Evolution OF Multi- stage flash desalination plants

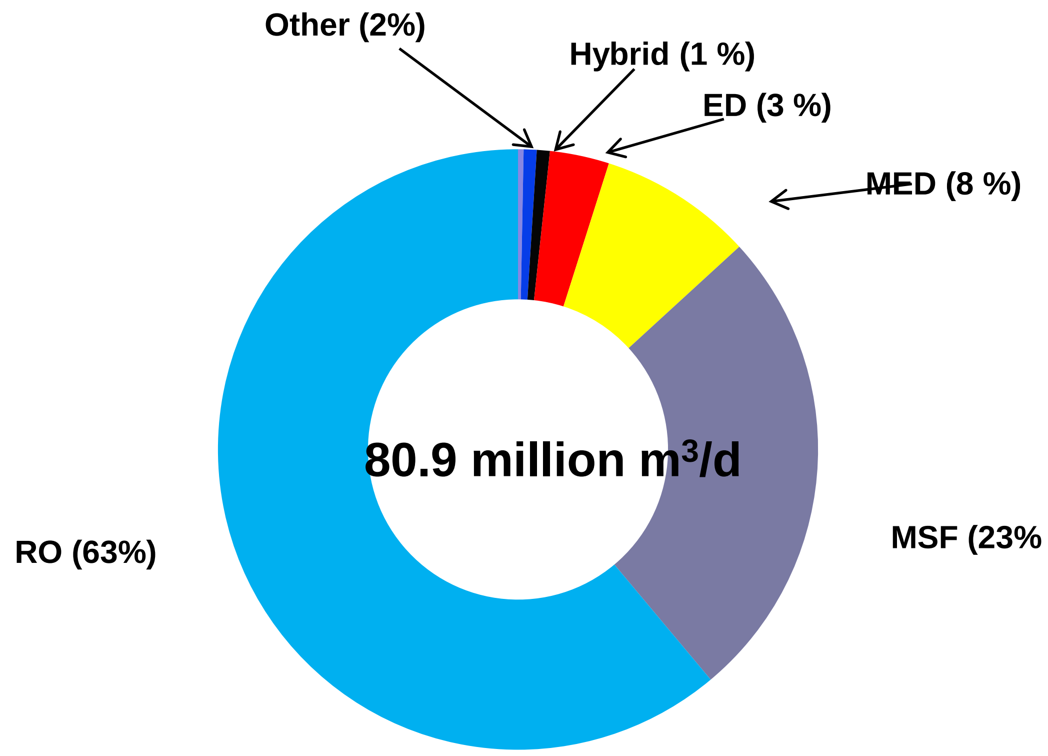
- Dr. Osman A. Hamed

Saline Water Desalination Research Institute (SWDRI)

Outline

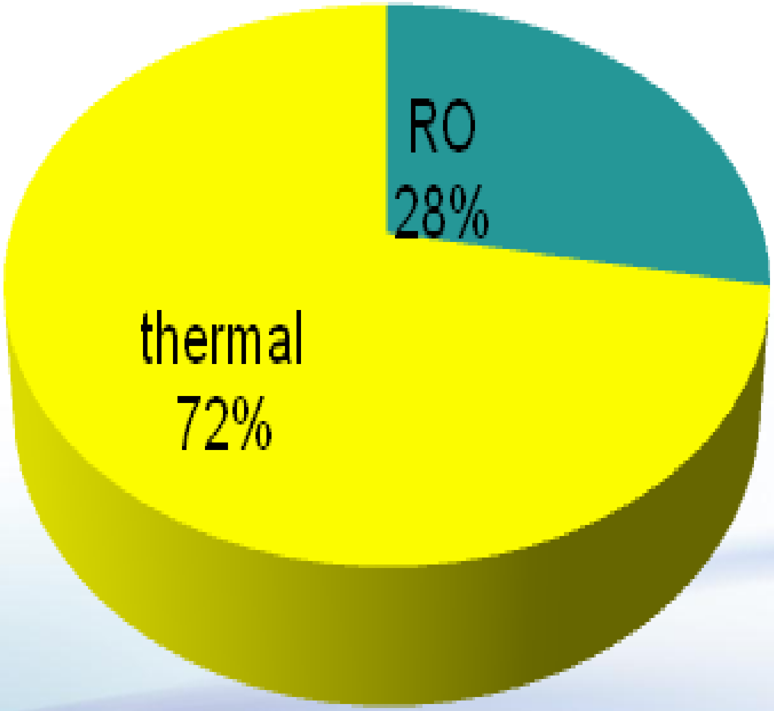
- Lessons learnt with respect to operation and availability of MSF desalination plants
- Development of MSF major design features
- Evolution of dual purpose power/MSF cogeneration plants
- Evolution of hybrid MSF/membrane technologies
- Future R&D directions to improve the techno-economic effectiveness of the MSF desalination industry

Breakdown of Total Worldwide Installed capacity by technology



The wide spread of RO processes is the result of the low energy requirements compared to other desalination processes by employing energy recovery devices, 3 to 8 kWh/m^3, Relatively low water production cost.

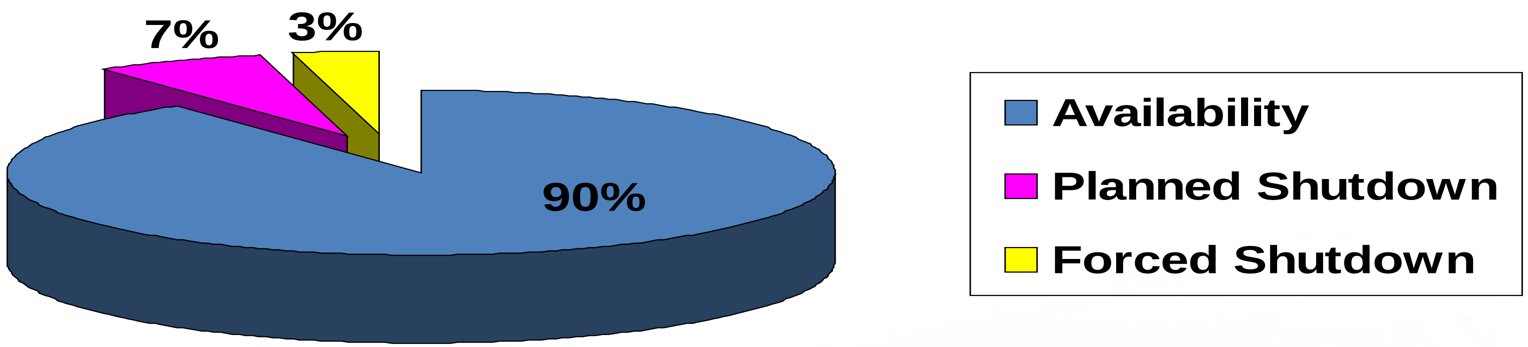
Breakdown of Total Installed capacity by technology in the GCC



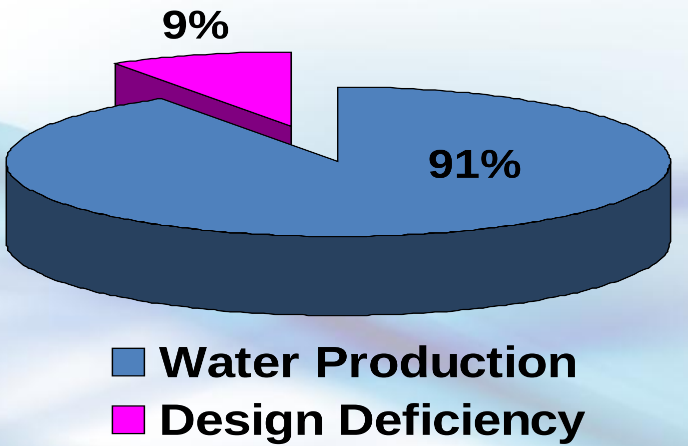
Domination of thermal desalination processes in the GCC region is mainly due the integration with power generation cycles

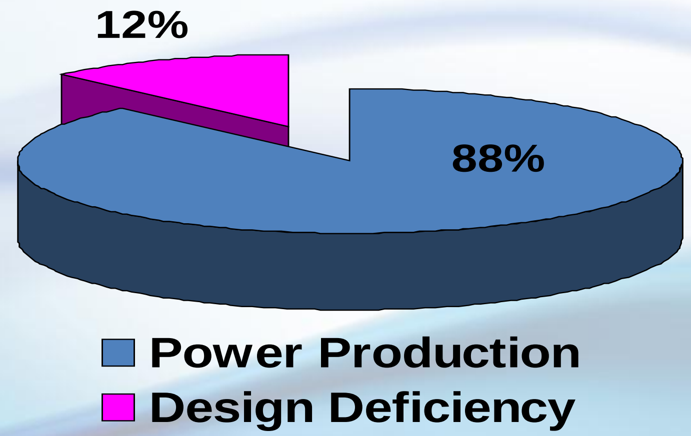
High reliability & availability. Life-time over 30 years

Lessons learnt with regard to operation and availability of MSF plants



Average Availability for Al-Jubail MSF Plant Phase II (1983-2012)





Average Water and Power Load Factors for Al-Jubail MSF Plant Phase II (1983-2012)

MSF Plants exceeded lifetime thirty years

S.	Plants	Year	Capacity (migd)	Life Time
1	Jeddah-III	1979	4x5	32
2	Jeddah-IV	1981	10 x 5	32
3	Al-Jubail-I	1982	6 x 6.2	31
4	Al-Khobar-II	1982	10 x 6	31
5	Al-Jubail-II	1983	40 x 5.38	30
6	Al-Khafji-II	1986	2 x 2.6	27
7	Shoaiba-I	1989	10 x 5.06	24
8	Shuqaiq-I	1989	4 x 6.5	24
9	Yanbu-I	1981	5 x 5	32
10	Yanbu-II	1999	4 x 7.94	14
11	Al-Khobar-III	2001	8 x 7.5	12
12	Shoaiba-II	2002	10 x 10	11

Improvement of operation and availability of MSF plants

- High reliability & availability. Life-time over 30 years
- Optimized use of scale inhibitors

Scale Control In MSF Desalination Plants

The major problem in operating seawater distillation plants is the formation of scale which is caused by some of the dissolved constituents within the seawater.

- **Scale control is a prerequisite for the safe and sustainable operation of MSF desalination plants**

HISTORICAL DEVELOPMENT OF CONTROL OF ALKALINE SCALE

1950's
Polyphosphate Based Chemical

To overcome temperature limitation (88 - 93 oC)

1960's, 1970's
Acid Addition

To overcome acid treatment problems

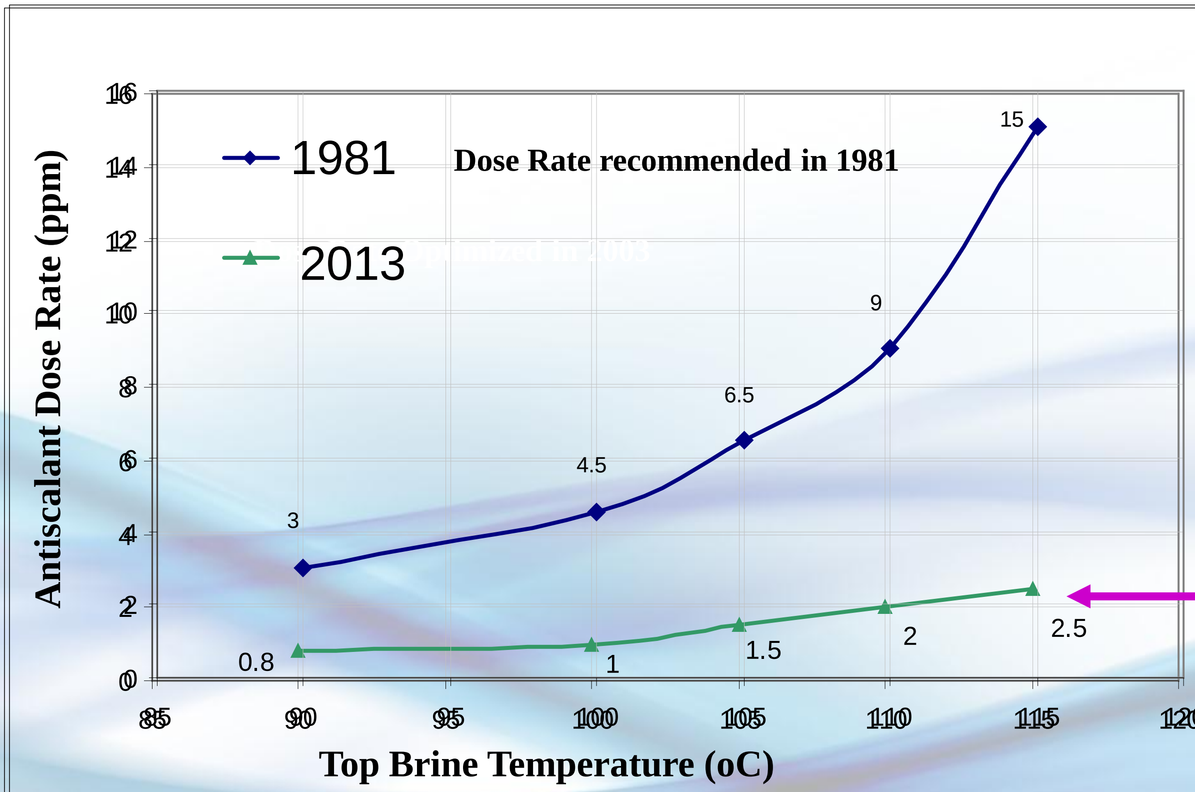
High Temperature Scale Control Additive (HTA) Threshold Agents

- **Inhibitors Based on Phosphonic Acid**
- **Inhibitors Based on Polycarboxylic Acid**

Hybrid Treatment

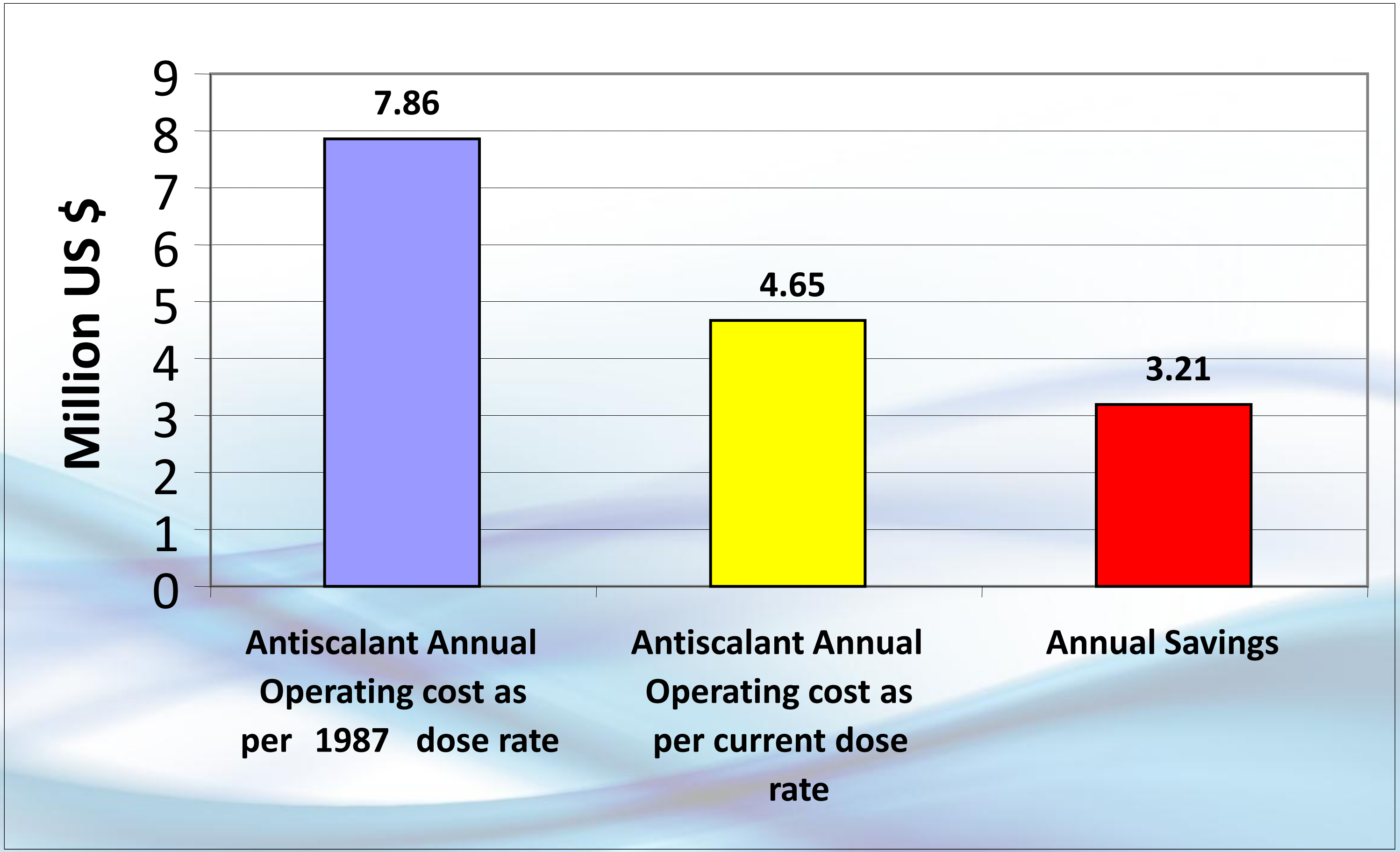
(Acid + Additive)

SWCC's ACHIEVEMENTS IN CONTROLLING ALKALINE SCALE FORMATION IN MSF PLANTS



- Optimization Tests
- Improvement of Chemical Formulation
- Adoption of On-Line Sponge Ball Cleaning System

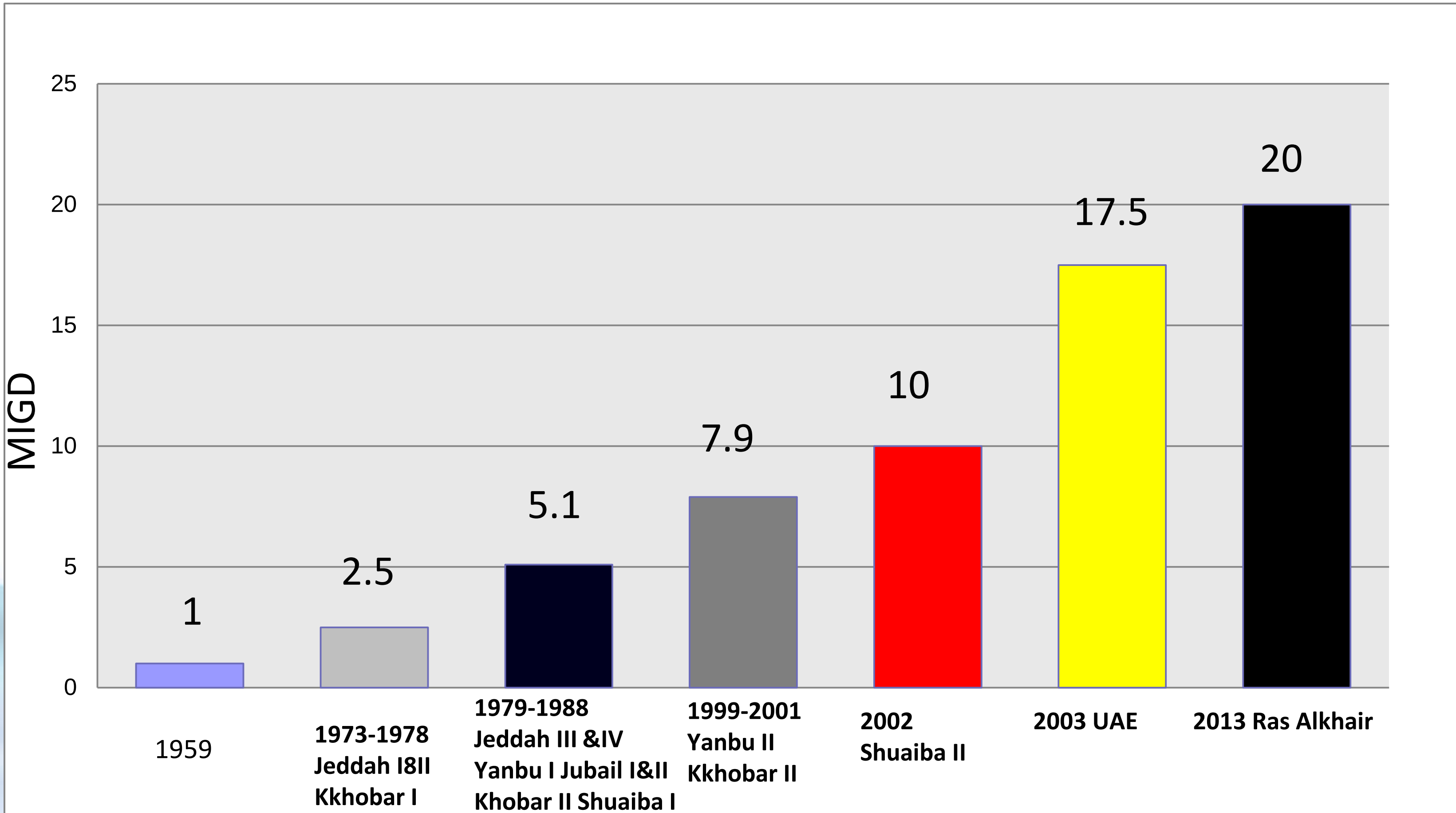
Economic Impact of Antiscalant Dose Rate Reduction in SWCC MSF Plants



Developments of major design features of MSF Plants

Increase in distiller size

EVOLUTION of MSF DISTILLER SIZE



ECONOMY OF SCALE

- Low investment cost for auxiliary equipment such as interconnection and control piping .
- Operating and maintenance people depends on the number of units installed.
- Savings in operationing cost.

Developments of major design features of MSF Plants

- Increase in distiller size
- Use of optimized Thermal design parameters

Optimized Thermo-Dynamic Design Parameters

BH Design Fouling Factors

- Al-Khobar III 0.264 m^2 $^oC/kW$
- Shuaiba II 0.211 m^2 $^oC/kW$
  Shuaiba I 0.30 m^2 oC//kW (1982)
- Al-Jubail II 0.176 m^2 $^oC/kW$ (1983)
- Jeddah II 0.086 m^2 $^oC/kW$ (1977)
  Yanbu 1 0.14 m^2 $^oC/kW$ (acid)
- Tawaleh ‘B’ 0.15 m^2 $^oC/kW$
  Jebel Ali 0.12 m^2 oC/kW

Developments of major design features of MSF Plants

- Increase in distiller size
- Use of optimized Thermal design parameters
- Optimized use of materials of construction

Optimized Use of Materials of Construction

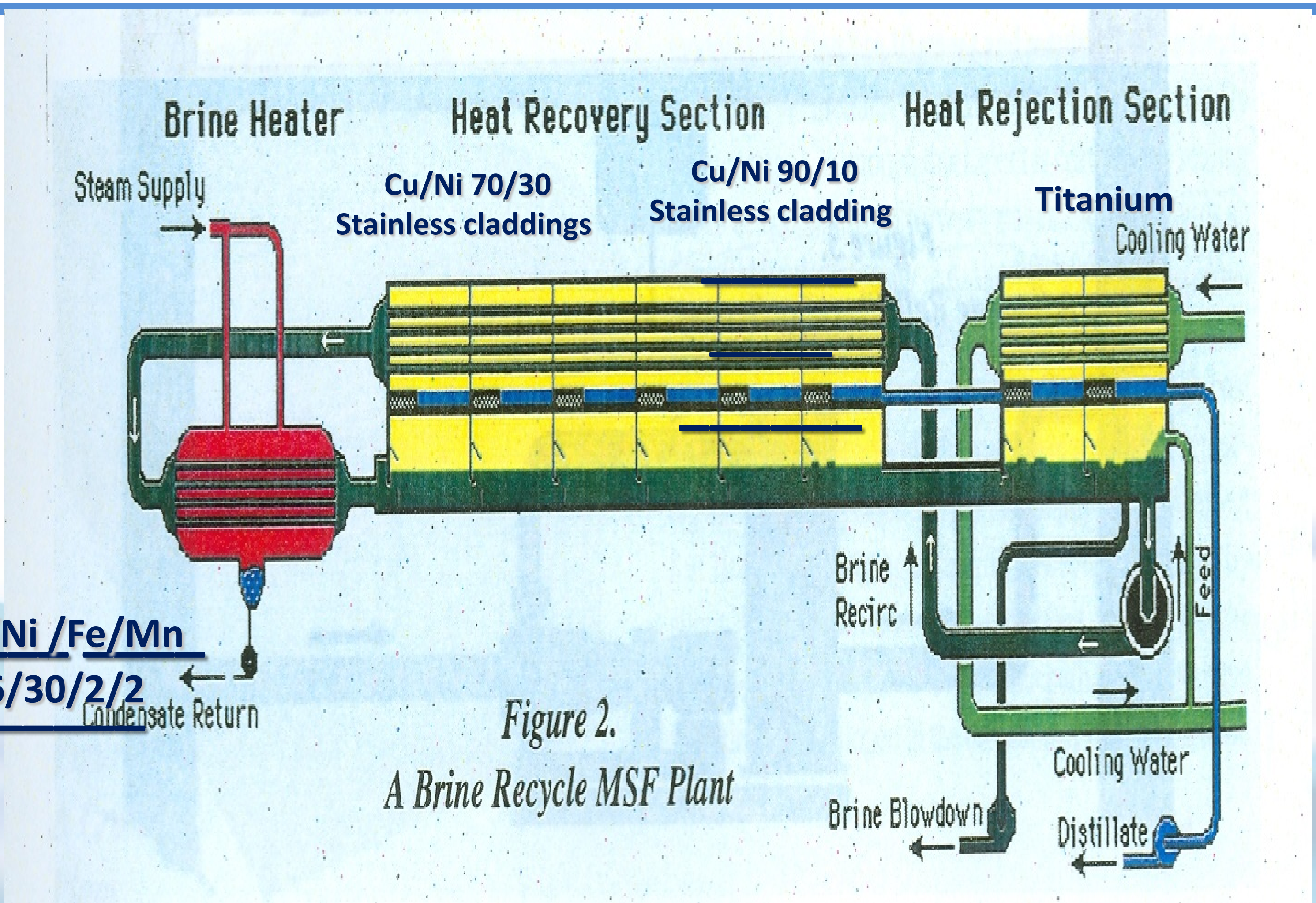


Figure 2.
A Brine Recycle MSF Plant

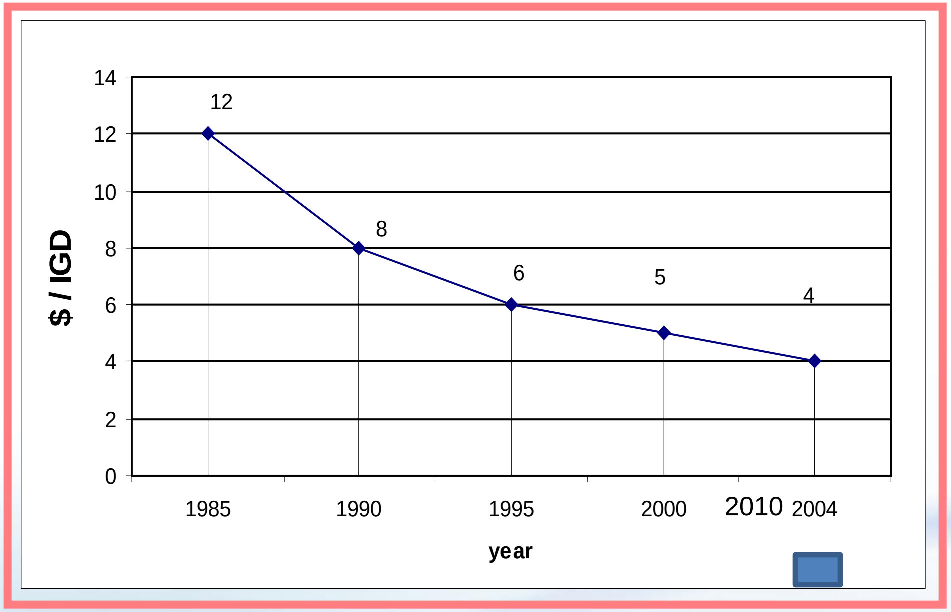
Cu/Ni 70/30
Stainless claddings

Cu/Ni 90/10
Stainless cladding

Titanium

Cu/Ni /Fe/Mn
66/30/2/2

Price Trend for turn-key complete MSF plants



<u>Reasons Constant Reduction of Investment per MIGD (inspite of inflation)</u>

- optimized use of materials of construction.
- Reduction of redundant equipment.
- Optimized mechanical design of evaporator vessel.
- Optimized thermo-dynamic design parameters.

EVOLUTION OF POWER/MSF COGENERATION PLANTS

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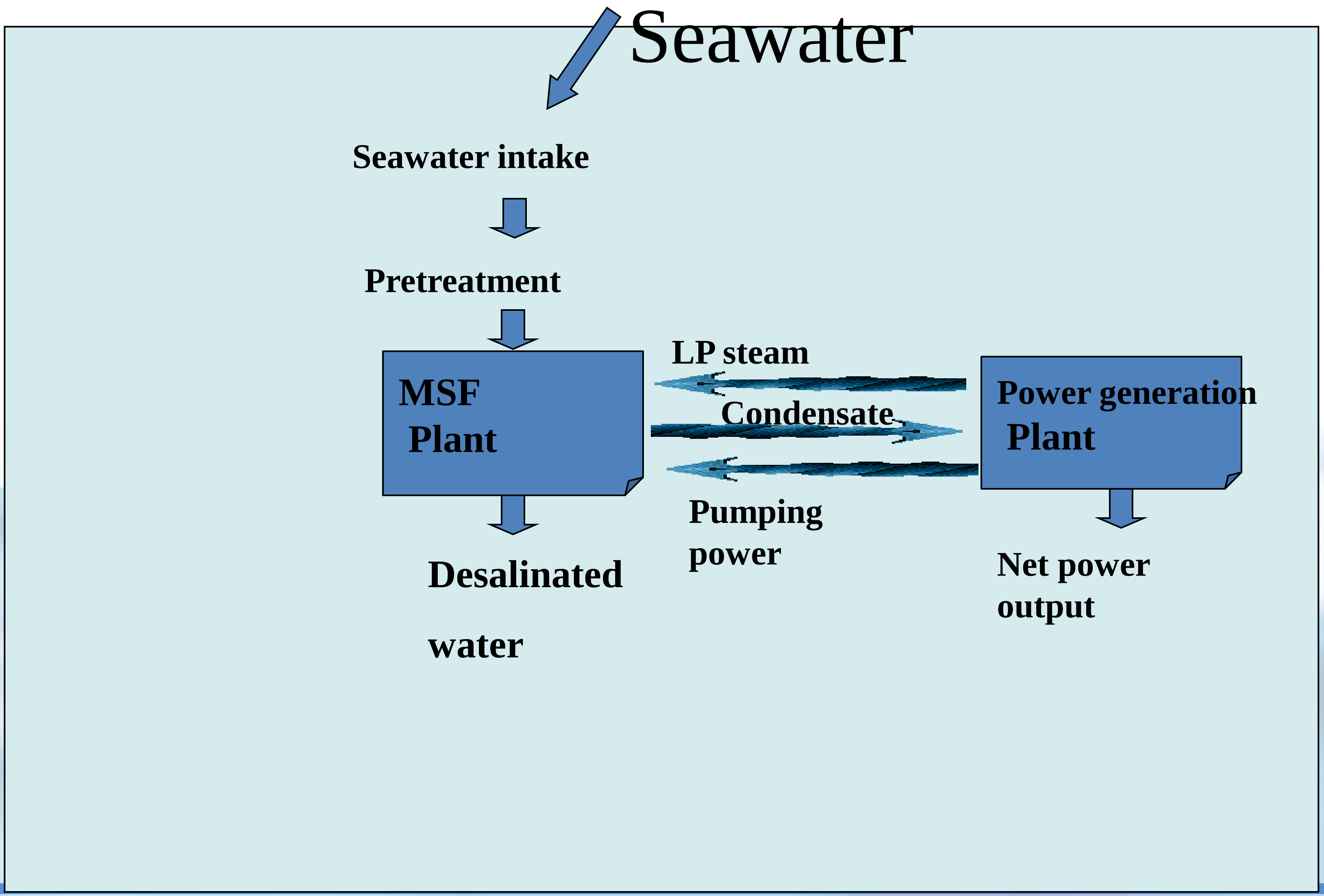
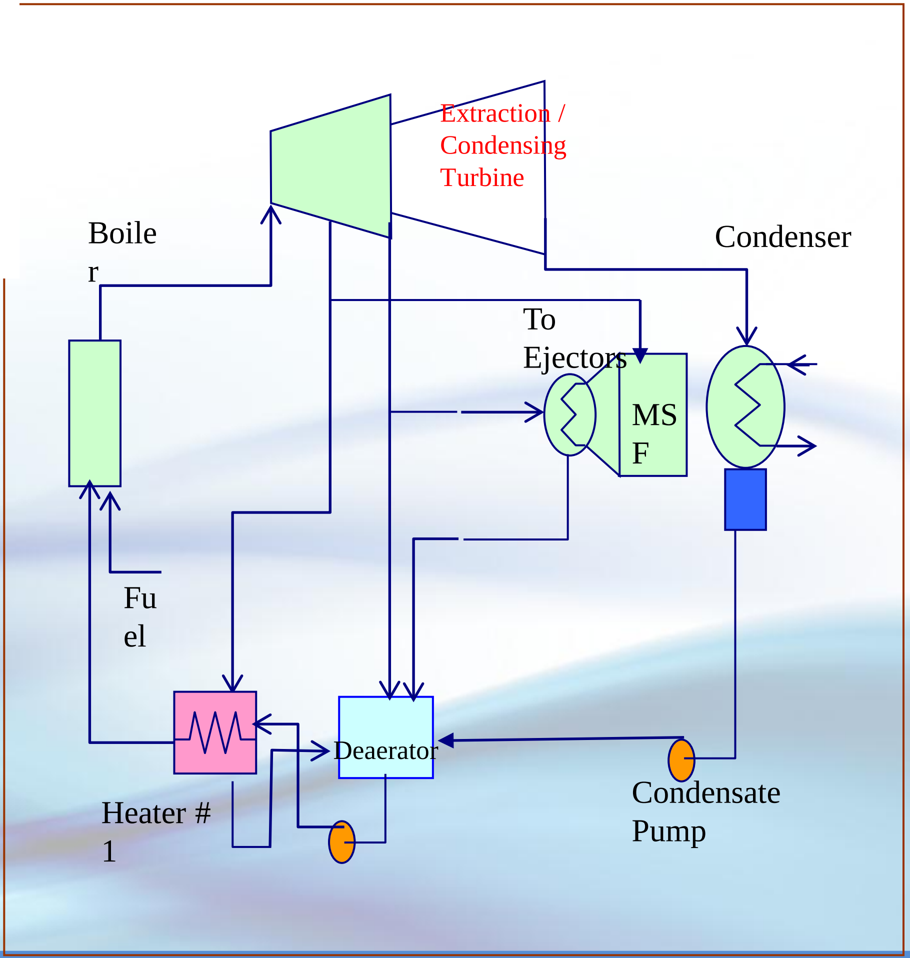


Operation flow chart for a water/power cogeneration plant

Before (1982) → Extraction/condensing (EC)

High Power/Water Ratio :
9.4 to 15.3 MW/MIGD

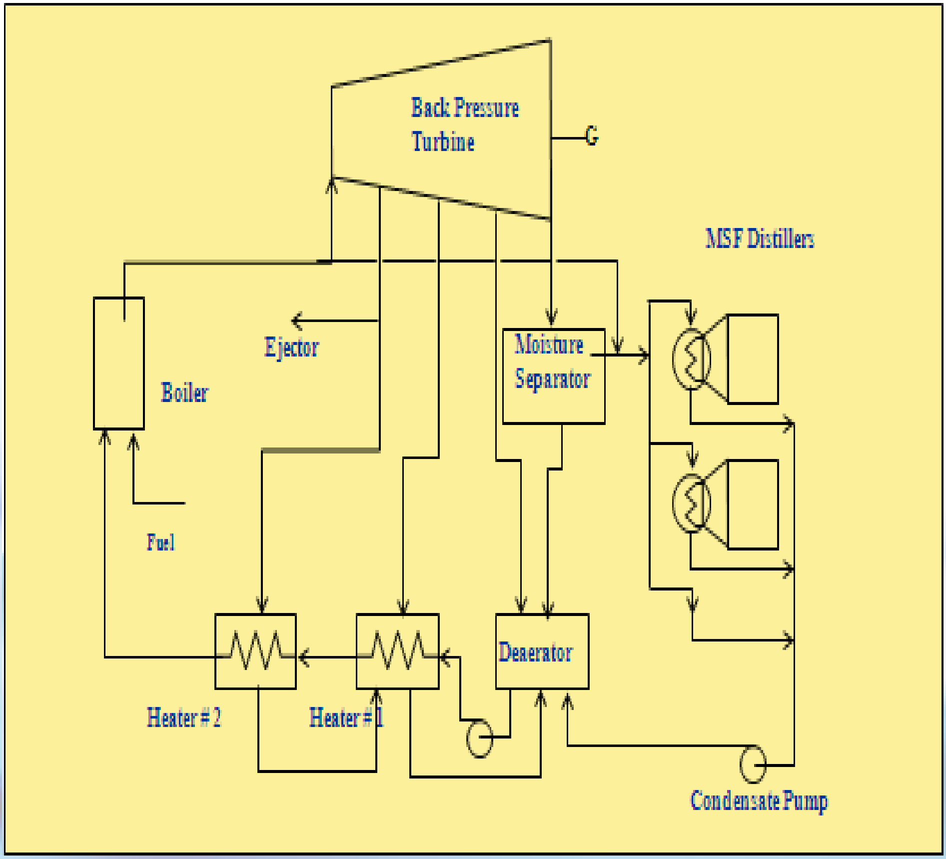
Jeddah II, III, IV (1978, 79, 81)	9.4, 12.7, 12.2
Jubail Phase I (1982)	13.8
Khobar phase II (1982)	14.5
Yanbu phase I (1981)	15



After 1982 → Backpressure (BP)

Low Power/Water Ratio
5 to 7.9 MW/MIGD

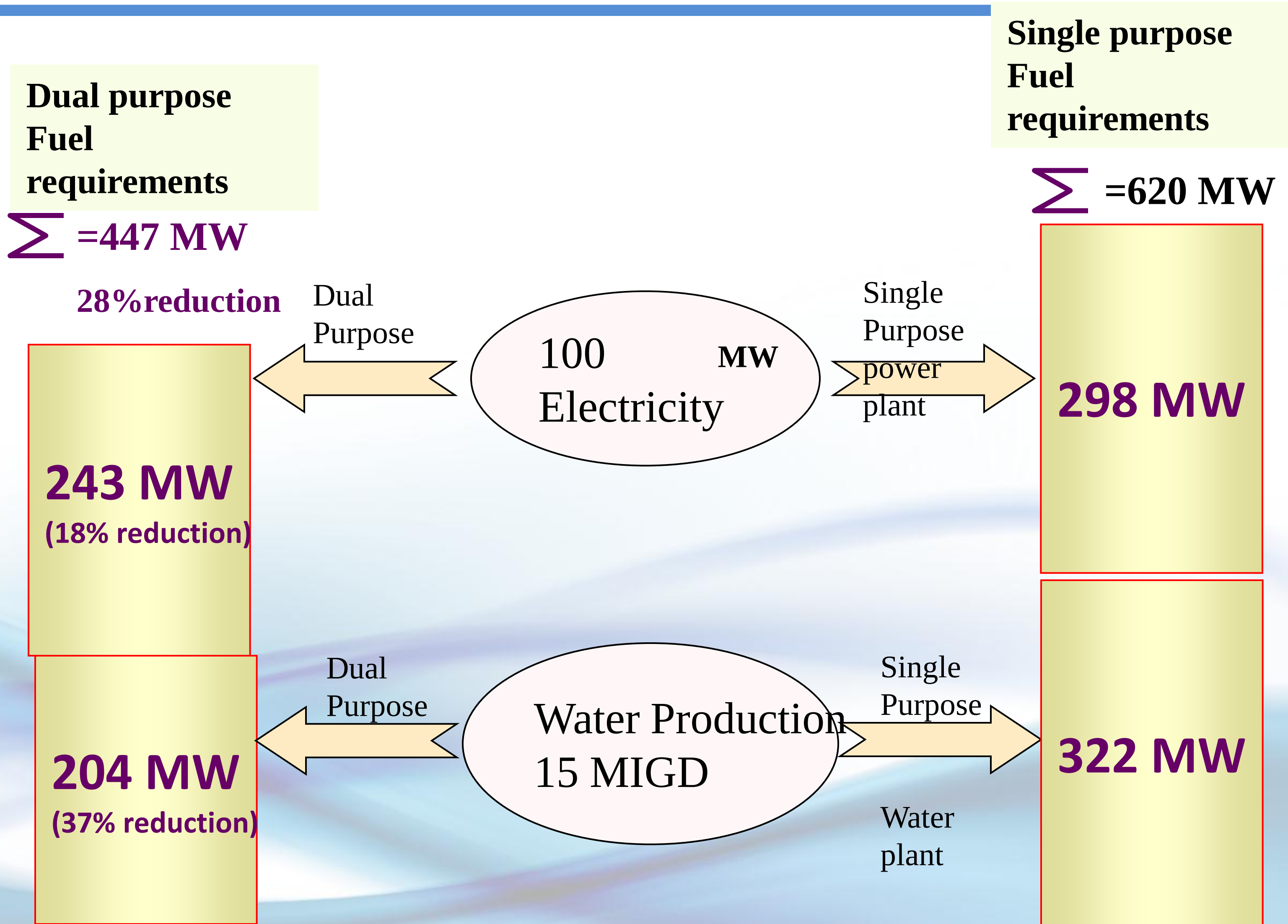
Jubail II (1983)	5.2
Khobar III (2000)	7.88
Khafji II (1986)	8.1
Yanbu II (2000)	5.15
Shoaiba I &II (1989, 2000)	5.3, 5.2
Shuqaiq (1989)	5.9



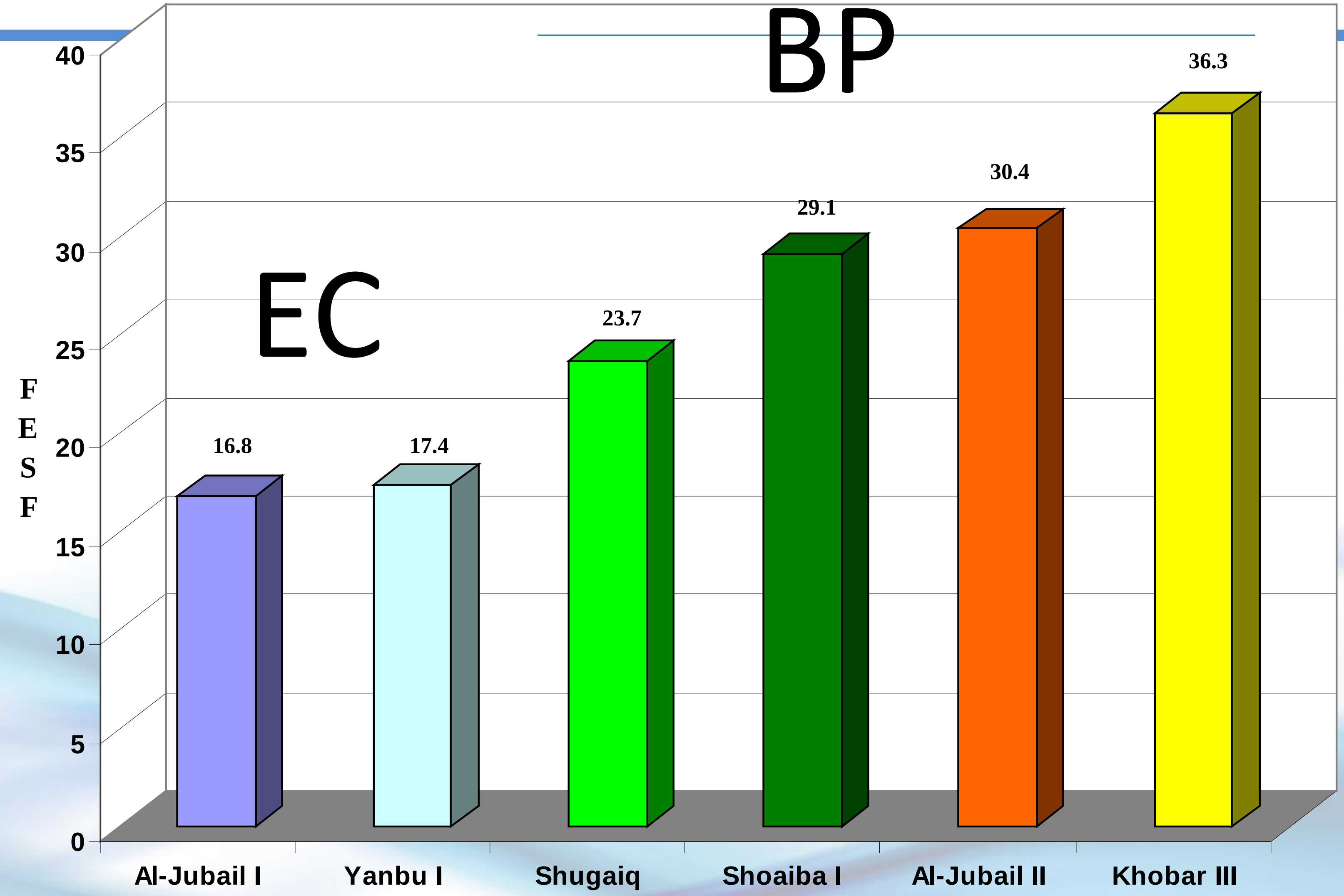
Financial Benefits for Dual Purpose Plants

Dual purpose power/water plants have an overall financial gain against two single purpose plants.

- **Sharing of some common equipment (boiler and its associated facilities, intake and outfall facilities).**
- **Elimination of some equipment (power plant condenser)**
- **Tremendous saving in fuel consumption related to the desalting process** →



Thermal Benefits of Cogeneration Plants

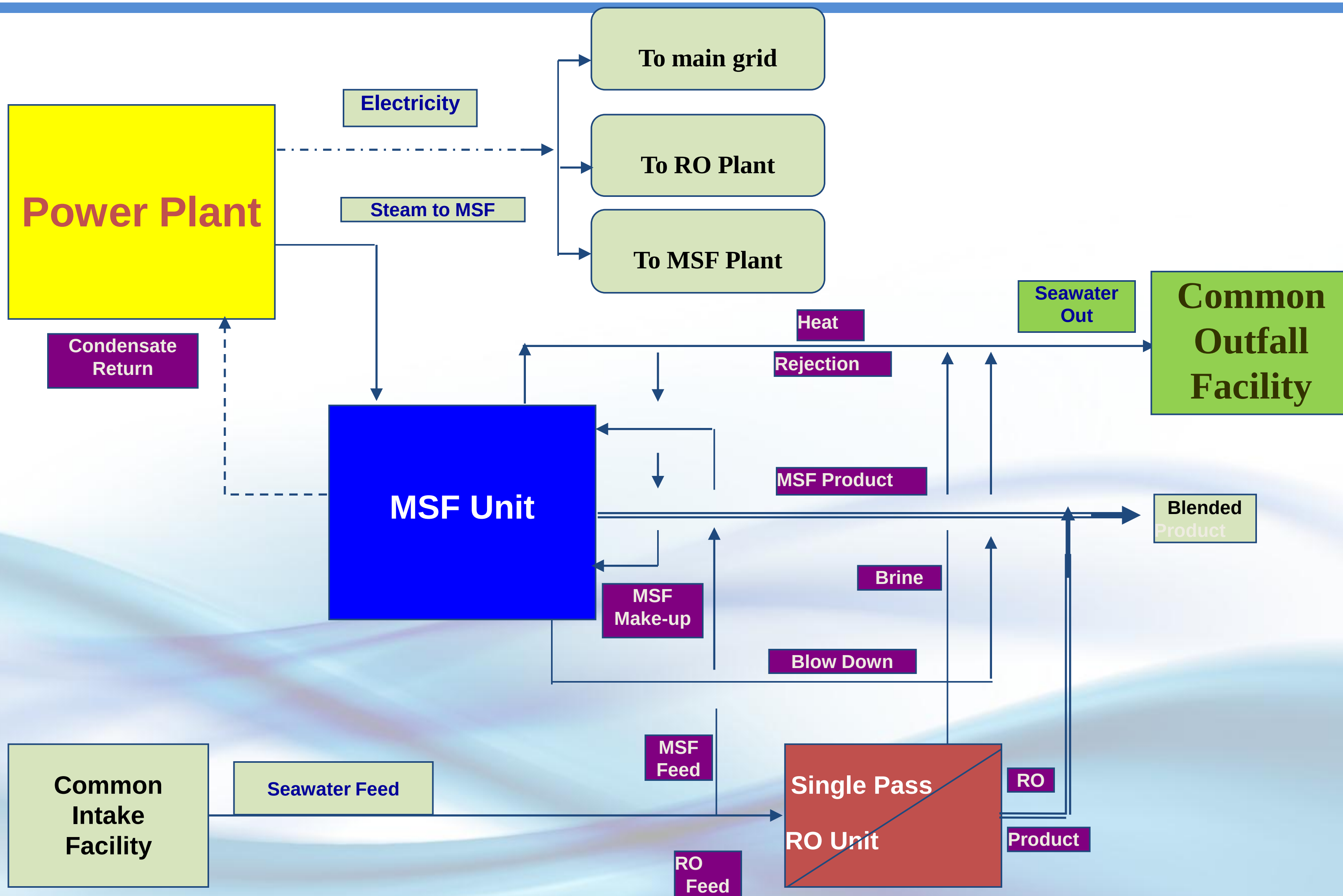


Thermal benefits of SWCC's dual purpose plants

TRADEOFF BETWEEN LOW COST SWRO PROCESS AND HIGH RELIABLE MSF PROCESS

ACHIEVED THROUGH

ADOPTION OF HYBRID MSF/MEMBRANE DESALINATION TECHNOLOGIES



Schematic diagram of simple hybrid configuration

Commercially Available Hybrid Desalination Plants

Jeddah MSF/SWRO

- 1989 , Phase I
  Single stage , 12.5 MIGD
- 1994 , Phase II
  Single stage , 12-5 MIGD

Product blended with MSF Product

Yanbu MSF / SWRO

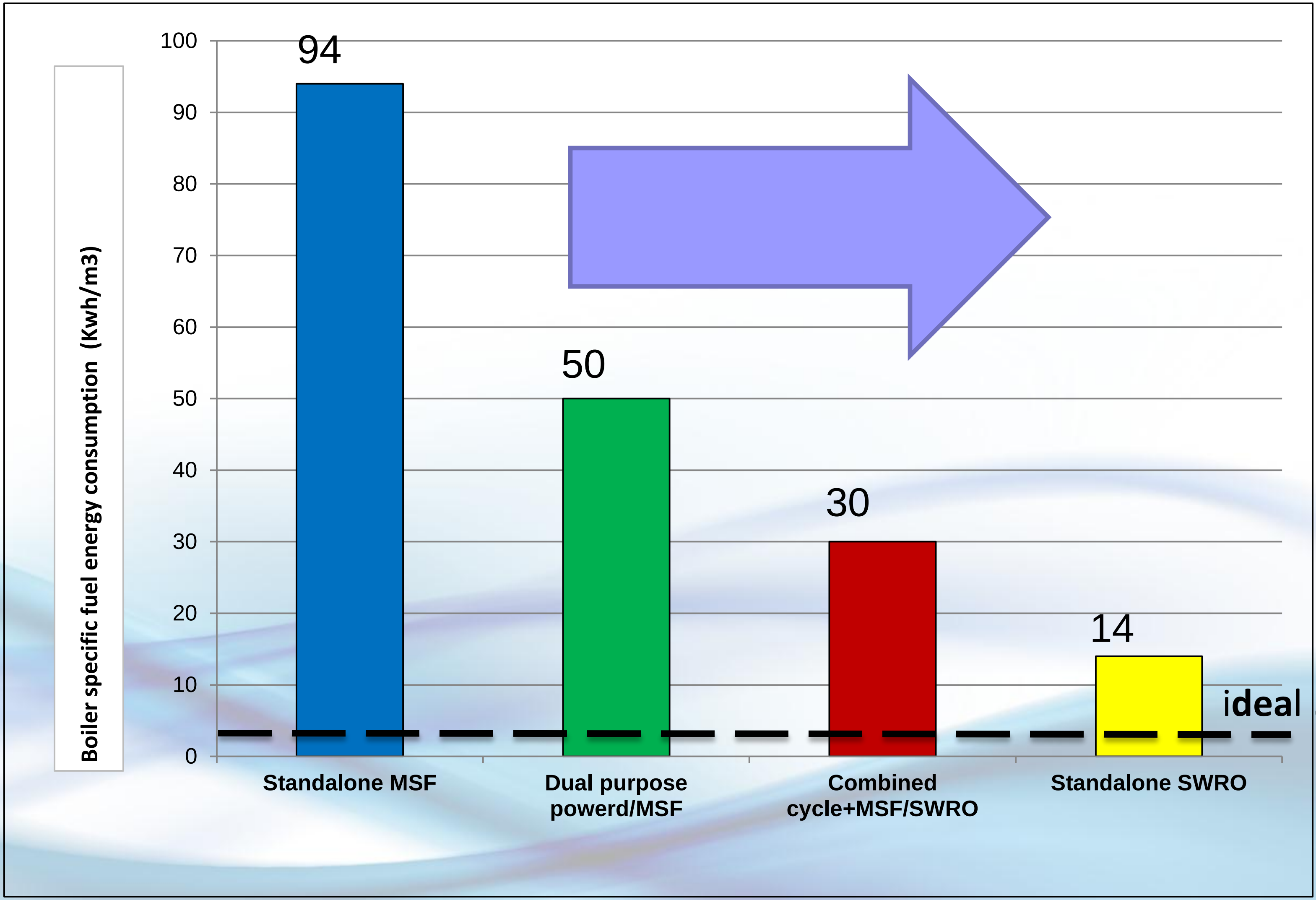
- SWRO 28.16 MIGD
- Phase II MSF 40 MIGD

Al-Jubail MSF/SWRO

- 20 MIGD
- Comman intake/outful with MSF
- Product blended with MSF

Ras Al Khair MSF/SWRO

Impact of adoption of hybrid MSF/SWRO on specific fuel energy consumption



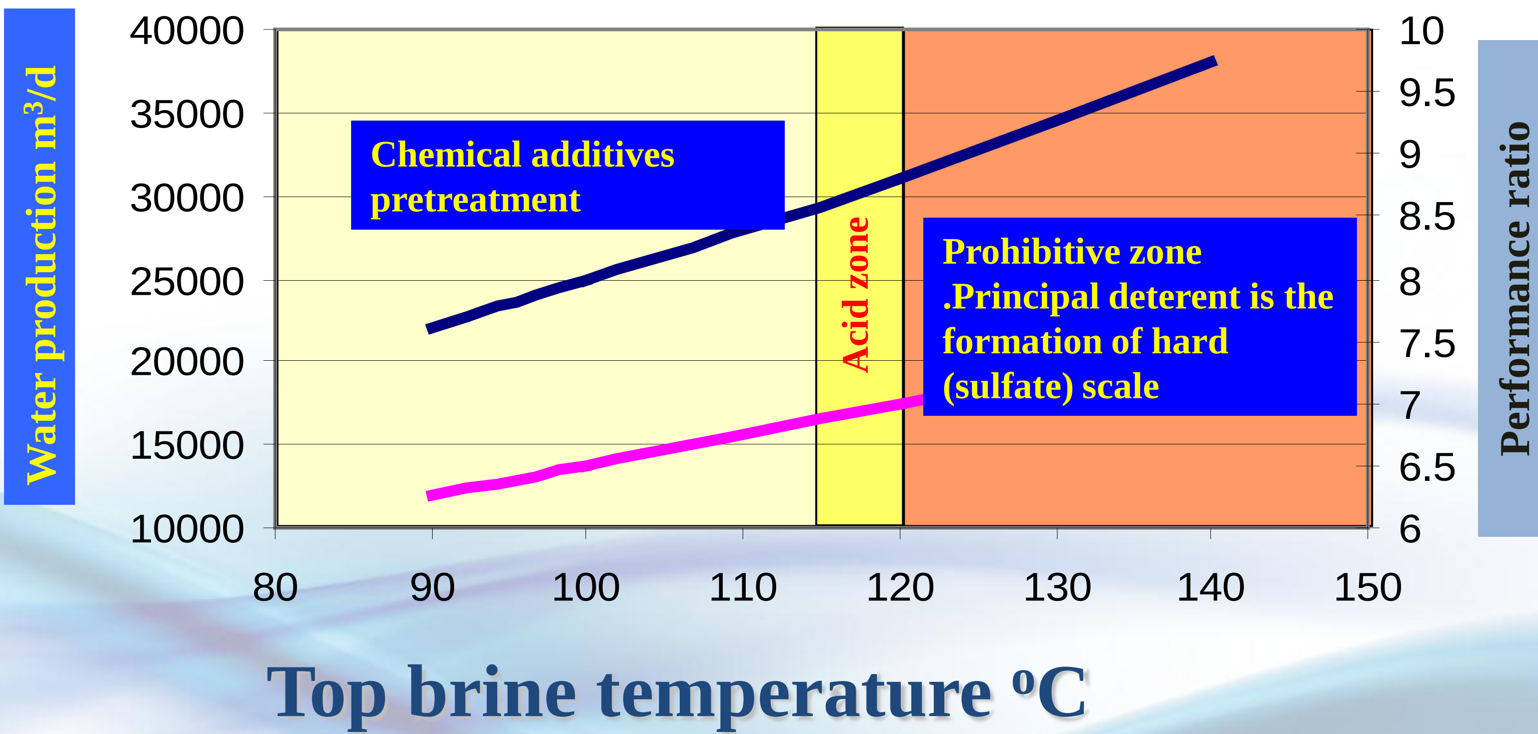
Future R&D Directions to improve the techno-economic effectiveness of MSF Desalination plants

- Employ plants with larger unit size
- Maximum available MSF unit size is 20 MIGD
- There is potential to increase it to 25 MIGD by reverting to the once through MSF mode due the design constraints inherited in the brine recycle mode.

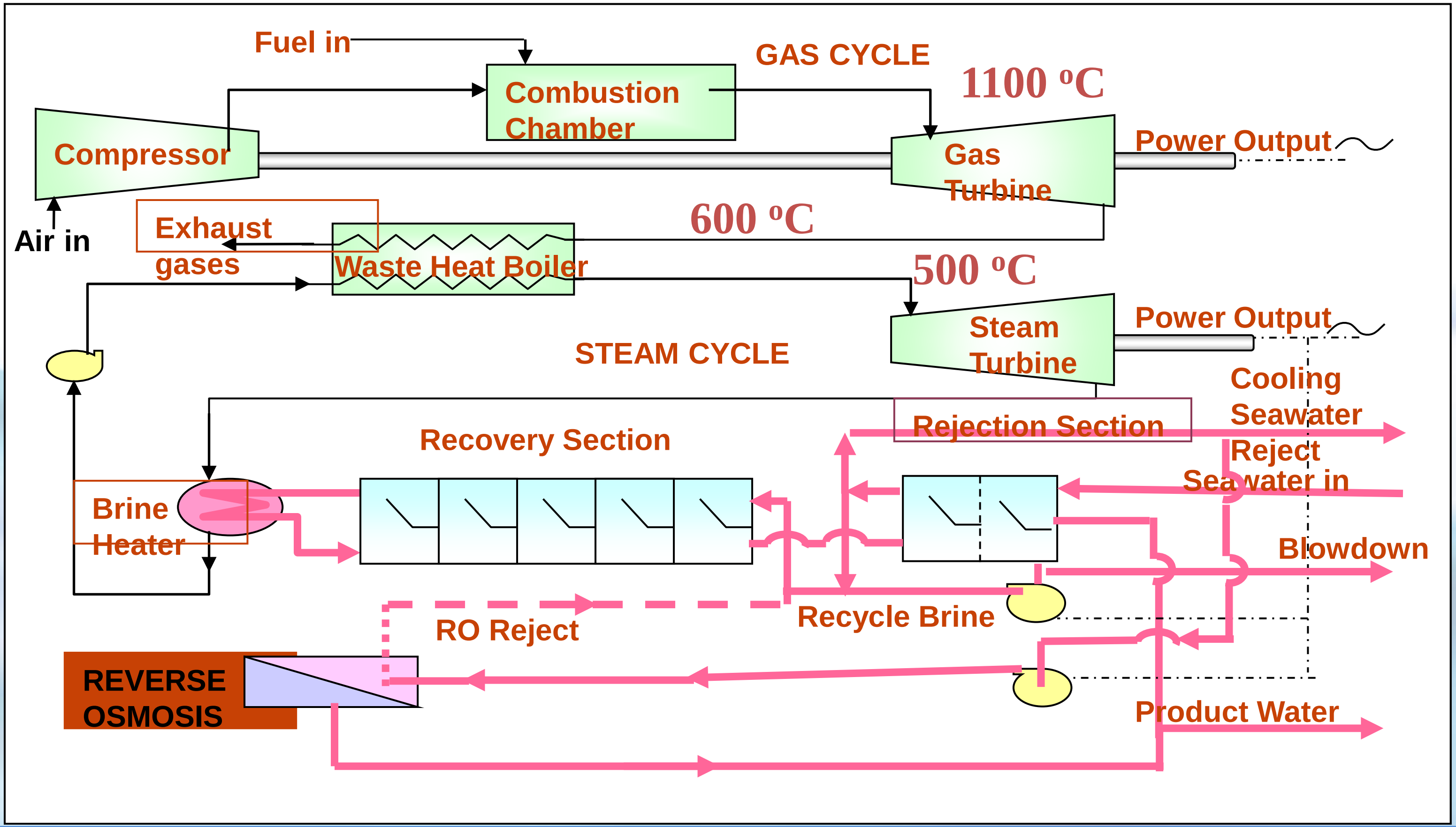
Future R&D Directions to improve the techno-economic effectiveness of MSF Desalination plants

- Employ methods that can reduce scaling, improve recoveries, enhance heat transfer and increase top brine temperatures

Process limitation of the MSF desalination process



❑ Integrate MSF plants within the context of energy efficient combined power cycles and cost effective hybrid desalination configurations



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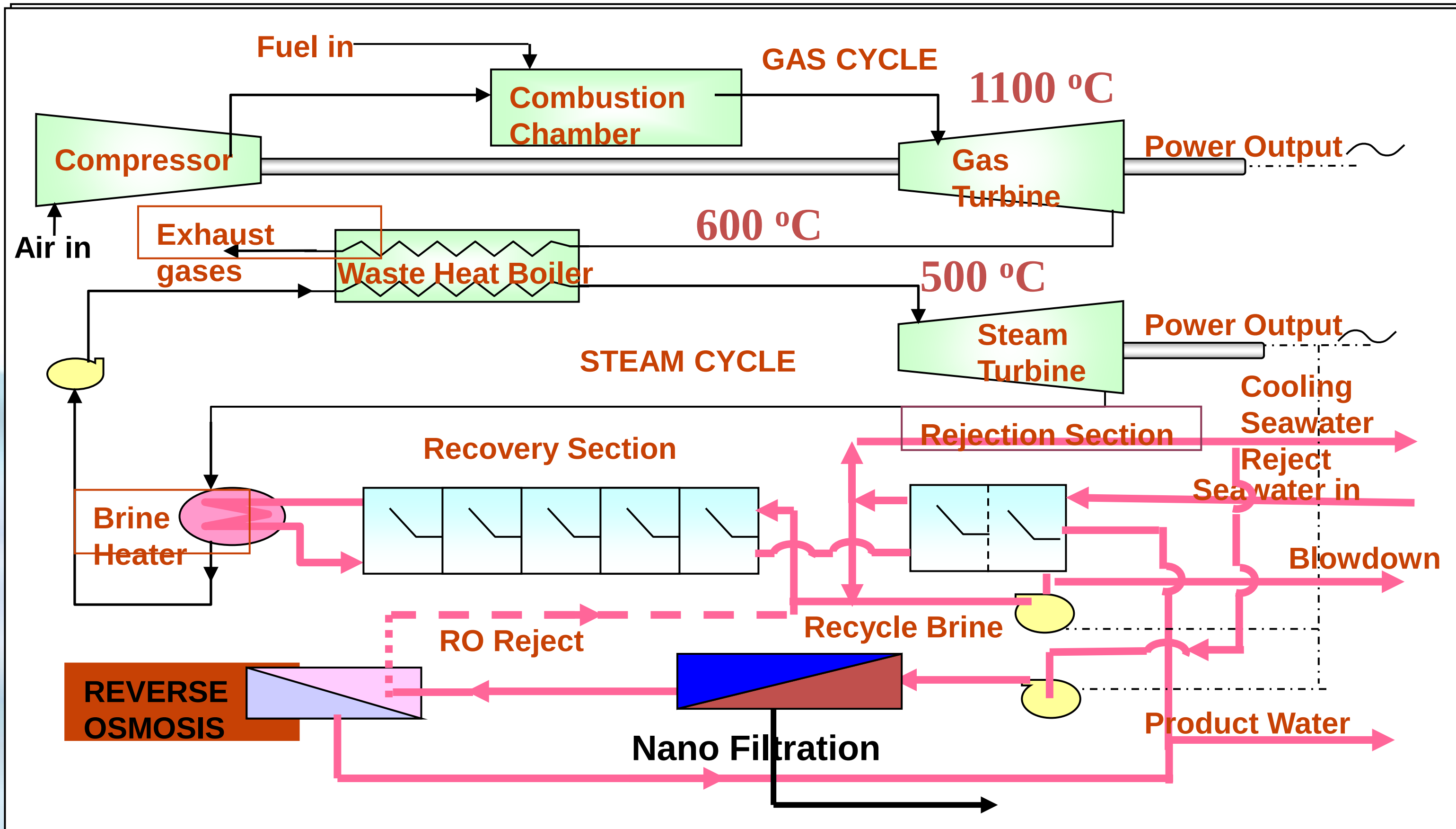

CONCLUSIONS

- During the last four decades MSF desalination plants acquired vast design and operating experience that resulted in optimized use of materials of construction and chemicals as well as the adoption of optimized thermo-dynamic design parameters

- MSF distillers which are over 20 year old, instead of being derated due to ageing, actually maintained production and performance ratios that equaled or, in most cases, surpassed the original design specifications. Thus, the service lives of some MSF distillers exceeded 30 years

CONCLUSIONS

- The MSF process is robust, highly reliable and economically feasible to be integrated with power generation cycles for the simultaneous production of water and electricity, and effectively utilizing the waste heat of power generation cycles .

- New dual-purpose power/MSF plants have to be designed on the basis of fully integrated hybrid concept

CONCLUSIONS Cont.

- MSF technology is now relatively mature . Are there more opportunities and scope for further improvements ?

- Improvements in materials : Use cheap materials while maintaining corrosion resistance

- There is more room for the development of scale techniques to allow MSF operation at high temperatures.

- Further reduction in energy consumption through the use of solar energy and optimizing power and MSF systems.

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Thank You







Optimized Use of Materials of Construction

Materials of construction for the major components of recently built MSF plants

Flash chamber of both recovery and heat rejection sections	Carbon steel lined with stainless steel (floor lined with 317L, walls with 316L and roof with either 316L or 304.
Water boxes	Carbon steel lined with 90/10 Copper-Nickel
Tubes	Brine heater tubes modified 66/30/2/2 Cu/Ni/Fe/Mn ; heat recovery tubes: Copper/Nickel (first four stages 70/30 and remaining stages 90/10)
Heat rejection tubes	Titanium & modified 66/30/2/2 Cu/Ni/Fe/Mn

Next generation Desalination Plants

- **In the search for a more energy-efficient desalination process, the next generation plants will use a combination of membrane processes with multi-stage flash (MSF)/multi-effect distillation (MED) thermal processes to harness the maximum thermal energy that would otherwise be wasted from a combined cycle power plant.**

- **Combined cycle power plants are highly efficient, flexible, reliable, cost-effective and environmentally friendly solutions to generate electrical power. CCPP can achieve electrical efficiencies up to 60%**

- **The high fuel utilization factor of the combined cycle plant contributes to low lifecycle costs.**

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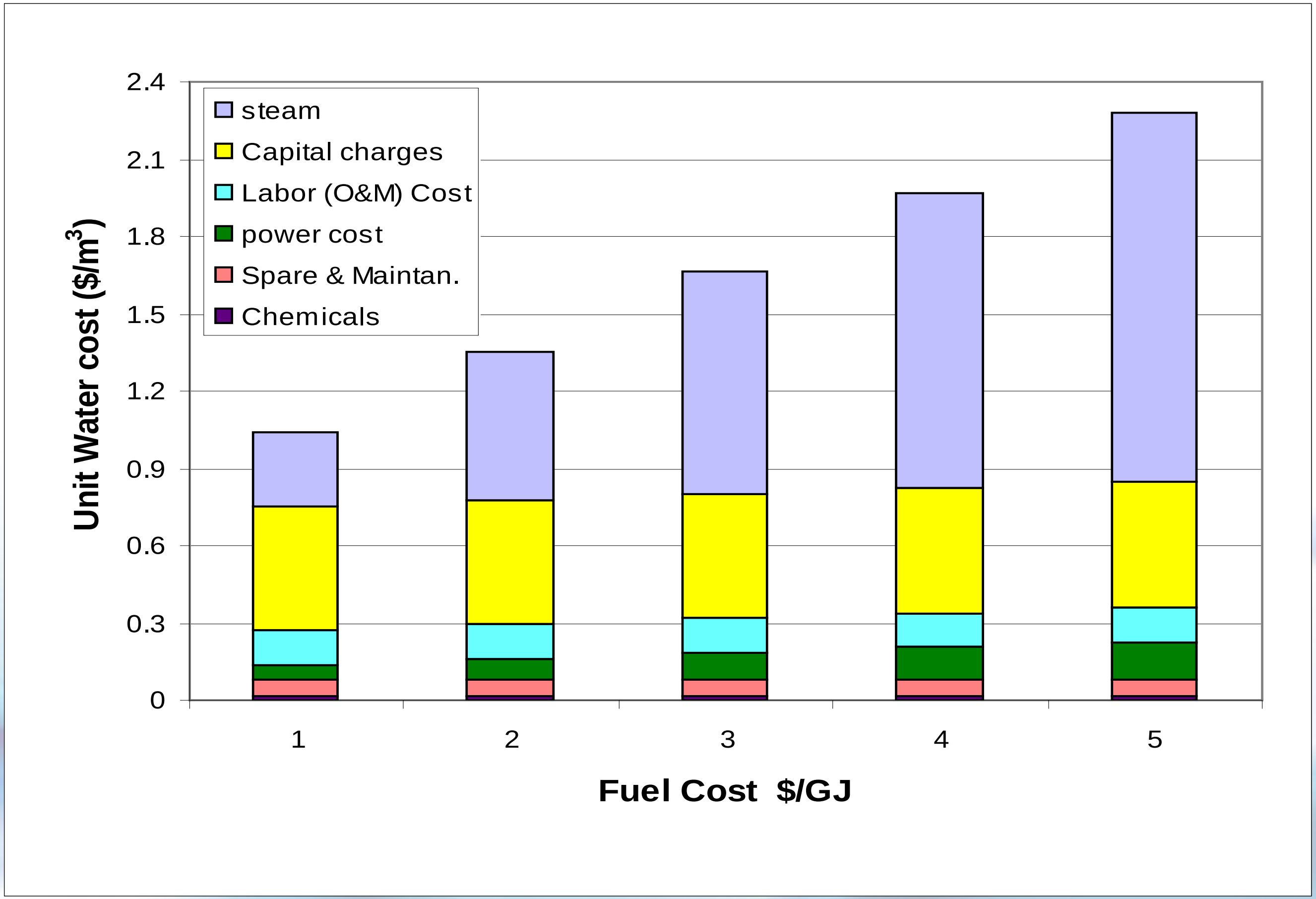

Impact of variation of fuel cost on unit water cost

Future R&D Directions to improve the techno-economic effectiveness of currently employed MSF desalination technologies

Development of solar assisted desalination technologies plants using solar energy

Future R&D Directions

Development of solar assisted MSF desalination plants using solar energy