WORSKSHOP 02

Uses of Alternative & Renewable Energy in Desalination Stations

Eng. Leon Awerbuch
IDA Director, Dean of the Academy
International Desalination Association (IDA)
United States of America

arwadex 2019

TUESDAY 23 APRIL 2019
09:00 - 11:00
InterContinental City Stars, Cairo

INTRODUCTION

The workshop topics include novel solutions and practical information about performance, operation, and conditions of USES OF ALTERNATIVE and RENEWABLE ENERGY in DESALINATION STATIONS. Most of the participants understand applications of electricity generated by photovoltaic or nuclear power to couple via grid to Reverse Osmosis (SWRO) desalination plants. It is much more complex when grid or large battery storage is not available. Multi-Effect Distillation (MED) Technology and Hybrid MED-RO systems for seawater desalination offer some unique opportunities in diversifying the energy mix, to include clean energy renewable or alternative nuclear to operate desalination plants not only to reduce carbon dioxide footprint but also that offers opportunity provide lower cost desalination. The desalination industry has already done much to decrease energy consumption and significantly reduce greenhouse gas emissions. MED technology is today the most efficient thermal technology and has made significant progress in recent years. The MED unit size and efficiency in recent years demonstrated full ability to reach unit size of 50,000 m^3/day and in near future up 91,000 m^3/day. The largest MED plant in the world is currently the Jubail Water and Power plant at Marafiq with 800,000 m^3/d production capacity. Today, the Gain Output Ratio is exceeding GOR=11 and in not too distant future will exceed GOR=16. The important aspect of MED technology is that has the lowest electrical energy consumption between .9 kWh/m^3 to 1.3 kWh/m^3.

WORKSHOP OBJECTIVES

Provide understanding of the novel linking Renewable and Nuclear thermal energy to Multi-Effect Distillation (MED) and Hybrid MED membrane processes. This is in the context of progress of Desalination in the World & in the Gulf, and dramatic possibility offered by use of solar, renewable, and nuclear energy in comparison to fossil energy sources. Underline Renewable and Nuclear Energy Future Role of Desalination in Ensuring Security and Sustainability of Water.

WORKSHOP LANGUAGE

English

WHO SHOULD ATTEND

Planners, policy makers, developers and engineers, researchers, and scientist as well as any organization concern with energy and water programs and projects should attend this 2-hour short course.

WORKSHOP CONTENT

The numerous studies and demonstrated real projects of solar power both PV and Thermal as well as Wind, Geothermal and Nuclear energy, shows that these technologies can be coupled to desalination, not only to reduce carbon footprint but offer economic more competitive solutions to water generation both for municipal, industrial and agricultural system. The course will review Critical Aspects of Design and Operation of Thermal Systems. Provide comparison to other desalination processes MSF and SWRO processes, dual purpose power and desalination. Learn from examples of large MED and Hybrid desalination plants. Review typical flow diagrams, understand definition of energy efficiency, GOR and Performance Ratio. Specifically learn novel coupling of thermal energy plants by hot water loop allowing separation of energy source location and provide ability to connect thermal renewable in the desert or nuclear thermal source to desalination plants being on the shore. Few examples of renewable revolution, ACWA Power announced the successful financial closure of US $ 320 million for a 300 MW solar PV project. Sakaka PV IPP, the first ever utility scale renewable energy project to be developed in the Kingdom of Saudi Arabia. The new world record tariff of US Cents 2.3417/kWh. The commercial operation date of the plant is scheduled to be towards the end of calendar year 2019

The 950 MW hybrid project (700 MW CSP & 250 MW PV) fourth phase of the Mohammed Bin Rashid Al Maktoum Solar Park, is the largest single-site concentrated solar power plant in the world using combination of a central tower and parabolic trough concentrated solar power (CSP) technologies. This will be supported with Photovoltaic panels to take the full phase to 950 MW at cost of US$ 3.9 billion. The project, which will deliver electricity at a levelized tariff of US $7.30 cents per kWh a cost level that competes with fossil fuel generated electricity without subsidy for dispatchable 24/7.

ABOUT WORKSHOP INSTRUCTOR

President & CEO, International Desalination Consultancy Associates (IDCA), President & CTO, Leading Edge Technologies Ltd.; Dean, IDA Desalination Academy, IDA Chair of Energy and Environment Committee. With Bechtel for over 30 years involved in R&D, BD and Projects as Vice President and Senior Representative for the Middle East. Currently International Consultant on Energy and Water providing technical/commercial consultancy to leading suppliers and utilities. Past President IDA. Granted 28 patents publishing over 90 papers. Chairman of 6 IDA World Congresses, Chairman of IDA Technical Programs for the 26 years and chaired over 50 International Conferences. Lifetime Achievement Award from IDA in 2007. Lifetime Achievement at the Inaugural Power Generation and Water Solutions Middle East Awards 2009. Won in 2007 the inaugural GWI Award for Innovation, first prize for Innovation at SWPF and first prize of Innovative Use of Technology by inaugural H20 Water Awards 2010. In 2015 Leon Awerbuch was voted one of Water & Wastewater International's top 25 industry leaders and in 2019 awarded 51 Most Impactful Leader in Water and Water Management.
Master's Degree in Chemical Engineering and Chemistry from Warsaw Technical University.

الشريك التقني الدولي

الراعي المشارك

المستشار الأكاديمي

تنظيم

المتعاونون

"USES OF ALTERNATIVE and RENEWABLE ENERGY in DESALINATION STATIONS "

Workshop Conducted

by

Eng. Leon Awerbuch,

President & CEO International Desalination Consultancy Associates LLC

Dean of the Academy, International Desalination Association (IDA) USA

presented at:

ARWADEX12 (23-24 April 2019) Cairo, Egypt

arwadex 2019

مؤتمر تحلية المياه في الدول العربية

Water Desalination Conference in the Arab Countries

About the instructor

Leon Awerbuch

Dean, IDA Desalination Academy, President & CEO, International Desalination Consultancy Associates (IDCA), President & Chief Technology Officer, Leading Edge Technologies Ltd.

Leon Awerbuch has been involved in the desalination industry for more than 35 years. He joined Bechtel Group in 1972 in R&D followed by increased responsibilities for power and water programs as International Bechtel Co. Ltd Vice President and Senior Regional Representative for the Middle East. Currently involved in providing technical and commercial consultancy to number of leading suppliers and utilities covering Reverse Osmosis and Thermal Desalination and Power Projects as well as assessment of new desalination technologies.

Past President of IDA, Chairman of six IDA World Congresses. He currently serves as a Director and Officer of the Association and has been a Chairman of IDA's Technical Programs for the past 25 years, he has organized and chaired over 40 conferences, around the world. He holds 28 patents and has published over 90 technical papers. Mr. Awerbuch was one of the early pioneers in Hybrid Power-Desalination concepts, DASR and Hybrids of NF MSF/MED. He received a Lifetime Achievement Award from IDA at the 2007 and Life Achievement at the Inaugural Power Generation and Water Solutions Middle East Awards October 2009. In January 2015 Leon Awerbuch was voted one of Water & Wastewater International's top 25 industry leaders. He is Board member of Global Clean Water Desalination Alliance (GCWDA). Mr. Awerbuch received a master's degree in Chemical Engineering and Chemistry from Warsaw Technical University.

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Introduction

USES OF ALTERNATIVE A and RENEWABLE ENERGY in DESALINATION STATIONS

The topics include novel solutions and practical information about performance, operating and maintenance skills and conditions of USES OF ALTERNATIVE and RENEWABLE ENERGY in DESALINATION STATIONS. Most of the participants understand applications of electricity generated by photovoltaic or nuclear power to couple via grid to Reverse Osmosis (SWRO) desalination plants. It is much more complex when grid or large battery storage is not available. The desalination industry has already done much to decrease energy consumption and significantly reduce greenhouse gas emissions. Since the mid- 1990s, energy requirements have been reduced by over 50 percent because of technological improvements. Technological advances include development of more efficient energy recovery devices (ERDs); improved efficiency, increased RO flux designs; pressure centers designs; improvement in pretreatment and posttreatment; introduction of large-scale high-performance thermal distillation plants (MED); higher recovery processes to minimize concentrate disposal; and indirect and direct coupling of renewable energy and desalination on a large scale. Multi-Effect Distillation (MED) Technology and Hybrid MED-RO systems for seawater desalination offer some unique opportunities in diversifying the energy mix, to include clean energy renewable or alternative nuclear to operate desalination plants not only to reduce carbon dioxide footprint but also that offers opportunity provide lower cost desalination

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Introduction

USES OF ALTERNATIVE A and RENEWABLE ENERGY in DESALINATION STATIONS

MED technology is today the most efficient thermal technology and has made significant progress in recent years. The MED unit size and efficiency in recent years demonstrated full ability to reach unit size of 50,000 m3/day and in near future up 91,000 m3/day. The largest MED plant in the world is currently the Jubail Water and Power plant (JWAP) at Marafiq with 800,000 m3/d production capacity. Today, the Gain Output Ratio is exceeding GOR=11 and in not too distant future will exceed GOR=16. The important aspect of MED technology is that has the lowest electrical energy consumption between .9 kWh/m3 to 1.3 kWh/m3. Therefore, that stimulates interest in basic and advanced understanding of Design and Operation of, Multi-Effect Distillation Technology (MED) as well as hybridization of Thermal and Membrane processes.

Dramatic progress of Multi-effect distillation assures that this technology will continue to be utilized alone or in hybrid systems combining the best features of thermal and membrane technologies as well as different sources of energy. and continue to improvement in performance, productivity and cost of desalination and an essential element of sustainable development

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Course Objectives and Content

Provide understanding of the linking Renewable and Nuclear thermal energy to Multi-Effect Distillation (MED) and Hybrid MED membrane processes. This is in the context of Desalination in the World & in the Gulf, use of solar, geothermal and nuclear energy in comparison to other energy sources. Critical Aspects of Design and Operation of Thermal Systems. Provide comparison to other desalination processes MSF and SWRO processes, dual purpose power and desalination,. Learn from examples of large MED and Hybrid desalination plants. Review typical flow diagrams, understand definition of energy efficiency, GOR and Performance Ratio. Learn who are the players in desalination, and economics considering both CAPEX and OPEX. Specifically learn novel coupling of thermal energy plants by hot water loop allowing separation of energy source location and provide ability to connect thermal renewable in the desert or nuclear thermal source to desalination plants being on the shore.

The numerous studies of solar power both PV and Thermal as well as Wind, Geothermal and Nuclear Energy, shows that these technologies can be coupled to desalination, not only to reduce carbon footprint but offer economic more competitive solutions to water generation both for municipal, industrial and agricultural system.

Course Outline

1. Desalination in the world & in the Gulf.
   - How much desalinated water is produced worldwide & in the Gulf.
   - How many desalination plants are there around the world?
   - What are the energy sources today and in the future
2. Understanding of thermal distillation desalination processes
3. Basic mass balances. Basic heat balance
   - Basic heat and mass flows for thermal plants
   - Gain Output Ratio (GOR) and Performance Ratio (PR)
4. Multi-Effect Distillation Process,
   - Multiple Effect
   - Multiple Effect with Thermal Vapour Compression
   - Multiple Effect with Mechanical Vapour Compression

Course Outline

4. Understanding MED process
- Electrical consumption
- MED key parameters
- Differences between MED, MED-Thermo Compression (MED-TVC) and Mechanical Vapor Compression (MVC)
- The Multi-Effect Distillation (MED) versus Multistage Flash (MSF)

5. Dual purpose power and desalination using MED technology
- Examples of exiting MED plants
- Typical Power to Water Ratios for Different Desalination Technologies,
- The consideration of steam flow make-up, feed flow patterns, flow diagrams,

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Course Outline

6. Development of coupling of thermal renewable and nuclear to MED desalination
- Coupling Concentrated Solar Power to Desalination
- Coupling Nuclear Energy to Desalination
- Photovoltaic Thermal PV/T to MED-MVC
- Low temperature thermal energy- geothermal, solar pond and solar water heater to MED

7. Critical Aspects of Design and Operation of Thermal Systems MSF and MED
- Top Brine Temperature
- Concentration Factors
- Wetting and scaling of the Tube Bundle, Venting, Pre-Heaters,
- Role and Requirements of the Steam Transformer in MED
- Impact of Oil slick and Red tide on the operation of MED Desal plant,

7. Economics and Management, Cost of water
- Cost comparison of real projects CAPEX and OPEX
- Independent Power and Water Projects (IWPP)

8. Closing of Workshop with Question and Answers.

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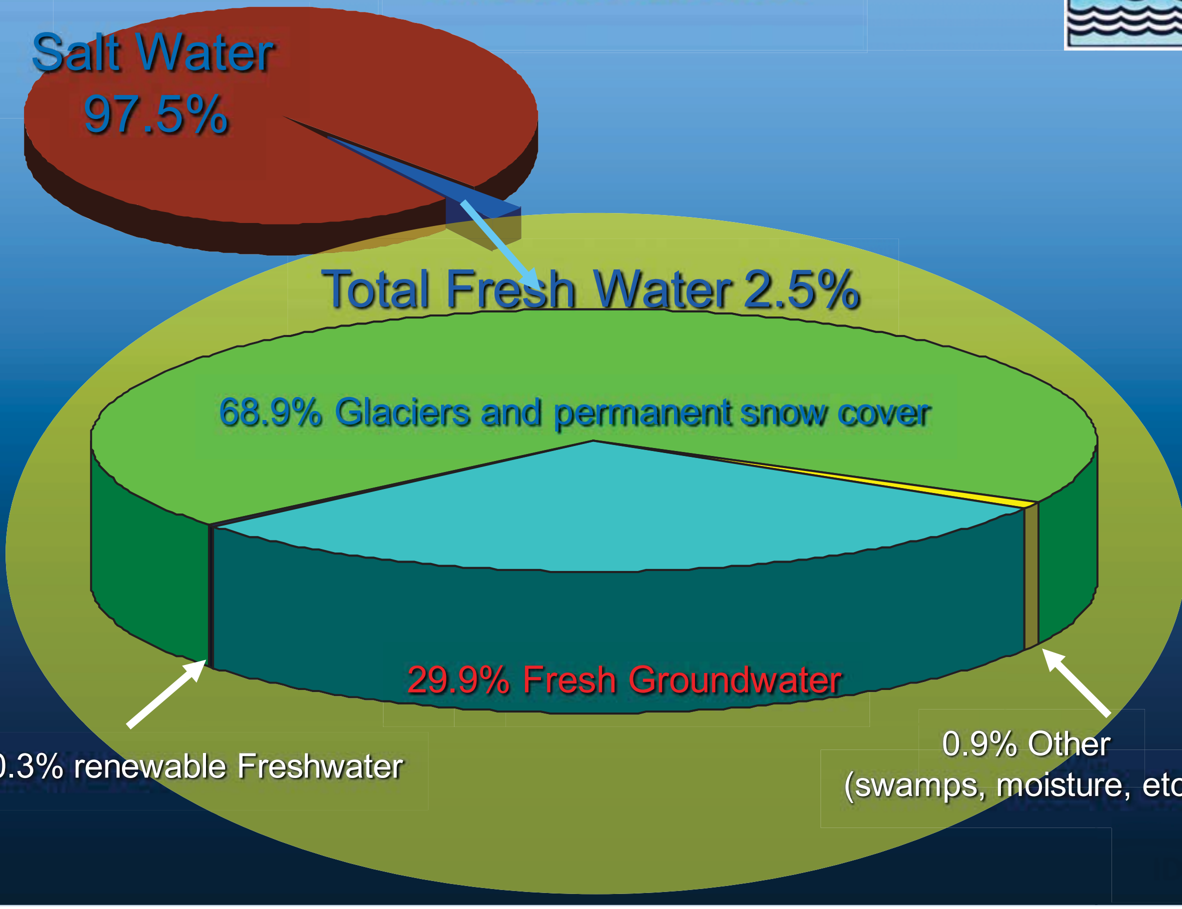
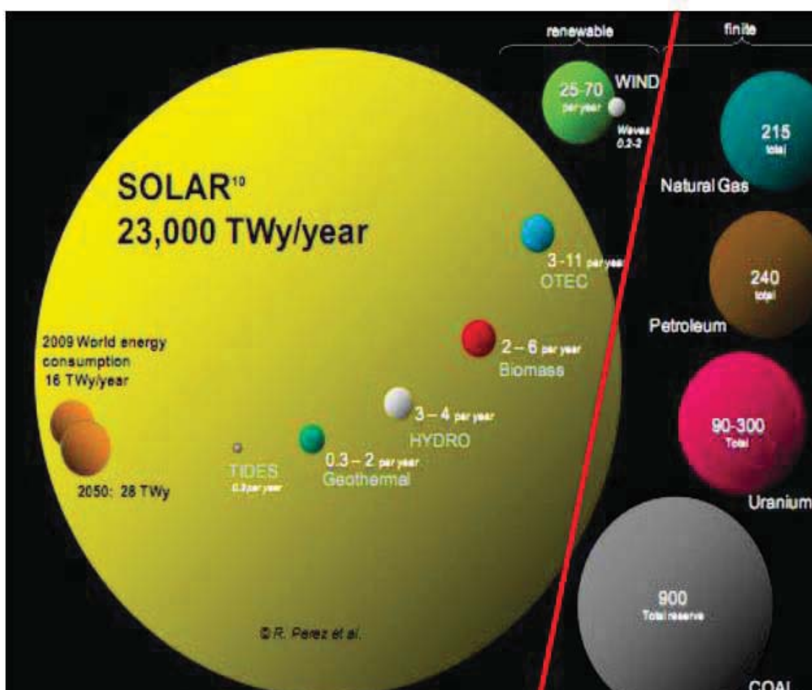
World Water

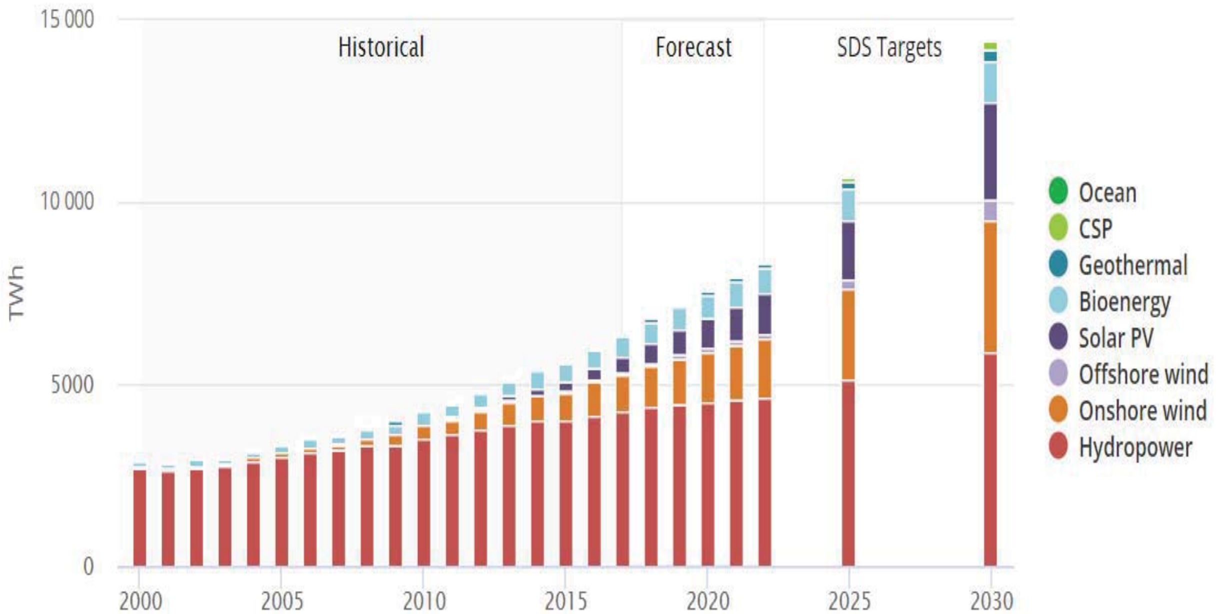


SOLAR and ENERGY SOURCES COMPARISON

The annual solar radiation on the earth surface is 1400 times higher than the annual world energy consumption and 25 times higher than the total coal reserves



Renewable generation by technology
Historical and targets by IEA



Renewable Energy Projects

Renewable energy auction prices continued to decline for solar PV and onshore wind, and ranged from 20 to 50 USD/MWh.

Record low prices were also achieved for offshore wind (55-80 USD/MWh) and CSP (73 USD/MWh in the United Arab Emirates) for projects to be commissioned over 2019-25. In Germany's first offshore wind auction, three projects (totaling 1.4 GW) bid at zero for the first time, meaning that if they are commissioned their electricity will be sold at the wholesale price starting from 2024/25.

Few examples of renewable revolution, ACWA Power, a leading developer, owner, and operator of power generation and water desalination plants, leading a consortium with AlGihaz Holding Company announced the successful financial closure of US $ 320 million for a 300 MW solar PV project. Sakaka PV IPP, the first ever utility scale renewable energy project to be developed in the Kingdom of Saudi Arabia under the landmark National Renewable Energy Program. The new world record tariff of US Cents 2.3417/kWh. The commercial operation date of the plant is scheduled to be towards the end of calendar year 2019

Renewable Energy Projects

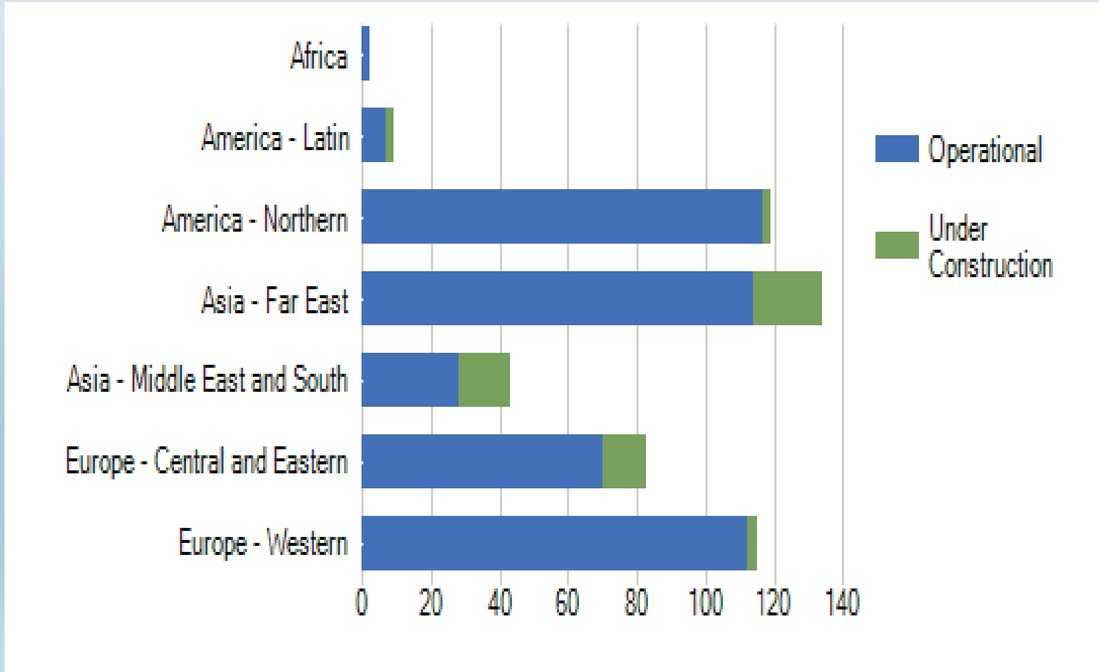
The Sweihan Solar Holding Company is a developer of (BOO) basis is project of a 1,177 MW solar photovoltaic (PV) being constructed in Abu Dhabi, UAE. It is expected to become the world's biggest solar PV plant upon completion, A consortium of Marubeni and JinkoSolar submitted a bid at a tariff of $2.94 cents per kWh, which is one of the lowest levelized cost of electricity (CLOE) bid for solar power, to the Abu Dhabi Water and Electricity Authority (ADWEA). Construction of the solar PV plant was started in May 2017, while commissioning is expected in April 2019. The estimated investment on the project is $US 870 million.

The 950 MW hybrid project (700 MW CSP & 250 MW PV) fourth phase of the Mohammed Bin Rashid Al Maktoum Solar Park, is the largest single-site concentrated solar power plant in the world using a state-of-the-art combination of a central tower and parabolic trough concentrated solar power (CSP) technologies to collect energy from the sun. This will be supported with Photovoltaic panels to take the full phase to 950 MW at cost of US$ 3.9 billion. The project, which will deliver electricity at a levelized tariff of US $7.30 cents per kilowatt-hour; a cost level that competes with fossil fuel generated electricity without subsidy for reliable and dispatchable solar energy through the night. The plant will support the Dubai Clean Energy strategy 2050 to increase the share of clean energy at Dubai to 25% by 2030 and will allow a saving of 2.4 Million tons of CO2.

Mohammed Bin Rashid Al Maktoum Solar Park 950 MW

Nuclear Power Today

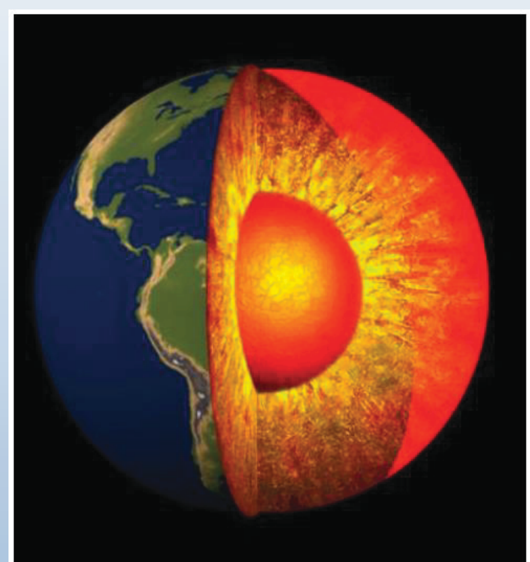
450 NUCLEAR POWER REACTORS IN OPERATION,
396,850 MWe TOTAL NET INSTALLED CAPACITY
55 NUCLEAR POWER REACTORS UNDER CONSTRUCTION
17 990 REACTOR-YEARS OF OPERATION



Geothermal energy in the world: where does this energy come from?

Deep underground: 45 TW flowing, 3X the total of fossil& fissil energies
•Global fossil fuel consumption15 TW
•Global installed geothermalpower generation: 13 Gwe (load factor = 0.67)
•Global installed direct geothermal capacity: 20 GWth
•Global direct geothermalcapacity70 GWth (loadfactor = 0,27)
•Global energy production:

- Power: 75,000 GWh
- Direct: 165,000 GWh
- Geothermal= 0.15 % of global energy consumption; 2% of installed renewable power generation capacity (except hydro); 6% compared to solarPV, but 1/3 when comparing annual energy production.



Geothermal Solution Low enthalpy (t>60°C) geothermal energy can effectively drive a sea or brackish water desalination unit in order to produce fresh water for drinking and/or irrigation. As a geothermal plant, whether used for power generation or for space heating or other applications, has large quantities of available heat at low cost, the most cost effective method for seawater desalination is to provide directly geothermal heat to a MED (multi effect distillation) plant.

Why should geothermal energy be preferred in a desalination process?

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How much desalinated water is produced worldwide?

The 31st GWI/IDA Worldwide Desalting Inventory which covers desalination plants contracted to June 2018. The Inventory is collected on an annual basis by Global Water Intelligence (GWI) and the International Desalination Association (IDA), and aims to be a comprehensive dataset of every desalination plant with a capacity greater than 500 m^3/d. The installed base of desalination plants around the world has a capacity of 105.4 million m^3/d (23,180 MIGD) and by year 2020 we expect to increase to 114.7 million m^3/d (25,220 MIGD). Long term forecast by 2030 the capacity will reach 198.8 million m^3/d .

How many desalination plants are there around the world?

There are now over 20,250 installed desalination plants worldwide, operating in over 150 countries.

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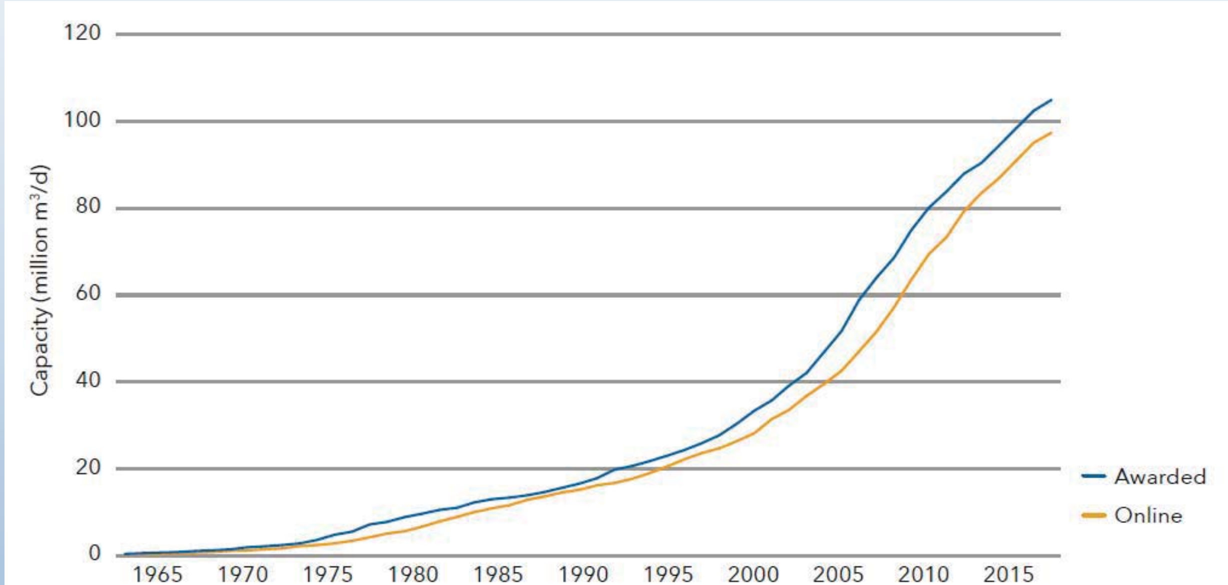
Cumulative contracted and online capacity, 1965–2018



Source: GWI DesalData/ IDA
*Values through June 2018
*Values through June 2018

How much of the worldwide installed capacity comes from seawater and what technology they use?

The MED production of potable water from seawater representing 7.36 million m^3/d number of plants 1298 and number of units 1225,

The MSF represents 19.47 million m^3/d with number of plants built is 808 and units 1490, The SWRO plants capacity is 53.9 million m3/d , plants 4491 and units 5,716.

The nanofiltration plants have capacity of 3.74million m^3/d , plants 144 and units 165.

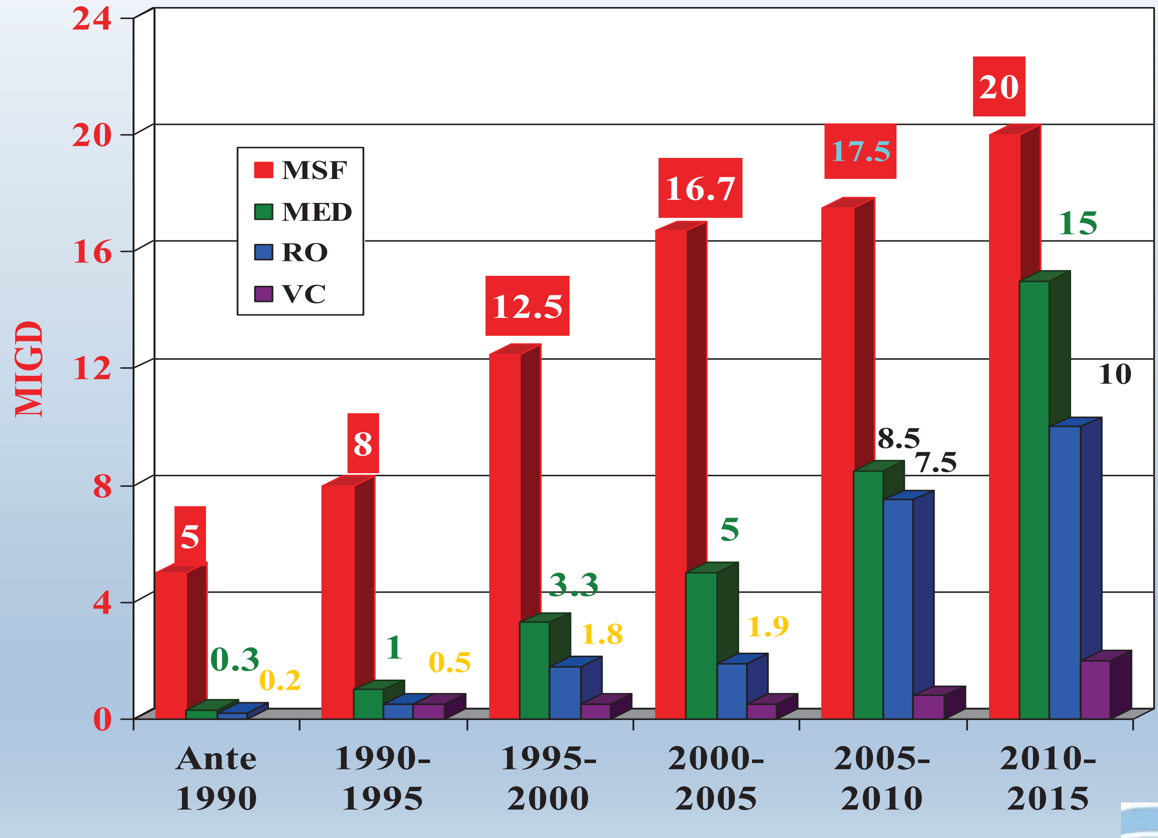
Seawater desalination constitute today about 76.6% of the total worldwide installed capacity.

- MED 9.1%,
- MSF 24.1%
- SWRO 66.8 %

Remaining desalination capacity is Brackish water desalination represents about 11.9%, followed by river water desalination at 4.8%.

Remaining 6.7% of the desalination capacity treats growing for industrial applications and treats wastewater streams, typically for water reuse.

Unit Size Development of Desalination Technology



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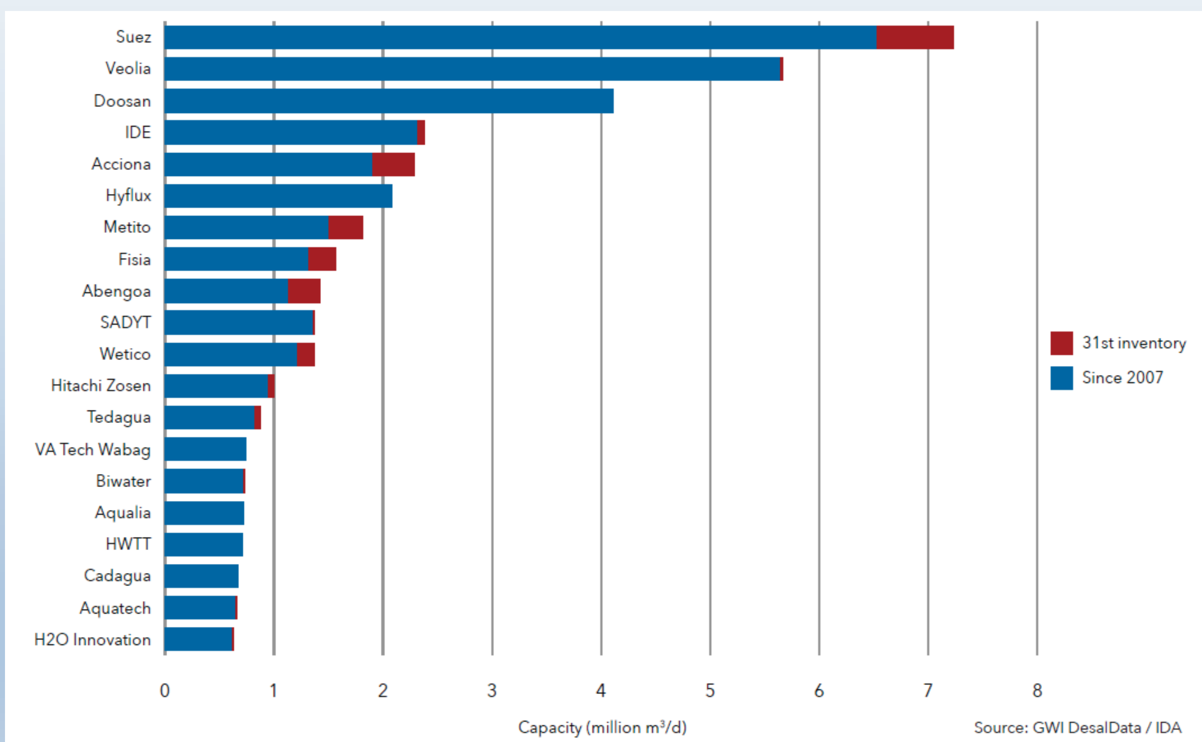
Top 20 plant suppliers by awarded capacity, 2007–2018



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Desalination in GCC

GCC	m3/day	MIGD	Number of Plants	Number of Units
Bahrain	1098380.0	241.68	169	257
Kuwait	4005603.0	881.14	104	235
Oman	2512833.0	552.7	223	870
Qatar	2838878.0	624.38	210	233
Saudi Arabia	11864846.0	2609.21	3078	3545
United Arab Emirates	9966644.0	2192.28	529	887
Total	32287184.0	7101.4	4313	6027

EGYPT DESALINATION PLANTS and PLAN EXPANSION

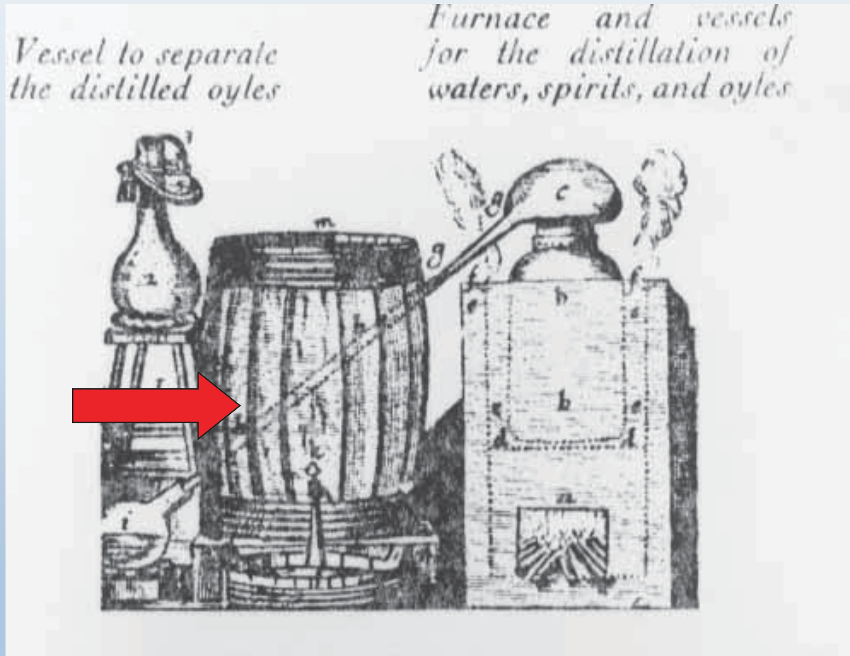
Governate	Currently installed, m^3/d	Capacity by 2037, m^3/d
Beheira	0	35,000
Dekhelia	0	34,000
Kafr El Sheikh	0	60,000
Matrouh	150,000	922,500
North Sinai	120,000	295,760
Port Said	0	150,000
Red Sea	242,000	788,600
South Sinai	121,000	318,000
Total	633,000	2,603,860

Desalination Technologies

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

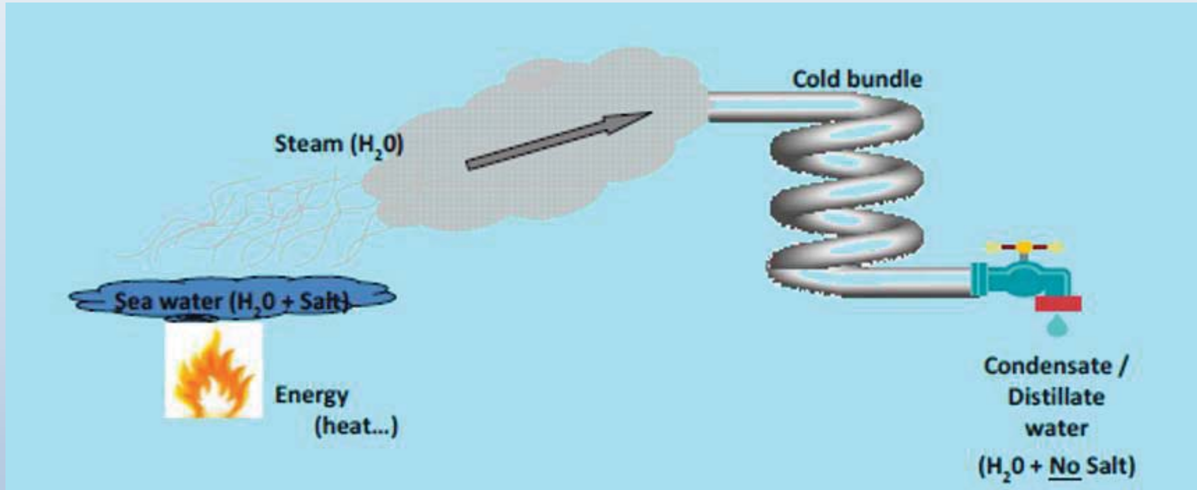
The principle is simple

- But, for nearly 2,000 years, there was no substantive progress in the technology



Distillation after N. Le Febure, 1664

Principle of distillation under vacuum



Pressure (bar)	1,0 bar	0,7 bar	0,47 bar	0,25 bar	0,1 bar
Boiling Temp.	100°C	90°C	80°C	65°C	45°C

Under vacuum distillation in order to :

1- boil sea water at low temperature,

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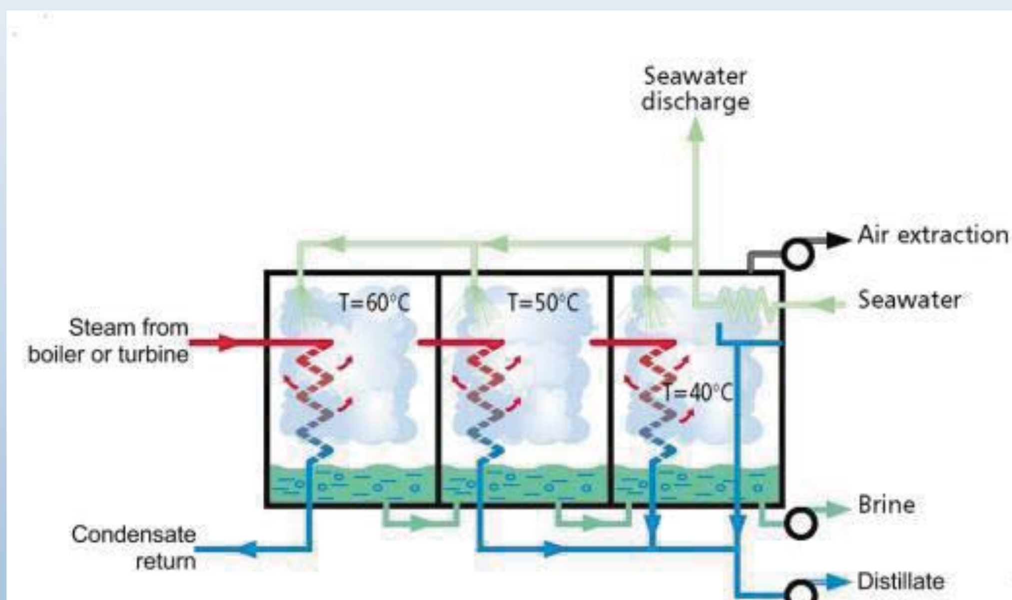
Multiple Effect Distillation Process
The heart of the process: the MED evaporator



http://www.sidem-desalination.com/en/process/MED/Process/

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Multiple- Effect Distillation (MED)

Widely used multi-effect distillation plant of the horizontal-tube type, in which the prime steam and all the downstream vapors flow inside the horizontal tubes, where they condense and contribute to the product water stream.

The seawater, meanwhile, is sprayed on the outside of the tubes, producing vapor.

The water vapor generated by brine evaporation in each effect of the horizontal-tube evaporator flows to the next effect, where it supplies heat for additional evaporation at a lower temperature.

Multiple- Effect Distillation (MED)

The basic principle is straightforward.

- **The feedwater flowing over a heat transfer surface in the first effect Is heated by prime steam, resulting in evaporation of a fraction of the water content of the feed.**

- **The partially concentrated brine is delivered to second cell (effect), maintained at a slightly lower pressure than the first effect. Likewise, the vapor liberated from the first effect feed is sent to the second effect. There the vapor condenses on the heat transfer tubes, giving up its latent heat to evaporate an additional fraction of water from the brine flowing on the opposite wall of the tube.**

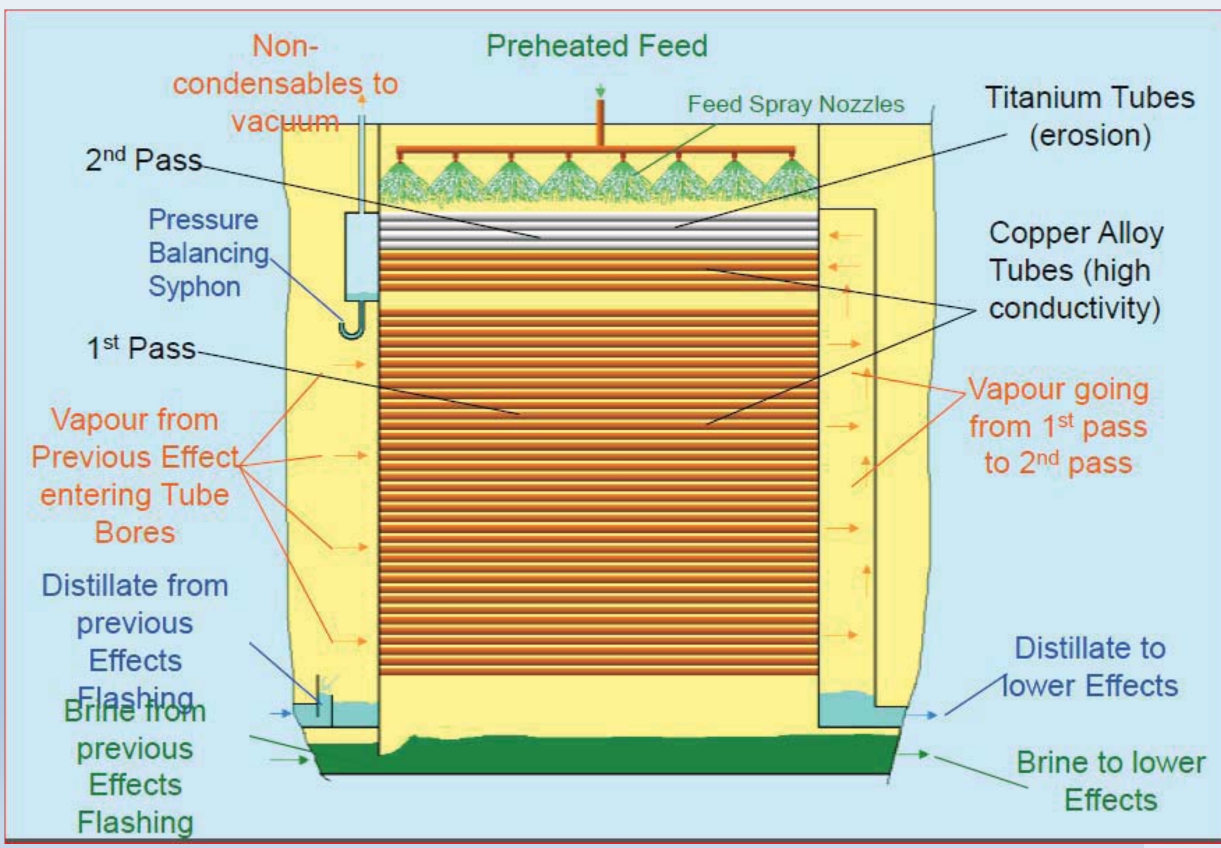
- **The process of evaporation-plus-condensation is repeated from effect to effect each at successively lower pressure and temperature. The combined condensed vapor constitutes the product water.**

Multiple- Effect Distillation (MED)

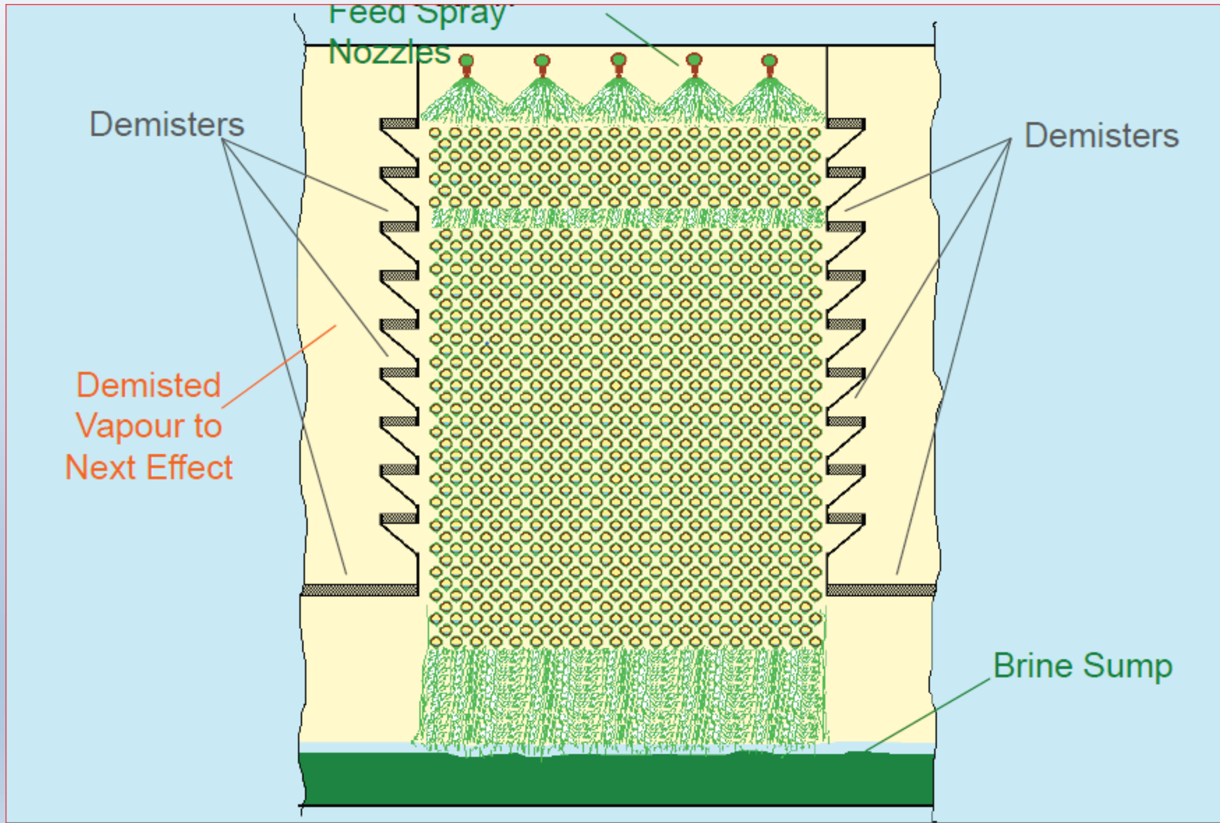
Each effect serves as a condenser for the vapor from the preceding effect; however, the vapor generated in the last effect is condensed in a final condenser, where the heat is rejected to a stream of cooling water.

Thus, in the unlikely event of a leaky tube wall, the vapor (which is at a higher pressure than the brine) would leak into the brine chamber, thereby avoiding contamination of the product water.

Typical MED Horizontal Tube Bundle



Horizontal Falling Film Bundle Cross-Section



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Multi Effect Distillation (MED)

- Raw seawater total dissolved solids (TDS): 35-47,000 mg/L
- Maximum brine temperature: 64^{o} C-75^{o} C
- Performance ratio: 9-16
- Electrical power: 1-2 kWh/m^3
- Scale inhibitors used for scale control
- Dual purpose plant

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http://www.vertexwater.com.au/userfiles/flash/med_2-En.swf

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MED distillation

- **Unit size has increased from 1 to 5 MIGD (now 15 MIGD) in 8 years**
- **Potential for further increase?**
- **Improvements in thermal vapour compressors and plant configuration**
- **Reduce steam supply pressure**
- **Trade off between steam consumption and supply pressure**
- **Distiller performance v power plant output**

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Energy Requirements for Desalination

Process/energy type	MED	MED -TVC	MSF	RO
Specific heat consumption, kJ/kg, PR kg/2326 kJ/kg	211 11	211-250 11.0-9.3	250-273 9.3- 8.5	
Steam pressure, ata	0.2 - 0.4	2.5-3.5	2.5-3.5	_
Electric energy equivalent, kWh/m^3	3-4.5	5.4-8*	5.6-8.0	_
Electric consumption, kWh/m^3	1.0--1.5	0.9-1.8	3.4-4.5	3.3-4.0
Total electric energy equivalent, kWh/m^3	4.0-6.0	6.3-9.8	9.0-12.5	3.3-4.0

Courtesy of Leon Awebuch

- Power and desalination plant combinations

Dual Purpose Power Desalination

Large dual - purpose power desalination plants are built to reduce the cost of production of electricity and water.
Over 50,000 MW of power is combined with desalination plants in the largest use of cogeneration concepts.

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MARAFIQ IWPP - SAUDI ARABIA

With more than 800,000 m3/day (178 MIGD) desalination capacity, a major landmark for Sidem

Limited Notice To Proceed	Jan 07	First water	Feb 09
Final Notice To Proceed	Jun 07	Completion dates	Jul 09 - Mar 10

Scope of work

Engineering, procurement, construction and commissioning of 27 desalination units of 30,000 m3/day (6.6 MIGD) each together with: Potabilization plant, CO_2 plant, sea water supply and reject lines, sea water booster pumping station and other ancillary equipment

Contract data

Client: Jubail Water and Power Company ; *End-user:* Marafiq
Work awarded to a consortium made up of General Electric, Hyundai Heavy Industries and Sidem in the frame of Marafiq Independent Water & Power Production (IWPP) project

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Examples of MED-TVC plants

MED unit 22,700 m^3/d in operation over two years at Layyah Power Desalination in Sharjah

AL HIDD IWPP - BAHRAIN

Scope of work

Engineering, procurement, construction and commissioning of 10 desalination units of 27,276 m3/day (6 MIGD) each, together with: 3 x 250 t/h auxiliary boilers and gas receiving station, black start generator, CO2 plant, limestone based re-mineralization plant, electrochlorination plant, sea water pumps and sea water filtration system, reject culvert, power water & gas fiscal metering systems, industrial buildings and ancillary equipment.

Contract data

Client: Hidd Power Company ; End-user: Electricity and Water Authority
Contract awarded in the frame of Al Hidd Independent Water & Power Production project

Key dates

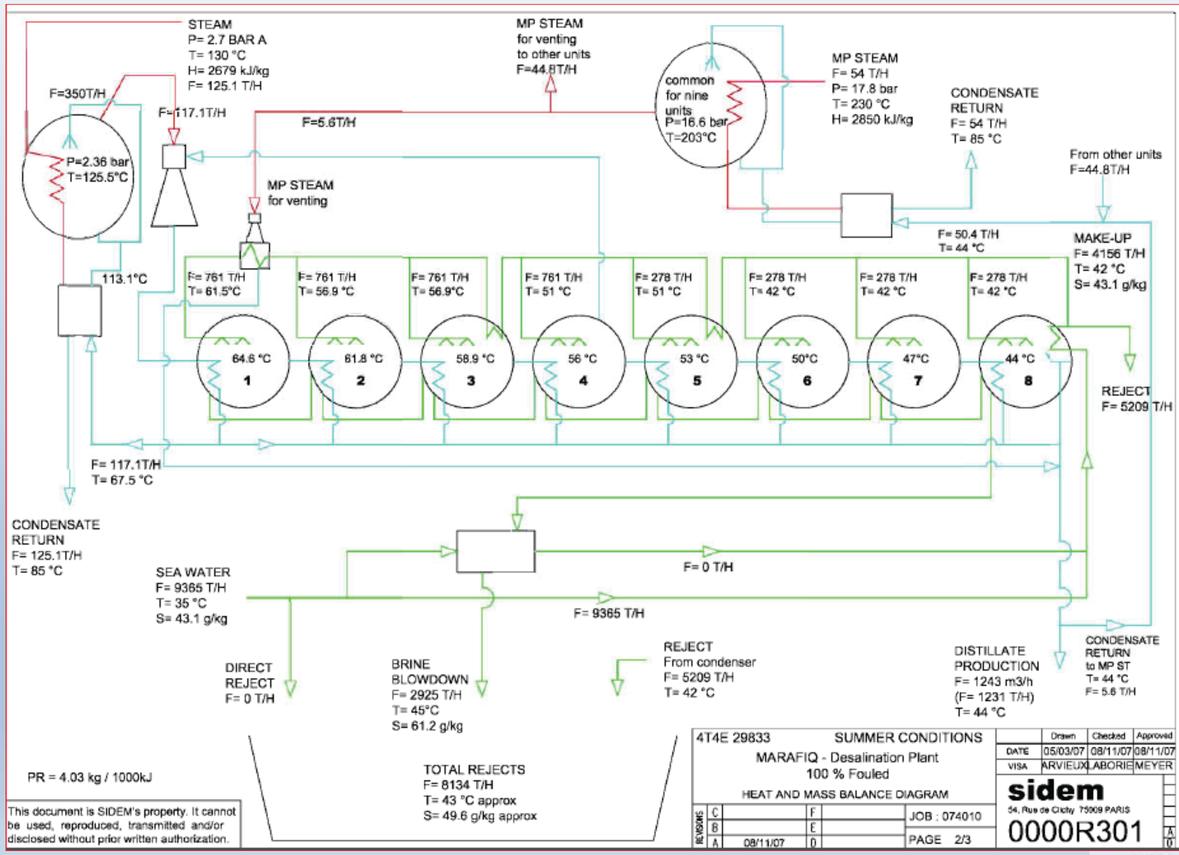
Limited Notice To Proceed	Jan 06	First water	May 07
Final Notice To Proceed	Apr 06	Completion dates	Jun 07 - May 08

Al Hidd - Kingdom of Bahrain *MED-TVC - 10 units of 6 MIGD (60 million gallons daily production)*

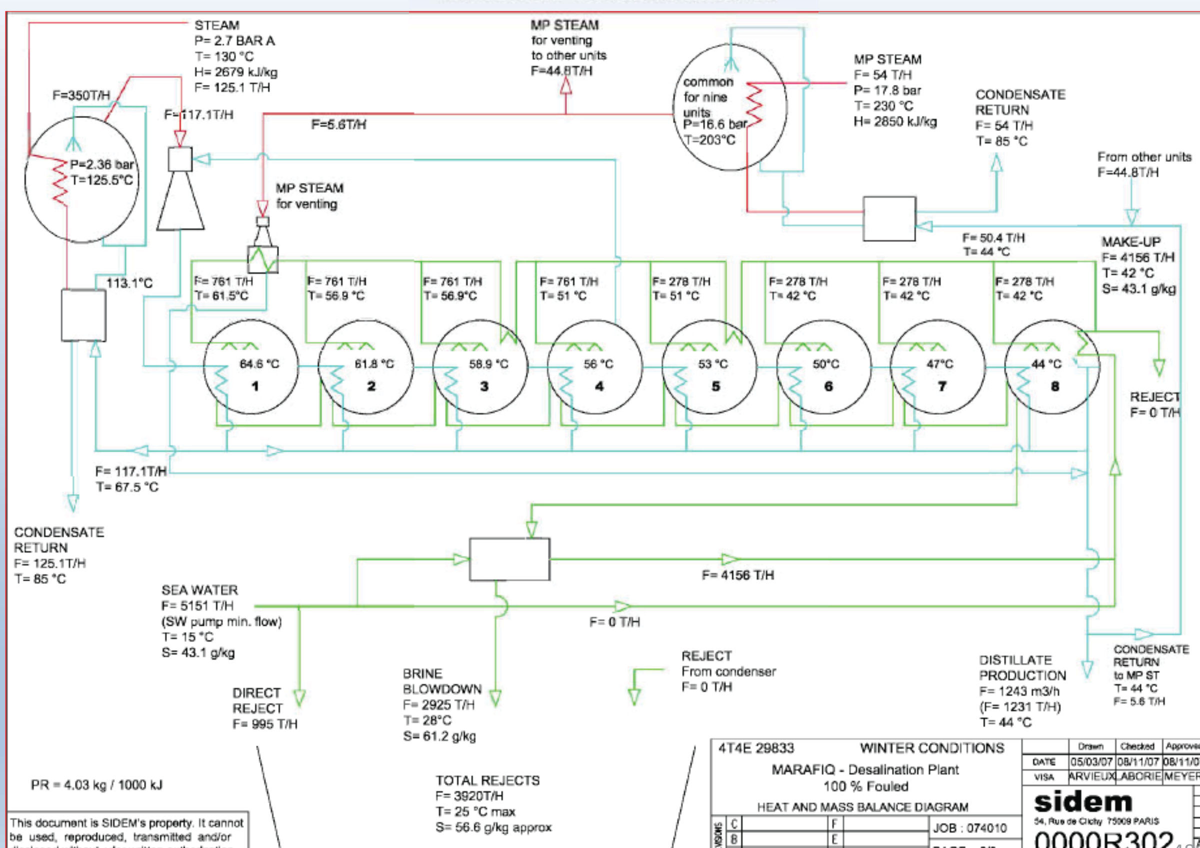
Marafiq IWPP - Saudi Arabia ***MED-TVC - 27 units of 6.59 MIGD (178 million gallons daily production) Sidem.***

Marafiq IWPP - Saudi Arabia ***MED-TVC - 27 units of 6.59 MIGD (178 million gallons daily production) Sidem.***

Marafiq MED Heat and Mass Flow Diagram Summer Conditions.



Marafiq MED Heat and Mass Flow Diagram Winter Conditions.



Az Zour North Phase 1 IWPP - 1550 MW +107 MIGD

- SIDEM's scope: Engineering, Procurement & Commissioning of a 107 MIGD Desalination Plant
- Amount of the Project: 435 MUS$
- 100% MED/TVC Desalination Technology
- 10 x 10.84 MIGD MED unit

- Site delivery of the 10 units within 17 to 23 months from NTP. Building of a jetty at site to deliver the MED evaporator fully assembled
- Low auxiliary power consumption: 0.9 kwh/m3 of produced desalinated water at MED unit boundary
- Low steam consumption: 1 ton of steam generates 11 ton of desalinated water (2.7 bar steam)

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AL-HIDD IWPP – KINGDOM OF BAHRAIN

- Contract Award: April 06
- End User: Electricity and Water Authority
- Owner: Hidd Power Company
- 10 units x 6 MIGD
- 7 effects
- GOR: 9.03

Al Hidd - Kingdom of Bahrain *MED-TVC - 10 units of 6 MIGD (60 million gallons daily production)*

Tianjin Project: 8 x MED 25,000 ton/day

IDCA

Tianjin Beijing 4000 MW Power Station station. with 200,000 m3/day MED and Salt Production from Brine

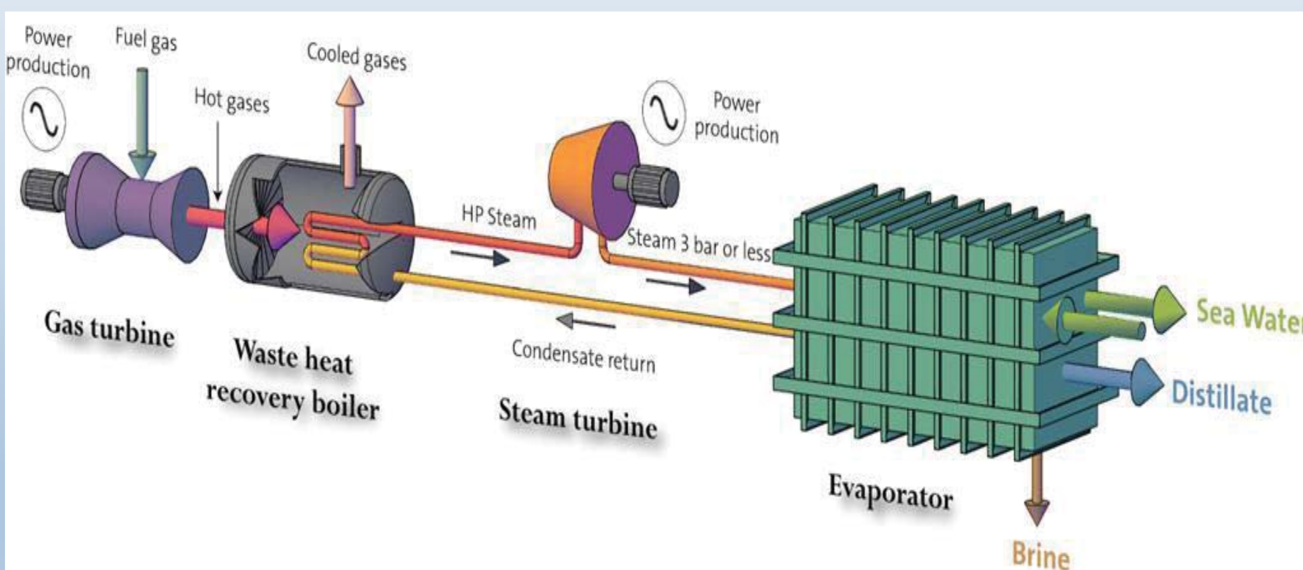
Tianjin Project: 8 x MED 25,000 ton/day

	Category	Tianjin MED-25,000
Site Limitations and demands	Feed water temperature	Min. -2°C Max. 30°C
	Feed water quality	High seawater TSS >100 ppm
	Ambient conditions	Summer: hot and humid Winter: Freezing cold -20°C
	Water usage	Power plant: 20% Potable: 80% *after post-treatment
Operation and Process Conditions	High recovery yield	50%
	Power consumption	1.2 kWh/m^3
	High quality product	< 10 ppm TDS
	Number of effects/stages	14
	Steam consumption & GOR * MED can be operated with different motive steam pressures, resulting in different GOR	The MED plant was designed to operate at steam pressures: • 0.3 bara GOR 11 • 1.2 bara GOR 13 • 5.0 bara GOR 15

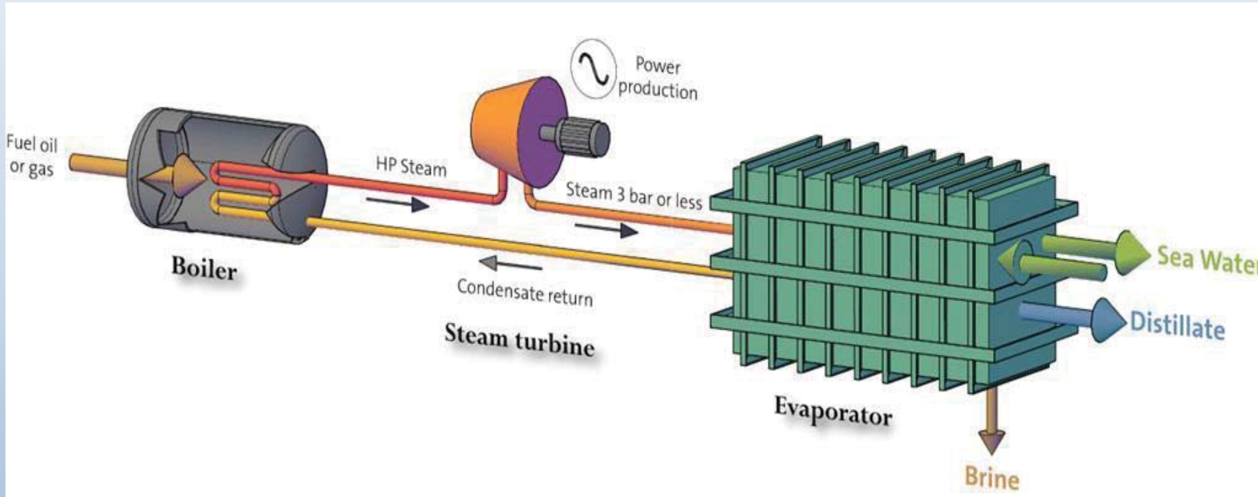
Tianjin Project: 8 x MED 25,000 ton/day

Description	Unit	Design	Measured
Maximum production	%	110	113
	ton/day	27,500	28,250
Minimum production	%	40	38
	ton/day	10,000	9,500
Distillate quality	ppm	5	2
ER		13	13 to 14
@ 1.2 bar abs steam		15	15 to 16
@ 5 bar abs steam			
Power consumption	kwh/ton	1.5	1.50

Combination of desalination plant with gas turbine, heat recovery boiler and steam turbine CCGT

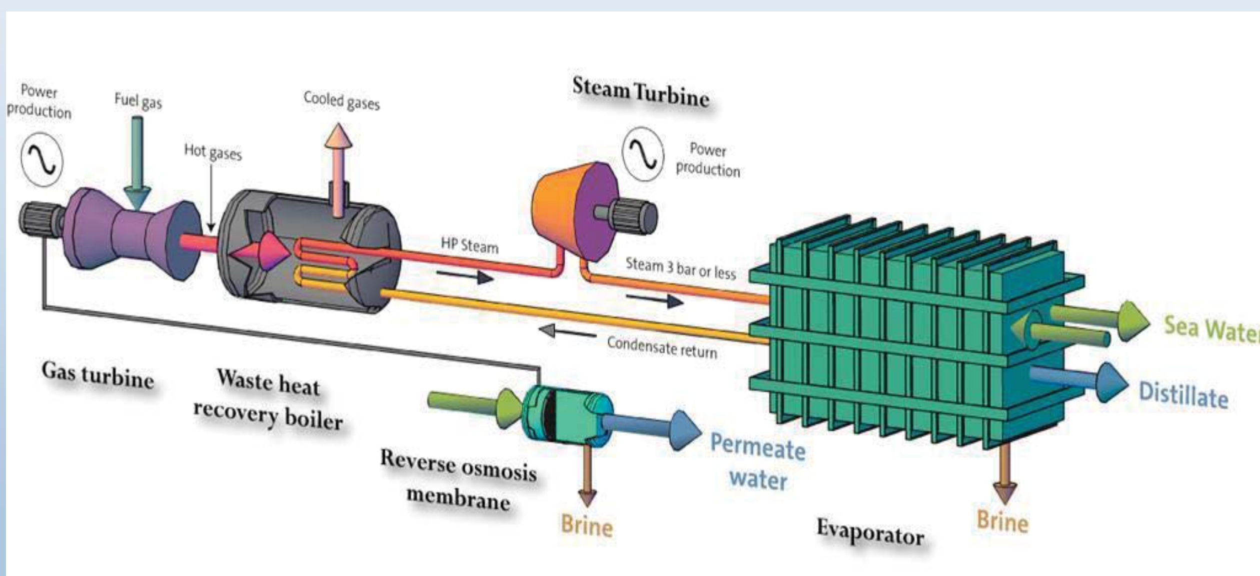


Combination of desalination plant with high pressure boiler and steam turbine



Hybrid Plants

Coupling Power generation with thermal and RO desal plants



Typical Power to Water Ratios for Different Technologies

Technology **PWR=MW required/Million Imperial Gallons per day**

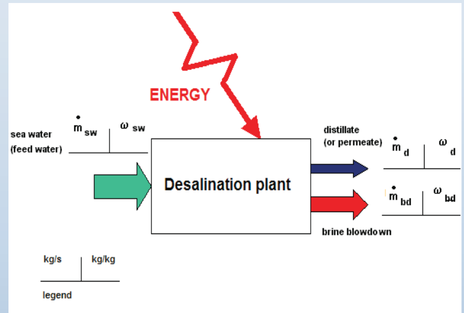
Steam Turbine BTG - MSF	PWR = 5.0
Steam Turbine EST - MED	PWR = 7.0
Steam Turbine EST - MSF	PWR = 10.0
Gas Turbine GT - HRSG - MED	PWR = 6.0
Gas Turbine GT - HRSF - MSF	PWR = 8.0
Combined Cycle BTG - MED	PWR = 10.0
Combined Cycle BTG - MSF	PWR = 16.0
Combined Cycle EST - MED	PWR = 12.0
Combined Cycle EST - MSF	PWR = 19.0
Reverse Osmosis RO	PWR = 0.6-.75

- Desalination plant Basic Mass Balances

Mass Balances relationships

1) mass conservation (overall mass balance)

$$\dot{m}_{sw} = \dot{m}_{bd} + \dot{m}_{d}$$



22) salt conservation (overall salt balance)

$$\dot{m}_{sw} \cdot \omega_{sw} = \dot{m}_{bd} \cdot \omega_{bd} + \dot{m}_{d} \cdot \omega_{d}$$

ω = Salt concentration (kg / kg)

$\dot{m}$ = Mass flow rate (kg / sec)

- Mass Balances relationships

- Concentration factor – production ratio : theoretically it would be best to concentrate as much as possible
- However it is not possible to concentrate seawater – blowdown above a certain limit.
- The following constraints occur :
- scale precipitation in tube bundle are more frequent the more salt is concentrated

Performance Ratio
Gain Output Ratio GOR

GAIN OUTPUT RATIO VS. PERFORMANCE RATIO

- **GOR = Gain Output Ratio**

  = Distillate mass flow (D) / Inlet steam mass flow (Q)

  - Does not account for steam to venting system
  - Does not give accurate information on unit efficiency

$$GOR = \frac{D}{Q}$$

- **PR = Performance Ratio** = quantity of distillate / quantity of heat
  - Given in kg of distillate per quantity of heat (usually 2326kJ, but can be 1000kJ)
  - Usually does not include steam to venting
  - Give a good information on unit efficiency

$$Y = \frac{Q \times (H - Hcond)}{D} \quad \text{(kJ/kg of distillate)}$$

$$PR = \frac{2326}{Y} \quad \text{(kg of distillate / 2326kJ)}$$

- Energy input : performance ratio

$$\eta = \frac{\dot{m}_d}{\dot{m}_s} \frac{\Delta H_{ref}}{\Delta H_{h.i.}}$$

- Reference enthalpy = 2326 kJ/kg of steam

- Energy input : GOR

$$G.O.R. = \frac{\dot{m}_d}{\dot{m}_s}$$

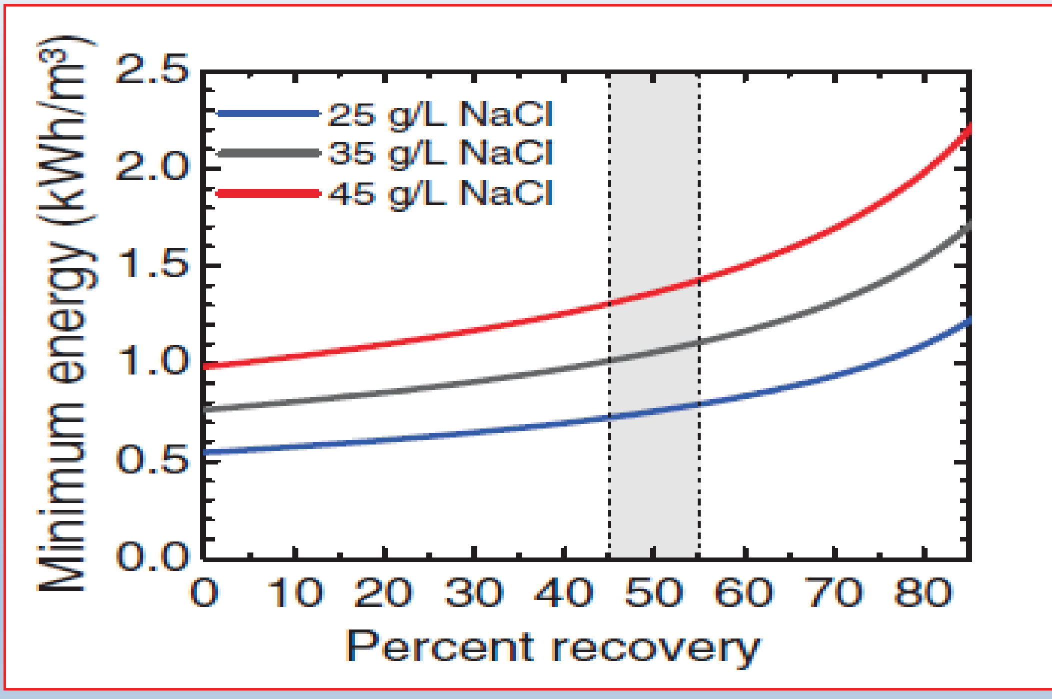
- Energy input : performance ratio

The basic relationship governing the heat transfer & distillate production in the desalination heat input section is

$$\eta = \frac{\dot{m}_d}{\dot{m}_s} \frac{\Delta H_{ref}}{\Delta H_{h.i.}}$$

Ref= reference (1000 Btu/lb. = 2326.0 kJ/kg)
h.i. = heat input section

The minimum energy for desalination depends on salinity of seawater and the percent of recovery as shown in the figure below. This theoretical minimum does not depend on the process of desalination.



The theoretical minimum energy of desalination as a function of percent recovery can be obtained from the figure. As the salinity of seawater or desired water recovery increases, so does the minimum energy required for desalination.

For example, the theoretical minimum energy of desalination for seawater at 35,000 parts per million (ppm) salt and at a typical recovery of 50% is 1.06 kWh/m3.

The actual energy consumption, however, is larger because desalination plants are finite in size and do not operate as a reversible thermodynamic process.

Reference prof. Menachem Elimelech, Yale University article in Science 5 August 2011: “The Future of Seawater Desalination: Energy, Technology, and the Environment”

Comparison MSF versus MED

	Main characteristics		Consequences
	MSF	MED	
Evaporator	• The sea water circulates inside the tubes • The steam condenses outside the tubes	• The sea water is sprayed outside the tubes • The steam condenses inside the tubes	• The material of the tubes is different: Cu-Ni or Ti for the MSF-Brass for the MED • The standard thickness of the tubes is different 1 to 0.7mm for MSF and 0.7 to 0.5 mm for the MED
Heating steam	Uses steam at pressure between 2 et 3 bar a	May use and be optimised for steam at pressure between 0.35 to 40 bar a	• MED may use and so improve the value of steam at a low low pressure • If the steam pressure is above **2.0 bar a**, a thermocompressor allows a higher efficiency.
Process	• For brine recirculation a large recycling pump is needed • Costly water boxes • No need for pre-treatment	• Based on steam recycling. • Recirculation is done by an ejector. • No need for pre-treatment	Electrical consumption **MSF: 3.5 to 4.5 kWh/m³** **MED: 1 to 1.5 kWh/m³**
Water Quality	• Any bundle tube leak would result in sea water polluting the distillate • Clogging of demisters by hard scale results in higher velocities through the demisters and carry over of brine into distillate	•Any heat bundle tube leak would result in vapour and distillate flowing into brine • Low temperature avoid clogging of demisters	MSF production quality is likely to worsen after years of operation whereas MED distillate quality will normally be steady during life time of the plant.
Scaling and corrosion	• Operation at a TBT as high as 120°C • Uses a ball cleaning system • Permanent injection of antiscale and antifoam	• Operation at low TBT (66°C max.) • Permanent injection of antiscale and antifoam	• MED and MSF: dependant on antiscale injection, but dosing rates for MSF can be lower due to sponge ball cleaning •MSF: scaling of demisters leading to stops for maintenance •Low temperature MED generates no scaling of demisters

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Co- locating Renewable Energy (RE) with **desalination**

- With RE like solar PV, wind the electricity can transferred from the inland desert to RO on the coast.
- With CSP parabolic trough collectors, solar tower or solar ponds to transfer the solar heat to desalination requires new solutions, which we suggested- trough hot water loop coupling with direct contact steam condensation, transporting 75º C fresh water to the desal plant and re-flashing the hot water to provide steam for MED. The cooled water at 67º is returned to solar power plant condenser.

IDCA

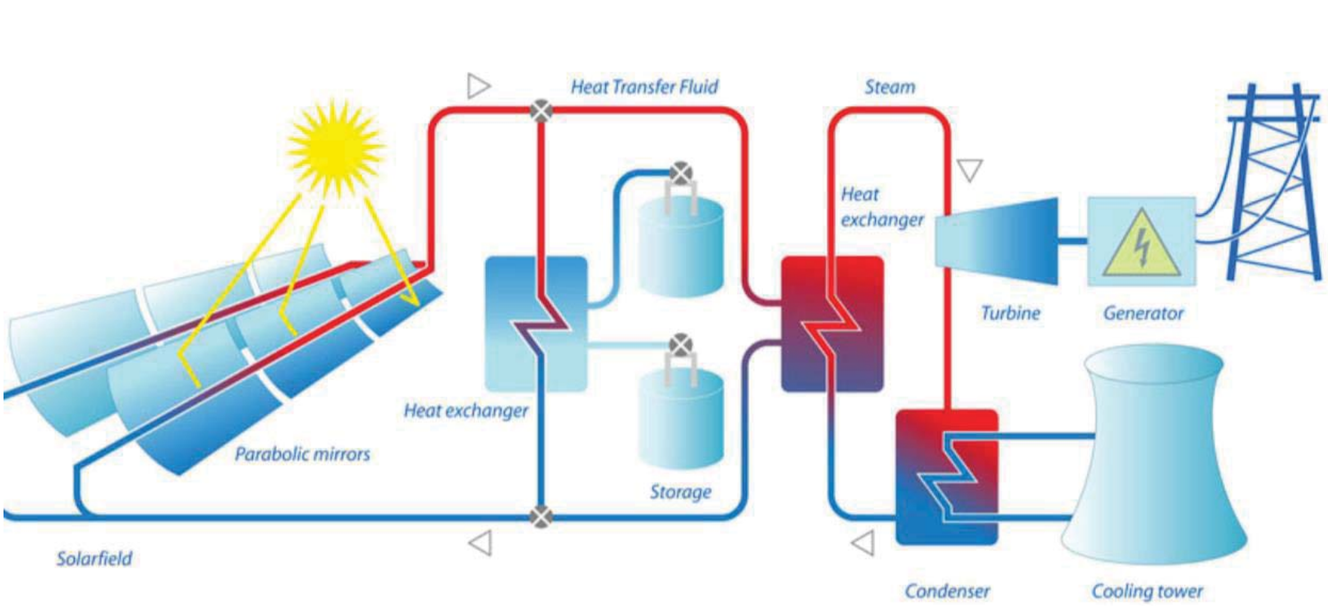
Novel Thermal Hybrid systems in combination with renewable solar energy.

Lets focus on use of Thermal Hybrid systems in combination with solar energy. Nanofiltration Softening Membranes with Multi–Effect Distillation solutions, which will be able to operate with low temperature solar thermal energy, like solar pond both with pure water or salinity gradient and using low temperature geothermal resource as well as coupled with more conventional lower temperature concentrated solar Parabolic Trough Collectors or Solar Dual purpose power and desalination solutions.

Solar Thermal Desalination

For large application of advanced solar power desalination system, the future requires effective integration of solar energy resources to produce power and desalinated water economically with proper consideration for the environment. The Concentrated Solar Thermal Power (CSP) plants, which require large areas must be located outside coastal areas and require a dry cooling system. The seawater desalination plant must be located close to the shore and it is therefore critical to find innovative solution to link solar energy with seawater desalination. It is also critical to significantly increase efficiency of thermal desalination plants to minimize solar field and maximize energy efficiency of the power cycle by reducing pressure of extracted steam for desalination.

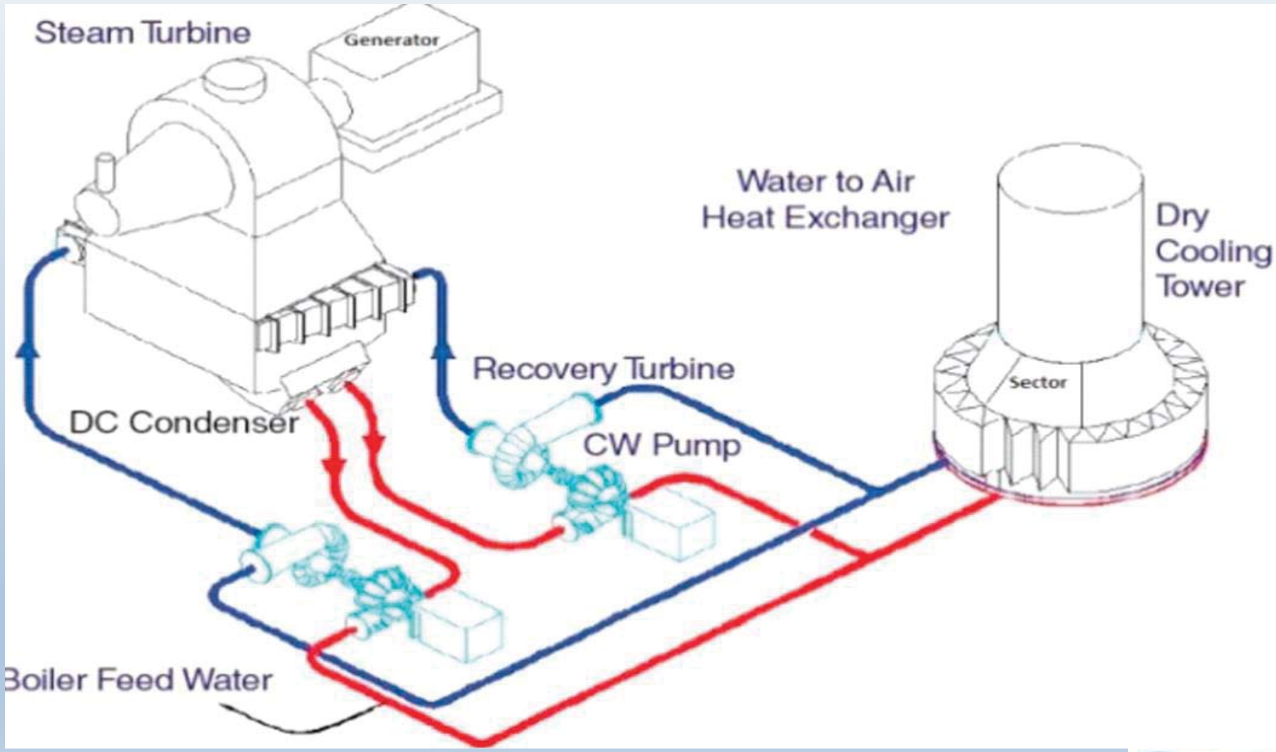
Parabolic trough technology for large-scale solar power generation



Innovative Heller-Awerbuch system coupling Steam Turbine to MED, applicable to Solar Thermal, Fossil or Nuclear power

The HELLER-AWERBUCH System is an indirect energy transfer. The power plant backpressure or extraction heat is initially exchanged in a condenser to a closed cooling water circuit. The heat absorbed by the water is transferred by pipeline to MED flashing chamber to provide steam for the first effect of MED. The modified HELLER-AWERBUCH System evolved from an idea to use a direct contact jet condenser in a similar way to the dry cooling towers solution of the professor HELLER developed in Hungary by EGI (now GEA).

Heller Dry Direct Contact Cooling System



The advantages of dry cooling towers and direct contact condensers

The advantages of dry cooling tower is minimizing water needs for in desert solar thermal CSP systems,
The direct contact condensers has low terminal temperature difference:

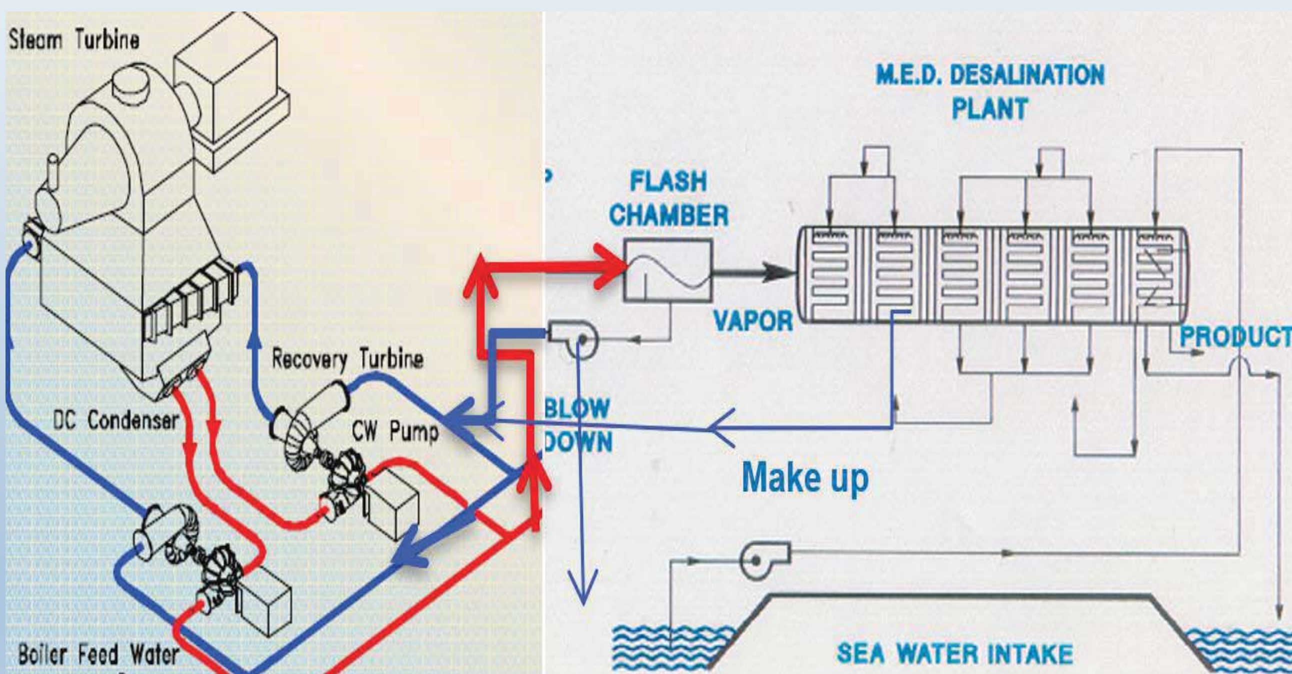
- Conventional Surface Condenser TTD ~ 3-4°C
- Direct Contact (DC) Jet Condenser TTD ~ 0.3°C
- Elimination of shell and tube, typical titanium condenser
- A completely closed and pressurized cooling circuit, where vacuum is limited to the small space of DC condenser.

Innovative solution for Solar CSP to couple to MED Desalination

Suggested innovation to increase solar power efficiency by direct contact condensing steam in order to obtain the following results:

1. **Maximum recovery of low temperature energy extracted or exhausted from CSP power plants for desalination production. It utilizes an advanced hybrid concept of combining High Temperature Nanofiltration softening membranes (HTNF) for Multi-Effect Distillation (MED) to significantly increase thermal efficiency and recovery of desalination process.**
2. **Provide a unique solution to transfer solar energy from low pressure exhausted turbine backpressure steam to MED distillation plant using modified Heller-Awerbuch approach of cooling loop allowing further turbine expansion of steam from 2.9 bars to .5 bar. Significantly increasing efficiency of power generation and improving performance of the MED process.**

Novel Heller-Awerbuch system for coupling Direct Condenser with MED via flashing loop



IDCA innovative system coupling steam turbine to MED via Water Transformer

The significant results and changes of such design is listed below:

•The power plant produces significant more power considering that steam can be expanded to 80-85°C and absolute pressure .4741-.5 bar versus current 2.8 bars. I estimate it will produce additional 110MW.

• Reducing cost of MED as design of effects is uniform compare with MED-TVC

•Elimination of the steam piping from power plant to the evaporators, including heat and steam pressure loss.

•Elimination of MED steam transformer as there is no thermocompressors. The condensate is re-flashed deareated and totally returns from first effect. No hydrazine contamination of the product.

• There is a need to add additional effects to achieve the same performance ratio.

• There is a need to add closed cooling water circuit piping and pumping

IDCA

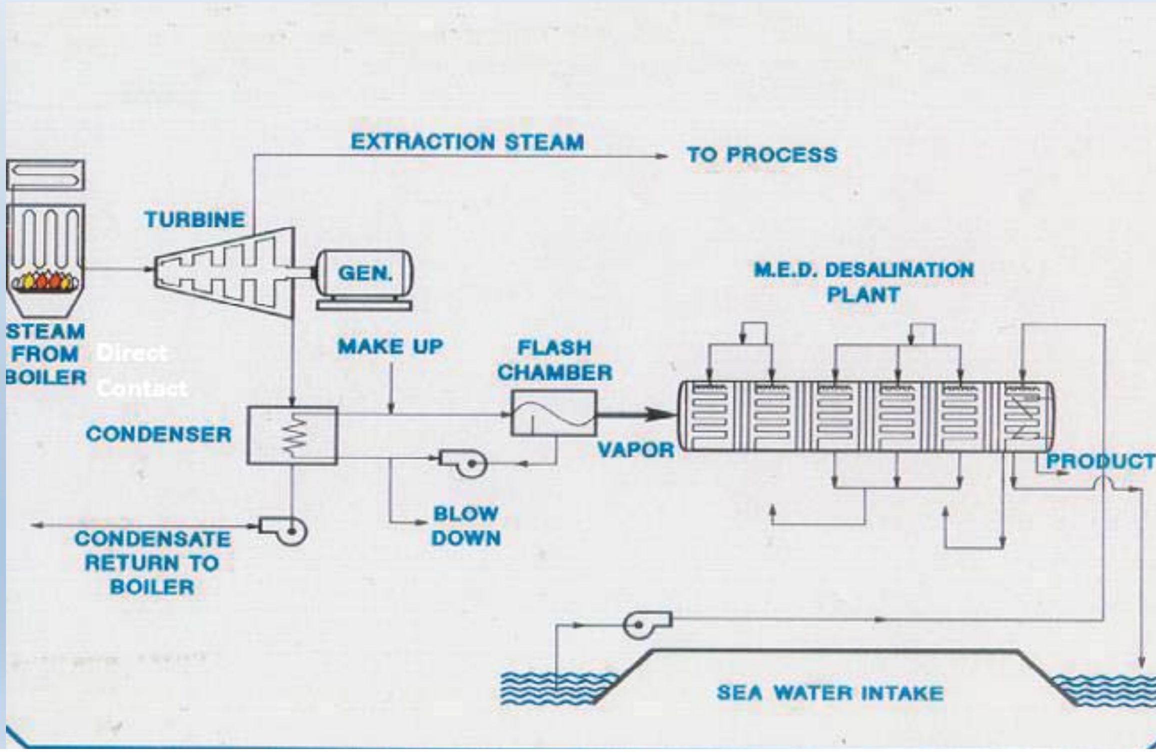
Innovative Heller-Awerbuch system coupling Steam Turbine to MED, applicable to Solar Thermal, Fossil or Nuclear power

The most dramatic change in increasing power output and efficiency and to reduce cost is a modified Heller-Awerbuch System adopted by me for Power-MED.

The concept is based on a condensation of steam from the turbine with recirculating condensate at 85 to 67.5°C. The condensate is in a closed cooling water circuit. This warm condensate is pumped by water pipeline to the distillers where generates steam for the MED process by re-flashed in flashing chamber. The flashed condensate at 67.5°C, together with steam condensed in the first effect is pumped again by water pipeline to DC..

IDCA

Novel Heller-Awerbuch Power condenser using pure water in circulation to preheat pure water to 85 ˚C is the simplest solution no changes to condenser, no risk of contamination. Flashing in one stage to provide steam to MED and return colder 67.5ºC to condensate loop.



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Progress in MED

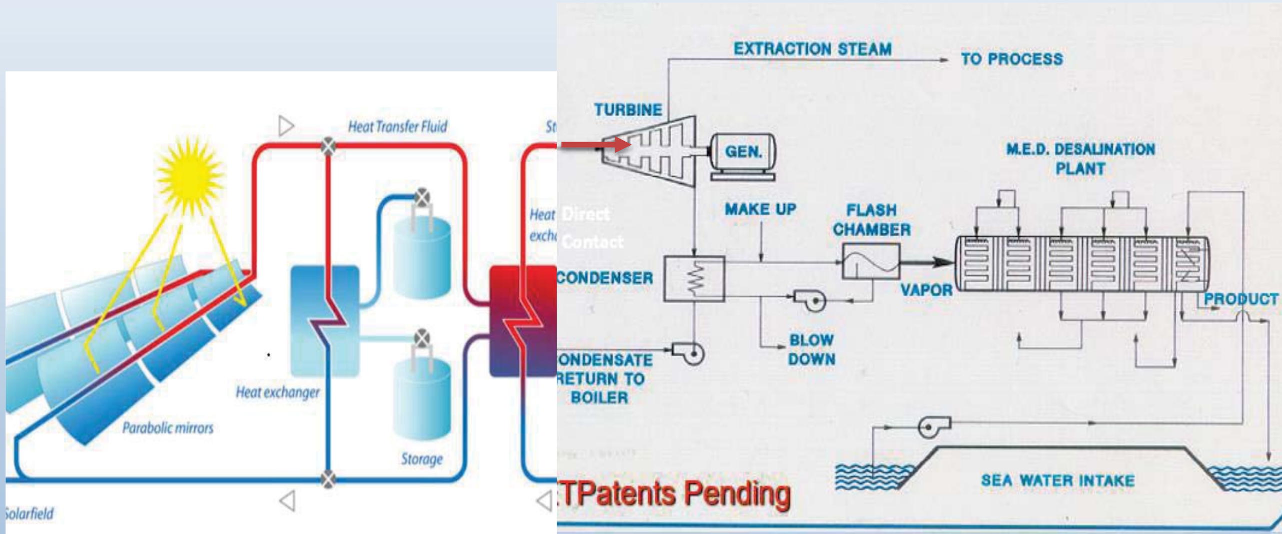
To further improve the MED thermal desalination with hybrid technologies we foresee plants optimized and integrated with a set of technologies including:

- There is a potential for adding HT NF to soften the feed for High temperature effects and increase the number of additional effects to achieve the higher performance ratio.
- We suggested a process to capture CO2 produced in greater quantities at higher operating TBTs and to use the CO2 to help control soft scale as well as for post-treatment of product.

Substantial efficiency improvements could be obtained if the energy available in low pressure steam from solar steam turbine could be effectively transferred to MED process via direct contact condensation of steam and hot water pipeline cooling loop.

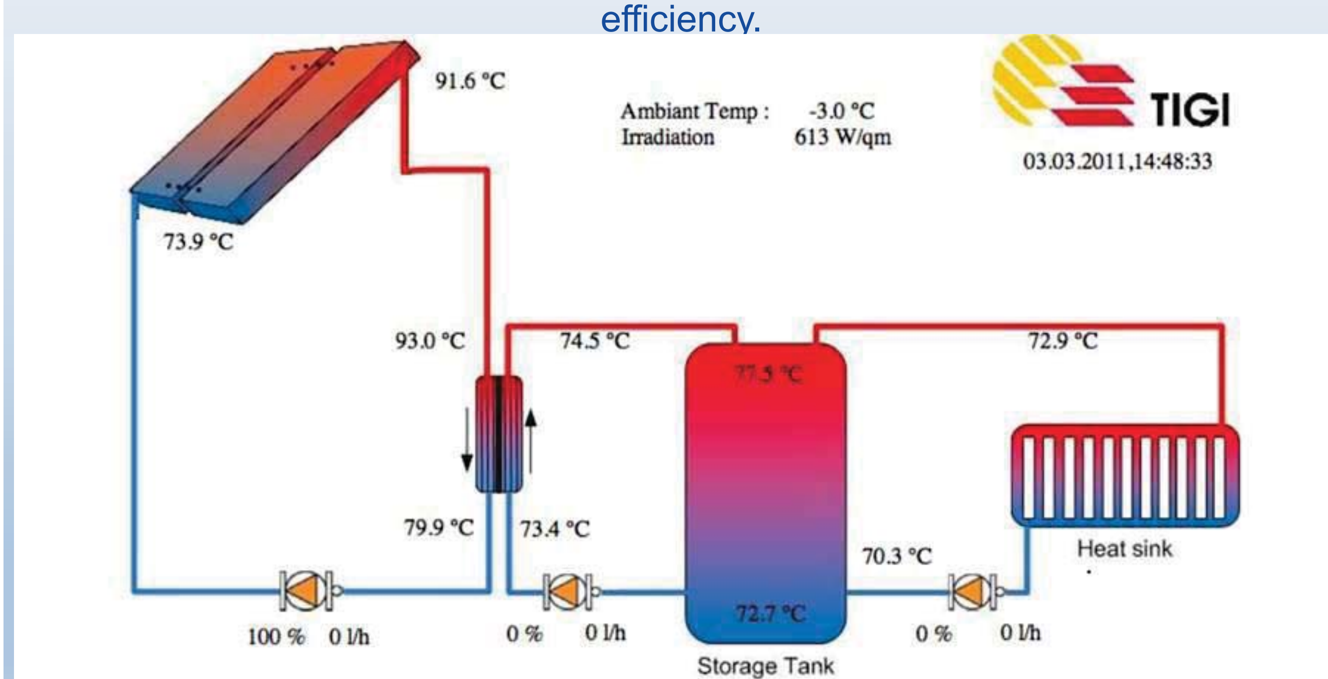
IDCA

Novel Parabolic solar power coupling to MED via Hot Water Transformer Loop



Producing Hot Water for MED Desalination TIGI's Honeycomb Collector

Substitute the heat sink for MED and return the condensate to solar collector efficiency.



Renewable Energy coupled to NF-MED

We already have done a preliminary design of Advanced Solar Desalination shown above, using 18 effects MED hybridized with Nanofiltration NF to soften feed for the hottest groups. This will decrease the specific thermal energy consumption to 168.2 kJ/kg or PR=13.8, never achieved without thermocompression TVC with heat input at 90 ºC. We have also designed a full size commercial unit of 25,000 m3/day with 20 effects desalination plant with thermal energy consumption to 137.6 kJ/kg or PR=16.25.

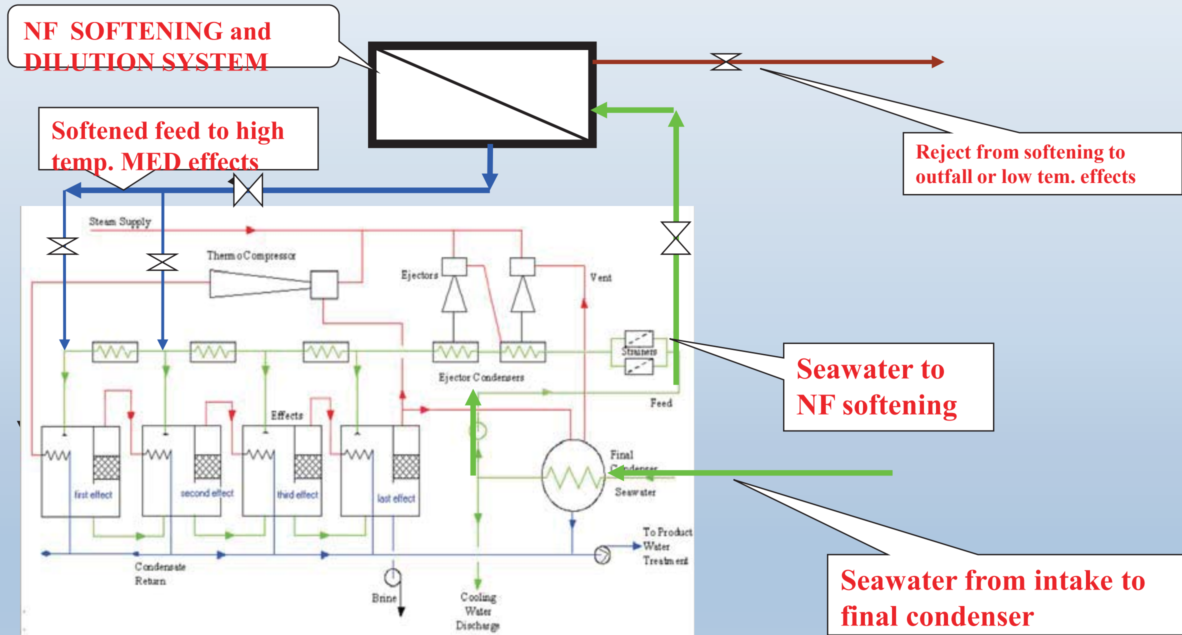
IDCA

Benefits of Nanofiltration

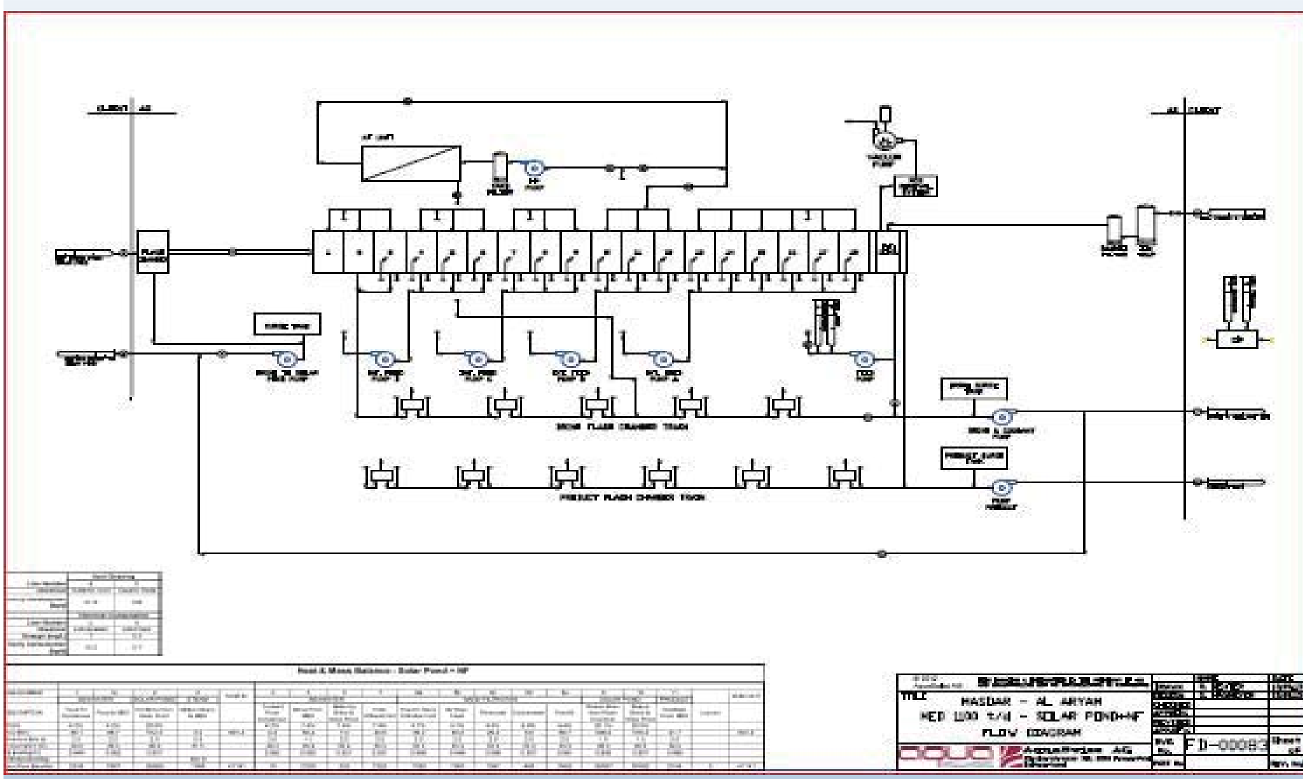
- **PREFERENTIALLY REMOVES SCALING (DIVALENT) IONS**
- **ALLOWS HIGHER TOP BRINE TEMPERATURE FOR MSF (121 vs. 110 °C AND FOR MED (100 vs. 63-75 °C)**
  - **Higher Flash Range Increases Production and Efficiency**
  - **Reduced Capital Costs**
  - **Reduced Operating Costs**

IDCA

Process and apparatus for partial blending of softened feed to high temperature effects of MED in order to increase TBT



Multi-Effect Distillation with Nanofiltration only for High Temperature Effects.



Nuclear Energy

Interest in using nuclear energy for producing desalinated water is growing and has been considered as an option by several countries around the world, as well as countries with existing operating nuclear power plants (NPPs).

- As of November 28, 2016 in 31 countries 450 nuclear power plant units with an installed electric net capacity of about 392 GW are in operation and 60 plants with an installed capacity of 60 GW are in 16 countries under construction.
- In USA 99 nuclear reactors are in operation producing net 98.868 MWe and 4 reactors are under construction to generate 4.468 MWe. The USA has 99 nuclear power reactors in 30 states, operated by 30 different power companies, and in 2015 they produced 798 TWh. Since 2001 these plants have achieved an average capacity factor of over 90%, generating up to 807 billion kWh per year and accounting for 20% of total electricity generated.
- In Abu Dhabi 4 units of 1400 MW are being constructed at Al Baraka site which will have significant implication on the Abu Dhabi power and desalination program.

IDCA

Nuclear Desalination Limited Experience

The use of nuclear reactors for seawater desalination has already been demonstrated in several countries with operational experience of over 200 reactor-years. However, there has so far been only one large-scale nuclear cogeneration plant for seawater desalination — the desalination unit at the Aktau NPP in Kazakhstan. The deployment of large scale nuclear cogeneration for desalination may face several challenges which can be mitigated by appropriate technical or institutional measures. Energy may be provided from the nuclear reactor to the desalination plant in form of thermal, electrical or both energies. This depends on the selected desalination technology and the reactor type. Water cooled reactors like pressurized light and heavy water cooled reactors (PWR, PHWR) are the most utilized reactors for desalination as in Japan, India, USA, Pakistan and China. In Aktau, Kazakhstan, the fast reactor BN-350 was operating from 1993 until 1999 for the production of power and fresh water.

IDCA

Nuclear Desalination Growing Interest

Currently, a worldwide renewed interest has been witnessed in nuclear desalination, such as in Saudi Arabia, UAE, Egypt, Algeria and China. For the last 25 years, the International Atomic Energy Agency (IAEA) have been recognizing seawater desalination using nuclear energy for fresh water production as one of the most promising alternatives for nuclear cogeneration. The challenges involved in nuclear desalination generally include: optimization of the plant design for cogeneration purposes; enhancing safety of coupling; establishing joint infrastructure; training of human resources for both disciplines (nuclear power industry and desalination); and assessing the financial capital and public acceptance. Both nuclear power and desalination technologies are highly mature, yet the coupling between the two is still an issue some due to perceived radioactivity risk, some due to the variety of nuclear reactor types and desalination systems. Each reactor type and available design presents a number of distinctive features, with advantages and disadvantages for the specific case under study.

IDCA

Objectives of the IAEA meeting in Vienna

The purpose of the meeting was: to bring users and vendors together to discuss common concerns and challenges related to the design and operation of nuclear cogeneration plants; to establish a common understanding of users' requirements and the terms under which vendors can supply suitable reactor designs and desalination technologies; to facilitate the free exchange of important design-, operational and infrastructure-related information; and to establish a link between the user and vendor communities that will help to resolve some pressing issues regarding the requirements for, and feasibility of, coupling seawater desalination technologies to NPPs for cogeneration applications.

IDCA

Preferred Technical Solutions for Nuclear Desalination

With dramatic interest in finding solutions to combat climate change in view of the impacts of global warming on water resources, nuclear desalination can offer significant potential to substitute fossil fuel as a source of energy for desalination.

There was a consensus among participant to the meeting on the use of straight MED technology hybridized with RO, being best suited for nuclear desalination. The optimum technology solutions for nuclear desalination was considered hybrid of Multi-Effect Distillation (MED) with Reverse Osmosis (RO).

The MED unit size and efficiency in recent year's demonstrated full ability to reach unit size of 50,000 m3/day and in near future up 91,000 m3/day. Today, the Gain Output Ratio is exceeding GOR=11 and in future will exceed GOR=15. The electrical energy consumption is between .9 kWh/m3 to 1.3 kWh/m3. The seawater Reverse Osmosis (RO) fully demonstrated its ability to reliably produce desalinated water with low electrical energy consumption of 3.5 kWh/m3, during construction of nuclear plant, as well as more important during nuclear refueling, during maintenance and non-availability of nuclear steam. RO has been also proven for its use during nuclear emergency.

IDCA

Preferred Technical Solutions for Nuclear Desalination

The integrated hybrid MED-RO design can make use of warmer seawater discharged from NPP or reject sections final condenser of MED to reduce energy consumption, reduce size of seawater intake and outfall. To minimize energy consumption and reduce power losses of NPP it is recommended to use straight MED with the lowest extractions steam pressure available using straight MED, rather than MED-TVC. To use steam from extraction section of NPP turbine .15 MPa cannot be send directly to MED, because of high volume of steam at lower pressure the piping would be too big with very large diameter, making economically not practical. We proposed an indirect energy transfer trough water transformer system. The power plant low pressure extraction steam is initially exchanged in a separate smaller Condenser to a closed cooling water circuit. The heat absorbed by the water is transferred by pipeline to MED flashing chamber to provide steam for the first effect of MED at about 68.5 °C. The flashed water cooled to 68°C together with portion of the vapor condensed in the first effect is pumped by return water pipeline to Condenser at the steam turbine proximity

IDCA

The significant benefits of preferred design of Nuclear Desalination

- Elimination of the large steam piping from power plant to the evaporators, including heat and steam loss.
- Elimination of the MED steam transformer as there is no need for a thermocompressor. The condensate is re-flashed deaerated and totally returns from first effect. No hydrazine contamination of the product.
- The heat can be transferred in water pipeline a long distance allowing NPP power and water islands to be at optimum location.
- We recognized that there is significant difference in construction time of NPP of at least 6 years versus desalination plant of 30 months, therefore it was recommended that the Feasibility Study and Minimum Functional Specification (MFS) be prepared at the beginning of the NPP project and the Final Specification for Desalination Plant with optimum Ratio of MED to RO portion will issue closer to beginning of constructions of desalination plant.
- The consideration has to be given to different life time design for NPP sixty years and desalination of 20-30 years with rapid changing and improving desalination technology.
- In specifying NPP and desalination islands it is recommended that the standards for desalination island both design and operations does not use nuclear design criteria but more conventional established desalination practice, however the monitoring of safety, radioactivity of air and water, quality of desalination products and brine needs to be responsibility of nuclear developer.

IDCA

The significant benefits of preferred design of Nuclear Desalination

- It is recommended that the isolation loops, steam and water transformers as well as first effect of MED make use of titanium for heat exchange surfaces. The Ti tubes although more expensive can use smaller wall thickness compensating with lower wait and for lower heat transfer in comparison with Al-Brass or Cu-Ni 90:10.
- Close cooperation is required between suppliers of NPP-Desal and the countries purchasing the projects, independent if this is based on privatized approach 0tv IWPP or EPC contacts. There was a consensus on the need for better working relationship and cooperation between owners/ developers, users and suppliers and engineers to address some of the issues that are unique to the nuclear power stations
- An important understanding is required of local standards and regulations.
- Carefully assessment of the technical, financial and political risk needs to be provided.
- There is very important need to educate both parties the NPP and desalination islands about technology implication, operational and maintenance requirements of both. It really needs to provide extensive courses and training for the future operators of NPP-Desal plants. Managerial and skills required for safety, operation and maintenance,
- It was recognized that continuous public relations campaign is needed to assure the public of safety, explain benefits and reliability of Nuclear Desalination.

IDCA

ROSATOM with Turbine K-1200, Power Machines JSC

Example of specific solution is based on the extraction steam from Turbine K-1200, Power Machines JSC can be effectively used in the design desalination capacity for each NPP of 170,000 m3/day, with the amount of steam available from extraction point III and IV, we could use the 0.823 MPa and .471 MPa steam and send by pipelines a reasonable distance to drive the Steam Transformers. The Steam Transformer provides clean steam for thermocompressors TVC. Steam Transformer also prevents from chemical contamination of the steam as is re-boiling pure water vapor-steam to drive MED-TVC.

El Dabaa, Egypt 2X1200 MW NPP & 2x170,000 m^3/day desalination

IDCA

IDA

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NF-MED Coupling with NPP steam/water transformer

- The heat for the MED unit will be supplied from steam water transformer.
- The hot water will be sent to a flash chamber and will generate the required steam to the MED unit.
- From the flash chamber the colder water will be pumped back to the steam/water transformer.
- In order to improve the overall specific energy consumption a nanofiltration unit has been added to treat the feed water to the hot group.
- The NF unit will remove all the sulphates dissolved in the feed, allowing to operate the MED at a top brine temperature of 80°C without scaling problems.

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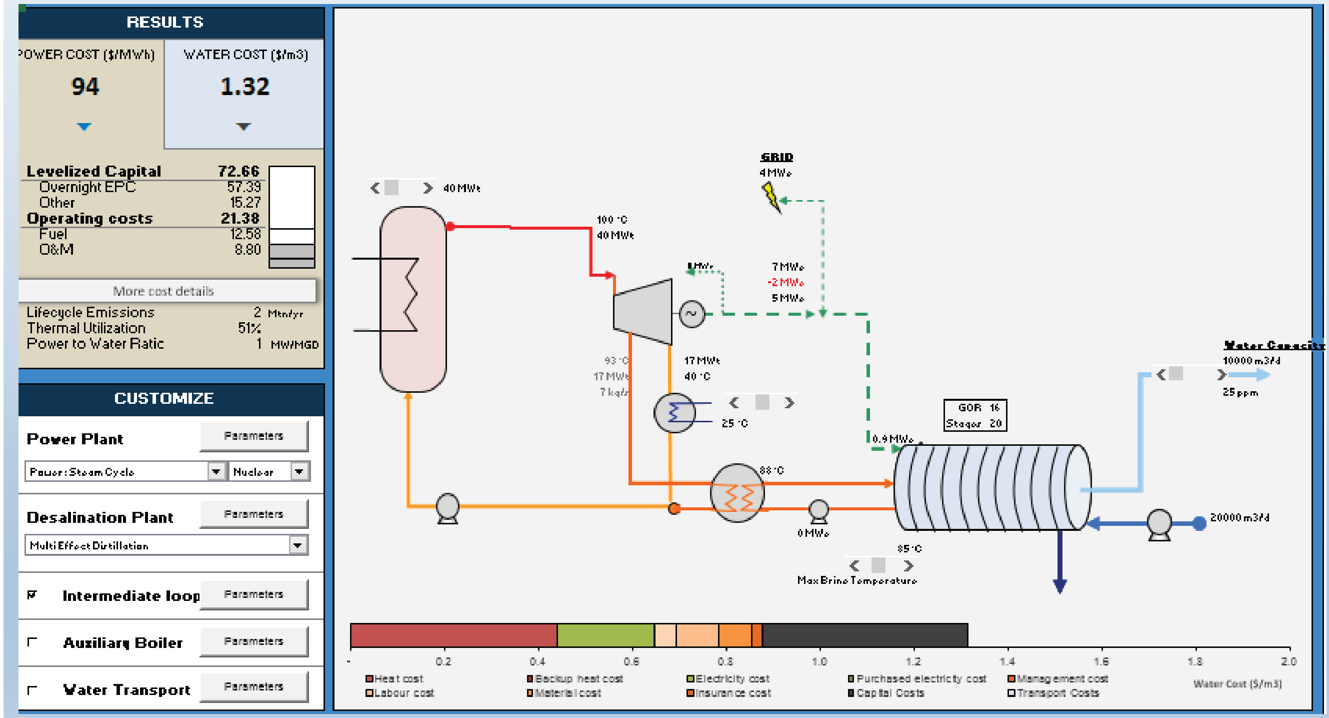
IDA

Extracted steam from 40 MWt NPP at 92 ˚C using hot water transformer to NF-MED having 20 effects resulting in GOR 16 and 10,000 m^3/day



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Geothermal energy for desalination has following advantages:

- Geothermal energy sources have a high capacity factor which provides a stable and reliable heat supply ensuring stability of thermal desalination and hybrid desalination processes. Geothermal energy provides heat supply 24 hours a day, 365 days a year, ensuring the stability of the thermal processes of desalination.
- Geothermal production technology (extraction of hot water from underground aquifers) is mature. It is unaffected by the seasonal changes and weather fluctuations.
- Typical geothermal source temperatures are in the range of 70–90 °C in most parts of the world, which are ideal for low temperature MED desalination. High grade sources above 100 °C can be used for power generation and combined with desalination in more conventional applications.
- Geothermal desalination is cost-effective, and simultaneous power and water production is possible.

IDCA

Geothermal energy for desalination has following advantages:

- Geothermal desalination saves imported fossil fuels and can considerably cheaper in islands and remote location when available and is environmentaly sustainable.
- Geothermal sources have relatively lower surface area or land requirements per unit (MW) of all renewable energy sources (for example: 20 MWth-10 X10 m well size) and energy demand can be matched from smallest to the largest energy consuming utilities.
- MED technology is well demonstrated in sizes up to 15 MIGD and GOR of 11, with consumption of electric energy as low as .9kWh/m^3
- Production of desalinated water can be arranged from geothermal fluid or by coupling with seawater, brackish water or reuse application.
- Coupling between geothermal resources and MED can be arranged with flashing or heat exchange pipeline loop.
- Geothermal desalination is environmentally friendly because it is the renewable energy used in the process with no emissions of air pollutants and greenhouse gasses related to fossil fuels

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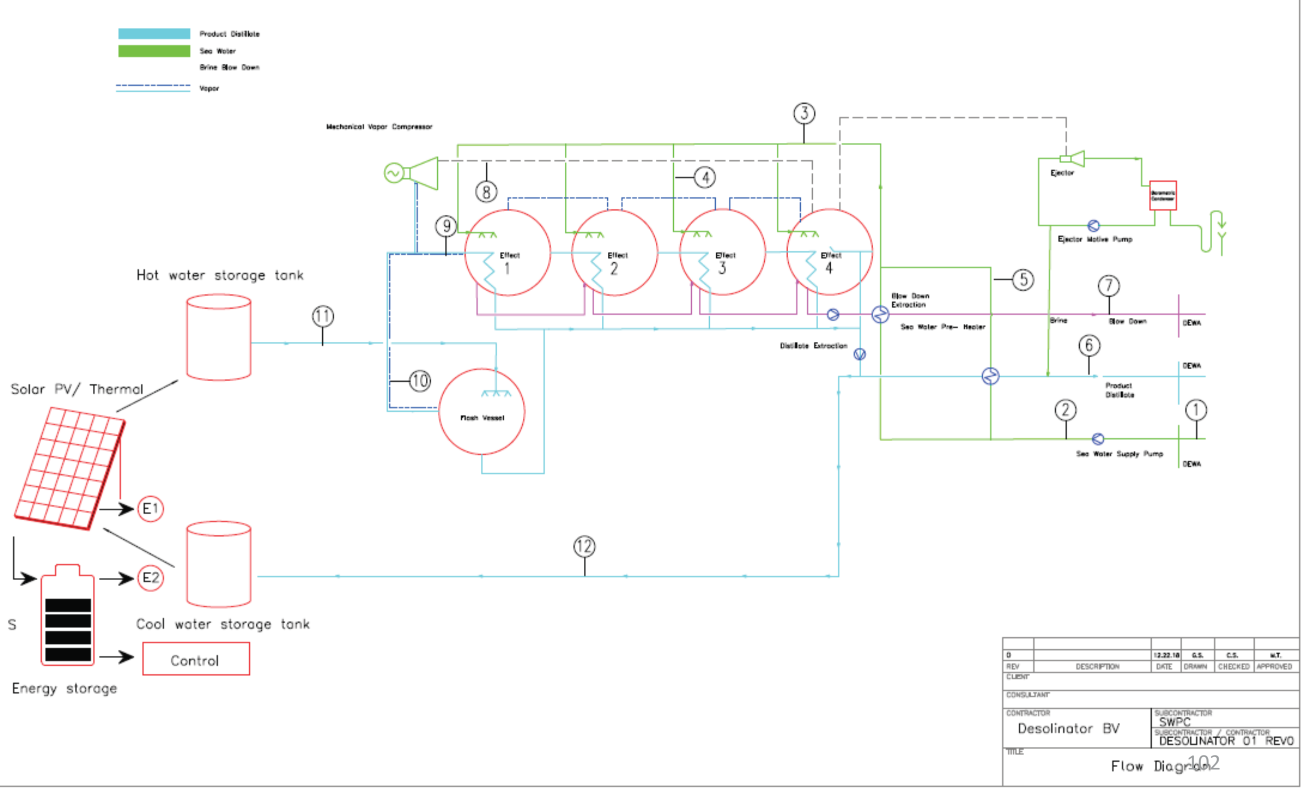
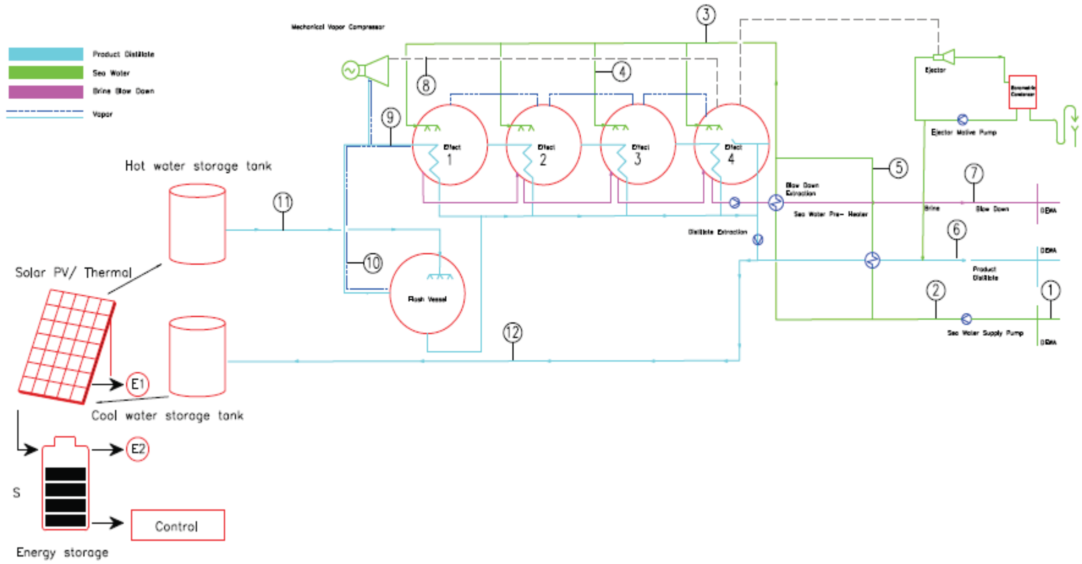
Desolenator Innovative Concept



Desolenator Innovative Concept



Description	Unit Measure	Sea water	Sea water	Sea water	Sea water	Sea water	Distil late	Blow Down	Vapour	Vapour	Vapour	Hot Water	Distil late
Stream Line	/	1	2	3	4	5	6	7	8	9	10	11	12
Flow Rate	kg/s	0.66	0.66	0.66	0.16	0.28	0.28	0.38	0.07	0.086	0.016	0.170	0.170
Flow Rate	l/s	0.642	0.642	0.643	0.161	0.273	0.282	0.362	1346	662	123	0.176	0.171
T.D.S.	ppm	44000	44000	44000	44000	44000	0	76421	N.A.	N.A.	N.A.	0	0
Temperature	°C	30	30	35	35	35	35	35	40	60	60	85	40
Pressure	bar	1.5	2.5	8	8	1	1.5	4	0.075	0.2	0	1	1
Density	kg/m³	1028	1028	1026	1026	1026	993	1050	0.052	0.13	0.13	968	992
Pipeline Diameter	mm	50	50	50	25	50	25	25	300	200	100	25	25
Velocity	m/s	0.33	0.33	0.33	0.33	0.14	0.57	0.74	19.05	21.07	15.68	0.36	0.35
Enthalpy	KJ/Kg	119	119	139	139	139	146	134	2574	2608	2608	356	167

CONTRACTOR: Desolinator BV
SUBCONTRACTOR: SWPC
DESOLINATOR 01
TITLE: Heat and Mass Balance (Day Operation)

NF-MED Coupling with Solar Pond

- The heat for the MED unit will be supplied from hot concentrated solar pond brine.
- The hot brine will be sent to a flash chamber and will generate the required steam to the MED unit.
- From the flash chamber the brine, now more concentrated and colder will be pumped back to the solar pond.
- Make up brine will be added from MED brine discharge in order to keep solar pond brine salinity constant.
- In order to improve the overall specific energy consumption a nanofiltration unit has been added to treat the feed water to the hot group.
- The NF unit will remove all the sulphates dissolved in the feed, allowing to operate the MED at a top brine temperature of almost 80°C without scaling problems.

Solar Pond coupled with NF-MED

- Advanced Solar Desalination with solar pond using 18 effects MED hybridized with Nanofiltration NF to soften feed for the hottest groups will decrease the specific thermal energy consumption to 168.2 kJ/kg or PR=13.8, never before achieved without thermocompression TVC with heat input at 90 ºC.
- We have design a full size commercial unit of 25,000 m3/day with 20 effects desalination plant with thermal energy consumption to 137.6 kJ/kg or PR=16.25.

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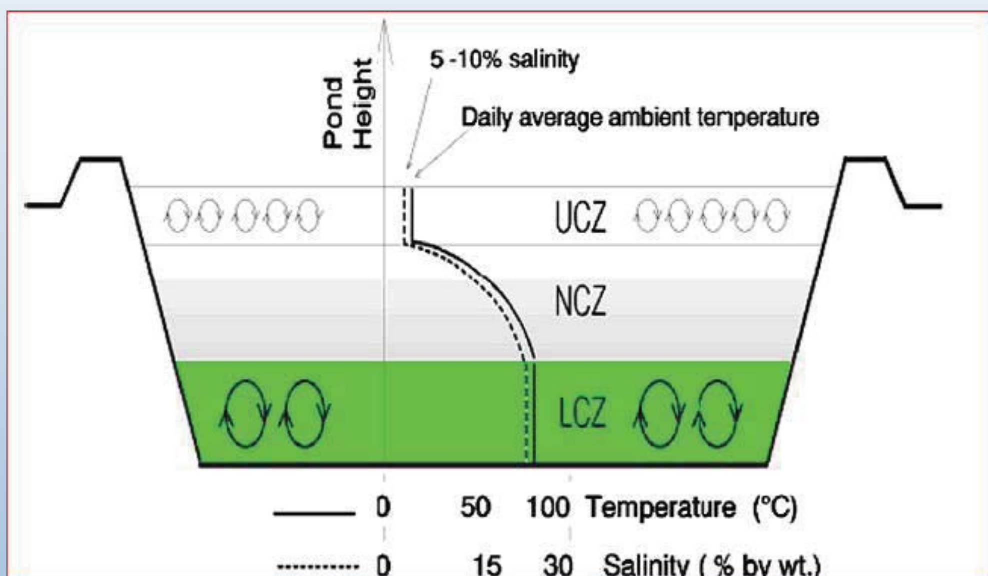
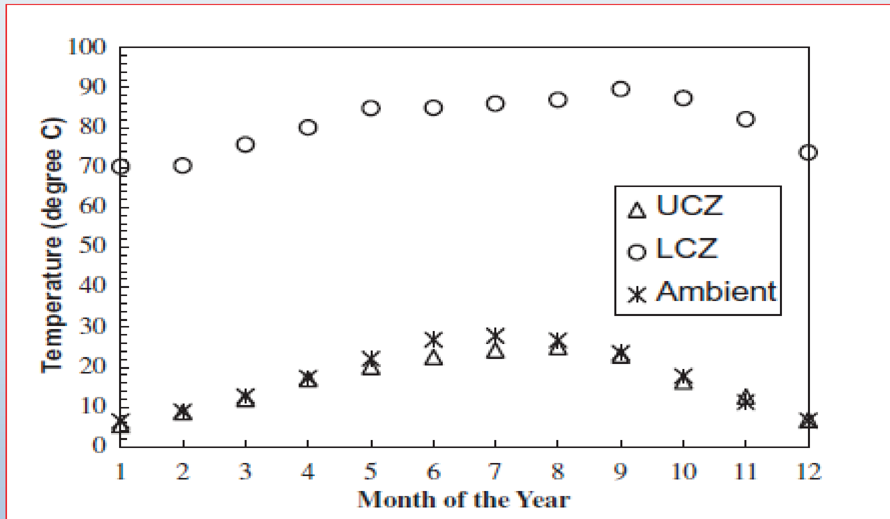


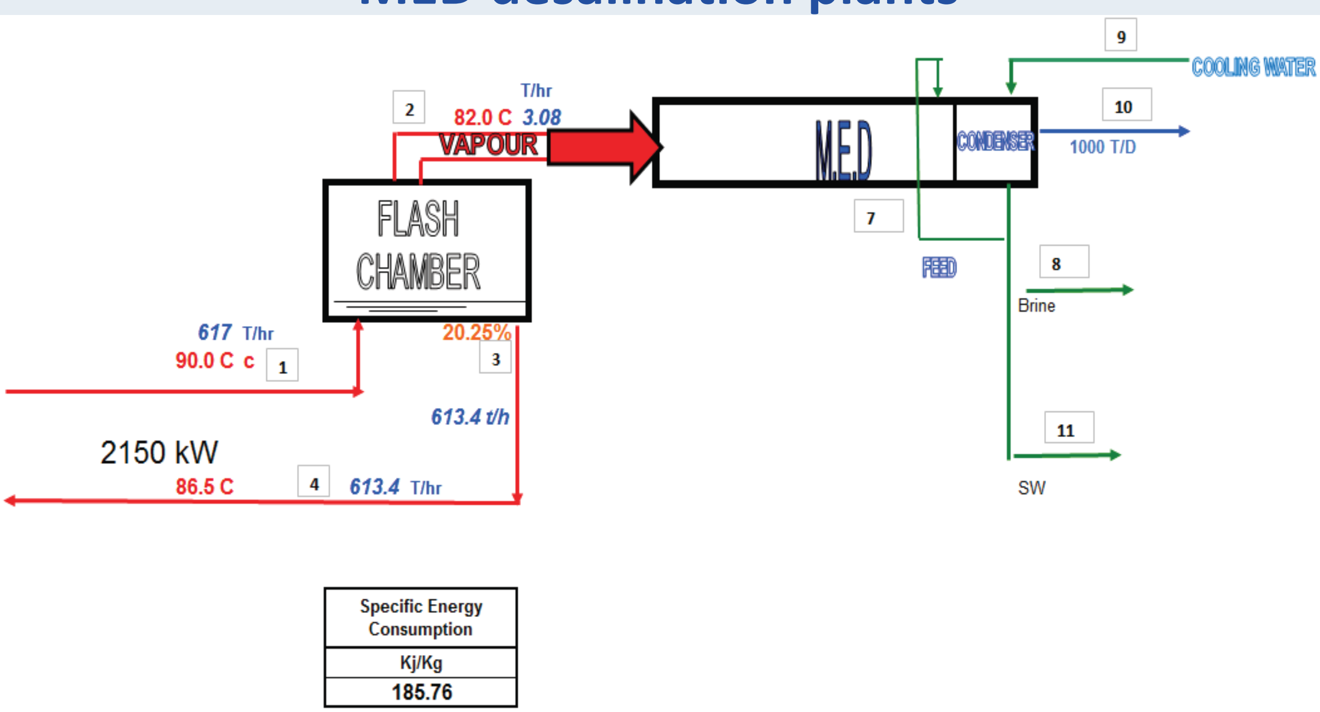
Solar Pond Salinity and Temperature Profiles

IDCA



Annual temperature profile of the El Paso solar pond (UCZ –temperature of upper convective zone; LCZ – temperature of lower convective zone; ambient – temperature of ambient air).

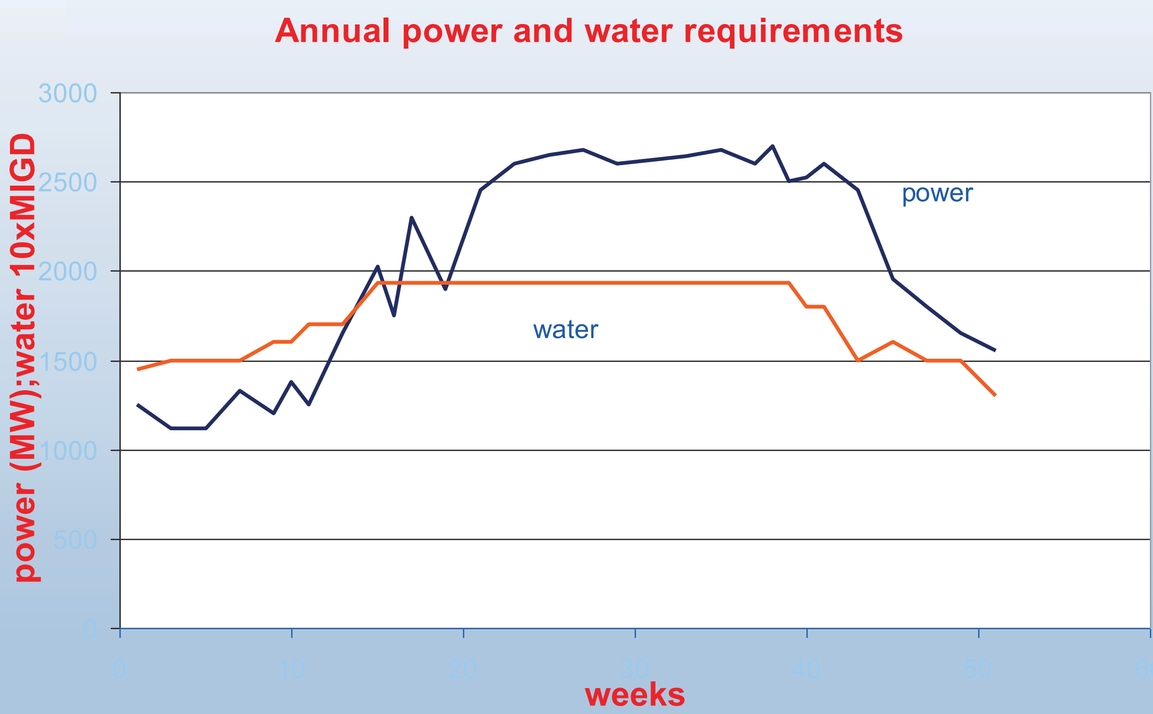
The challenge is coupling of thermal energy to MED desalination plants



Seasonal variation in power and water

- In many countries, particularly in the Middle East, peak power demand occurs in summer and then drops dramatically to 30-40%. In contrast, the demand for desalinated water is almost constant throughout the year. This creates a situation where over 50% of power generation is idled.
- This inequality of demand between electricity and water can be corrected by diverting the excess of available electricity to water production.
- Water can be stored, while electricity storage is not practical.

Opportunities for optimisation



DASR - Creating Storage and Recovery for desalinated and hot water

- **Water and heat can be stored, electricity waits for large battery development**
- **Desalinated and hot water can be stored in, and recovered from protected, underground aquifers using proven *Aquifer Storage Recovery (ASR)* technology**
- **Surface storage of large volumes of desalinated or hot water is more expensive**

IDCA

Seasonal variation in power and water

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DASR - Creating Additional Water

- Electricity demand drops to 30-40% of peak during the winter months
- As a result, over 50% of power generation capacity of power-desalination plants is idle
- This idle power can be used to produce low-cost water (above normal demand) using membrane desalination technologies

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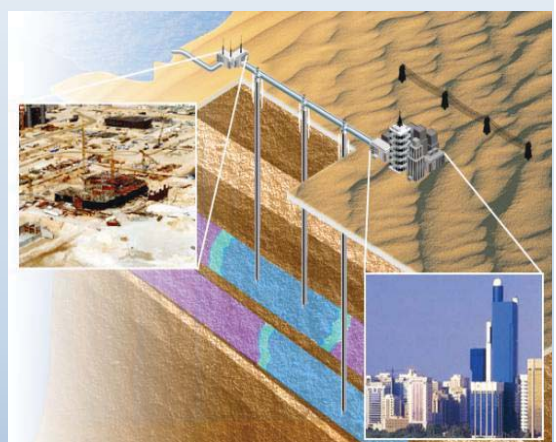
Establishing Strategic Reserves to Address Water Security

- Create protected, underground reserves of potable water using surplus low-cost desalinated water – Desalination Aquifer Storage Recovery (DASR)
- Water reserves of desalinated water can be created to cover several weeks or even months of need



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Simple hybrid

In the simple hybrid MSF, MED+RO

- A common, considerably smaller seawater intake can be used.
- Product waters from the RO and MSF plants are blended to obtain suitable product water quality.
- Product waters from the RO and MSF plants are blended, therefore allowing higher temperature of distillate.
- A single pass RO process can be used.
- Blending distillation with membrane products reduces strict requirements on boron removal by RO.
- The useful 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.

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Integrated hybrid

In general, the hybrid idea allows part of the distillation plant's heated seawater coolant reject to be de-aerated, using low-pressure steam from the distillation plant (to reduce corrosion and residual chlorine), and used as the feed to the SWRO plant. The higher temperature of the feed improves membrane performance (flux, at constant pressure, increases by 1.5–3% for each degree C). This is particularly important during the winter, when seawater temperatures can drop to as low as 15°C.

IDCA

Integrated hybrid

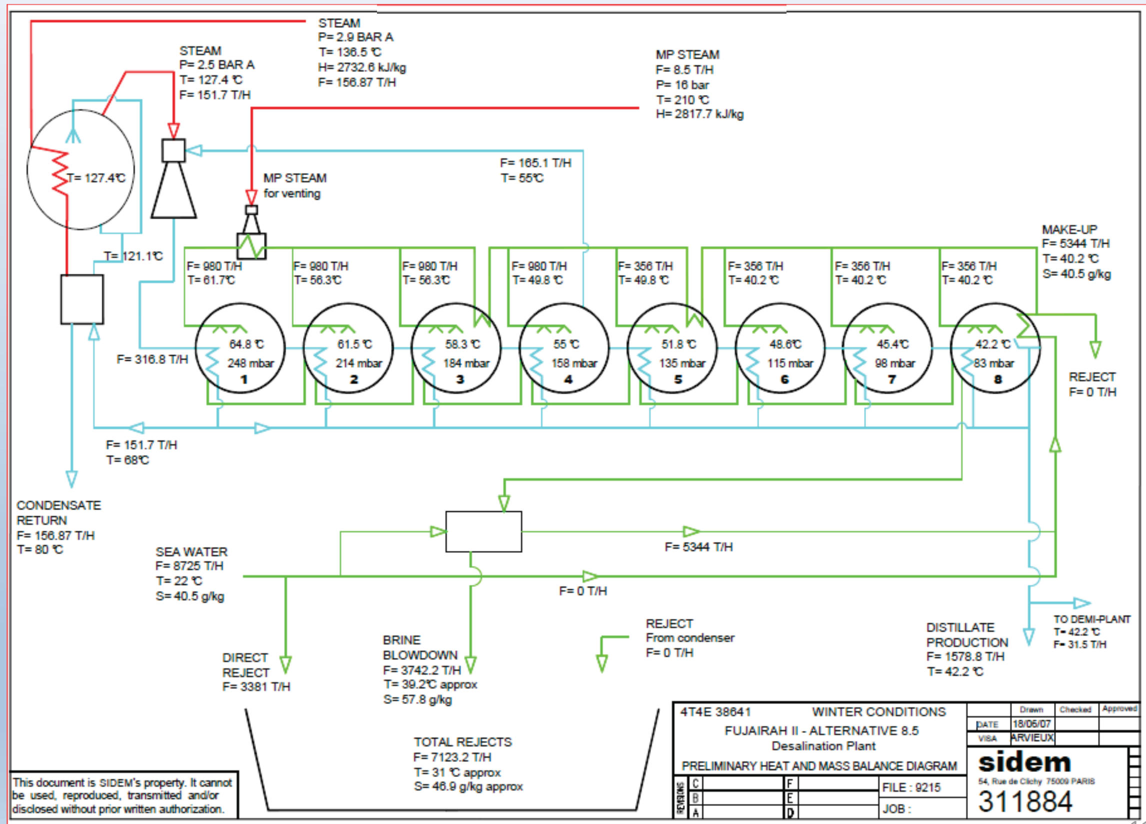
- Blending distillate and membrane permeate will reduce requirements on Boron removal by RO.

- 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 2 MED Heat and Mass Flow Diagram Winter Conditions.



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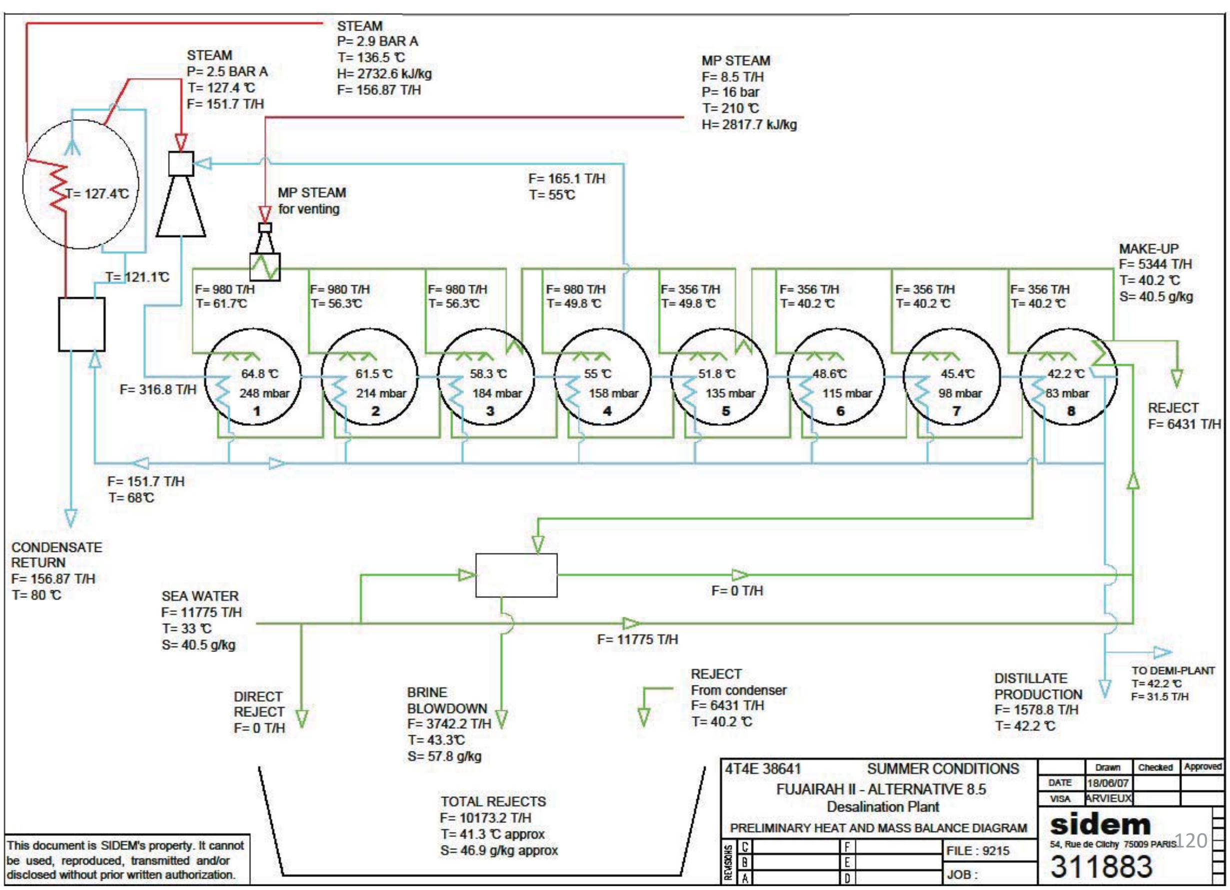
Fujairah 2 MED Heat and Mass Flow Diagram Summer Conditions.



Fujairah II IWPP - UAE

A mixed MED 100 MIGD / SWRO 30 MIGD project, landmark in the hybrid IWPP market

Scope of work

Engineering, procurement, construction and commissioning of 12 desalination units of 38,640 m3/day (8.5 MIGD) each and 30 MIGD reverse osmosis plant, together with: Potabilization plant, CO2 plant, limewater injection system, sea water pumps, 4 x 90,000 m3 storage tanks and other ancillary equipment

Contract data

Client: Fujairah Asia Power Company ; End-user: Abu Dhabi Water and Electricity Authority
The contract was awarded to a consortium made up of Alstom (for the power plant) and Sidem (water plant) in the frame of Fujairah II Independent Water & Power Production project.
Largest MED units to date (8.5 MIGD each)

Fujairah 2 Hybrid.

The largest hybrid MED-RO plant is the Fujairah II desalination project was constructed by SIDEM and Veolia and provides 591,000 m3/d of water.
The Greenfield development is producing 2000 MW of power and 130 MIGD of water. It will use five high-efficiency Alstom GT26 gas turbines in combined cycle mode and 12 SIDEM 8.3 MIGD Multi Effect Distillation desalination units with a 30 MIGD Reverse Osmosis desalination plant.

Ras Al- Khair Hybrid.

As the world's largest seawater desalination plant, for which Doosan won the construction order in September 2010 from the Saline Water Conversion Corporation, the Ras Al-Khair plant produces 1,036,000 m3/d, sufficient to meet the daily water requirements of around 3.5 million people. The plant produced its first freshwater earlier this year, although the project was actually scheduled for completion in December 2015. As the world's largest hybrid plant, the project uses both membrane technology (reverse osmosis, RO at 309,360 m3/d) and thermal technology (multi-stage flash evaporation, MSF with a capacity of 727,130 m3/d). This plant also features the largest single MSF trains composed of 8 units with capacity of over 91,000 m3/d each. The RO plant has 17 trains.

Ras Al Khair, 20 MIGD (91,000t/d) MSF unit the largest in the world first out of 8.

The evaporator is also the world's largest in size, as it measures 123 meters long, 33.7 meters wide, and weighs 4,150 tons

DESALINATION IS THE SUSTAINABLE SOLUTION AND HOPE FOR THE FUTURE GENERATIONS

LET Proprietary