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FOUR SIMPLE INNOVATIONS TO REDUCE CO_2 EMISSIONS ON LARGE SWRO PLANTS

Mike Sinfield, Research Chemist *(Genesys International)*

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IDA World Congress Sydney, 2022, Sinfield *et al.*

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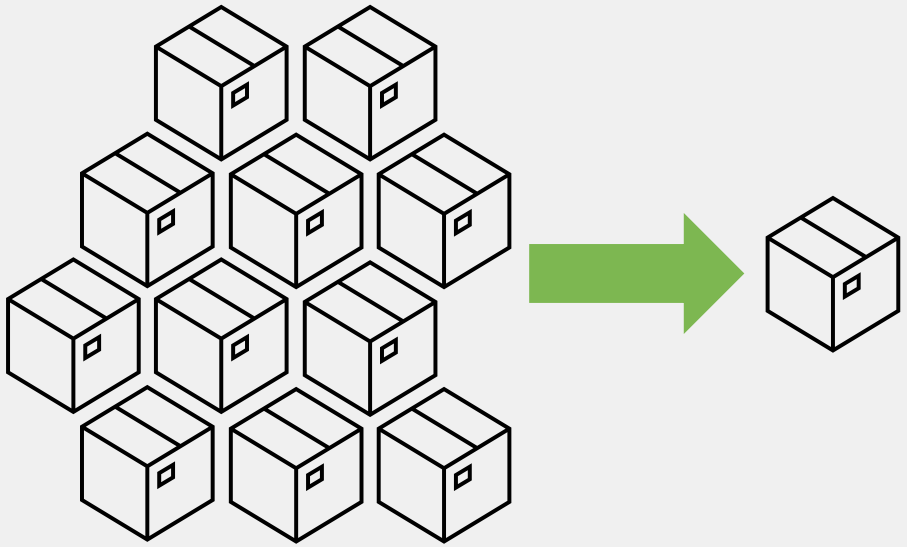
Super-concentrated antiscalant



- Lots of CO_2 emissions result from international shipping of bulk chemicals.
- For example, shipping 1 TEU (18 IBCs) from California to UAE costs *ca.* 3 400 $kgCO_2$.
- Reducing the shipped volume of antiscalant will reduce the carbon footprint of delivering the antiscalant.
- <u>Formulate a super-concentrated antiscalant which can be diluted to functional antiscalant on site, on demand.</u>

Super-concentrated antiscalant

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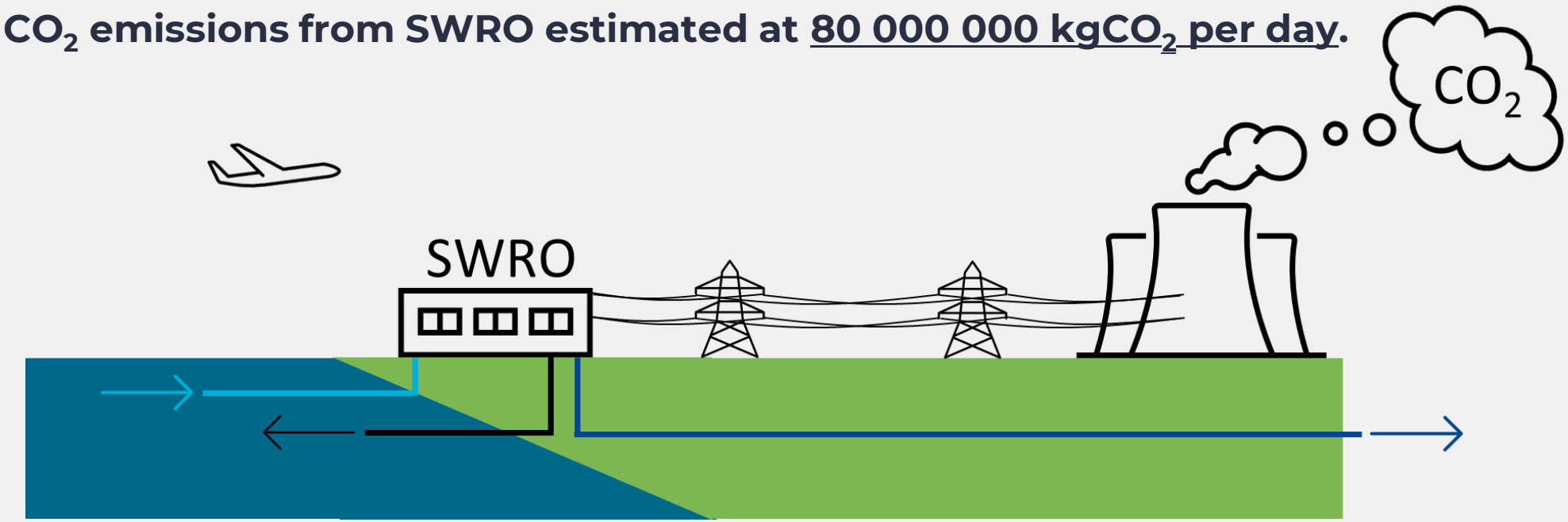
Super-concentrated antiscalant

- A real SWRO plant in Israel producing 326 144 m^3/day (72 MGD) used 98 IBCs of antiscalant annually to protect the 1st RO stage.
- Switching to super-concentrated antiscalant has reduced the number of IBCs required annually to 8.
- Concentrated antiscalant is diluted on site to produce functional antiscalant (see image).
- Freight costs and associated CO_2 emissions reduced by 92%.

CO_2 emissions from large SWRO

- **>50 000 000 m^3 permeate produced daily from SWRO.**
- **Conservative estimate of power consumption of 3.7 kWh/m^3 means 185 000 000 kWh used daily for SWRO.**
- **World CO_2 emissions from SWRO estimated at 80 000 000 $kgCO_2$ per day.**



Sources: Desal Data / EPA Greenhouse Gas Equivalencies Calculator

CO_2 emissions from large SWRO

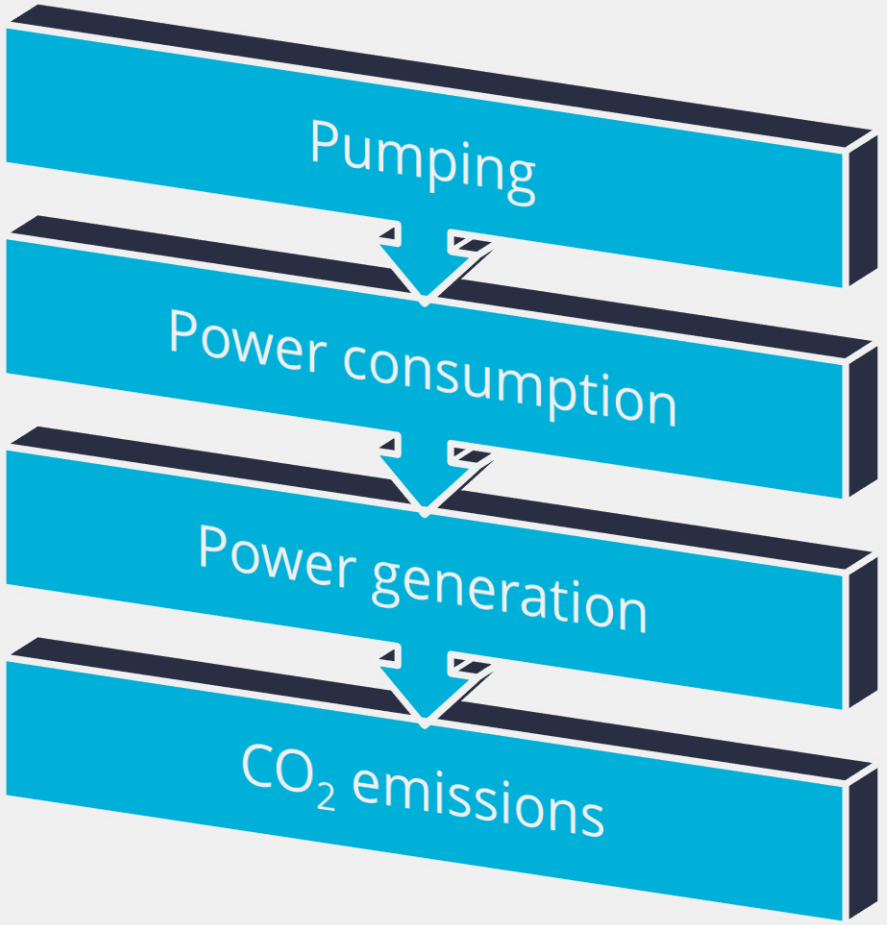
- **Despite improvements in SWRO design, power consumption per tonne of permeate remains above 3.1 kWh/m³.**
- **Most power consumption in SWRO is associated with pressurising feed water to *ca.* 80 bar.**

2005		2018	
Site	kWh/m³	Site	kWh/m³
Ashkelon, Israel	3.9	Agadir, Morocco	3.67
Carboneras, Spain	4.08	Djerba, Tunisia	3.5
Fujairah, UAE	4.3	Mirfa, UAE	3.55
Tuas, Singapore	4.34	Barka 4, Oman	3.15

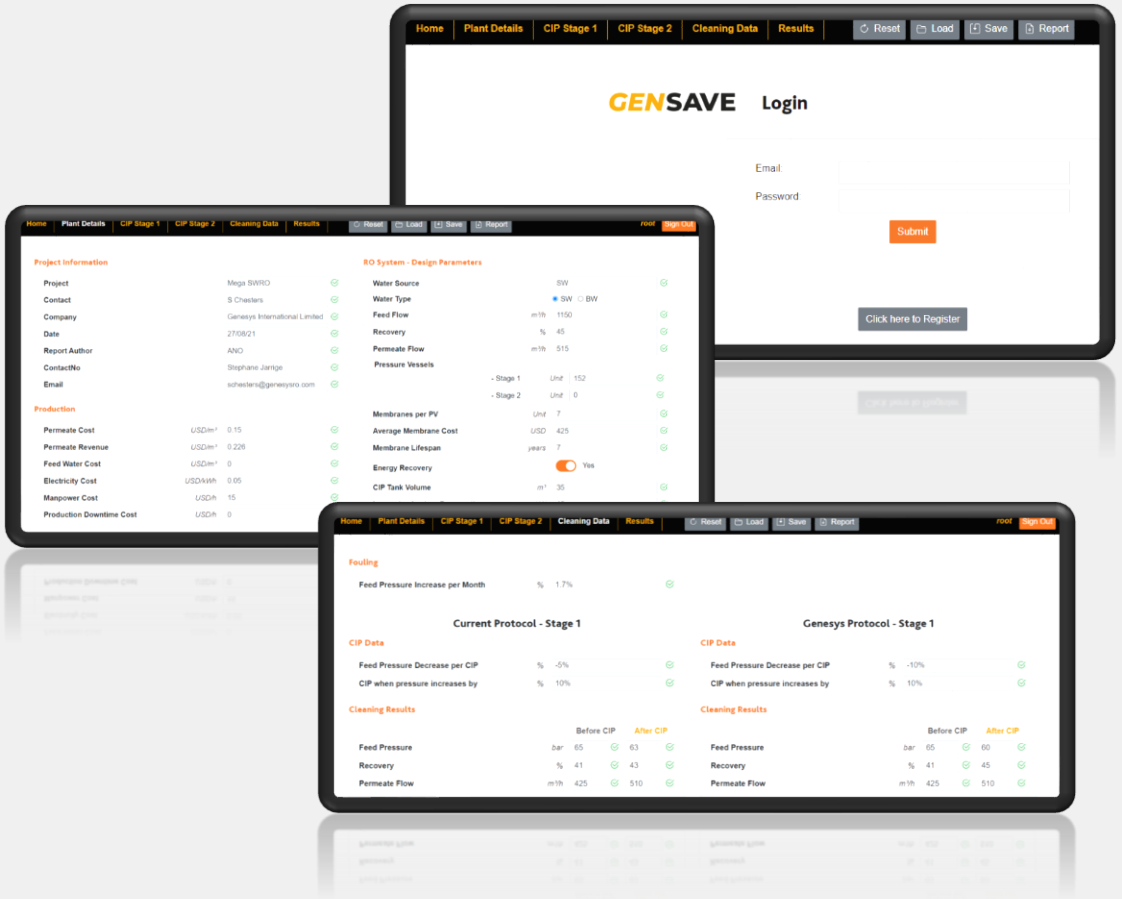
Sources: IDA Desalination Yearbooks

Reduced CO_2 through reduced pumping

- **Despite wide employment of energy recovery devices, pressurising feed water remains the major contributor to SWRO power consumption.**
- **Generating this electricity is the root cause of most SWRO CO_2 emissions.**
- **<u>Three innovations which reduce pumping demand in SWRO.</u>**



Monitoring power consumption



- Maintaining high ΔP in SWRO demands elevated pumping.
- Impossible to quantify the effectiveness of other innovations without a complete solution to monitor power consumption from pumping.
- <u>Develop a software platform which can convert ΔP into power consumption and CO_2 emissions, informing when CIP is required.</u>

Software to convert ΔP into pumping costs

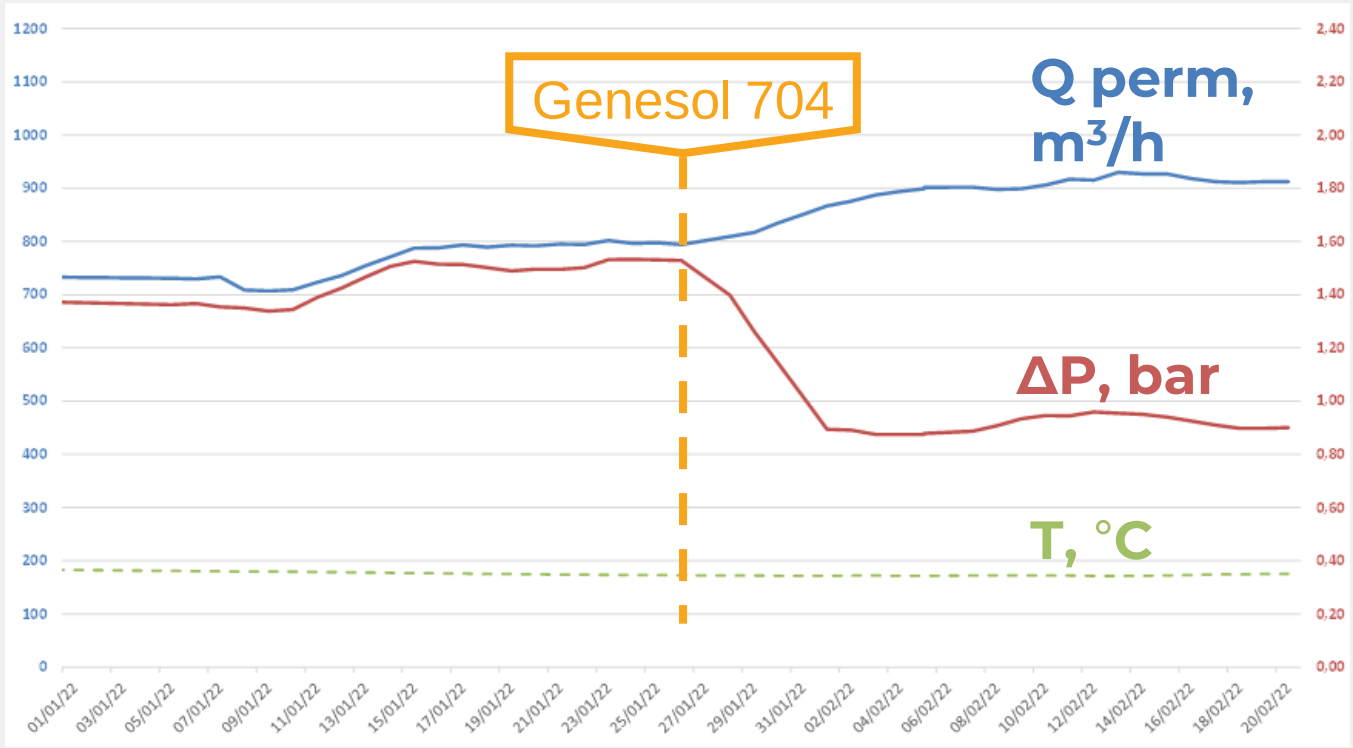
GenSave Case Study – Large SWRO

- **200 000 m³/day**
- **46% recovery**
- **10 × RO units**
- **Hydronautics SWC5-Max membranes**

- **2 × 100 m³ CIP tanks**
- **Main foulants are organics and aluminosilicates**

Software to convert ΔP into pumping costs

GenSave Case Study – Large SWRO



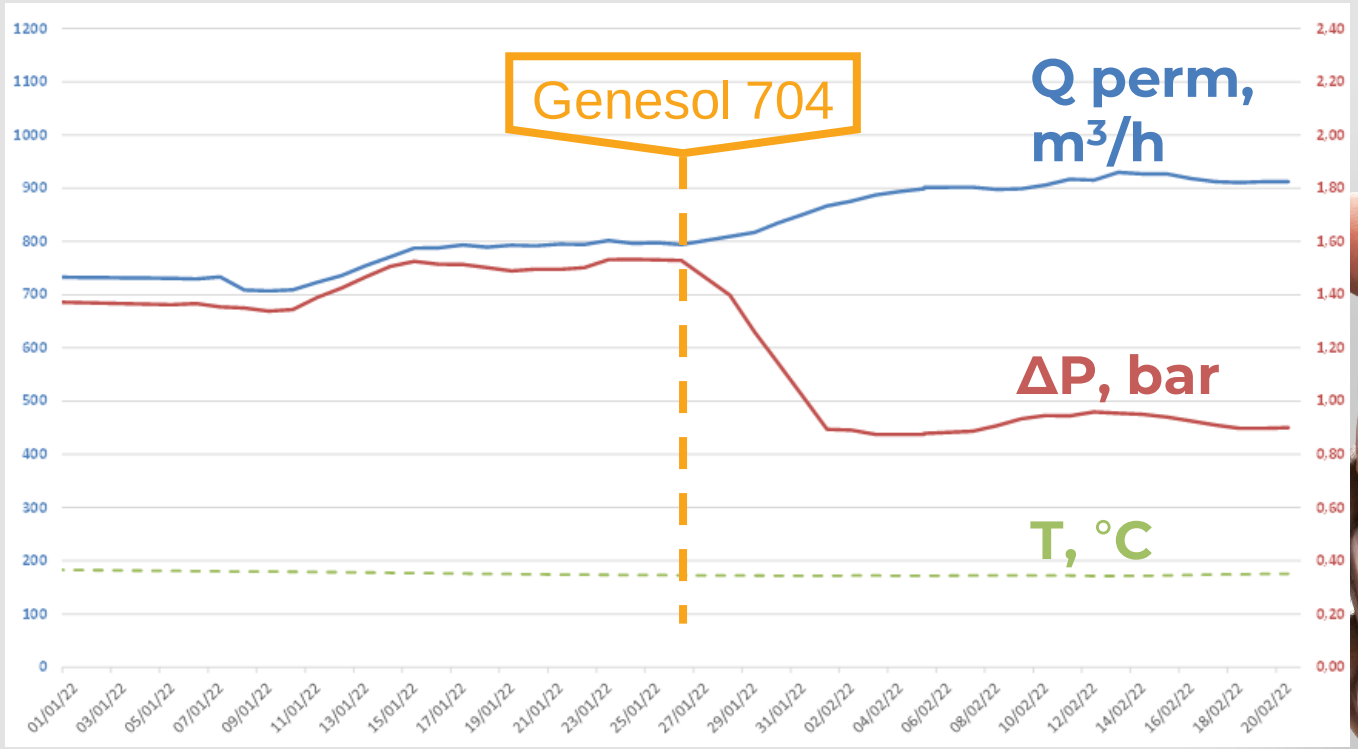
CIP:

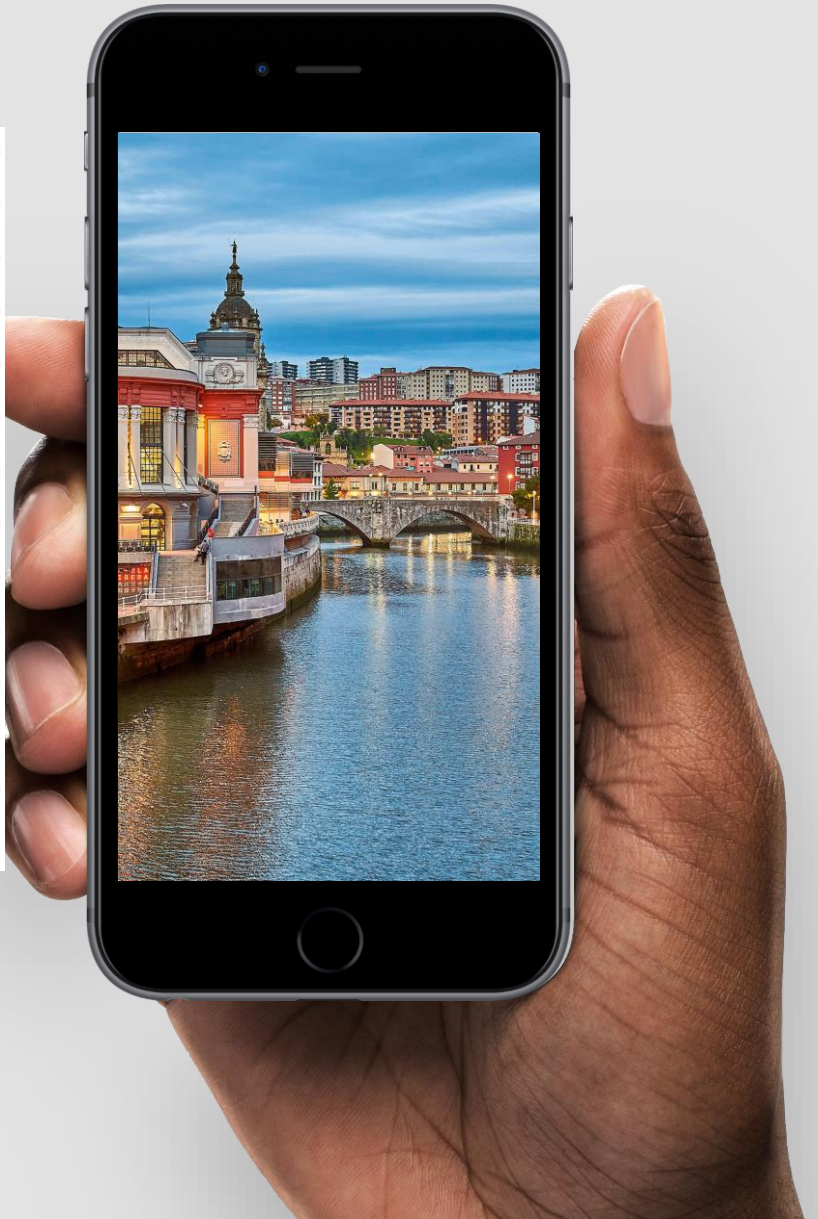
- **Increases permeate flow from ~790 to ~890 m³/h**
- **Reduces ΔP from ~1.5 to ~1.0 bar.**

- **How much does this CIP event save the plant operator?**
- **Hint: between 10 000 and 50 000 USD.**

Software to convert ΔP into pumping costs

EventMobi

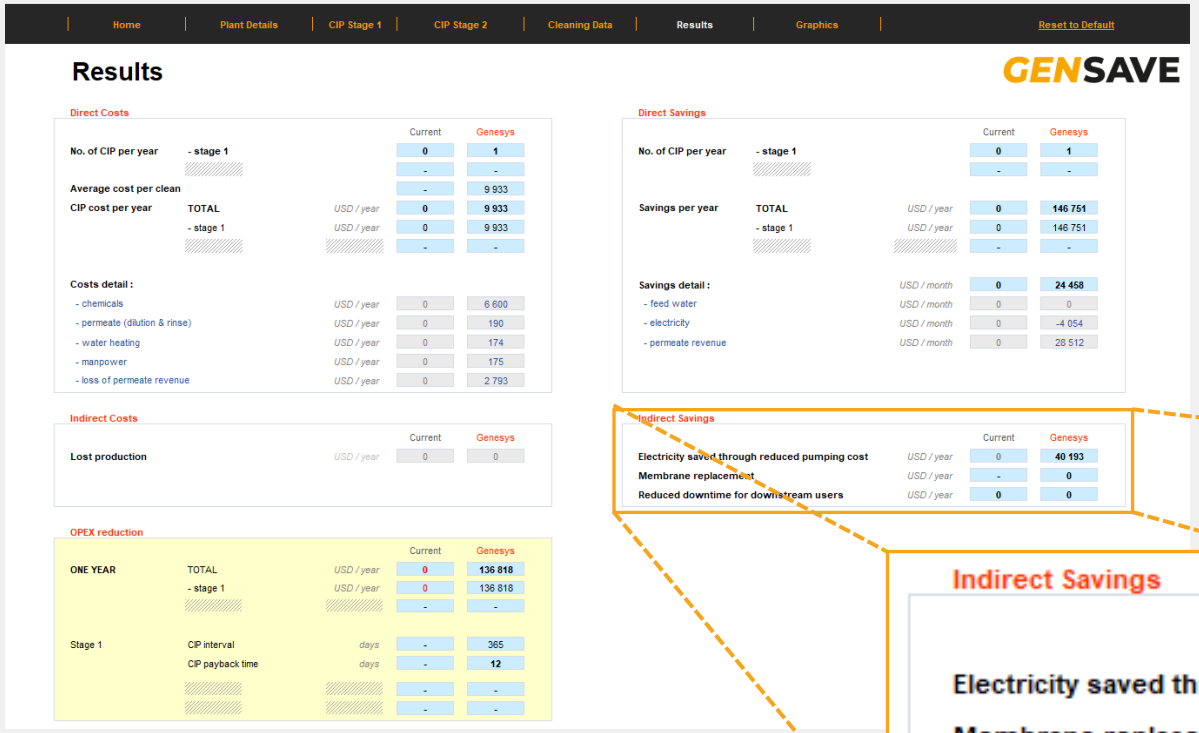




Q. How much does this CIP event save the plant operator?

Hint: between 10 000 and 50 000 USD.

GenSave Case Study – Large SWRO



- Input production costs, plant info, feed pressure, recovery, permeate flow before & after CIP.
- Software determines pumping reduction.
- Software estimates OPEX savings.

Indirect Savings

		Current	Genesys
Electricity saved through reduced pumping cost	USD / year	0	40 193
Membrane replacement	USD / year	-	0
Reduced downtime for downstream users	USD / year	0	0

Software to convert ΔP into pumping costs

EventMobi

Indirect Savings

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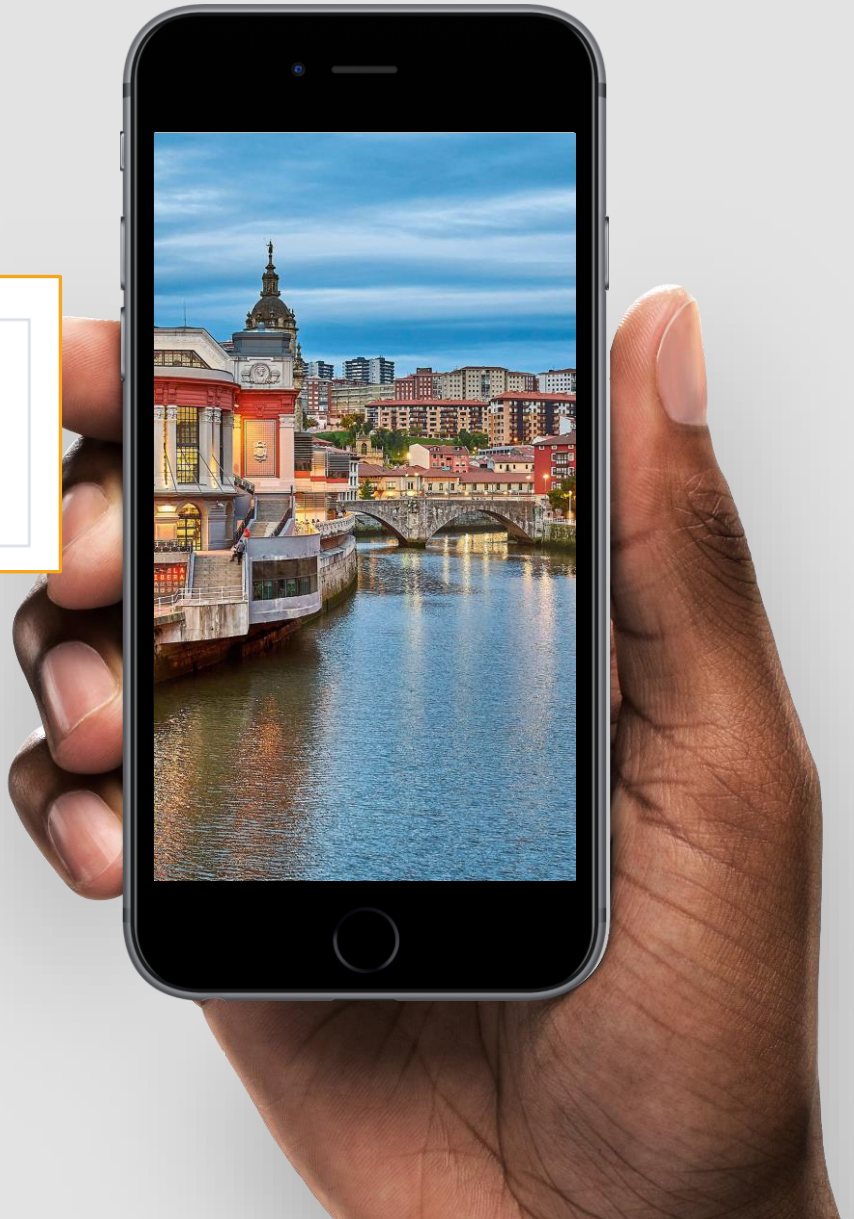


Q. How many kgCO_2 will this CIP event save?

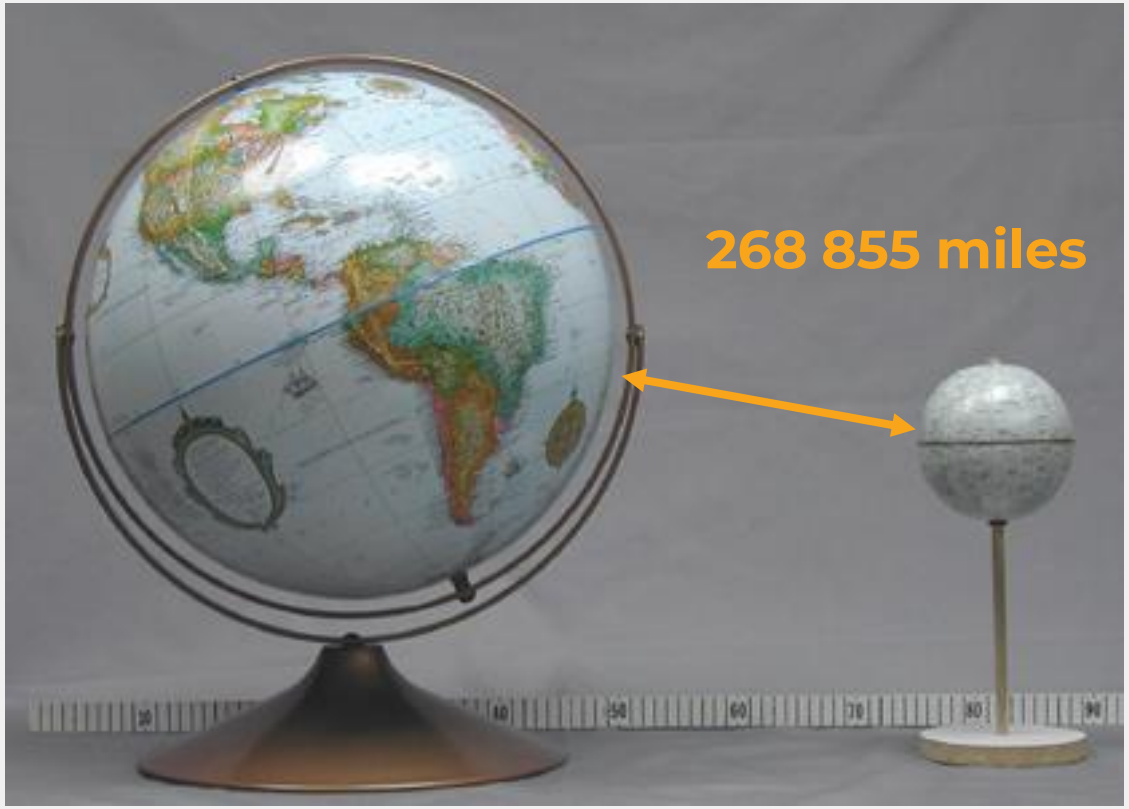
Hint: *GenSave* estimates 804 000 kWh saved.

Reduced CO_2 through reduced pumping

- *GenSave* estimates saving 40 193 US$ / year
- Input 0.05 US$ / kWh
- Means energy saving of 803 860 kWh

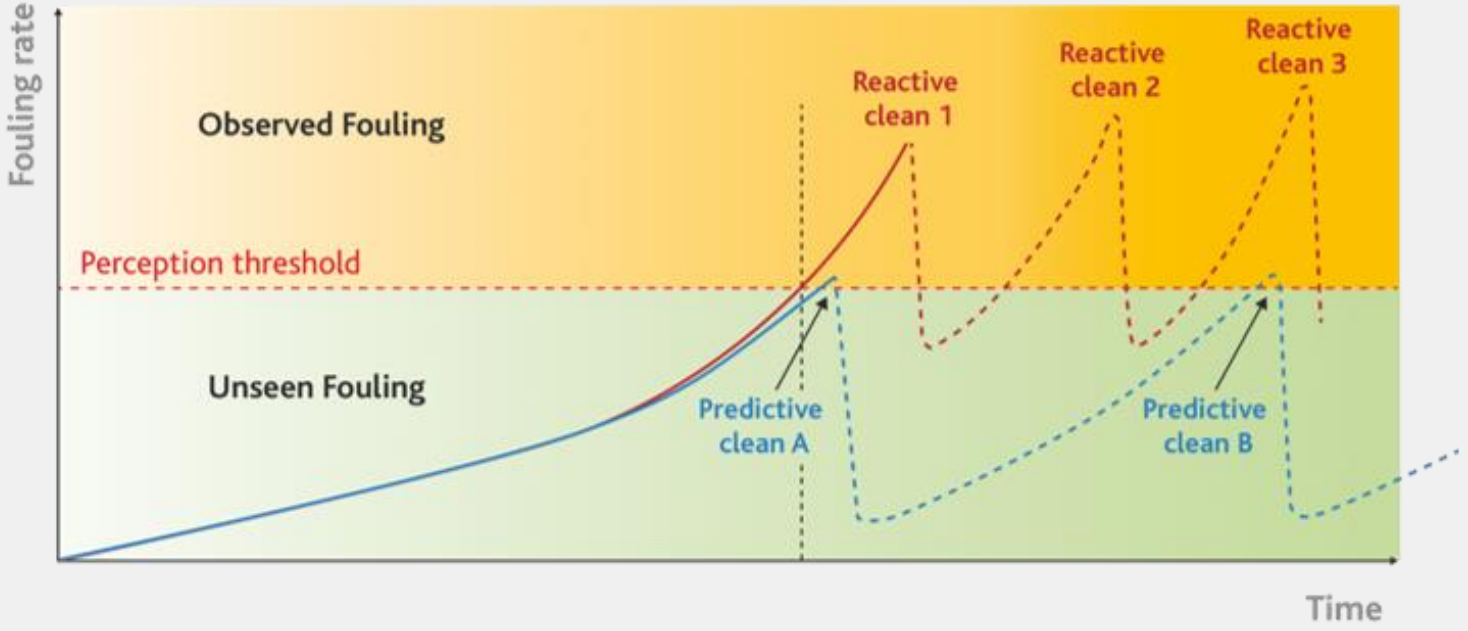
- How many kg of CO_2 will this save?

- ~570 000 kgCO_2 saved per year
- Equivalent to driving from Earth to the moon and back three times!



Software to convert ΔP into pumping costs

Monitoring power consumption



- Allows operators to better understand the wider benefits of cleaning RO membranes.
- Encourages predictive CIP, rather than reactive CIP.
- Extending the lifetime of membranes saves OPEX and CO_2 emissions by reducing the frequency with which membranes need to be replaced.

Software to convert ΔP into pumping costs

Source: Chesters *et al.*, IDA World Congress 2013

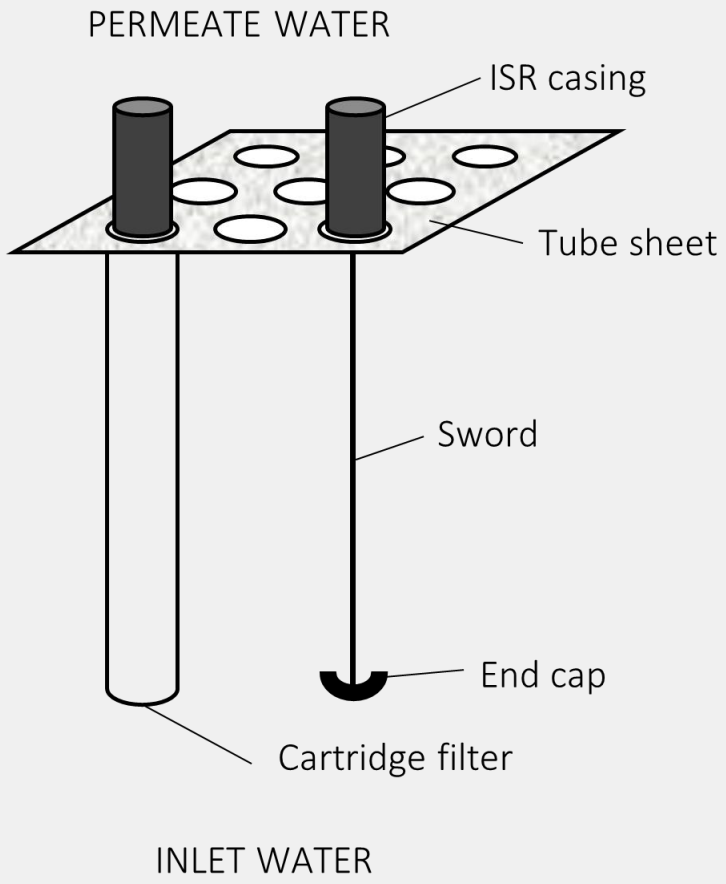
Cartridge filter internal support rod (ISR)

Cartridge filters are an essential precursor to protect RO membranes from rapid fouling.

How cartridge filters are installed:

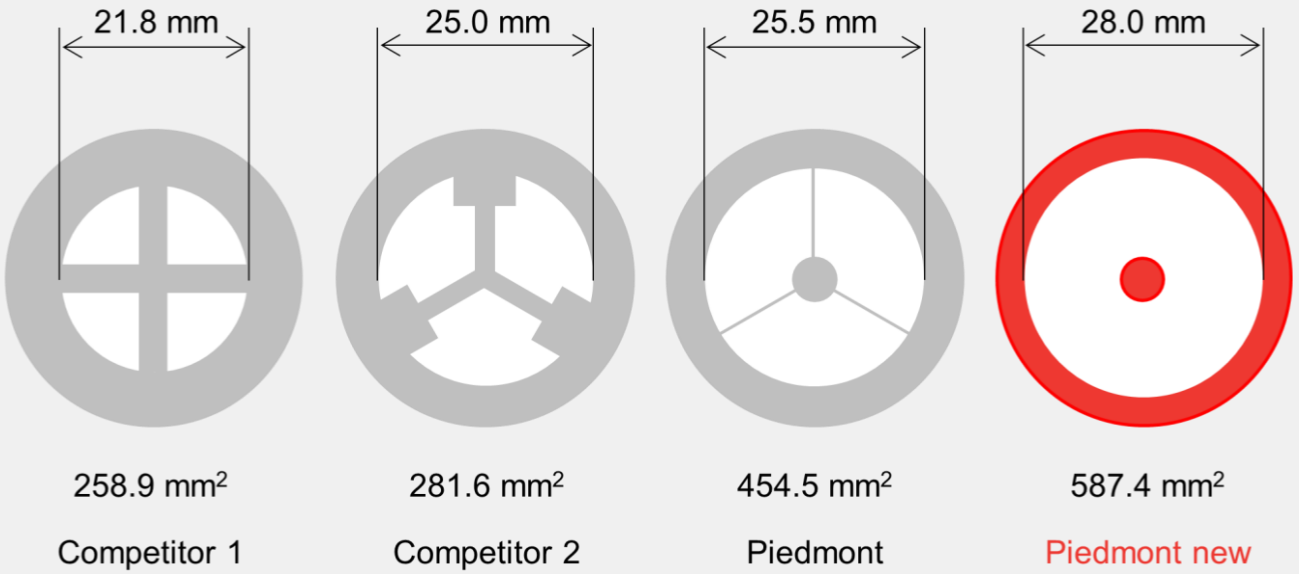
- **Tube sheets hold internal support rods (ISRs).**
- **Cartridge filters are threaded over the sword and secured in place by an end cap.**
- **Feed water passes through the cartridge filter then through the ISR casing into the permeate side.**

Revolutionary cartridge filter ISR design



Cartridge filter internal support rod (ISR)

- **ΔP in the cartridge filter stage can be reduced by optimising the design of the ISR.**
- **Successive generations of ISR have increased the free area through which the filtrate can flow, reducing ΔP.**
- **Some free area is occupied by the sword, which connects the end cap to the ISR casing.**
- **<u>A revolutionary design tweak to CF ISRs which maximises the free section, minimising ΔP, OPEX and CO_2 emissions.</u>**

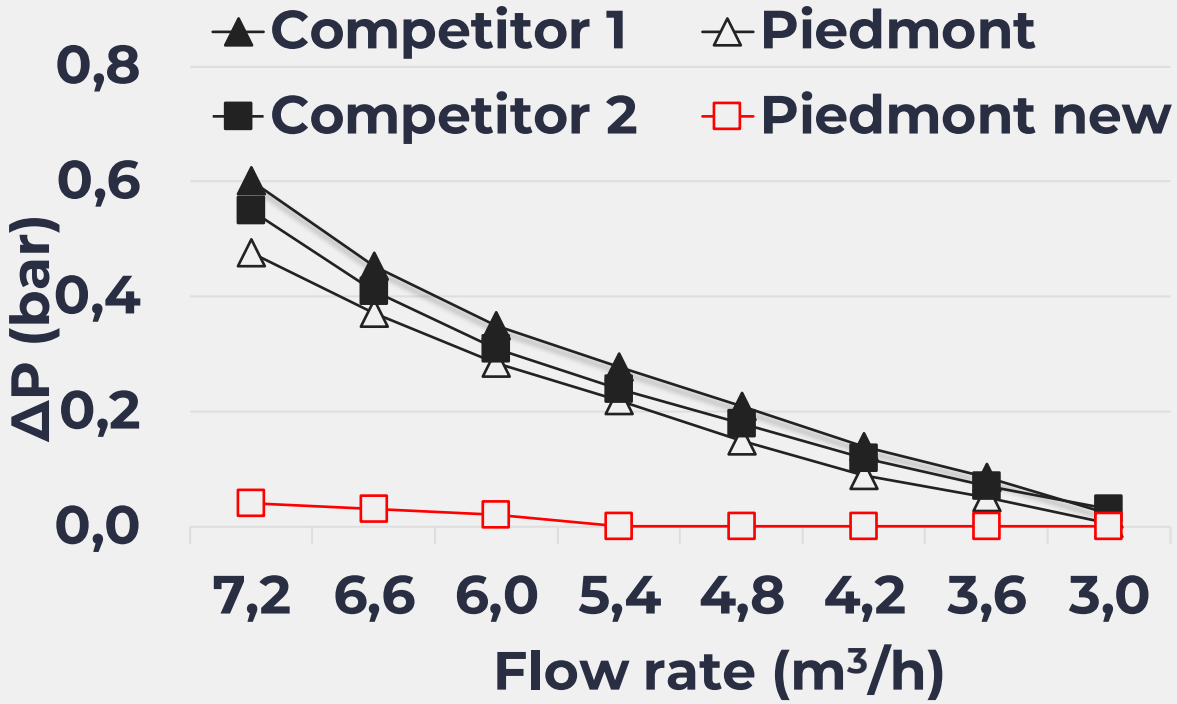


Revolutionary cartridge filter ISR design

Cartridge filter internal support rod (ISR)

- A larger aperture through which water can flow reduces pressure build up in the filtrate.
- Plant scale trials in Alicante, Spain, have showed that the new ISR can reduce ΔP by 50%.

ISR	ΔP, bar
Control*	0.35
Piedmont	0.27
Piedmont new	0.18



Revolutionary cartridge filter ISR design

*the previous ISR used at the plant

Cartridge filter cleaning

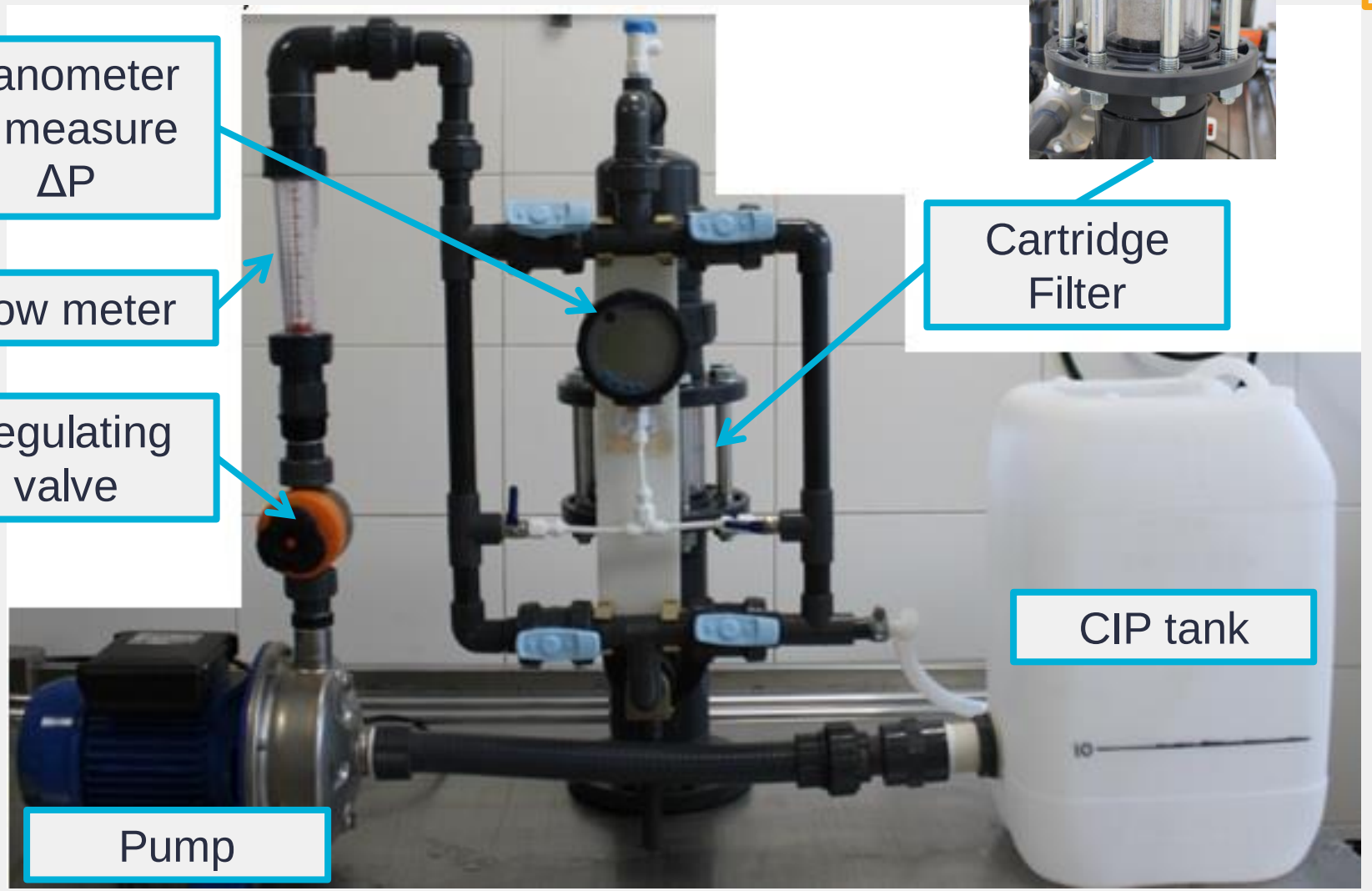
Specialty chemicals for CF cleaning

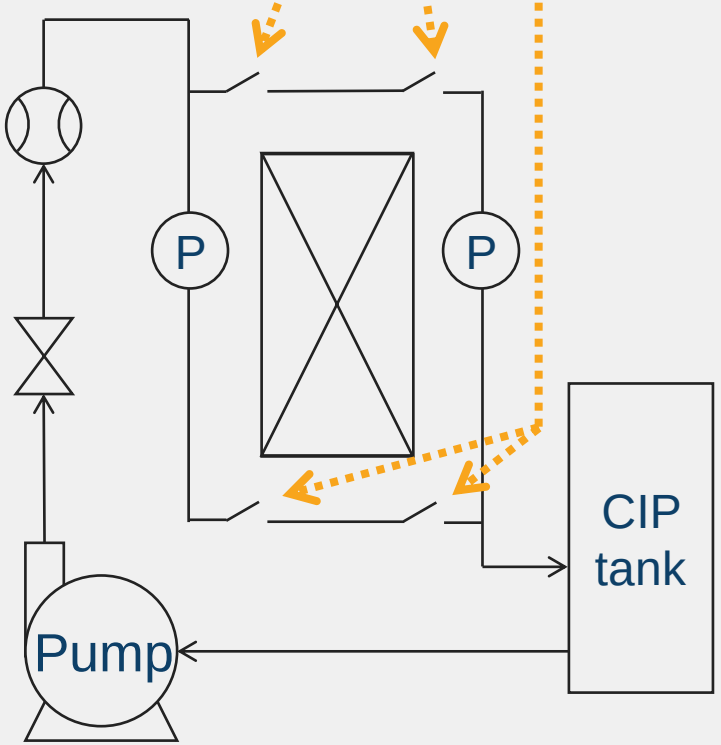
- **Recent plant-scale case studies have found that performance of cartridge filters can be partially restored by cleaning with commodity cleaning solutions.**
  - **SWRO plant in Saudi Arabia extended useable lifetime of cartridge filters by 51%, saving 109 000 US$/year by reducing the frequency of cartridge filter replacement.**
- **Specialty chemicals have proven to be more effective at removing foulant in RO.**
- **A new range of specialty cleaning chemicals designed to clear foulant from cartridge filters *via* clean in place (CIP).**

Source: Abutaleb *et al.*, EDS Conference, Las Palmas, 2022

Cartridge filter cleaning

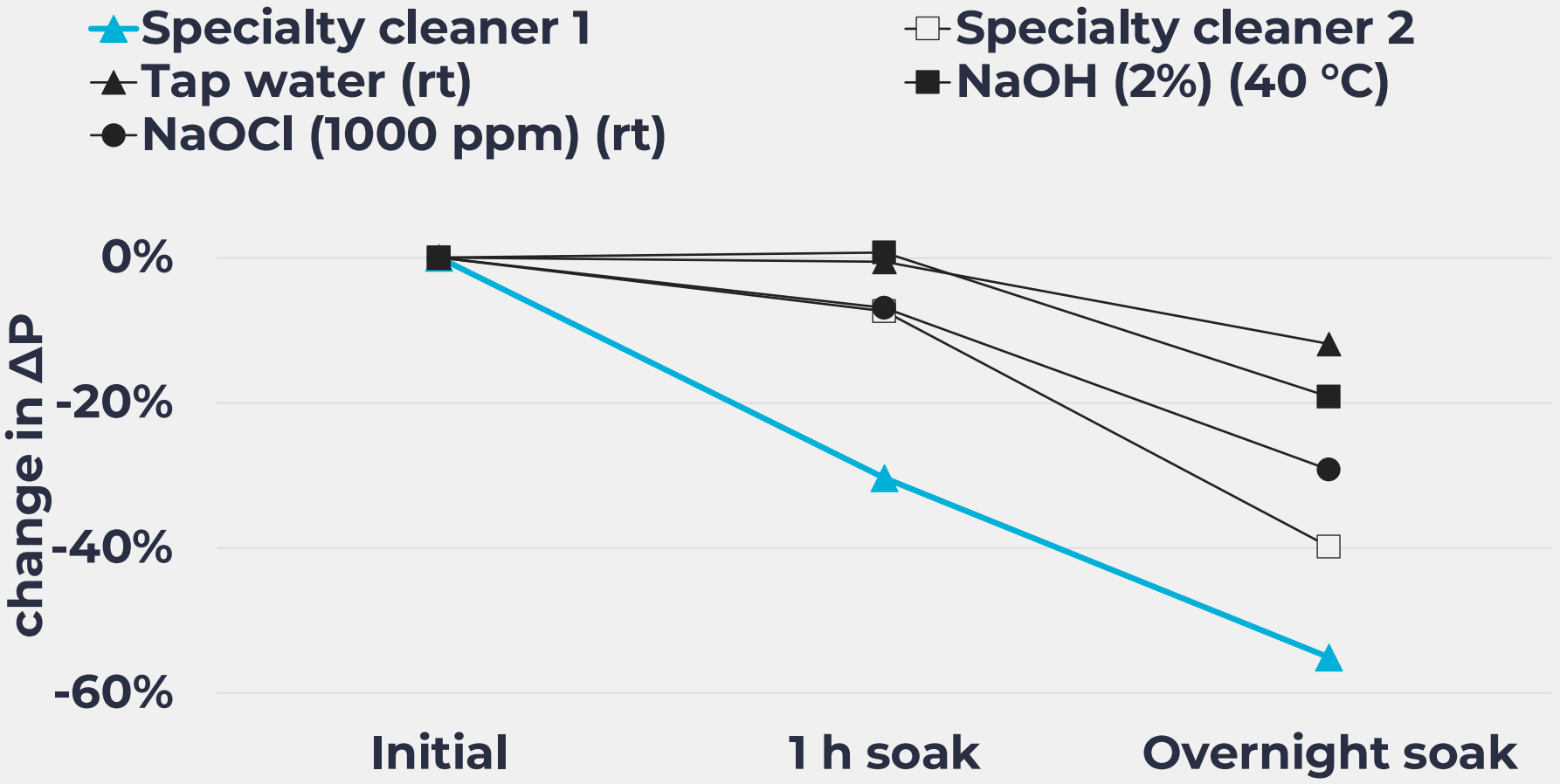
Open taps in diagonally opposite pairs to set forward flow or backwash





Cartridge filter cleaning

Specialty chemicals for CF cleaning



Source: GMP Laboratory, Madrid

Four innovations to reduce CO_2 emissions

Super-concentrated antiscalant 

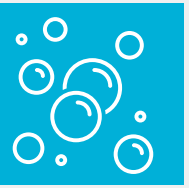
⇨ **Reduce shipping by up to 92%.**

Software to convert ΔP into pumping costs 

⇨ **Extend membrane lifetime.**

Revolutionary cartridge filter ISR design 

⇨ **ΔP reduced by 0.2 bar ⇨ energy saving 400 kWh/ element ⇨ 13M elements in the industry ⇨ 5.2B kWh saved ⇨ 3 700 000 000 $kgCO_2$ saved.**

Specialty chemicals for CF cleaning 

⇨ **1 kg CO_2 / element ⇨ 52M elements consumed / year ⇨ 52 000 000 $kgCO_2$ / year ⇨ reduced by 50% if cleaning doubles lifespan of element ⇨ 26 000 000 $kgCO_2$ / year saved**

Four innovations to reduce CO_2 emissions

Super-concentrated antiscalant

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Revolutionary cartridge filter ISR design

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