliverable	Dimitris Xevgenos

[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other; **ETHICS**=Ethics requirement, **ORDP**=Open Research Data Pilot

[2] **PU**=Public; **CO**=Confidential, only for members of the consortium (including the Commission Services); **EU-RES** Classified Information: RESTREINT UE (Commission Decision 2005/444/EC); **EU-CON** Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC); **EU-SEC** Classified Information: SECRET UE (Commission Decision 2005/444/EC)

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Executive Summary

This deliverable comprises the fourth deliverable of Work Package 3 and presents the two demo systems that are being installed at the two case studies of WATER-MINING project, namely CS1 in SELIS, Italy and CS2 in Plataforma Solar di Almeria, in Spain.

After providing an overview of the project (Section 1) and the objectives and scope of this deliverable (Section 2), an introduction is given, providing detailed information about the two case studies in Section 3.

In Section 4, the demo system that is being installed at Lampedusa island, at the site of SELIS in Italy is provided. For each process unit details about the capacity, the operating conditions, the dimensions and energy (and utility) requirements are provided, as well as pictures from the constructed equipment. Each process unit has been given a unique code according to the case study that is being used and the main operation performed (BP: Brine Purification, BC: Brine Concentration, BCr: Brine Crystallization), these include the following:

- CS1/BP-1: Nanofiltration 1
- CS1/BP-2: Nanofiltration 2
- CS1/BP-3: Electrodialysis Bipolar Membranes
- CS1/BC-1: Multiple Effect Distillation 1
- CS1/BC-2: Multiple Effect Distillation 2
- CS1/BC-3: High Pressure Nanofiltration
- CS1/BCr-1: Eutectic Freeze Crystallization
- CS1/BCr-2: Laser Induced Cavitation Crystallization
- CS1/BCr-3: Multiple Feed Plug Flow Reactor

In Section 5, the demo system that has been installed at Plataforma Solar di Almeria, in Spain is provided, following the same approach as the previous section. The system components described are:

- CS2/BP-1: Nanofiltration 3
- CS2/BC-1: Multiple Effect Distillation 3

Finally in Section 6, some concluding remarks are given, providing an overview of all demo components, as well as information for next steps, including the installation, start-up and operation of the demo systems.

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Acronyms

CE	Circular Economy
CS	Case Study
EFC	Eutectic Freeze Crystallization
EDBM	Electrodialysis Bipola Membranes
HPNF	High Pressure Nanofiltration
LICC	Laser Induced Cavitation Crystallization
MED	Multiple Effect Distillation
NF	Nanofiltration
WP	Work Package

1. Overview of the project

WATER-MINING is a project funded by the European Commission (Horizon 2020 – Grant Agreement No 869474) with a total duration of 48 months (Start date: 01/09/2020 – 31/08/2024) and a total budget of approx € 19 million (EU Contribution: € 16,876,959.59). The project is entitled "Next generation water-smart management systems: large scale demonstrations for a circular economy and society" and it is a project granted under the call topic "CE-SC5-04-2019: Building a water-smart economy and society". Further information about all the sister projects funded under this topic can be found at the CORDIS website here. The WATER-MINING consortium comprises 38 partners from 12 countries, led by the Delft University of Technology (TU Delft). More information about the project can be found at the project website (https://watermining.eu) as well as the dedicated website at CORDIS database (https://cordis.europa.eu/project/id/869474), while an overview is provided below.

The WATER-MINING project aims to provide for real-world implementations of Water Framework Directive (and other water related legislation), as well as the Circular Economy and EU Green Deal packages by showcasing and validating innovative next generation water resource solutions at pre-commercial demonstration scale. These solutions combine WATER management services with the recovery of value-added renewable resources extracted/MINED from alternative water resources ("WATER-MINING").

The project integrates selected innovative technologies that have reached proof of concept levels under previous EU projects. The value-added end-products (water, platform chemicals, energy, nutrients, minerals) are expected to provide regional resource supplies to fuel economic developments within a growing demand for resource security. Different layouts for urban wastewater treatment and seawater desalination are proposed, to demonstrate the wider practical potential to replicate the philosophy of approach in widening circles of water and resource management schemes. Innovative service-based business models (such as chemical leasing) are being introduced to stimulate progressive forms of collaboration between public and private actors and access to private investments, as well as policy measures to make the proposed water solutions relevant and accessible for rolling out commercial projects in the future. The goal is to enable costs for the recovery of the resources to become distributed across the whole value chain in a fair way, promoting business incentives for investments from both suppliers and end-users along the value chain. The demonstration case studies are to be first implemented in five EU countries (NL, ES, CY, PT, IT) where prior successful technical and social steps have already been accomplished. The broader project consortium representation will be an enabler to transferring trans-disciplinary project know-how to the partner countries while motivating and inspiring relevant innovations throughout Europe.

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2. Scope of the deliverable

Within WATER-MINING project, Work Package 3 (WP3) is focusing on the "Demonstration of renewable desalination and sustainable brine management". WP3 is structured on the following four (4) Tasks:

- **Task 3.1**: Detaled design for renewable desalination/brine minimization and salt recovery;
- **Task 3.2**: Manufacturing and installation of the demo plants;
- **Task 3.3**: Operation and optimization of the large-scale demonstration plants; and
- **Task 3.4**: Coordination of WP3 activities and interrelation with other WPs.

The results from the implementation of this work package are presented through six (6) deliverables:

- **Deliverable 3.1**: Design procedure bench-scale tests (connected to Task 3.1);
- **Deliverable 3.2**: Report operation & optimization process (connected to Task 3.3);
- **Deliverable 3.3**: Report on technical results from the implementation of WP3 – input for interrelated WPs (connected to Task 3.4);
- **Deliverable 3.4**: Demo systems used in CS1 and CS2 (connected to Tasks 3.2 & 3.3);
- **Deliverable 3.5**: Report on technical results from the implementation of WP3 – input for interrelated WPs (1st update) (connected to Task 3.4); and
- **Deliverable 3.6**: Report on technical results from the implementation of WP3 – input for interrelated WPs (2nd update) (connected to Task 3.4);

The current deliverable comprises the fourth deliverable of WP3. The work was led by TU Delft within Task 3.2, and it involved the technology suppliers for the different process units that are installed in the two demo locations, namely in Lampedusa island, Italy (Case Study 1, CS1) and Plataforma Solar di Almeria, Spain (Case Study 2, CS2).

This deliverable comprises the "Demonstrator" deliverable foreseen within WP3. The two demo systems that are installed in the two case studies comprise the physical demonstrators developed within WP3, while this deliverable aims to provide information on the demo systems (and its components) in the form of a report.

This deliverable is also a "Public" deliverable, thus not containing any confidential information.

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3. Introduction

Within WP3 two Case Studies (CS) are foreseen:

- Case Study 1 (CS1): Lampedusa island, Italy; and
- Case Study 2 (CS2): Plataforma Solar di Almeria, Spain.

More information about the case studies are provided in the sections below, while the demo systems installed at CS1 is presented in Section 4, and at CS2 in Section 5.

3.1. Case Study 1 : SELIS - Lampedusa island, Italy

In CS1, seawater is fed to the nanofiltration unit, resulting in two different streams: one that is rich in monovalent ions, and one that is rich in multi-valent ions. The former is directed to a process line of conventional units, which first includes the Multiple Effect Distillation unit that produces water via an evaporation process. Following this unit, the stream goes to a thermal crystallizer and then to a dryer to finally obtain NaCl crystals. The concentrate stream from NF unit is fed to a Multiple feed plug flow reactor (MF-PFR) to recover Mg(OH)2, Ca(OH)2. The residual stream is treated by an Eutectic freeze crystallizer (EFC) to recover Na2SO4. Finally, an Electrodialysis with Bipolar Membranes (EDBM) is used to recover HCl and NaOH from a NaCl rich stream. Overall, this treatment chain represents a Zero Liquid Discharge (ZLD) system aiming to maximize the freshwater recovery and to recover valuable resources from brine, such as NaCl, Mg(OH)2, Ca(OH)2, Na2SO4, HCl, NaOH. Below a process flow diagram, the numbers indicate the number of buffer tanks in between the different process units.

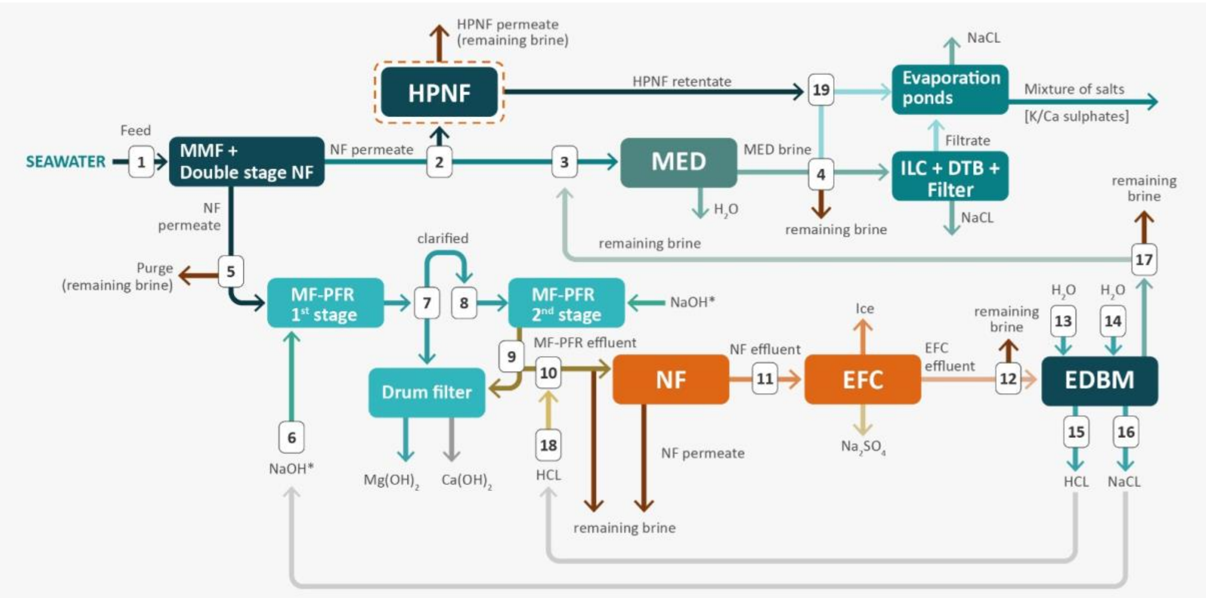


Figure 3-1: Process flow diagram for Case study 1 in Italy.

Below a description of the status of the case study before the project and the expected impact after the project completion is also provided.

Table 3-1: Case Study 1 – summary description

CS1 Name **CS1 Owner** **Scale & capacity**	S.EL.I.S. Lampedusa - Italy SELIS (Partner No: 6) Large demo – 2,250 l/h	S.EL.I.S. LAMPEDUSA S.p.A. 
Key CE intervention	▪ Zero Liquid Discharge Seawater Desalination ▪ Internal use of recovered resources ▪ Waste heat integration	
Relevant sectors	▪ Power Industry, ▪ Drinking water, ▪ Salt Industry	
Special focus	▪ Economic innovation: Public Private Partnership / creation of spin-off for full-scale implementation /recovery of magnesium & other compounds ▪ Environmental damage from brine discharge ▪ Social focus: water security	

Status of the case study at the start of the project:
Lampedusa is a small island close to Sicily, experiencing sever water stress. Desalination was introduced in 1972. Currently there is one desalination plant covering almost 100% of the total drinking water needs of the island: the plant is located in Cala Pisana, very close to the main village of Lampedusa. The energy consumption of the desalination sector accounts for **approx. 10%** of the total energy consumption. The desalination plant in Lampedusa has been developed by Private Partnerships through Built, Own, Operate, Transfer (BOOT) Contracts, where private companies using their own funds, undertake the design, construction and operation of the Plants over a fixed period. The Government has the obligation to buy 100% of desalinated water each year over that fixed period (10 years). With private-sector entities, the governments can use the private sectors' knowledge, experience and financing capacity to improve the quantity and quality of basic public services. Lampedusa power station has an installed capacity of 22 MW (8 diesel engines of different power) generating the 100% of the total electric output of the island. The private consortium operating the desalination plant is made by 3 different private partners (SOFIP, ACCIONA, PROTECNO) and is operating today a seawater desalination unit of a total installed capacity of around 3,500 m^3/day (2x1,500, 1x1,000 m^3/day) installed very close to the Lampedusa power station. The desalination unit (Reverse Osmosis) covers the drinking water needs of Lampedusa. The water is being sold at a fixed and guaranteed price to the Water Department of Sicily.

<u>**Demonstration:** The demo system is being installed at the power plant site in Lampedusa island. The WP3 demo is able to produce approx. 50 m^3 of water per day, which corresponds to **5%** of the installed desalination capacity from one of the 3 RO units.</u>

Ambition at the end of the project and beyond:
Full-scale implementation. Adoption of proposed SEA-MINING technique for development of multiple purpose plants for production of power / water / salts, using power plants as the driving force for implementation through the use of waste heat. High replicability potential in more than 2,200 islands within Europe and beyond.

3.2. Case Study 2 : Plataforma Solar di Almeria (PSA) - Spain

The demo system to be operated by CIEMAT at Plataforma Solar de Almería (PSA), in Tabernas, Spain, comprises a 14 effects Multi-Effect Distillation (MED) plant as the most efficient thermal desalination technology at an industrial scale. The plant has a nominal feed water flow rate of 8 m^3/h and produces 3 m^3/h of distilled water with a maximum operating temperature of 70ºC, using a thermal power of 190 kWth with a performance ratio almost 10. The MED plant will be powered by low temperature solar heat. The demo will use solar thermal energy from stationary flat plate collectors (a solar field composed of 60 collectors with total aperture area of 606 m^2), but the same energy can come from waste heat from Concentrated Solar Power plants. By integrating the desalination in that co-generation scheme, the main obstacle (high investment cost of the solar collectors) can be avoided. In addition, the coupling of the MED plant would have no detrimental effect on the efficiency of the power cycle because we propose to use innovative CSP configurations with high temperature power cycles (air Brayton cycles with central receiver solar towers) with enough waste heat to integrate a thermal desalination system with no penalty.

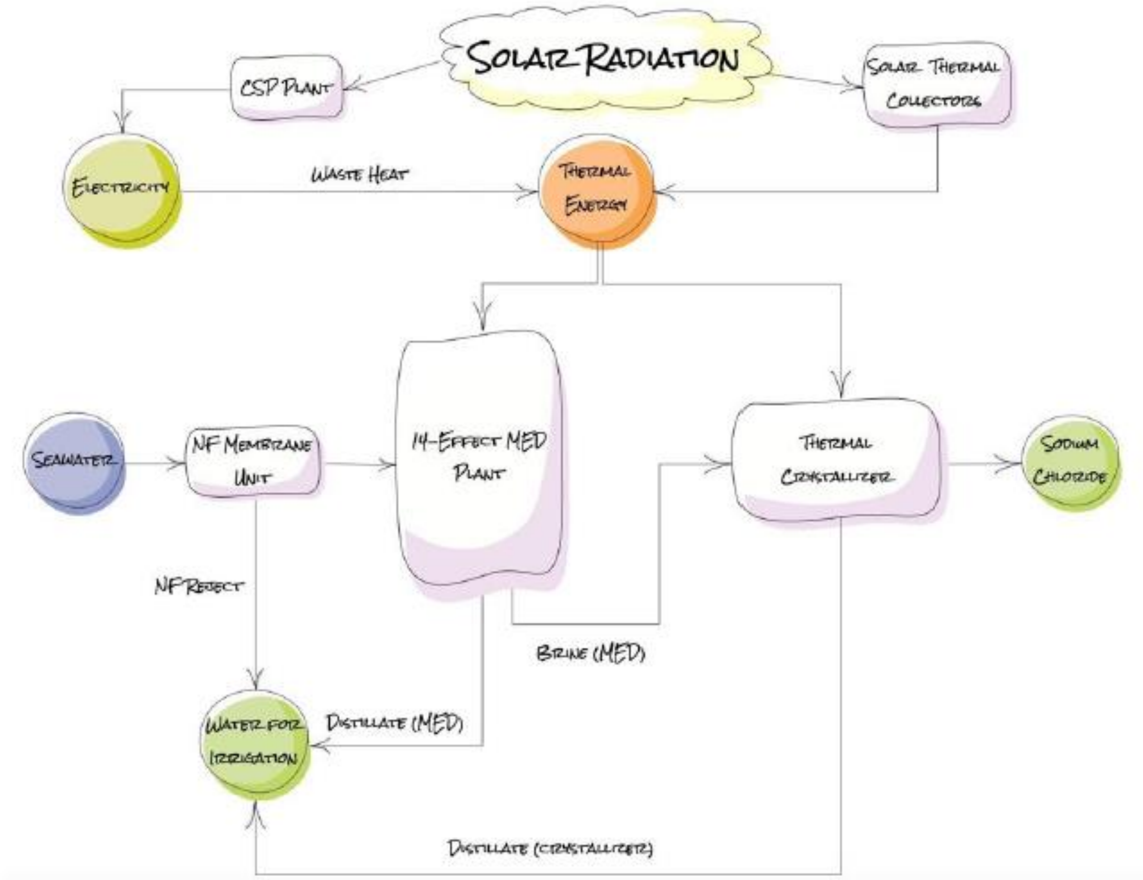


Figure 3-2: Process flow diagram for Case study 2 in Spain.

To improve the efficiency of the thermal desalination process, the seawater being fed to the MED will be pre-treated by a nanofiltration (NF) system to retain the divalent ions (Mg^{2+}, Ca^{2+}, SO_4^{2-}), resulting in a sodium chloride (NaCl) rich and purified permeate stream. By using this as feed, the recovery of the MED plant can be increased, and also the operating temperature (typically limited to 70ºC to avoid scaling), enhancing the thermal efficiency significantly. The aim is to demonstrate the potential of reaching a record-breaking lowest energy consumption in thermal desalination (below 25 kWh_{th}/m^3) without exceeding 100ºC in the Top Brine Temperature. In addition, the use of polymeric materials in the MED plant replacing metallic evaporator tubes will be evaluated to decrease the cost of the desalination plant. To achieve Zero Liquid Discharge desalination, the concentrated brine released from the MED plant will be treated with solar-powered crystallization. After the NF pre-treatment of the feed, the brine from the MED will be free from divalent salts and thus the salts produced in the crystallizer can be pure NaCl with higher added value. Furthermore, the brine from the NF system, with a larger concentration of divalent salts, will be used to remineralize the distilled water produced in the MED, to be used for irrigation (divalent ions are tolerated by crops, as a matter of fact some act as fertilizers). The products recovered from the seawater will therefore be water for irrigation and high quality NaCl salts.

Table 3-2: Case Study 2 – summary description

CS2 Name **CS2 Owner** **Scale & capacity**	Plataforma Solar di Almeria - Spain CIEMAT (Partner No: 7) Large demo – 2,5000 l/h	
Key CE intervention	▪ Zero Liquid Discharge Seawater Desalination ▪ Renewable energy & Decarbonization of energy in desalination & brine concentration	
Relevant sectors	▪ Renewable Power Industry, ▪ Drinking water, ▪ Agricultural Water, ▪ Salt Industry	
Special focus	▪ Social focus: co-creation with stakeholders ▪ Establishment of a Living Lab focused on renewable powered desalination	

Status of the case study at the start of the project:
Plataforma Solar di Almeria (PSA) comprises a site of 400,000 m^2 belonging to CIEMAT. This site is the largest concentrating solar technology research, development and test centre in Europe. The site is recognized by the EU as a "Large European Science Facility" and by the Spanish Government as an ICTS ("Unique Scientific and Technical Infrastructure"). Moreover, it houses the biggest renewable driven, thermal desalination system in Europe. The thermal desalination system has been developed thanks to EU Funding (FP7) and being upgraded thranks to Sturtural Funding. It comprises the largest multi-effect distillation (MED) unit (of forward-feed, vertically stacked design) made up of 14 effects with direct seawater supply to the first effect (forward feed configuration) and one of the largest renewable powered thermal desalination systems at global scale. It is powered by a solar field composed of 60 stationary flat plate solar collectors with a total aperture area of 606 m^2. At a nominal 8 m^3/h feedwater flow rate, the distillate production is 3 m^3/h, and the thermal consumption of the plant is 190 kW_{th}, with a performance ratio almost 10, one of the highest achieved in thermal desalination.

<u>**Demonstration:** The demo system will be installed at CIEMAT and will treat 5**0%** of the brine effluent generated from the thermal desalination system.</u>

Ambition at the end of the project and beyond:
Demonstration of record-breaking lowest energy consumption of thermal desalination (below 25 kWh_{th}/m^3 of low enthalpy heat solar heat at 100 ºC maximum) and integration with renewable energy. CIEMAT will also become a Living Lab for "Renewable Powered Desalination and Brine Recycling", with a strong focus on Concentrated Solar Power (CSP) developments to support sustainable desalination concepts.

4. Demo system used in CS1

The demo system used in Case Study 1 comprises the following process units:

- **Nanofiltration (NF):**
  There are two nanofiltration units developed: one owned by LENNTECH, described in Table 4-1 with the code CS1/BP-1 and one owned by TU Delft, described in Table 4-3 with the code CS1/BP-2.

- **Electrodialysis with Bipolar Membranes (EDBM):**
  This process unit is owned by UNIPA and is described in Table 4-4 with the code CS1/BP-3.

- **Multiple Effect Distillation (MED):**
  There are two MED units developed: one owned by THERMOSSOL, the manufacture was based on the design made by SOFINTER. This unit is described in Table 4-6, with the code CS1/BC-1. Annother MED unit owned by NTUA & SEALEAU is also available for use, this MED unit is described in Table 4-8, with the code CS1/BC-2.

- **High Pressure Nanofiltration (HPNF):**
  This process unit is owned by LENNTECH and is described in Table 4-9 with the code CS1/BC-3.

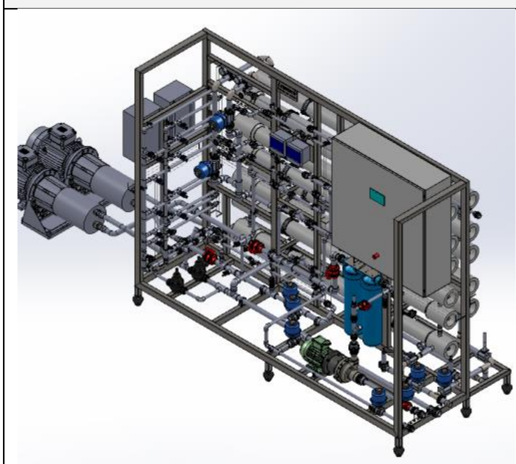
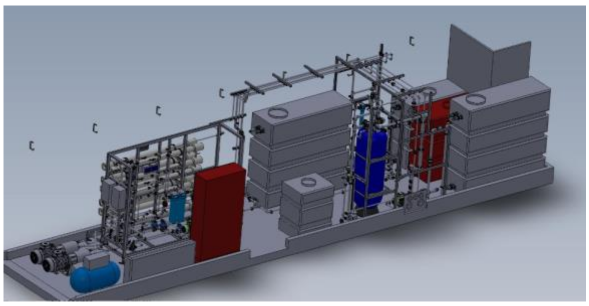
- **Eutectic Freeze Crystallization (EFC):**
  This process unit is owned by TU Delft. The description of the EFC unit is provided in Table 4-11, with the code CS1/BCr-1.

- **Laser Induced Cavitation Crystallization (LICC):**
  This process unit is owned by TU Delft. The description of the LICC unit is provided in Table 4-13, with the code CS1/BCr-2.

- **Multiple Feed Plug Flow Reactor (MF-PFR)**
  This process unit is owned by UNIPA and is described in Table 4-14 with the code CS1/BCr-3.

4.1. CS1/BP-1: Nanofiltration 1 (NF-1)

Table 4-1: Summary of nanofiltration demo system used in CS1 (code: CS1/BP-1)

CS1 equipment:	**BP-1**		☐ Bench-scale system
Owner:	Lenntech		☐ Pilot-scale System
			☑ Large pilot/Demo System
Capacity ~1,700 L/h		**Operating pressure**	0-40 bars
Product streams • NF permeate: Purified sodium chloride (NaCl) stream • NF concentrate:Concentrate stream rich in magnesium (Mg^{2+}), calcium (Ca^{2+}) and sulfate (SO_4^{2-}) ions		**Working temperature**	5°C to 40 °C
		Power supply	Main power supply: 3-phase, 400 V/50Hz, max 100A
		**NF skid height**	2,154 mm
		NF skid length	4,682 mm (including the HPP)
		Power consumption	Max 33 kW
		Construction / materials	Low pressure parts in PVC High pressure parts in SS316 Skid in SS304
		Container	40ft HC container (12m x 2.35m x 2.69m) (Length x Width x Height) Thermal and acoustic insulation (50 mm EPS with aluminum 0.4mm plates)
Other The pilot requires an electric power supply (3-phase, 400 V/50Hz, max 100A) and clean non-chlorinated water (demi water from RO plant). The pilot is fully automatic. The pilot should run at least 6 hours per day.			
3-D sketch of the NF skid		**3D sketch of the container**	
			

CS1 equipment:	**BP-1**	☐ Bench-scale system
Owner:	Lenntech	☐ Pilot-scale System
		☑ Large pilot/Demo System

Safety

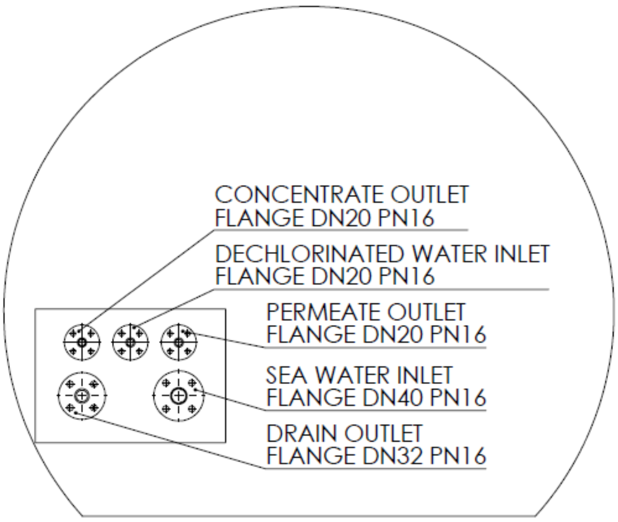
Detailed safety instructions will be provided in the IOM manual of the system

Contact Persons

Dionysia Diamantidou (dionysia@lenntech.com),
Tomas Giele (tomas@lenntech.com)

Table 4-2: Connections of the NF-1 system to other process units

No	Size	Type	Description
1	DN20	Flange (Concentrate Outlet)	To feed tank of MF-PFR
2	DN20	Flange (Dechlorinated Water Inlet)	From RO permeate (Desalination Plant)
3	DN20	Flange (Permeate Outlet)	To feed tank of MED or to staged NF
4	DN40	Flange (Sea Water Inlet)	From well pump
5	DN32	Flange (Drain Outlet)	To drain



4.2. CS1/BP-2: Nanofiltration 2 (NF-2)

Table 4-3: Summary of the nanofiltration pilot system used in CS1 (code: CS1/BP-2)

CS1 equipment:	**BP-2**	☐ Bench-scale system
Owner:	TUDELFT	☑ Pilot-scale System
		☐ Large pilot/Demo System
Capacity 300 l/h	**Operating pressure**	40bar
	Working temperature	25 °C
	Applied voltage	N/A
Main product Concentrate stream	**Inlet chemicals**	N/A
	Outlet chemicals	N/A
	Refrigeration fluid	N/A
By-products Permeate stream	**Power supply**	Pressure booster: single phase, 220V
		Pressure pump: 3 phase, 380V
	**Frame height**	1.6m
	Frame length	0.7 m
	Power consumption	0.5kW (pressure booster) 2.58 kW (high pressure pump) Total: 3.5 kW (3-phase)
	Construction / materials	Stainless steel (316) reactor mounted in aluminium frame
	Container	Part of EFC container 20'' container (6m x 2.5m x2.5 m) (Length x Width x Height) Thermal and acoustic insulation (foam) and wooden wall frame (for thermal insulation and fixing/mounting purposes).
Other The pilot requires only an electric power supply (both single and 3-phase) and water for cleaning purposes. Set-up is automated. End of the operation membrane flushing (manual)		
Safety High pressure		
Contact Persons Dr. Dimitris Xevgenos (d.xevgenos@tudelft.nl), Dr. Marcos Rodriguez (m.rodriguezpascual@tudelft.nl)		

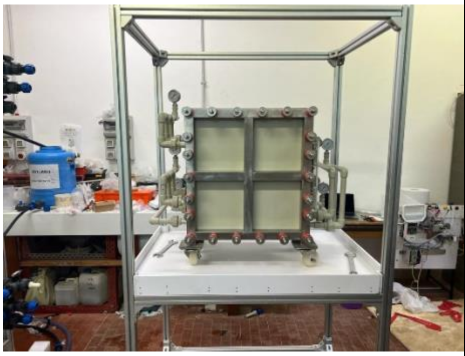
4.3. CS1/BP-3: Electrodialysis with Bipolar Membranes (EDBM)

Table 4-4: Summary of the EDBM demo system used in CS1 (code: CS1/BP-3)

<table>
<tr><td>CS1 equipment:
Owner:</td><td>BP-3
UNIPA</td><td>☐ Bench-scale system
☐ Pilot-scale System
☑ Large pilot/Demo System</td></tr>
<tr><td rowspan="6">Capacity
100 L/h</td><td>Operating pressure</td><td>Depending on the operating flow rate:
At minimum flow rates 0-0.5 barg
At maximum flow rates 0-3.5 barg</td></tr>
<tr><td>Working temperature</td><td>From 5°C to 40°C</td></tr>
<tr><td>Applied voltage (for EDBM stack)</td><td>20-70 V DC</td></tr>
<tr><td>Applied current (for EDBM stack)</td><td>10-80 A DC</td></tr>
<tr><td>Flow rates (inside EDBM, including recycles)</td><td>Acid compartment: 4-20 L/min
Base compartment: 4-20 L/min
Salt compartment: 4-20 L/min
ERS compartment: 20-30 L/min</td></tr>
<tr><td>Inlet chemicals</td><td>Acid compartment: Demi-water
Base compartment: Demi-water
Salt compartment: Synthetic or real brines (0.5-3M)
ERS compartment: Na_2SO_4 solution ~0.2M</td></tr>
<tr><td rowspan="4">Main product
Sodium hydroxide solution,
Hydrochloric acid solution,
Low salty solution</td><td>Outlet chemicals</td><td>Acid compartment: Hydrochloric (and sulfuric) acid solution 0.5-2M
Base compartment: Sodium (and potassium) hydroxide solution 0.5-2M
Salt compartment: Low salty solution 0.1-1M (max 2M)
ERS compartment: similar to the inlet ERS.</td></tr>
<tr><td>Refrigeration fluid</td><td>not used</td></tr>
<tr><td rowspan="6">Power supply:
2 x 3-phases (400V) power
Peak current 2 x 63A
Max Power ~ 2 x 20kW
Nominal Power (total) ~ 15-18 kW

Further details for each single unit ---></td><td>4xPump: 3-phase, 400 V/50Hz</td></tr>
<tr><td>DC drive: 3-phase, 400V/50Hz</td></tr>
<tr><td rowspan="4">By-products
not applicable</td><td>Air conditioner: single phase, 230 V/50 Hz</td></tr>
<tr><td>Fan: single phase, 230 V/50 Hz</td></tr>
<tr><td>2xPower suppliers (data acquisition & control), 230 V/50Hz</td></tr>
<tr><td>Electric transformer (DC drive control) 230 V/50Hz</td></tr>
</table>

CS1 equipment:	**BP-3**	☐	Bench-scale system
Owner:	UNIPA	☐	Pilot-scale System
		☑	Large pilot/Demo System


Frame 1 - EDBM

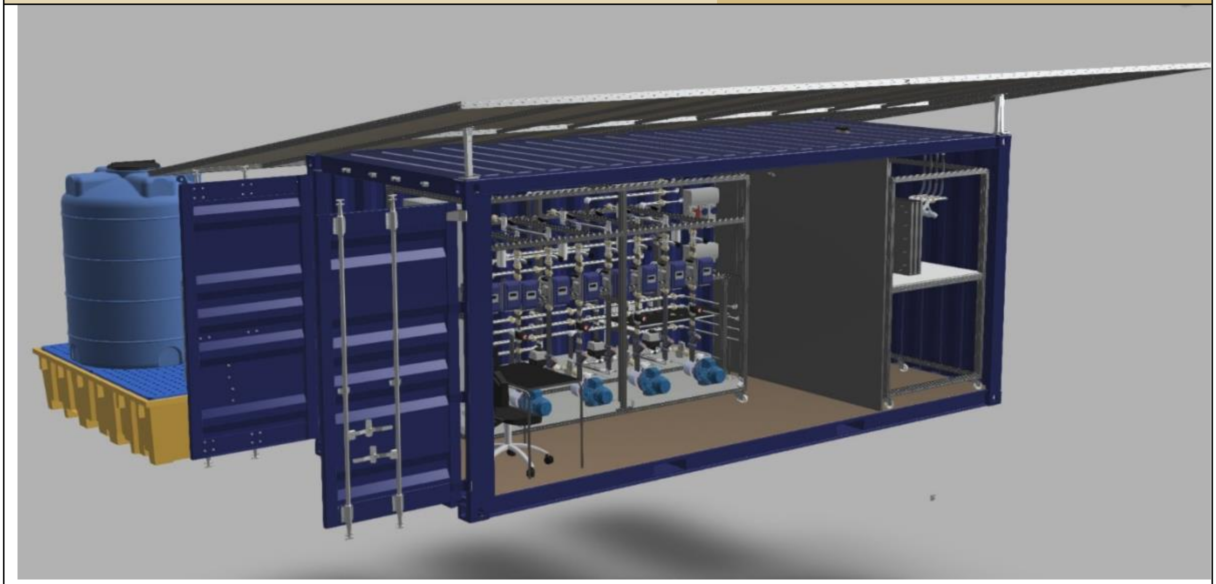

Frame 2 - Auxiliaries

Frame 1 height	2,045 mm (EDBM)
Frame 1 length	800 mm (EDBM)
Frame 1 width	1,100 mm (EDBM)
Frame 2 height	2,120 mm (Auxiliaries)
Frame 2 length	3,000 mm (Auxiliaries)
Frame 2 width	1,300 mm (Auxiliaries)
Power consumption	5 kW (Pump motors) 10 kW (DC drive) 0.4 kW (Power supplies) 0.1 kW (Electric transformer) 1.4 kW (Air conditioner) 0.1 kW (Fan) Total: 17 kW
Construction / materials	Two aluminium frames are included. The first frame is comprised of an EDBM module (Fumatech) with 40 repeating units and pressure gauges (Varisco); the second frame is comprised of all necessary auxiliaries, including four regenerative turbine pumps (Teorema), four filters (Atlas), three electro-valves (FIP), all required sensors (Krohne), and data acquisition systems (National Instrument). The DC drive (Giussani) is positioned on a stainless steel support.
Container	20'' container (6.1m x 2.5m x2.6 m) (Length x Width x Height)

Other

The pilot requires single- and 3- phase electric power supplies. Demi water is required for the acid and base tanks, and for the preparation of the synthetic brine solutions. The preparation of the Electrode Rinse Solution is required every 20-30 working days. No need for compressed air. Although the system is automated, the presence of an operator is required for the opening and closing of the manual valves at the beginning and end of the test and for sampling operations.

CS1 equipment:	**BP-3**	☐ Bench-scale system
Owner:	UNIPA	☐ Pilot-scale System
		☑ Large pilot/Demo System



3D Sketch

Possible operational and safety issues

- Actuated valve failure may result in poor performance;
- Fouling of electrode compartments may cause a reduction in the electrical current flowing in the stack;
- Manual ball valves closed or not functioning may cause bursts on the pipe (if the valve is closed), damage to the pumps and internal leakage in the stack;
- Clogged filters can cause bursts on the pipe or damage to the pumps;
- Broken pipes cause external leakage of the electrolyte solutions or possible flooding and internal leakage in the stack;
- Flow rate transmitter not working/out of service may cause overpressures, internal leakage in the stack, pumps shutdown;
- Level switches not properly working may cause overflow of solutions from tanks, damage to pumps, and internal leakage.
- Stack leakages during functioning may expose operators to medium-high voltage (max 70V DC), for this reason a transparent wall divides the container area where the DC drive and EDBM stack are positioned from the rest.

Contact Persons

Dr. Andrea Culcasi (andrea.culcasi@unipa.it),
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Table 4-5: Connections of the EDBM system (Code: CS1/BP-3) to other process units

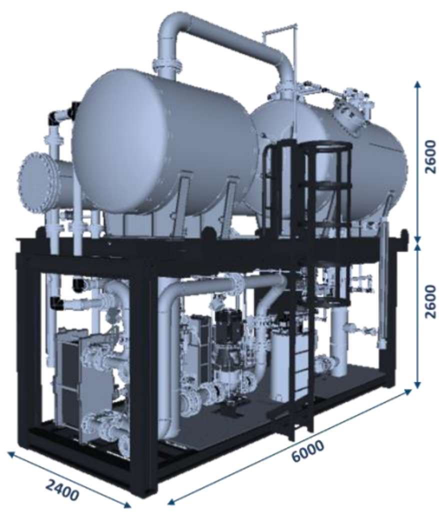
No	Size	Type	Description
4	DN20	PVC Reinforced Hose Pipe	From container 3 EFC effluent tank to container 4 feed tank of EDBM (0.1m3/h)
12d(1)	DN20	PVC Reinforced Hose Pipe	From container 4 to drain
12d(2)	DN20	PVC Reinforced Hose Pipe	From container 4 to drain
7b	DN20	PVC Reinforced Hose Pipe	From container 4 saline solution tank to feed tank MED or container 5 (0.2m3/h)
5a	DN20	PVC Reinforced Hose Pipe	From container 4 acid tank outlet to container 2 acid storage tank or SWRO civil plant (0.2 m3/h)
6a	DN20	PVC Reinforced Hose Pipe	From container 4 base tank outlet container to container 2 base storage tank or SWRO civil plant (0.2m3/h)
11d	DN20	PVC Reinforced Hose Pipe	From RO permeate (SWRO civil plant) to container 4 (max 4m3/day)
22(1)	DN20	PVC Reinforced Hose Pipe	From container 4 to neutralization tank
22(2)	DN20	PVC Reinforced Hose Pipe	From container 4 to neutralization tank

4.4. CS1/BC-1: Multiple Effect Distillation demo system (MED-1)

Table 4-6: Summary of MED demo system used in CS1 (code: CS1/BC-1)

CS1 equipment:	**BC-1**	☐ Bench-scale system
Owner:	THERMOSSOL	☐ Pilot-scale System
	(design by SOFINTER)	☑ Large pilot/Demo System

Capacity 1700 l/h	**Operating pressure**	Atmospheric pressure
	Working temperature	0 °C to 45 °C
	Applied voltage	400V
	Inlet chemicals	Additive: antifoam solution
	Outlet chemicals	N/A
	Refrigeration fluid	N/A
	Power supply	Flash water circulation pump: 3-phase, 400 V/50Hz
Main product Fresh distilled water		Brine extraction pump: 3-phase, 400 V/50Hz
		Distillate extraction pump: 3-phase, 400 V/50Hz
		Vacuum pump: 3-phase, 400 V/50Hz
By-products NaCl concentrate stream		Additive dosing pump: 1-phase, 230 V/50Hz
		Control system 230 V/50 Hz

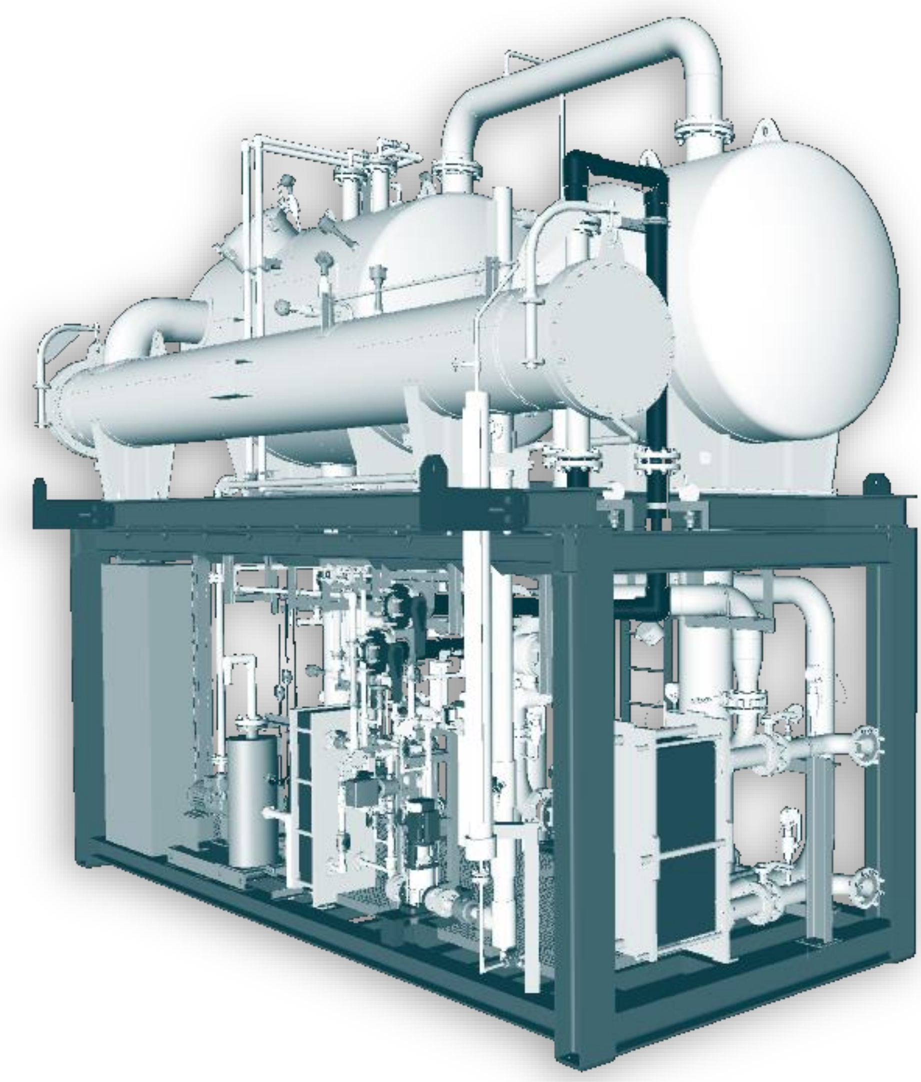
	**Frame height**	5500 mm (after assembly)
	Frame length	6000x2500 mm (footprint)
	Power consumption	8.9 kW (flash water circulation pump) 2.7 kW (brine extraction pump) 0.6 kW (distillate extraction pump) 3.6 kW (vacuum pump) 0.2 kW (dosing system) 0.7 kW (control system) Total: 16.7 kW
	Construction / materials	Evaporator: super duplex ss (SAF 2507) with Titanium heat exchange tubes. Flash drum and distillate condenser : stainless steel (316L). Two pre-coolers.
	Skids	No. 2 skids simil size 20'' container (6m x 2.5m x2.5 m) (Length x Width x Height) shop pre-assembled

CS1 equipment:	**BC-1**	☐	Bench-scale system
Owner:	THERMOSSOL	☐	Pilot-scale System
	(design by SOFINTER)	☑	Large pilot/Demo System

Other

The pilot requires only an electric power supply (3-phase). No other utilities (such as instrument air, steam etc) are required. No need also for compressed air (built-in air compressor is provided). Set-up is automated. During daily operation (8 hours: 2hour for startup, 5.5 hours operating, 0.5 hour for shutdown), the operator needs to be discontinuously attending the operation.

3D Sketch



CS1 equipment:	**BC-1**	☐ Bench-scale system
Owner:	THERMOSSOL	☐ Pilot-scale System
	(design by SOFINTER)	☑ Large pilot/Demo System




Safety
Possible salty solution leakages in case tubes or pumps break.

Contact Persons
Thermossol : Dr. Christina Xenogianni (thermossol@yahoo.gr)
Sofinter : Dr. Alessandro Trezzi (alessandro.trezzi@swsonweb.com)

Table 4-7: Connections of the MED-1 system (Code: CS1/BC-1) to other process units

No	Size	Type	Description
1	DN25	PVC-C Reinforced Pipe	Feed water inlet
2	DN25	PVC-C Reinforced Pipe	Brine outlet
3	DN25	PVC-C Reinforced Pipe	Distilled water outlet
4	DN100	316L stainless steel	Hot water inlet
5	DN100	316L stainless steel	Hot water inlet
6	DN100	PVC-U Reinforced Pipe	Cooling water inlet
7	DN100	PVC-U Reinforced Pipe	Cooling water outlet
8	DN20	PVC Reinforced Hose Pipe	to drain

4.5. CS1/BC-2: Multiple Effect Distillation pilot system (MED-2)

Table 4-8: Summary of MED pilot system used in CS1 (code: CS1/BC-2)

CS1 equipment:	**BC-1**	☐ Bench-scale system
Owner:	NTUA & SEALEAU	☑ Pilot-scale System
		☐ Large pilot/Demo System

Capacity 2 m^3/day	**Operating pressure**	0.15 bar(a) – 1^{st} effect
		0.10 bar(a) – 2^{nd} effect
	Working temperature	55 °C– 1^{st} effect
		45 °C– 2^{nd} effect
	Power supply	Three phase
		Single phase, 230 V/50Hz

	**Height**	2690mm
	Length	5,910 mm
	Width	2,345 mm
		Inside the container 4 polypropylene tanks with a capacity 300 L each (2 feed brine containers, 1 distillate water container and 1 concentrated) have been installed. Moreover, a heat exchanger have been installed in order to improve the efficiency of the system.

Construction

The evaporator consists of two effects, each operating at different pressure. Each effect has cylindrical shape, placed vertically on the supporting scaffold.

Other

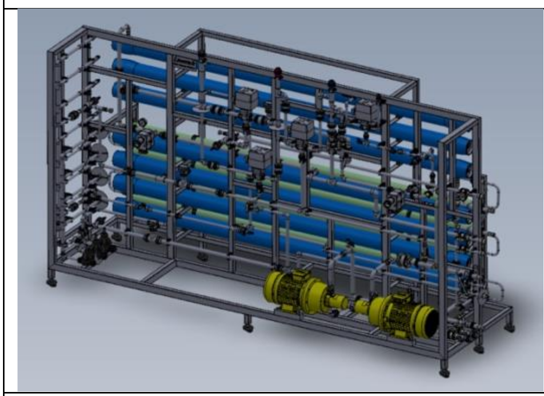
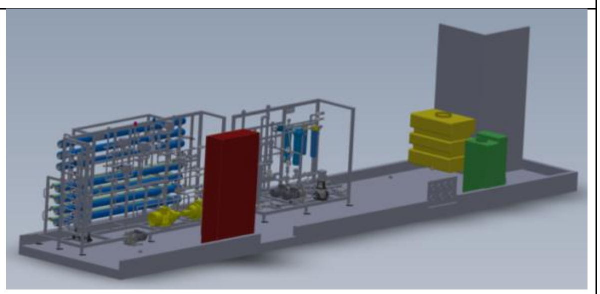
The pilot-scale evaporator can run either with the use of low-grade heat (~90 °C) or with electricity, since it is equipped with electrical heaters (3.7 kW). With reference to electric supply, it needs both single phase and three-phase (for the vacuum pump) power supply. Control of the system is performed via a PC-based SCADA interface.

Contact Person

Prof. Maria Loizidou (mloizidou@sealeau.com)

4.6. CS1/BC-3: High pressure nanofiltration (HPNF)

Table 4-9: Summary of HPNF demo system used in CS1 (code: CS1/BC-3)

<table>
<tr><td colspan="2">CS1 equipment: BC-2
Owner: Lenntech</td><td colspan="2">☐ Bench-scale system
☐ Pilot-scale System
☑ Large pilot/Demo System</td></tr>
<tr><td>Capacity
~1,700 L/h feed – 200L/h brine 18-20%</td><td>Operating pressure</td><td colspan="2">50-70 bars</td></tr>
<tr><td rowspan="2">Product streams
HPNF permeate: Purified stream, drinking water quality
NF concentrate:Concentrate stream rich in sodium chloride up to 20% concentration</td><td>Working temperature</td><td colspan="2">15°C to 40 °C</td></tr>
<tr><td>Power supply</td><td colspan="2">Main power supply: 3-phase, 400 V/50Hz</td></tr>
<tr><td rowspan="6">(under construction)</td><td>HPNF skid height</td><td colspan="2">Unknown at this stage</td></tr>
<tr><td>HPNF skid length</td><td colspan="2">Unknown at this stage</td></tr>
<tr><td>Power consumption</td><td colspan="2">Estimated 45 kW installed power</td></tr>
<tr><td>Construction / materials</td><td colspan="2">Low pressure parts in PVC
High pressure parts in SS316
Skid in SS304 (to be confirmed)</td></tr>
<tr><td>Container</td><td colspan="2">40ft HC container (12m x 2.35m x2.69 m)
(Length x Width x Height)
Thermal and acoustic insulation (50 mm EPS with aluminum 0.4 plates)</td></tr>
<tr><td></td><td colspan="2"></td></tr>
<tr><td colspan="4">Other
The pilot requires an electric power supply (3-phase, 400 V/50Hz,) and clean non-chlorinated water (demi water from RO plant). The pilot is fully automatic. The pilot should run at least 8 hours/day.</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="4">Safety
Detailed safety instructions will be provided in the IOM manual of the system</td></tr>
</table>

Contact Persons
Dionysia Diamantidou (dionysia@lenntech.com),
Loic AUBLE (loic@lenntech.com)

Table 4-10: Connections of High Pressure Naniflitration (Code: CS1/BC-3) to other process units

No	Size	Type	Description
1	DN25	Flange (Feed inlet)	From Container 1 (NF pilot)
2	DN25	Flange (Dechlorinated Water Inlet)	From RO permeate (Desalination Plant)
3	DN25	Flange (Brine Outlet)	Brine to further treatments
4	DN40	Flange (Cooling water inlet)	From well
5	DN32	Flange (Permeate and Drain Outlet)	To drain

4.7. CS1/BCr-1: Eutectic Freeze Crystallization (EFC)

Table 4-11: Summary of the EFC demo system used in CS1 (code: CS1/BCr-1)

CS1 equipment:	**BCr-1**	☐ Bench-scale system
Owner:	TUDELFT	☐ Pilot-scale System
		☑ Large pilot/Demo System

Capacity 100 – 200 l/h	**Operating pressure**	Atmospheric pressure
	Working temperature	-40 °C to 25 °C
	Applied voltage	N/A
	Inlet chemicals	N/A
	Outlet chemicals	N/A
	Refrigeration fluid	Silicone oil (Lauda: Kryo 51)
	Power supply	Cooling Machine: 3-phase, 400 V/50Hz
Main product Sodium sulfate (Na_2SO_4), Ice		Crystallizer: single phase (6 plugs), 230 V/50 Hz
		2xPre-cooler: single phase, 230 V/50 Hz
		Re-crystallizer: single phase, 230 V/50 Hz
By-products NaCl concentrate stream		Settler: single phase, 230 V/50 Hz
		2xBelt filer: 3-phase, 400 V/50Hz
		Compressor: single phase, 230 V/50 Hz

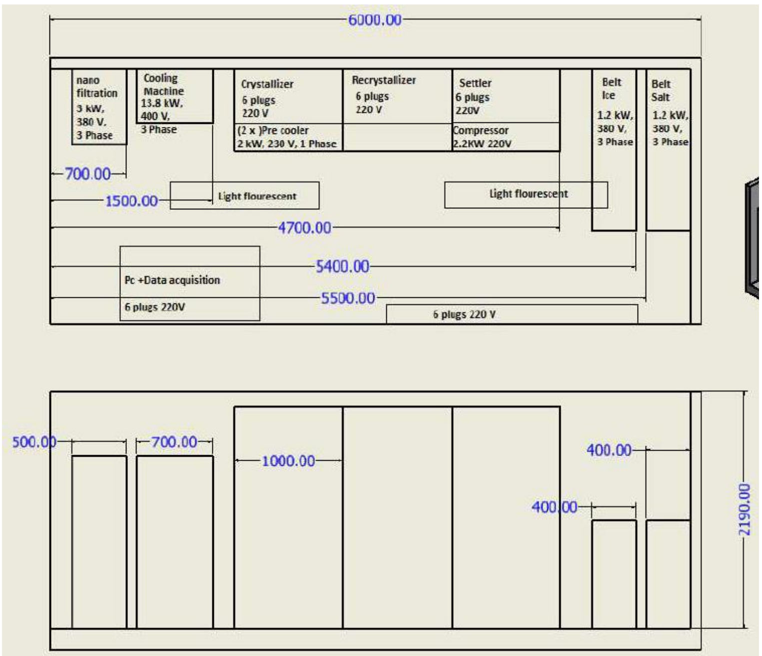
Frame height	2,050 mm (reactor)
Frame length	1,000 mm (reactor)
Power consumption	0.24 kW (Crystallizer: scraper & stirring motors) 0.12 kW (Re-crystallizer: stirring motor) 0.12 kW (Settler: stirring motor) 13.8 kW (Cooling machine) 2.2 kW (pre-coolers) 2.4 kW (Belt filters) 2.2 kW (compressor) Total: 21.08 kW (16.2 kW, 3-phase)
Construction / materials	Stainless steel (316) reactor mounted in aluminium frame. Separate cooling unit (Lauda) with secondary cooling fluid. Two pre-coolers, one re-crystallizer, two belt filters and one settler.
Container	20'' container (6m x 2.5m x2.5 m) (Length x Width x Height)

CS1 equipment:	**BCr-1**	☐ Bench-scale system
Owner:	TUDELFT	☐ Pilot-scale System
		☑ Large pilot/Demo System
		Thermal and acoustic insulation (foam) and wooden wall frame (for thermal insulation and fixing/mounting purposes).

Other

The pilot requires only an electric power supply (both single and 3-phase). No other utilities (such as chemicals, steam etc) are required. No need also for compressed air (built-in air compressor is provided). Set-up is not / cannot be automated. During daily operation (8 hours: 1hour for startup, 6hours operating, 1 hour for shutdown), the operator needs to be continuously working on the set-up.

3D Sketch



2D top view (top picture) and frontal view (bottom picture)

Safety

3 phase equipment. Possible salty solution leakages in case tubes or pumps break.

CS1 equipment:	**BCr-1**	☐ Bench-scale system
Owner:	TUDELFT	☐ Pilot-scale System
		☑ Large pilot/Demo System

Contact Persons
Dr. Dimitris Xevgenos (d.xevgenos@tudelft.nl),
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Table 4-12: Connections of the EFC (Code: CS1/BCr-1) with other process units

No	**Size**	**Type**	**Description**
1	DN20	PVC Reinforced Hose Pipe	From Container 2 to feed NF (pre-concentration step) tank (0.3m3/h)
2	DN40	PVC Reinforced Hose Pipe	To Container 4 to feed tank of EDBM (0.1m3/h)
3	DN20	PVC Reinforced Hose Pipe	to drain
4	DN20	PVC Reinforced Hose Pipe	From RO permeate (Desalination Plant) (0.3 m^3/h)
5	DN20	PVC Reinforced Hose Pipe	Water reservoir

4.8. CS1/BCr-2: Laser induced cavitation crystallization (LICC)

Table 4-13: Summary of the LICC pilot system used in CS1 (code: CS1/BCr-2)

<table>
<tr><td colspan="4">CS1 equipment: BCr-2
Owner: TUDELFT
☐ Bench-scale system
☑ Pilot-scale System
☐ Large pilot/Demo System</td></tr>
<tr><td rowspan="7">Capacity
100 – 200 l/h</td><td colspan="2">Operating pressure</td><td>0.5-0.8Mpa</td></tr>
<tr><td colspan="2">Working temperature</td><td>40 °C to 80 °C</td></tr>
<tr><td colspan="2">Applied voltage</td><td>N/A</td></tr>
<tr><td colspan="2">Inlet chemicals</td><td>N/A</td></tr>
<tr><td colspan="2">Outlet chemicals</td><td>N/A</td></tr>
<tr><td colspan="2" rowspan="9">Power supply</td><td>Steam generator: 3-phase, 400 V/50Hz</td></tr>
<tr><td>Feed pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td rowspan="3">Main products
NaCl</td><td>1-effect forced pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td>2-effect forced pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td>Discharge pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td rowspan="4">By products
N/A</td><td>Condensate pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td>Water ring vacuum pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td>Pulsed Laser 400W : single phase 230 V/50 Hz</td></tr>
<tr><td>Water pump: 3-phase, 400 V/50 Hz</td></tr>
<tr><td colspan="2" rowspan="4"></td><td>Frame height</td><td>2,050 mm (reactor)</td></tr>
<tr><td>Frame length</td><td>5,000 mm (reactor)</td></tr>
<tr><td>Power consumption</td><td>48 kW (Steam Generator)
0.37 kW (Feed pump)
1.5 kW (1-effect force pump)
1.5 kW (2-effect force pump)
2.2 kW (Discharge pump)
2.2 kW (Condensate pump)
2.35 kW (Water ring vacuum pump)
0.4 kW(Pulsed Laser)
1.5 kW(Water pump)
Total: 60.02 kW</td></tr>
<tr><td>Construction / materials</td><td>100L per hour double-effect forced circulation
crystallization evaporator, 316 material. Steam generator. Cold water tower. Feeding tank 100L, 316 material. 1st-effect separator, 316 material. 2nd-effect</td></tr>
</table>

CS1 equipment:	**BCr-2**	☐ Bench-scale system
Owner:	TUDELFT	☑ Pilot-scale System
		☐ Large pilot/Demo System

		heater, 316 material. 2nd-effect separator, 316 material. Condenser, condensate water tank, 304 material. Electric control cabinet
	Container	20’’ container (6m x 2.5m x2.5 m) (Length x Width x Height) Thermal and acoustic insulation (foam) and wooden wall frame (for thermal insulation and fixing/mounting purposes).

Other

The pilot requires only an electric power supply (both single and 3-phase). No other utilities (such as chemicals, steam etc) are required. No need also for compressed air . Set-up is automated although requires some supervision.

Safety

The Thermal Crystallizer operates under high pressure. Steam is created and can achieve high temperatures if not properly handle.

Contact Persons

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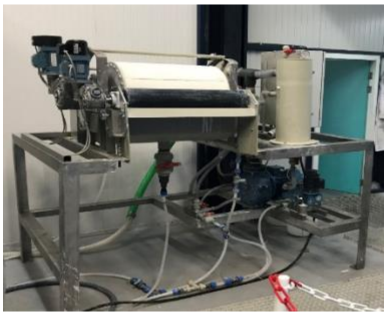
4.9. CS1/BCr-3: Multiple Feed Plug Flow Reactor (MF-PFR)

Table 4-14: Summary of the multiple feed plug flow reactor demo system used in CS1 (code: CS1/BCr-3)

CS1 equipment:	**BCr-3**	☐ Bench-scale system
Owner:	UNIPA	☐ Pilot-scale System
		☑ Large pilot/Demo System

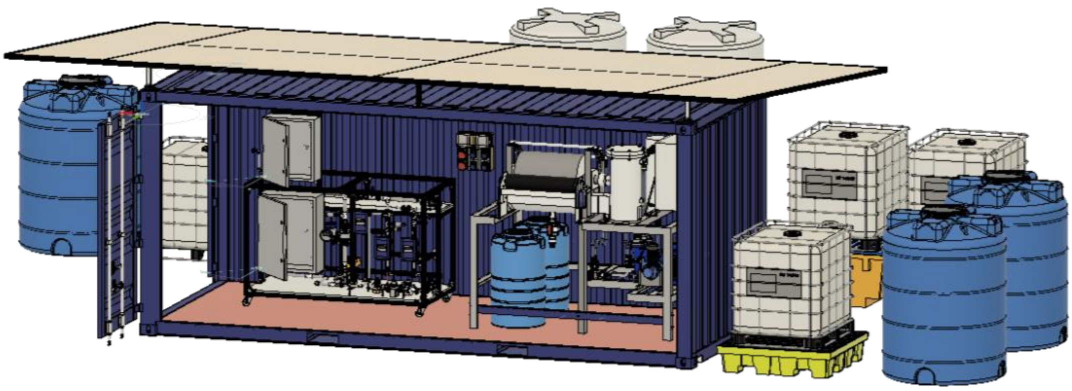
Capacity 150 l/h	**Operating pressure**	0.5-2 Bar(a)
	Working temperature	15°C to 40°C (ambient temperature)
	NaOH concentration	0.5-2 [mol/L], nominal [1 mol/L]
	Inlet chemicals	NaOH-water solution HCl- water solution
Main product Magnesium Hydroxide Calcium Hydroxide Brine without bivalent cations	**Outlet chemicals**	No chemicals produced, apart from the main products
	Refrigeration fluid	Cooling water for the vacuum pump (in the Drum Filter), about 0.5-1.5 m^3/h or (Max)30 kW_{th}
	Power supply **3-phases (400V) power** **Peak current 63A** **Max Power ~ 20kW** **Nominal Power (total) ~ 10 kW** **Further details for each single unit --->**	2xGear Pump: 24 VDC 4x Centrifugal pump: Mono phase, 230 VAC/50 Hz 4xMembrane pump: 12 VDC
By-products not applicable		Drum Filter: 3-Phase/50Hz
		Air conditioner: single phase, 230 V/50 Hz
		Fan: single phase, 230 V/50 Hz
		2x 24 VDC Power suppliers (data acquisition & control), 230 V/50Hz
		24 VDC Power supply (Gear Pumps and fluxmeters and conductivity meter), 230 V/50Hz
		4X 12VDC Power Suppliers (Membrane Valves), 230 VAC/50Hz
 Frame 1 – MF-PFR	**Frame 1 height**	2,070 mm (MF-PFR)
	Frame 1 length	2,000 mm (MF-PFR)
	Frame 1 width	1,000 mm (MF-PFR)
	Frame 2 height	2,000 mm (DRUM-FILTER)
	Frame 2 length	2,200 mm (DRUM-FILTER)
	Frame 2 width	1,500 mm (DRUM-FILTER)

<table>
<tr><td>CS1 equipment:</td><td>BCr-3</td><td>☐ Bench-scale system</td></tr>
<tr><td>Owner:</td><td>UNIPA</td><td>☐ Pilot-scale System</td></tr>
<tr><td></td><td></td><td>☑ Large pilot/Demo System</td></tr>
</table>

<table>
<tr><td rowspan="3">
Frame 2 - Drum Filter</td><td>Power consumption</td><td>2.3 (Pump motors)
1.4 kW (Air conditioner)
7 kW (Drum Filter)
Total: 10.7 kW, 3-phase, 400 Vac/50Hz</td></tr>
<tr><td>Construction / materials</td><td>The aluminium frame is composed of a crystallizer (a tube in which precipitation occurs) and all necessary auxiliaries, including two gear pumps (Teorema), one centrifugal pump (Schmitt), all necessary sensors (Krohne), and data acquisition systems (National Instrument).</td></tr>
<tr><td>Container</td><td>20’’ container (6.1m x 2.5m x2.6 m)
(Length x Width x Height)</td></tr>
</table>

Other

The pilot requires single- and 3- phase electric power supplies. No need for compressed air. Although the system can be automated, the presence of an operator is required for the opening and closing of the manual valves at the beginning and end of the test and for sampling operations.



3D Sketch

Safety

- Manual ball valves closed or not functioning may cause bursts on the pipe (if the valve is closed), damage to the pumps;
- Flow rate transmitter not working/out of service may cause overpressures, pumps shutdown;
- Level switches not properly working may cause overflow of chemical solution/brine from tanks, damage to pumps,
- Missing cooling water into the vacuum pump causing damage/failure of vacuum pump;

Contact Persons

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Prof. Andrea Cipollina (andrea.cipollina@unipa.it),
Prof. Giorgio Micale (giorgiod.maria.micale@unipa.it).

Table 4-15: Connections of the MF-PFR (Code: CS1/BCr-3) with other process units

No	Size	Type	Description
4	DN20	PVC Reinforced Hose Pipe	From container 3 EFC effluent tank to container 4 feed tank of EDBM (0.1m3/h)
12d(1)	DN20	PVC Reinforced Hose Pipe	From container 4 to drain
12d(2)	DN20	PVC Reinforced Hose Pipe	From container 4 to drain
7b	DN20	PVC Reinforced Hose Pipe	From container 4 saline solution tank to feed tank MED or container 5 (0.2m3/h)
5a	DN20	PVC Reinforced Hose Pipe	From container 4 acid tank outlet to container 2 acid storage tank or SWRO civil plant (0.2 m3/h)
6a	DN20	PVC Reinforced Hose Pipe	From container 4 base tank outlet container to container 2 base storage tank or SWRO civil plant (0.2m3/h)
11d	DN20	PVC Reinforced Hose Pipe	From RO permeate (SWRO civil plant) to container 4 (max 4m3/day)
22(1)	DN20	PVC Reinforced Hose Pipe	From container 4 to neutralization tank
22(2)	DN20	PVC Reinforced Hose Pipe	From container 4 to neutralization tank

5. Demo system used in CS2

5.1. CS2/BP-1: Nanofiltration-3

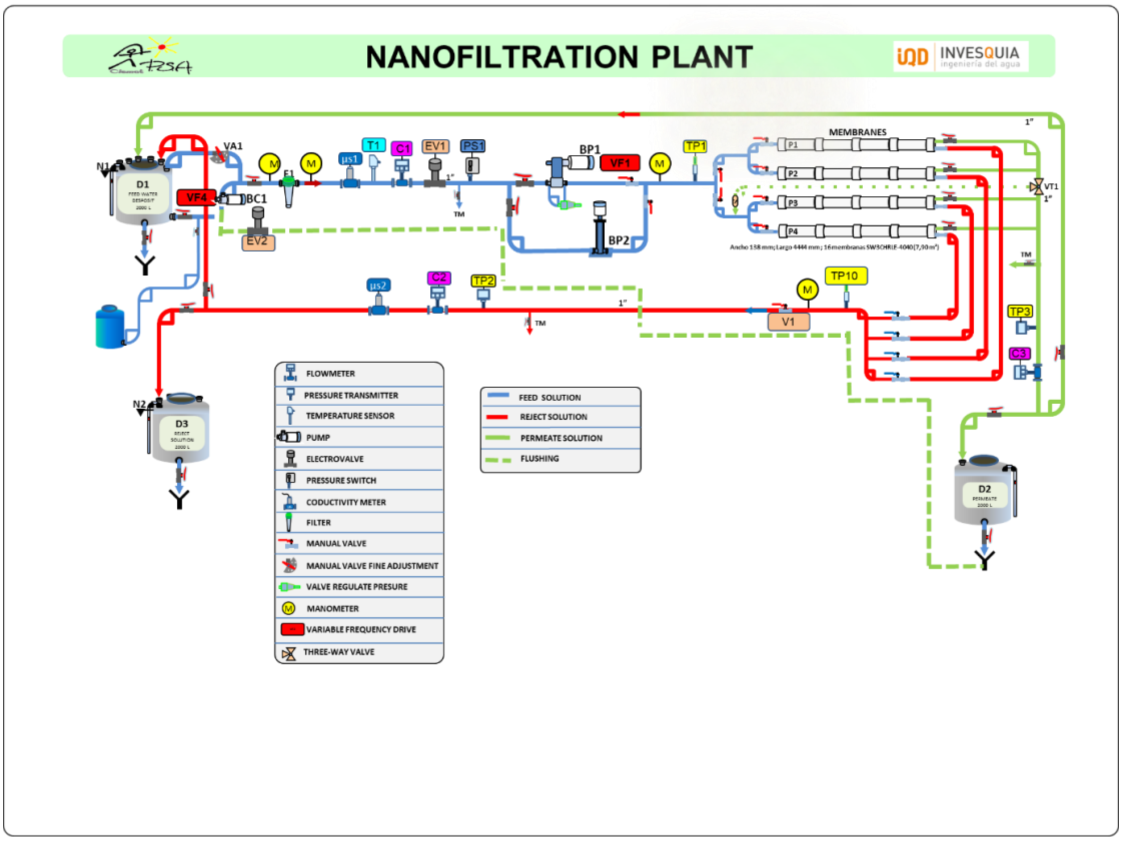
Table 5-1: Summary of nanofiltration demo system used in CS2 (code: CS2/BP-1)

CS2 equipment:	**BP-1**	☐ Bench-scale system
Owner:	CIEMAT-PSA	☐ Pilot-scale System
		☑ Large pilot/Demo System

Capacity 3 m³/h	**Operating pressure**	4-13 bar (the limit value is 14 bar)
	Working temperature	Ambient
	Applied voltage	N/A
	Inlet chemicals	N/A
	Outlet chemicals	N/A
	Refrigeration fluid	N/A
	Power supply	3 phase, 400 V/50 Hz
	Number of pressure vessels	4
Main product Permeate	**Membrane size**	4”
By-products Brine reject	**Maximum number of membranes in vessel**	4
	**Power consumption**	0.50 kW (BC1 pump) 3 kW (BP1 pump)
	Construction / materials	Stainless steel and PVC pipes, composite vessels.

Other
The pilot requires only an electric power supply (3-phase). No other utilities (such as chemicals, steam etc) are required. No need also for compressed air (built-in air compressor is provided). Set-up is not / cannot be automated. During daily operation (5 hours: 30 min for initial flushing, 5 hours operating, 30 min for final flushing), the operator needs to be continuously working on the pilot plant. The desposits have only visual levels (no level sensors)

CS2 equipment:	**BP-1**	☐ Bench-scale system
Owner:	CIEMAT-PSA	☐ Pilot-scale System
		☑ Large pilot/Demo System



Layout Nanofiltration plant

Safety

The pressure difference in the membrane (difference between the feed water inlet pressure and the reject solution pressure) should not be higher than 2.1 bar because of possible deformation in the porous of the membranes.

Contact Persons

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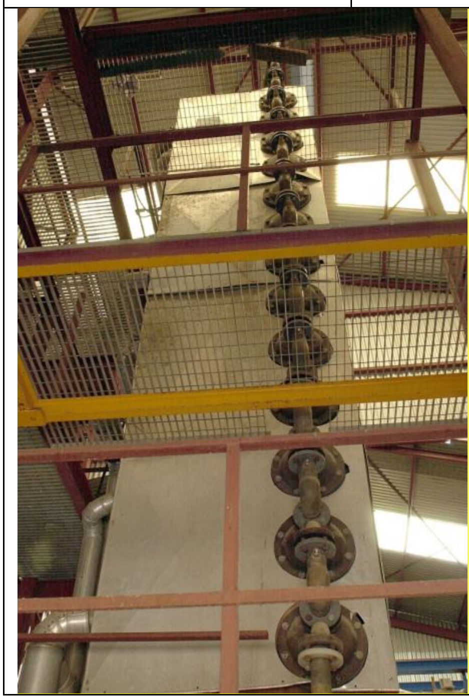
Table 5-2: Sensors and components of nanofiltration demo used in CS2

Label	Description
D1	Feed water desposit, 2000 L
D2	Permeate deposit, 2000 L
D3	Reject solution desposit, 2000 L
BC1	Centrifugal pump, Lowara 3HM06S05T 3 bar/1400 L/h, 0.5 kW
BP2	Low Pressure Pump, LOWARA SV F 3SV31F030T/D, 3 KW, maximum flow rate 30 m3/h, operating pressure 16-25 bar
F1	Filter, Centripur, 5 microns, Model NW25
$\mu S1-2$	Conductivity meter, Prominent, precision 0.5% of the measured limit value
C1-C3	Flow meter burket, measurement with conductivity over 20 µS/cm and less than 20 mS/cm, with range of error ± 0,5%.
EV1	Electrovalve, RSG, 24V AC, 0.3-6 bar.
EV2	Electrovalve, J4C Model S20, 24-240 V AC, -20-70 ºC
PS1	Pressure switch, Danfoss, range 0.5-1.6 bar, Error ± 0.1 bar.
T1	Temperature sensor, IFM error ± 2 ºC.
TP1-10	Pressure transmitter, Burket, range 0 bar - 100 bar (TP1) and 0 bar - 20 bar (TP2, TP3 y TP10).
M	Manometer, Error ± 0.2 bar.
P1-4	Membranes, FilmTecTM NF270 (P1, P2, P3 y P4) with maximum rejection of 97% (brackish water), and a maximum limit pressure up to 15 bar.

5.2. CS2/BC-1: Multiple Effect Distillation unit (MED-3)

Table 5-3: Summary of the MED demo system used in CS2 (code: CS2/BC-1)

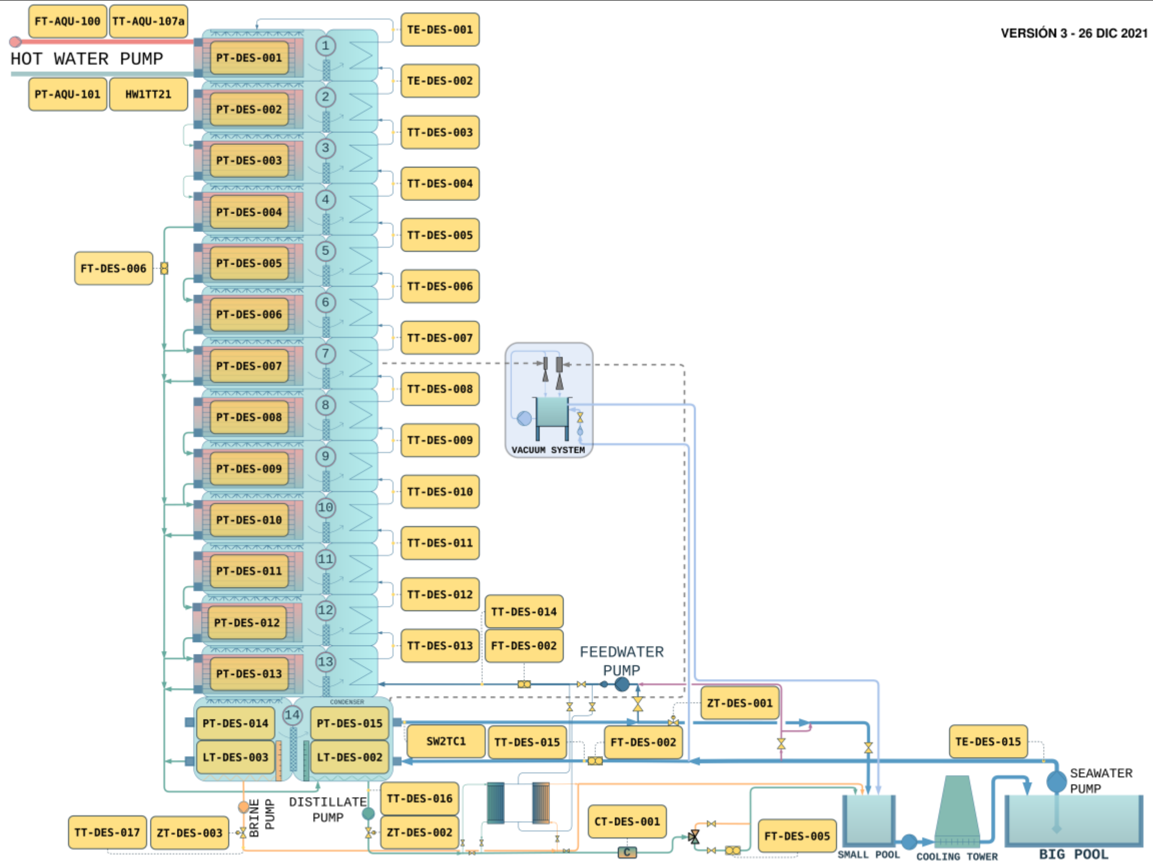
CS2 equipment: **BC-1** Owner: CIEMAT-PSA		☐ Bench-scale system ☐ Pilot-scale System ☑ Large pilot/Demo System
Capacity 72 m³/day	**Feedwater flow**	8 m³/h
	Brine reject	5 m³/h
	Distillate production	3 m³/h
	Seawater flow at condenser: **@ 10 °C** **@ 25 °C**	 8 m³/h 20 m³/h
	Product output salinity	< 50 ppm TDS
	Number of stages	14 effects (13 preheaters + end condenser)
	Feedwater configuration	Forward-feed vertical stack
	Vaccuum system	Hydroejectors (seawater @3 bar)
Main product Distillate	**Top brine temperature**	70 °C (312 mbar abs)
By-products Brine reject	**Condenser temperature**	35 °C (56 mbar abs)
	**Frame height**	7.5 m
	Frame depth	2.4 m
	Frame width	1 m
	Thermal power consumption	200 kW (Performance ratio = 9.6) Working fluid: hot water Inlet/outlet hot water: 75/71 °C Hot water flow rate: 12 kg/s
	Power consumption	1.5 kW (Distillate pump) 1.5 kW (Brine pump) 2.2 kW (Feedwater pump) 5.5 kW (Hydroejector pump) 0.1 kW (Antiscalant dosage pump) 5 kW (Feedwater pool to MED pump) 3 kW (Distillate+Brine+Cooling rejection pool to cooling tower pump)

CS2 equipment:	**BC-1**	☐ Bench-scale system
Owner:	CIEMAT-PSA	☐ Pilot-scale System
		☑ Large pilot/Demo System

Other

The MED plant is composed by 14 cells or effects at successively decreasing temperatures and pressures from effect(1) to effect(14). The seawater is preheated from stage to stage in the 13 preheaters. From effect(1), the seawater passes on from one stage to another by gravity before being extracted from effect(14) by the brine pump. Part of the seawater used to cool the condenser is rejected and the rest is used for the feedwater required to spray the effect(1) tube bundle. The first effect is powered by hot water coming from a static flat plate solar field (606 m^2) with a 40-m^3 thermal storage system (2-tanks)

Water in Cell(1) is evaporated at 70°C/ 0.31 bar. The vapor produced in Cell(14) at 35°C/0.05 bar is condensed in a final condenser cooled by seawater. The product water is then extracted from the condenser by means of the distilled water pump.



Layout Multi-Effect Distillation plant

Safety

Three-phase equipment

Contact Persons

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Table 5-4: Sensors and components of the MED demo used in CS2

Label	Description
FT-AQU-100	Inlet hot water flow from solar field
TT-AQU-107a	Inlet hot water temperature from solar field
HW1TT21	Outlet hot water temperature
PT-AQU-101	Outlet hot water pressure
PT-DES-0XX	Absolute pressure inside effect XX
TT-DES-0XX TE-DES-0XX	Outlet temperature from preheater XXd
LT-DES-003	Brine level inside last effect
LT-DES-002	Distillate level inside final condenser
SWTC1	Final condensder outlet temperature
TT-DES-015	Final condenser inlet temperature
FT-DES-002	Cooling water flow in at final condenser
TT-DES-017	Brine temperature
TT-DES-016	Distillate temperature
TE-DES-015	Raw seawater temperature
FT-DES-005	Distillate flow
CT-DES-001	Distillate conductivity

6. Concluding remarks

6.1. Overview of the demo system components

The process units applied for brine processing have been grouped in the following three (3) categories:

- Brine Purification (BP)
- Brine Concentration (BC)
- Brine CRystallization (BCr)

Following this coding, we have reported the different characteristics of the system components by case study. An overview of all the system components is provided in Table 6-1.

6.2. Installation, start-up and next steps

The components from both demo systems, as described in Sections 4 and 5 (see also table below) have been successfully commissioned at the premises of the individual technology suppliers.

With reference to the installation of the demo systems, the complete demo has been successfully installed for Case Study 2 in Almeria, Spain on 19 January 2022. For Case Study 1 it is expected that the full demo will be installed at the site of SELIS in Lampedusa island in the first two weeks of March 2022.

With the complete demo systems installed at the sites for both case studies, Task 3.3 entitled “Operation and optimization of the large-scale demonstration plants” can start on time, that is in March 2022 (M19), running until March 2024 (M42).

Table 6-1: Overview of the demo systems used in CS1 & CS2, and their main componets/process units

Technology Groups	Code	Modules	Owner	Description
Brine purification / Ion Separation	**CS1/BP-1**	Nanofiltration – 1	LENNTECH	Table 4-1
	CS1/BP-2	Nanofiltration - 2	TUDELFT	Table 4-3
	CS1/BP-3	Electrodialysis (EDB – EDBP)	UNIPA	Table 4-4
	CS2/BP-1	Nanofiltration - 3	CIEMAT-PSA	Table 5-1
Brine Concentration	**CS1/BC-1**	Forward-feed MED evaporator	THERMOSSOL / SOFINTER	Table 4-6
	CS1/BC-2	Forward-feed MED evaporator 2	NTUA/SEALEAU	Table 4-8
	CS1/BC-3	High Pressure Nanofiltration	LENNTECH	Table 4-9
	CS2/BC-1	Forward-feed MED evaporator 3	CIEMAT-PSA	Table 5-3
Brine Crystallization	**CS1/BCr-1**	Eutectic Freeze Crystallization (EFC)	TU DELFT	Table 4-11
	CS1/BCr-2	Laser induced cavitation crysatllization	TUDELFT	Table 4-13
	CS1/BCr-3	Multiple Feed Pulg Flow Reactor	UNIPA	Table 4-14

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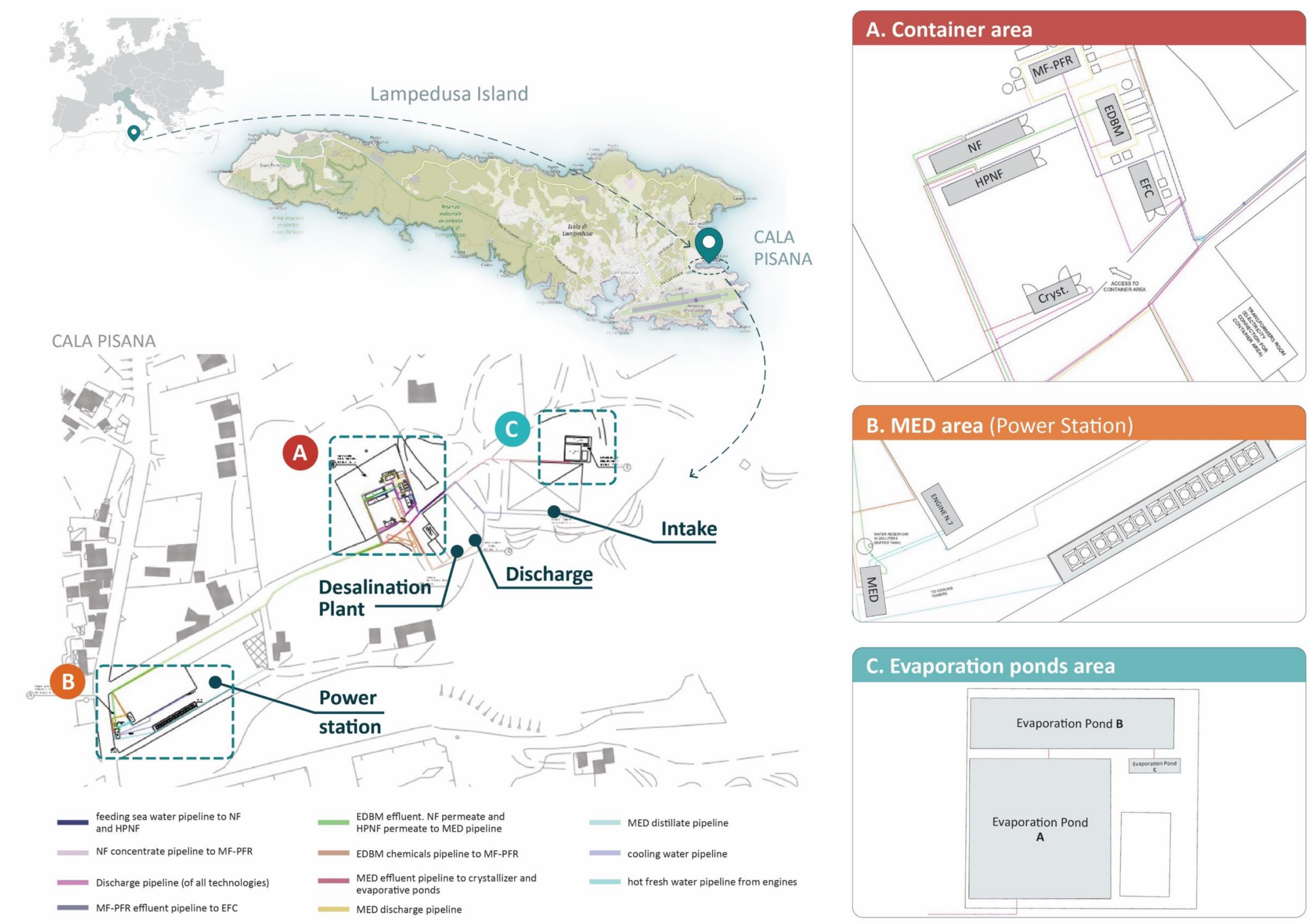

Visual graphic design by SEALEAU

Figure 6-1: Installation site of Case Study 1 demonstration at the premises of SELIS power station, Lampdedusa Island, Italy

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Visual graphic design by SEALEAU

Figure 6-2: Installation site of Case Study 2 demonstration at the premises of CIEMAT, Almeria, Spain

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