High Pressure Pumps
Article

Energy efficiency by design: The Danfoss APP and iSave® platform for brine mining

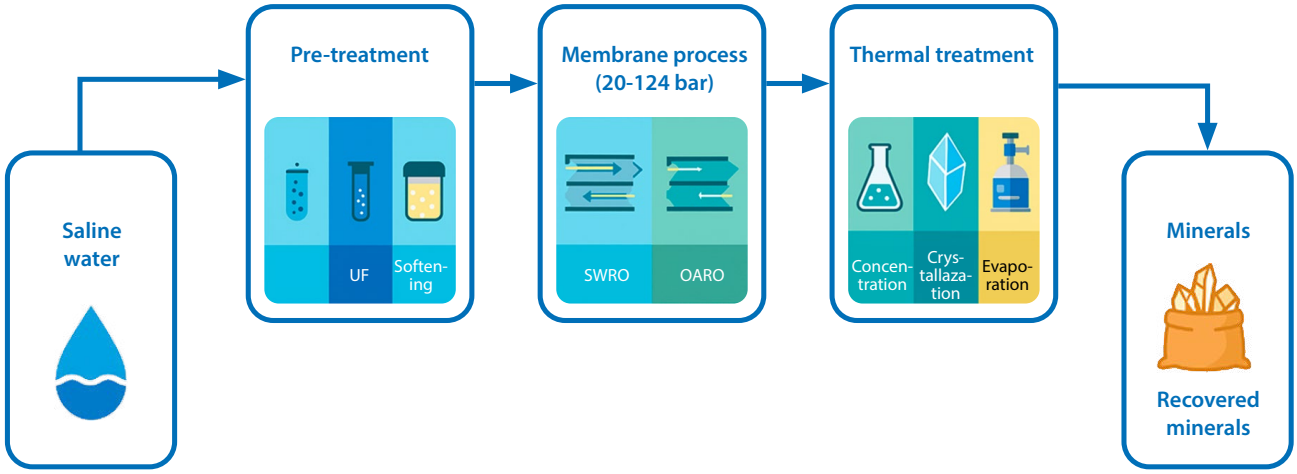
Brine mining is rapidly moving from niche projects into mainstream mineral recovery. From salt flats to seawater desalination reject, operators are transforming high-salinity brines into valuable resources such as salt, lithium, and magnesium while reducing the environmental footprint of traditional mining.

Today, advances in reverse osmosis (RO) are changing the economics of brine valorization. By pre-concentrating brines more energy efficiently than thermal methods can, RO reduces brine mining's operating costs and CO^2 emissions.

At the heart of this shift is the Danfoss platform of APP high-pressure pumps and iSave energy recovery devices (ERDs). Already today, innovative system designers rely on these components to deliver the energy efficiency, precision, and operational flexibility needed to make modern brine mining commercially viable at scale.

RO cuts the thermal load and transforms brine mining economics

At its core, brine mining is about concentration: removing water until the dissolved minerals are ready for recovery. The oldest example is traditional sea salt production, where evaporation ponds and sunlight have been used for millennia to produce salt from seawater. While solar evaporation is still used in some brine mining processes – even large-scale ones – relying on the sun alone is far too slow and land-intensive for many modern industrial applications.



↑ Typical brine mining process flow diagram.

Brine mining plants depend on thermal evaporators and crystallizers for the final concentration stages. These complex systems are indispensable for producing solid minerals, but they are also highly capital- and energy-intensive. Until recently, thermal systems have been used not just for the final stages, but also to drive pre-concentration of brines through processes like multi-stage flash (MSF) distillation, a strategy that works but at a very high energy cost.

This is where RO changes the game. By pre-concentrating brines via high-pressure membrane systems, brine mining operators can remove water from brines far more energy efficiently than they can with thermal methods only. This has several benefits. First, pre-concentration of brines prior to the final evaporation and crystallization stages can reduce the size and CAPEX of these complex components. Furthermore, every cubic meter of water removed by high-pressure membrane processes instead of distillation or vapor compression reduces overall energy use, OPEX, and emissions – and lowers the brine mining plant's total cost of operation (TCO).

SWRO innovations make smarter brine mining possible

Over the past few decades, the specific energy consumption (SEC) of seawater reverse osmosis (SWRO) has fallen dramatically, from what was often higher than 6 kWh/m3 to as low as 2 kWh/m3. Advances in membranes, high-pressure pumps, and energy recovery devices have driven this evolution, and now make it possible for RO to handle a significant share of the concentration workload once left to thermal systems in brine mining plants. This is why membrane-based pre-concentration, especially seawater reverse osmosis (SWRO) and osmotic-assisted reverse osmosis (OARO), is becoming a game changer in brine mining. The same logic applies in ZLD and MLD wastewater treatment, where reducing the thermal load can also improve both efficiency and economics.

At the center of every RO system are its high-pressure components. To reduce OPEX and CO2 emissions, plants depend on energy-efficient high-pressure pumps and energy recovery devices that can maintain performance under varying conditions. That is exactly what the Danfoss APP pump and iSave ERD platform is designed to deliver.

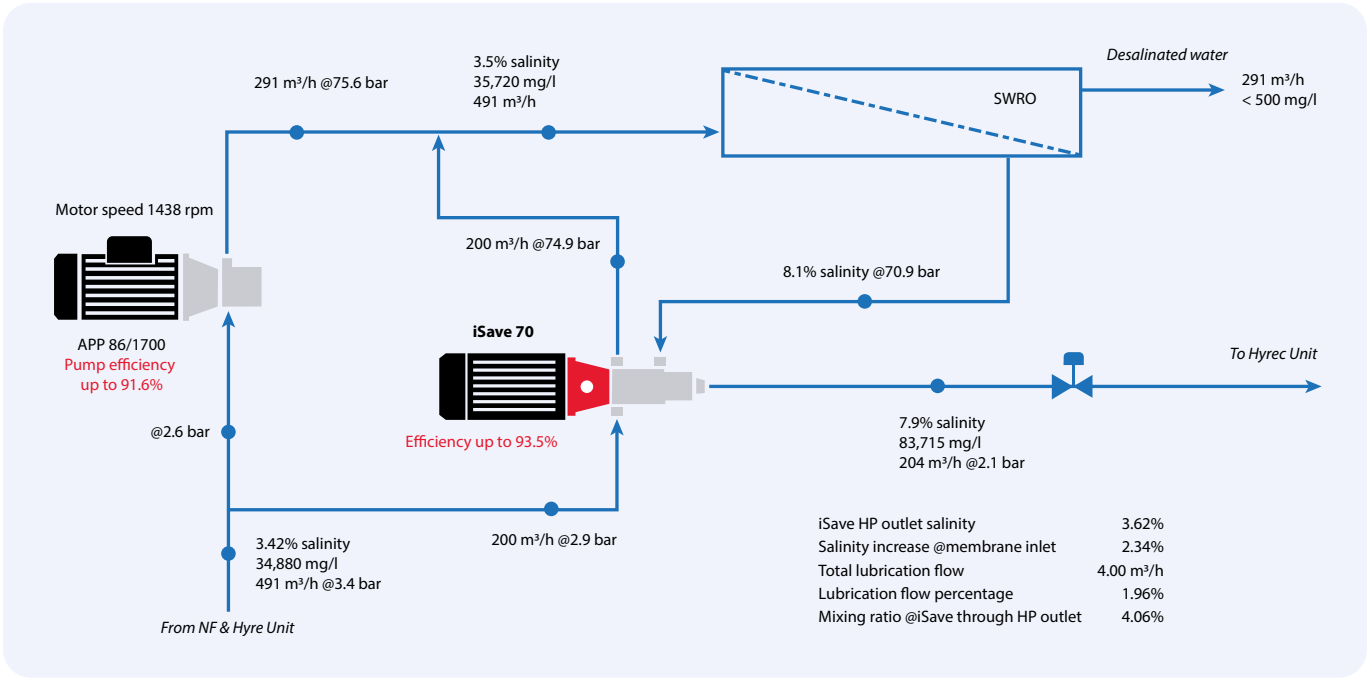
APP pumps: Energy efficiency at the core of brine mining

Energy efficiency in brine mining starts with high-pressure pumps. Danfoss APP axial piston pumps are positive displacement pumps that maintain consistently high efficiency across the full operating range, whether running at higher pressure in SWRO or at reduced pressure in OARO. At Hyrec's brine mining plant in Indonesia, for example, APP pumps have demonstrated efficiencies above 91 percent in both stages, even if operating conditions change.

↑ Two APP 78 pumps per OARO train.

This is where APP pumps stand apart from centrifugal pumps. Centrifugals operate best at a narrow best efficiency point (BEP) but lose efficiency quickly when conditions shift. By contrast, APP positive displacement pumps deliver constant flow at any pressure. Operators can reduce flow by lowering pump speed, or by shutting down units in a parallel array, without any efficiency penalty. Operators can also easily add additional APP pumps to increase system capacity without affecting the performance of existing pumps.

That flexibility makes the APP platform especially valuable in brine mining, where pressures and salinities can vary significantly from stage to stage and from day to day. With APP pumps, system designers can rely on a single pump platform for both SWRO and OARO, simplifying design while market-leading ensuring energy efficiency throughout.



↑ APP high-pressure pump and iSave energy efficiency in Maven brine mining plant.

iSave ERDs: Energy recovery with active control

The iSave energy recovery device (ERD) is built for more than energy efficiency. Like all isobaric ERDs, it captures the pressure left in the brine reject stream and reuses it, reducing pump workload and energy consumption. But the iSave goes further: it combines this high efficiency with the ability to actively manage mixing between feed and brine streams. This makes the iSave not only one of the most efficient ERDs available, but also a powerful tool for controlling the balance of pressure and salinity in advanced brine mining processes.

In osmotic-assisted RO, controlled mixing is not a flaw but an advantage. The ability to carefully adjust both the degree and direction of mixing provides unique process control benefits, giving engineers more flexibility to tune the OARO loop across a wide range of operating conditions.

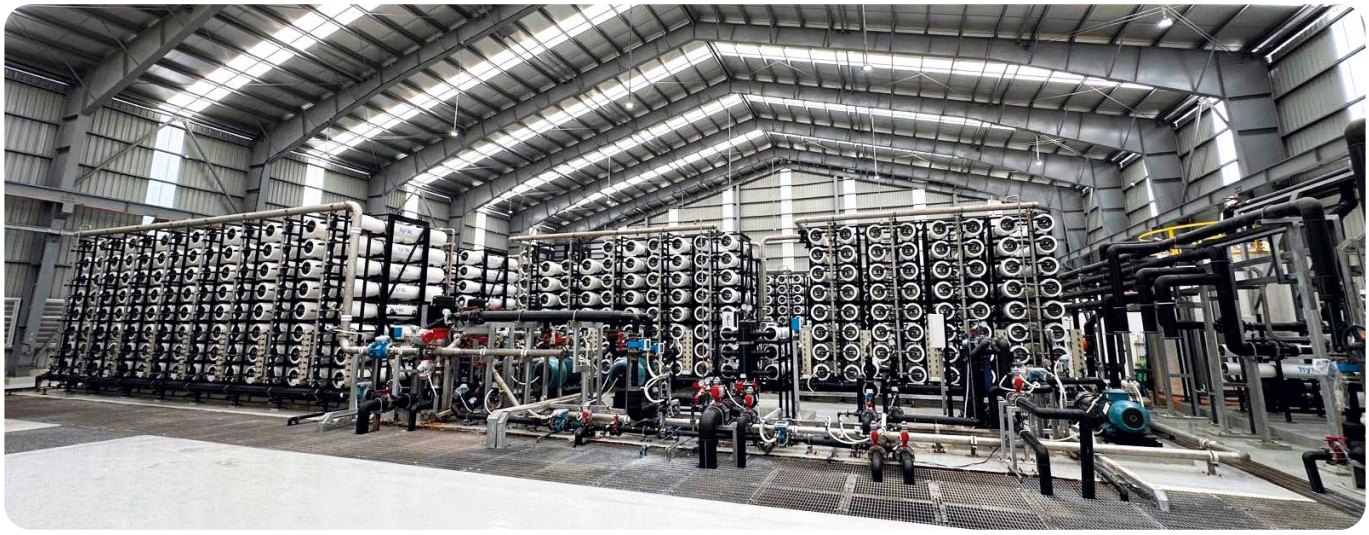
This is where the iSave active ERD stands apart. Most ERDs are passive: they efficiently transfer pressure from the brine stream but offer little ability to influence the process itself. The iSave is different. As an active ERD, it combines an isobaric pressure exchanger with a variable-speed booster pump and a motor, giving operators precise, real-time control over both pressure and mixing. That turns the ERD from a passive energy saver into an active process control tool. In multi-stage brine mining, where salinity and operating conditions can vary considerably, this active control helps keep systems balanced, efficient, and reliable.

At Hyrec's Indonesian plant, which produces 220,000 tons of food-grade salt annually and 27,120 m3 of desalinated water daily, this advantage is proven in the field. iSave units operate at over 93 percent efficiency in both SWRO and OARO, while delivering stable flow and pressure under widely varying conditions. More importantly, as active ERDs, they give operators the ability to fine-tune mixing and pressure in real time, something passive ERDs cannot do. The result is lower energy use, longer membrane life, and more stable operation in the most demanding stages of brine mining.

Parallel systems: Built-in redundancy and operational flexibility

At the Hyrec plant, both the SWRO and OARO stages run on parallel arrays of pumps and ERDs: four APP 86 pumps with four iSave 70 units per SWRO train, and two APP 78 pumps with two iSave 50 units per OARO train.

This parallel setup offers two key advantages. First, redundancy: if one unit needs maintenance, the others keep the system running without interruption.



↑ Whole Hyrec plant consisting of both SWRO and OARO trains.

Second, operational flexibility: during periods of lower demand, pumps or ERDs can be slowed or shut down entirely, while the remaining units continue to operate at high efficiency.

This operational flexibility is possible because APP pumps and iSave ERDs maintain efficiency across their full operating range. Unlike centrifugal pumps, which lose efficiency when running away from their best efficiency point, APP positive displacement pumps keep their energy-efficient performance steady even as flow and pressure requirements shift. Similarly, multiple active iSave ERDs ensure consistently high efficiency despite variations due to mixing management. For operators, this flexibility means stable efficiency and reliability, no matter how conditions change.

The platform advantage: One system for multiple stages

The real strength of combining APP pumps and iSave ERDs is that together they form a unified, energy-efficient high-pressure management platform. The same pump technology powers both SWRO and OARO, and the same ERD technology recovers energy and controls process pressures in both stages.

For operators, this consistency pays off across the plant. A single platform means fewer spare parts, simpler training, and easier integration into automation and maintenance systems.

Energy efficiency and precision control may win the headlines, but this platform effect makes plants easier to design, operate, and maintain over the long term. In continuous operations like brine mining, that kind of built-in simplicity becomes just as valuable as raw performance.

Designed for the real-world demands of brine mining

Brine mining is a 24/7 operation that demands reliability, energy efficiency, and the ability to handle widely varying feed conditions. The combination of APP pumps and iSave ERDs delivers on all counts:

- → High energy efficiency in both SWRO and OARO, proven above 91 and 93 percent in field operation
- → Precision control to manage osmotic loads efficiently and protect membranes
- → Operational flexibility to adjust flow and pressure without losing efficiency across different stages or changing conditions
- → High uptime through parallel configurations that provide redundancy and operational flexibility
- → Platform consistency that simplifies operation and maintenance

From seawater to ultra-concentrated brines, the APP + iSave platform makes energy-efficient pre-concentration practical and reliable, cutting thermal load, protecting membranes, and improving the economics of mineral recovery.