White paper
Two-stage freshwater generation

Securing freshwater generation amid competing and increasing demands

Why vessel specifications should allow for two-stage freshwater generators

"We have set ambitious targets for the entire A.P. Moller - Maersk business to achieve net zero emissions in 2040. As we lead the way in decarbonizing global logistics, we seek the most efficient technologies for all onboard processes. This also includes generating fresh water in the most efficient way."

Benny Hilstrom
Head of Machinery, Fleet Technology Department, A.P. Moller - Maersk

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Introduction

As the maritime industry deepens its commitment to sustainability and adapts to evolving environmental requirements through measures such as EEDI, EEXI and CII, shipowners are increasingly turning to strategies like slow steaming and waste heat recovery. Likewise, they are adopting additional technologies that utilize waste heat to meet decarbonization goals. Making use of waste heat is a sustainable approach that can support a wide range of onboard processes, including freshwater generation.

As new systems such as Organic Rankine Cycle (ORC) units are introduced, and as the number of chillers and HVAC systems also increases on board, competition for the available waste heat is growing. Factoring in the lower engine loads that are typical of slow steaming, this makes it more important than ever to use waste heat as efficiently as possible. For vessels with smaller main engines, which generate less waste heat overall, there is a further layer of complexity – making smart utilization and efficient recovery of waste heat even more critical.

By designing to use waste heat economically, vessels can maximize its value and ensure it continues to support essential functions like freshwater generation – even under changing operational conditions. To keep the supply of fresh water reliable, vessels need technology that is not only resource efficient but also adaptable to varying availability of thermal energy. In light of shifting operating profiles, contesting demands for waste heat and the uncertainty of future demands for fresh water, it is essential to prioritize flexibility in vessel specifications.

Flexibility can be achieved by specifying the possibility of two-stage freshwater generators. In scenarios with limited waste heat or increasing demand for fresh water, or where shipowners have ambitious targets for energy efficiency, two-stage freshwater generators provide a future-proof and cost-effective solution. This white paper will exemplify the benefits using the Alfa Laval AQUA Blue E2, a two-stage freshwater generator whose unique plate technology enables additional savings.

Plate-based freshwater generators and their evolution

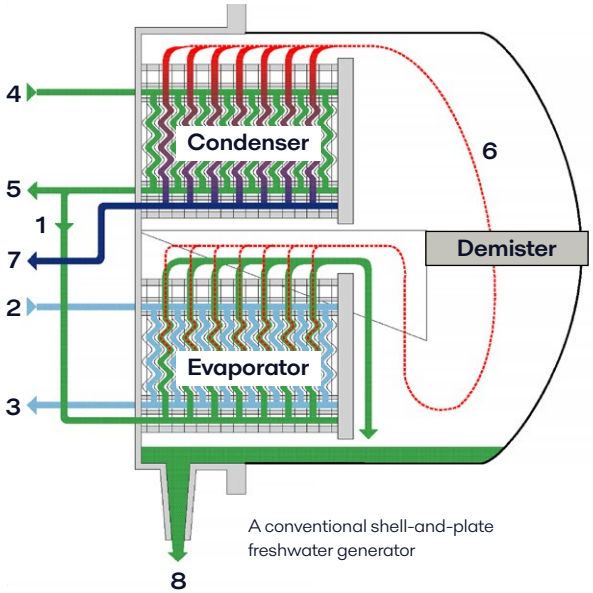
Vacuum distillation using plate-based freshwater generators is the standard for producing fresh water on today's marine vessels. Many freshwater generators still use shell-and-plate designs, which took over from earlier shell-and-tube models due to their smaller size and significantly greater heat transfer efficiency. Such conventional freshwater generators have individual plate packs for evaporation and condensation, which are divided by a demister to separate brine from the rising vapour. These are surrounded by an outer shell that contains the process vacuum.

In 2008, Alfa Laval introduced a further development of the vacuum distillation concept: AQUA plate technology, which is used in the Alfa Laval AQUA Blue family of freshwater generators. AQUA plates have a 3-in-1 design, which enables evaporation, separation and condensation within a single plate pack. The process vacuum is contained in the plate pack itself, which is suspended in a frame and sealed with gaskets.

Besides making the freshwater generator even more compact, AQUA plate technology cuts seawater flow needs in half compared to conventional freshwater generators. This means only half the energy is needed for pumping, which is a major contributor to overall power consumption in fresh-water generation. These revolutionary benefits gain added significance during two-stage freshwater generation, as will be discussed later in this paper.

Key benefits of 3-in-1 AQUA plate technology

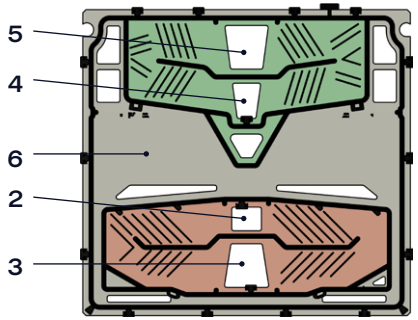
- Half the seawater flow and pumping needs
- Lower energy consumption and related emissions
- Reliable production of high-quality fresh water (salinity <2 ppm)
- Non-glued gaskets for DIY maintenance

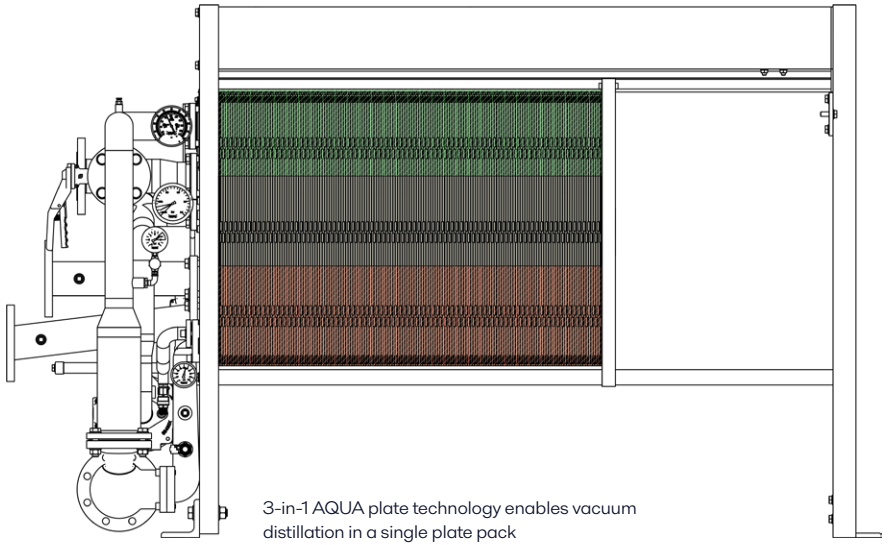


A conventional shell-and-plate freshwater generator

1 Seawater feed
2 Heating medium in
3 Heating medium out
4 Seawater cooling in
5 Seawater cooling out
6 Evaporated steam
7 Fresh water out
8 Brine out

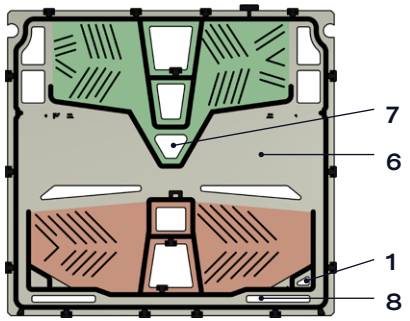
Utility plate





3-in-1 AQUA plate technology enables vacuum distillation in a single plate pack

Process plate



Green Condensation
Grey Separation
Red Evaporation

Future-proofing freshwater generation with two stages

The majority of today's freshwater generators are single-stage models, which is why single-stage freshwater generation is assumed in most vessel specifications. But there is good reason to include the possibility of two-stage freshwater generation. In a two-stage freshwater generator, where the vacuum distillation occurs twice, output heat from the first stage becomes input heat for the second stage. This conserves energy within the system, meaning less waste heat is needed to drive the process.

The two-stage principle is useful as regulations, operating conditions and demands continue to evolve. In a fast-changing operating environment, it is difficult to predict the specific challenges that vessels may face over their lifetime. Two-stage freshwater generators, with their greater efficiency, are a future-ready alternative with long-term flexibility. They can maint capacity when waste heat is limited or variable – or provide additional capacity to meet increasing demands for fresh water.

In the following chapters, these scenarios will be exemplified using the Alfa Laval AQUA Blue E2. The two-stage AQUA Blue E2, which is the latest addition to the AQUA Blue family, will be compared to the single-stage AQUA Blue E1. Comparisons between the AQUA Blue E2 and conventional two-stage freshwater generators will be made in a final chapter on page 8, focusing on the major differences in size and energy consumption.

Key data for all AQUA Blue E1 and AQUA Blue E2 models (both C-type and S-type configurations) is provided below.

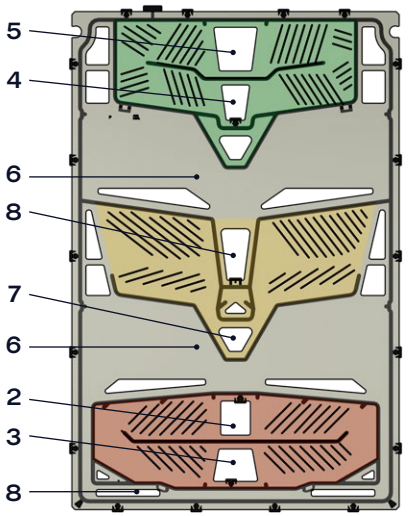
Comparison between AQUA Blue E1 and AQUA Blue E2 models for 25 t and 60 t capacities

Freshwater generator type	AQUA Blue E1 C80-HW-FS	AQUA Blue E1 S80-HW-FS	AQUA Blue E2 C80-HW-FS
Stages	1	1	2
Capacity, 24 h (m^3)	25	25	25
Heat consumption (kW)	730	730	415
Electrical power consumption: ejector pump, freshwater pump and E2 brine pump (kW)	4.9	4.5	5.5
CO_2 emissions per m^3 (kg)	3.53	3.24	3.96
Footprint (m^2)	1.53	1.35	1.35
Weight in operation (kg)	940	884	1358

Freshwater generator type	AQUA Blue E1 C125-HW-FS	AQUA Blue E1 S125-HW-FS	AQUA Blue E2 C100-HW-FS	AQUA Blue E2 S100-HW-FS
Stages	1	1	2	2
Capacity, 24 h (m^3)	60	60	60	60
Heat consumption (kW)	1750	1750	970	970
Electrical power consumption: ejector pump, freshwater pump and E2 brine pump (kW)	11.3	8.6	10.8	3.5
CO_2 emissions per m^3 (kg)	3.39	2.58	3.24	1.05
Footprint (m^2)	2.10	1.94	1.76	2.95
Weight in operation (kg)	1282	1158	1509	1897

3-in-1 AQUA plate technology as applied in the two-stage Alfa Laval AQUA Blue E2

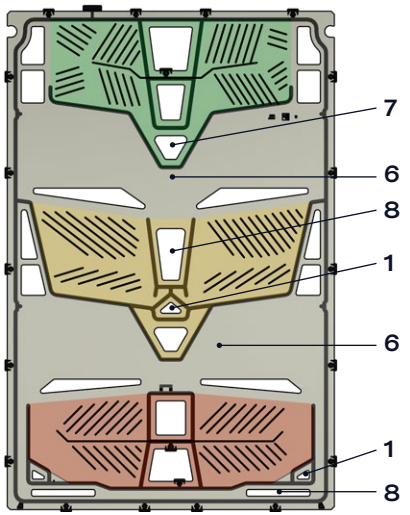
Utility plate



Green Cooling
Yellow Condensation
Red Heating
Grey Separation

1 Seawater feed
2 Heating medium in
3 Heating medium out
4 Seawater cooling in

Process plate



Green Condensation
Yellow Evaporation
Red Evaporation
Grey Separation

5 Seawater cooling out
6 Evaporated steam
7 Distillate out
8 Brine out

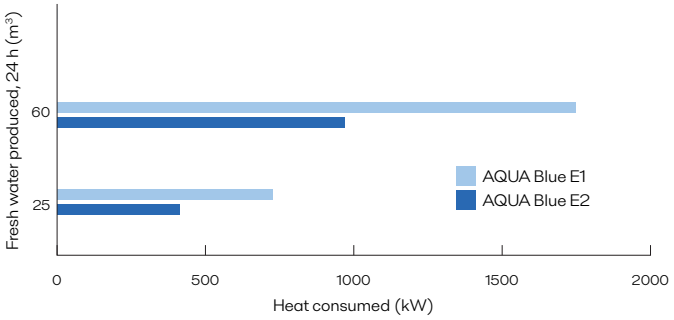
When waste heat is limited: ensuring reliable freshwater generation

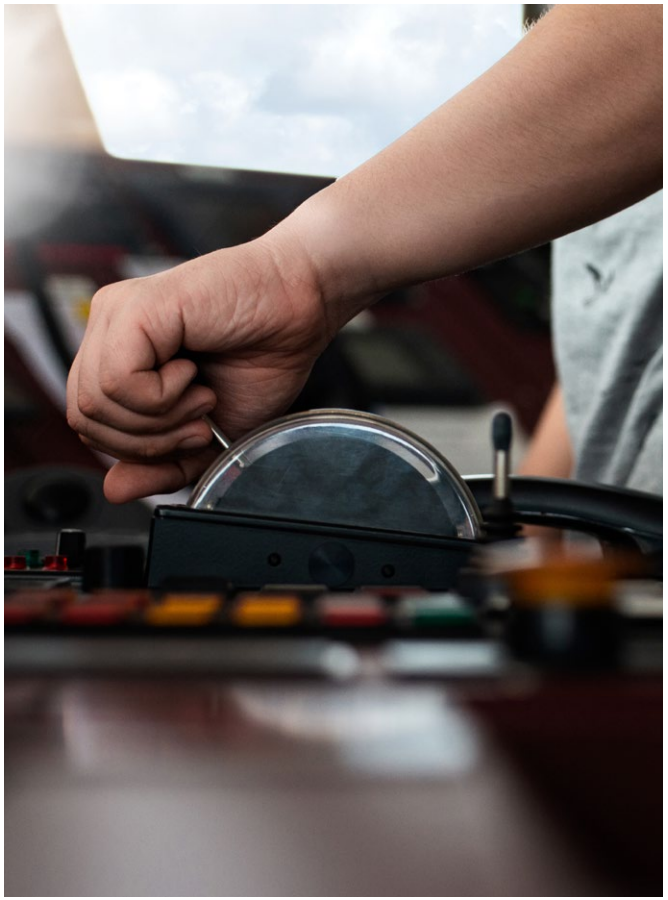
Waste heat continues to be one of the most valuable energy sources on board. Yet with more vessel systems – from chillers and HVAC to power-producing ORC units – relying on it to support sustainable operations, it has become important to use it efficiently, in order to achieve the greatest possible benefit in all areas. This is especially challenging when combined with efficiency measures like slow steaming, which reduces the amount of waste heat generated, or with the naturally lower heat output from smaller main engines.

Overall, the push for sustainability has created a more complex thermal landscape for today's vessels. In this context, two-stage freshwater generators play a valuable role, as they recapture and reuse thermal energy within the system to maximize the output of fresh water. By using the heat transferred in the first stage as the heating medium in the second, two-stage systems can maintain production with significantly less waste heat input. This makes them well suited for vessels where waste heat is limited or variable.

The AQUA Blue E2 takes the two-stage concept further, combining it with the higher efficiency of Alfa Laval's AQUA plate technology. As well as leaving more waste heat for potential power generation with ORC, freshwater generation with the AQUA Blue E2 requires up to 80% less electrical power (depending on configuration) than a conventional two-stage freshwater generator. This will be explored in detail on page 8.

Waste heat consumption, single-stage vs two-stage freshwater generation





Wider reasons to conserve waste heat

When assessing freshwater generation, it is important to consider the vessel's entire energy ecosystem. While feeding water to other systems, a freshwater generator draws from the same finite pool of thermal and electrical energy on board. Choosing a two-stage freshwater generator allows optimization – or, in some cases, elimination – of additional heating systems, depending on the operating scenario.

When additional heat is needed to maintain the production of fresh water, it can be provided by a hot water loop module, which circulates steam-heated water to the freshwater generator. If fresh water is required while the main engine is not in operation, either a hot water loop or a steam injection arrangement can be used, receiving steam from an auxiliary boiler. These configurations are the usual setup for securing continuous, maximized production of fresh water when operating a single-stage freshwater generator.

In scenarios when the main engine is not running, when steam must be used to drive freshwater generation, a two-stage freshwater generator offers clear advantages over a single-stage solution. By using thermal energy more economically, it consumes nearly 50% less steam, which results in significant fuel savings from the fired auxiliary boiler. This means lower emissions, reduced operating costs and a faster return on investment.

In other scenarios, a two-stage freshwater generator can operate on waste heat alone, even where a single-stage freshwater generator would require a hot water loop for the same capacity. Removing the need for a hot water loop reduces the number of onboard components, along with system weight and space needs overall. In turn, these factors simplify installation and reduce the associated costs. Finally, with no need for a pump to drive the hot water loop, there is no electrical power consumed for its operation – further contributing to energy efficiency.

Example 1:
Savings achieved with a two-stage freshwater generator compared to a single-stage freshwater generator by making more efficient use of the hot water loop

- Payback time: 41 days
- Boiler fuel cost savings (yearly, 5000 h): USD 211,312
- CO_2 emissions reduction (yearly, 5000 h): 1104 t

AQUA Blue	E1	E2
Capacity, 24 h (m^3)	60	60
Example CAPEX (proportional) for unit, HWL and HWL installation	1	1.34
Required heat (kW)	1733	969
Available heat (kW)	0	0
Heat deficiency (kW)	1733	969
Required steam (kg/h)	2667	1454
Required fuel, 24 h (kg)	3885	2118
Boiler fuel cost, 24 h (USD)	2230	1216
Boiler fuel cost, 5000 h (USD)	464,609	253,296
CO_2 emissions, 5000 h (t)	2428	1324

Example 2:
Savings achieved with a two-stage freshwater generator and no hot water loop compared to a single-stage freshwater generator with hot water loop

- Payback time: 7 days
- Boiler fuel cost savings (yearly, 5000 h): USD 196,514
- CO_2 emissions reduction (yearly, 5000 h): 1027 t

AQUA Blue	E1	E2
Capacity, 24 h (m^3)	60	60
Example CAPEX (proportional) for unit, HWL* and HWL installation*	1	1.06
Required heat (kW)	1733	969
Available heat (kW)	1000	1000
Heat deficiency (kW)	733	0
Required steam (kg/h)	1128	0
Required fuel, 24 h (kg)	1643	0
Boiler fuel cost, 24 h (USD)	943	0
Boiler fuel cost, 5000 h (USD)	196,514	0
CO_2 emissions, 5000 h (t)	1027	0

* Only for the AQUA Blue E1

In both examples above, the steam savings alone ensure rapid payback on the two-stage freshwater generator, despite the higher initial investment in a two-stage solution. The exact time to payback depends on the system capacity and the operating scenario.

When the demand for fresh water is high: efficiently safeguarding capacity

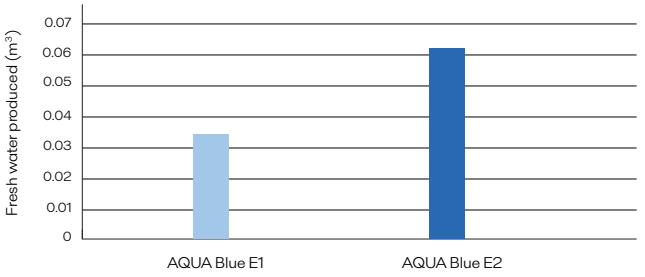
Specifying a two-stage freshwater generator is not only about preparing for energy challenges, present or future. There are also capacity benefits that are immediate and tangible.

The demand for fresh water can vary significantly depending on the type of vessel and the operations it pursues. For example, chemical tankers often require large volumes of fresh water for tank cleaning between cargoes. For any vessel with a high consumption of fresh water today, or with uncertainty as to how onboard needs for fresh water may evolve, a solution that increases both production capacity and operational flexibility is valuable.

Two-stage freshwater generators are ideal in this regard. By using thermal energy more economically, they can produce nearly twice as much fresh water as a single-stage system using the same amount of waste heat. This makes them well suited for vessels that need higher capacity or that want to have capacity in reserve.

One two-stage freshwater generator can replace two single-stage freshwater generators, effectively halving the total system footprint. In the case of the AQUA Blue E2, the already smaller footprint can be reduced by a further 45% (depending on configuration) compared to a conventional two-stage model. This will be explored in detail on page 8.

Output per kW of waste heat, single-stage vs two-stage freshwater generation



Additional two-stage benefits with AQUA plate technology

Including the possibility of two-stage freshwater generation in vessel specifications has a major impact in itself. Additional opportunities – and substantially greater benefits – are possible by choosing the AQUA E2 over a conventional two-stage freshwater generator.

Some of these benefits are a result of the underlying 3-in-1 AQUA plate technology. Because evaporation, separation and condensation all occur within a single plate pack, the AQUA Blue E2 requires just half the seawater flow needed by a conventional model, which reduces energy needs tied to pumping.

Other benefits are tied to the choice of AQUA Blue E2 configuration. A C-type configuration offers major space savings over conventional models, while an S-type configuration amplifies the energy savings.

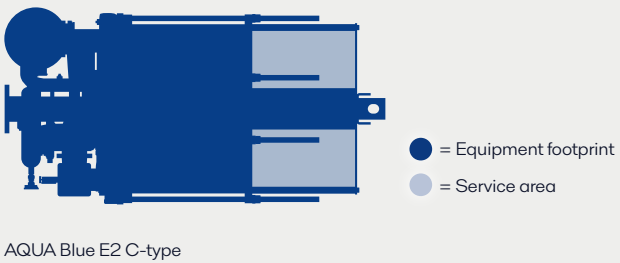
Saving additional space and weight

Selecting a two-stage freshwater generator cuts size in half compared to a single-stage freshwater generator. One unit can do the job of two, even when using conventional plate technology.

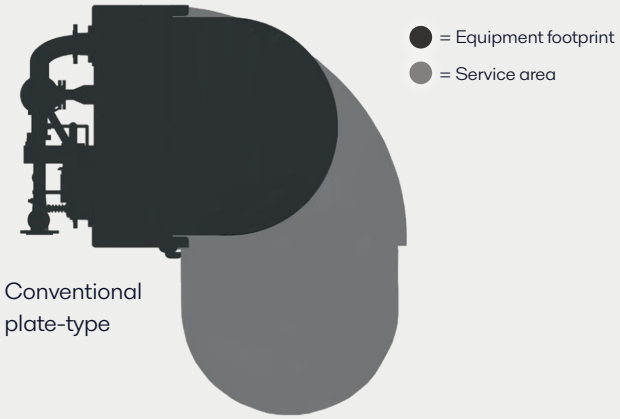
With the AQUA Blue E2, larger savings are possible. Both configurations remove a significant amount of weight compared to a conventional two-stage freshwater generator: nearly 60% for the C-type and just under 30% for the S-type at a capacity of 60 m^3 per day. Choosing a C-type configuration reduces footprint as well, shrinking it by a further 45% compared to a conventional model.

A further aspect to consider is that of service area. A conventional freshwater generator requires additional space for the opening of its shell, whereas the plate pack of AQUA Blue E2 slides open within the unit's frame. No additional service area is required for maintenance, which simplifies installation – especially in retrofit projects where space is at a premium.

Freshwater generator footprint and service area compaison



AQUA Blue E2 C-type



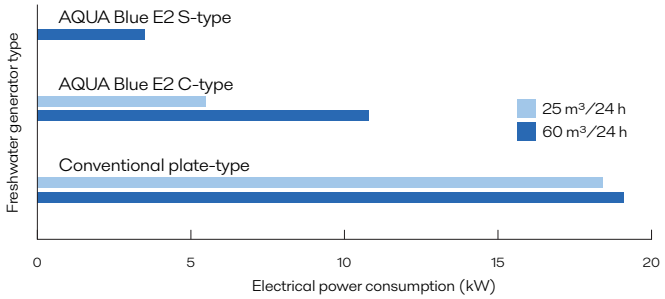
Saving additional energy

The choice of a two-stage freshwater generator means greater thermal efficiency. It leaves more waste heat for other processes or to generate electricity using ORC technology. Likewise, it can reduce auxiliary boiler use and eliminate the need for a hot water loop.

With the AQUA Blue E2, there are electrical power savings as well. By cutting seawater flow in half, its 3-in-1 plate technology reduces pumping needs and related power consumption. In the fully integrated C-type configuration, the AQUA Blue E2 consumes around 40–50% less electrical power than conventional freshwater generators.

The modular S-type configuration does even more for energy efficiency. It lets the AQUA Blue E2 utilize the vessel's existing seawater cooling system pump, with integrated automation systems optimizing the cooling flow. This further limits electrical power needs. Compared to conventional freshwater generators, the S-type configuration reduces electrical power consumption by around 70–80%.

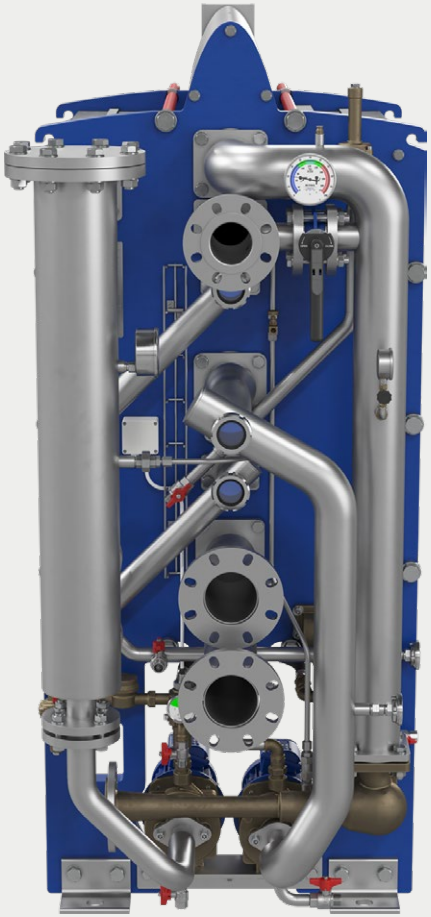
Electrical power comparison for two-stage freshwater generators



Let’s discuss freshwater generation and your needs

Each vessel is different – and so are the needs it may encounter. Whether you face limited waste heat, increasing demand for fresh water or tightening energy efficiency requirements, the right freshwater generation solution depends on your operational context. In a constantly evolving maritime environment, making the smartest specification can have a lasting impact on performance, compliance and costs.

At Alfa Laval, we understand the complexities on board. Even if you’re uncertain about future waste heat availability or coming needs for fresh water, we’re here to help you navigate the options. With deep experience in both freshwater generation and waste heat recovery, we can assess your vessel’s setup to identify the best-fit solution. Applying our uniquely efficient AQUA plate technology, we can ensure that you meet your needs – today and into the future.



“We choose our equipment with care for both efficiency and our crews. The AQUA Blue E2 combines energy efficiency with ease of maintenance, the goals we aim for every day.”

Antonietta De Rosa
Ship Design Project Engineer, Grimaldi Group

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