Geothermal Desalination in KSA

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Outline

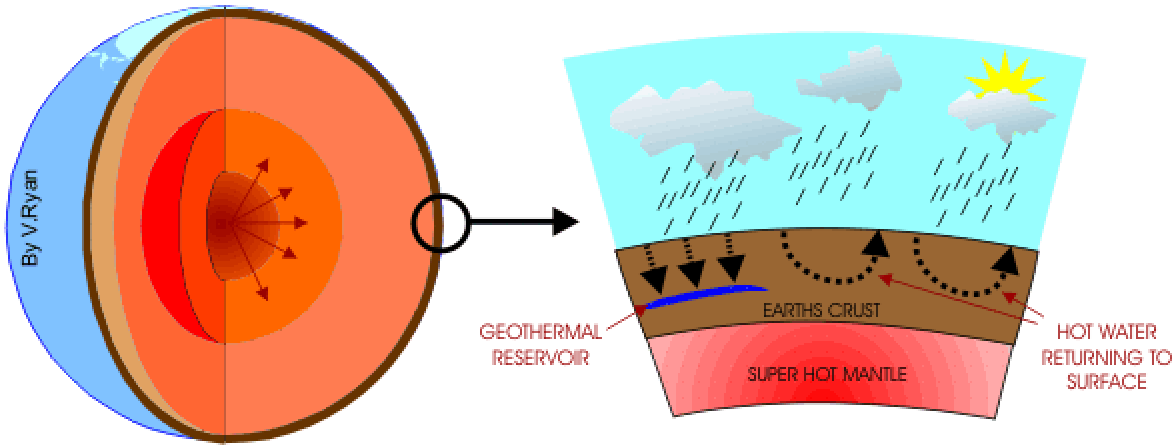
- Introduction
- Geothermal energy in KSA
- Desalination technolgies
- Some configurations of Geothermal desalination
- Conclusion

Introduction:

- Geothermal energy (Geo= Earth, Therme=heat) is energy derived from the heat of the earth.

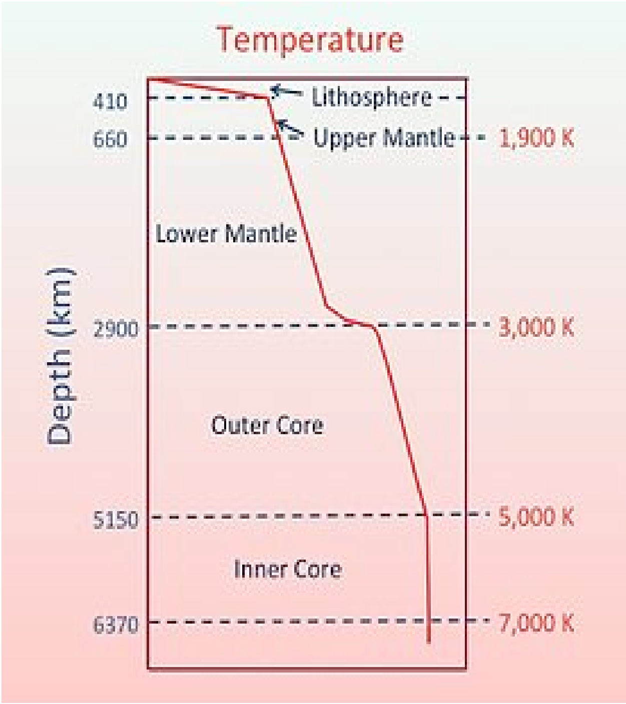
-A steady heat flow (that will not deplete) from the earth's interior reaches the surface of the earth

- 99% of the earth's interior is hotter than 1000 °C
- 99% of the rest is hotter than 100 °C



SECTION OF EARTH - TEMPERATURES REACH 5000 DEGREES CENTIGRADE AT THE CENTRE

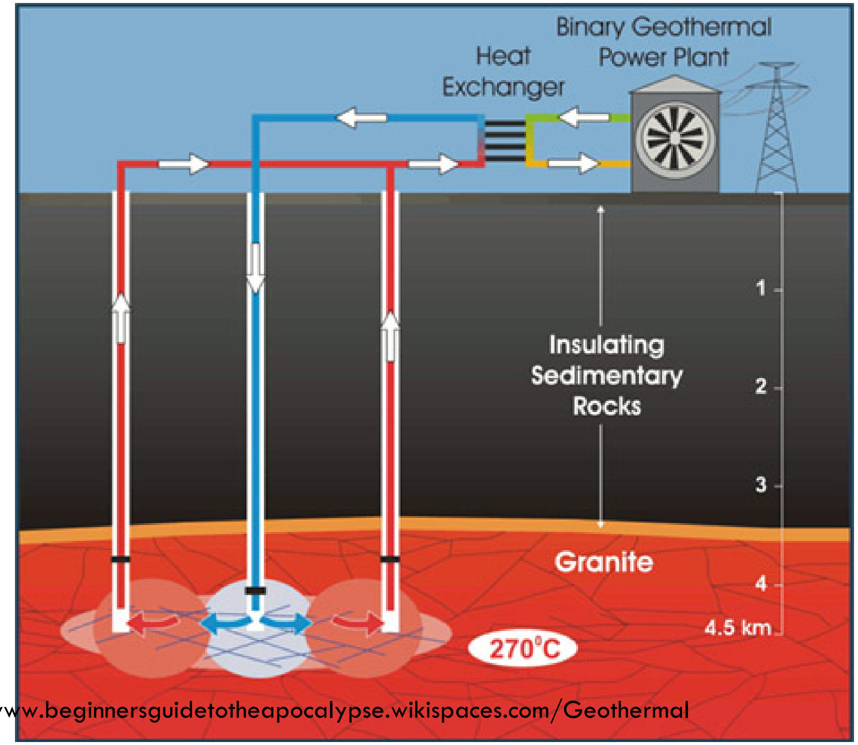
RAIN FALLS ON THE EARTHS SURFACE AND SEEPS DOWN TO THE HOT ROCKS BELOW. THE WATER HEATS AND RETURNS TO THE SURFACE



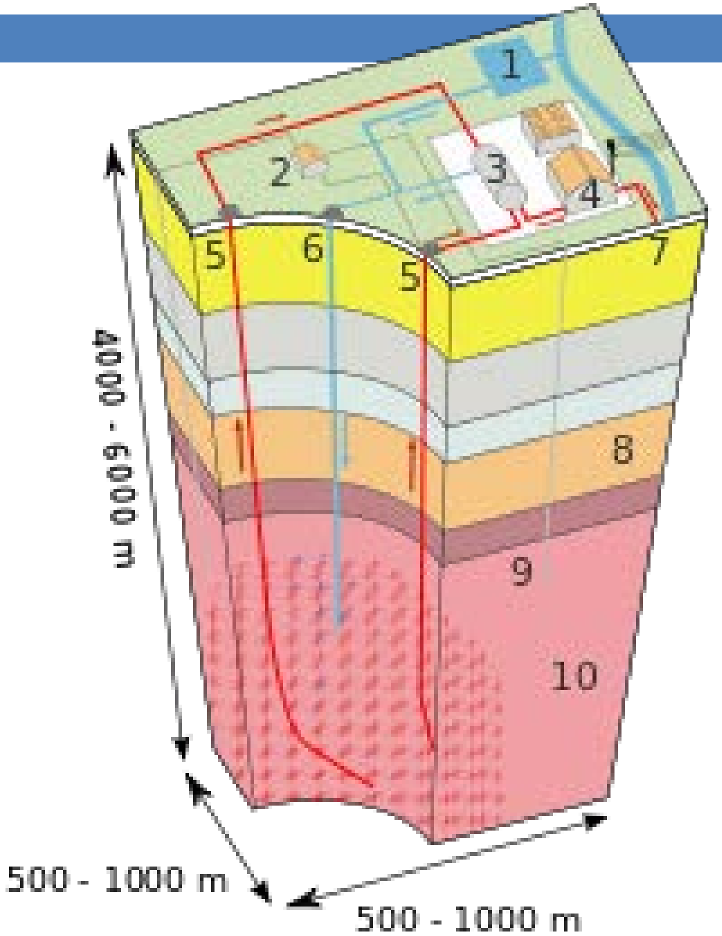
www.technologystudent.com

Introduction:

Deep geothermal systems (outside volcanic zones) are:
-Hydrothermal (2-3 km)
-Enhanced geothermal systems (5 km +), 150 °C +
Construction of production and re-injection wells



www.beginnersguidetotheapocalypse.wikispaces.com/Geothermal



Enhanced geothermal system 1:Reservoir 2:Pump house 3:Heat exchanger 4:Turbine hall 5:Production well 6:Injection well 7:Hot water to district heating 8:Porous sediments 9:Observation well 10:Crystalline bedrock

Introduction: Geothermal project phases

Identification | **Exploration** | **Drilling** | **Production**

Identification

Initial research
Reconnaissance

Exploration

-Prospection
-Geological and geophysical experiences
-Studying data
- Exploratory drilling

Drilling

-Project feasibility
- Reservoir management
- Initial drilling Seismic and geological risk management
- Production drilling

Production

-Financial closure
-Facility design and construction
-…

Introduction: Advantages vs Disadvantages

+ Sustainable energy source: Heat extraction is small compared to the size of heat reservoir

+ Clean and safe energy: emissions of undesirable substances are small

+ Independent of climate and seasonal variations: geothermal plants can work continuously: Base load energy source.

+ High degree of scalability : modular systems to feed remote areas with power and water

+ Diversity in energy sources/conservation of fossil fuels.

+Inexpensive in operation ?

- Constructions can affect land stability in the neighbouring regions
- Hot water from geothermal sources can contain dangerous parts
- Scaling problems due to dissolved solid impurities (i.e. on turbines), separators, demisters, treatment…
- Geographic distance between source and use
- High initial costs

Introduction:

Geothermal Resources can be:

1- Medium/High-Enthalpy Resources

Reservoir temperatures of 150-300+°C

Ideal for power generation

Low availability (only found in volcanic regions)

Location	T,[°C]	Drilling depth [m]	Feed rate [m^3/h]	Power system	Start up	Thermal energy [MW]	Electric capacity [MW]
Neustat glewe, GR	97	2250	40-110	ORC	2003	6.5	0.21
Unterhaching, GR	130	3580	150	Kalina	2008	38	3.36

2- Low-Enthalpy Resources

Reservoir temperatures of 100-150°C

Available

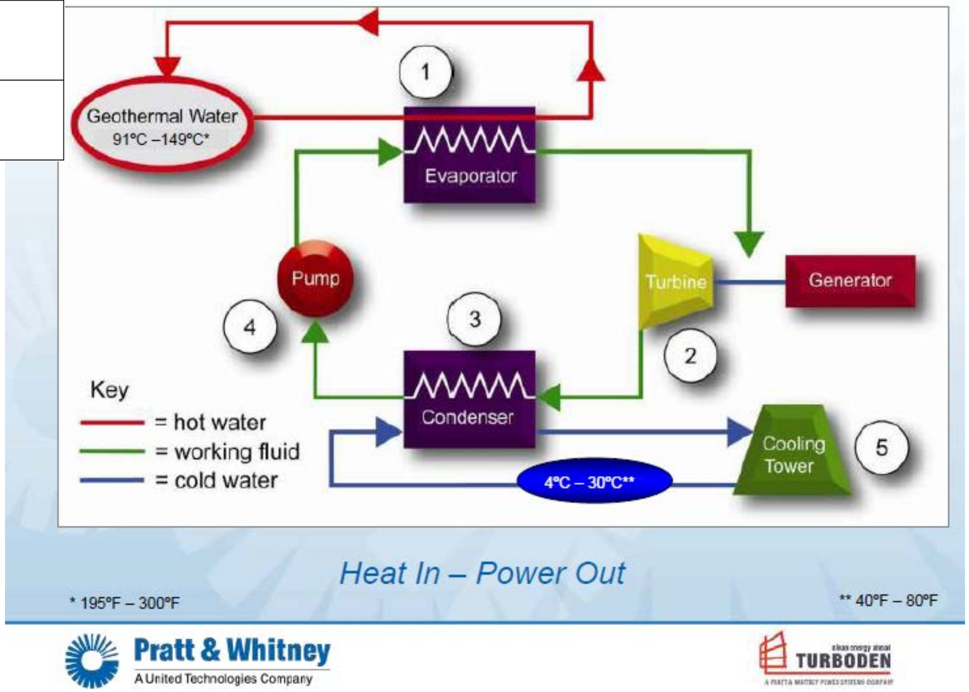
Ideal for direct applications: heating, cooling, desalination and steam generation

1- **Flash technology**: direct expansion of geothermal steam in a turbine

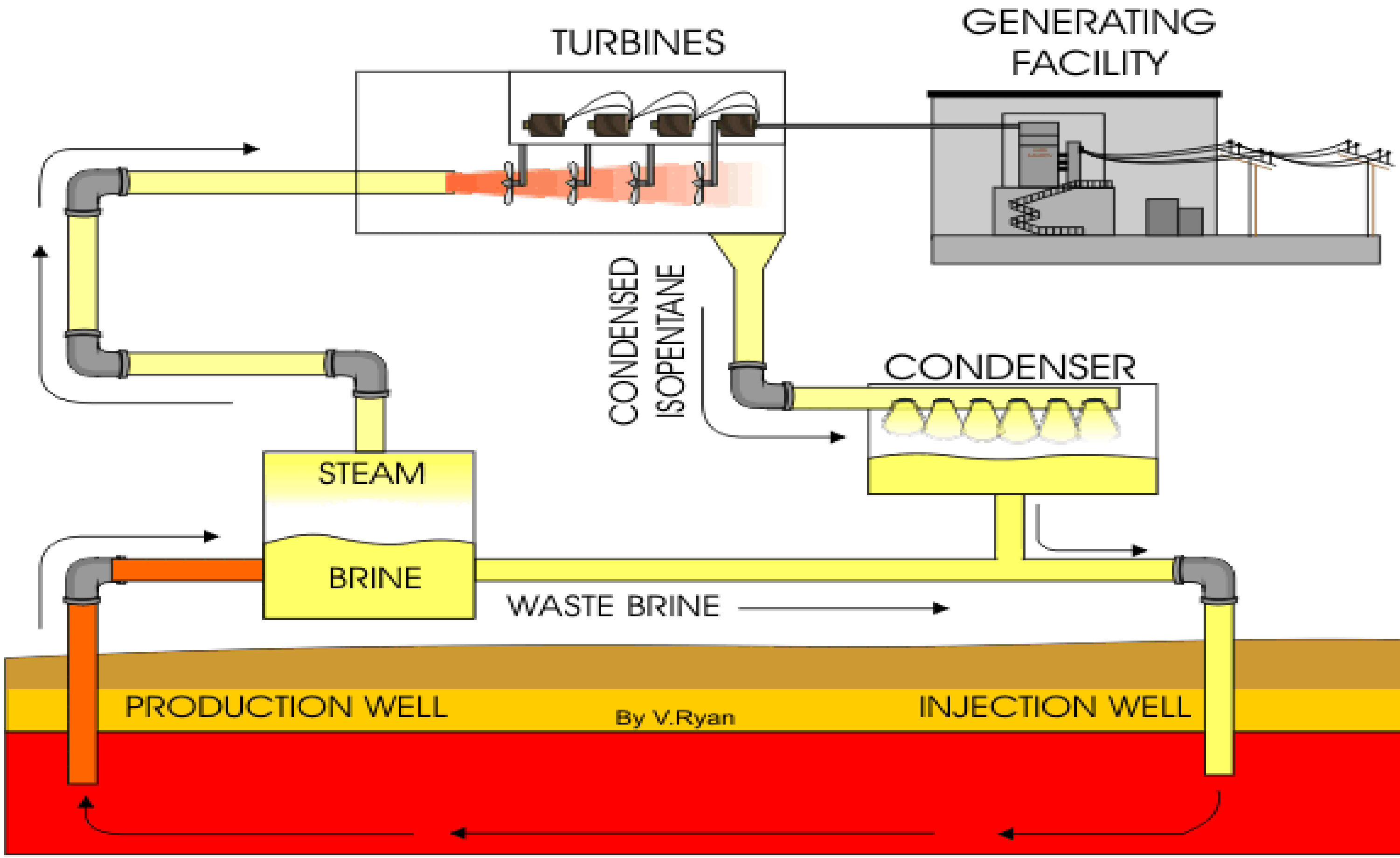
2- **Binary cycle**: geothermal heat transmitted to a closed power cycle:

-ORC: with low boiling temperatures

-Kalina cycle: Binary fluids are used (ammonia/water)



Introduction: Single Flash Steam Power Plants



Geothermal energy classification

Classification of geothermal resources by their reservoir temperatures

	Reservoir temperature level (°C)				
	Ref 1	Ref 2	Ref 3	Ref 4	Ref 5
Low enthalpy	< 90	< 125	< 100	< 150	20 – 70
Medium	90 - 150	125 –225	100 – 200	-	70 – 150
High enthalpy	> 150	> 225	> 200	> 150	> 150

-Geothermal fluids can be classified, as fuels by their Calorific Values, by the maximum work available.

- Lee (Geothermics,2001) proposed to use the concept of available energy (exergy) as it defines the quality of the energy content of a geothermal fluid.

- Lee proposed a normalized specific exergy parameter called specific exergy index or Specifc exergy rate (SER) defined as:

- SER = (h-273.15 s)/1192; SER is independent of the reference (sink) conditions.

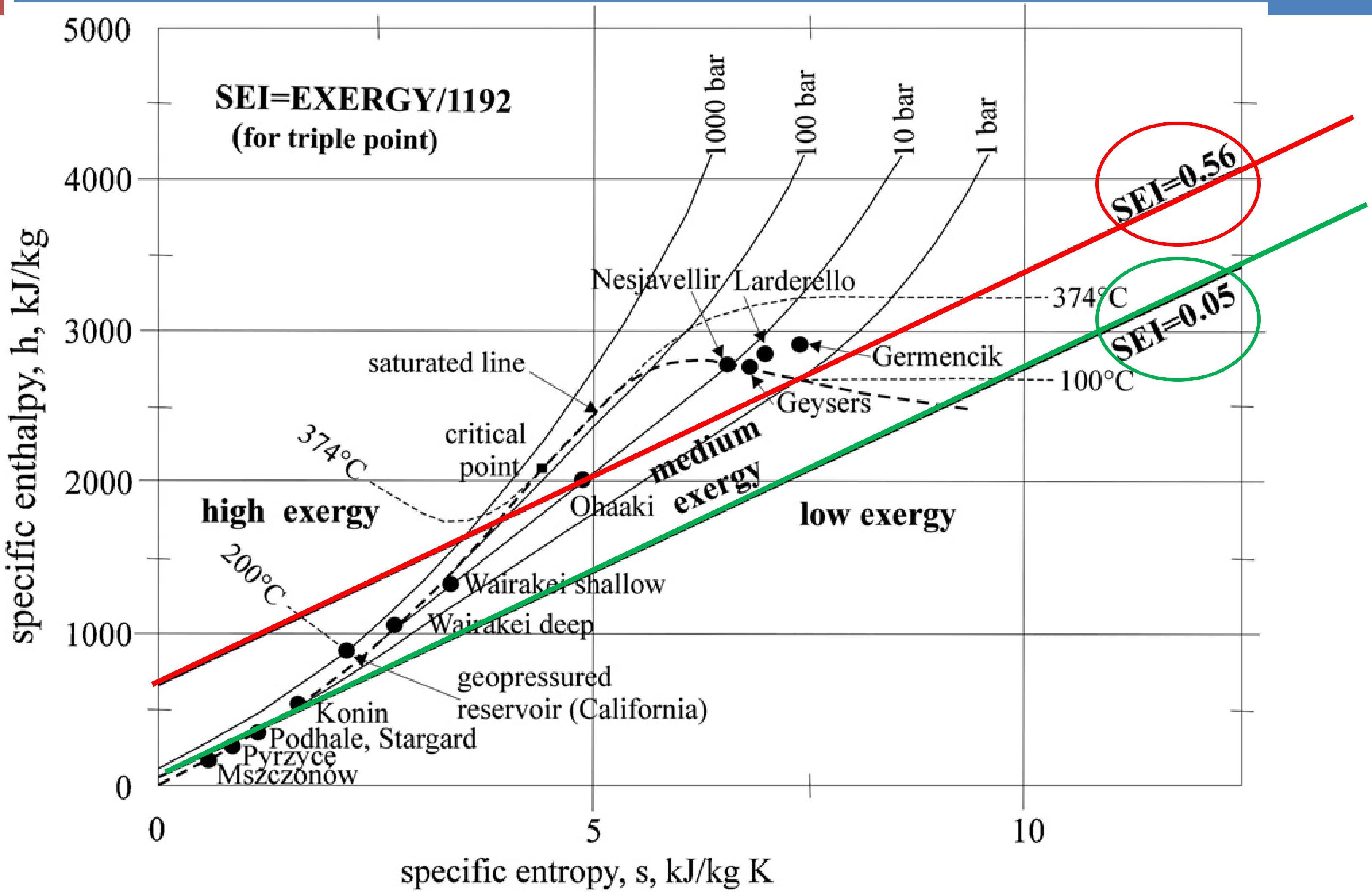
- Saturated steam at 1 bar has SER of 0.56 while saturated liquid has 0.52

  $SER < 0.05$ for low quality geothermal resources

  $0.05 \leq SER < 0.5$ for medium quality

  $SER \geq 0.56$ for high quality

Geothermal energy classification: Example of Poland



A. Barbacki / Renewable and Sustainable Energy Reviews *16 (2012) 123– 128*

Geothermal energy in KSA

- Several studies identified 10 thermal springs:
    Six in Jizan (southwest near the Yemen border) and
    Four in Al- Lith area (west-central on the Red Sea).

-Lund (based on the work of Rehman (2005)) claim that none of these springs are being exploited.

-Al Dayel (1988): Temperature levels measured are ranging from 70 to 100 °C.

-Rehman and Shash (2005): varying deep temperatures : 50 to 120 °C.
-Hanan and Taleb (2009) discussed about the barriers hindering the utilization of geothermal resources in Saud Arabia.

Few studies were concerned with geothermal energy in the Kingdom.

Geothermal energy in KSA

Recent works:

-A. Lashin and N. Al Arifi (2014), Renewable and Sustainable Energy Reviews 30, 771 "Geothermal energy potential of southwestern of Saudi Arabia "exploration and possible power generation": A case study at AlKhouba area – Jizan

The work aimed aims mainly to explore and locate the potentiality of these resources through analyzing the available satellite images and performing a geophysical survey, as well as estimating the geothermal reserve potential for possible energy production.

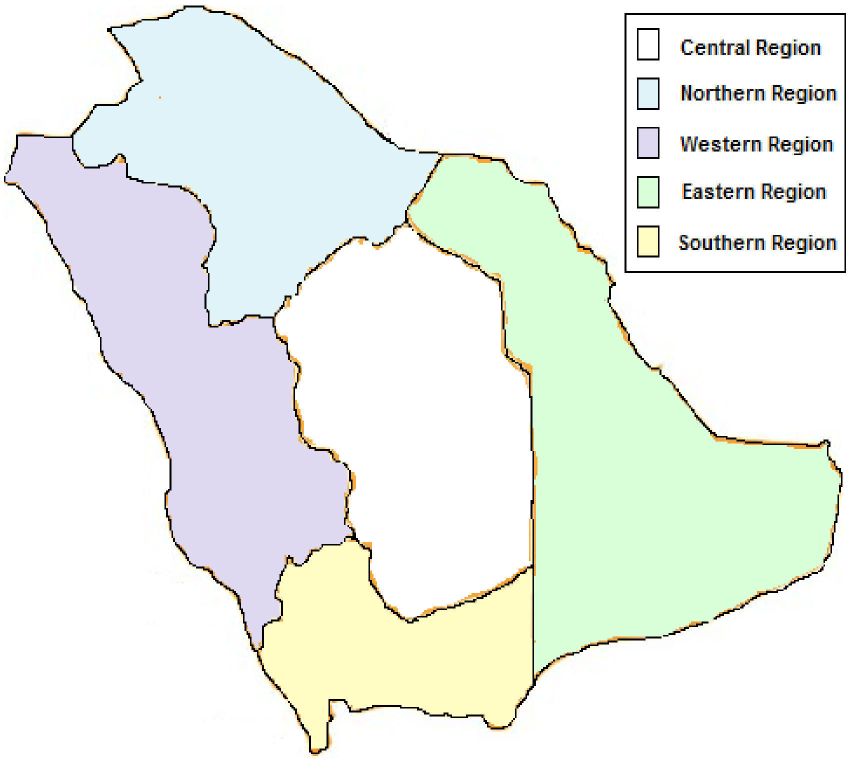
* Hussain et al. (2013): Wadi Al-Lith is considered one of the most promising geothermal targets with many hot springs with a surface temperature up to 95 °C

•Recent data: Rubu Alkhali: surface temperature = 97 °C; TDS 4127 ppm, Flow rate = 454.2 m3/h.

•Renewable energy targets for KSA: 50% of electricity from non-hydrocarbon resources by 2032: 54GW from renewables (of which: 41GW from PV and CSP, 9GW wind, 3GW waste-to-energy, 1GW geothermal), 17.6GW from nuclear

D. Chandrasekharam Visiting Prof., KSU, claimed that the Saudi Power Potential can reach 5 GW.

Geothermal energy in KSA



Information and data were supplied by NWC,
MSc project of Eng Majed Alharbi, KSU.

Geothermal energy in KSA

Region	Department	Longitude	Latitude	Range of Temperature	Range of TDS	Range of Flow Rate	Range of Depth
				°C	ppm	m^3/h	m
Riyadh	Central	-	-	**34-70**	**500-1800**	158-360	-
Asir	Southern	-	-	**15-26**	**155-1630**	20-1500	11-350
Gizan	South	-	-	**31.4-75.5**	**-**	2.16-28.8	-
Medina	Western	39.73343	24.1834	**31-41**	**300-600**	6750-46187	75-262
Tabuk	Western	36.097	29.126	**27**	**350-500**	114000	550
Al-Lith	Western	-	-	**39.5-79**	**-**	0.144-6.48	-
Hail	Northern	42.029	27.983	**27**	**500-700**	44500-64500	350
Arar	Northern	40.899	30.965	**48**	**500**	13300	1450

Geothermal energy in KSA

Regions	Temperature	TDS	Volume Flow Rate
Riyadh	°C	ppm	m^3/h
Alwasia (الوسيع)	34	1000	225
Alhani (الحني)	34	500	360
Nasah (نساح)	35	500	158
Riyadh (الرياض)	65	1900	180
Salbukh (صلبوخ)	70	1800	225
Albobb (البويب)	70	1800	225

Regions	Temperature	TDS	Volume Flow Rate
Jizan	°C	ppm	m^3/h
Ain Khulab field	75.5	-	2.16
Wadi Khulas field	31.4	-	14.4
Ain Khulab Quwa field	59	-	2.88
Ain al Wagrah field	55	-	2.16
Ain al Wagrah Dam field	59	-	28.8

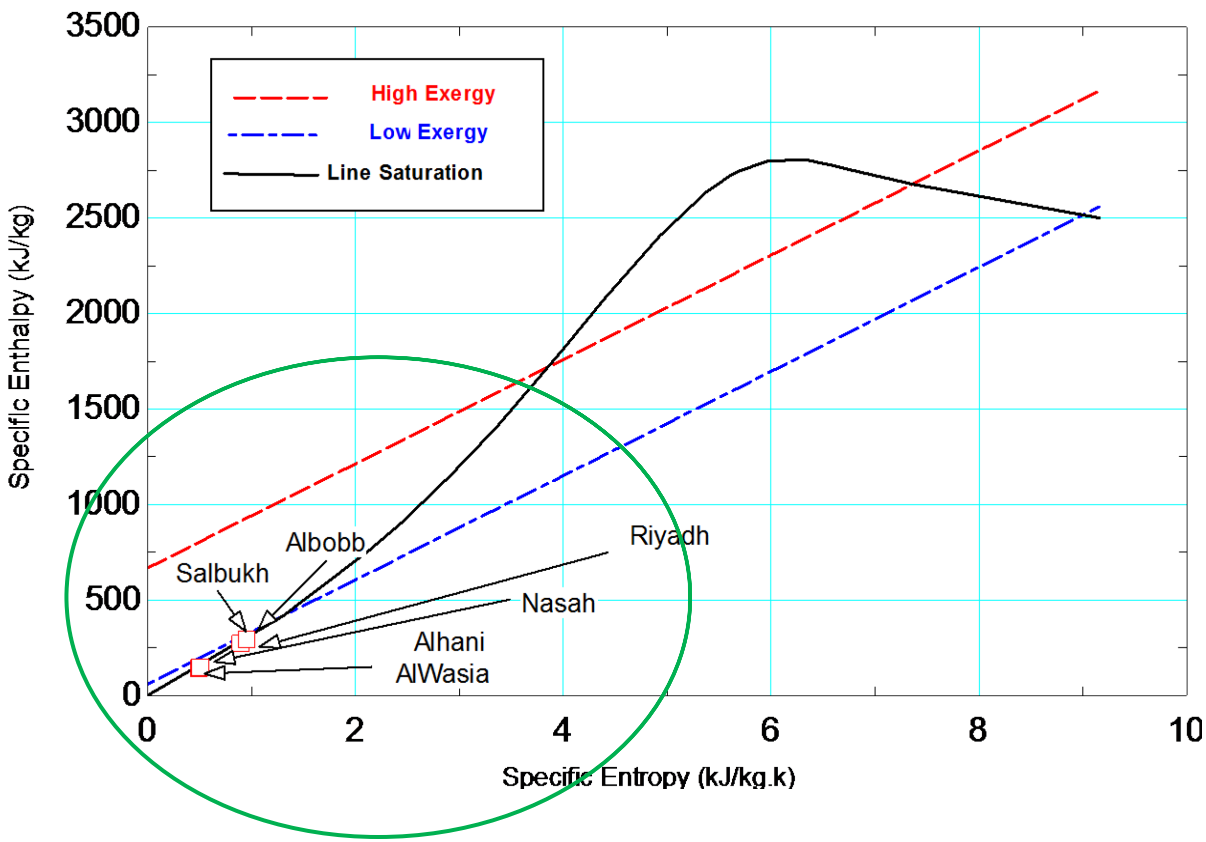
Geothermal energy in KSA

Groups	Temperature	TDS	Volume Flow Rate	Depth
Assir	°C	ppm	m^3/h	m
Group-A	15	285 - 897	30 - 80	17 - 25.5
Group-B	16	231 - 1028	30 - 70	17 - 26
Group-C	17	266-986	40 - 100	14 - 25
Group-D	18	256 - 1252	50 - 230	14 - 28
Group-E	19	270 - 1408	30-170	11.5 - 35
Group-F	20	230 - 1540	30 - 280	14 - 95
Group-G	21	155 - 1520	30 - 650	15 - 70
Group-H	22	277 - 1630	30 - 180	11 - 110
Group-I	23	292 - 1204	50 - 1500	15 - 80
Group-J	24	588 - 1577	50 - 600	17 - 350
Group-K	25	389 - 694	60 - 320	12 - 25
Group-L	26	376 - 630	20 - 40	26.5 - 35

Geothermal energy in KSA

Regions	Temperature	TDS	Volume Flow Rate	Depth
Madina	°C	ppm	m3/h	m
Alashira field	31	600	46187	100-262
Acol field	34	550	6750	75-225
Whitan field	41	300-500	23169	152-235
Ain Alzarka	36	600	26944	200
Tabuk	°C	ppm	m3/h	m
Tabuk city field	27	350-500	114000	550
Al-Lith's wells	°C	ppm	m3/h	m
Ain al Harra field	79	-	6.48	-
Ain al Jumah field	46	-	0.432	-
Ain Markus field	46	-	0.432	-
Ain al Darakah field	39.5	-	0.144	-
Hail	°C	ppm	m3/h	m
Alhamema field	27	700	64500	350
Alshakek field	27	500	44500	350

Geothermal energy



These geothermal wells have low available energy.

Desalination technology

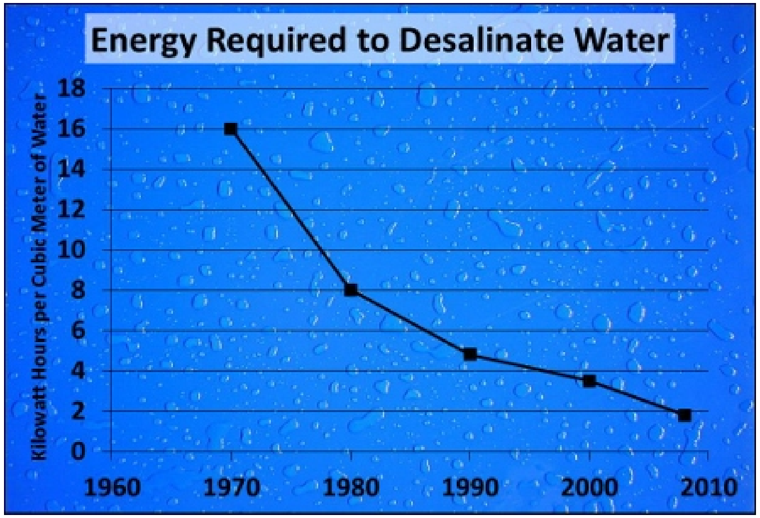
Water Conservation

Effective Water Use

Developing Cost Effective, Energy Efficient Water Supply

Waste/recycling water

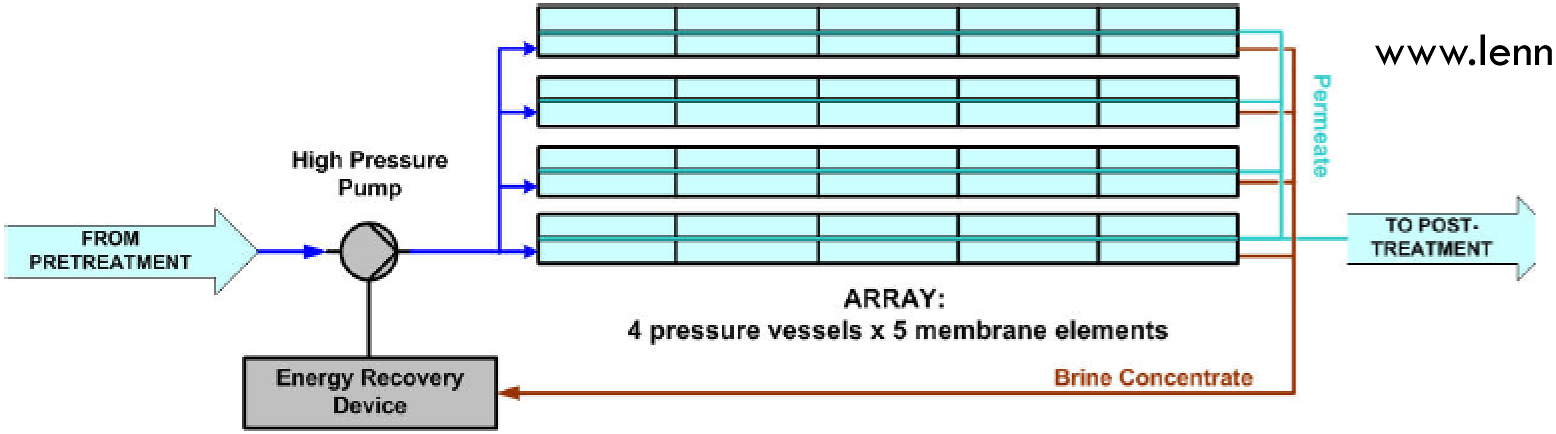
Desalination: An Integral Part of the Future Water Supply Portfolio



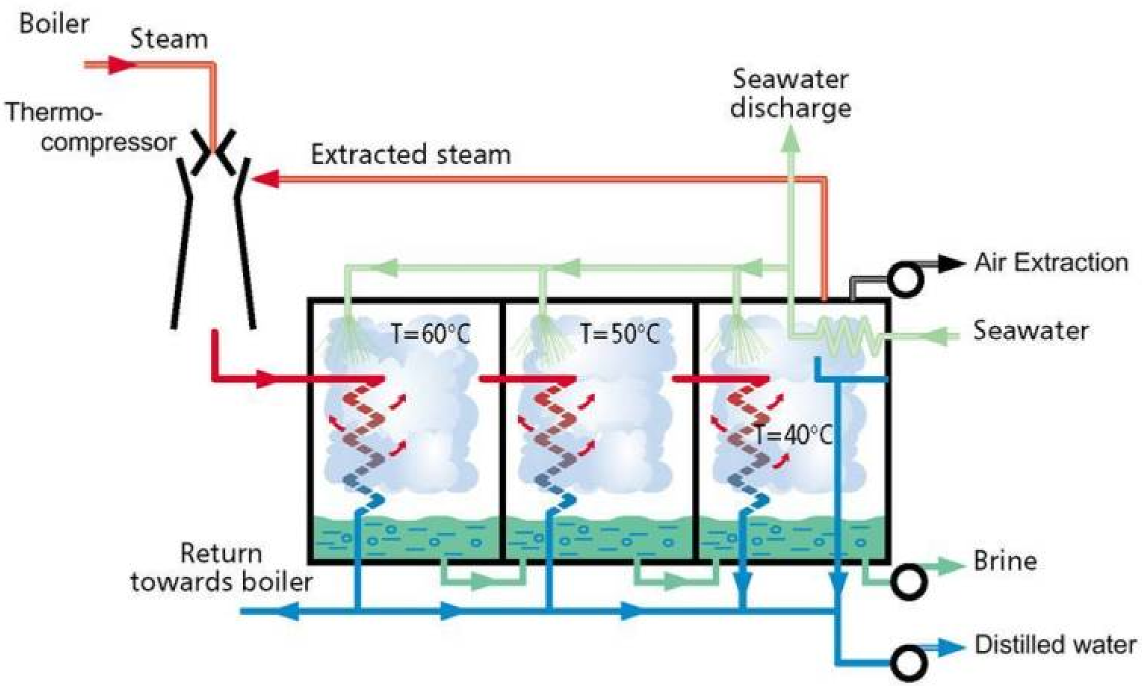
The amount of energy required to desalinate water has dropped by nearly a factor of 10 since 1970

Menachem and Elimelech, "The Future of Seawater Desalination", Science (2011)

Desalination technology



www.lennetech.com



www.sidem-desalination.com

Example: Energy consumption and Costs in Reverse Osmosis

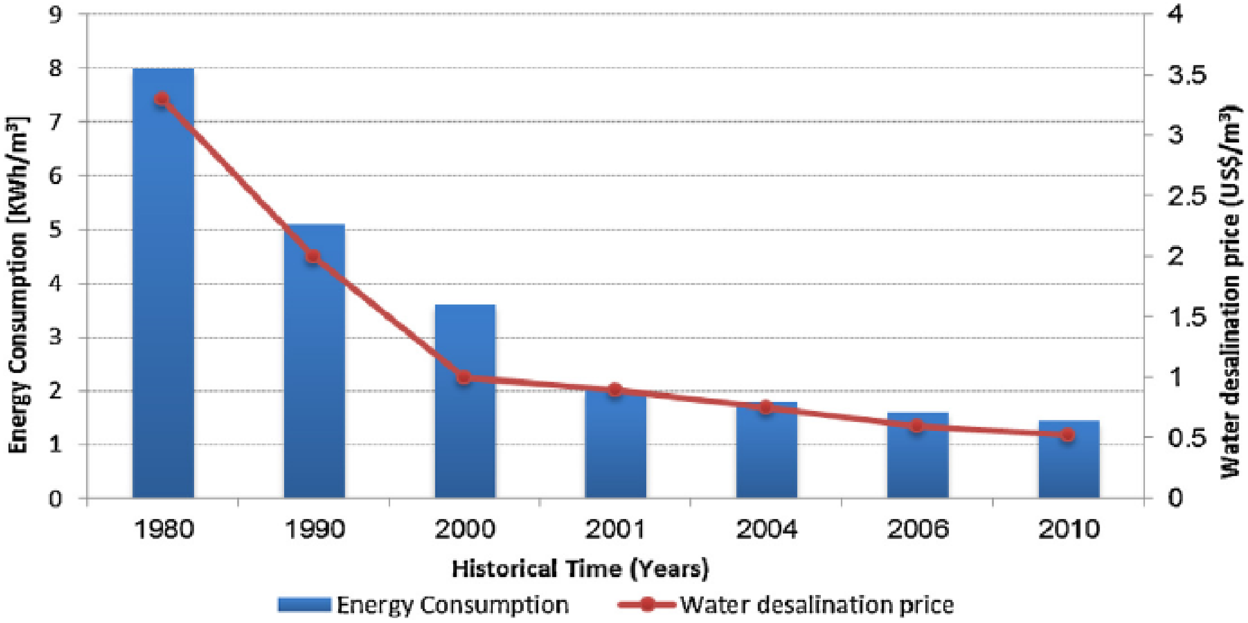


Fig. 17. Development of achievable energy consumption and cost in RO desalination processes.

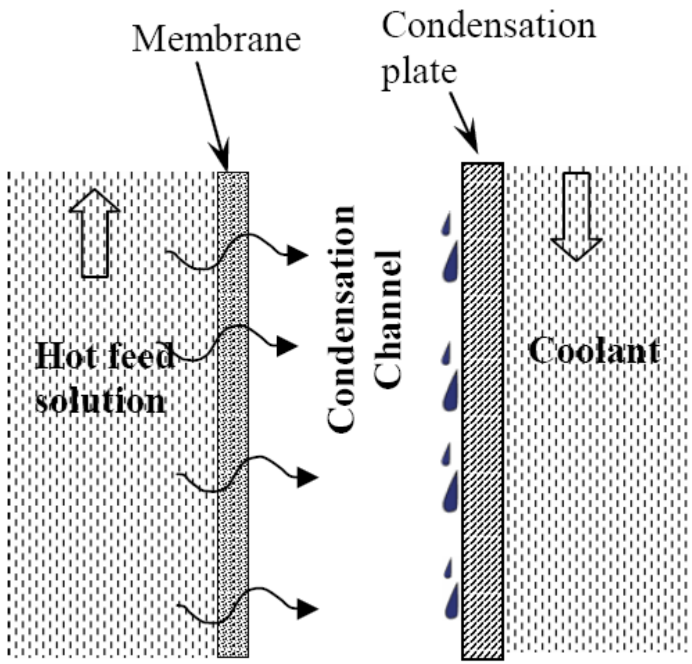
Reverse Osmosis

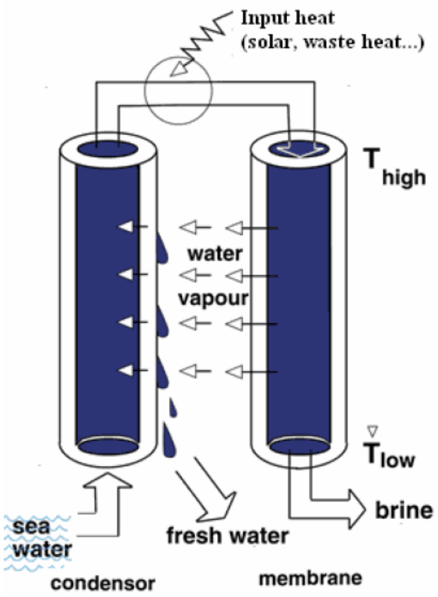
Type of feed water	Capacity of desalination plant (m^3/day)	Desalination cost per m^3 (US$)
Brackish water	Less than 20	5.63–12.9
	20–1200	0.78–1.33
	40,000–46,000	0.26–0.54
Seawater	Less than 100	1.5–18.75
	250–1000	1.25–3.93
	15,000–60,000	0.48–1.62
	100,000–320,000	0.45–0.66

M. Shatat et al. / Sustainable Cities and Society 9 (2013) 67–80

Non conventional Desalination technology:

Membrane Distillation

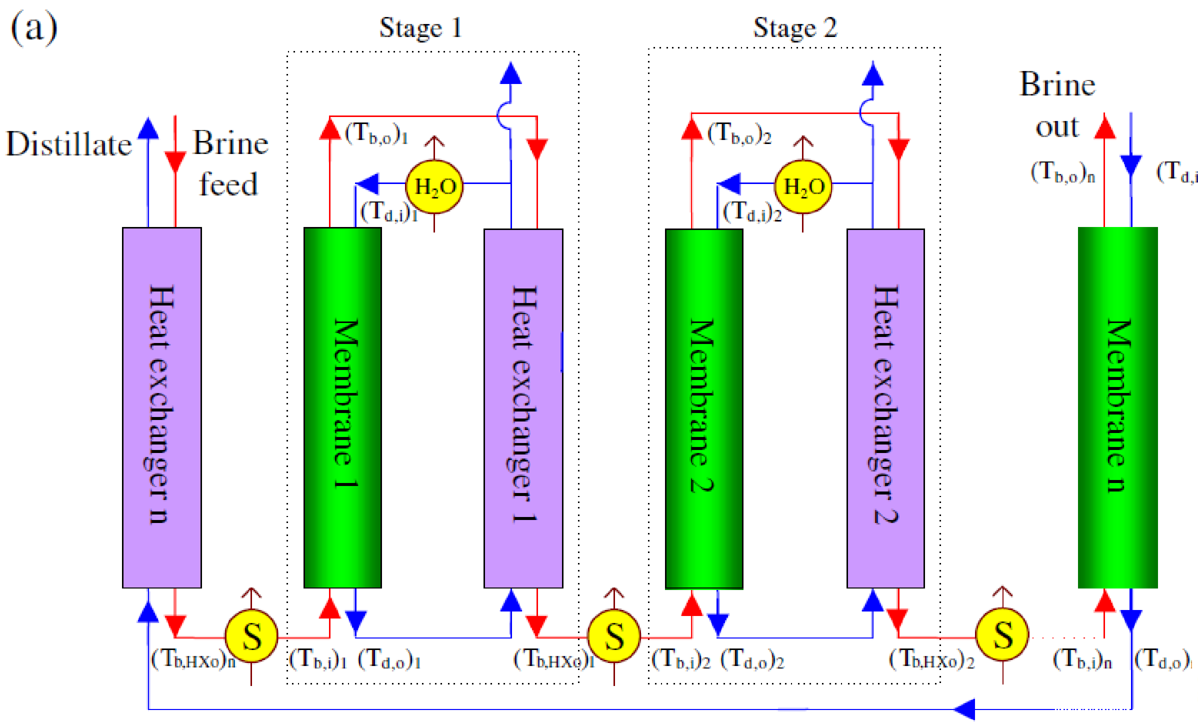


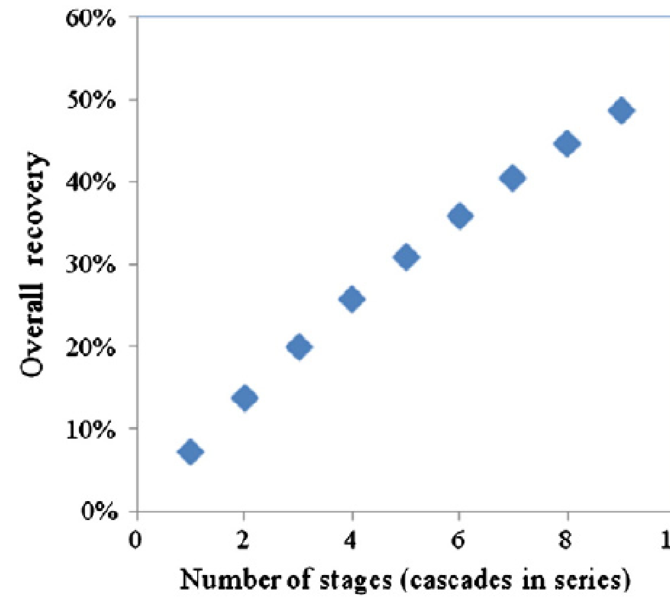


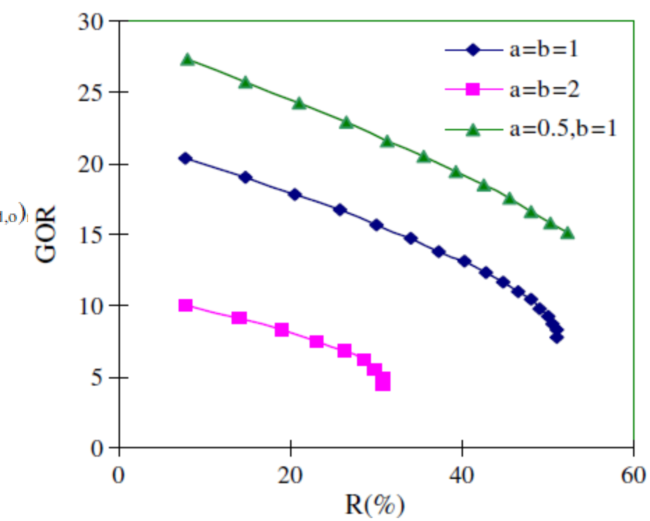
- Membrane + Evaporation Processes in one unit,
- Water Vapor passes through a hydrophobic Membrane via the Temperature Gradient across the Membrane sides
- Operation at Patm and low Temp. (30 – 90 C),
- High salt rejection.
- Can be used when low grade energy is available: geothermal
- Under development ?

Non conventional desalination processes

- Membrane distillation: Multiple stages







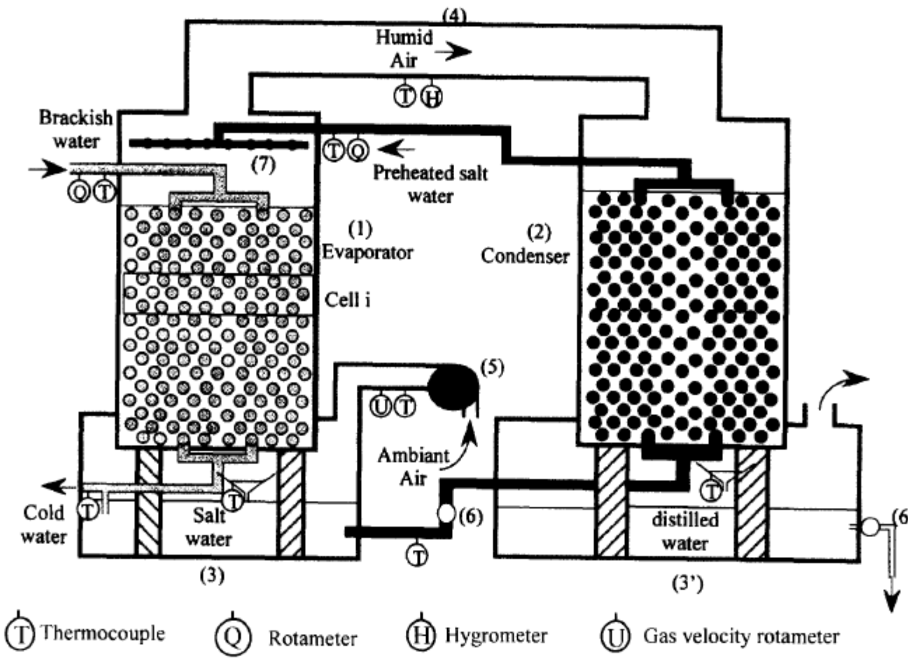
(GOR=m3 distillate per heat equivalent of m3 of saturated steam)

He et al. Desalination 323 (2013) 48–54

Non conventional desalination processes

-Humidification – dehumidification: Multiple stages

-Limited to small capaciy



K. Bourouni et al. / Desalination 125 (1999) 147–153

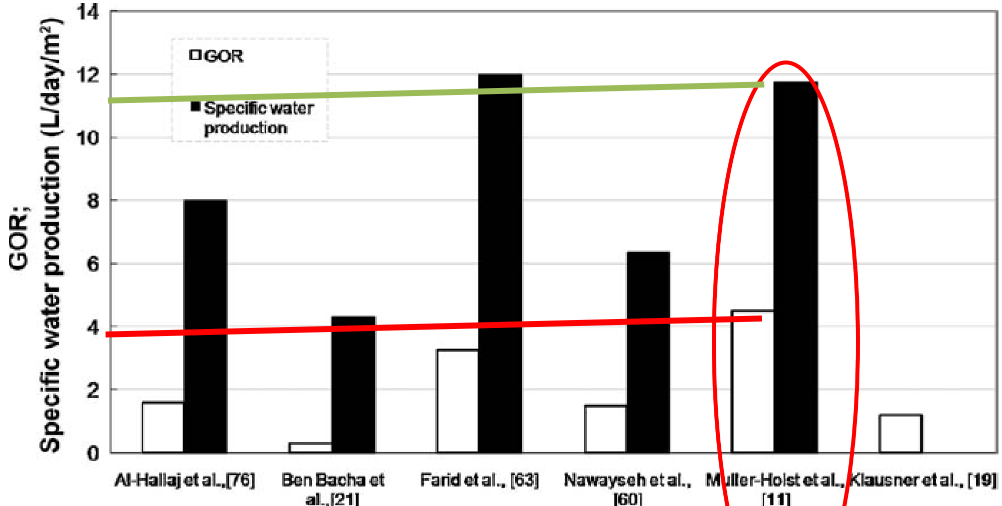
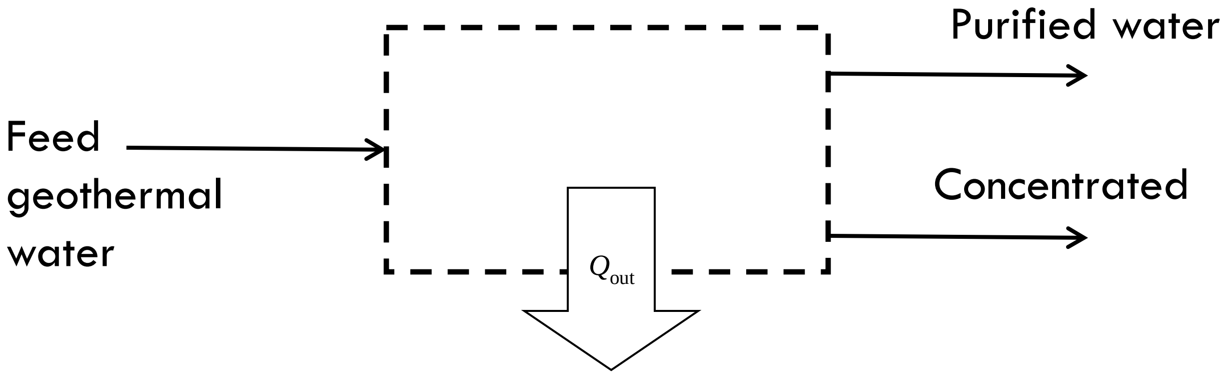


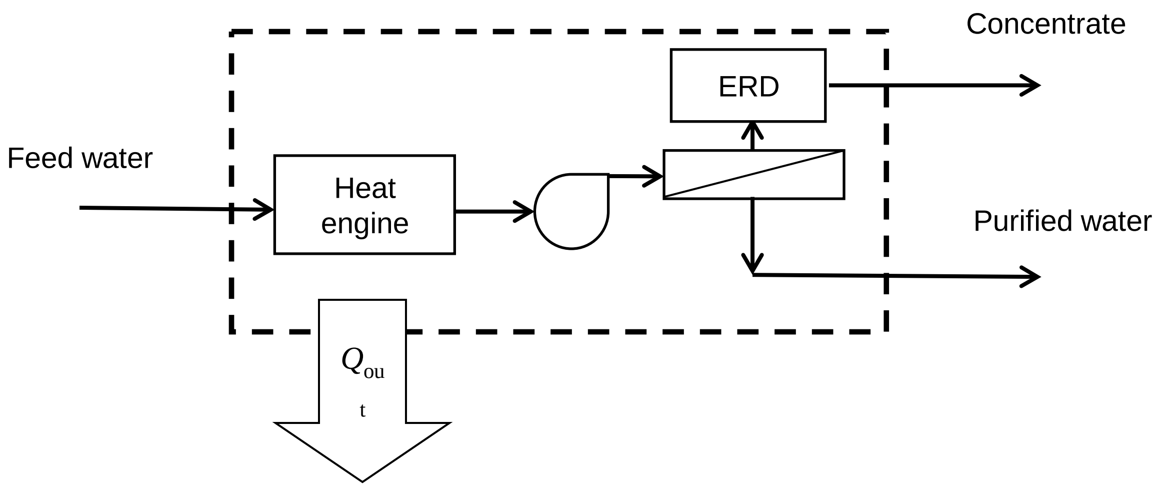
Fig. 6. Performance parameters for various works on water-heated CAOW HDH cycle.

G.P. Narayan et al. / Renewable and Sustainable Energy Reviews 14 (2010) 1187–1

Geothermal desalination

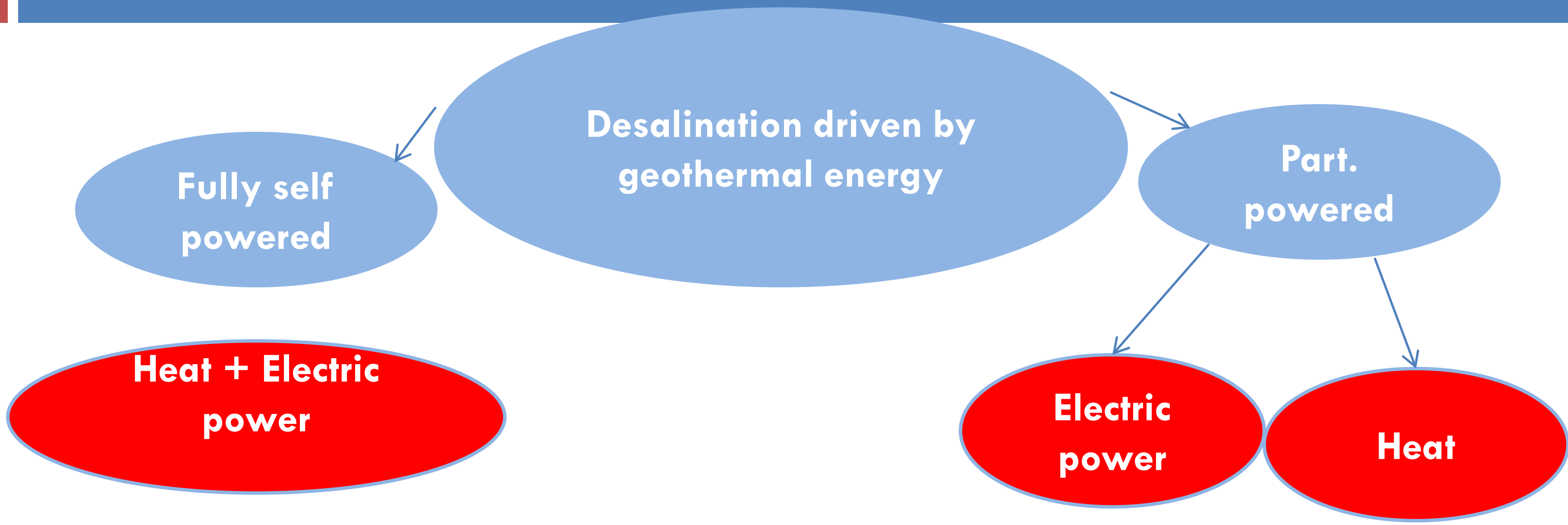


Self-powered geothermal desalination plant represented as a control volume that includes geothermal energy conversion and desalination equipment



$$\dot{W}_t = \dot{m}_w c_p \left[(T_{win} - T_0) - T_0 \ln\left(\frac{T_{win}}{T_0}\right) \right] = \dot{W}_{min}$$

Geothermal desalination: various combinations



- **RO-ORC**
- MD
- **Integrated MD- RO (ORC)**
- HDH
- **MED-TVC**

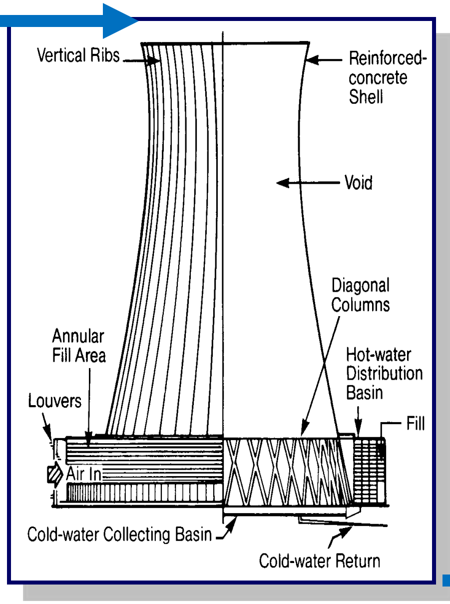
- RO
- ED
-

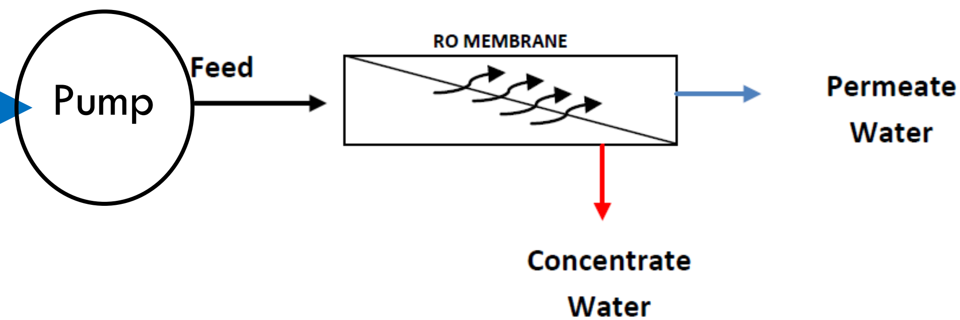
- **RO (External sourc**
for electricity)
- **MED-TVC**
- MD
- Integrated MD- RO
- HDH

Geothermal desalination

Geothermal water,
70 C,
Flow rate:

Salbukh wells



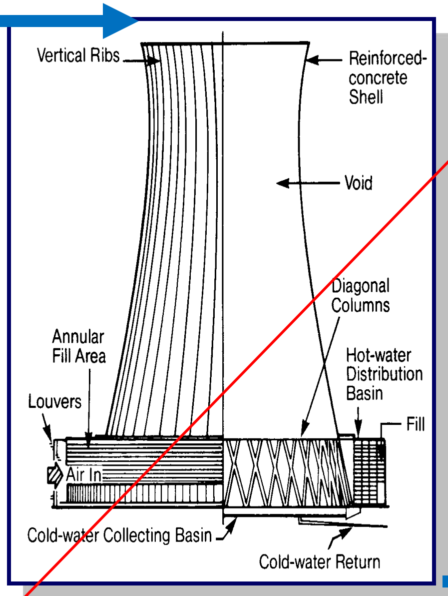


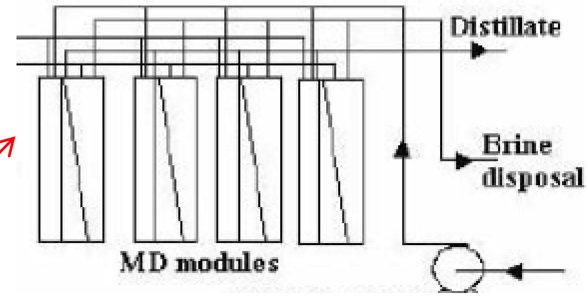
Cooled water, less than 35 C

Waste heat: can be used ?

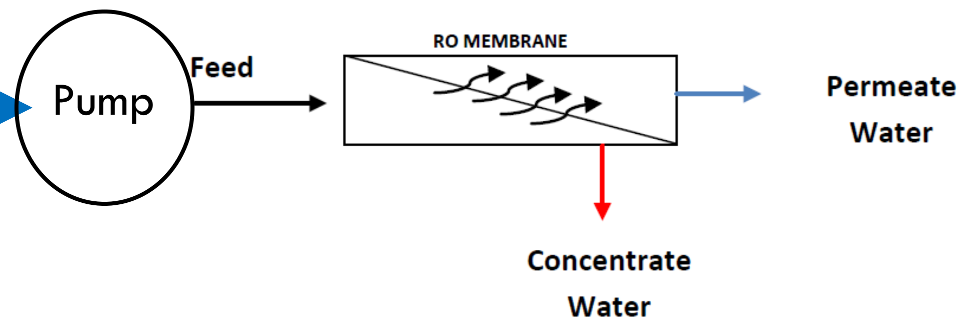
Geothermal desalination

Geothermal water,
70 C,
Flow rate:





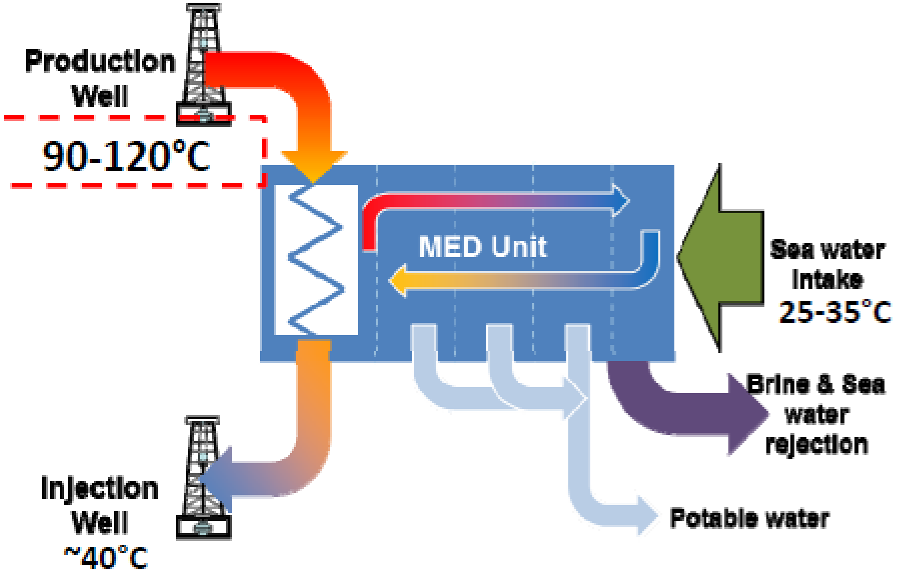
Cooled water, less than 35 C



Desalination technology

Two proven technologies can be combined:
Geothermal heat and MED process

Characteristics of MED desalination	
Inlet temperatures	100-70°C
Process temperatures	50-70°C
Electrical load	1-2 kWe /m³
Thermal load	60-80 kWth/m³
Unit Capacities	600-70,000 m³/ day



Examples:

1- Milos Island in Greece

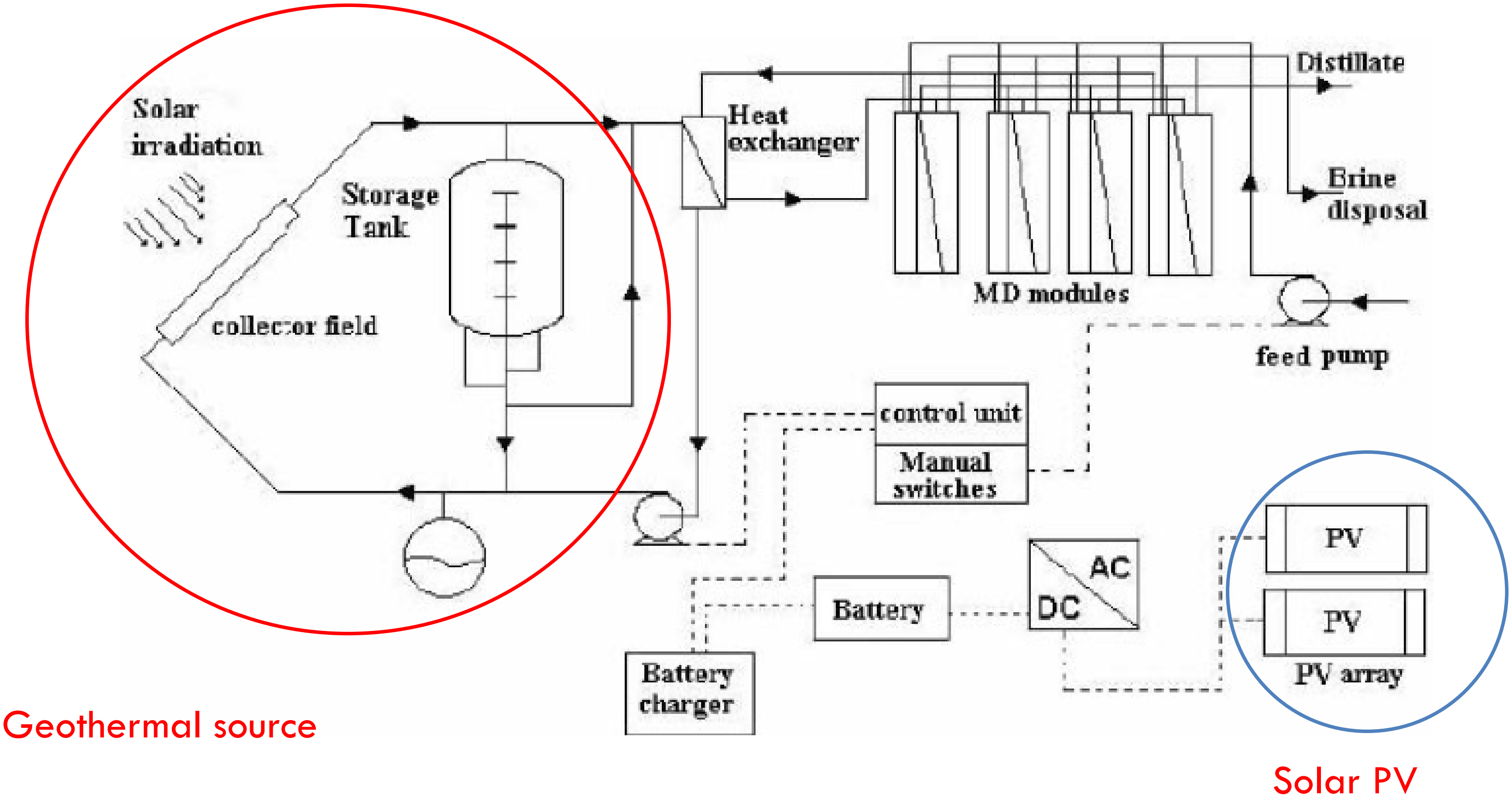
2- a pilot geothermal MED plant producing 80 m³/day was installed in Kimolos Island, operating at 61°C with a 2-stage MED unit. Geothermal sources with temperatures of 80–100°C.

- Acceptable costs

Source:

RG-TES and Saad, Mohammad Amin (2012)

Geothermal desalination



From Banat et al. Desalination, 2007

Conclusion

•Low enthalpy geothermal resources in KSA are important

• they could be matched effectively with existing/promising desalination processes (RO, MED, MD)

But

•Missing exploration hinders the utilization of this sustainable energy.

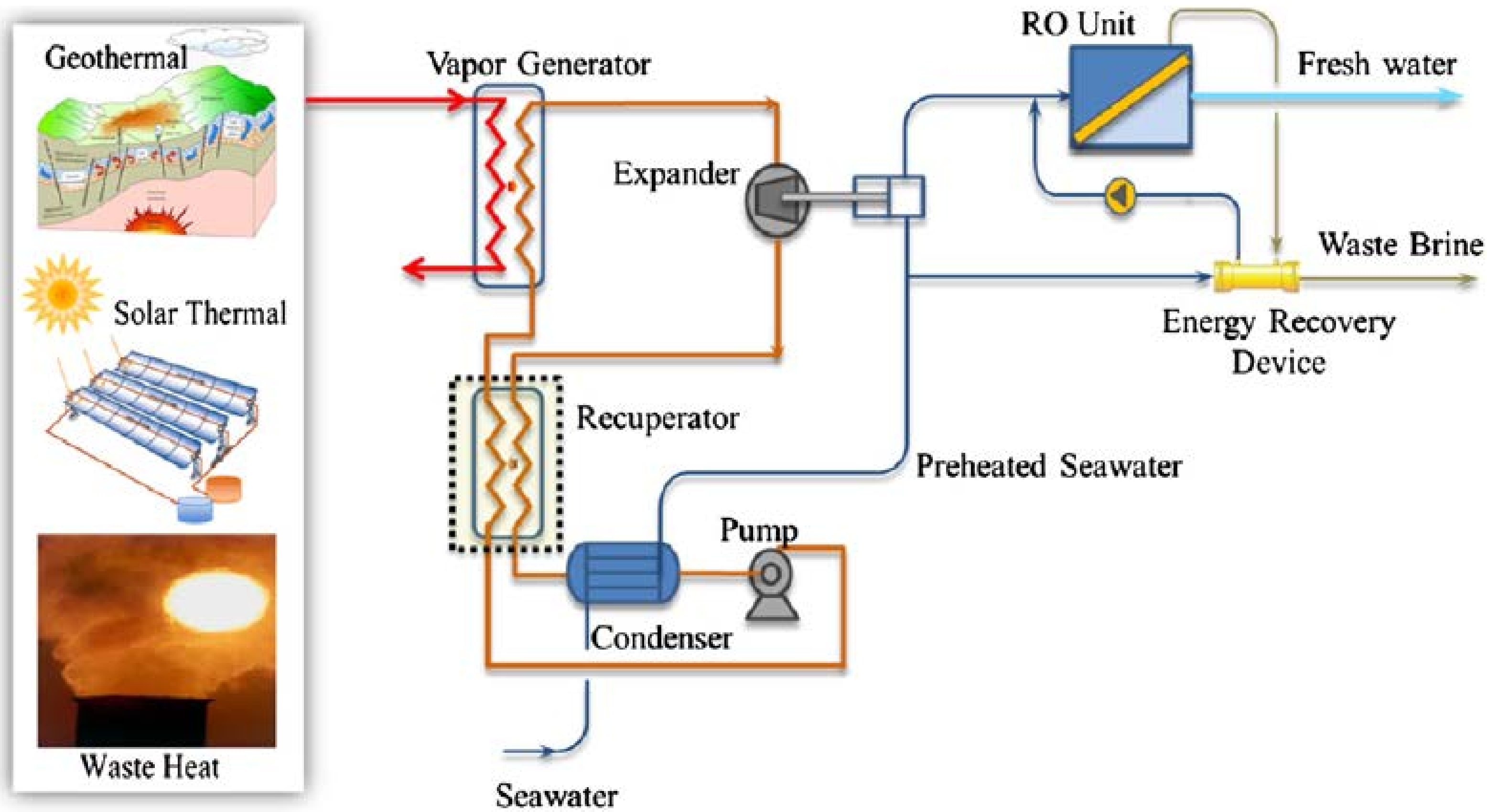
•More investigations:

- On perfect matching between Geothermal/Desalination Technologies.
- On treatment Technologies;

•The economics of geothermal desalination should be undertaken

The region could benefit from the use of geothermal energy

Other configurations



C. Li et al. / Applied Energy 102 (2013) 1071–1080