Saline Water Conversion Corporation
Saline Water Desalination Research Institute (SWDRI)

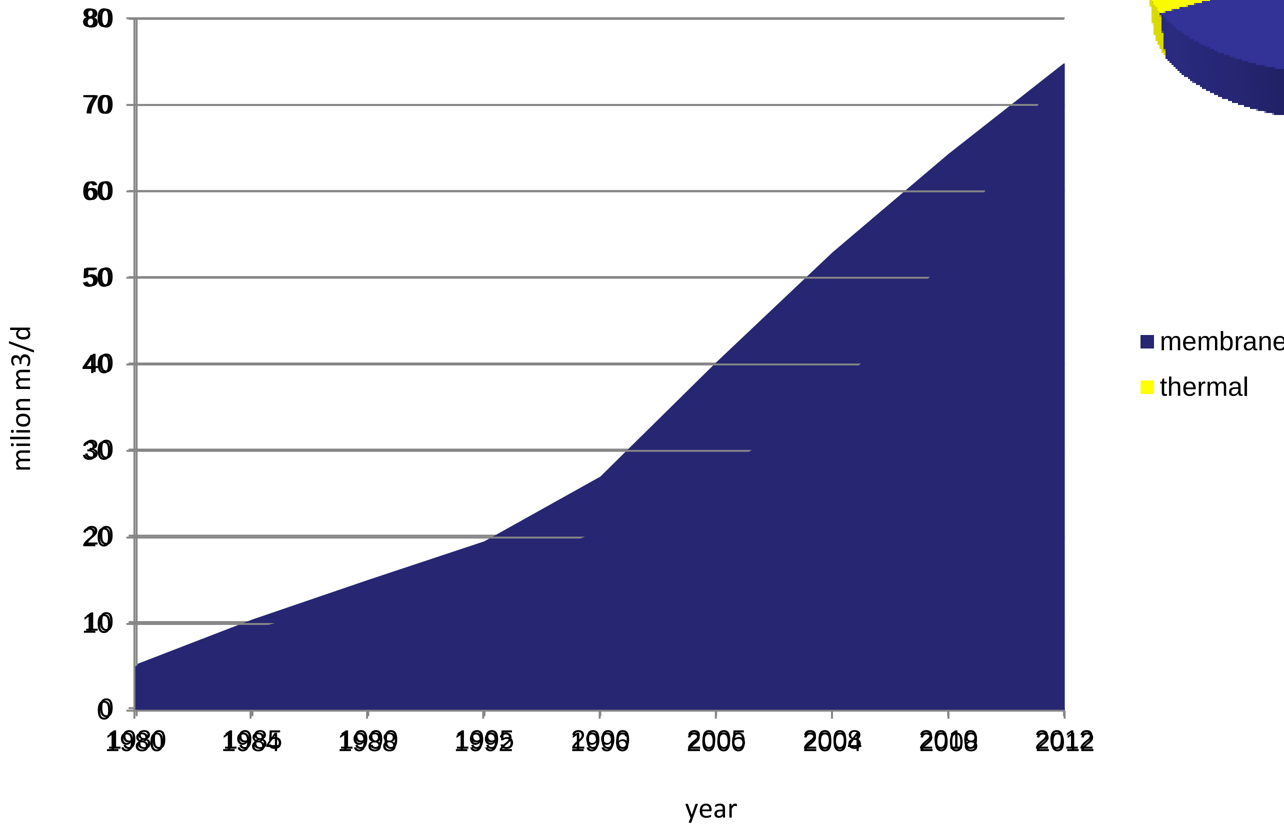
Evolution of Thermal Desalination Processes

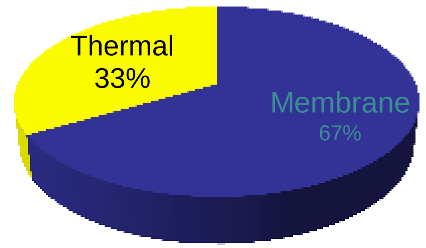
Dr. OSMAN AHMED HAMED

OUTLINE

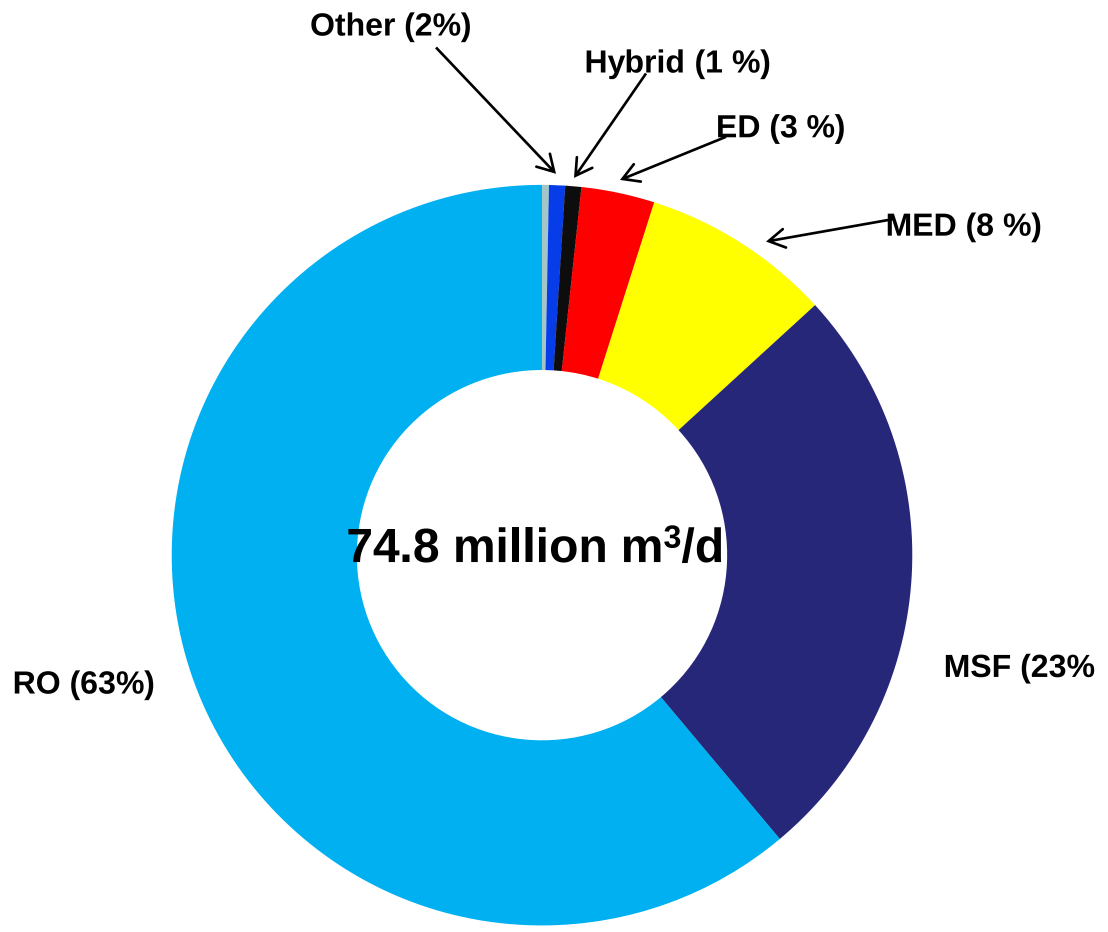
- ❑ Background
- ❑ Evolution of MSF desalination plants
- ❑ Evolution of MED desalination plants
- ❑ Dual purpose power/water and hybrid desalination plants
- ❑ R&D Prospects

Evolution of Installed membrane and thermal capacity (cumulative) 1980-2012

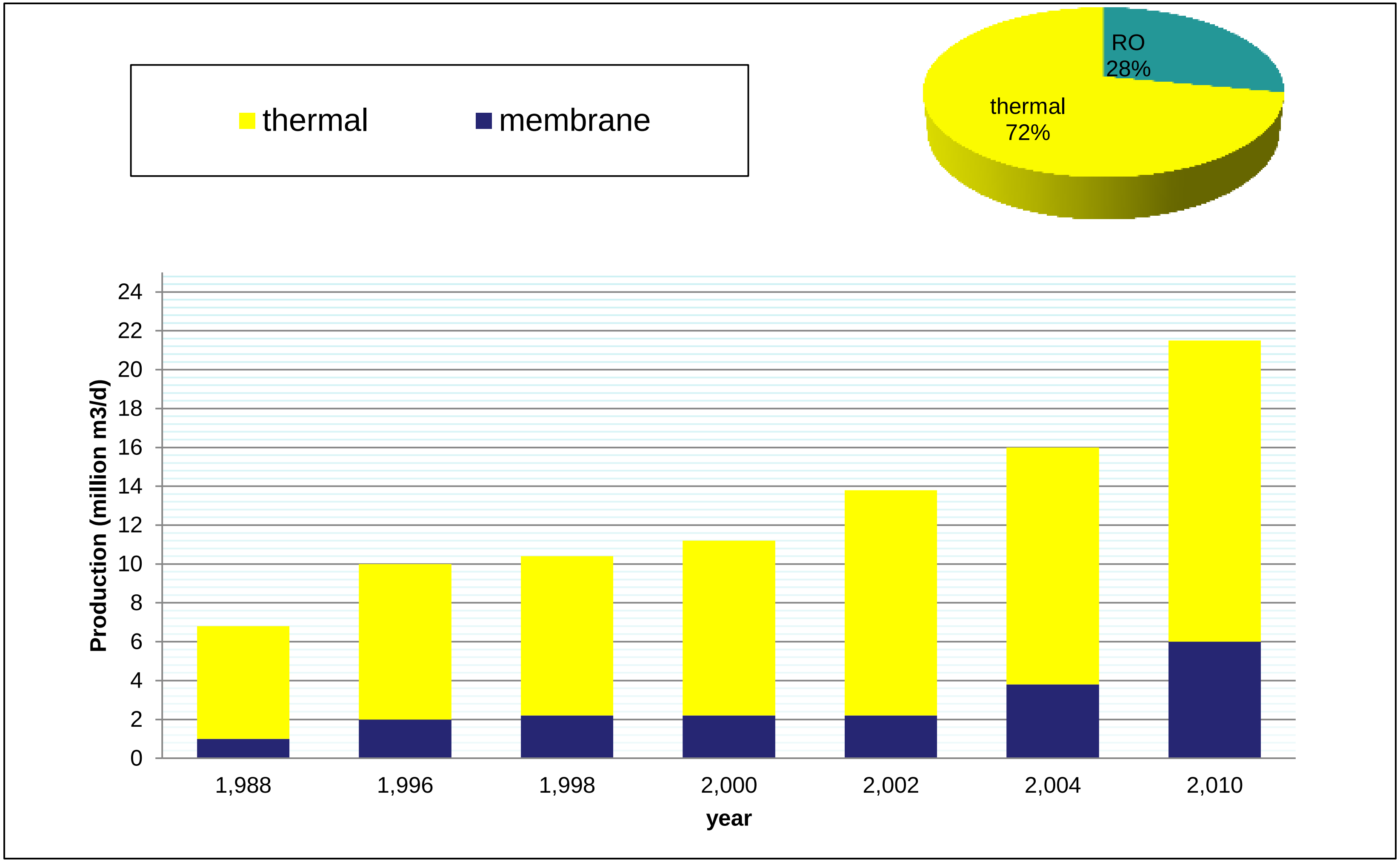




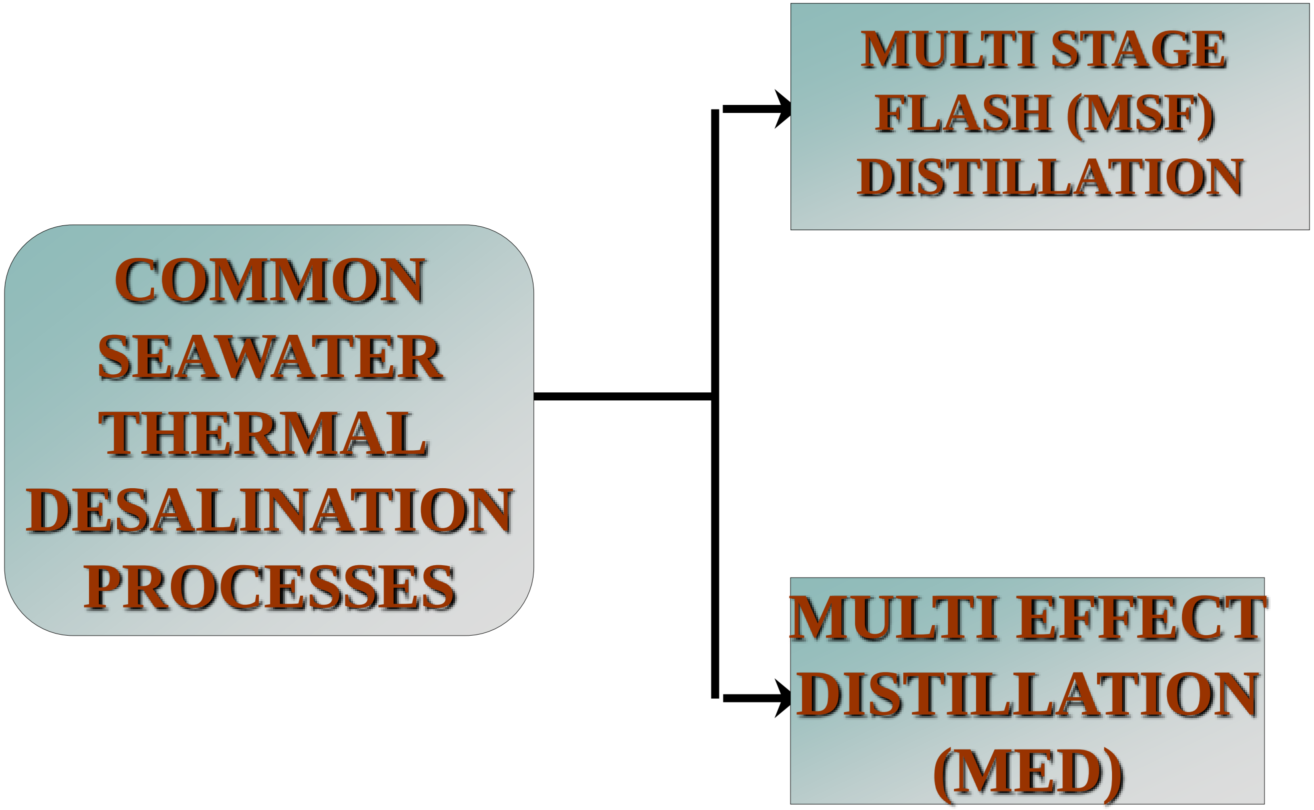
Breakdown of Total Worldwide Installed capacity by technology



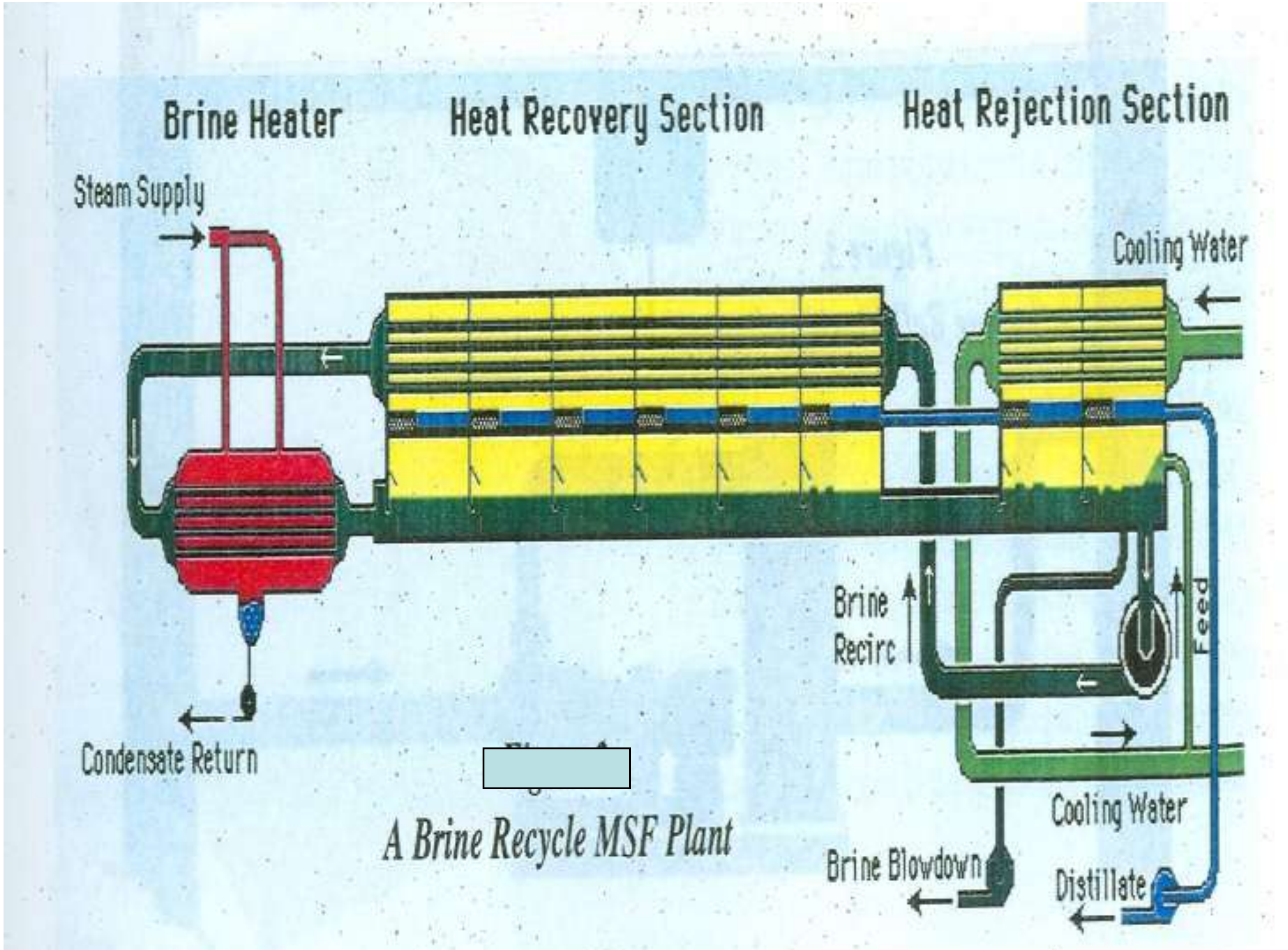
Historical evolution of total installed capacities of desalination plants in the GCC countries



Evolution of Thermal Desalination Processes



The multi-stage flash (MSF) desalination process

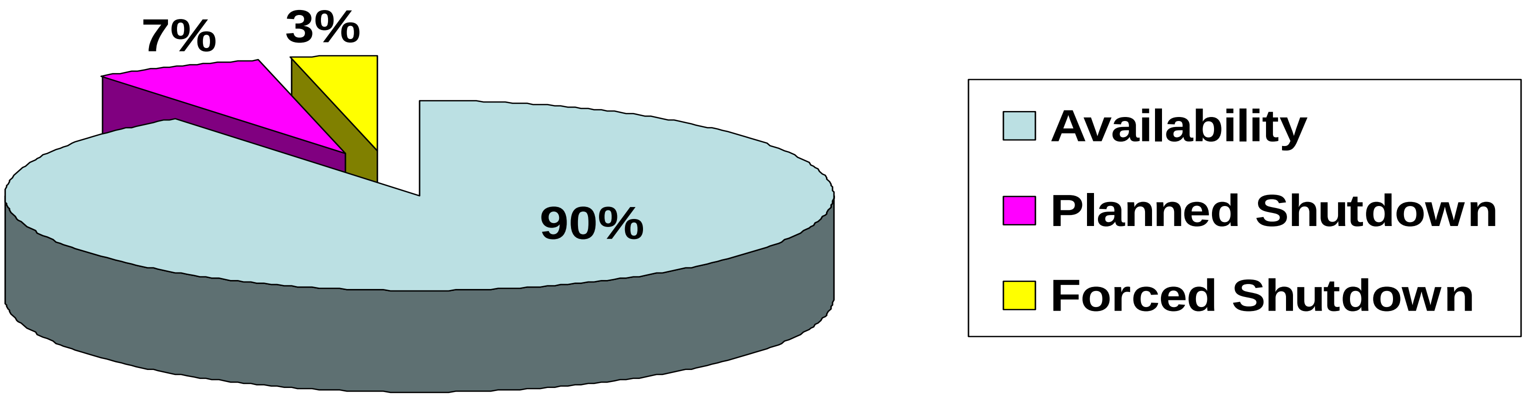


A Brine Recycle MSF Plant

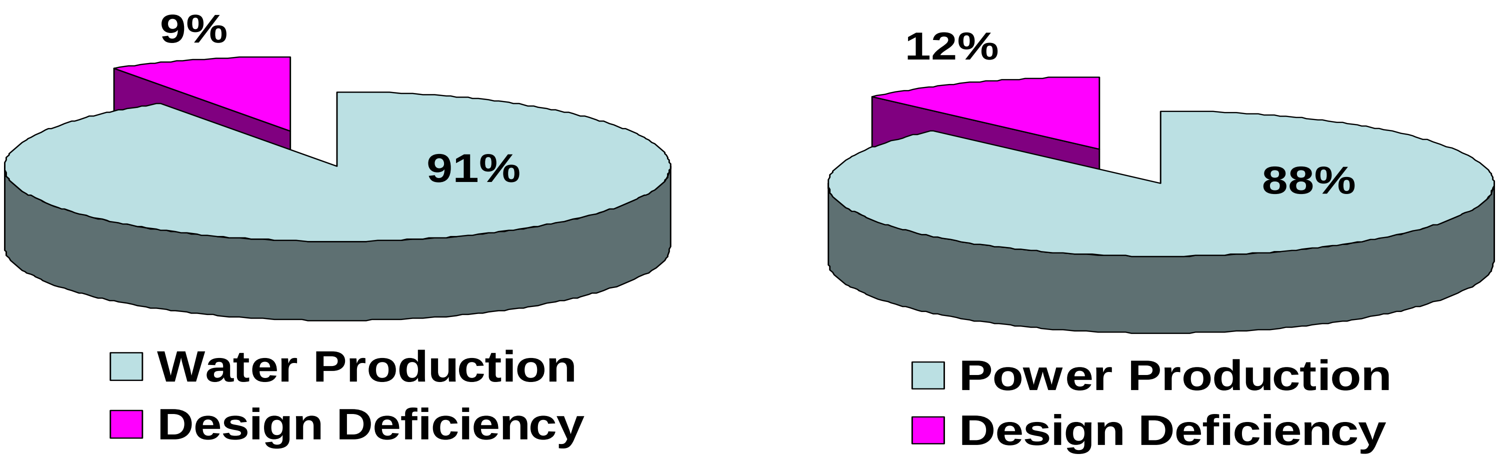
Evolutionary Developments of MSF Plants

High reliability & availability. Life-time over 30 years

S. #	Plants	Year	Capacity (migd)	Life Time
1	Jeddah-III	1979	4x5	34
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



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



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

Reasons For high reliability and availability

Selection of High Design Fouling Factor

BH Design Fouling Factors

- Al-Khobar III — 0.264 m^2 $^oC/kW$
  Al-Khobar II — 0.160 m^2 oC/kW (1982)
- 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)
- Tawaleh 'B' — 0.15 m^2 $^oC/kW$
  Jebel Ali — 0.12 m^2 oC/kW

Reasons For high reliability and availability

- Selection of High Design Fouling Factor
- Effective alkaline scale control

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

Hybrid Treatment

(Acid + Additive)

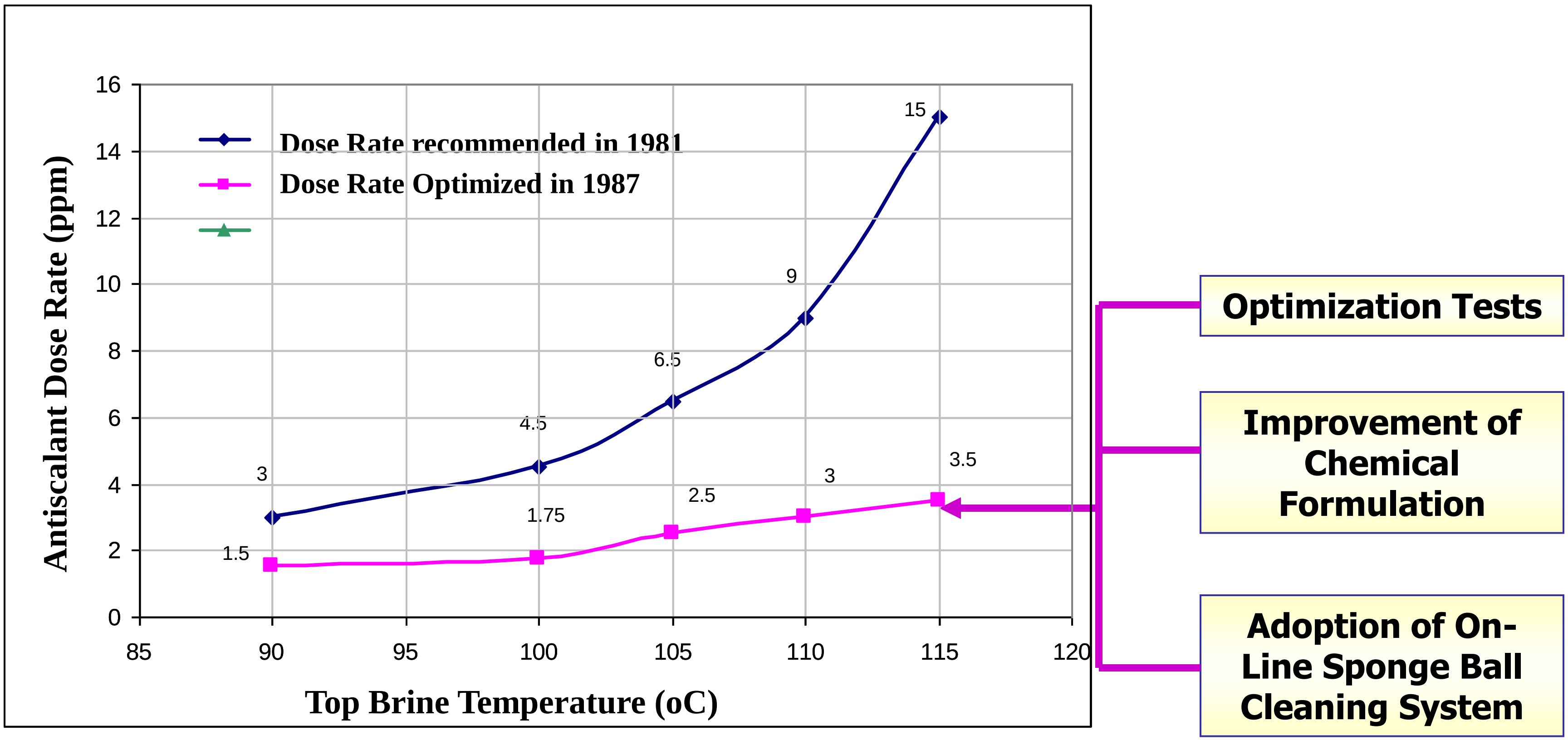
To overcome acid treatment problems

High Temperature Scale Control Additive (HTA) Threshold Agents

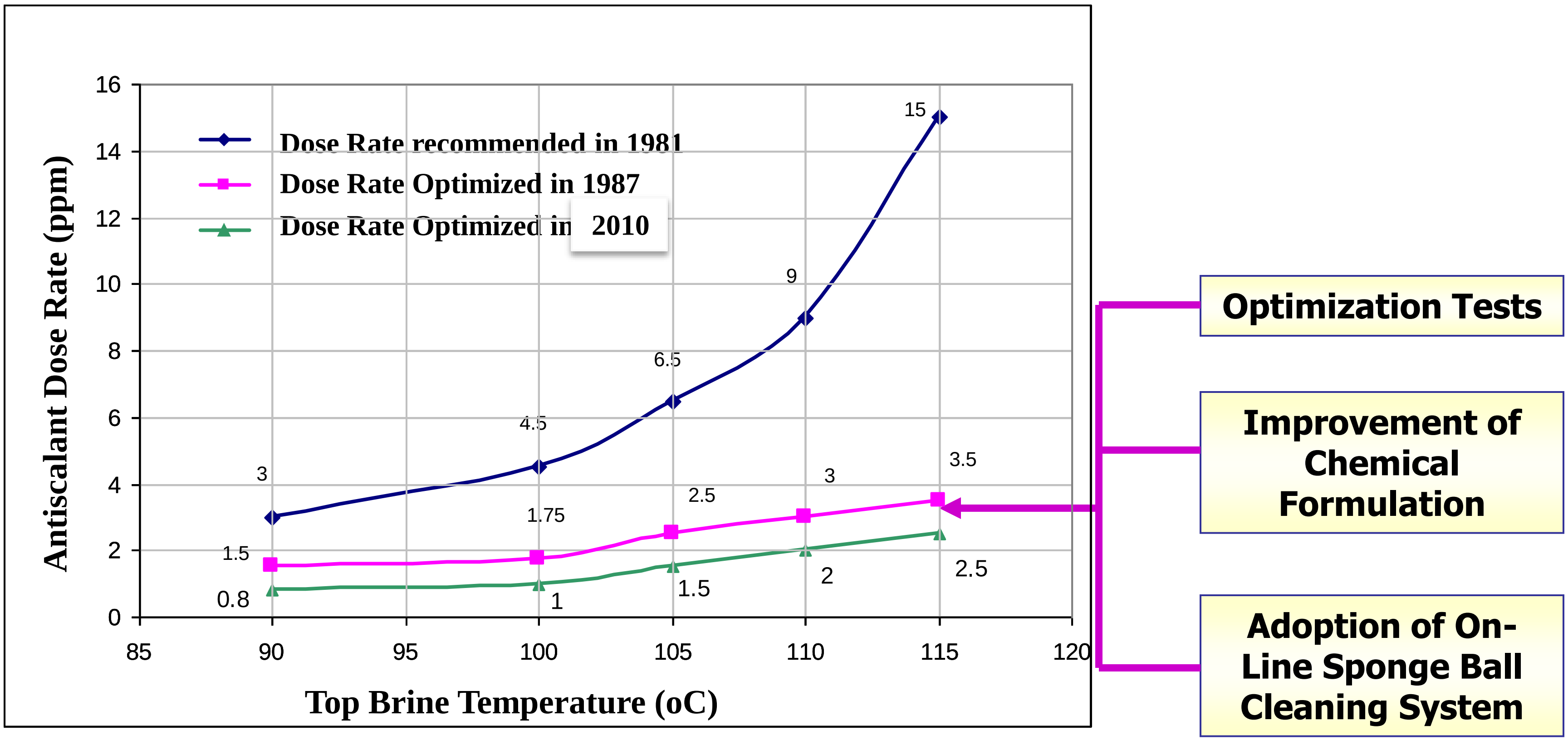
Inhibitors Based on Phosphonic Acid

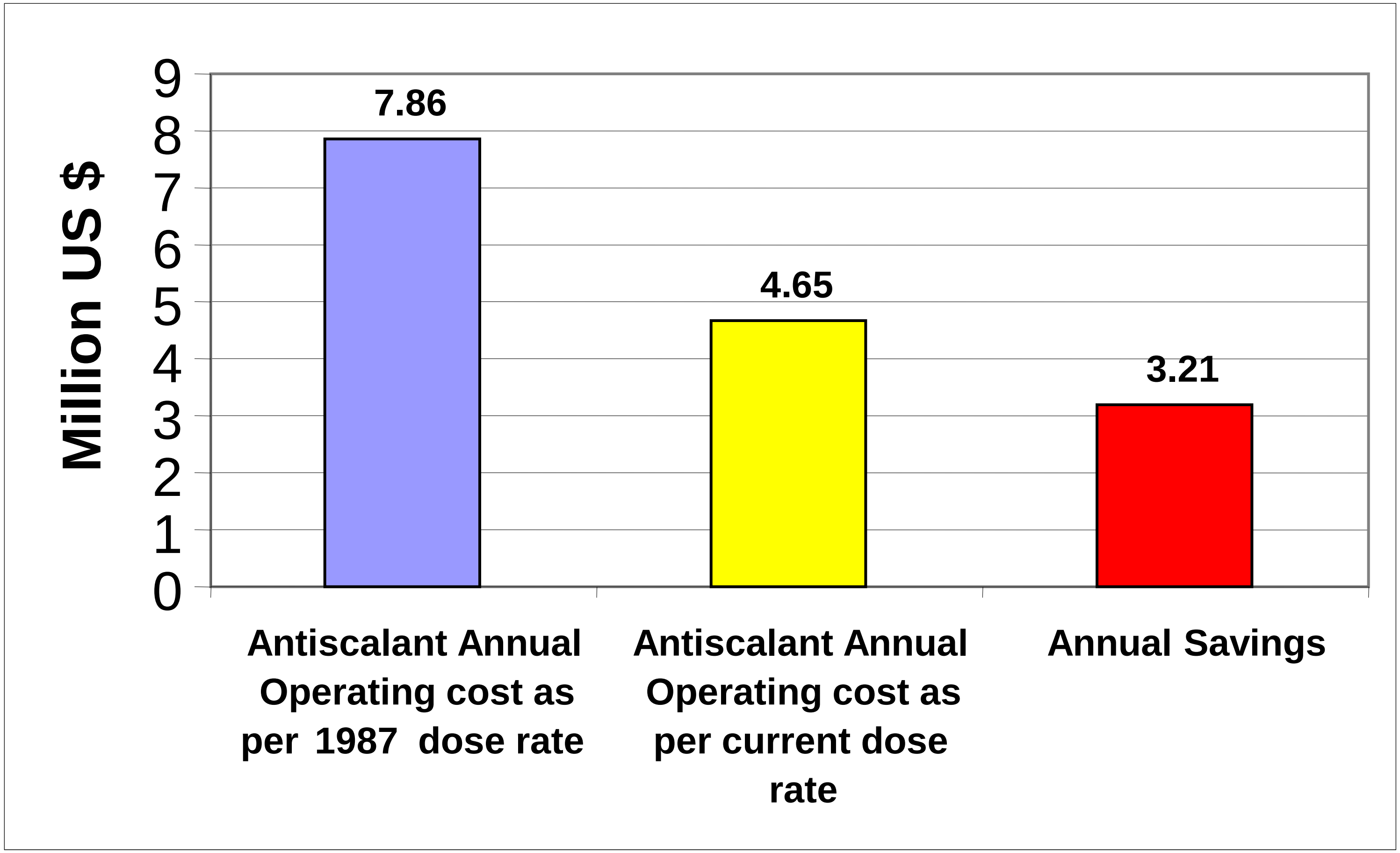
Inhibitors Based on Polycarboxylic Acid

SWCC's ACHIEVEMENTS IN CONTROLLING ALKALINE SCALE FORMATION



SWCC's ACHIEVEMENTS IN CONTROLLING ALKALINE SCALE FORMATION




Million US $
9
8
7
6
5
4
3
2
1
0
7.86
4.65
3.21
Antiscalant Annual Operating cost as per 1987 dose rate
Antiscalant Annual Operating cost as per current dose rate
Annual Savings

Reasons For high reliability and availability

- Selection of High Design Fouling Factor
- Effective alkaline scale control
- Good Selection of Material of Construction

Section		Material of Construction
Brine Heater	**Shell**	Carbon steel (all plants)
	Tubes	Either 70/30 o,90/10 Cu-Ni or modified 66/30/2/2 Cu/Ni/Fe/Mn except Al-Jubail I (Titanium)
Heat Recovery Section	**Flash Chamber**	• First high temperature stages Al-Jubail, Al-Khafji and the first two modules of Jeddah IV cladded with stainless steel • Al-Khobar II completely cladded with 90/10 Cu/Ni • Al-Shuqaiq 1completely claded with stainless steel
	Tubes	All plants except Yanbu and Al-Jubail I: 90/10 Cu Ni Jubail I: Titanuim Yanbu 70/30 (1 to 10 stages) 90/10 (11 to 21 stages)
Heat Rejection	**Tubes**	All plants except Jeddah & Shoaiba : Titanium Jeddah II, III, IV 90/10 Cu/Ni Shoaiba 70/30 Cu Ni

Projects which were recently built use the following materials of construction for the major components

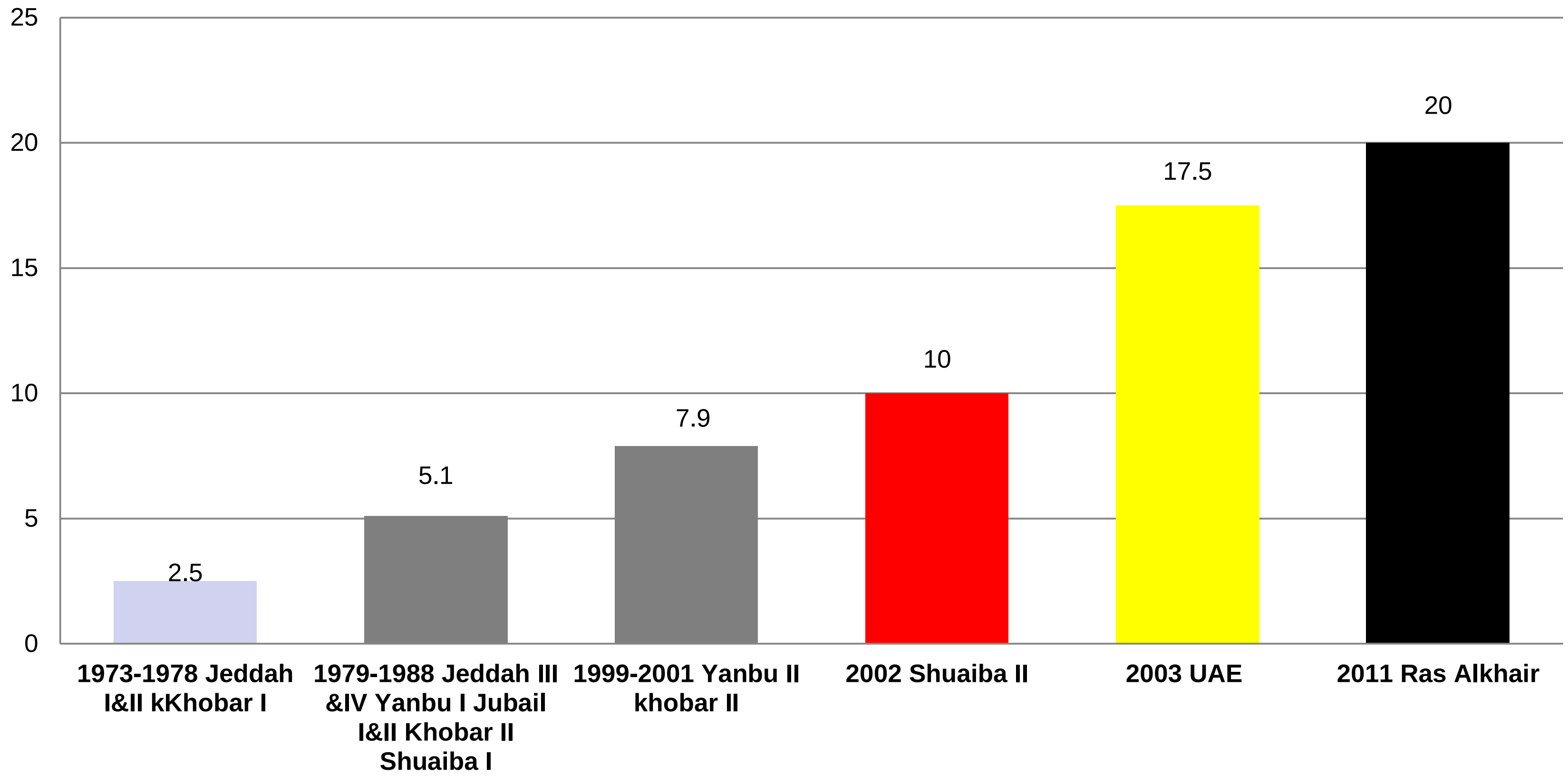
Flash chamber of both recovery and heat rejection sections	Carbon steel lined with stainless steel (floor lined with 317L, walls with 316L and roof with either 316L or 304.
Water boxes	Carbon steel lined with 90/10 Copper-Nickel
Tubes	Brine heater tubes modified 66/30/2/2 Cu/Ni/Fe/Mn ; heat recovery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

Evolutionary Developments of MSF Plants

High reliability & availability. Life-time over 30 years

Increase in distiller size

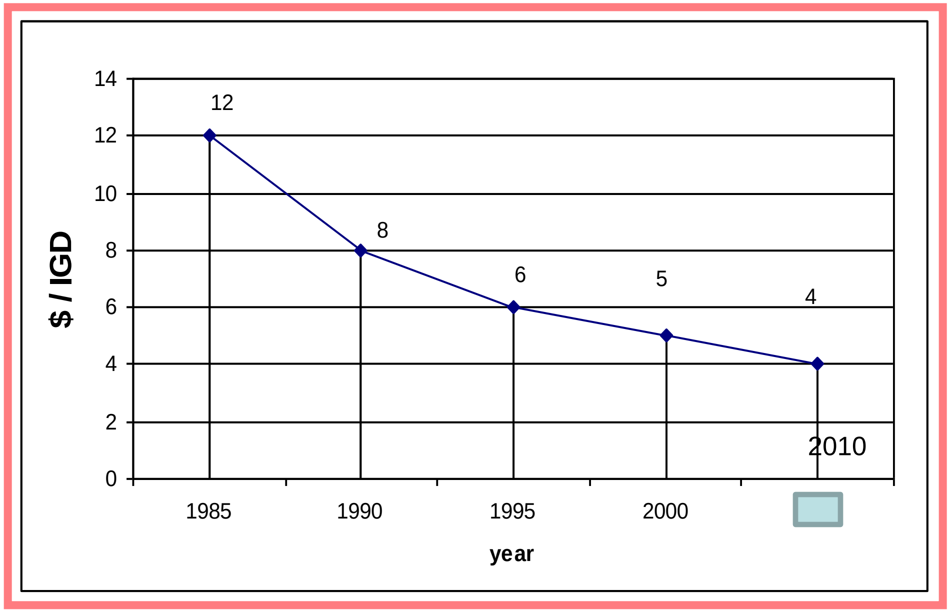
Historical Growth of MSF Distiller Size



Large unit size:

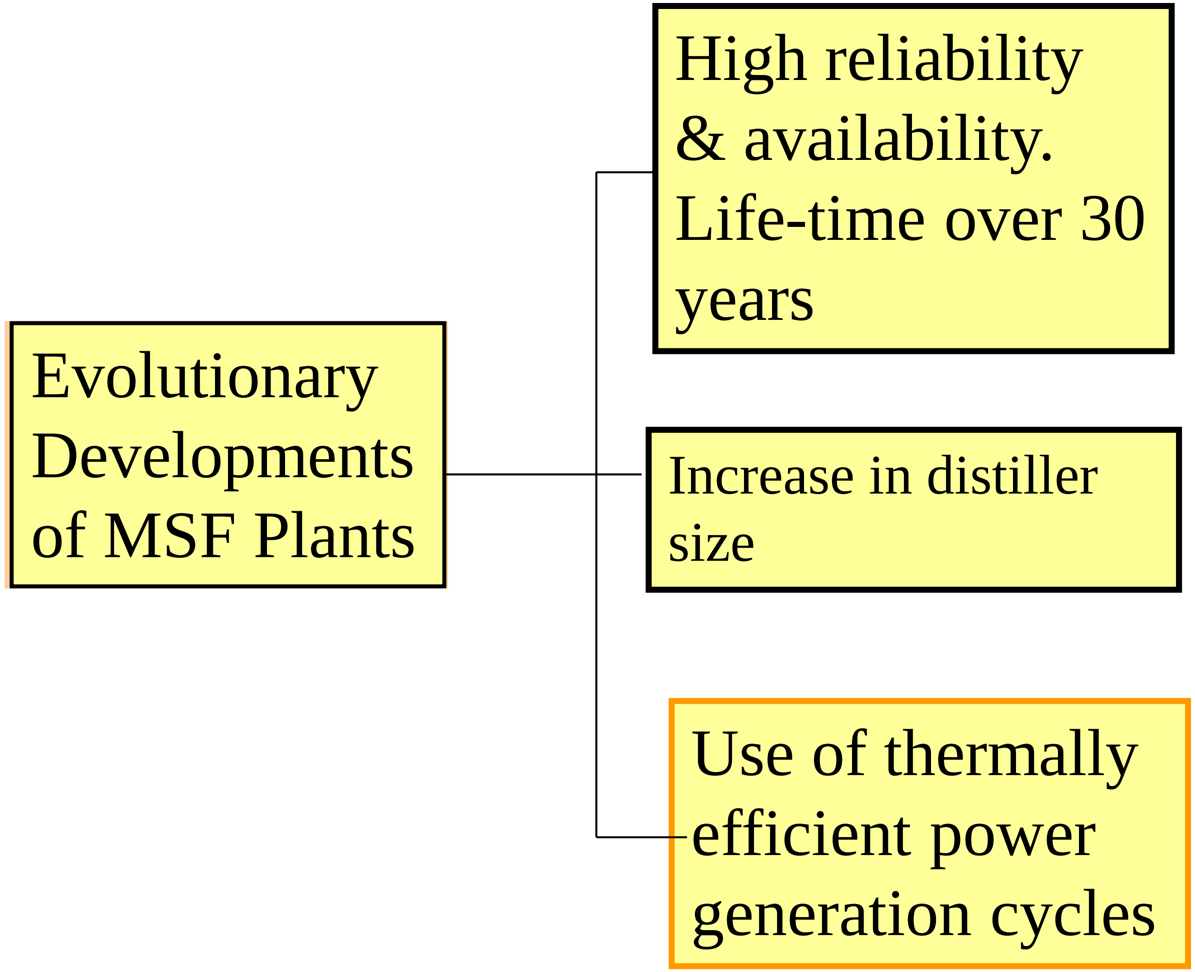
- Low investment cost for auxiliary equipment such as interconnection and control piping .
- Operating and maintenance people depends on the number of unit installed.
- Savings in operational cost.

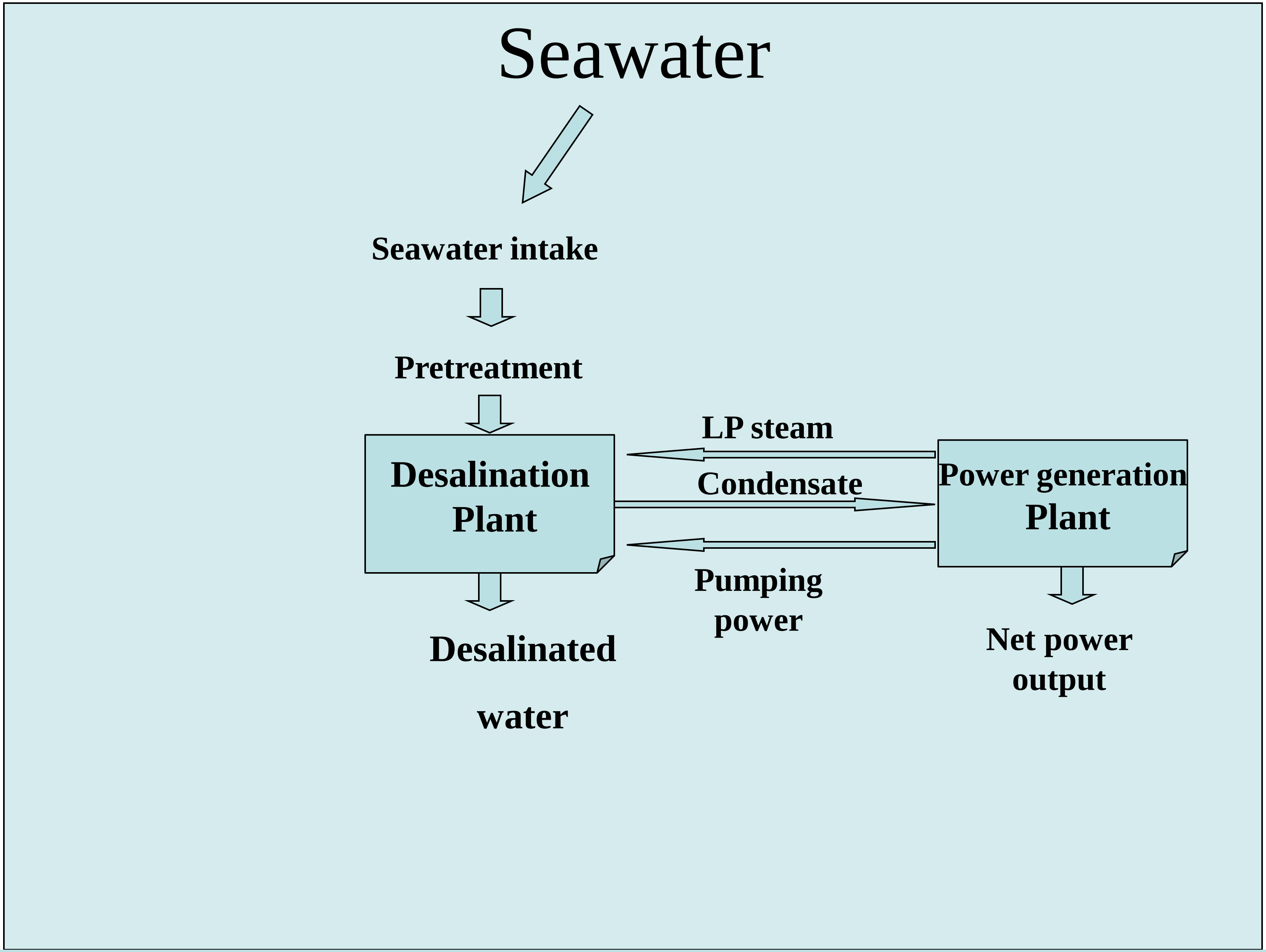
Price Trend for turn-key complete MSF plants



Reasons Constant Reduction of Investment per MIGD

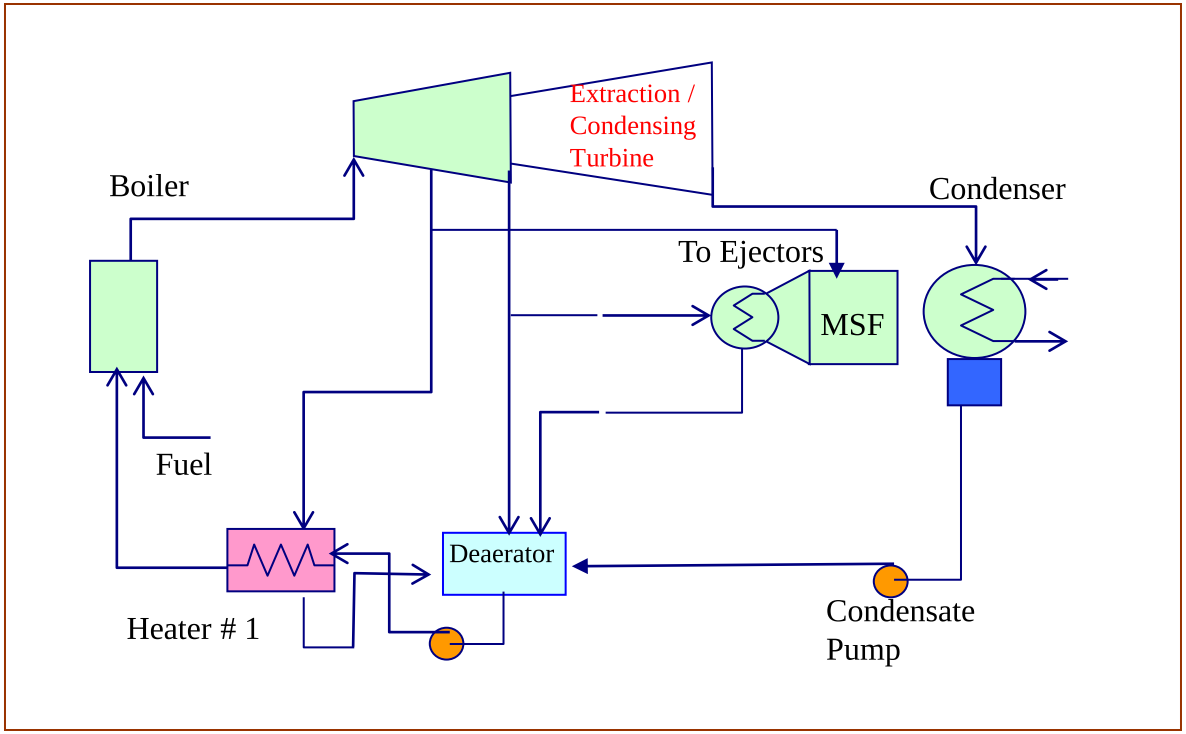
- optimized use of material of construction.
- Reduction of redundant equipment.
- Optimized mechanical design of evaporator vessel.
- Optimized thermo-dynamic design parameters.


Evolutionary Developments of MSF Plants
High reliability & availability. Life-time over 30 years
Increase in distiller size
Use of thermally efficient power generation cycles



Power/Water Flow Chart

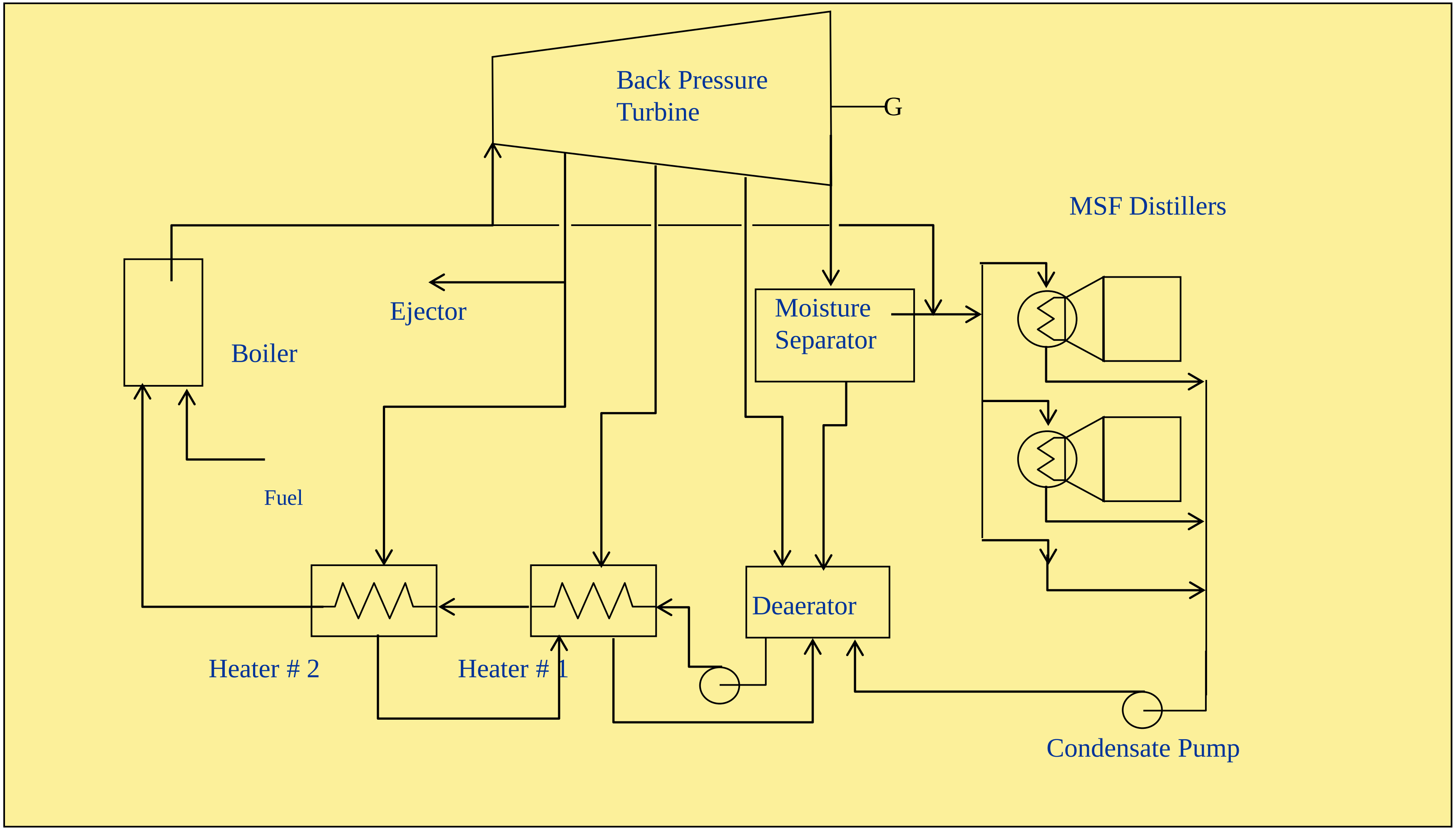
Before 1982 SWCC employed Extraction-condensing turbine arrangement



Power to water ratio 12 to 15 MW/MIGD

Jeddah II,III,IV AlJubail I Yanbu I Alkhobar II

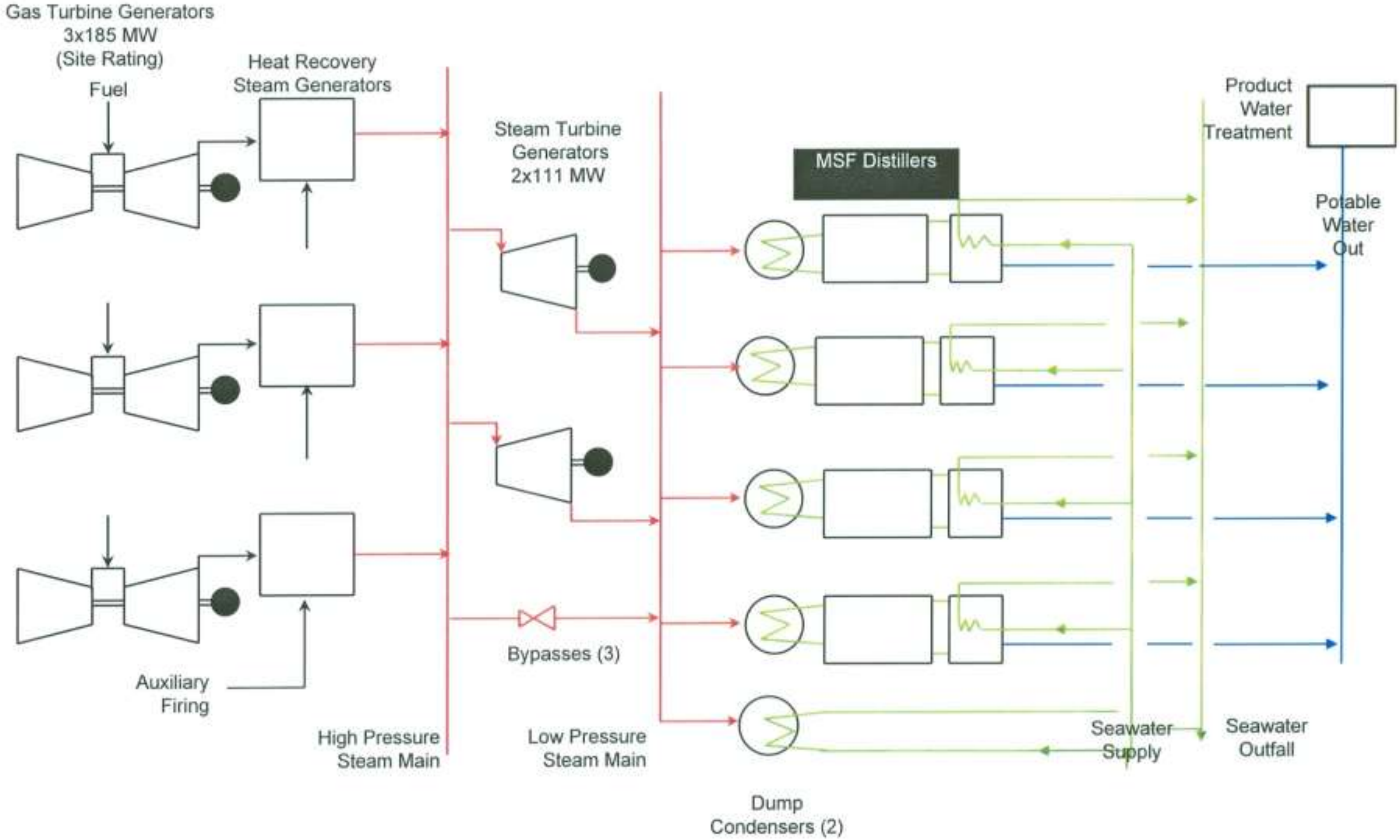
After 1983 SWCC employed back-pressure turbine arrangement



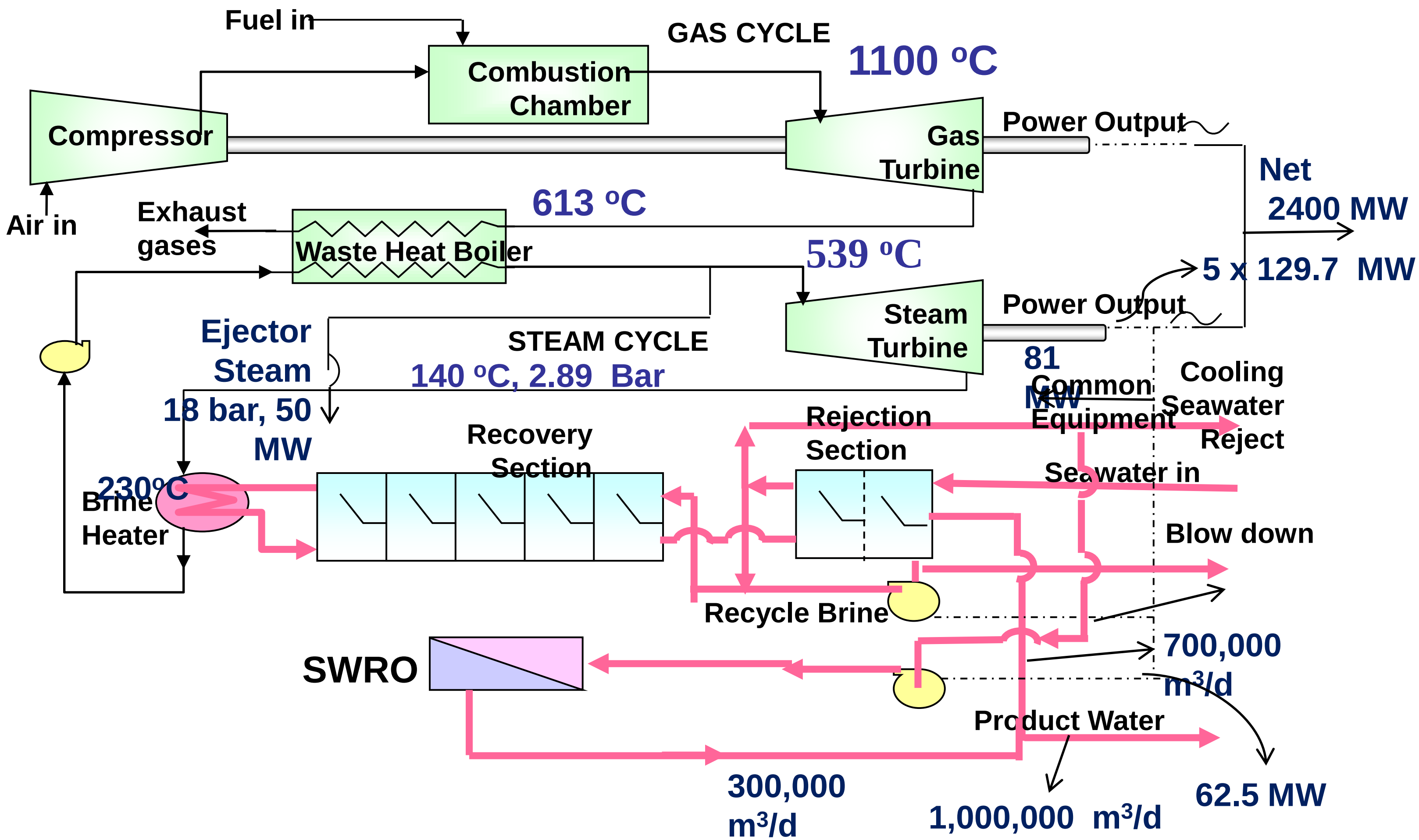
Power to water ratio 5 to 7.9 MW/MIGD

After 1983 SWCC employed back-pressure turbine arrangement

Combined cycle and MSF distillers block flow diagram



2012 Combined Gas-vapor power generation cycles coupled with MSF/RO desalination plants

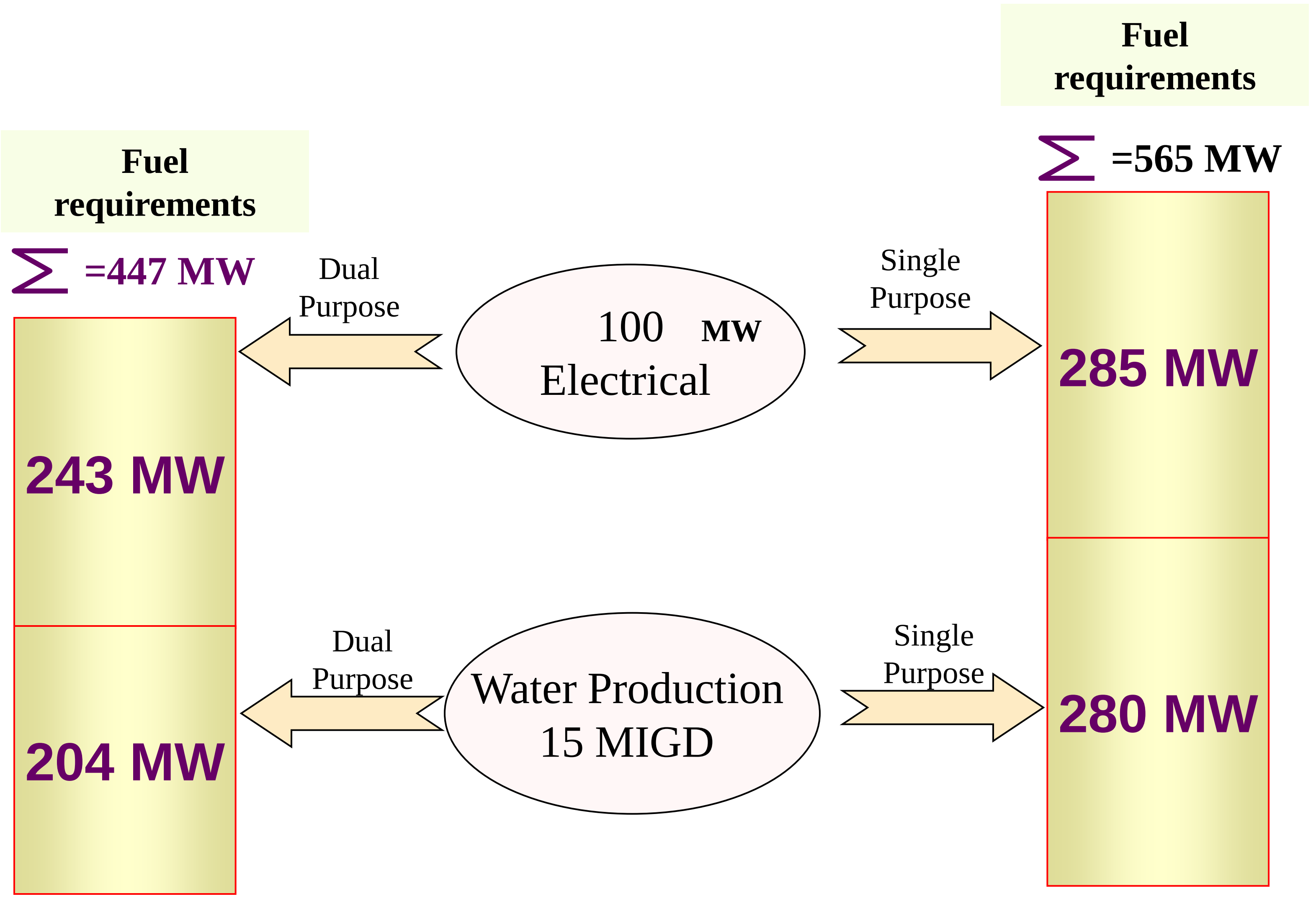


Typical power to water ratios for different technologies	
Technology	**PWR (MW installed/Million Imperial Gallopns per)**
Steam turbine BTG-MED	**3.5**
Steam turbine BTG-MSF	**5**
Steam turbine EST-MED	**7**
Steam turbine EST-MSF	**10**
Gas turbine GT-HRSG-MED	**6**
Gas turbine GT-HRSF-MSF	**8**
Combine cycle BTG-MED	**10**
Combine cycle BTG- MSF	16
Combine cycle EST-MED	12
Combine cycle EST-MSF	19

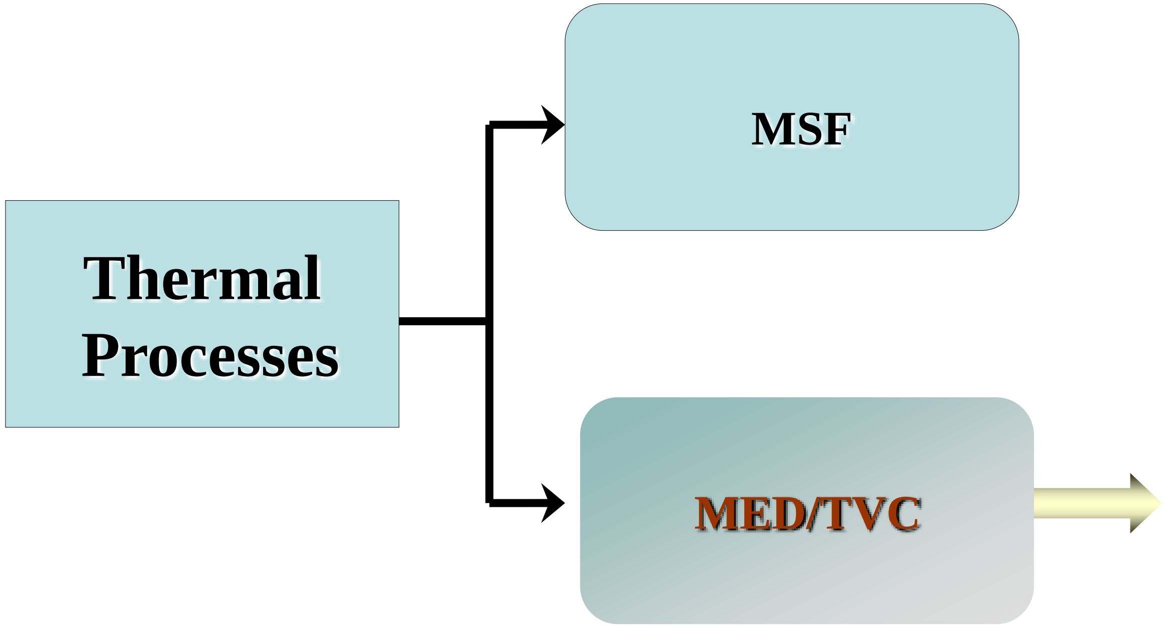
Financial Benefits for Dual Purpose Plants

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** →

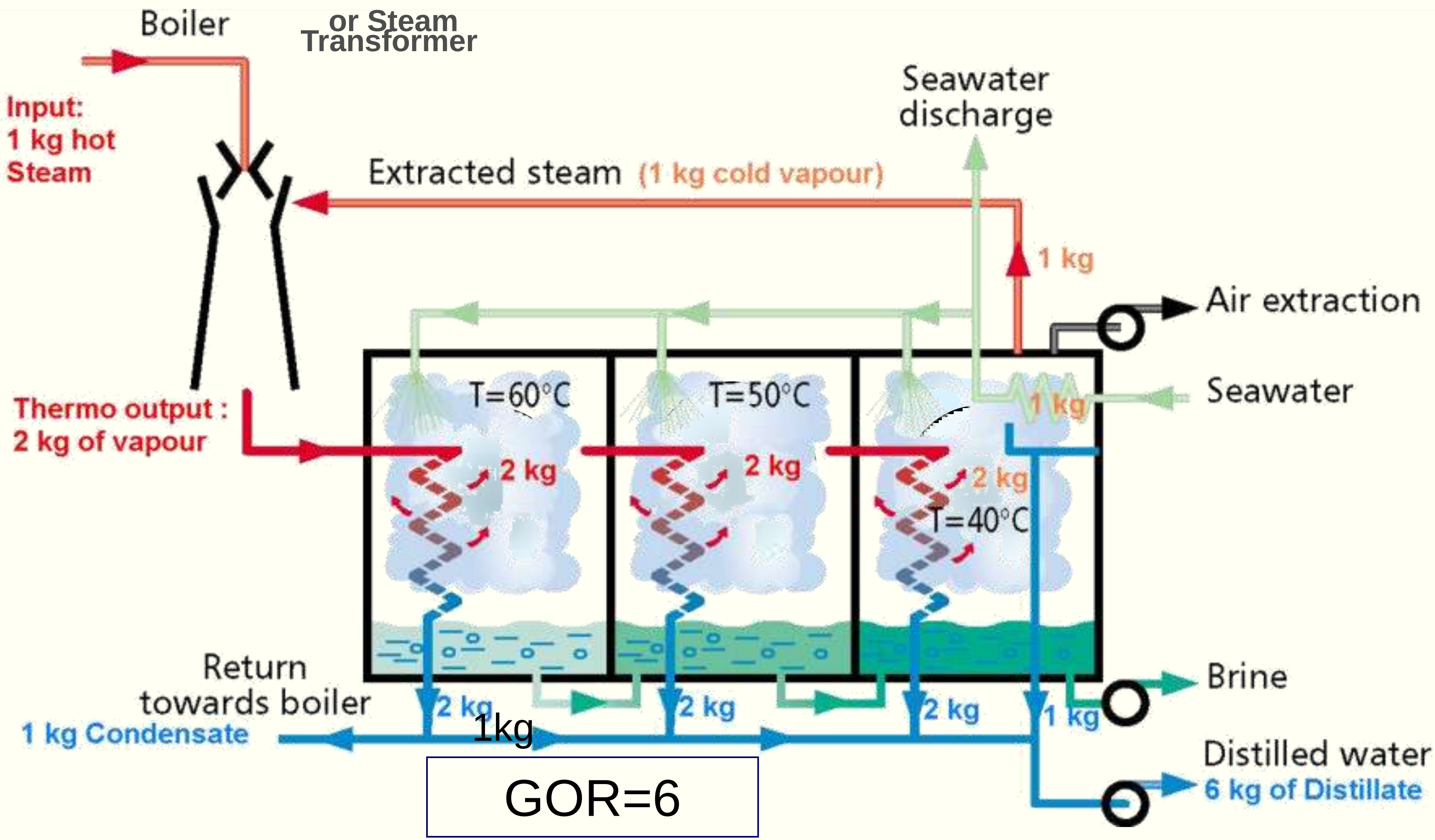


Thermal Benefits of Cogeneration Plants

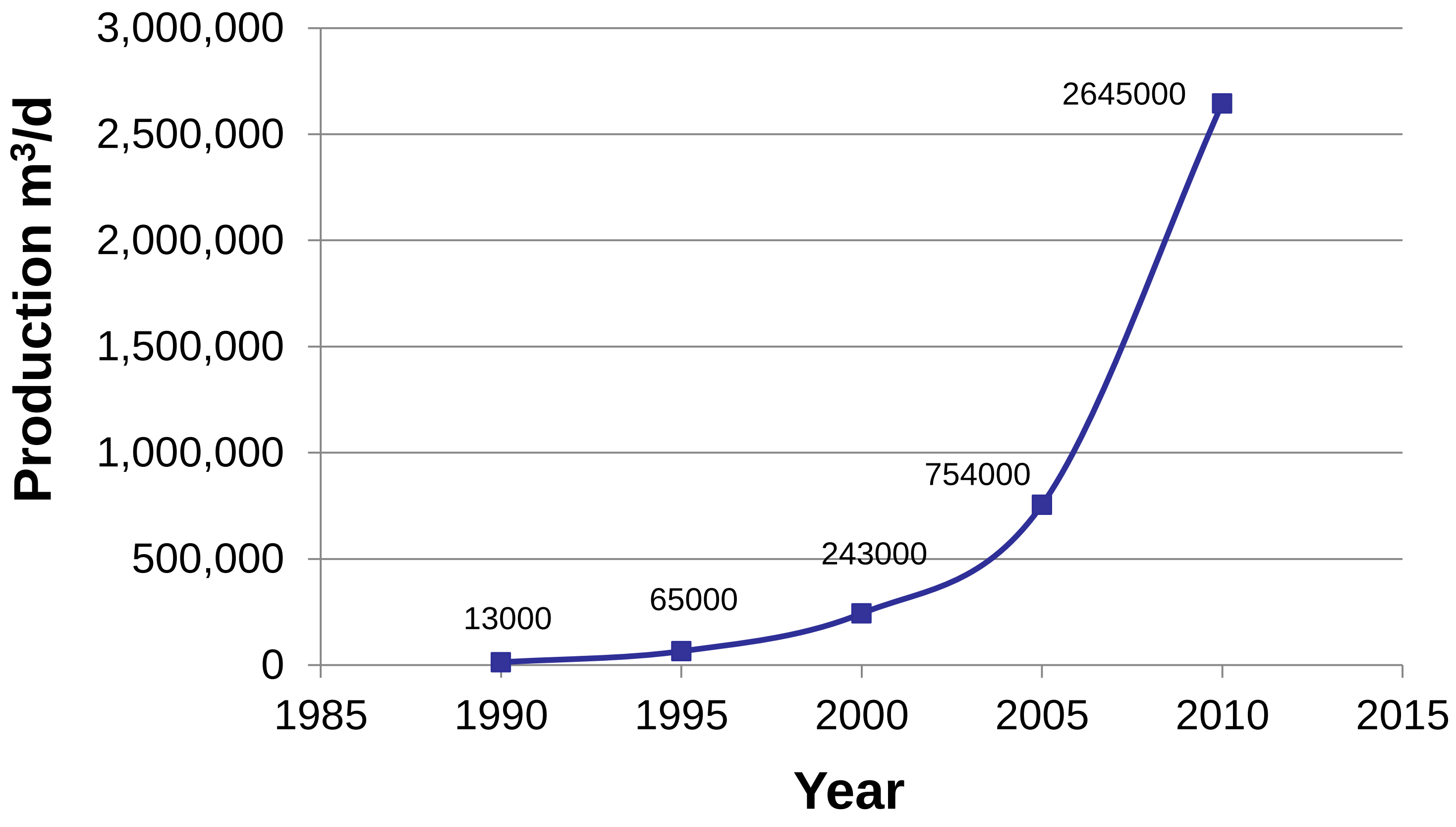

Thermal Processes
MSF
MED/TVC

MED_TVC

offers the best potential method of improving the performance of straight MED desalination plants and achieving high performance ratios and hence low water cost.



Historical evolution of the installed capacities of MED desalination plants in the GCC states.



MARAFIQ POWER/WATER COGENERATION PLANT

Four power cycles : each power cycle incorporates 3 GT,3HRSG and one ST
Three of the power cycles are coupled with 27 MED units.

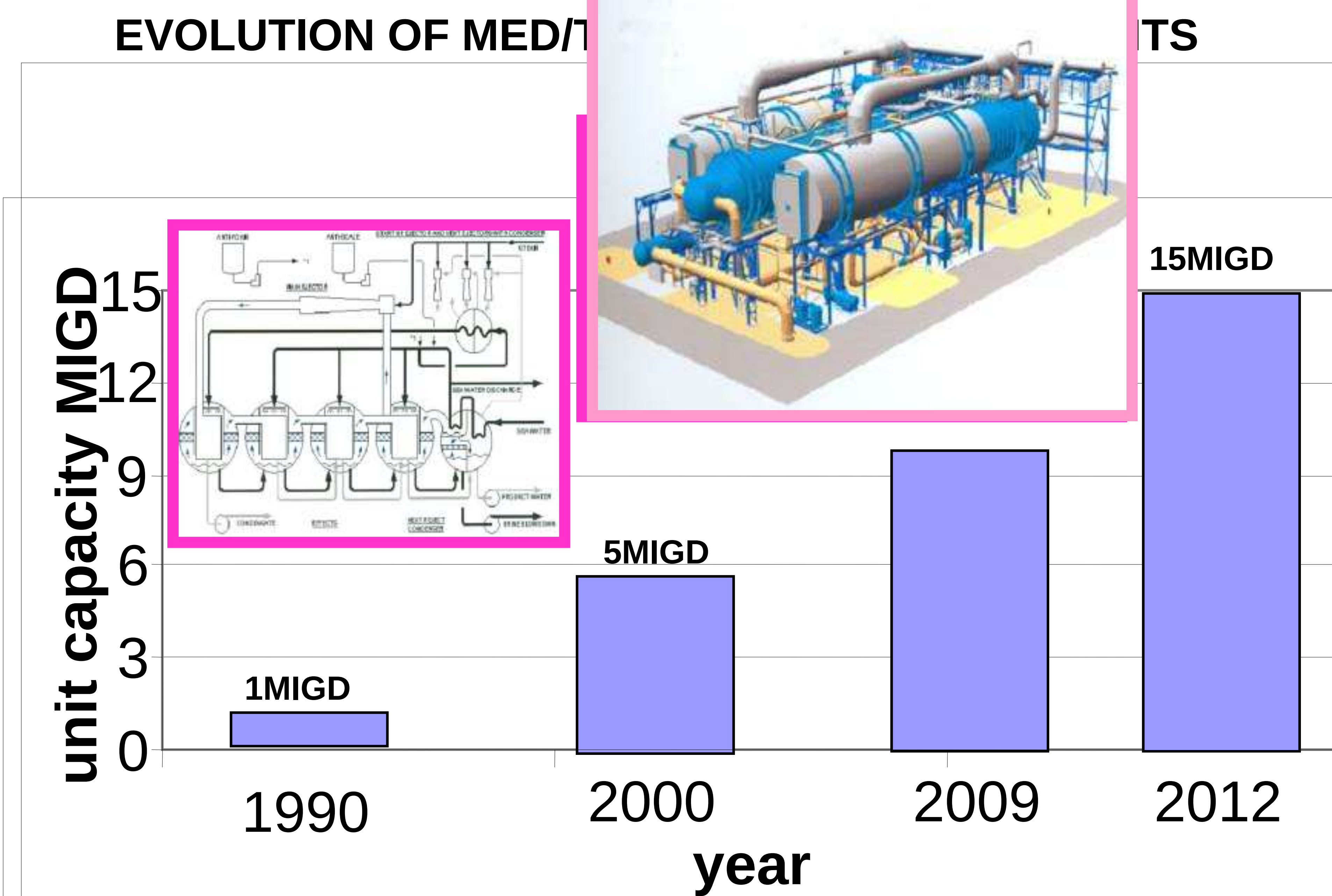
Marafiq Power/Water Cogeneration Plant

- 27 MED/TVC Desalination units each produces 6.56 MIGD, total 177.2 MIGD
- Power generation 2750 MW
- Independent water and power production project (IWPP)
- Contract of water plant US$ 945 million
- Project completed in 2010.

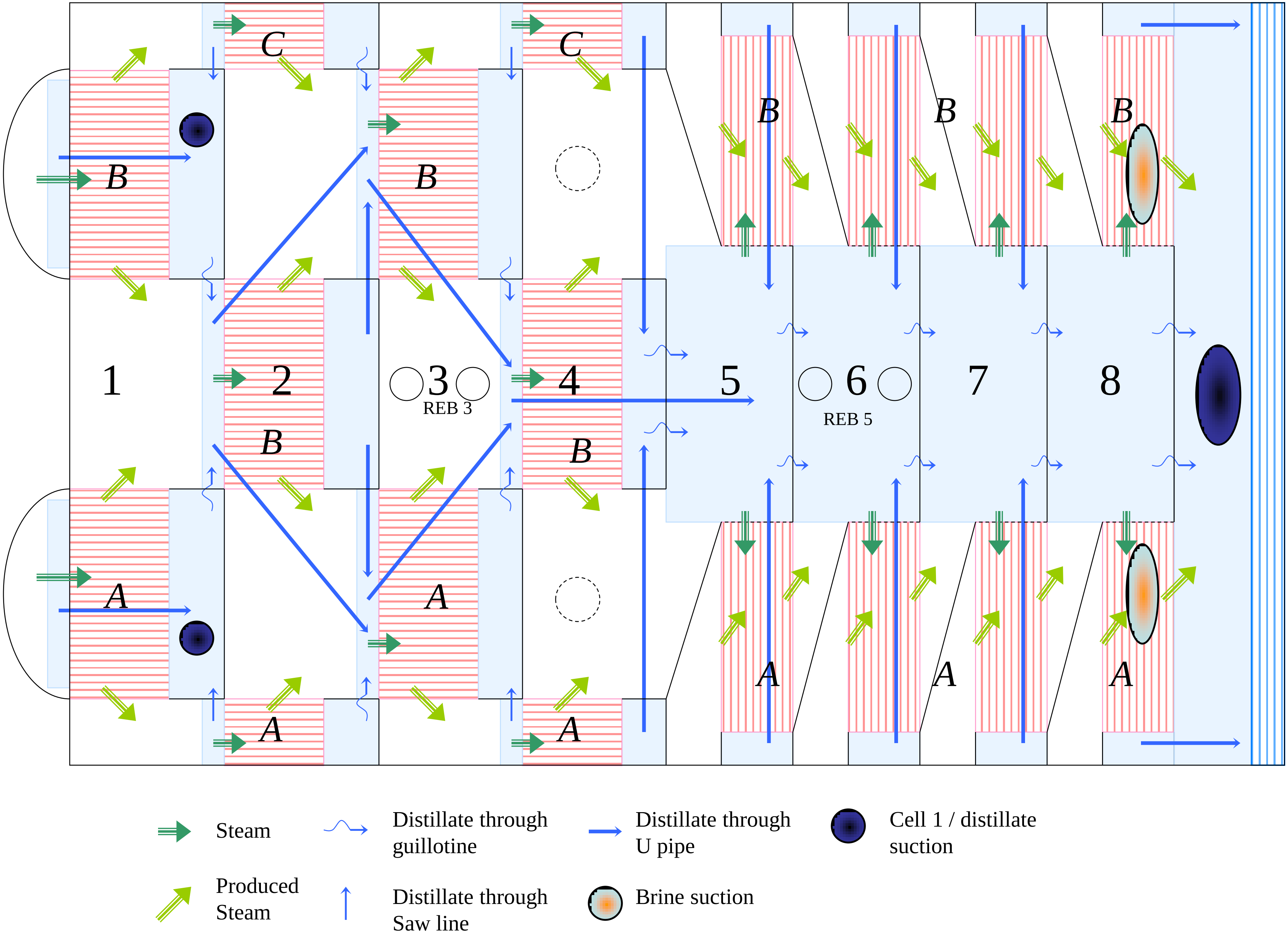
Factors responsible for the recent market emergence of MED-TVC desalination plants

- ❑ **They provide higher overall heat transfer coefficients when compared to multistage flash (MSF) desalination systems.**
- ❑ **MED does not employ recycling and are thus based on the once through principle and have low requirements for pumping energy.**
- ❑ **The power consumption of MED/TVC plants is only around 1.5 kWh/m^3 as there are no requirements to re-circulate large quantities of brine.**
- ❖ **Increase of MED unit capacity results in the decrease of the investment cost.**

EVOLUTION OF MED/T ... TS



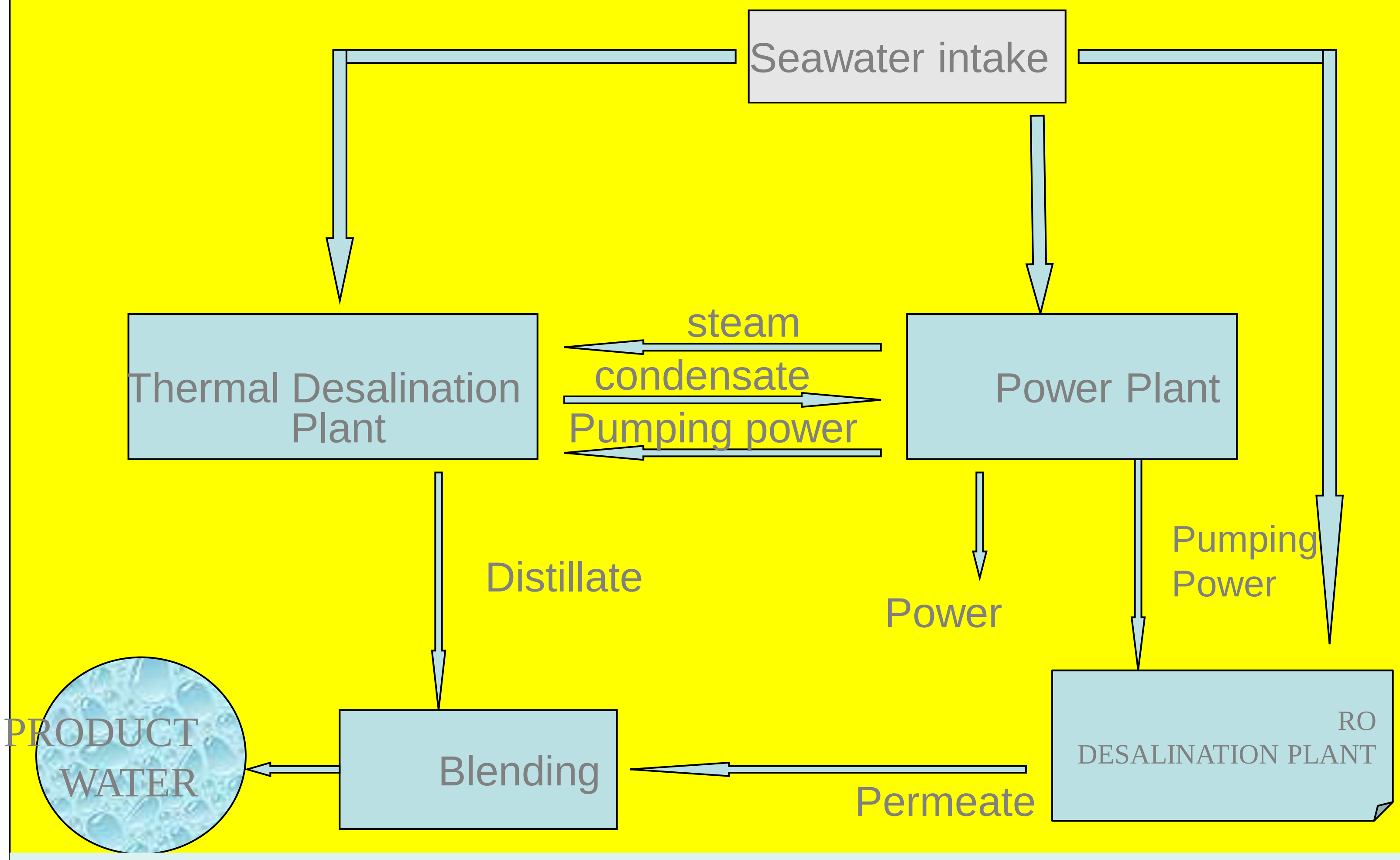
MED UNIT CAPACITY GROWTH



C
C
B
B
B
B
B
B
1
2
3
REB 3
4
5
6
REB 5
7
8
A
A
A
A
A
A
A
Steam
Produced Steam
Distillate through guillotine
Distillate through Saw line
Distillate through U pipe
Brine suction
Cell 1 / distillate suction

HYBRID CONCEPTS

Seawater

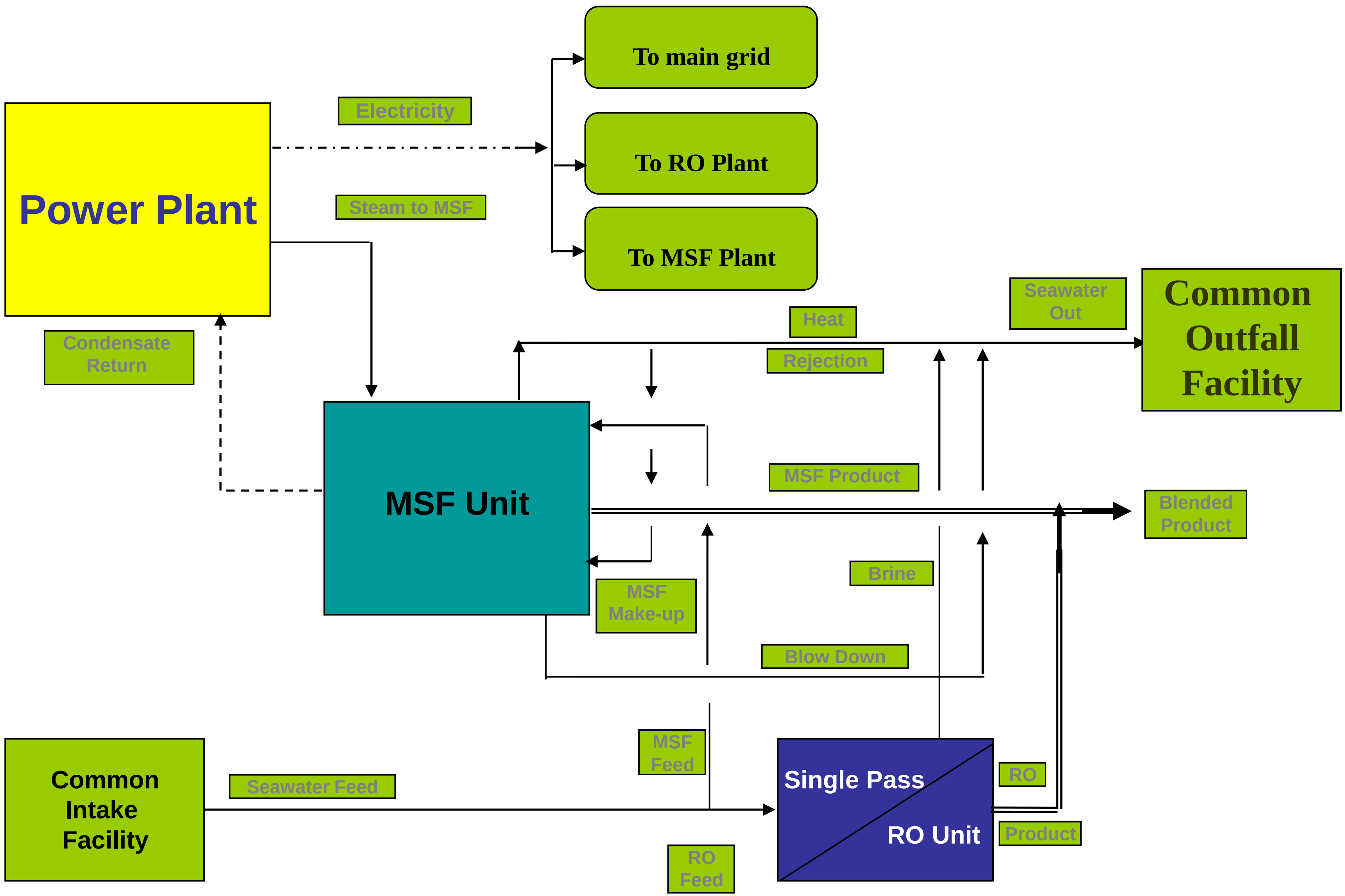


Power/Water Hybrid Flow Chart

HYBRID SYSTEMS

- **Simple hybrid Systems**
  adding a stand- alone
  RO desalination
  plant to an existing MSF complex

- **Integrated Hybrid systems**
  the plant is designed from
  the beginning
  as a combined plant .



Schematic diagram of simple hybrid configuration

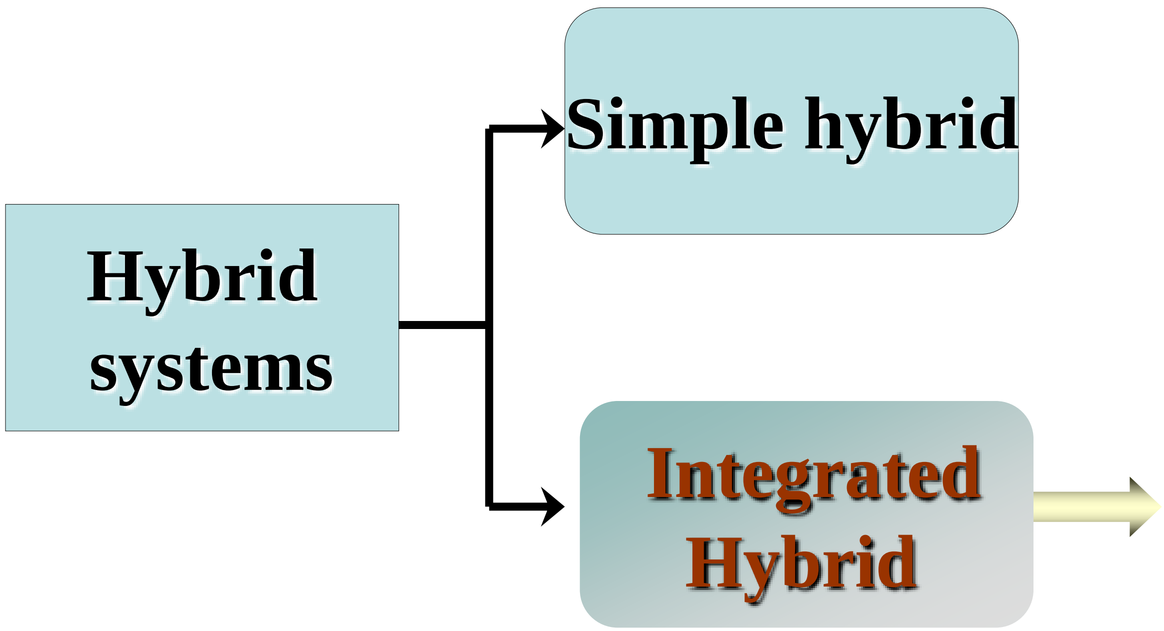
ADVANTAGES

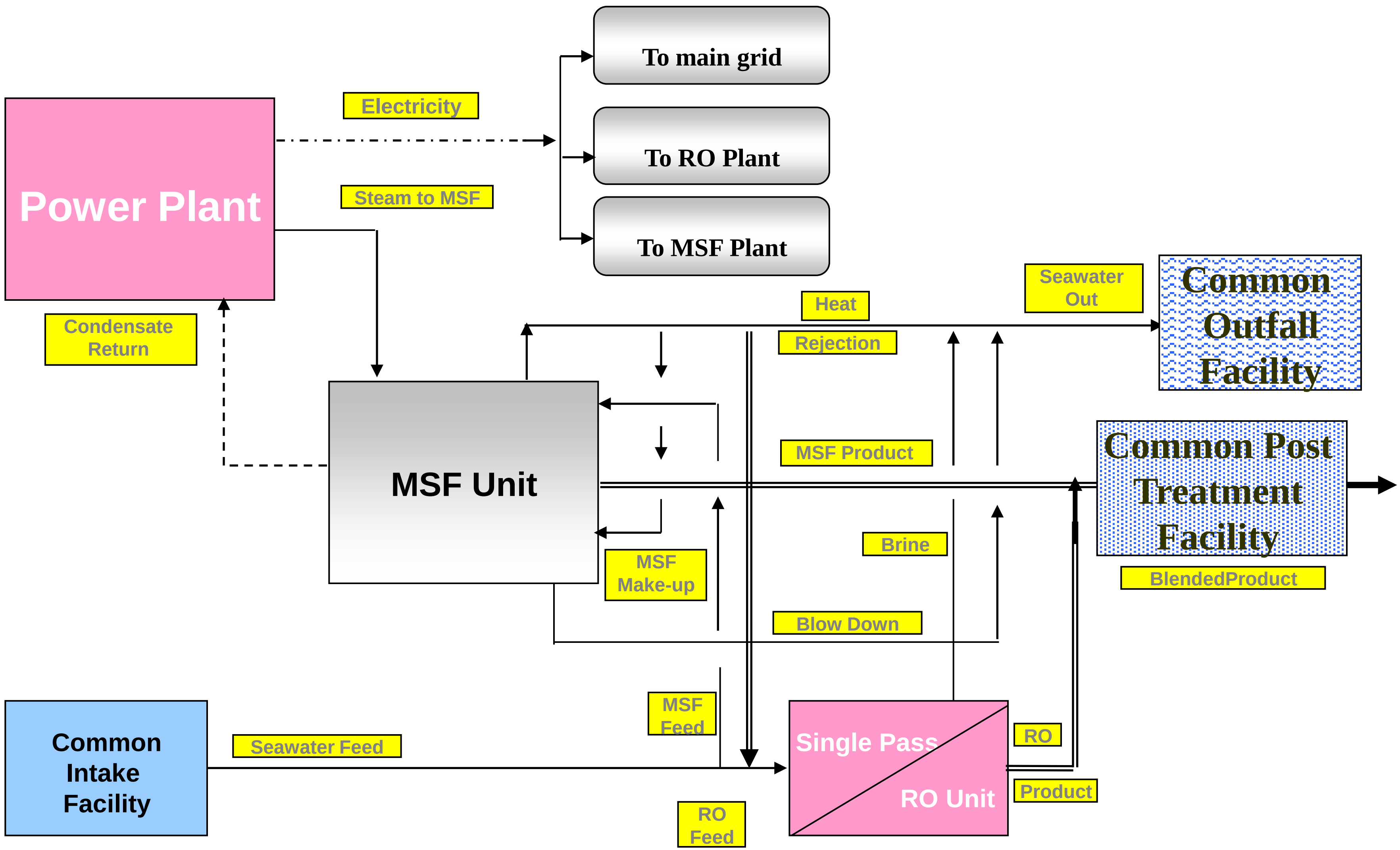
- **Such arrangement allows to operate the RO unit with relatively high TDS and consequently allows to lower the replacement rate of the membranes.**

- **If the useful life of the RO membrane can be extended from 3 to 5 years the annual membrane replacement cost can be reduced by nearly 40 percent . Blending the products of the thermal and SWRO allows for the use of a single stage SWRO instead of the two stage SWRO plant normally employed in standalone SWRO plants.**

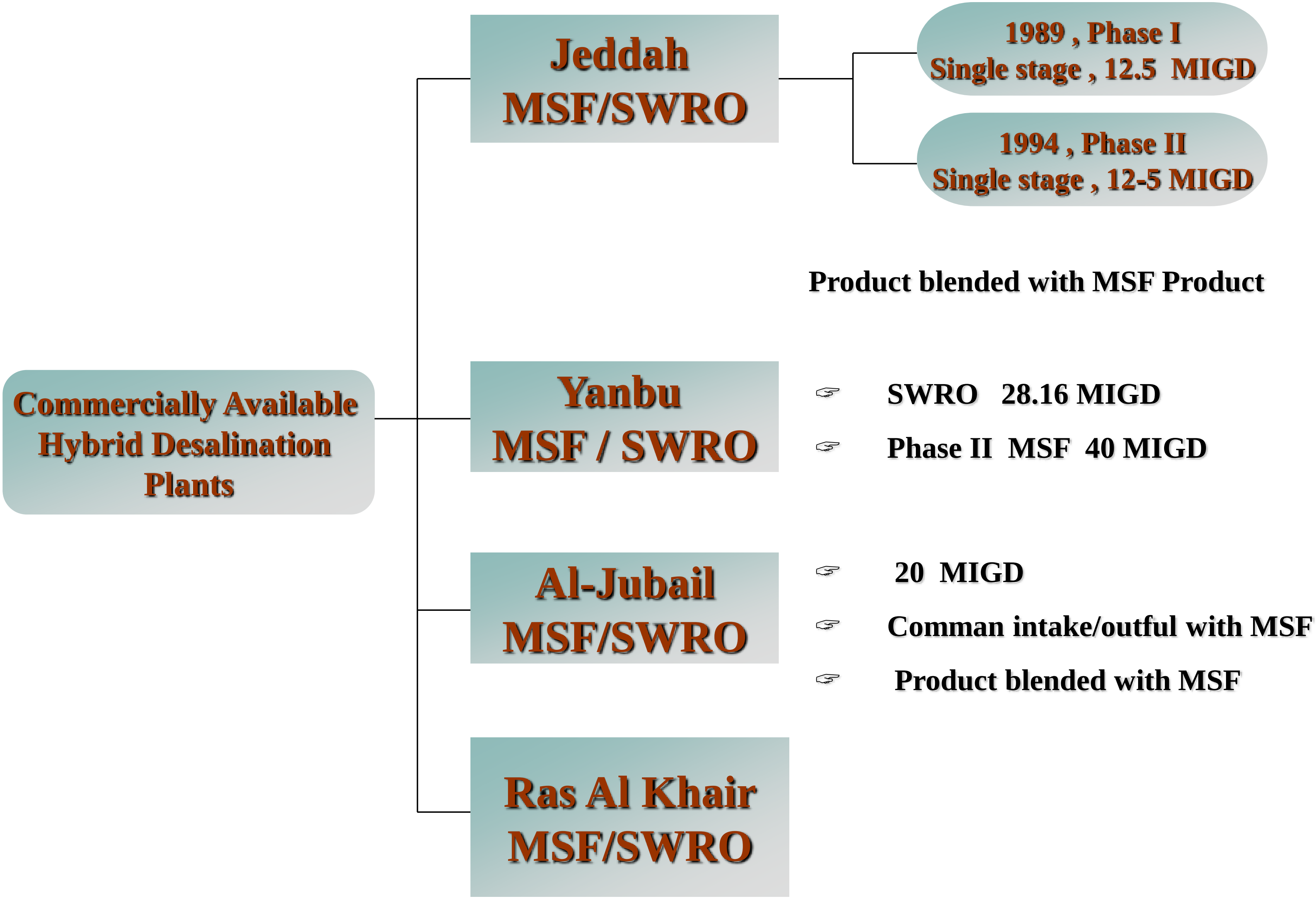
- **Combining thermal and membranes desalination plant in the same site will allow to use common intake and outfall facilities with less capital cost.**

- **An integrated pretreatment and post-treatment operation can reduce cost and chemicals.**

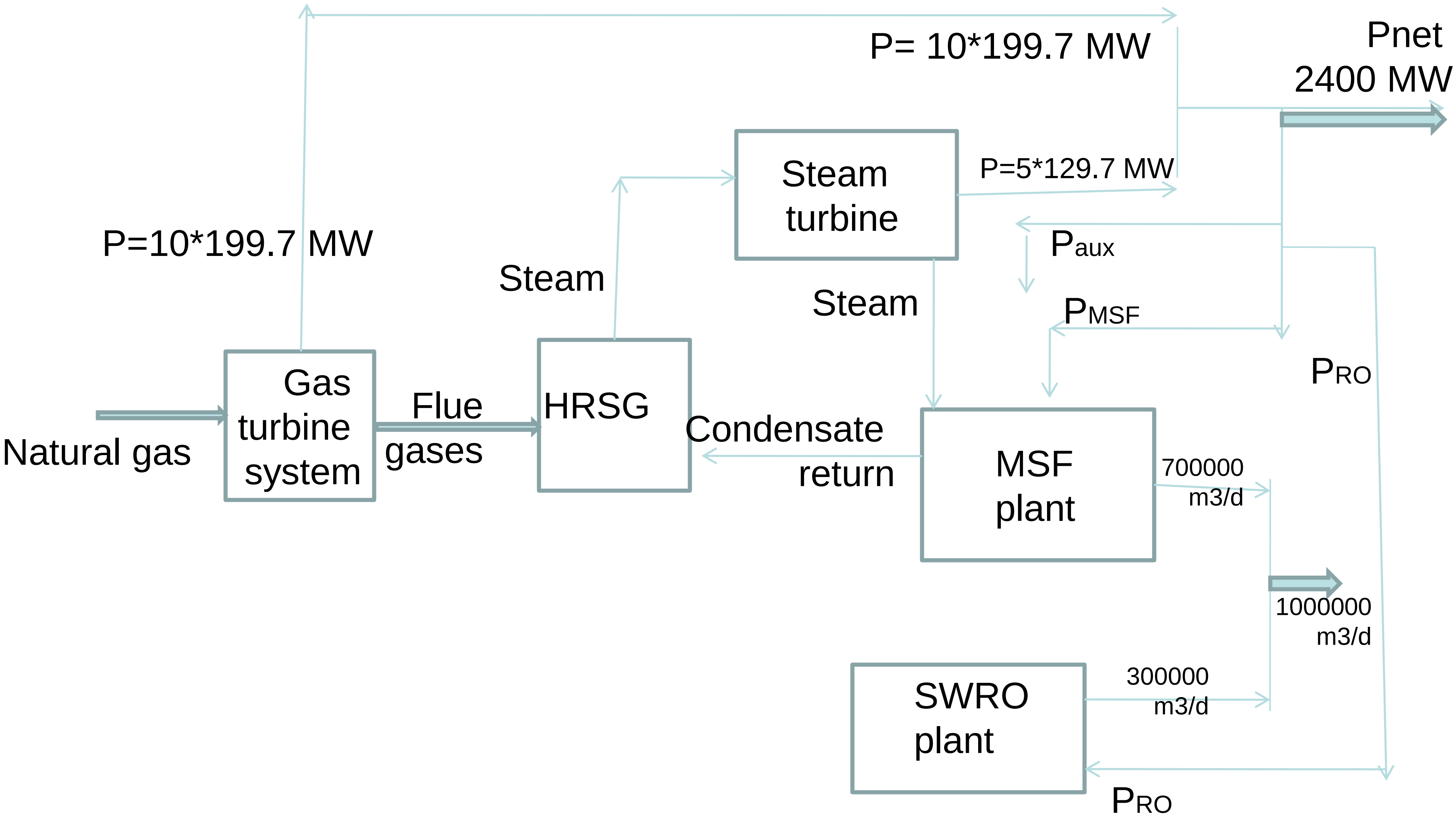

Hybrid systems
Simple hybrid
Integrated Hybrid



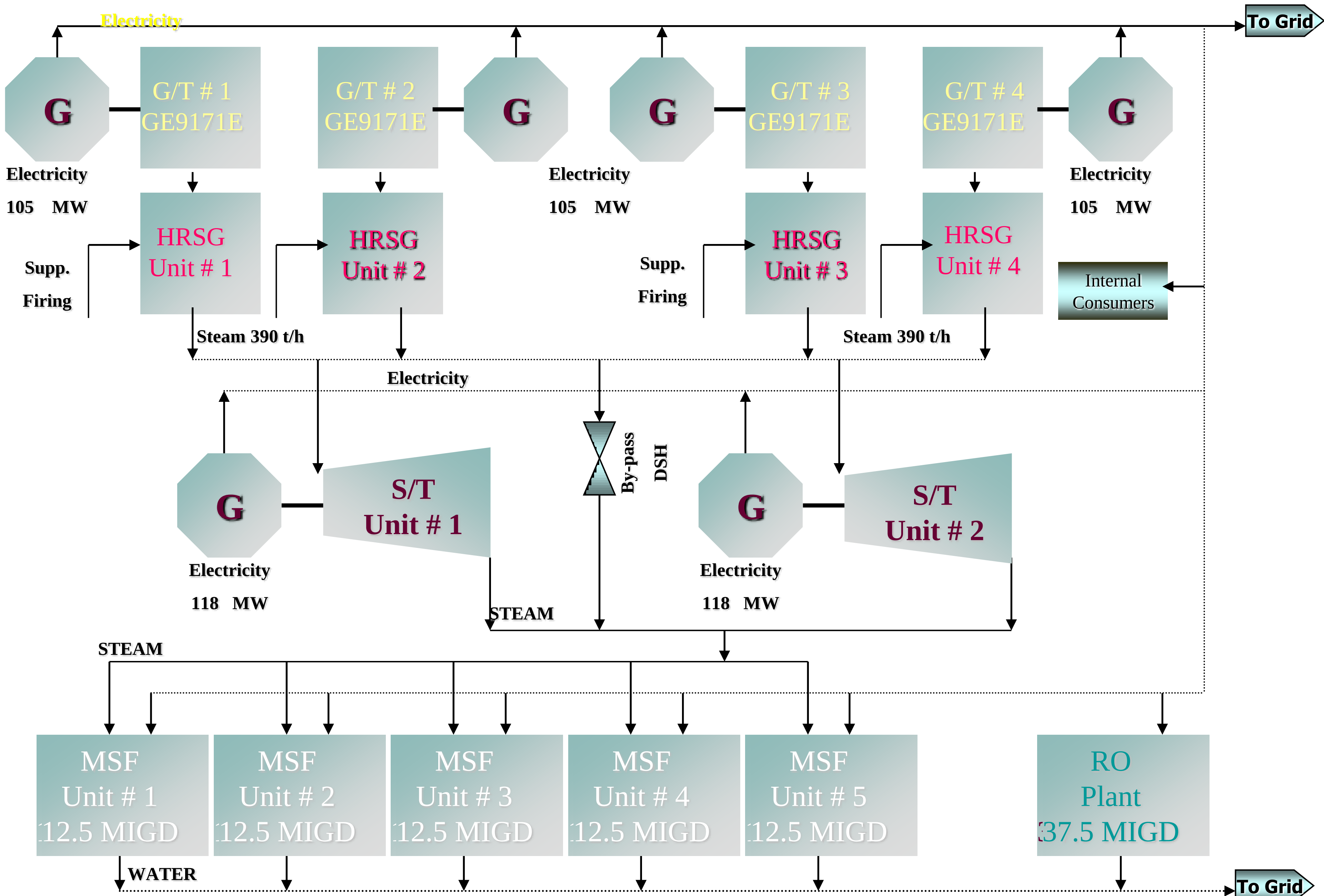
Schematic diagram of fully integrated hybrid configuration



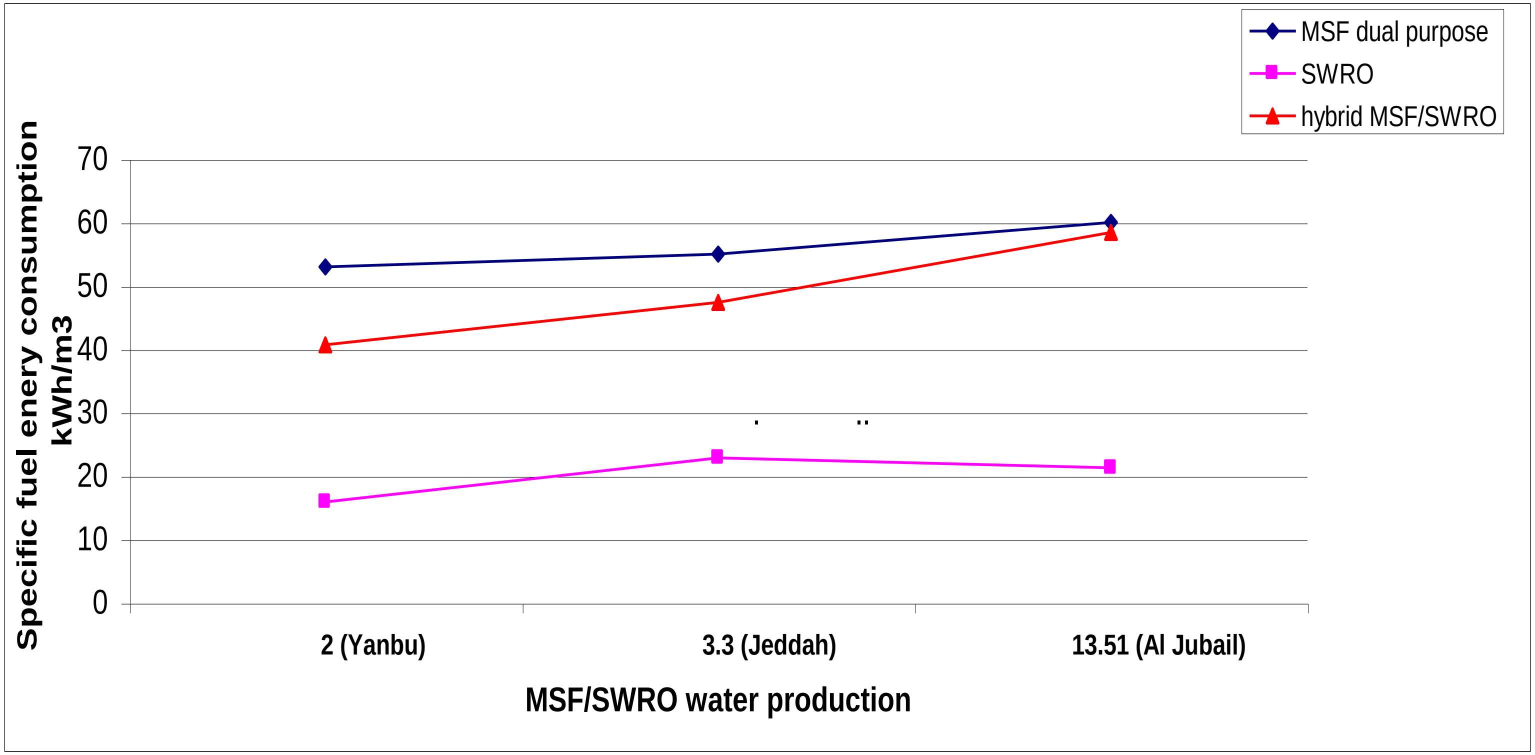
Commercially Available Hybrid Desalination Plants
Jeddah MSF/SWRO
1989 , Phase I Single stage , 12.5 MIGD
1994 , Phase II Single stage , 12-5 MIGD
Product blended with MSF Product
Yanbu MSF / SWRO
SWRO 28.16 MIGD
Phase II MSF 40 MIGD
Al-Jubail MSF/SWRO
20 MIGD
Comman intake/outful with MSF
Product blended with MSF
Ras Al Khair MSF/SWRO



Block diagram of the combined power cycle integrated with the hybrid MSF/SWRO desalination plant

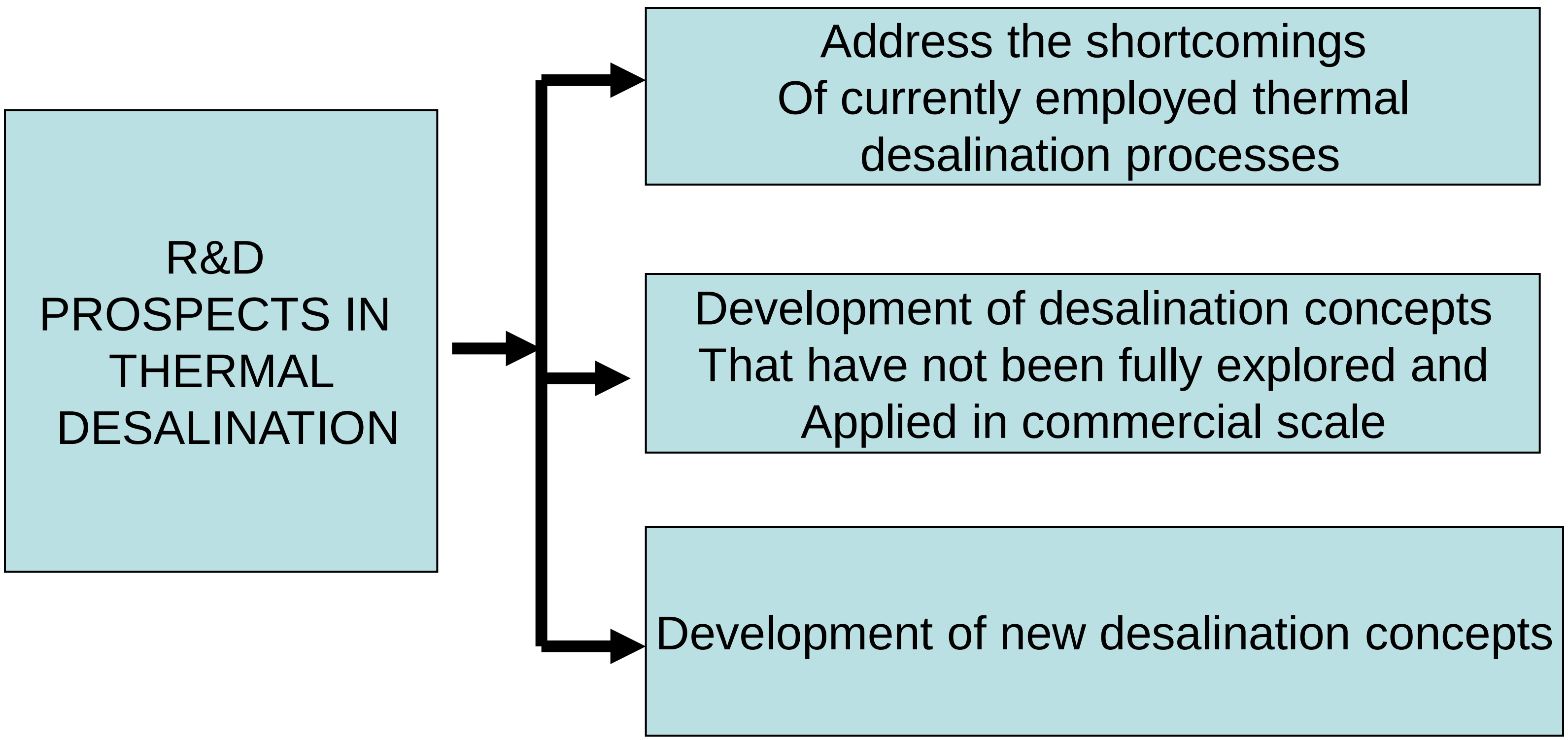


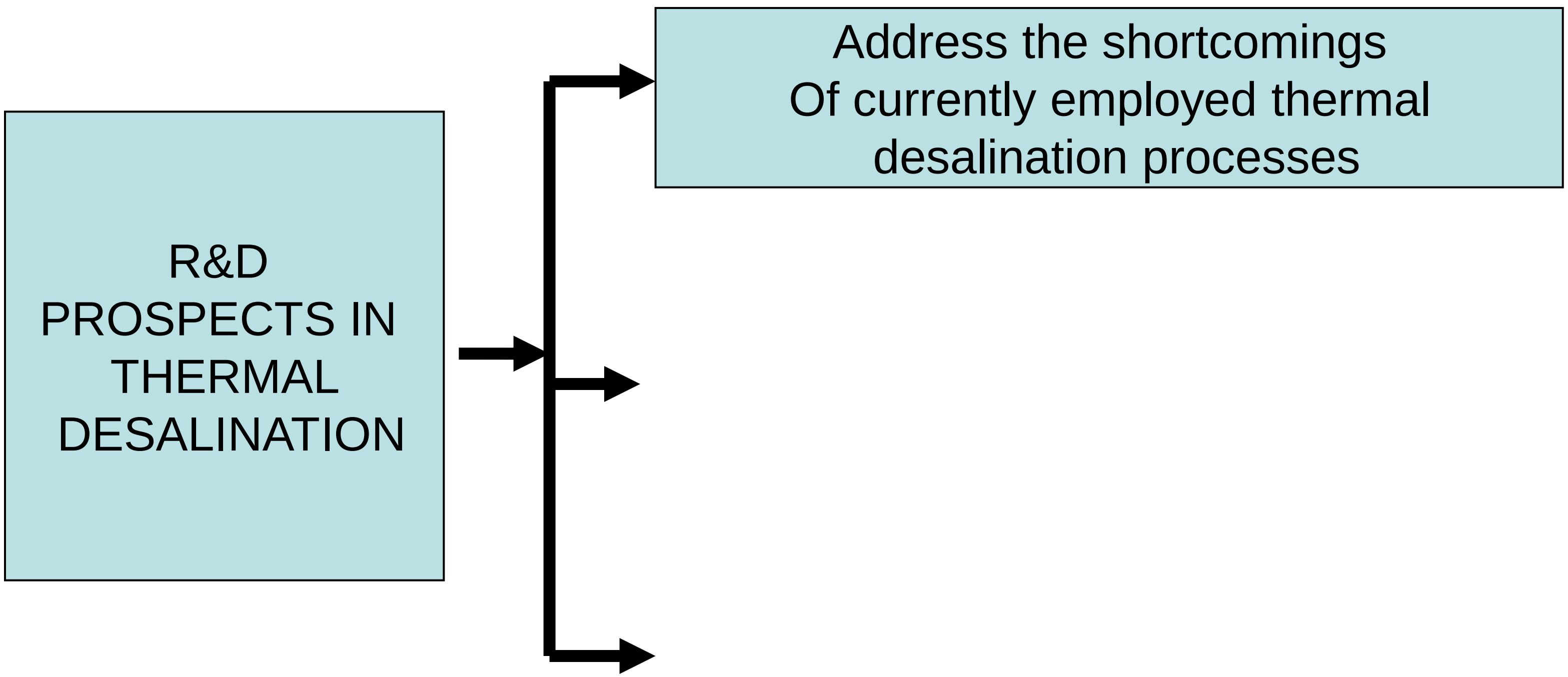
(Fujairah Power/Water Plant (Combined cycle))



Specific fuel energy consumption of SWCC hybrid MSF/SWRO desalination plants

R&D PROSPECTS


R&D PROSPECTS IN THERMAL DESALINATION
Address the shortcomings Of currently employed thermal desalination processes
Development of desalination concepts That have not been fully explored and Applied in commercial scale
Development of new desalination concepts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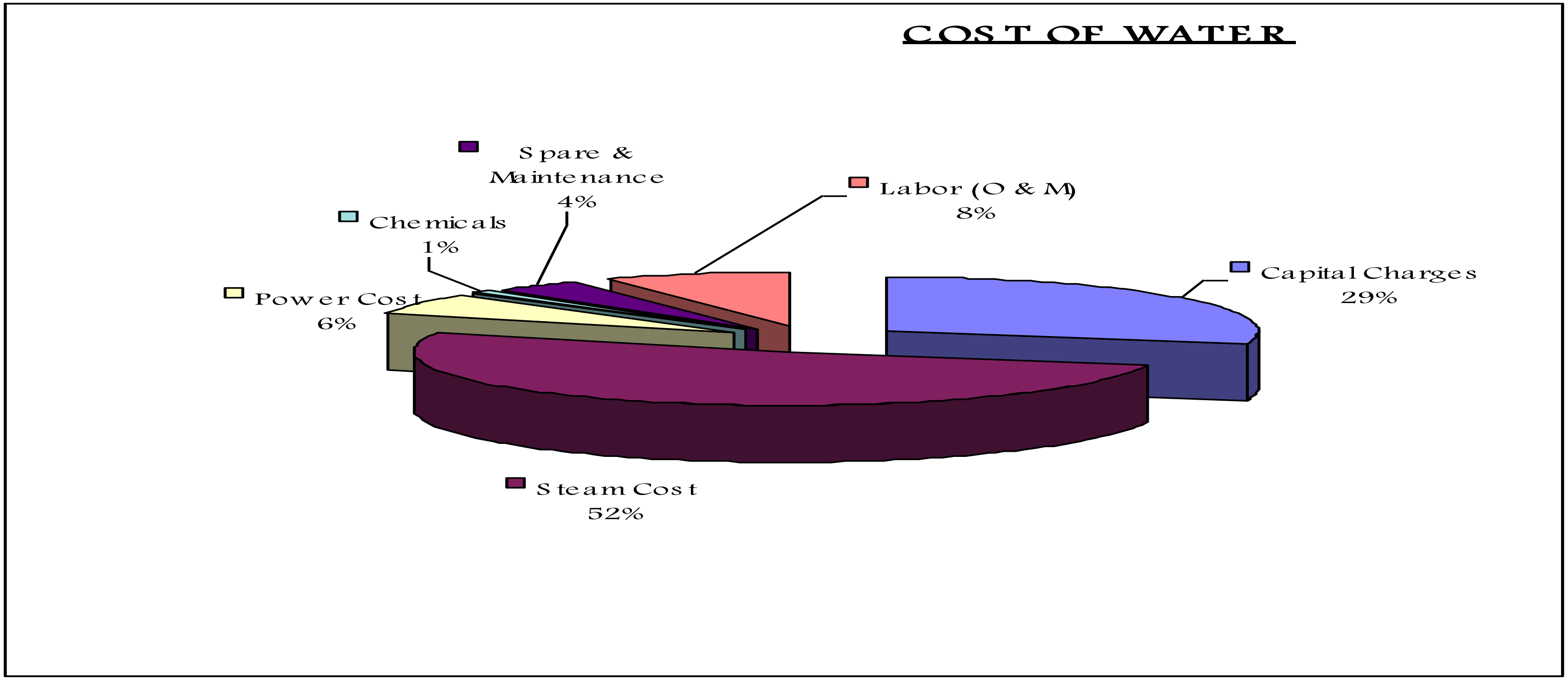
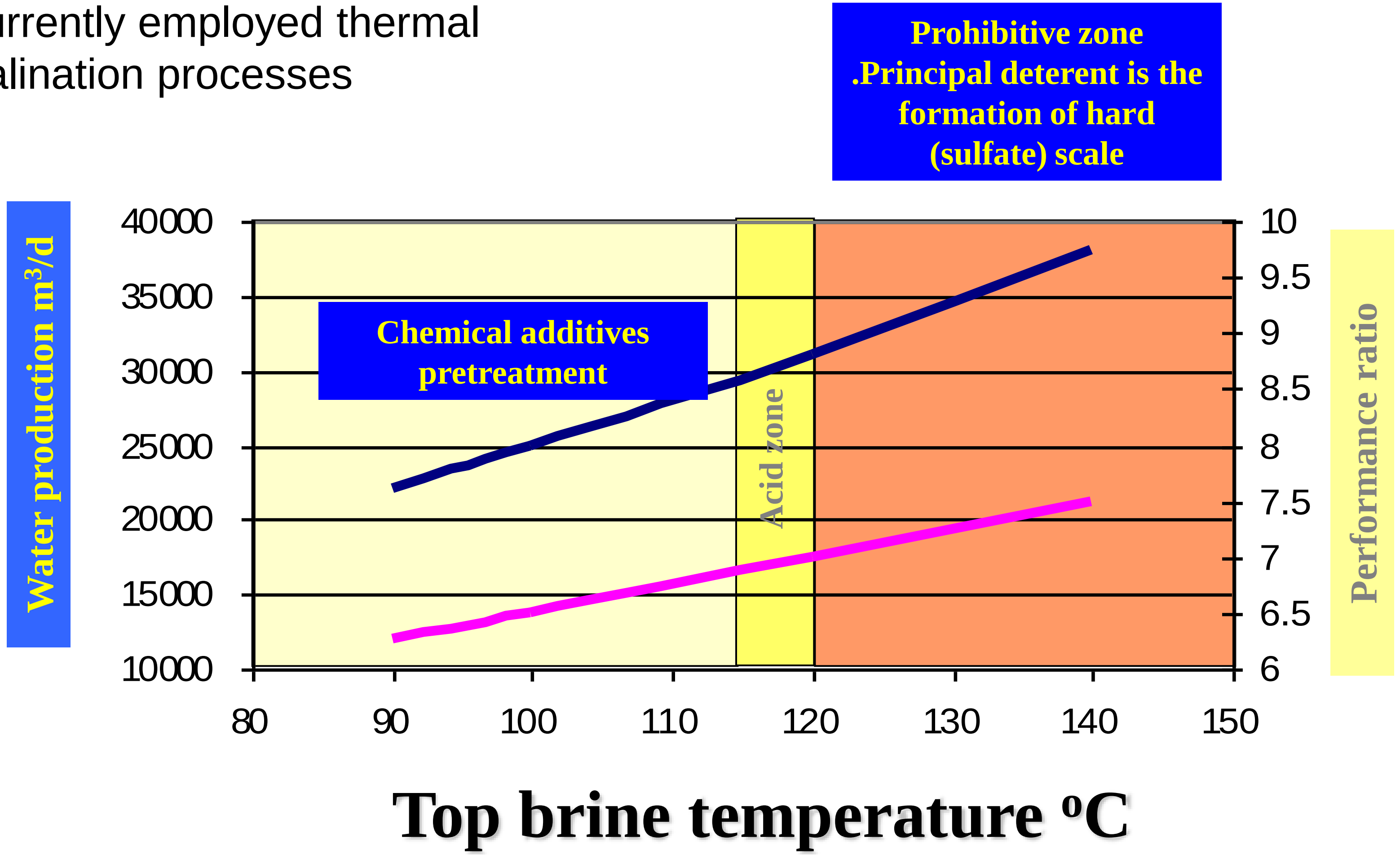
R&D PROSPECTS

Address the shortcomings of current thermal desalination processes.



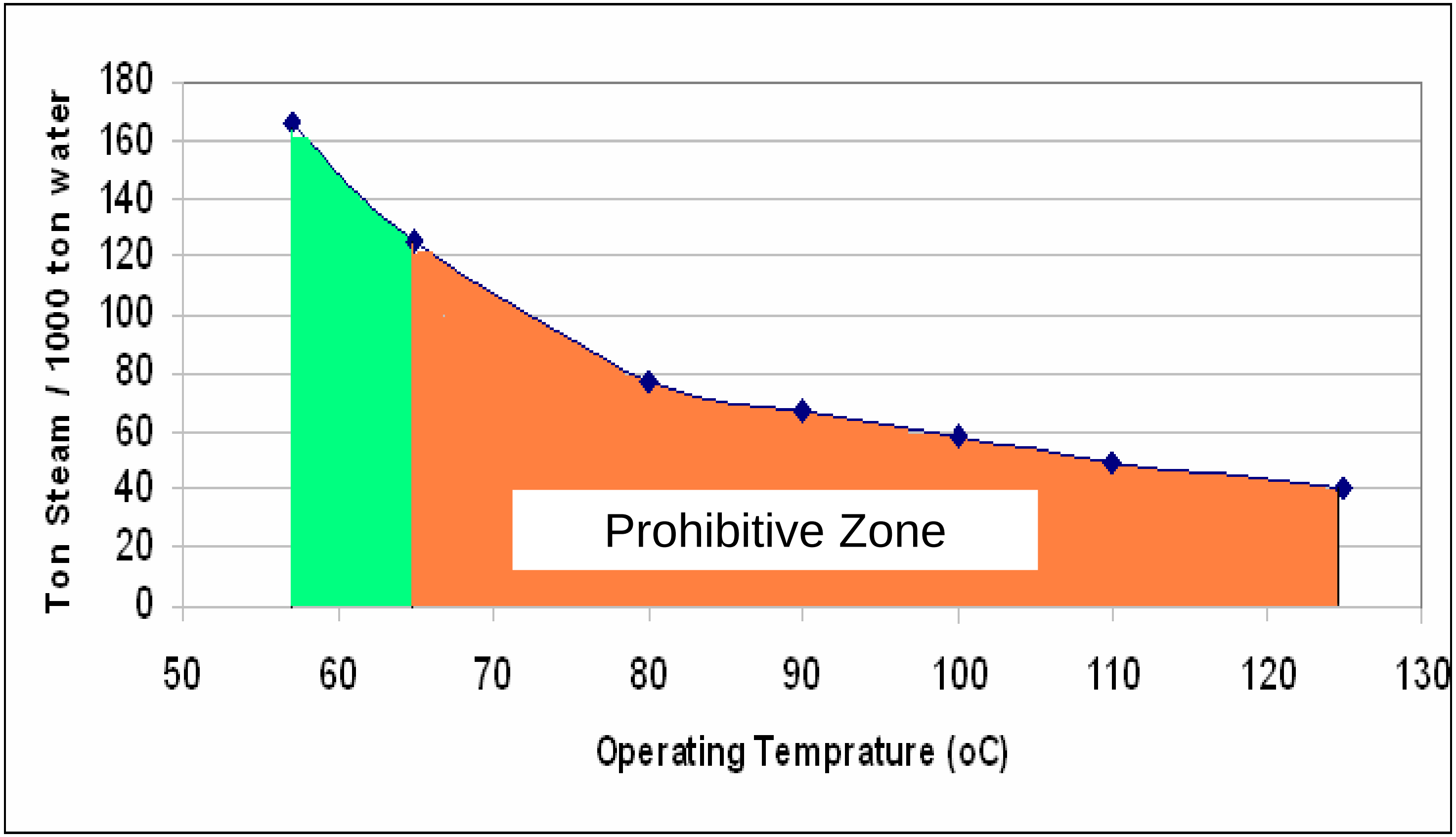
Breakdown of water production cost

Address the shortcomings
Of currently employed thermal
desalination processes



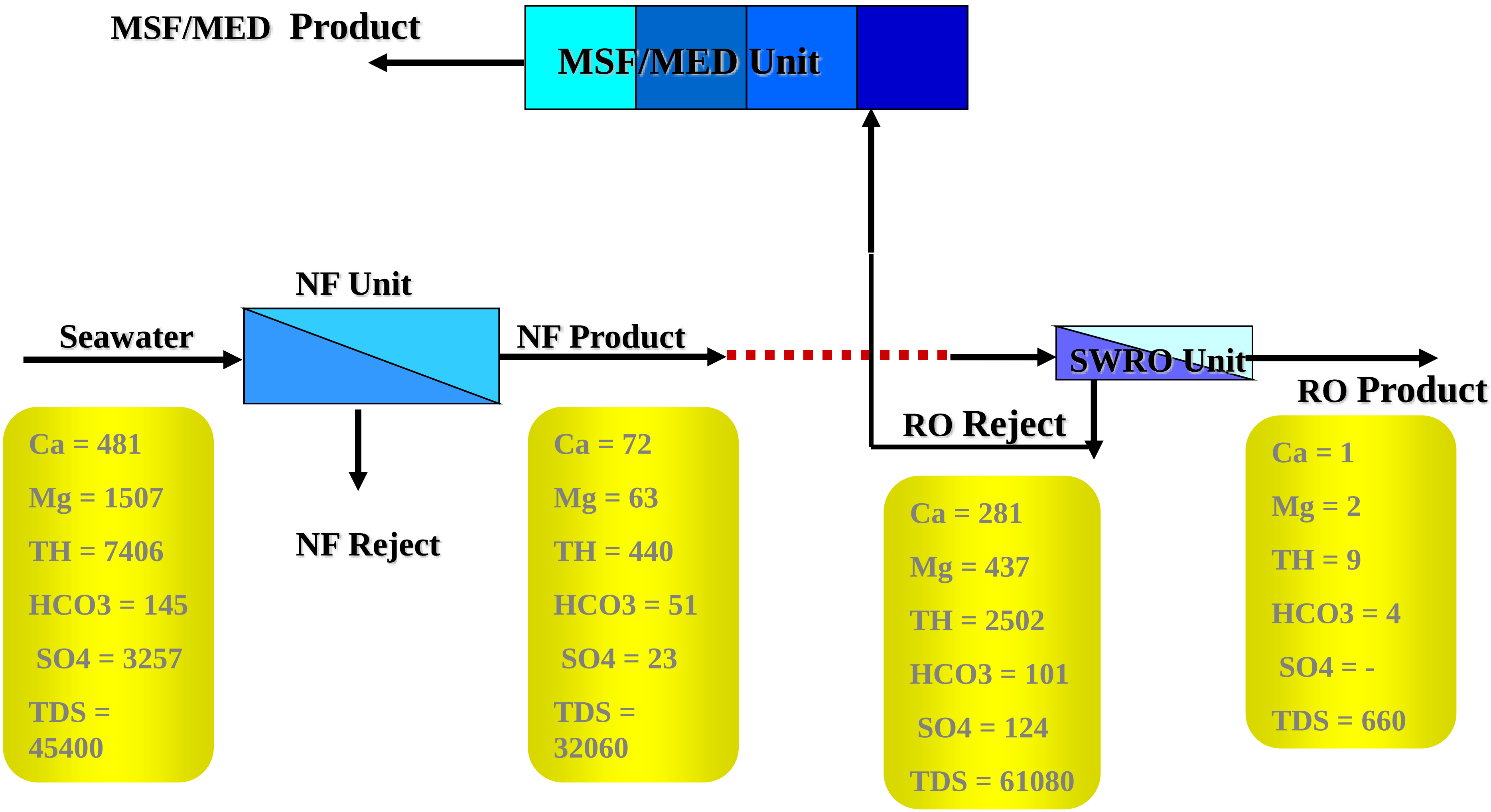
Impact of variation of TBT on MSF water production and performance ratio

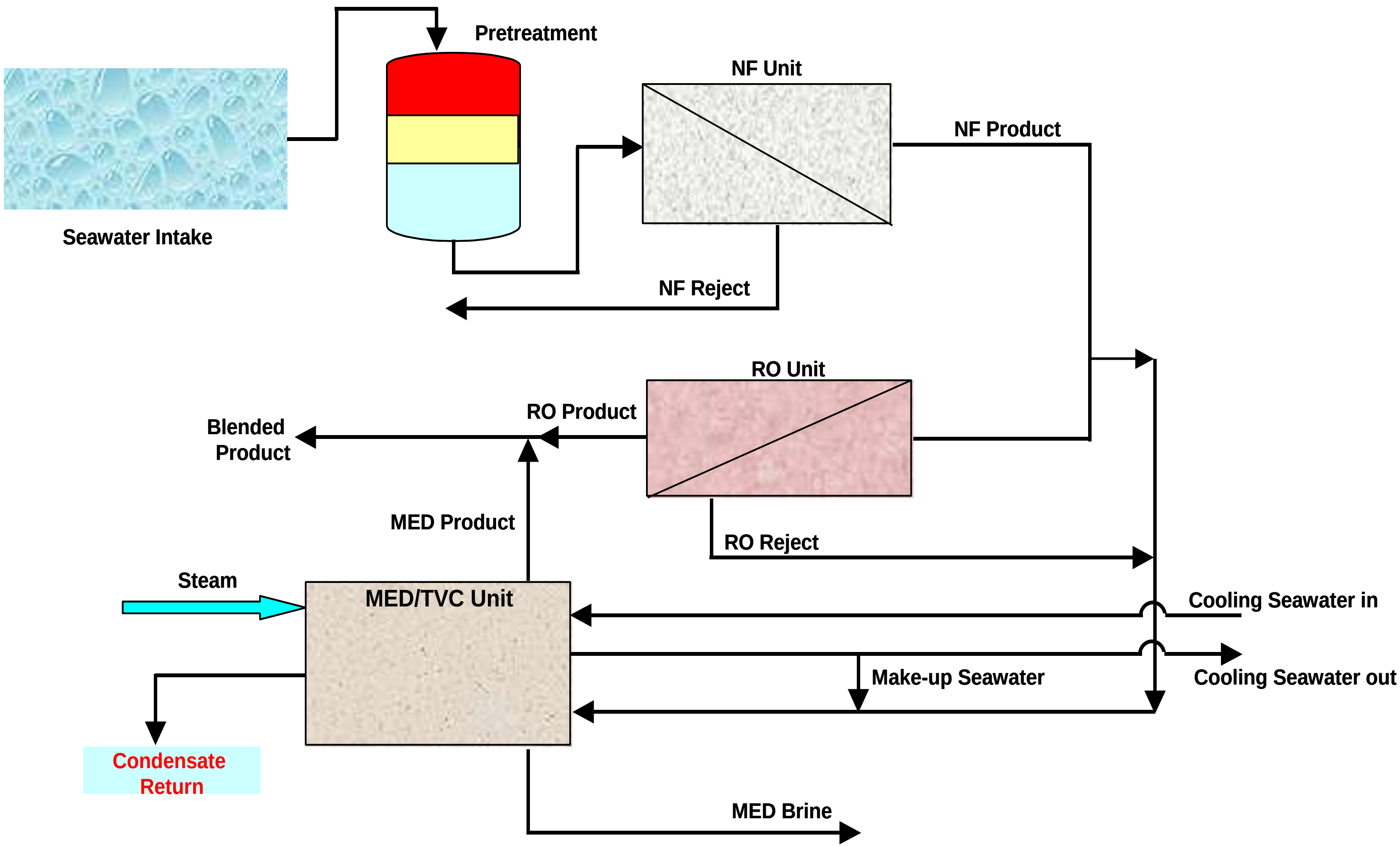
To eliminate the possibility of scale formation, commercial MED desalination plants are currently operating with TBT up to 65 ºC .



Impact of the variation of operating temperature on the energy consumption of the MED Process

NF/RO/MSF or NF/RO/MED Tri-hybird System

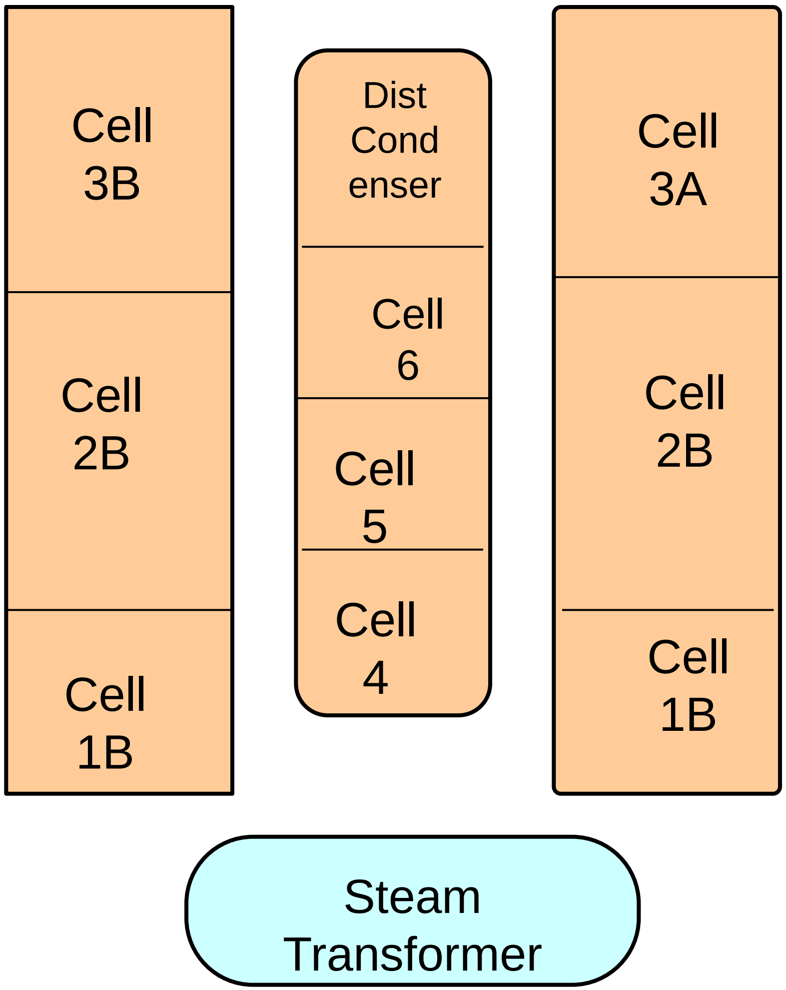




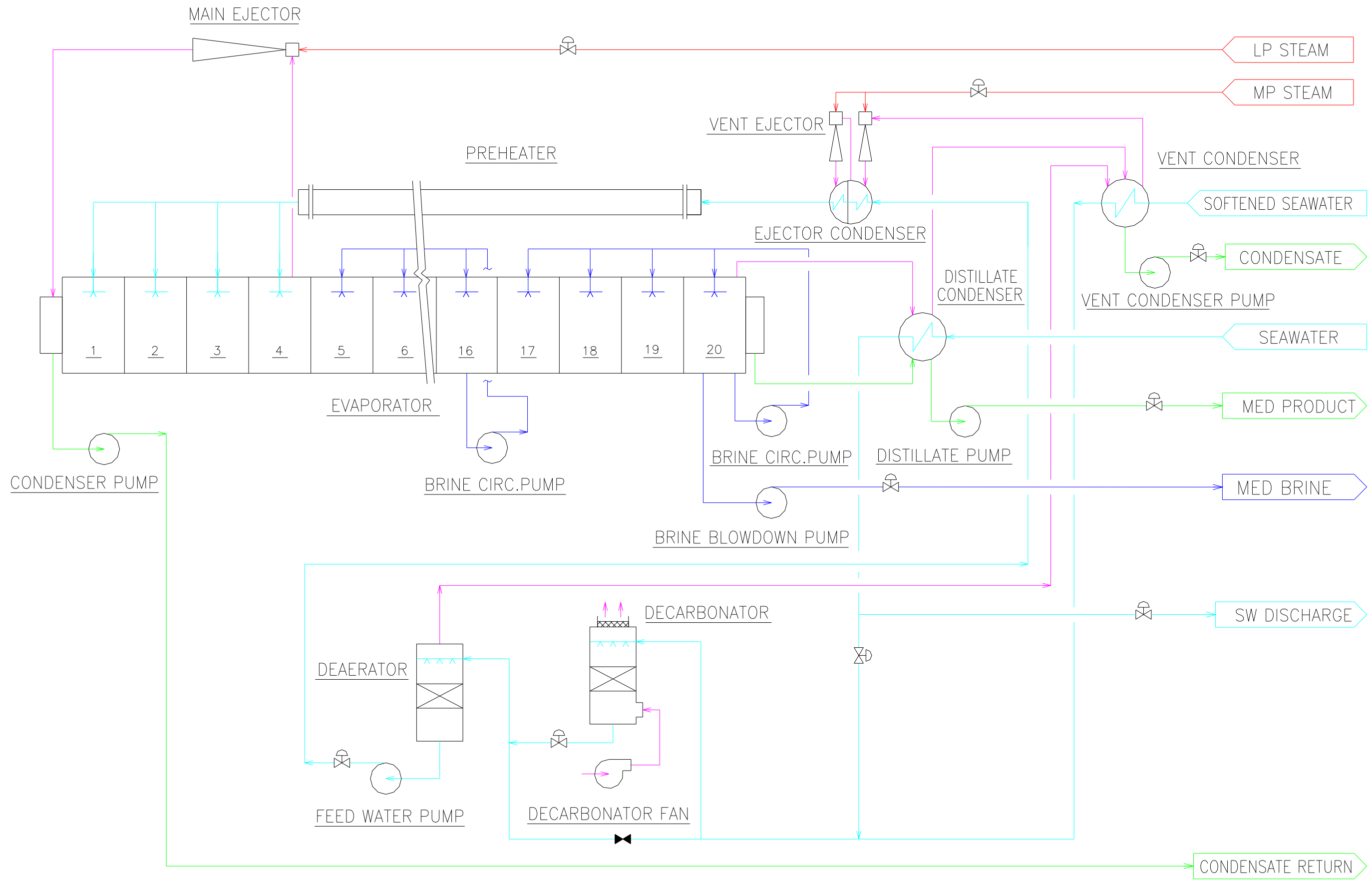
Schematic flow diagram of trihybrid NF/RO/MED desalination system

CONCEPTUAL DESIGN OF THE HIGH TEMPERATURE AND UNIT CAPACITY MED-TVC DESALINATION PLANT

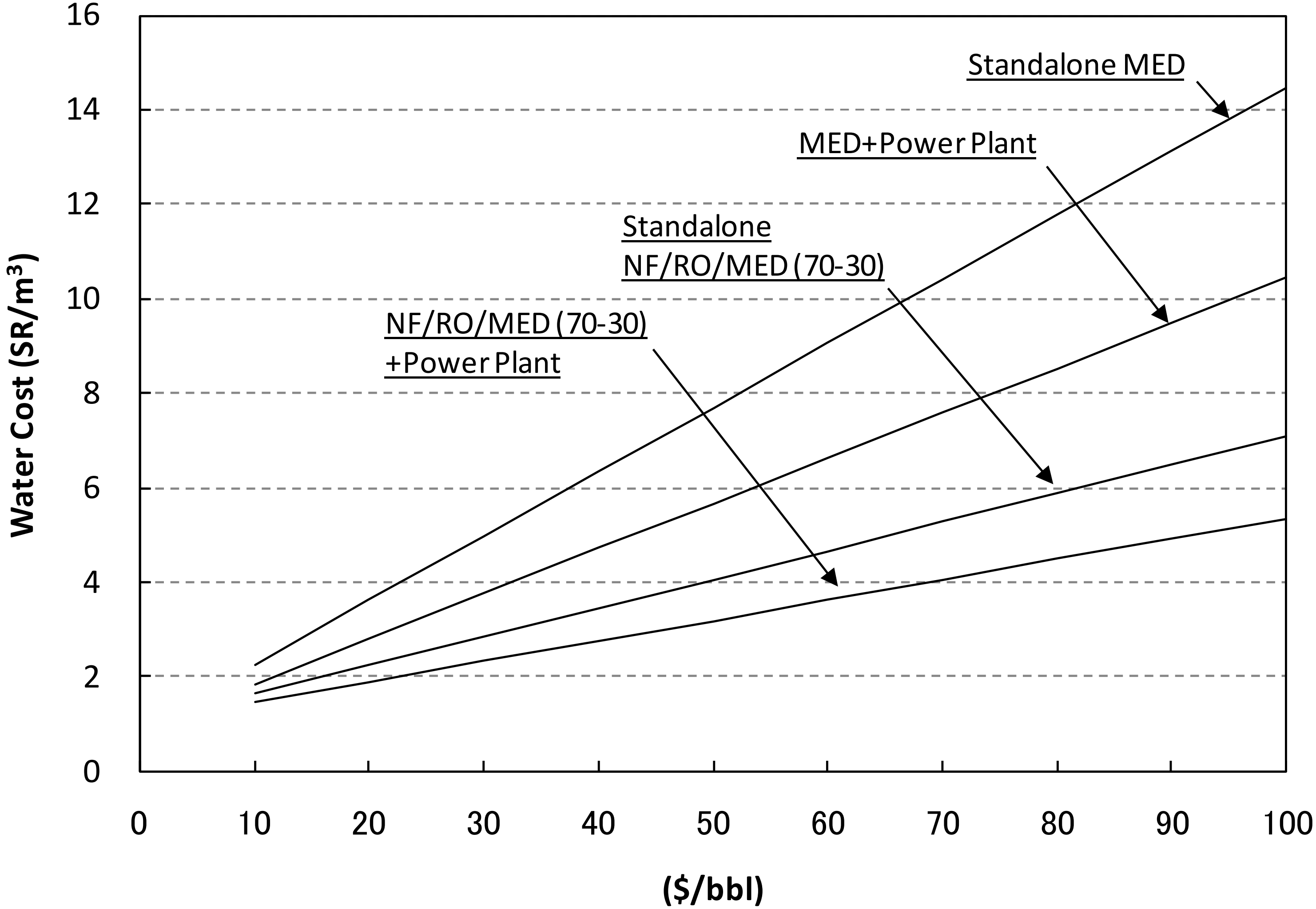
Configuration of new MED/TVC desalination plants

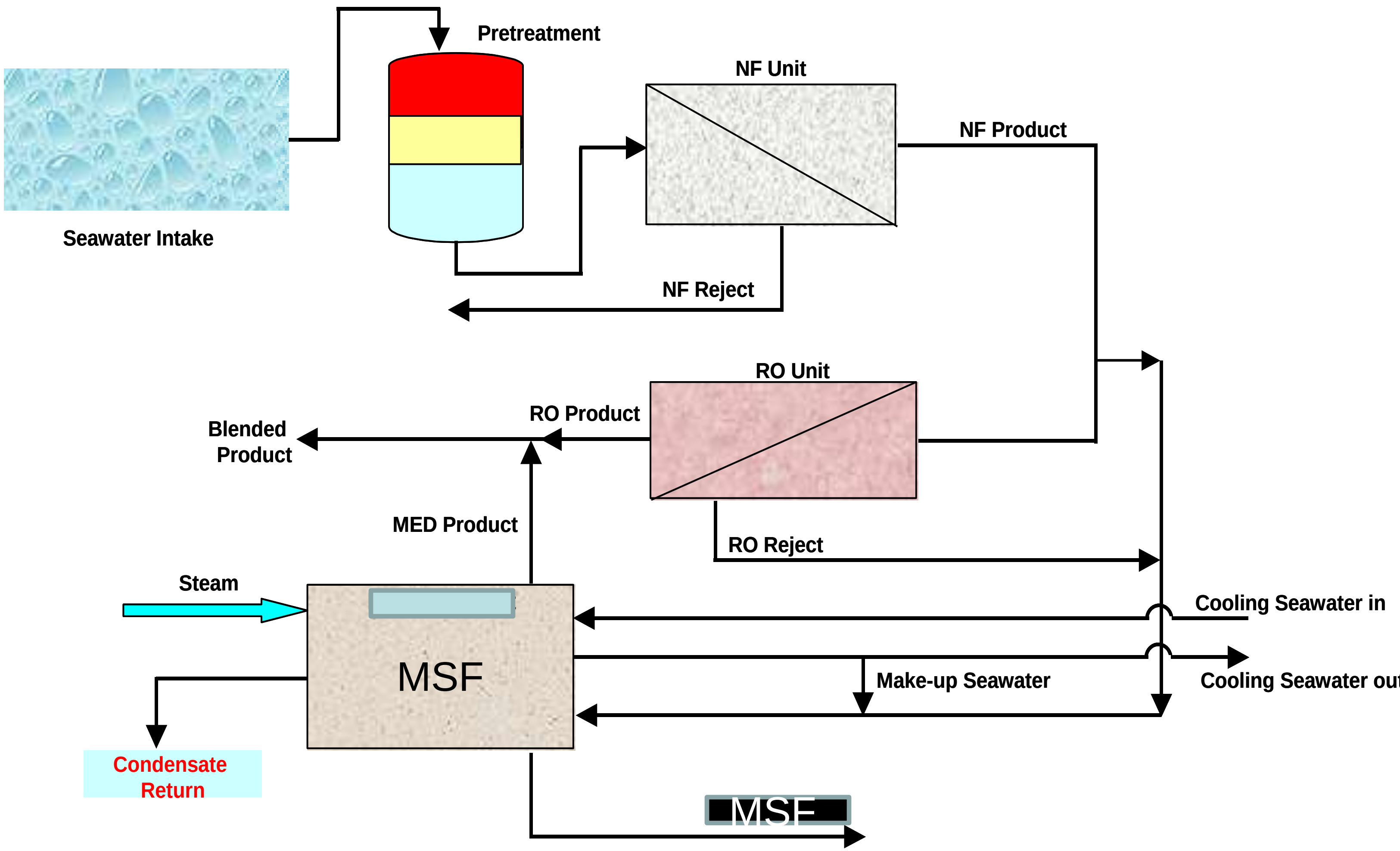


Schematic flow diagram of MED unit of Tri-Hybrid Desalination Plant



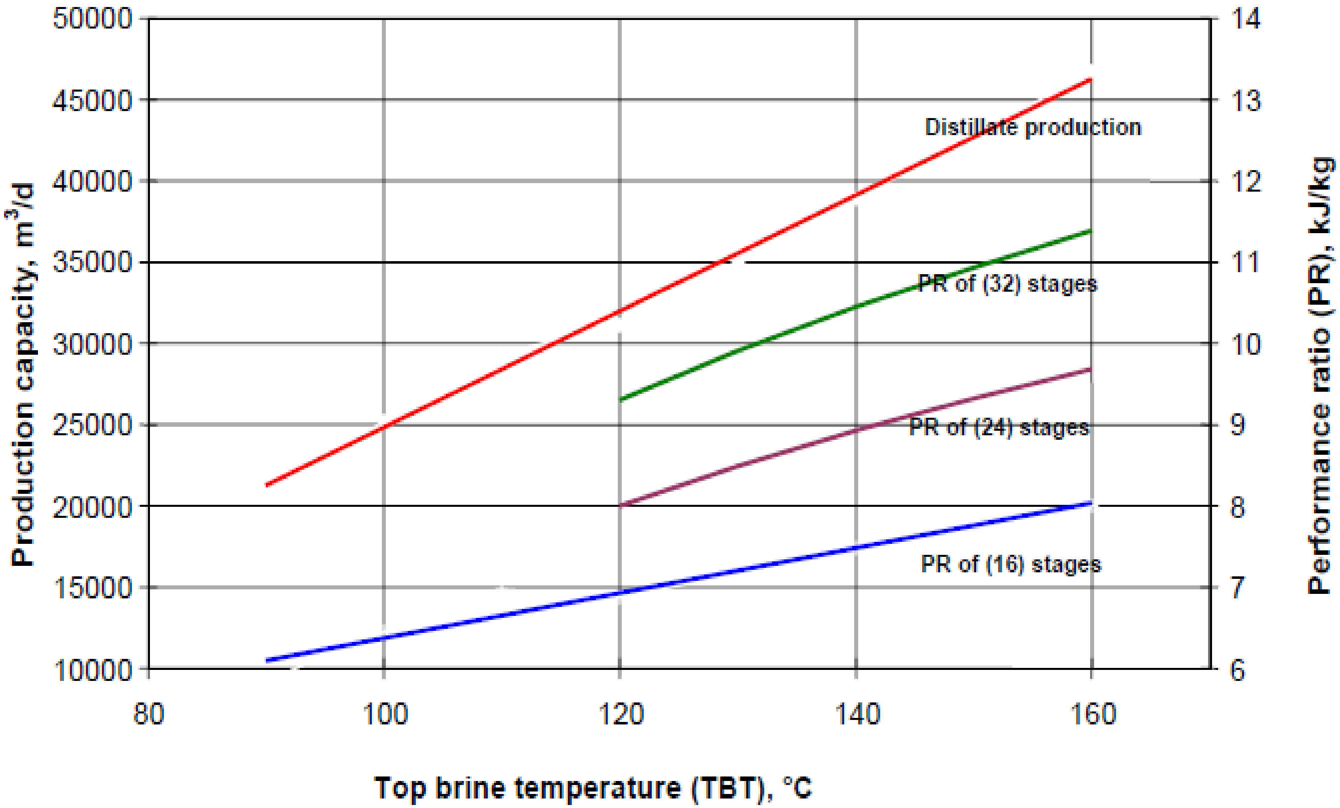
The impact of energy cost in $/bbl oil equivalent on the water production cost



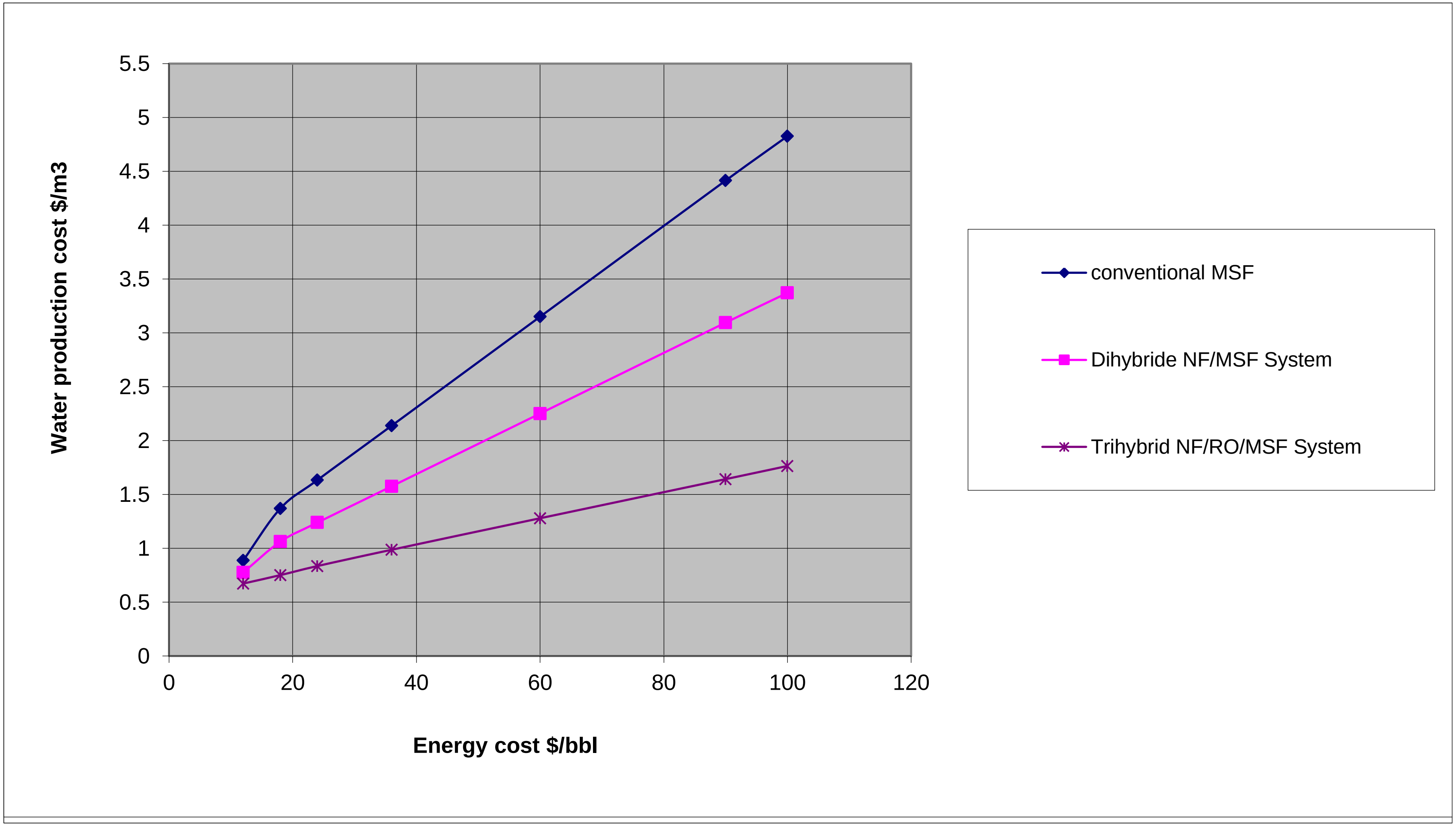


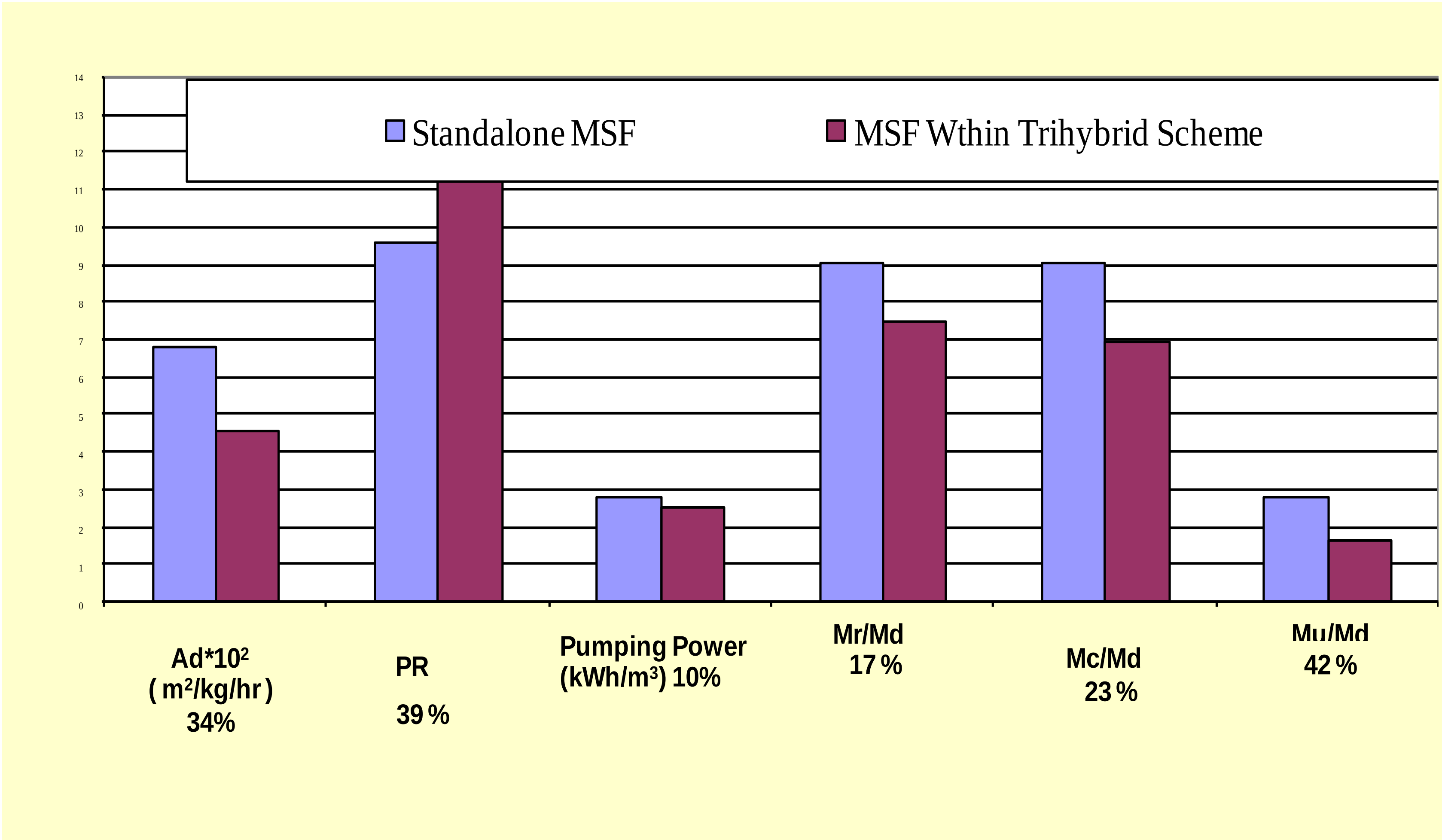
Schematic flow diagram of trihybrid NF/RO/MSF desalination system

The impact of TBT on water production and energy consumption



The impact of energy cost in $/bbl oil equivalent on the water production cost



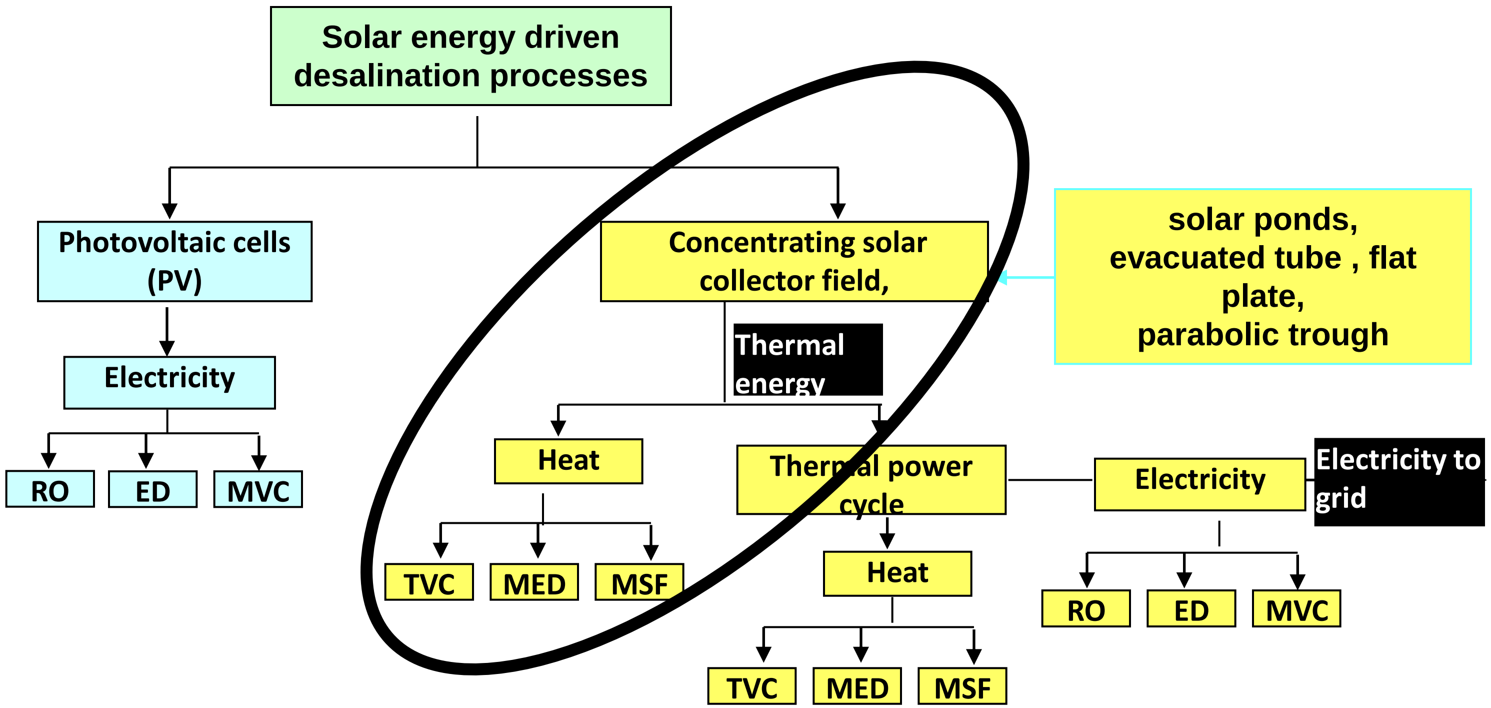


Comparison between the standalone MSF and MSF combined with NF/RO configuration

Saline Water Conversion Corporation (SWCC)

Prospects of reduction of operational cost of SWCC small scale thermal desalination plants using solar energy

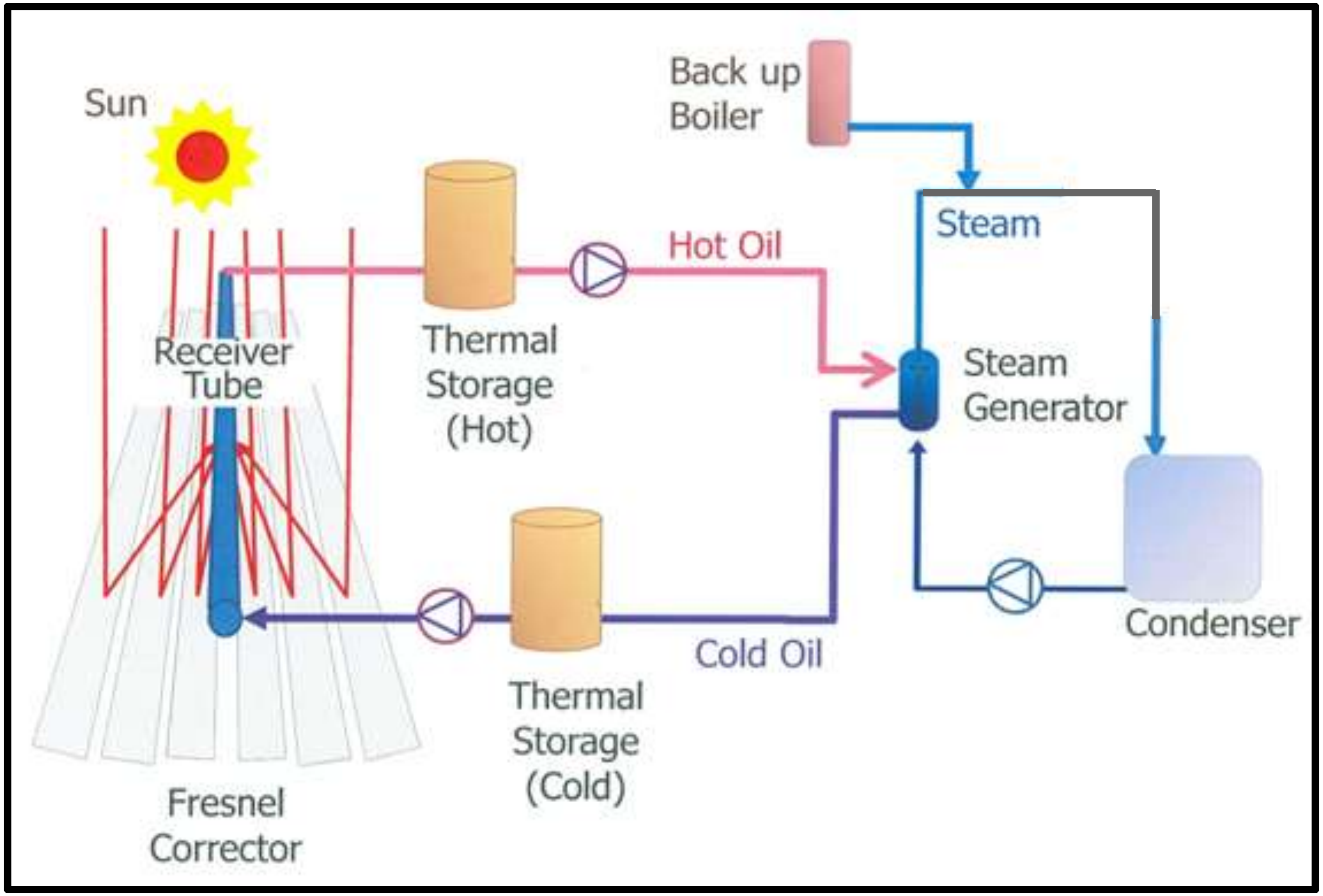
Synergy between desalination and solar energy
Solar desalination combinations



RO = Reverse Osmosis
ED = Electrodialysis (ED)
MVC = Mechanical vapor compression
TVC = Thermal Vapor compression
MED = Multieffect distillation
MSF = Multistage flash distillation

SWCC-SWDRI/HITACHI ZOSEN Joint Solar Research Project

Schematic diagram of the solar assisted thermal desalination experimental set-up



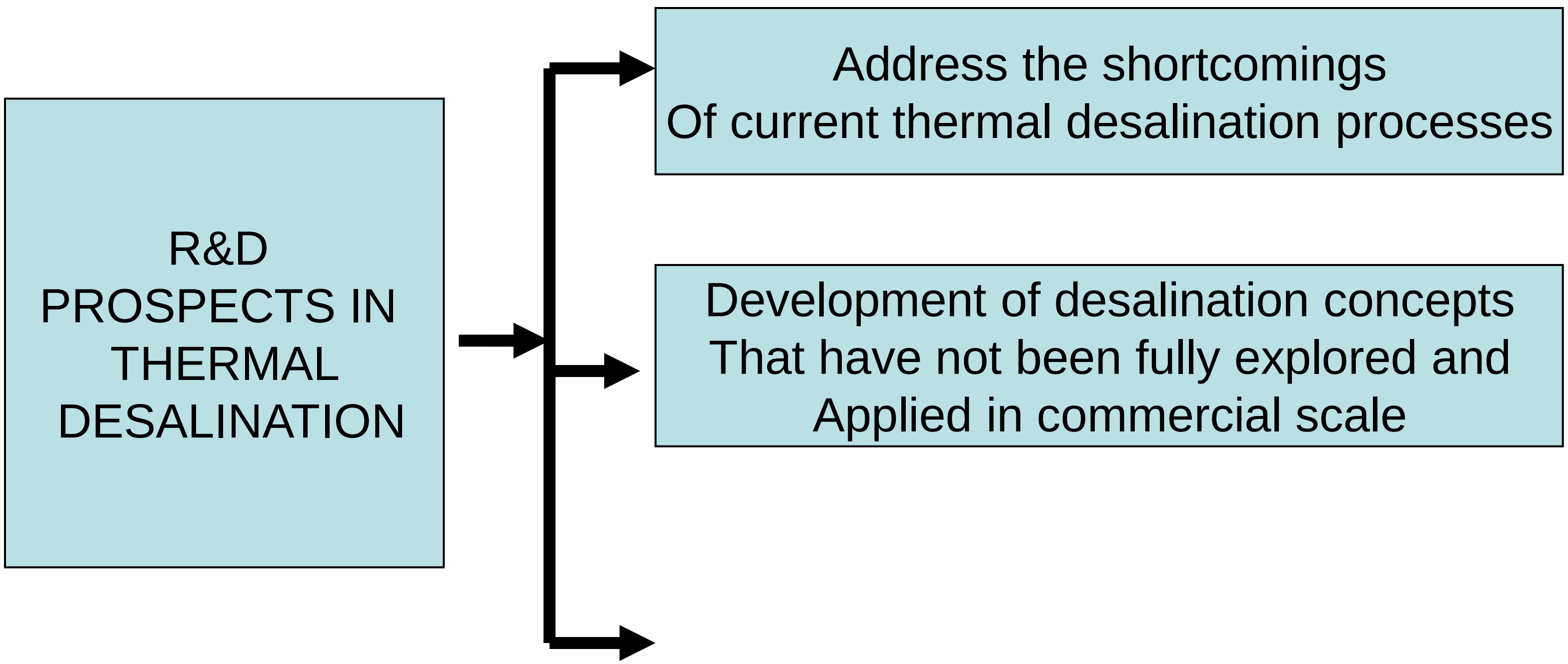
SWCC

SWDRI

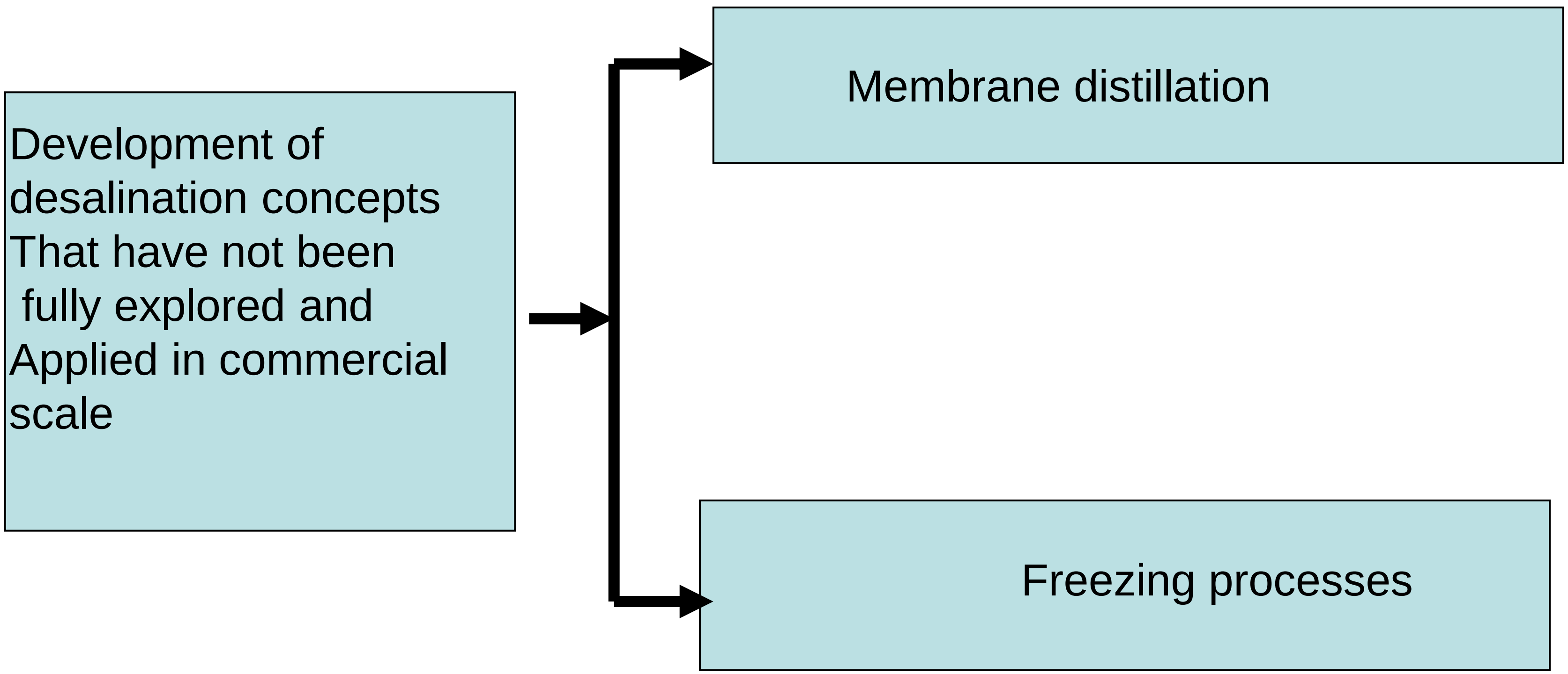
Solar Energy for Desalination Plants

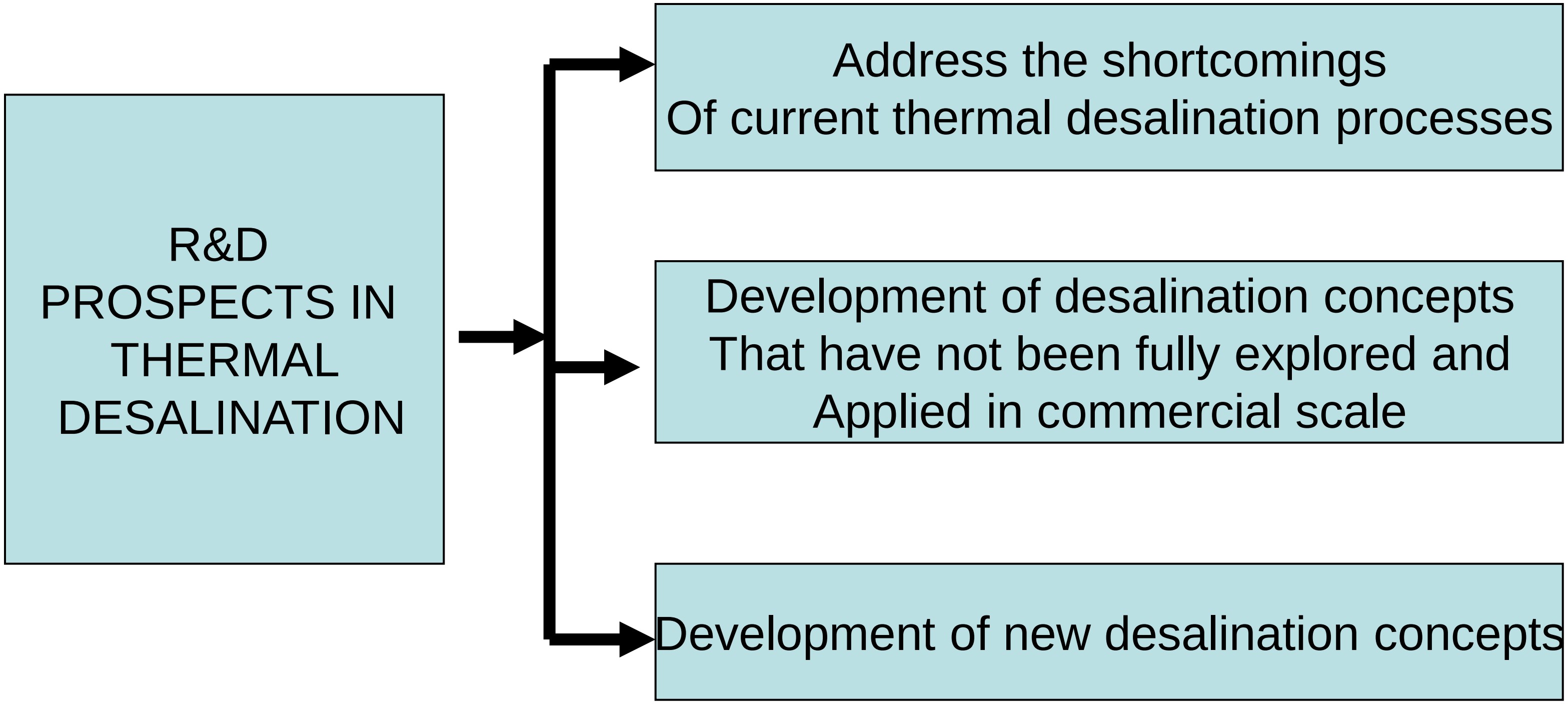
Hitz

Hitachi Zosen


R&D PROSPECTS IN THERMAL DESALINATION
Address the shortcomings
Of current thermal desalination processes
Development of desalination concepts
That have not been fully explored and
Applied in commercial scale

R&D PROSPECTS




R&D
PROSPECTS IN
THERMAL
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Address the shortcomings
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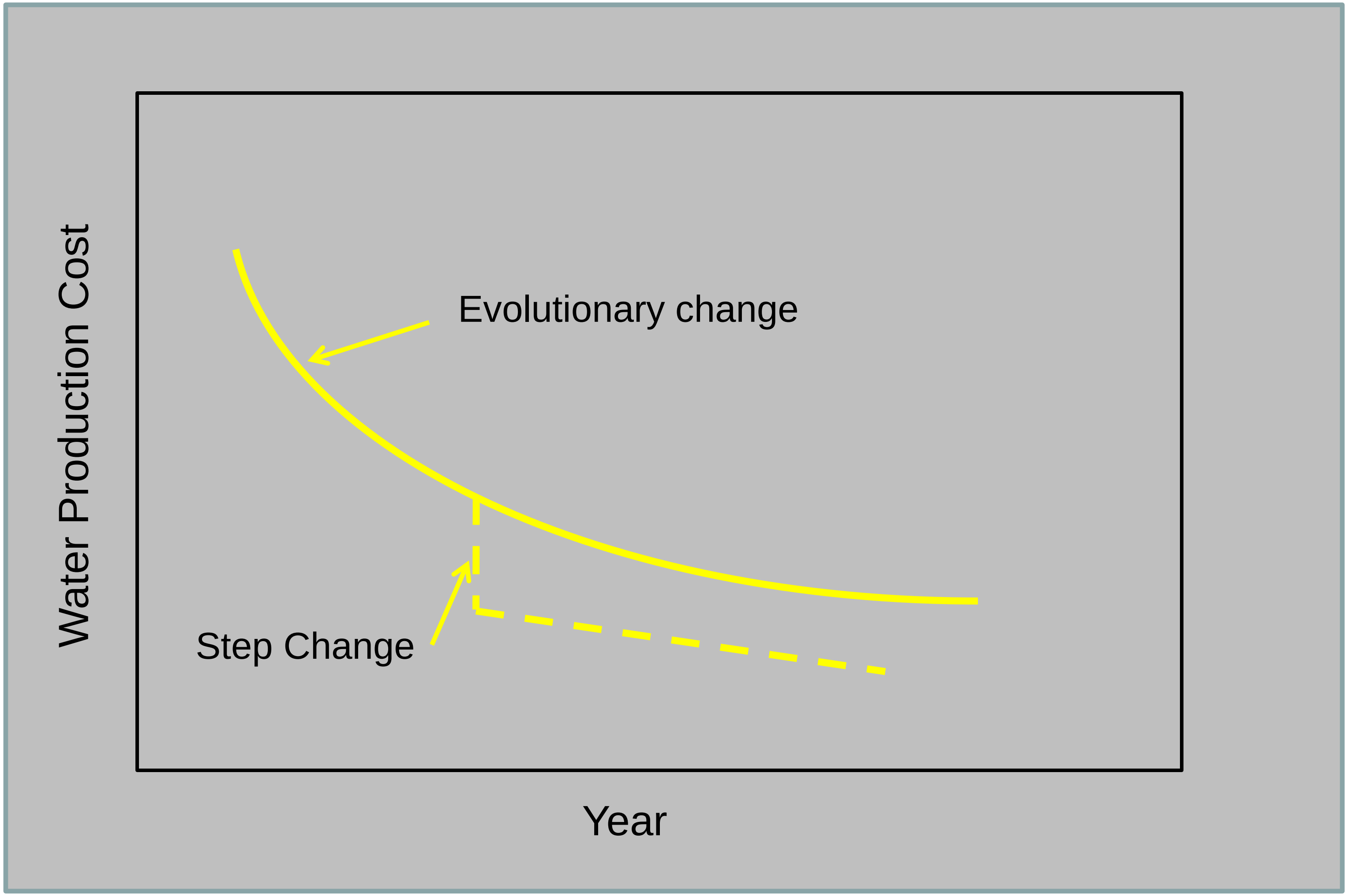
Development of new desalination concepts


Evolutionary change
Step Change
Water Production Cost
Year

Thank You