International
Desalination
Association

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"Desalination: The Vision of Today and the Future"

"Recent Advancements in Desalination"

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4 March 2009

Top Five Advancements in Seawater RO Desalination and Pretreatment Breakthroughs

More Efficient Energy Recovery Devices
Improved Pretreatment
Large Diameter RO Technology
Improved Membrane Properties
Hybrid RO/Thermal Plants in the Middle East

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Energy Recovery Devices (ERDs)

- Purpose
  - To improve energy efficiency of the RO system by capturing energy remaining in the RO concentrate stream

- Types
  - Direct coupled Pelton-wheel
  - Turbocharger
  - Isobarics
    - Pressure exchanger
    - Work exchanger

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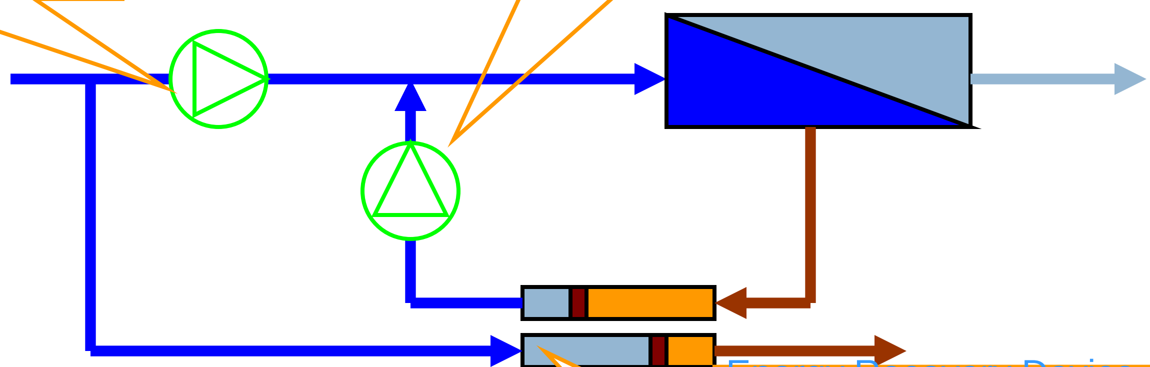
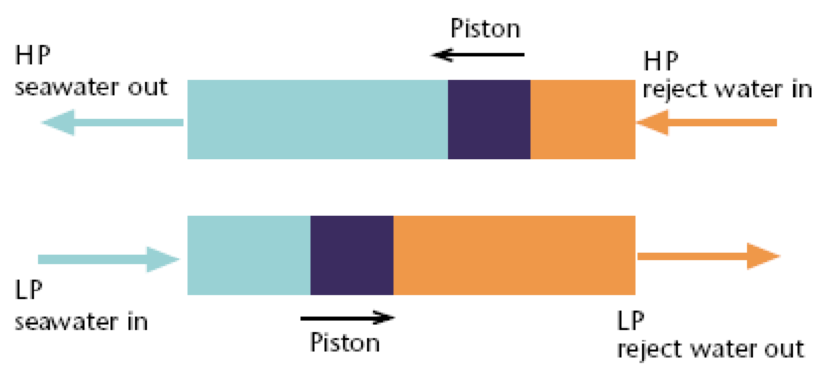
Isobaric Pump Arrangements

HP Pump
- Pressure: Max Design P
- Flow: ~Qp
- Typically w/ VFD

HP Booster Pump
- Pressure: TMP + losses
- Flow: ~Qc
- Typically w/ VFD to adjust for fouling





Energy Recovery Device
- Positive Displacement
- Losses in ERD up to 15 psig
- Leakage of TDS from concentrate to feed
- Raises membrane feed TDS ~2-3%
- Raises required feed pressure slightly.

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	Isobaric Pressure Exchanger	Turbocharger (Centrifugal)	Direct Coupled (Centrifugal)
Efficiency	90% – 92%	55% - 70%	65 – 75%
Principle of Operation	Positive displacement	Centrifugal – transfer shear energy	Centrifugal – transfer shear energy
System flexibility	Must place multiple units together for large flows	Wide hydraulic capacity range available	Wide hydraulic capacity range available
HP Pump Pressure	Sized for max design pressure	Sized for fraction of design pressure (less boost pressure)	Sized for max design pressure
HP Pump Flow	Sized nominally for permeate flow. Booster pump sized for nominal concentrate flow.	Sized for max design flow. (recovered energy boosts HP discharge)	Sized for max design flow (recovered energy reduces power requirement)

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Final Thoughts on ERDs

- Important to conduct life cycle analysis to determine overall ‘best’ energy recovery for application
- Isobarics being developed in larger capacity configurations
- Centralized pumping/ERD has met minimal acceptance to date

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Pretreatments at Work

- Dissolved Air Flotation (DAF)
- Membrane Filtration
- Diatomaceous Earth Filters
- Chemical-Free Pretreatment

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Perceived Membrane Filtration Benefits

- Improved pretreated water quality
  - lower suspended solids
  - lower biological foulling
  - resulting improved RO performance
- Fewer RO cleanings – lower operating cost
- Reduced RO fouling – lower energy consumption
- Longer RO membrane life
- Smaller footprint size for pretreatment and RO
- Potentially lower chemical and sludge handling cost

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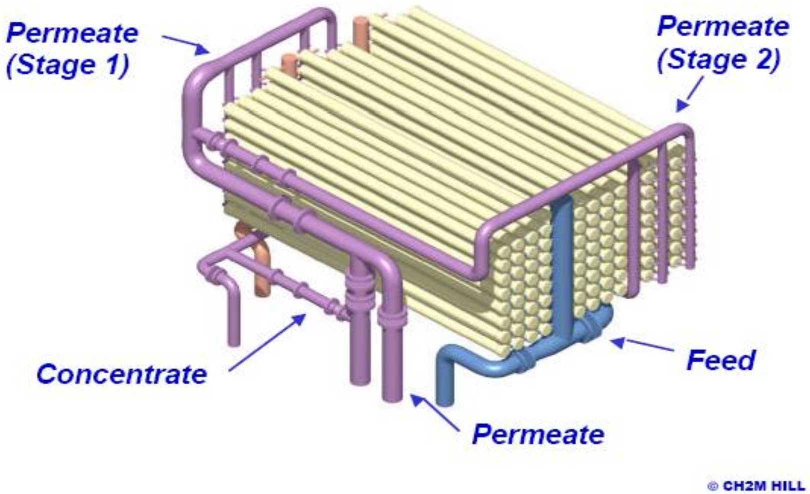
Why Large-Diameter Elements?

- Expected that economics for large plants will improve with larger elements
- Standard size helps in the bidding process – multiple suppliers
- Overall impact – reduce the cost of RO/NF plants

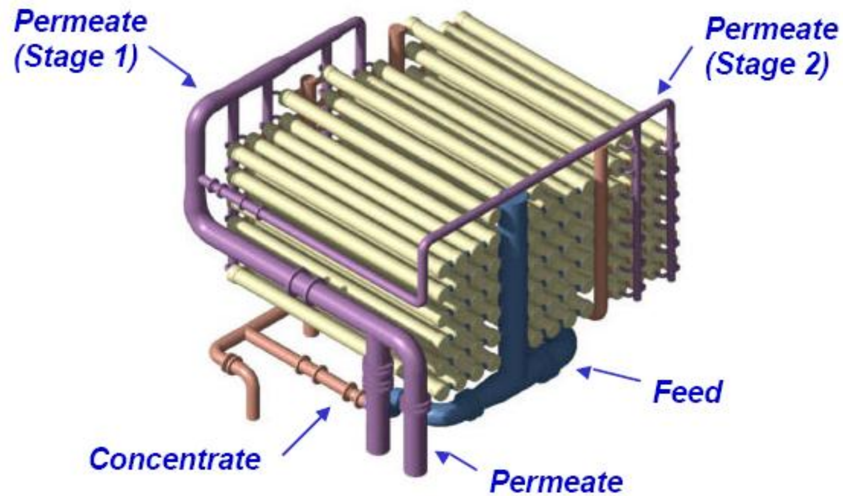
Henthorne et al, IDA 2005

Comparison 8 inch vs 16 inch train



8-inch
Train-size: 4.17 mgd
Vessels: 99 Footprint: 588 ft2

16-inch
Train-size: 12.5 mgd
Vessels: 75
Footprint: 1015 ft2



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Active Area Comparison - FilmTec

Full utilization of the element volume allows a 4.3X increase in membrane active area versus 8-inch.

Nominal Module Diameter	Feed Spacer Thickness in (mm)	Permeate Tube Outer Diameter in (cm)	Scroll End Area in^2 (cm^2)	Active Membrane Area ft^2 (m^2)	16:8 Ratio
8-inch	0.028 (0.71)	1.5 (3.8)	40.7 (263)	400 (37)	4.3
16-inch		3.5 (8.9)	175.4 (1132)	1725 (160)	
8-inch	0.034 (0.86)	1.5 (3.8)	40.7 (263)	365 (34)	4.3
16-inch		3.5 (8.9)	175.4 (1132)	1570 (146)	

Courtesy FilmTec

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Element Design Summary

16-inch Comparison to 8-inch:

- **4.3-times increase in active area and permeate flow**
- **Same materials**
- **Same rejection**
- **Same feed pressure**
- **Same pressure drop**

Membrane	Feed Spacer Thickness Inch (mm)	Active Membrane Area ft^2 (m^2)	Permeate Flow gpd (m^3/d)	Stabilized Rejection (%)
BW30	0.028 (0.71)	1725 (160)	45,000 (170)	99.5
BW30	0.034 (0.86)	1570 (146)	40,800 (155)	99.5
SW30HR	0.028 (0.71)	1725 (160)	32,000 (121)	99.8

Courtesy FilmTec

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Handling Options

The increased weight of 16-inch elements is both a barrier and an opportunity.

- 16-inch elements weigh 120 pounds (54 kg)
- 8-inch elements weigh 30 pounds (14 kg)

Use of technology to reduce manual lifting and loading will

- ensure better safety
- provide greater speed

than current 8-inch handling.

Koch Membranes cradle and cable winch for staging, pushing, pulling

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Handling Options

A mechanical loading tool was developed by Dow to demonstrate the value of improved technology for element handling.

Features include:

- **support and alignment derived solely from attachment to vessel**
- **electric motor for element pushing and pulling**
- **levers for element coupling and decoupling**
- **feedback sensors for element positioning**

Loading tool attached to 16-inch pressure vessel

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Improved Membrane Performance

Year	Salt Passage	Normalized Salt Passage	Membrane Life, years	Normalized Membrane Life
1978	1.4	1	3	1
1989	1	0.71	3	1
1995	0.8	0.57	5	1.7
2000	0.5	0.36	5	1.7
2002	0.4	0.29	5	1.7
2006	0.2	0.14	7	2.3

J. Birkett & R Truby, 2007

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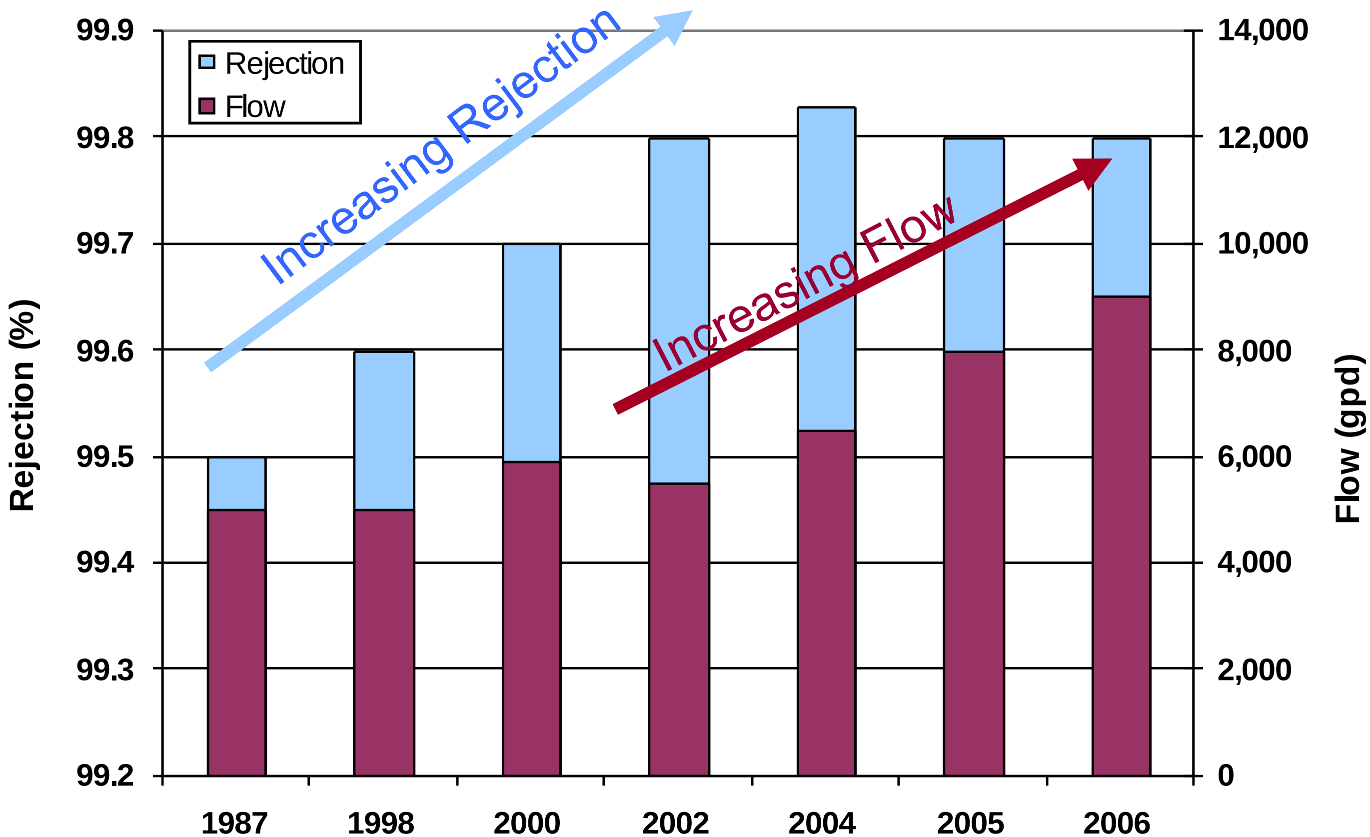
Reduced Membrane Pricing

Year	Element Price	Price ft^2	Normalized Price/Area	CPI	1978= 1 CPI	Norm 78 Price/Area
1978	$950	$6.33	1	71	1	1
1989	$875	$2.92	$0.46	124	1.75	0.26
1995	$750	$2.27	$0.36	152	2.14	0.17
2000	$645	$1.79	$0.28	172	2.42	0.12
2002	$435	$1.18	$0.19	180	2.54	0.07
2006	$550	$1.38	$0.22	200	2.82	0.08

J. Birkett & R Truby, 2007

Increased Salt Rejection & Capacity



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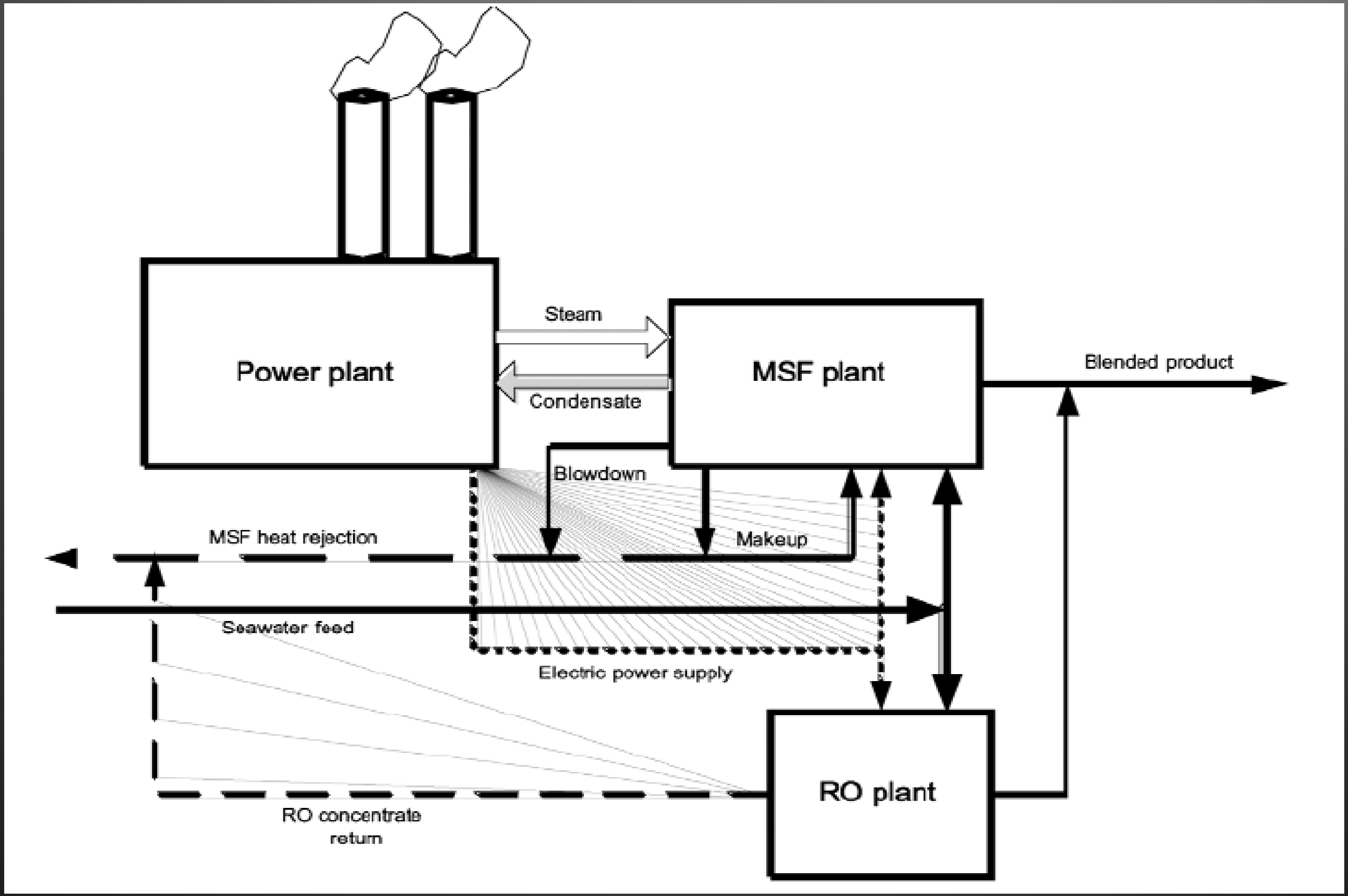
Hybrid system components and their relations.



Combining the best features of membrane and distillation and power

Multistage Flash (MSF)

- Not sensitive to seawater (TDS):
- Top brine temperature:100-112° C
- Performance ratio: 8
- Steam consumption 23.7 tons/1MIGD
- Electrical power: 3-4 kWh/m^3
- Scale inhibitors used for scale control
- High purity distillate
- Recycle type plant, Dual purpose plant
- Capital cost 5.5-10 US MM$/1MIGD
- Unit size 16.7-20 MIGD

Multi-Effect Distillation (MED)

- Not sensitive to seawater (TDS):
- Top brine temperature: 63° C
- Performance ratio: 8-12
- Steam consumption 15.8 tons/1MIGD @ PR12
- Electrical power: 1.2-2 kWh/m^3
- High purity distillate
- Scale inhibitors used for scale control
- Dual purpose plant
- Capital cost 4.5-9 US MM$/1MIGD
- Unit size reached 8 MIGD in Sharjah, new design for unit sizes 10-15 MIGD

IDA Seawater Reverse Osmosis (RO)

- RO is a mature technology with high degree of reliability with challenge on pre-treatment.
- Sensitive to seawater (TDS)
- High Recovery 40-45%
- Permeate meeting WHO guidlines
- Scale inhibitors used for scale control
- Using electric energy recovery devices results in total plant energy requirements of 3.5 kWh/m^3
- The capital cost of the RO plant today vary from $4.0-$7.5 per IGPD.

Improvements in distillation processes

- TOP BRINE TEMPERATURE : The Increase of TBT can Allow Higher Production With Almost Same Desal Trains
- HYBRIDIZATION : The Application Of Hybrid Technologies (MSF + RO+NF, or MSF+RO+NF + MED) can Improve Overall Efficiency
- THERMAL IMPROVEMENT : Better HTC , new materials, New MSF+MED Schemes And Ancillary Equipment.

Potential for MED technology improvements

- Increasing TBT from 63°C to 80-100°C with Nanofiltration

- Increase efficiency to PR 12-16 from current 9.

- Increase unit size to 15 MIGD from current 8 MIGD

- Improve HTC by oval and corrugated plates

- Hybridize with MSF-RO-NF

Energy Requirements (Steam/Electricity)

	Process Live Steam (ton product/ton steam)	Electricity kWhr/ton product
Multi Stage Flash	8	4
Vapour Compression	n/a	8
Multi Effect Distillation	12	2
Reverse Osmosis:		
with energy recovery	n/a	3.5-5.5

Energy Requirements for Desalination

Process/energy type	MED	MED - TVC	MSF	VC	RO
Steam pressure, ata	0.2 - 0.4	2.5-3.5	2.5-3.5	_	_
Electric energy equivalent, kWhr/m^3	4.5	9.5-11*	9.5-11.0	_	_
Electric consumption, kWhr/m^3	1.2--1.8	1.2--1.8	3.2-4.0	8.5	3.5-5.0
Total electric energy equivalent, kWhr/m^3	5.2-6.3	10.7-12.8	12.7-15	8.5	3.5-5.0

Past Simple hybrid

- Product waters from the RO and Distillation plants are blended to obtain suitable product .
- Power to water ratio can be significantly reduced.
- A single stage RO process can be used.
- Higher Recovery, lower pretreatment

Integrated hybrid

- The feedwater temp. to the RO plant is optimized using cooling water from the heat-reject section of the MSF/MED or power plant condenser. Constant feed temperature
- The low-pressure steam from the MSF/MED plant is used to de-aerate or use de-aerated brine as a feedwater to the RO plant to minimize corrosion and reduce residual chlorine.

Integrated hybrid

- Blending distillate and membrane permeate will reduce requirements on Boron removal by RO.
- The RO and NF membrane life can be extended. (12 years)

Integrated hybrid environmental benefits

- Cool RO Reject and Feed to be used as a cooling source for heat reject section of distillation plants.
- The blend of reject stream from RO with warm seawater and blowdown from distillation or power plants reduces heavy density plume of RO outfall.
- Blend of RO permeate reduces temperature of distillate.
- A common, smaller seawater intake & outfall.

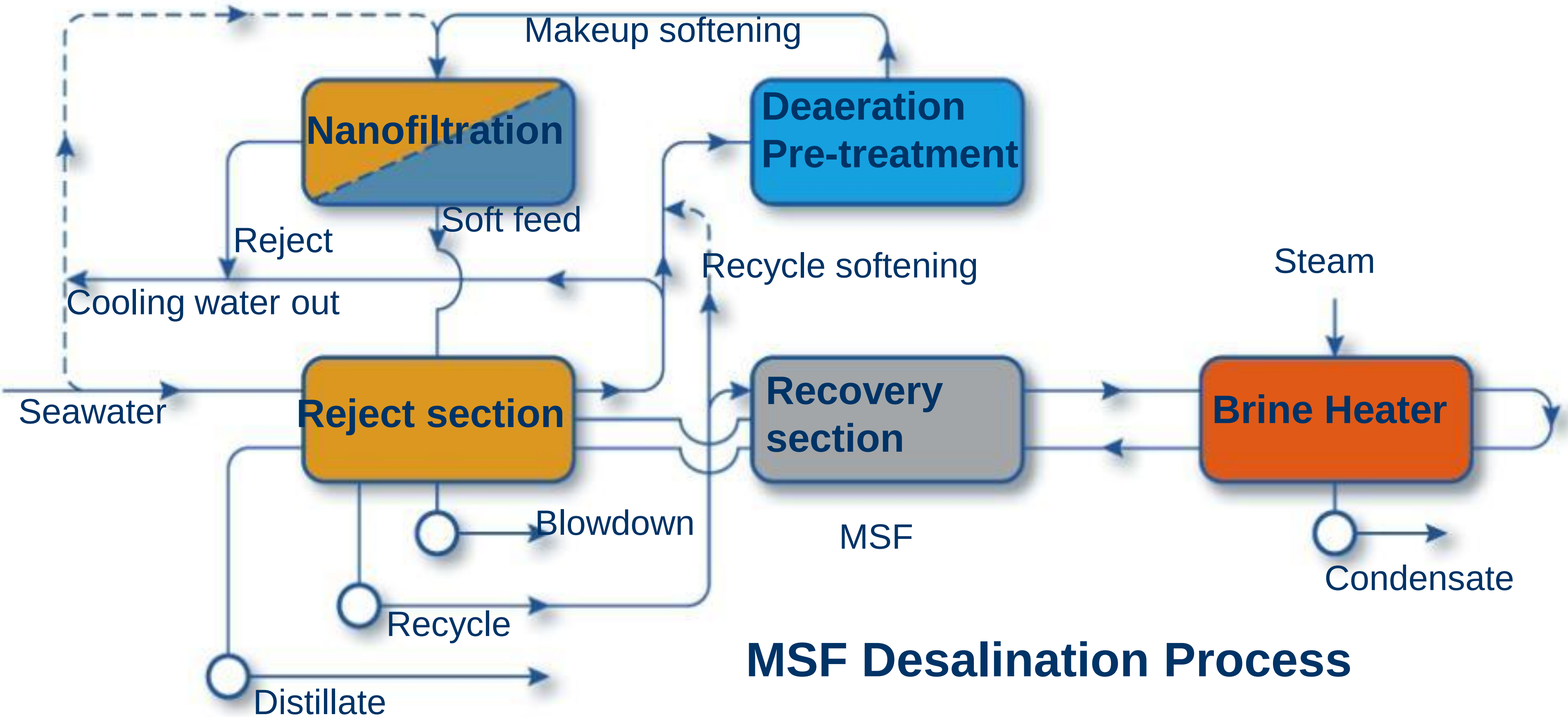
Fujairah Hybrid.

The Fujairah1 plant due to hybridization generates only 500 MW net electricity for export to the grid, and 662 MW gross for water production capacity of 100 MIGD. Otherwise similar MSF only plant in Shuweihat required 1500 MW for the same 100 MIGD capacity. The Fujairah desalination plant is split into 62.5 MIGD from the thermal part and 37.5 MIGD from the membrane process.

Fujeirah 2 will be 100 MIGD MED and 30 MIGD RO

Fujeirah Plant - Power Desalination Hybrid

LET Nanofiltration NF System



MSF Desalination Process

LET Proprietary

Benefits of Nanofiltration

- PREFERENTIALLY REMOVES SCALING (DIVALENT) IONS
- ALLOWS HIGHER TOP BRINE TEMPERATURE
- FOR MSF (121°C vs. 105°C),
- FOR MED (80°C vs 63°C)
  - Higher Flash Range Increases Production
  - Reduced Capital Costs
  - Reduced Operating Costs

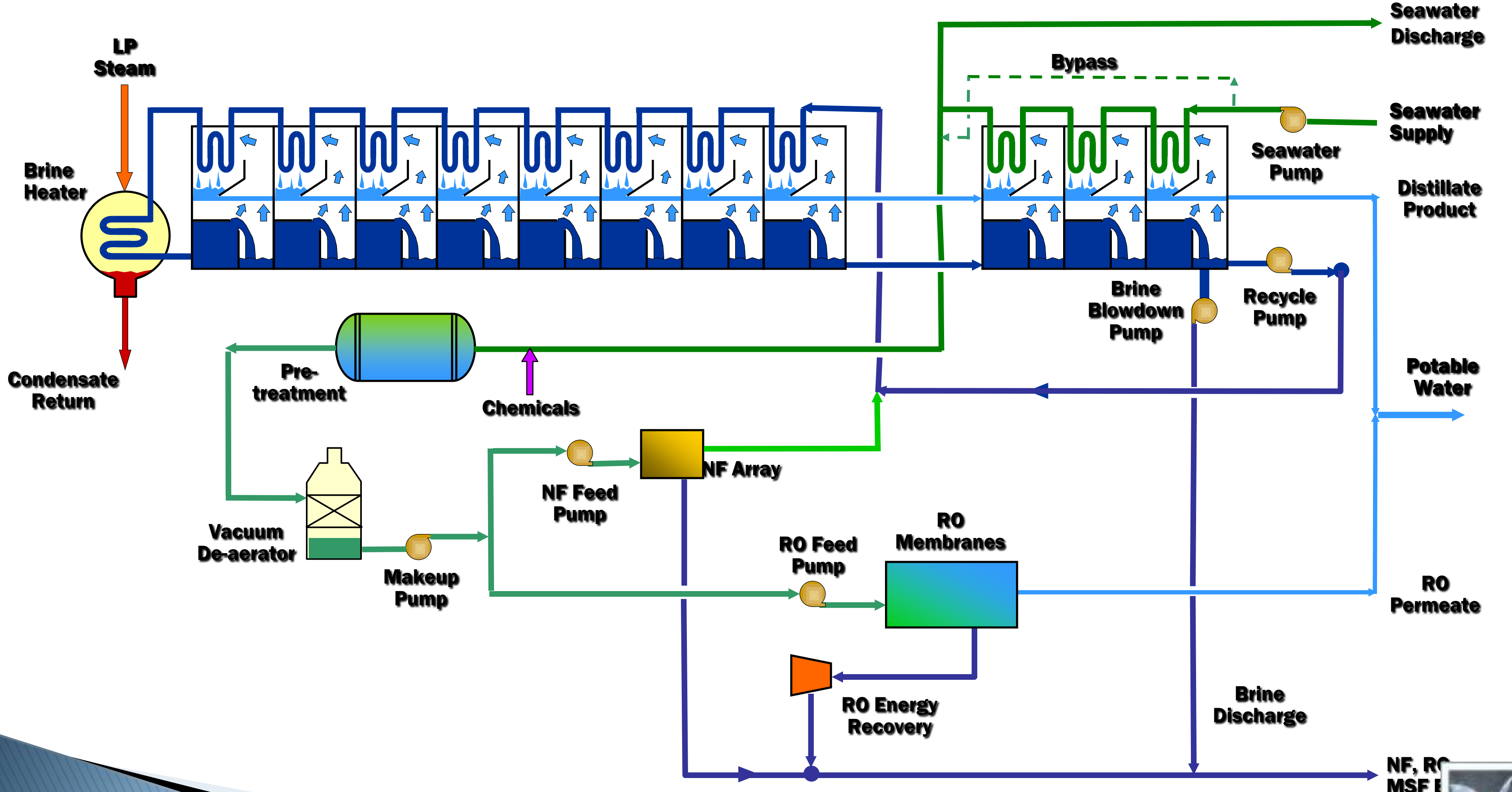
THE SEWA LET INTEGRATED UPGRADING

- DESIGN TO INCREASE 44% THE CAPACITY OF EXISTING MSF FROM 5 MIGD to 7.2 MIGD, ACHIEVED 50 % to 7.5 MIGD
- MIMIMUM FOOT PRINT, NO ROOM FOR NEW DESALINATION PLANTS
- REDUCE OPERATING COST
- NO CHANGES TO INTAKE STRUCTURE
- NO INCREASE IN POWER FACILITIES
- CUTTING MSF CAPITAL COST FOR ADDITIONAL CAPACITY BY 40%

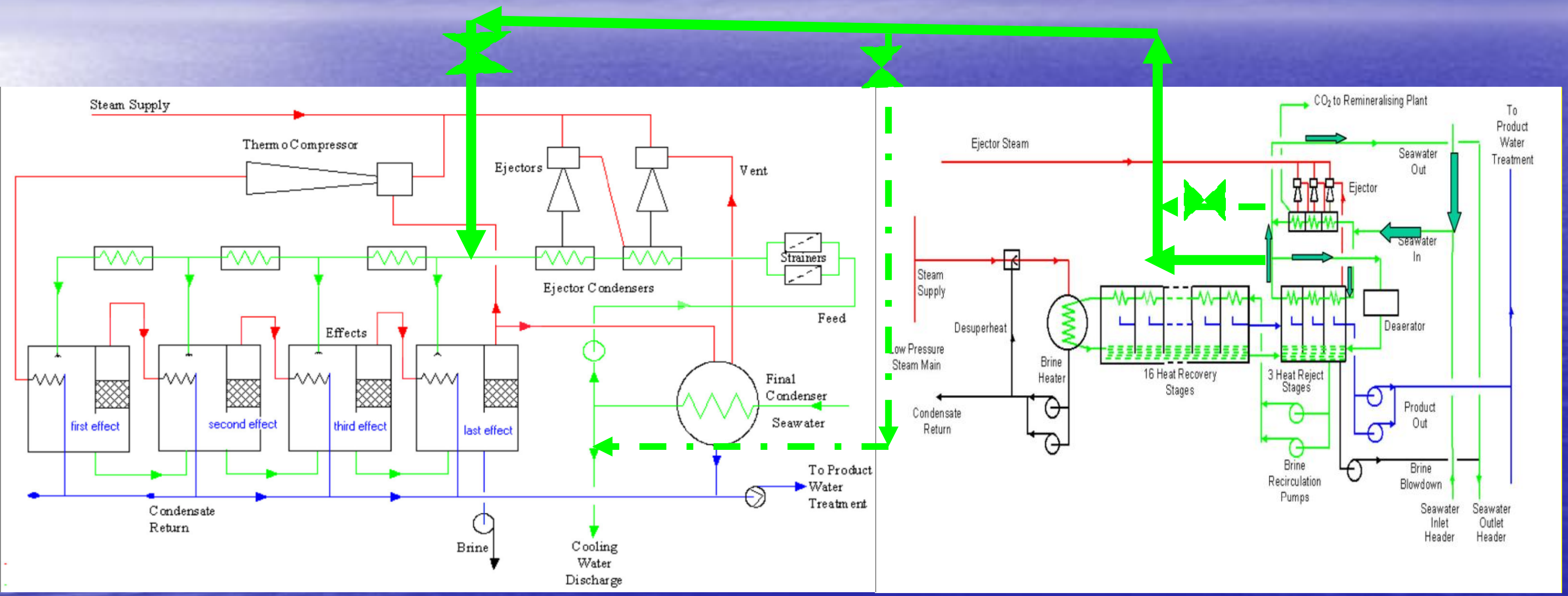
MSF 5 MIGD Layyah Plant subject of Integrated Upgrading

Layyah Integrated Upgrading the NF System

HYBRID WITH NF PRIOR TO MSF



Warm Seawater HYBRID
Discharge from MSF as source of Heat and Feed to MED process.



Flow diagram of heat and seawater utilization from seawater of MSF Reject section to feed MED-TVC

LET

Patents Pending

DESALINATION IS THE SUSTAINABLE SOLUTION AND HOPE FOR THE FUTURE GENERATIONS

With innovation and integration, hybridization better match power and water requirements, Innovations to upgrade existing assets. New solutions for the environment.

Desalination provides hope to the world community that we can provide water, the essence of life, at a reasonable cost, solving the scarcity of existing water supplies, avoiding regional and territorial conflicts, and providing the water resource for sustainable development.