Non-electrical Application of nuclear Power

"Desalination and Water Reuse-
A technology for the future"

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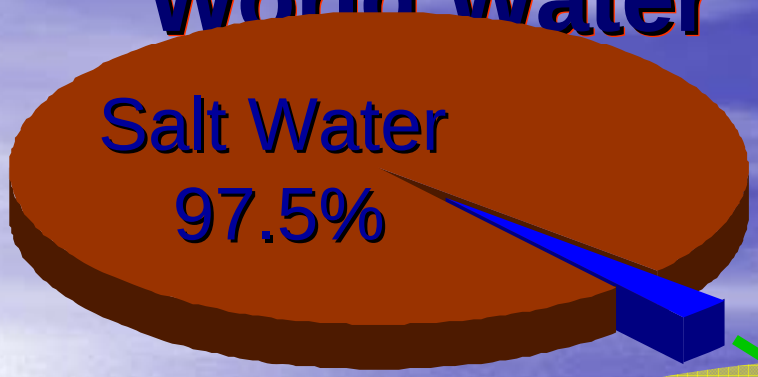
17 April 2007, Oarai

World Water



Total Fresh Water 2.5%

68.9% Glaciers and permanent snow cover

0.3% renewable Freshwater

29.9% Fresh Groundwater

0.9% Other (swamps, moisture, etc.)

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Increased Water Demands:

Greater extraction of groundwater resulting in depletion of the aquifers, The only available choice, to meet the demand

is

SEA WATER DESALINATION

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Desalination will create sustainable development of extra water resources

Help minimize regional and international conflicts, over sharing of water.

Will offer commercial opportunity of 80 billion dollars plus, in the next 10-20 years.

The Challenge

- The need for ever increasing quantities of low cost desalinated water
- To ensure environmentally sustainable expansion in supply
- To create a product which is reliable and can attract finance

MARKET DRIVERS for DESALINATION and POWER

- Increasing water demand
- Decreasing unit cost of desalination through technology improvement
- Lack of alternatives to desalination
- Environmental constraints increasing the cost of traditional water resources
- Imbalance between rapid growth of water demand and slower growth of peak power
- Water can be stored, whereas electricity cannot

TRENDS IN DESALINATION AND POWER MARKETS

- Movement towards market pricing of water
- Privatisation of water supply
- Introduction of Build Own and Operated (BOO) concept to power and desalination projects
- Profitability moving from manufacturing to ownership and O&M
- Hybrid and Nanofiltration (NF) as a solution to the power surplus and need for cost reduction.

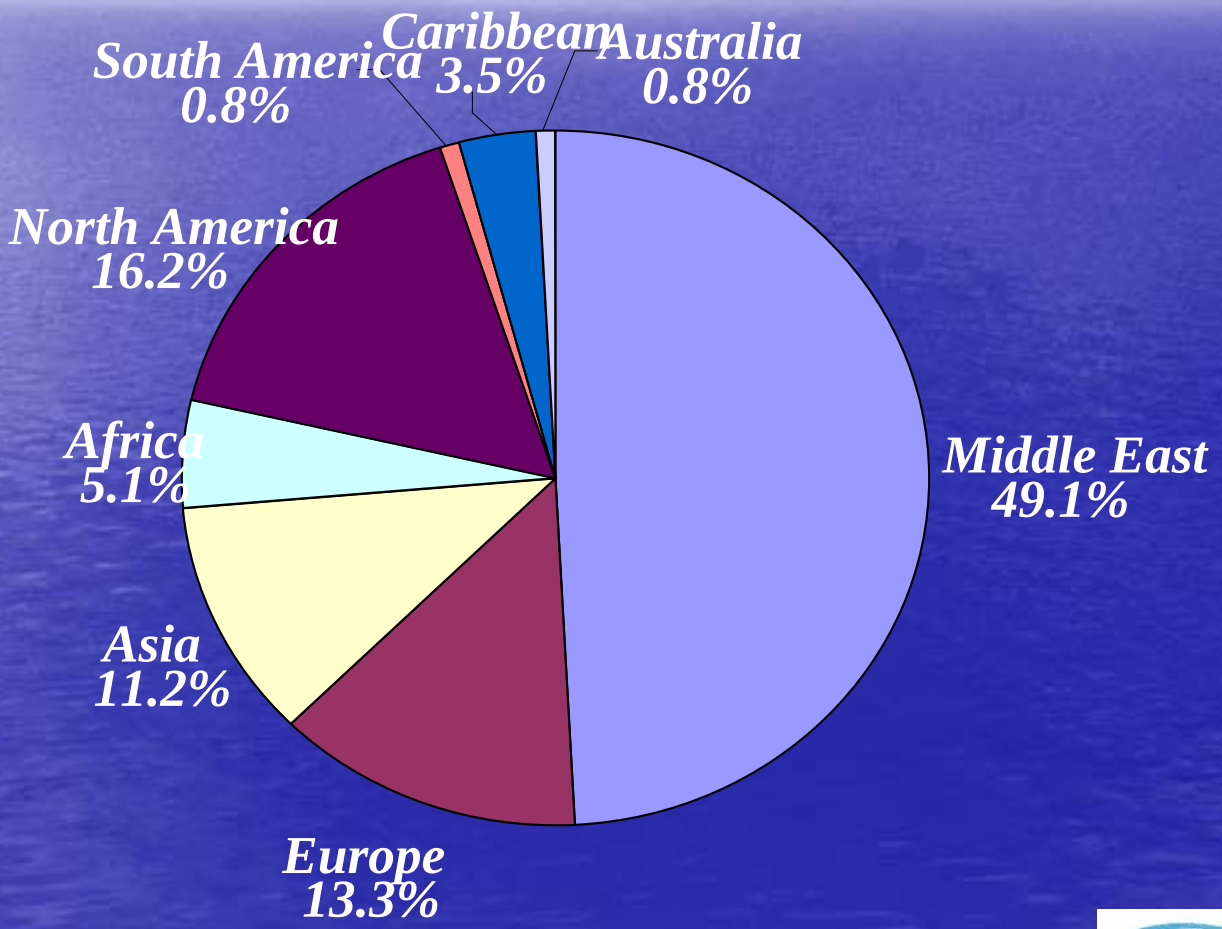
Desalting Inventory

Worldwide there are 15,233 desalting units with total capacity of 32,400,000 m3 /d or 5,706 MIGPD

- **Over the last two years the increase averaged 10.5% / year**
- **The Middle East is still the dominant market**
  - **Saudi Arabia 22.4%**
  - **UAE 20.4%**
  - **USA 12.0%**
  - **Kuwait 8.4%**

Total desalination capacity worldwide

By Region



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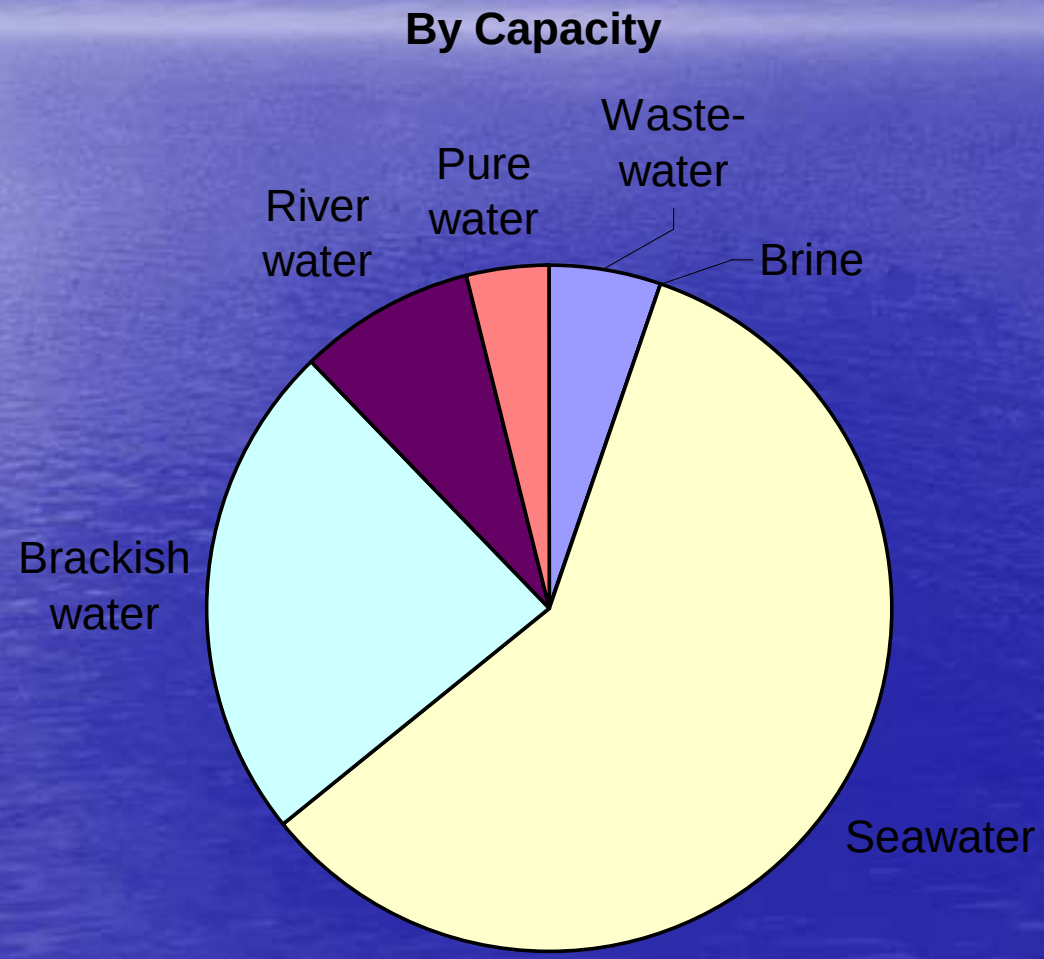
Total desalination capacity worldwide by the source water.



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Desalting Inventory Technology

For all plants installed and contracted

- MSF represents 43.5%
- RO represents 43.5%

For seawater as a feed

- MSF represents 66.3%
- RO represents 22.4%
- MED and HYBRIDS coming strong

The significant increase in fuel-energy and material cost has a dramatic impact on capital and operational cost of Desalination and Power plants.

Impact of US$ 60-75 per barrel oil, natural gas exceeding 11 $/MMBTU and high demand for raw materials, steel, copper, nickel and concrete has dramatically increased pressure to develop novel solutions.

Can we minimize energy consumption and reduce volume and weight of desalination plants?

Desalination is an energy and capital intensive process.

All major desalination technologies Multistage Flash (MSF), Multi-effect Distillation (MED and MED TVC), and Mechanical Vapor Compression (MVC) as well as Reverse Osmosis (RO) and Hybrids will be significantly affected by energy costs

Energy Requirements (Steam/Electricity)

product	Process Live Steam (ton product / ton steam)	Electricity kwh / ton
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
without energy recovery	n/a	8.5

Desalination Technologies

- Multi-Stage-Flash Distillation (MSF)
- Multi-Effect-Distillation (MED)
- Reverse Osmosis (RO)
- Vapour Compression Distillation (VCD)

Thermally driven Desalination Technologies

- Multi-stage Flash (MSF)
- Multi-effect Distillation (MED)
- Multi-effect Distillation with Thermocompression (MED - TC)

Multi Stage Flash (MSF)

- Raw seawater total dissolved solids (TDS): 35-47,000 mg/L
- Maximum brine temperature: 112^{o} C
- Performance ratio: 8
- Electrical power: 3-4 kWh/m^{3}
- Scale inhibitors used for scale control
- Recycle type plant
- Dual purpose plant

- MSF well established reliable technology with the limits for Performance Ratio (PR) of PR=10 typical PR=8, internal power consumption of 4kWhr/ton of water, with turndown ratio from 110-70% of nominal capacity capital cost $4.00-$8.00 per gallon per day installed (GPD).

Al-TAWEELAH A2 MSF 4x12.5 MIGD

Unit on Barge

MSF KEY PARAMETERS

Capital Cost MSF	**5.5**	**US$ MM per MIGD**
Capital Cost –Intake /Outfall	**0.1**	**US$ MM per MIGD of cooling**
MSF GOR	**8**	**Tons of product/ton of steam**
LP Steam Supply	**2.5-3**	**Bar. A**
Lost Power Potential	**1.225**	**MW/MIGD**
Power Consumption	**4**	**kW.hr/m^3 of distillate**
Steam Consumption	**23.7**	**Tons/MIGD**
Chemical Costs	**40,000**	**US$/yr per MIGD**
MSF R&R	**1%**	**TIC/yr**
Labor	**40,000**	**US$/yr per MIGD**

Multi Effect Distillation (MED)

- Raw seawater total dissolved solids (TDS): 35-47,000 mg/L
- Maximum brine temperature: 76^{o} C
- Performance ratio: 12
- Electrical power: 2 kWh/m^{3}
- Scale inhibitors used for scale control
- Dual purpose plant

- MED with wide range of performance ratios from PR-8 to PR-16, typical PR=12, internal power consumption of 1.8 kWhr/ton of water with turndown ratios from 120 to 45% of nominal capacity, capital cost of MED plants vary from $3.50-$7.00 per GPD.

  MED unit Thermocompression (MED-TC) are similar in characteristic to MED but require higher pressure steam-jet compressor acting as the heat pump. They are designed where 2 to 10 atm steam is available, for water vapour to be thermocompressed across several effects. MED-TC is particularly in use with Gas Turbines.

Multi-Effect Distillation

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MED KEY PARAMETERS

Capital Cost MED	**4.5**	**US$ MM per MIGD**
Capital Cost –Intake /Outfall	**0.1**	**US$ MM per MIGD of cooling**
MED GOR	**12**	**Tons of product/ton of steam**
LP Steam Supply	**2.5-3**	**Bar A**
Lost Power Potential	**1.225**	**MW/MIGD**
Power Consumption	**1.8**	**KWh/m³ of distillate**
Steam Consumption	**15.8**	**Tons/MIGD**
Chemical Costs	**40,000**	**US$/yr per MIGD**
MED R&R	**1%**	**TIC/yr**
Labor	**40,000**	**US$/yr per MIGD**

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Electrically driven Desalination Technologies

- Reverse Osmosis (RO)
- Vapour Compression Distillation (VCD)
- Hybrids

Reverse Osmosis (RO)

- Raw seawater total dissolved solids (TDS): 35-47,000 mg/L
- Feed pressure: 1000 psia (70 bars)
- Conversion factor: 35%-50%
- Membrane life: 5 years
- Electrical energy consumption: 4.5 kWh/m^3

- Seawater RO has become a mature technology with high degree of reliability. It is using electric energy to operate and with energy recovery devices can recover 25% to 30% of total energy, from the high pressure RO reject brine stream. As a result the total plant energy requirements can vary from 4.2 to 7.4 kWhr per ton of product. The RO system can vary some output, but its big advantage is quick start-up allowing its shut-down during peak power operation. The capital cost of the RO plant vary from $3.50-$6.5.00 per GPD.

RO KEY PARAMETERS

Capital Cost RO	**4.0**	**US$ MM per MIGD**
Capital Cost –Intake /Outfall	**0.1**	**US $MM per MIGD feed**
Power Consumption	**5**	**Kwh/m^3 of Permeate**
Membrane Replacement Rate	**20%**	**Per yr**
RO Chemical Costs	**50,000**	**US$/yr per MIGD**
RO R&R	**2%**	**TIC/yr**
RO Labor	**50,000**	**US$/yr per MIGD**

Advantages of Simple Hybrid MSF-RO Power System

- A common, considerably small seawater intake can be used
- Product waters from the RO and MSF plants are blended to obtain suitable product water quality
- A single stage RO process can be used
- The RO membrane life can be extended
- Excess power production from the desalting complex can be reduced significantly, or power to water ratio can be significantly reduced
- Increase Recovery Ratio

Fujeirah Plant - Power Desalination Hybrid

Fujeirah Plant - SWRO Racks and Feed Pump/ER Turbine Arrangement

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Power Generation Technologies

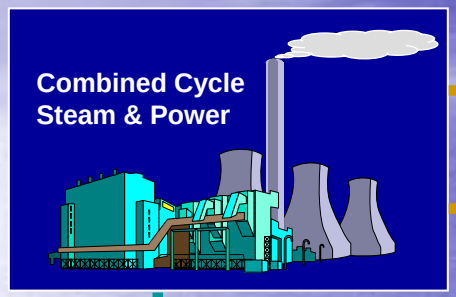
- Back-pressure Steam Turbines
- Extraction Steam Turbines
- Gas Turbines
- Combined Cycle Plants
  - Gas Turbines
  - Steam Turbines

Typical Power to Water Ratios for Different Technologies

Technology PWR=MW required/Million Imperial Gallons per day

Steam Turbine BTG - MSF	PWR = 5.0
Steam Turbine EST - MED	PWR = 7.0
Steam Turbine EST - MSF	PWR = 10.0
Gas Turbine GT - HRSG - MED	PWR = 6.0
Gas Turbine GT - HRSF - MSF	PWR = 8.0
Combined Cycle BTG - MED	PWR = 10.0
Combined Cycle BTG - MSF	PWR = 16.0
Combined Cycle EST - MED	PWR = 12.0
Combined Cycle EST - MSF	PWR = 19.0
Reverse Osmosis RO	PWR = 0.8-1.5

Traditional Power Desalination



Power for Sale

Power to Desal

Multi Stage Flash Distillation

Feed

SEA

Brine
Reject CW

Steam to
Desal

Lost Power Revenue
Opportunity

Product
Water

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POWER AND DESALINATION PRIVATE PROJECTS IN THE MIDDLE EAST

Authority	plant	Power contractor Lot P	Water contractor Lot D
ADWEA	Al Taweelah A2	Siemens	Hanjung
ADWEA	Al Taweelah A1	Siemens	Sidem
MEW Oman	Barka	Enelpower	Hitachi
MEW Qatar	Ras Laffan	Enelpower	FI-Italimpianti
ADWEA	Shuweihat	Siemens	FI-Italimpianti

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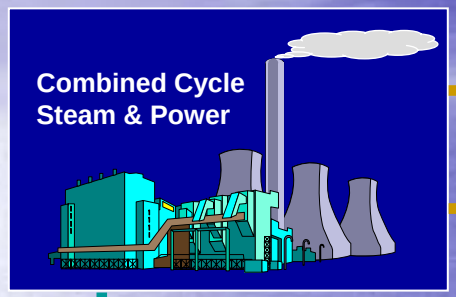
POWER AND DESALINATION PRIVATE PROJECTS IN MIDDLE EAST

Authority	Plant	Water cap MIGD	Power MW	Technology	Developer
ADWEA	Al Taweelah A2	50	710	MSF	CMS
ADWEA	Al Taweelah A1	50	1100	MED	TRACTEBEL TOTALFINA
MEW Qatar	Ras Laffan	40	750	MSF	AES
MEW Oman	Barka	30	600	MSF	AES
ADWEA	Shuweihat	100	1500	MSF	CMS
MEW Oman	Barka	30	500	MSF	AES

New Hybrid Power Desalination



Power for Sale

Power to Desal

Lost Power
Revenue
Opportunity

Steam to
Desal

Multi Stage Flash Distillation

Reverse
Osmosis

Nanofiltration

SEA

Product
Water

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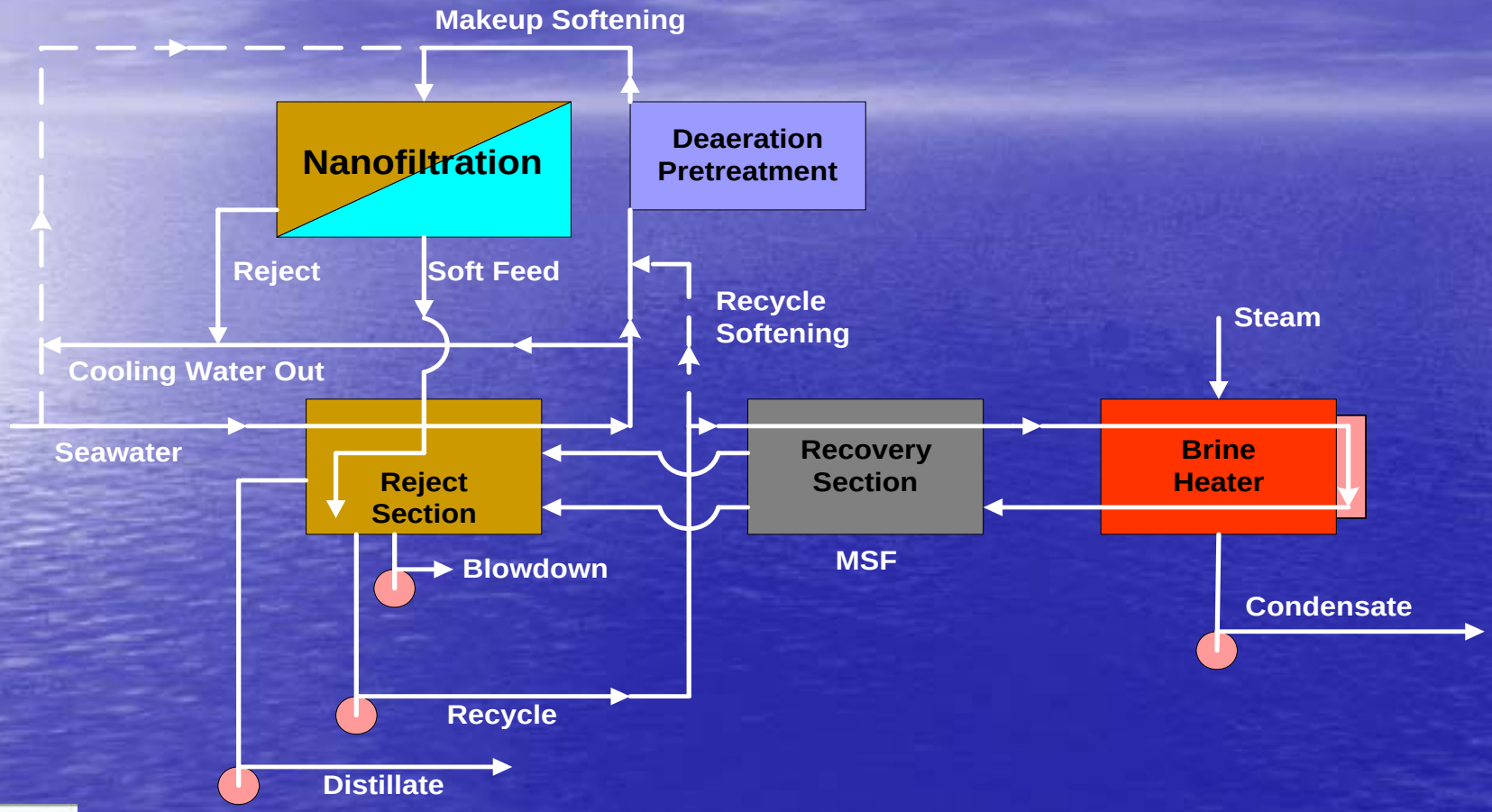
Nanofiltration NF with Multistage MSF Flash Process



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Water Security is based on:

- Enough desalination capacity.
- Enough Storage capacity to cover strategic and seasonal variations.

Water Supplies are Scarce

- Groundwater reserves are being depleted and becoming more saline
- There is an increasing demand due to population growth, agricultural needs, industrialization and socio-economic improvements

Energy is Power Power is Water, Water is Security

Combining Desalination and Aquifer Storage: The DASR Concept

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Creating Additional Water

- Electricity demand drops to 30–40% of peak during the winter months
- Over 50% of power generation capacity of power– desalination plants is idle in winter
- Idle power can be used to produce low-cost water (above normal demand) using nano-filtration and other membrane desalination technologies

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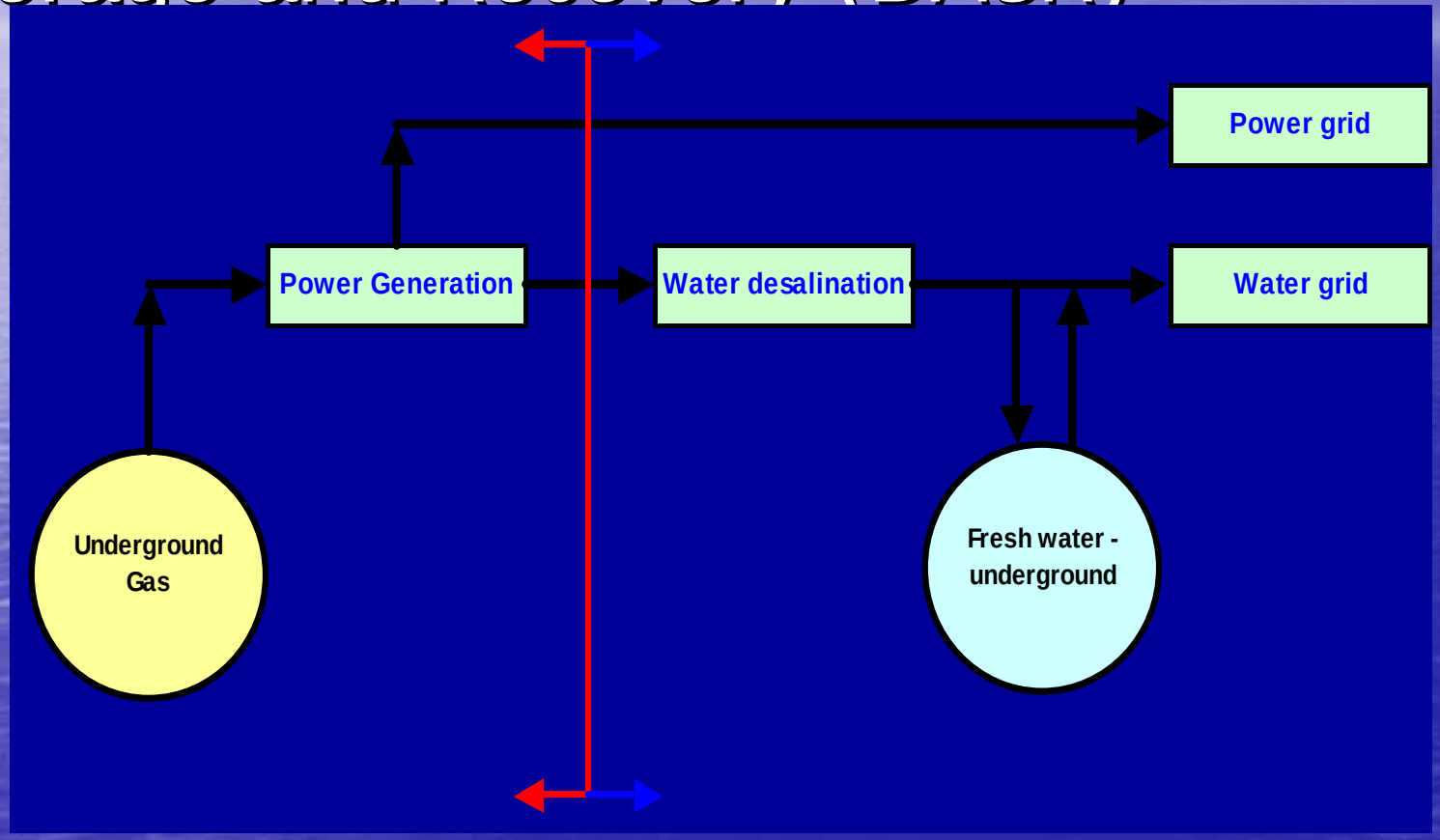
GAS to Power, Power to Seawater Desalination and Storage/Aquifer Storage and Recovery (DASR)



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BESIX LEADING EDGE WATER TECHNOLOGIES MISSION

ECONOMICALLY INCREASE THE OUTPUT OF MSF PLANTS BY:

- ADDING THE LET NF SYSTEM
- OPTIMIZING MSF PLANT PERFORMANCE
- CUTING CAPITAL COSTS BY AT LEAST 25%
- NO NEED FOR NEW INTAKE AND POWER PLANT

The Nanofiltration system will utilize idle electricity for production of water at low marginal cost of power.

Growth for Integrated Hybrid

- Increasing capacity of existing plants – upgrade alongside rehab
- NF able to capitalize on the effluent water
- Provide new plants with a clear advantage through a better IGD/$ invested (Capex)
- Reduce power to water ratio (Kwh/IGD)
- Improve thermal and membrane based processes

Benefits of Nanofiltration

- **PREFERENTIALLY REMOVES SCALING (DIVALENT) IONS**
- **ALLOWS HIGHER TOP BRINE TEMPERATURE FOR MSF (121 vs. 110 °C)**
  - **Higher Flash Range Increases Production**
  - **Reduced MSF Capital Costs**
  - **Reduced MSF Operating Costs**

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THE SEWA CASE of INTEGRATED HYBRID

- INCREASE 44% THE CAPACITY OF EXISTING MSF FROM 5 MIGD to 7.2 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%

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PLANT OPTIMIZATION IS BASED ON:

- COMPUTER SIMULATION OF PLANT OPERATIONS

RESULTING IN:

PLANT MODIFICATIONS TO INCREASE WATER PRODUCTION AND IMPROVING EFFICIENCY

- COMPREHENSIVE ENGINEERING REVIEW

Investment Costs Comparison

$ inv / IGD	RO	NF + MSF
MSF modifications	N/A	0.5
Desalination plant	3.3	2.3
Civil & Engineering	0.9	0.25
Misc. and commercial	0.1	0.1
Total Direct Investment	4.3	3.4
Intake	0.7	N/A
Total Investment	5.0	3.4

Unit Cost Analysis

	RO $ / m³	NF + MSF $ / m³
Annual Investment return *	0.330	0.177-.245
Operating Costs	0.268	0.226-.234
Total	0.598	0.403-.479

* Based on a 20 year life and 6% interest rate

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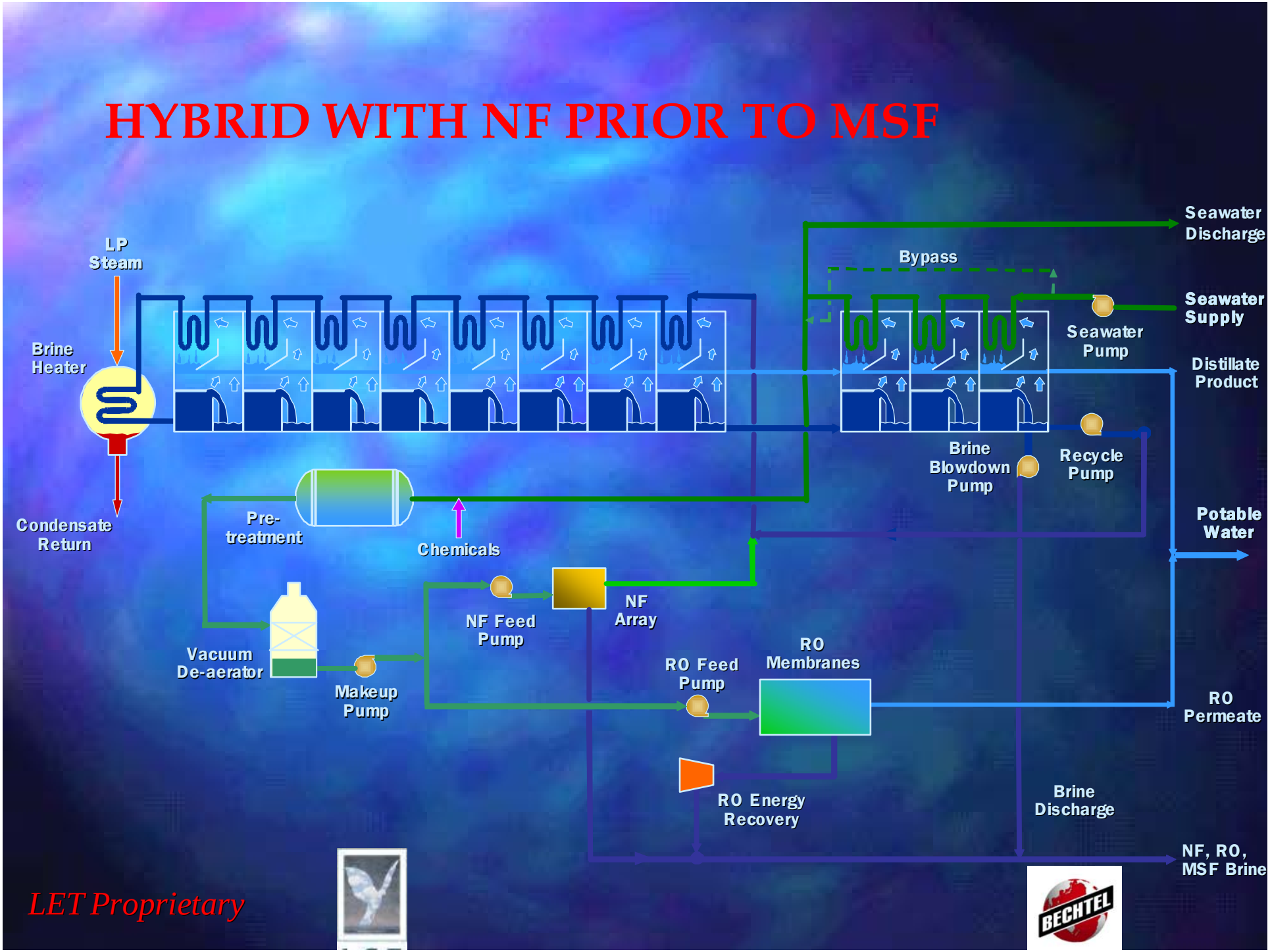
Improvements in distillation and membrane processes

- R. Borsani in the presentation "**MSF Innovation – Beyond Large Size Unit"** at the IDA Forum on Innovation and Integration in Desalination Dubai described the new frontiers, as
- TOP BRINE TEMPERATURE : The Increase of TBT can Allow Higher Production With Almost Same Desal Trains
- HYBRIDISATION : The Application Of Hybrid Technologies (MSF + RO Or MSF + MED) Can Improve Overall Efficiency
- THERMAL IMPROVEMENT : New MSF Schemes And Ancillary Equipment.

HYBRID WITH NF PRIOR TO MSF

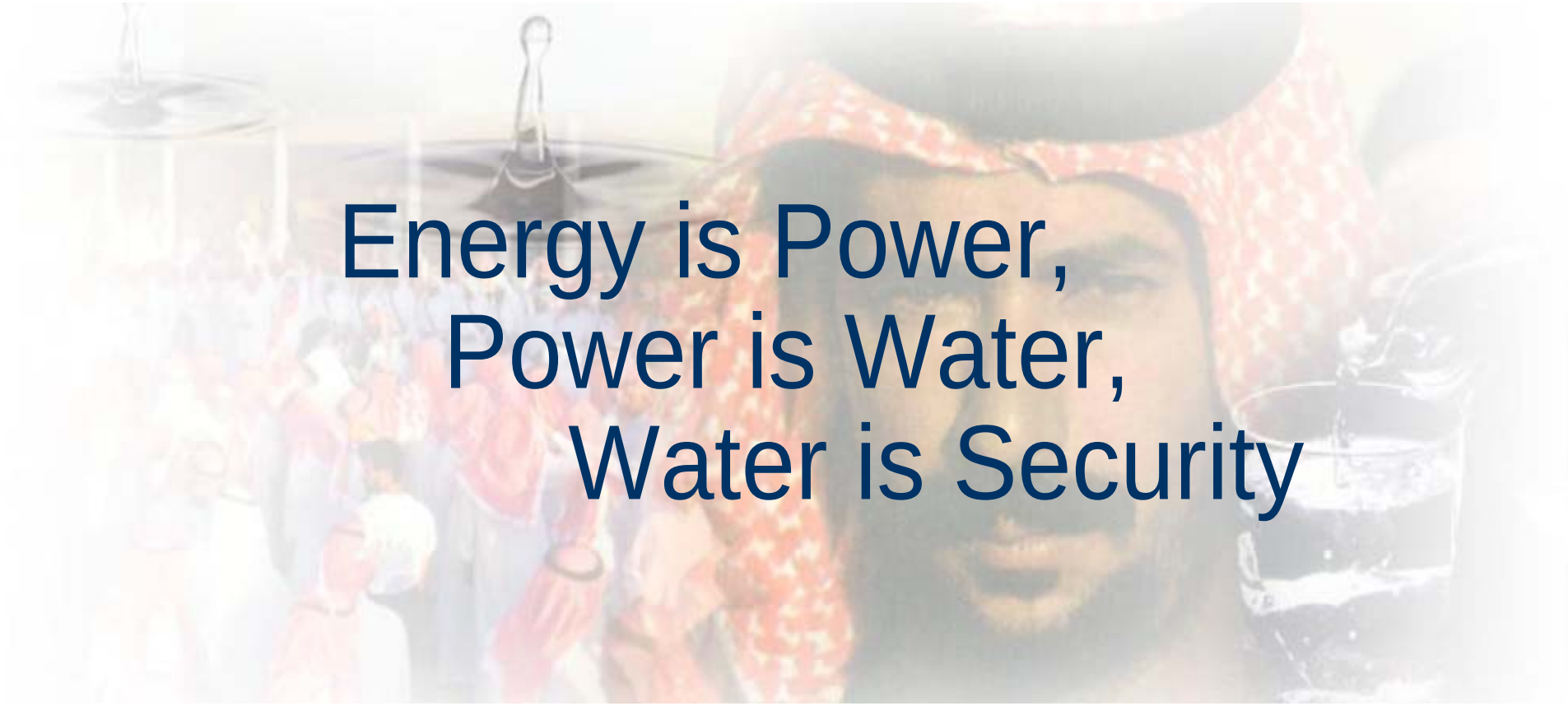


Potential for MED technology improvements.

At IDA Forum on Innovation G. Canton in presentation “The Recent Progress and Next Generation of MED Plants” outline the significant growth and potential for the Multi-effect distillation technology. The 8 MIGD MED, plant started production in Sharjah August 2006, it is the largest single unit and 10X 6 MIGD=60 MIGD Hidd-Bahrain plant awarded is the world largest MED plant.

Future Developments

- Further reduction of $ invested / IGD to $2.5/IGD through optimization
  - Introduction of UF/MF as pre treatment
- Reduce operating costs through
  - Energy reduction – energy recovery, one pass
  - Chemical reduction
- NF for MED
- NF for RO


Energy is Power,
Power is Water,
Water is Security