Potential for NF in the Future of Desalination

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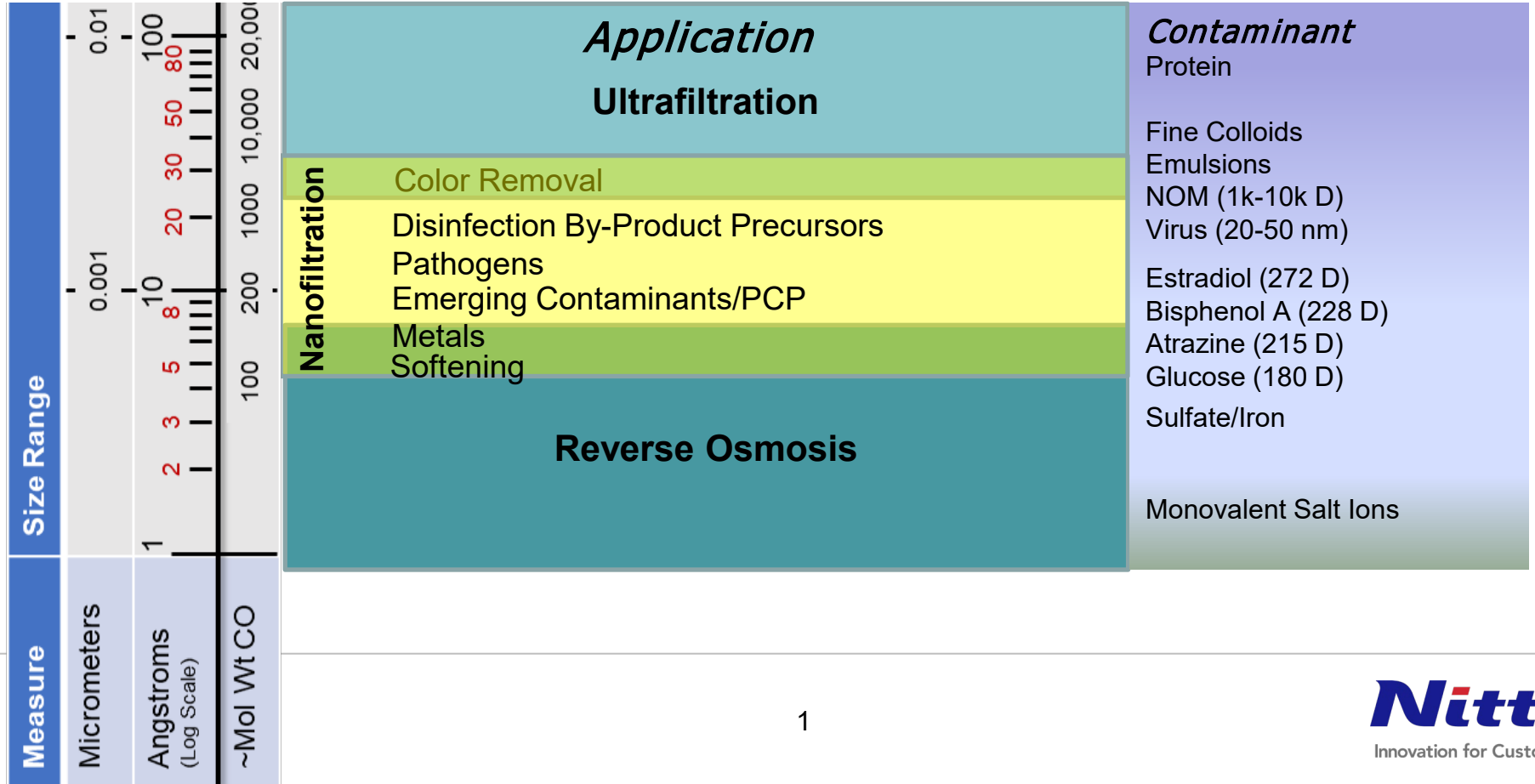
NF Membranes Have Approximately 150-3000 MWCO and are Ion Selective

HYDRANAUTICS



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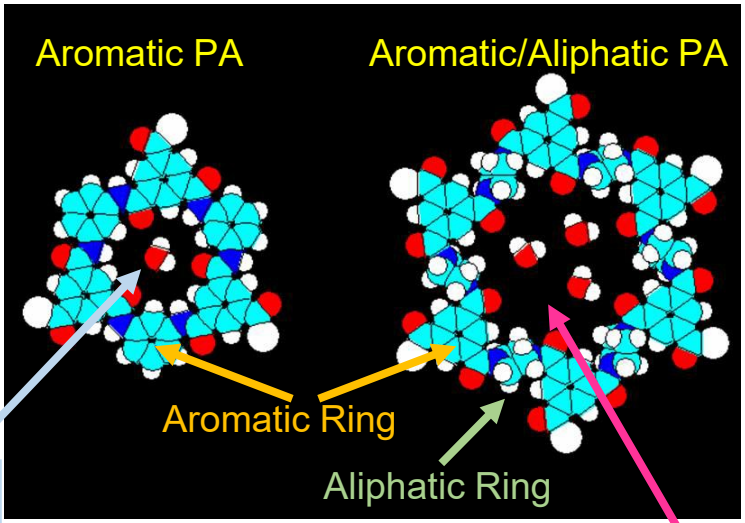
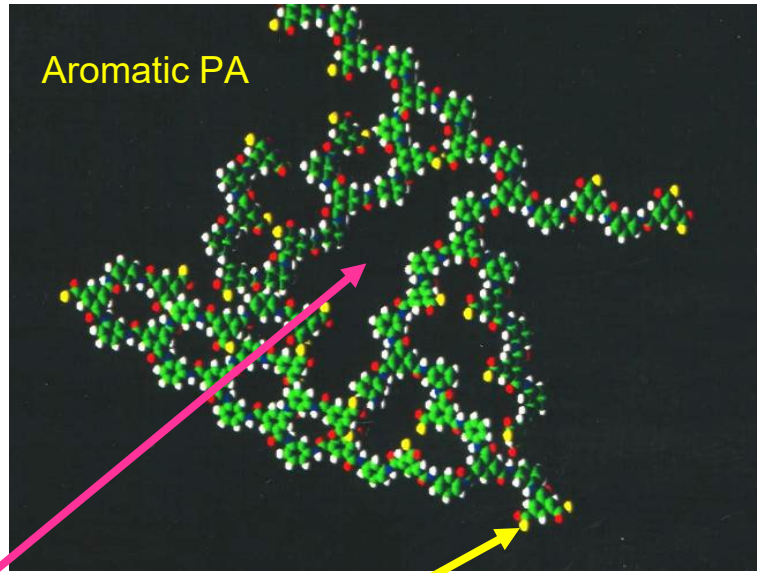
Source of Ion Selective Properties: Polyamide NF

HYDRANAUTICS

- Negative Charge
- Size of Macro Cycles
- Packing Geometry
- Anion Selective





Hydrogen Bonded Water Molecule

Free Volume

Negatively Charged Carboxylates

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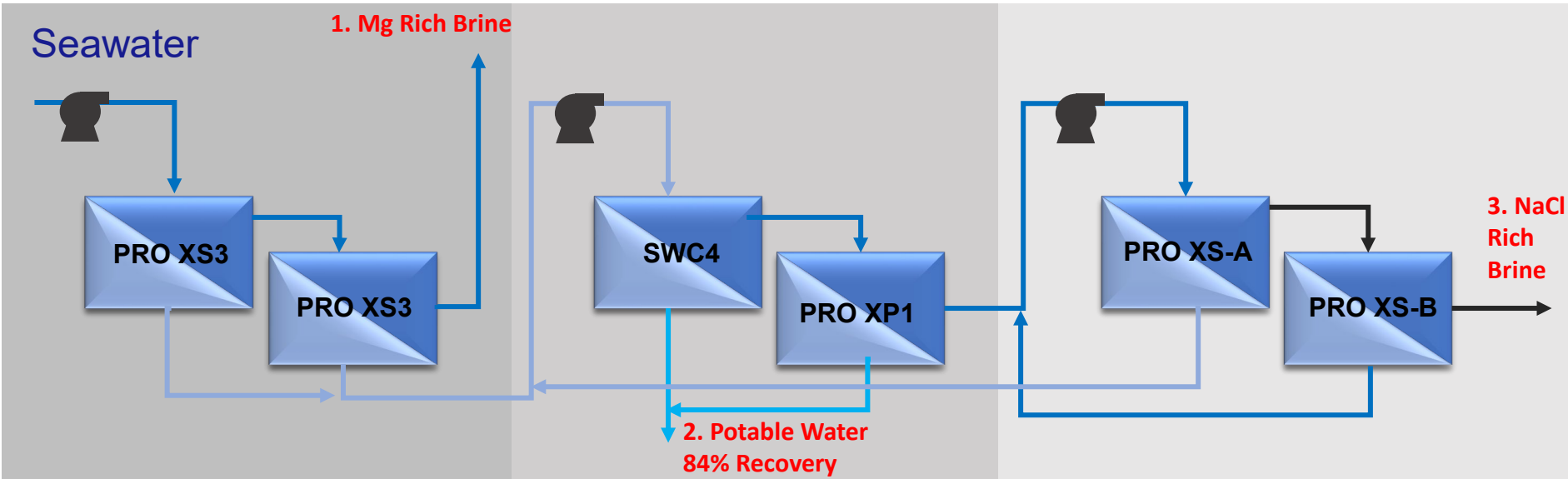
Value of Ion Selectivity & Controlled Rejection: Example of Ultra-High Recovery with NF, RO & BCM

HYDRANAUTICS



Low Pressure NF
- Max Hardness removal
- Maximum monvalent passage

SWRO/UHP-RO

* Potable Water

Brine Concentration
* NaCl super concentration
* Pass large amount of salt

New, High Mg Rejection NF Membrane

HYDRANAUTICS

PRO-XS-X
SPECIFICATION

Specified Performance & General Product Description

Salt rejection	99.8%
Permeate flow	9,000 gpd (37.9 m^3/d)
@ 110 psi (7.6bar), 2,000 mg/l $MgSO_4$, 15% Rec	

Details

Memb Area	Max Press*	Feed Spacer	Temperature
400 ft^2 (37.2 m^2)	1200 psi (82.7 bar)	34 mil	See Chart

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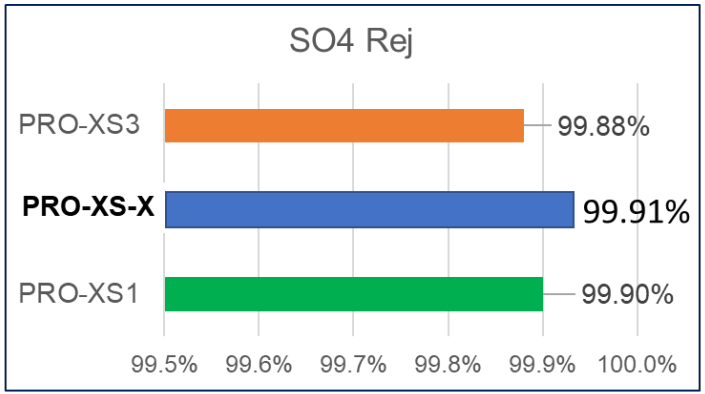
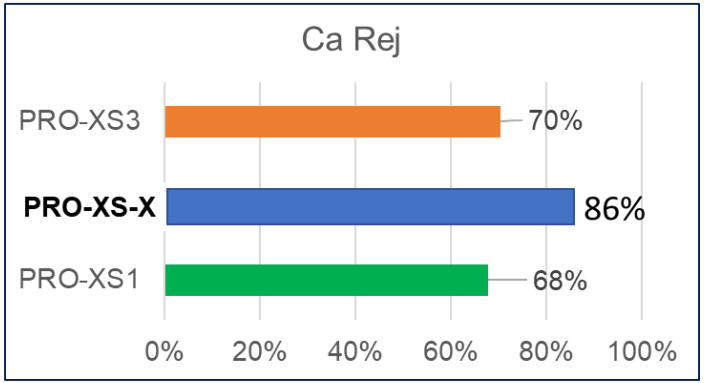
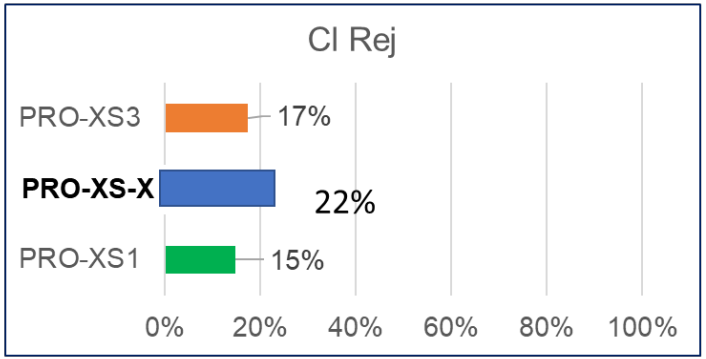
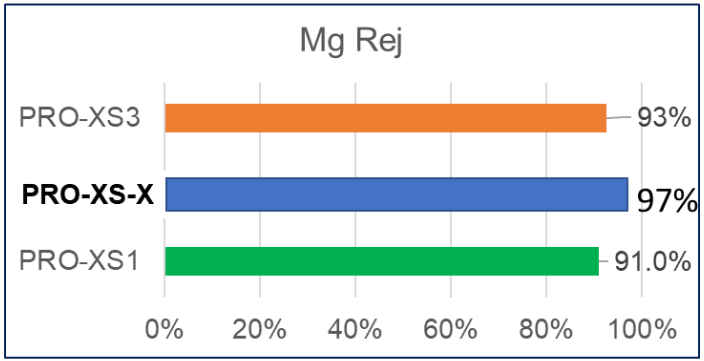
Comparative Performance of PRO XS Products

HYDRANAUTICS









Lab Testing on Synthetic Seawater: 15 gfd flux, 15% recovery, 25 C

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New, Xtra Concentration (XC) Membranes

HYDRANAUTICS

PRO-XC
SPECIFICATION

Specified Performance & General Product Description

	XC-A	XC-B	XC-C
Salt rejection (%)	93	88	96
Perm flow (gpd)	12,000	15,000	9,000
(m^3/d)	45.5	56.8	34.1
400 ft^2 (37.2 m^2) area, 34 mil feed spacer			

Test Conditions

Feed NaCl	Applied pressure	Permeate Recovery rate	Temperature	Feed pH
32,000 ppm	600 psi (41 bar)	10%	25° C (77° F)	6.5 – 7.0

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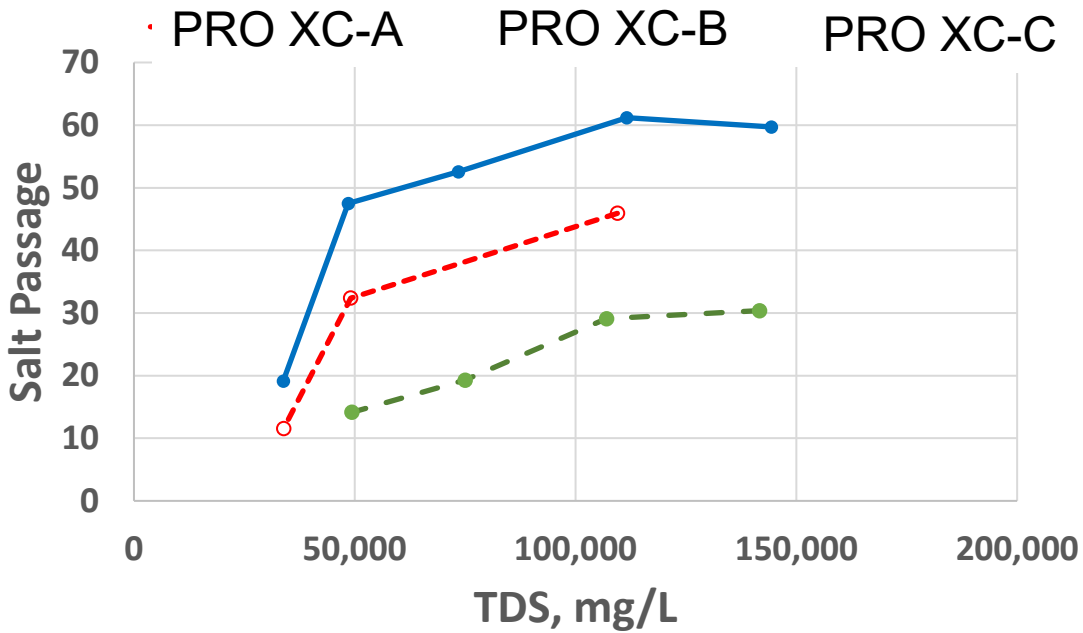
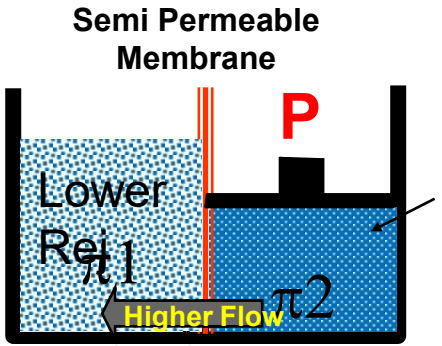
New, Brine Concentration Membranes

HYDRANAUTICS





$$P > (\pi_2 - \pi_1)$$

- Lower rejection membranes increases π_1, which decreases applied Press
- High TDS Permeate is recycled to preceding stages

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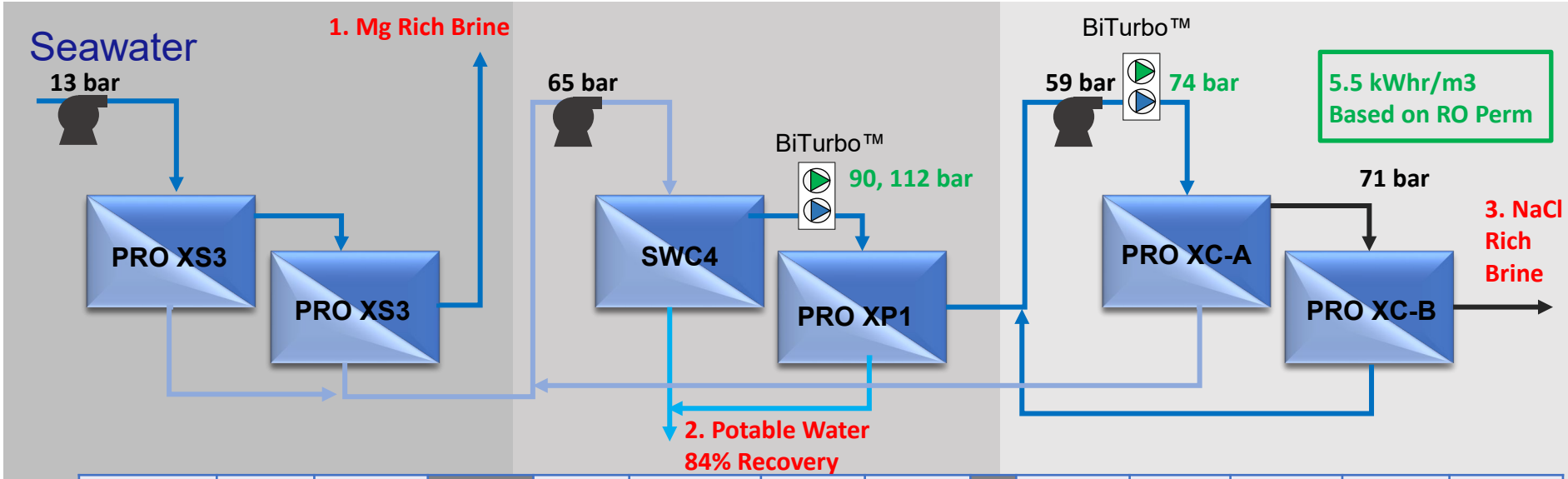
Ultra-High Recovery System: NF, RO & BCM

HYDRANAUTICS



	Feed	Perm	Conc		Feed	Perm Tot	Conc 1	Conc 2		Feed	Perm 1	Conc 1	Perm 2	Conc 2
Flow	1330 m3/hr	1000	330		1250	840	760	400		540	240	300	130	170
TDS	45,000 mg/l	39,000	63,000		44,000	750	68,000	120,000		125,000	66,000	174,000	124,000	214,000
Cl	23,500 mg/l	20,000	36,500		24,000	450	41,500	76,000		65,000	40,000	85,000	61,000	105,000
Mg	1600 mg/l	1650	7200		125	0.15	200	400		300	21	550	40	950

Low Pressure NF

- Hardness removal

SWRO/UHP-RO

* Potable Water

Brine Concentration

* NaCl super concentrate

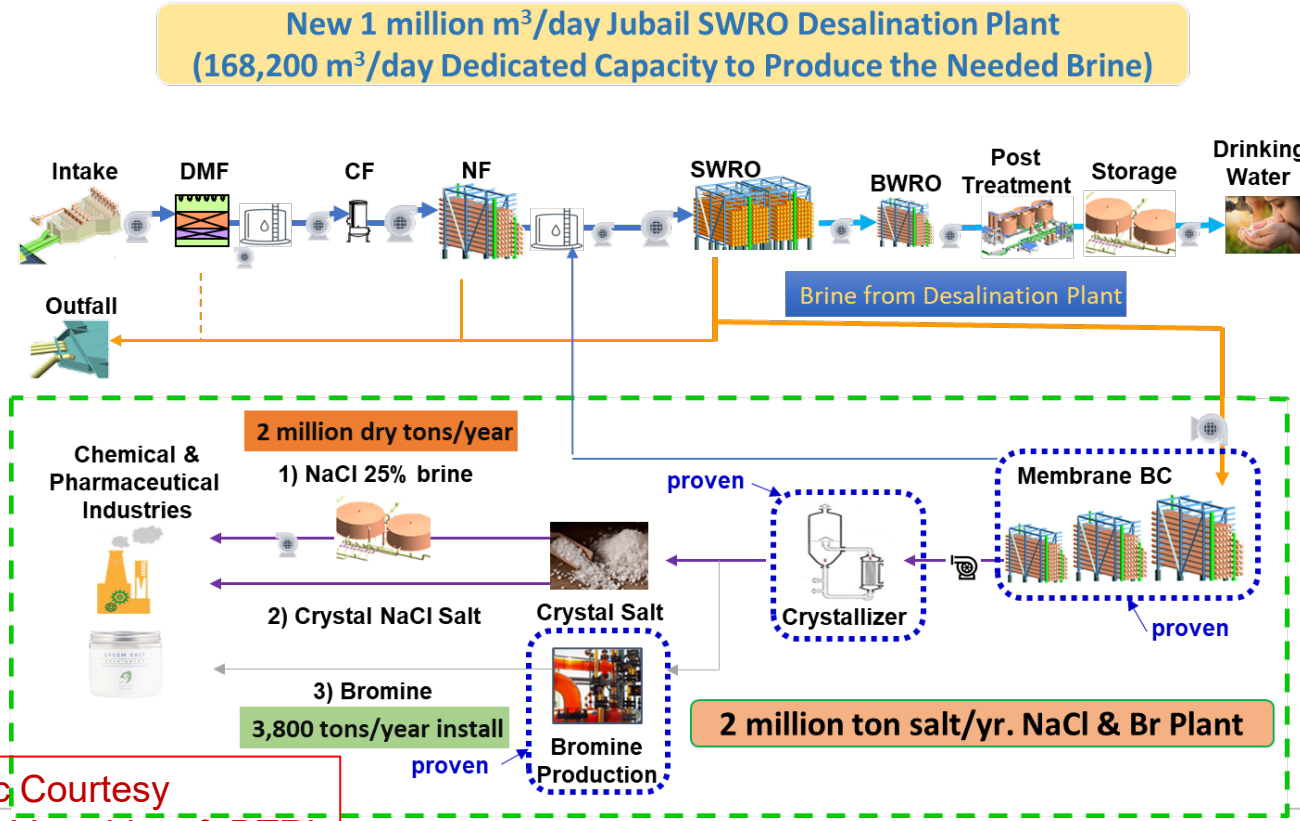
Commercial Potential

HYDRANAUTICS

- Plans for a commercial plant in 2025
- 2 Million tons per year of dry salt

For a 100k m3/d plant:

- Annual Water Production Cost @ US$0.60/m3
- =US$22 million/year
- NaCl Salt Sale Revenue @ US$65/dry ton
- = US$65 million/year



"Overview of DTRI System for Brine Mining of NaCl and Br" by Nikolay Voutchkov
Ocean Brine Mining Conf
Al Khobar, KSA
Mar 21-23

Graphic Courtesy
Nikolay Voutchkov & DTRI

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Conclusions

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- NF Membranes will play a much bigger role for the treatment of seawater in the future
- Two very different types of NF characteristics have been developed for seawater treatment
  - High divalent rejection, High monovalent passage
  - High pressure NF that pass variable amounts of monovalent salts
- Testing has shown these two types of NF combined with SWRO and UHPRO can achieve TDS values of 250,000 mg/l, making the concentrate ideal for chlor alkali feedstock
- Plans are in place of commercialization of this technology

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