CapDI©

vs Traditional Technologies

Highlighted Features

LET'S EXPLAIN

Comparing CapDI to Reverse Osmosis

At Voltea, we are firm believers in the benefits of Membrane Capacitive Deionization, our CapDI. The technology is relatively new to the industry and there are often many questions as to how CapDI differs to Reverse Osmosis (RO) and other traditional deionization or softening technologies, such as ED(R) and Ion Exchange (IX). We hope that this document will help answer those questions. Let's begin with comparing CapDI and RO:

How do the Membranes in CapDI Differ to Those in RO?

CapDI behaves like a flow-through capacitor where the feedwater travels through stacks of capacitor plates. Ions are adsorbed by carbon electrodes covered with cation and anion ion exchange membranes. The membranes are employed to keep positive and negative ions from migrating to their respective opposite poles during the regeneration sequence. These membranes are impermeable to water, allowing only ions to pass. Alternately, RO water desalination technology employs semi-permeable spiral wound membranes, operating under high pressure, to remove ions, molecules, and larger particles from water.

How Does This Affect Performance?

RO is very good at removing >95% of salts as the membrane rejects them. To achieve this, the water must be fed at high pressure to force the water through the semi-permeable membranes. The downside to this is twofold; the membrane, behaving as a barrier, can easily become fouled with particulate matter. Also, the energy cost associated with a high pressure pump can be steep. With CapDI, the membranes are not physical barriers and are much more resistant to fouling.

Another impact of the difference in membranes is the efficiency of operation with regards to changing salt concentrations and water temperature. As RO removes the water and leaves the salt at low salt content, the system must work hard to move a lot of water. Since CapDI removes the salt and leaves the water, at these lower feed concentrations it can be significantly more efficient and hence have a lower OPEX.

Additionally, there are numerous applications where high salt removal is not required. In these cases, RO permeate is typically blended with raw feed water (sometimes the RO's brine stream) or re-mineralized with select media. Here, blend consistency can be challenging and often with less than optimum results. With CapDI, the potential across the capacitor can be simply and easily adjusted (tuned) to proportionally control the amount of salt removed from the feed water. This can also reduce OPEX.

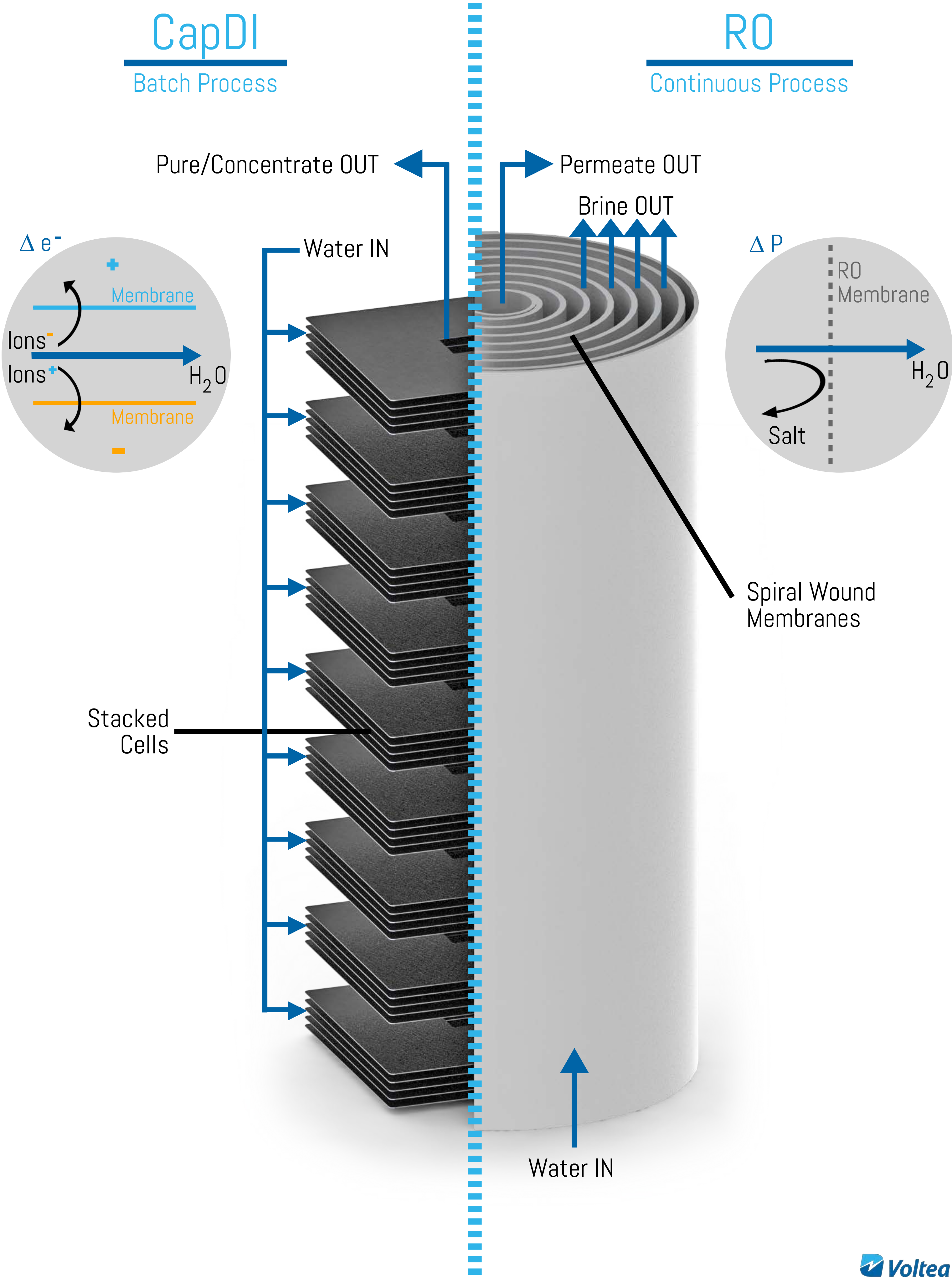
How Does the Flow Pattern Differ?

Unless configured in a batch operation scheme, RO produces a continuous permeate and concentrate waste stream. Consequently, the exposure time to precipitates is high, increasing the fouling potential. CapDI produces a batch of purified water, then regenerates producing a batch of concentrate. If a more continuous output stream is required, two modules (or systems) can be operated out of phase so that one is regenerating when the other is purifying. By producing in batches, the CapDI carbon electrodes are not continuously exposed to concentrate water, which reduces the precipitate fouling risk.

What is the Online Operation Time?

RO is more often than not configured for continuous operation. However, in situations where frequent start/stops can occur, such as batch operations, membrane life can be shortened and potential failure increases. Being an electrochemical process (no moving parts), CapDI affords the benefit of not having any issues associated with frequent start/stop cycles occurring.

CapDI vs. RO


CapDI
Batch Process
RO
Continuous Process
Pure/Concentrate OUT
Permeate OUT
Brine OUT
Water IN
Δ e-
+
Membrane
Ions-
Ions+
H2O
Membrane
-
Δ P
RO Membrane
H2O
Salt
Spiral Wound Membranes
Stacked Cells
Water IN

COST EFFECTIVENESS

CapDI, when comparing to RO, is highly cost effective on an OPEX basis at low to mid-level brackish TDS. Chart 1 below displays the cost benefit of CapDI versus RO at TDS levels below 2,500 ppm.

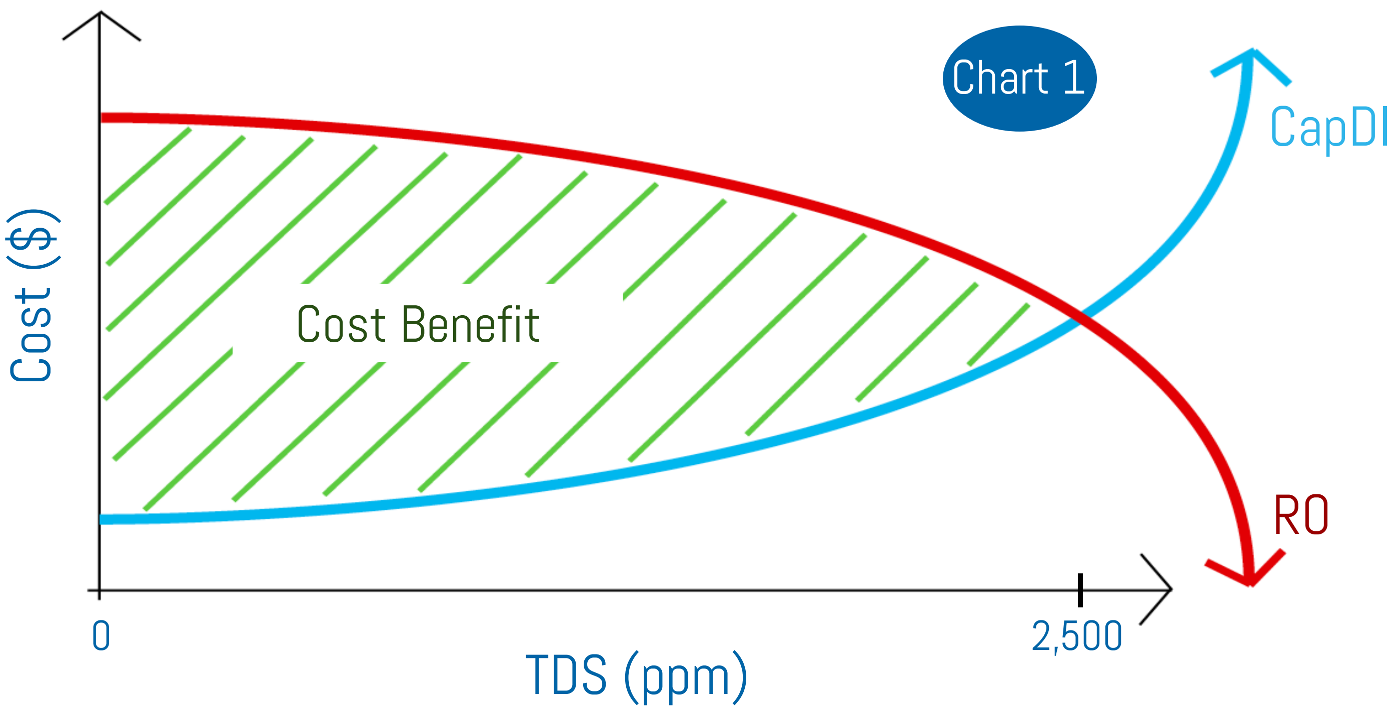
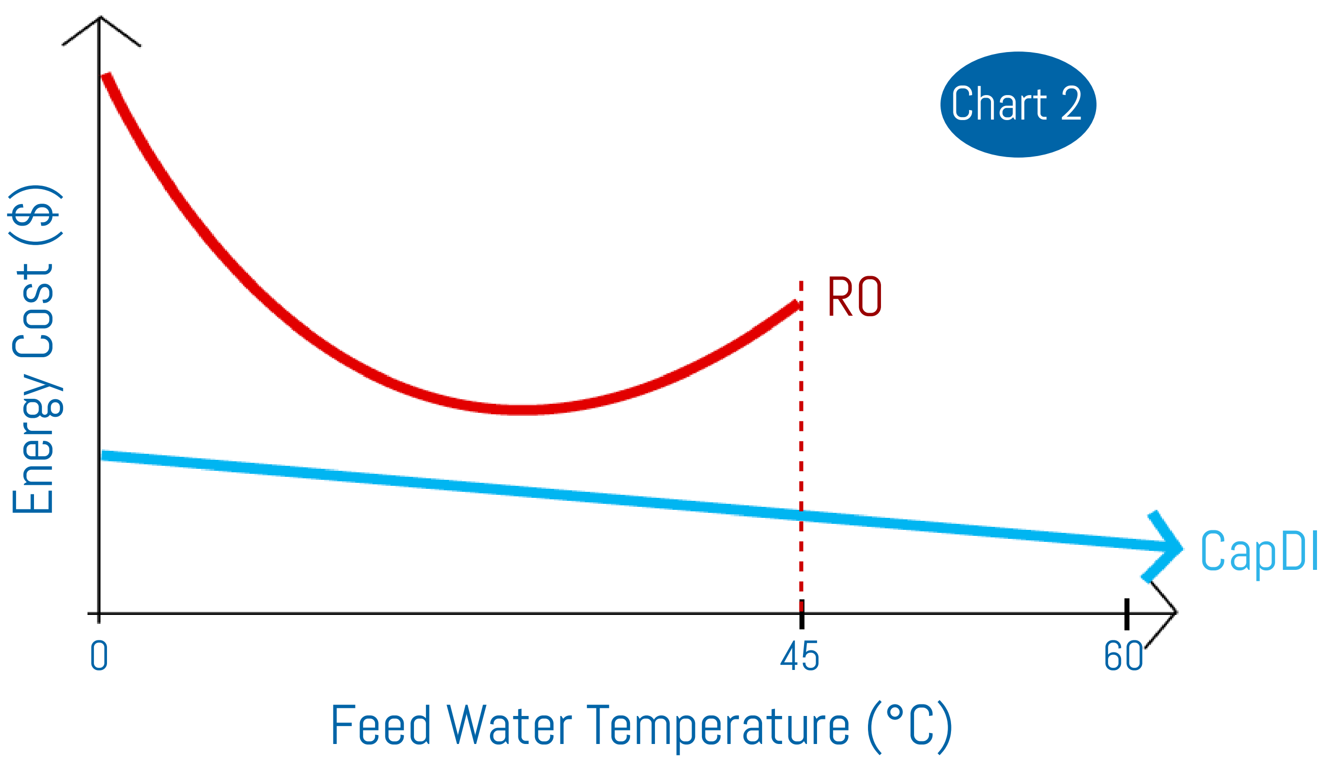


Chart 2 below illustrates the energy cost benefit of CapDI versus RO, with CapDI maintaining a consistent energy cost across all water temperatures. While RO no longer works at higher temperatures, CapDI specializes in deionization at low and elevated temperatures, all while maintaining energy efficiency.



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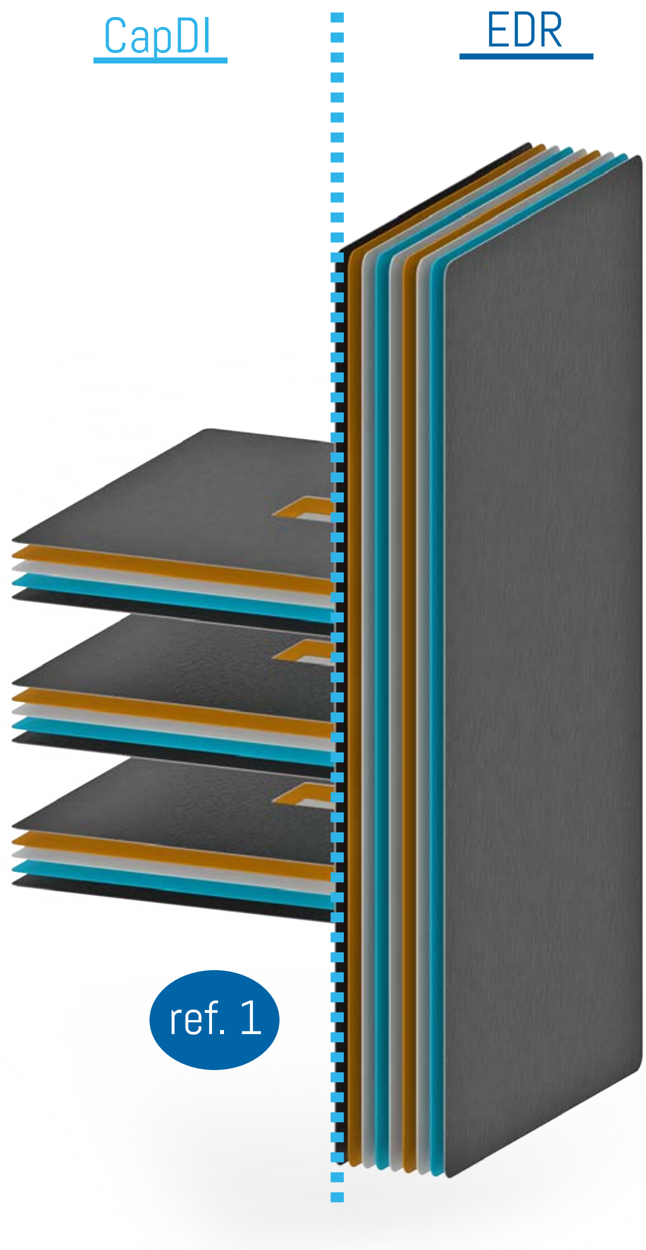
GETTING MORE SPECIFIC

Comparing CapDI to Electrodialysis/Reversal (ED/EDR)

Membranes ✓ Electrodes ✓ Electrochemical Process ✓

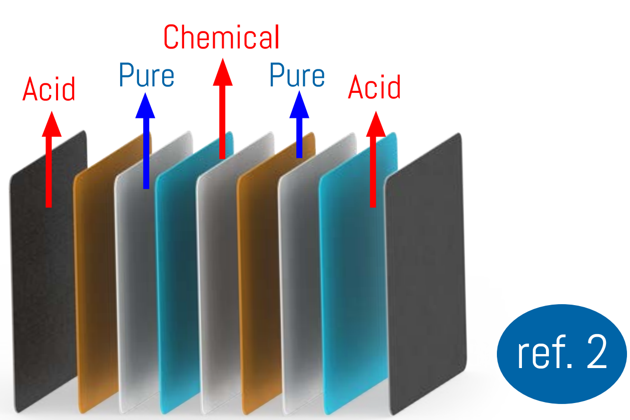
With so much in common, what makes CapDI different from ED and EDR? Let's start with the set-up differences. CapDI has an electrode pair for each membrane pair, in contrast to ED(R) where there is one electrode pair for several membrane pairs (ref. 1).



This difference in arrangement drives several other differences. The first being how the electrical force is applied across the membranes. In CapDI, the distance between the electrodes is smaller, so a lower voltage can be applied. In ED(R), a higher voltage is required to compensate for the larger distance between the electrodes. At higher voltages, more water splitting occurs, potentially damaging the membranes closest to them and increasing fouling risk. This may also cause a higher electricity operating cost, as well as the need for degasification.

Another strong difference is that ED(R) allows for continuous or semi-continuous pure and concentrate streams. This means that some end users benefit from the continuous nature of the process. There is a downside, however, in that there are areas of the set-up that are continually exposed to high concentrations of combined anions and cations, and as such, are at high fouling risk. To mitigate this, HCl (acid) and anti-scalants are often employed (ref. 2).

CapDI does not have a continuous concentrate stream, so the fouling risk is significantly reduced and hence less (if any) chemicals are necessary.



What is the difference between ED and EDR?

EDR is ED with the addition that after a set time, the polarity switches to reduce some of the fouling that may have occurred at the membrane and spacer surface within the concentrate channels and at the electrodes.

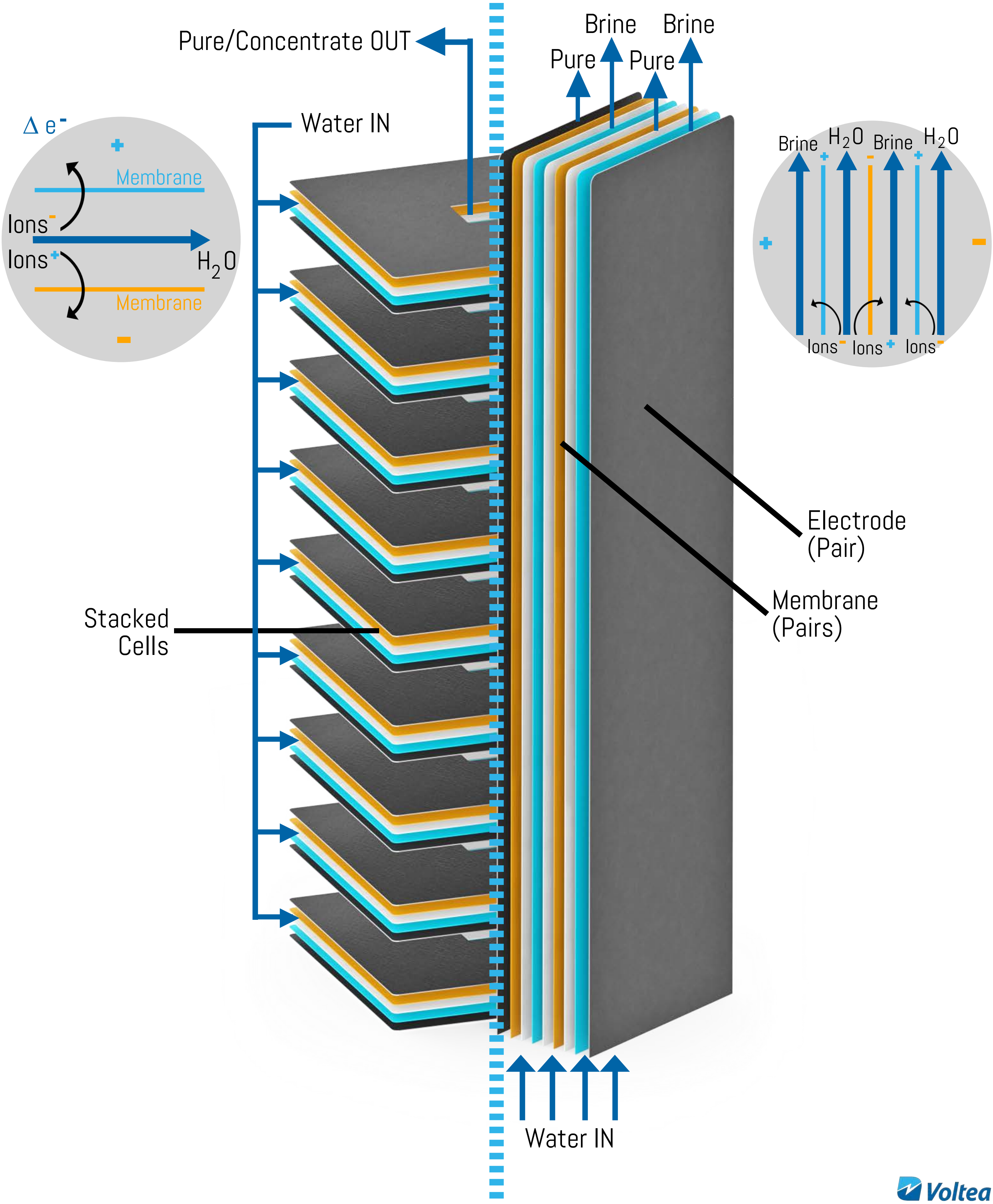
CapDI vs. ED/EDR

CapDI

Batch Process

ED(R)

Continuous Process



THE ELEPHANT IN THE ROOM

Comparing CapDI To Ion Exchange Resin Softening (IX)

With IX being cheap and simple, why would anyone use anything else? The answer is multi-faceted, but first let's break down what IX is and how it works:

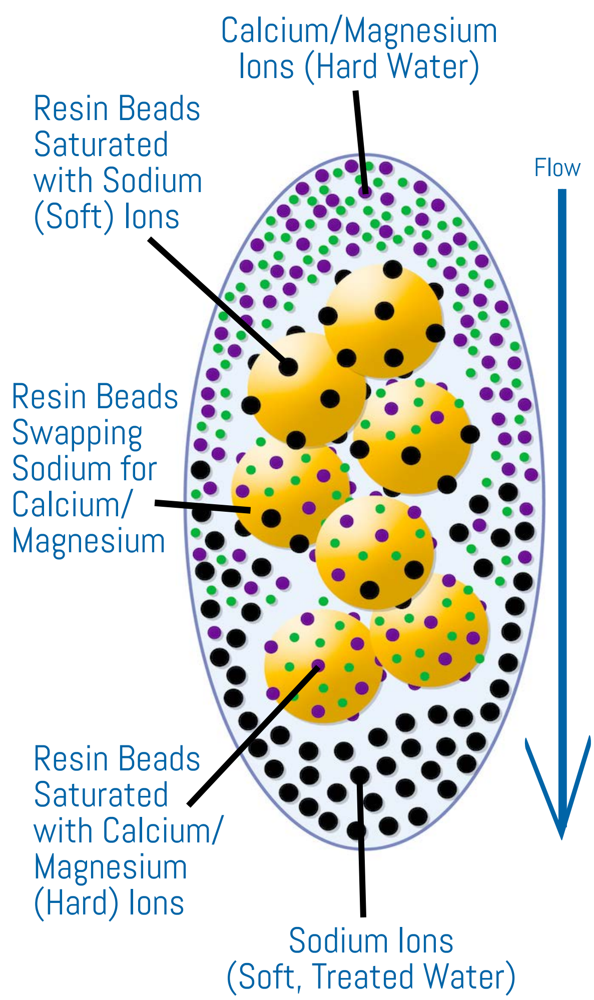
The IX device passes water over the resin beads that in turn exchange soft ions (normally sodium) on their surface for hard ions, such as calcium and magnesium. Over time, the resin becomes saturated and the exchange efficiency will drop. To replenish the resin with soft ions, a brine solution (lots of salt and sodium chloride) is flushed through the device, picking up the hard ions before going to the drain.

So why does that matter? By exchanging soft salts for hard salts, the softener is not reducing the salt content. In fact, for every hard ion (like calcium) that comes out, two soft ions need to be put in. This is because sodium carries a single positive charge and calcium carries two. Therefore, if you have a need to reduce the salt in your application, IX is not going to help. A great example of this is in agriculture where high salt concentrations can impede plant growth, or industrial plants where the chlorides could accelerate corrosion.

For some areas, including residential, it is the brine (waste) that can be a gating factor. The brine is a high salt concentrated solution that can affect the local ecology and cause strain on wastewater treatment plants. Consequently, in some drought-stricken areas there are salt bans preventing the use of these devices.

<u>In comparison, CapDI's concentrate (waste) is only ions removed from the feed water, so no additional salt is being added and dumped into local/municipal water sources.</u>

<u>Inside an Ion Exchange Resin Softener</u>

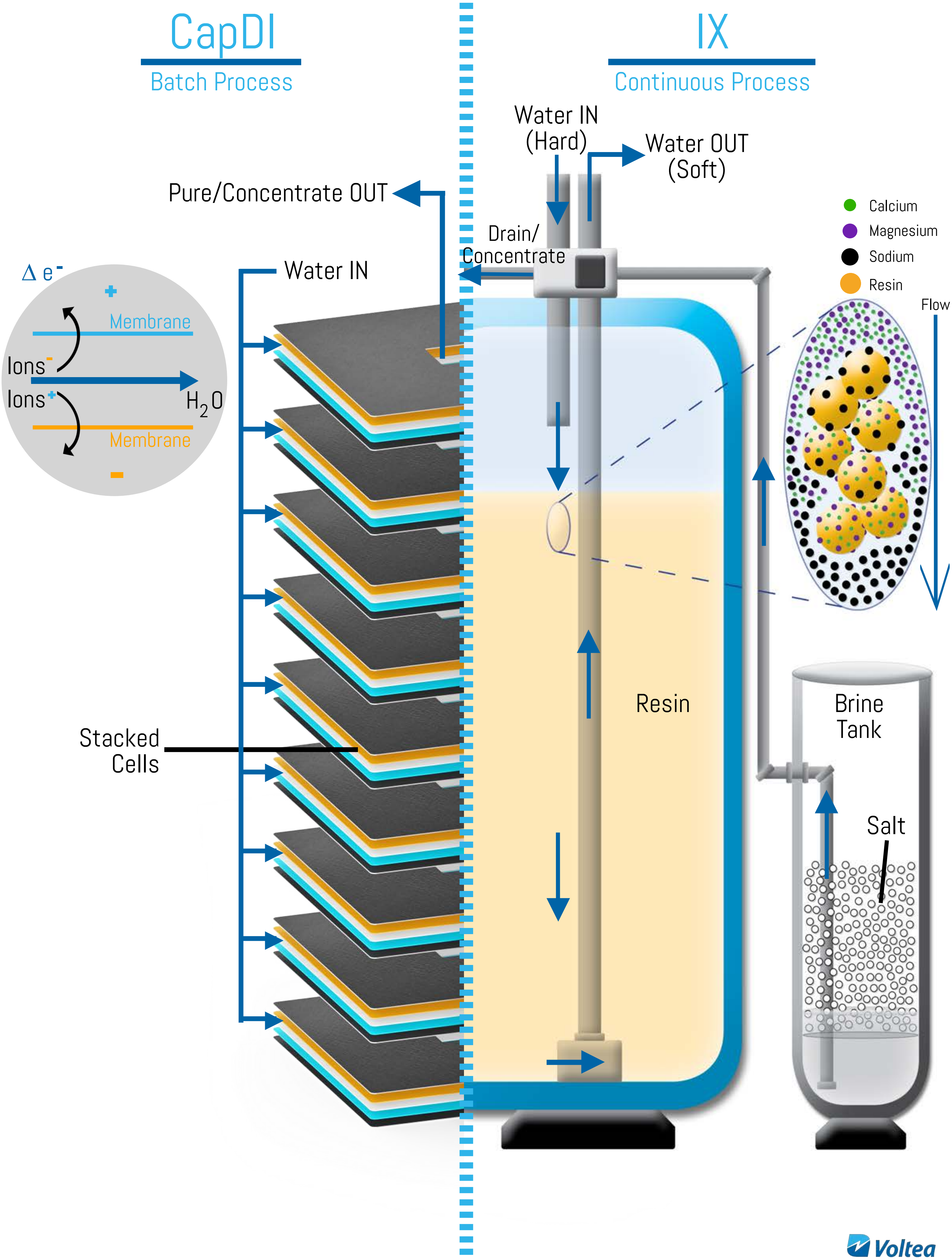


If you are not in a salt ban region, you don't have a corrosion problem and you don't mind the higher salt concentrations, then why would you consider anything other than a softener?

Softeners are typically simple devices that don't require much maintenance apart from replacing the salt and renewing the resin, which is great, but it also means they typically don't come with onboard monitoring to tell you if your water quality is what you think it is or if the salt in your brine tank needs topping up.

Voltea's CapDI comes with a data connection that allows you to utilize the electronic nature of the technology, enabling a much more interactive experience to ensure that you get the water quality that you expect.

CapDI vs. IX



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COMPARISON CHART

This comparison table shows what we believe to be some of the most important differentiating factors of CapDI, RO, EDR and IX.

	CapDI©	RO	EDR	IX
Modular (Size)	✓	✓	✓	✓
Built-In Automatic CIP	✓	✗	✓	✓
Remote Monitoring/Control	✓	✗	✓	✗
Removes TDS at High Temps	✓	✗	✗	✗
Chlorine Tolerance	✓	✗	✓	✓
Fouling Potential	Low Risk	High Risk	Medium Risk	Low Risk
Chemical Usage	Low	High	High	High (Salt)
Energy Consumption	Low	High	Medium	Low
Consumables	Low	High	High	Low
Maintenance Requirements	Low	High	High	Medium
TDS Reduction	Tunable	> 97%	Tunable	Only Hardness
Process	Electrical	Mechanical	Electrical	Chemical

Questions?
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