IRENA
International Renewable Energy Agency

CEREEC ECREEE

Alliance for Rural Electrification
Shining a Light for Progress

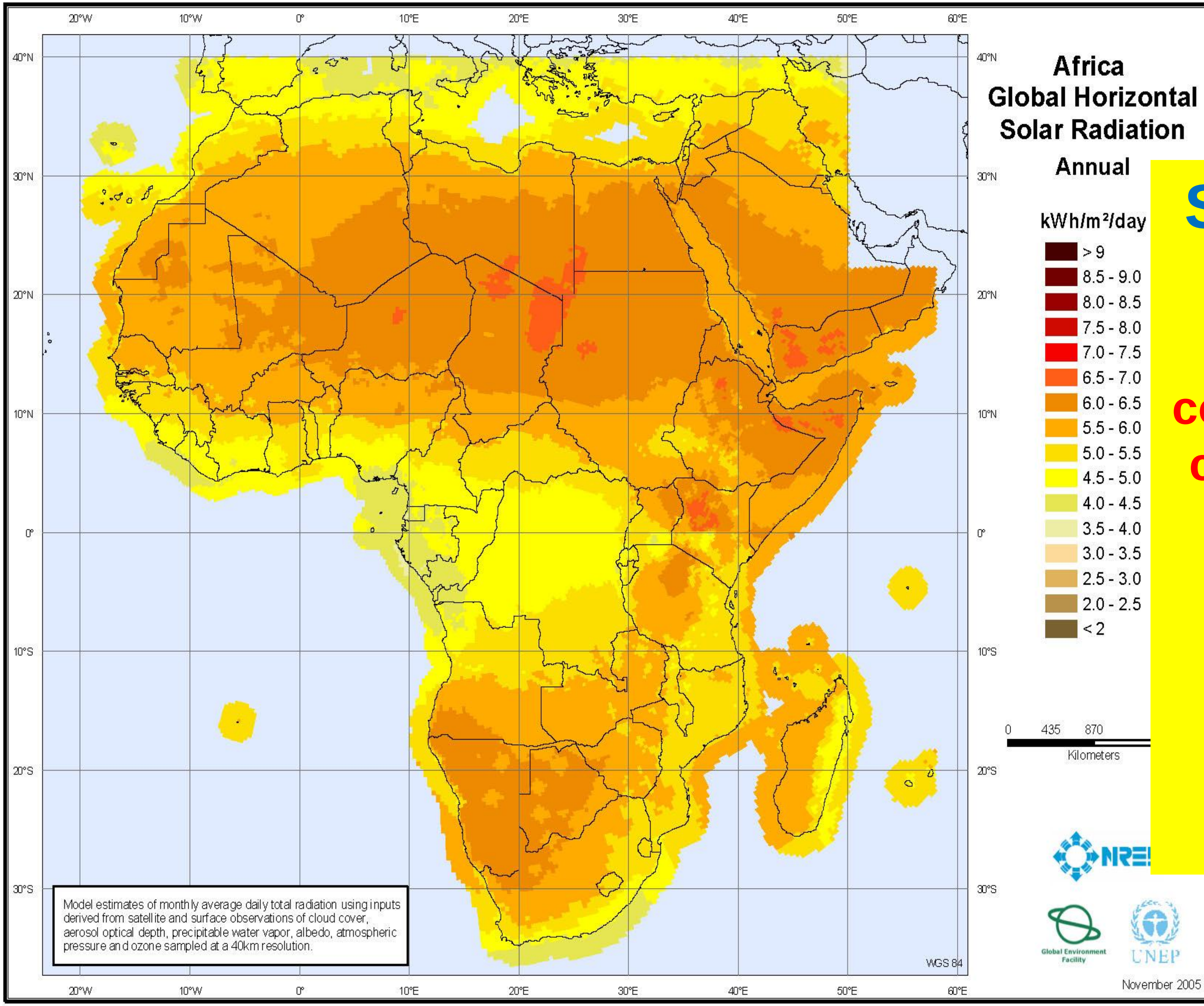
International Off-Grid Renewable Energy Conference

November 1-2 2012
International Conference Centre, Accra, Ghana

Renewable Energy for Desalination

Source: Gerindtec (India)

Dr. Jürgen Rheinländer – Solar Thermal Power Adviser - Germany



Solar GHI

utilized for <u>non</u>-concentrating collection of irradiance

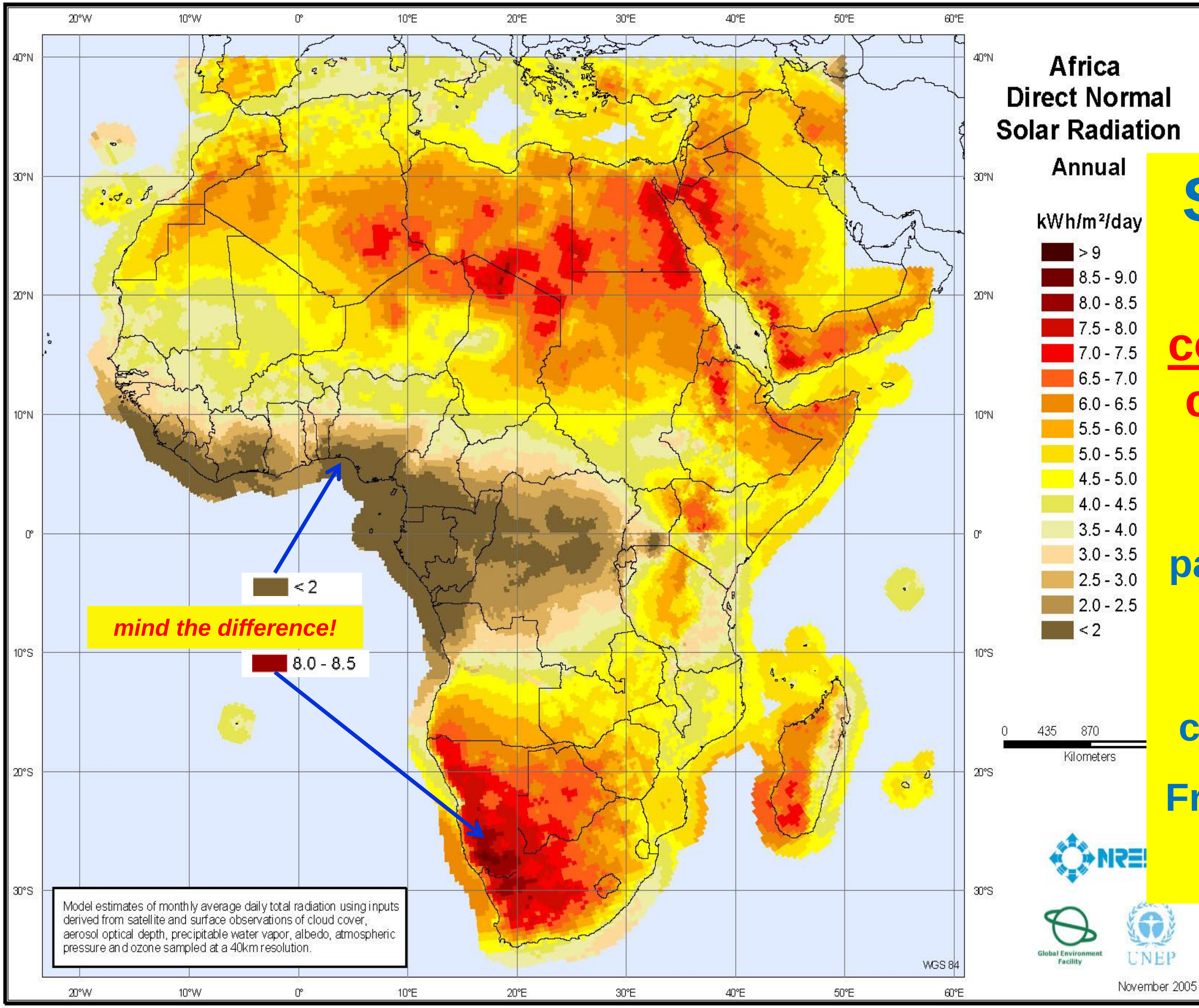
➔

PV

FPC

ETC

Solar still



Solar DNI

utilized for <u>concentrating</u> collection of irradiance

➔

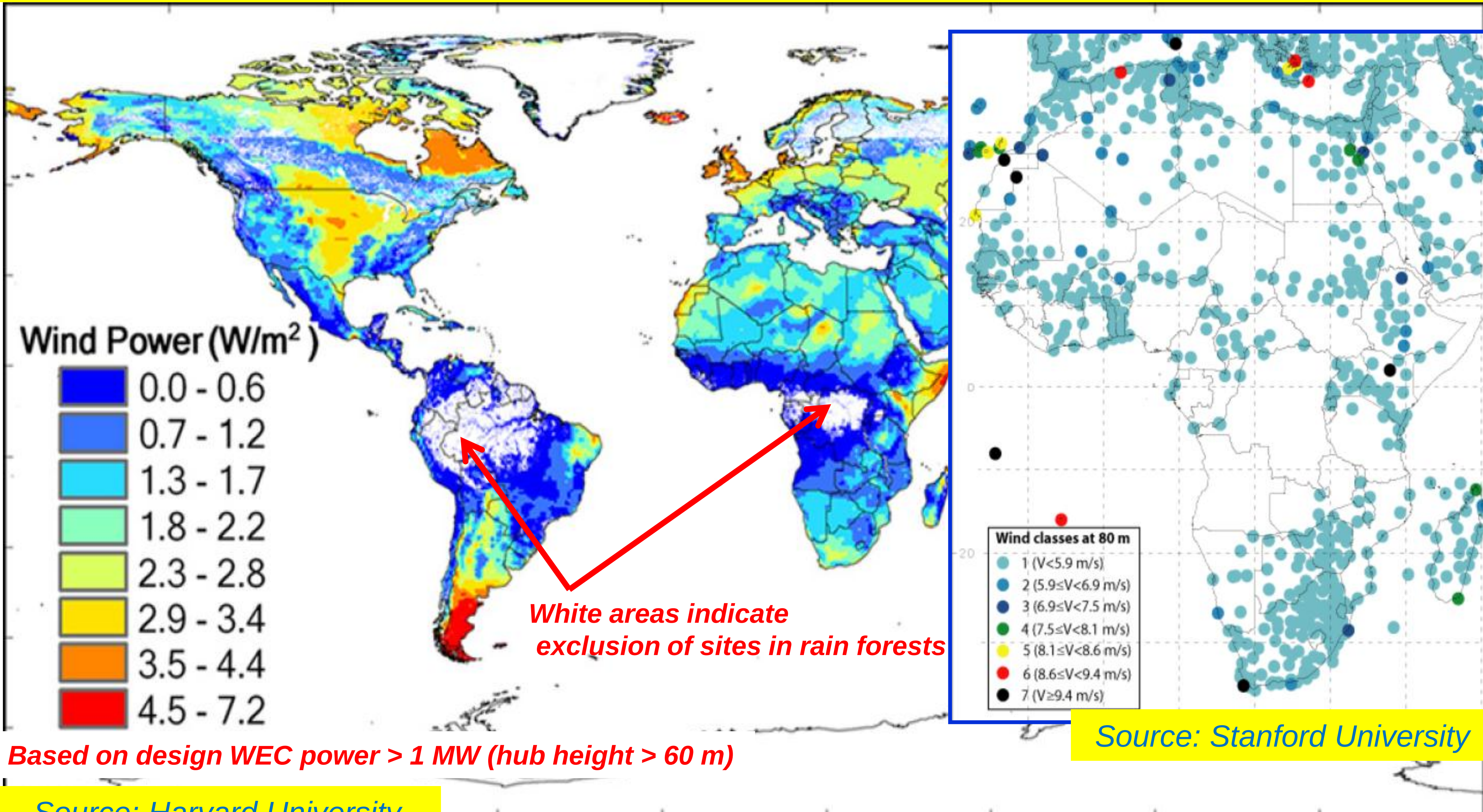
parabolic trough and dish

heliostat + central receiver

Fresnel-collector

CPV

Annual Average Wind Power Potential



Source: Stanford University

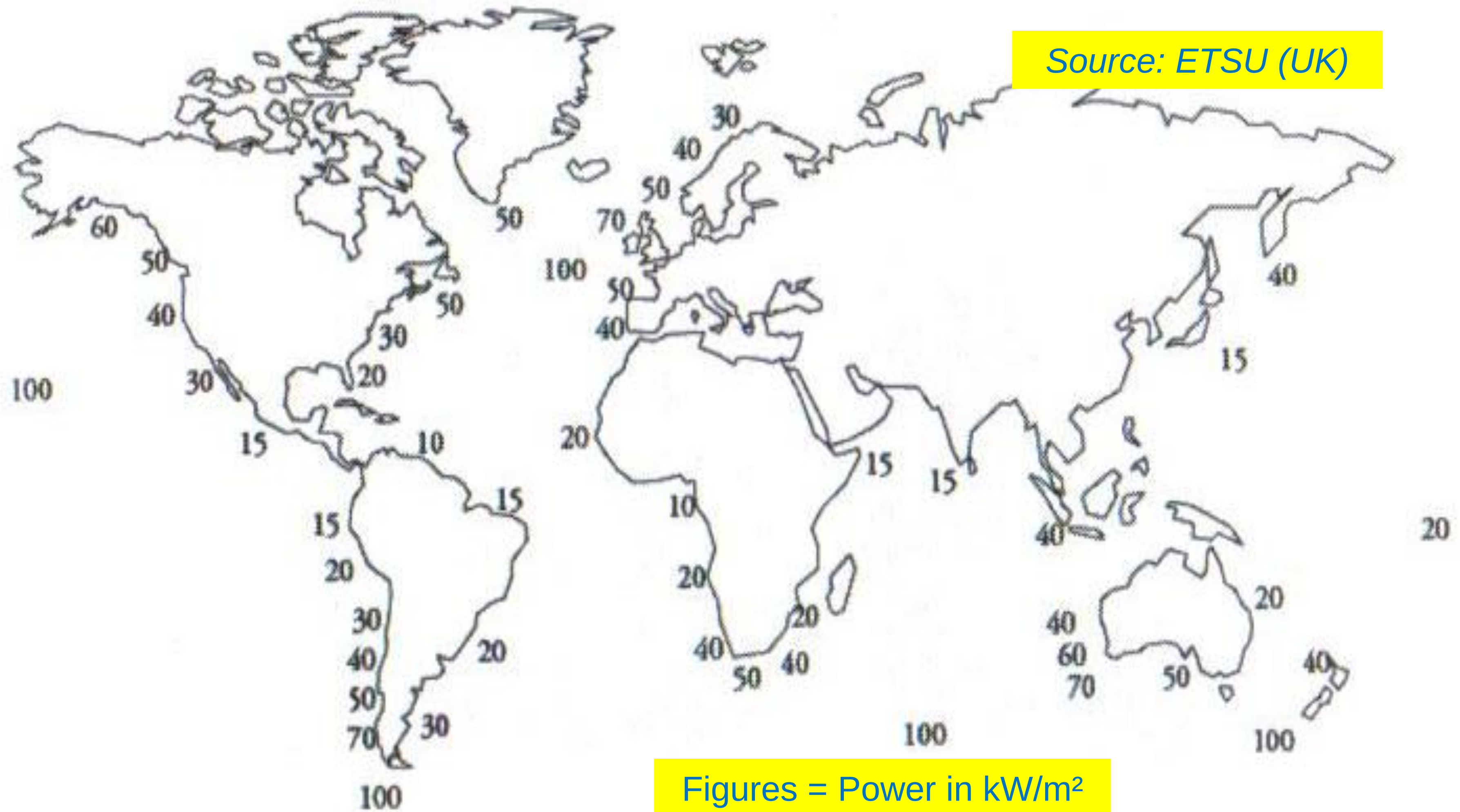
Based on design WEC power > 1 MW (hub height > 60 m)

Source: Harvard University

➔ *The tropical belt is <u>not really promising</u> for wind power utilization!*

Annual Average Wave Power Levels

Source: ETSU (UK)

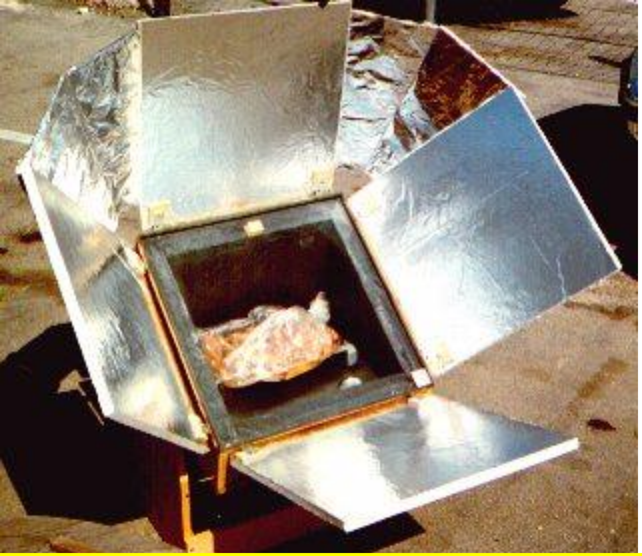


Figures = Power in kW/m²

The tropical belt is <u>not promising</u> for wave power utilization!

Solar Water Pasteurization

in solar cookers at end user’s place



Source: www.cookwiththesun.com

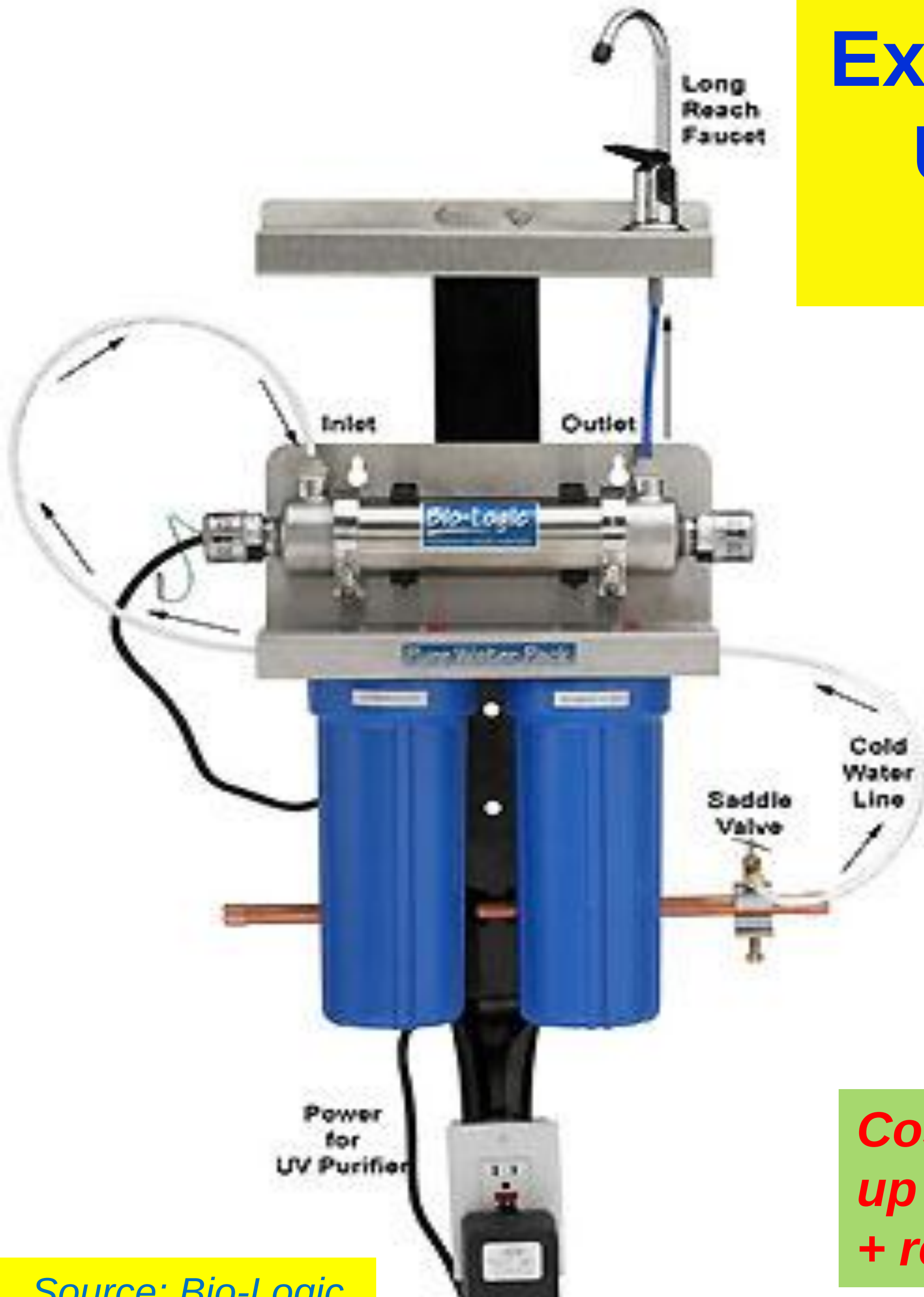
Large potential for local manufacturing in developing countries

Water can be pasteurized at temperatures well below boiling, as can milk, which is commonly pasteurized at 71°C (160°F) for 15 seconds

Source: Punjab energy development agency (India)

Source: www.atlascuisinesolaire.com

Example for Combination of UV water purification with dual cartridge filter



UV water purifier utilizes a germicidal short wave radiation lethal to microorganisms.

sediment filter (5 micron) cartridge removes suspended particles.

carbon filter (5 micron) cartridge removes volatile organic hydrocarbons.

Flow Rate (30mJ/cm2 Dose): 340 l/h

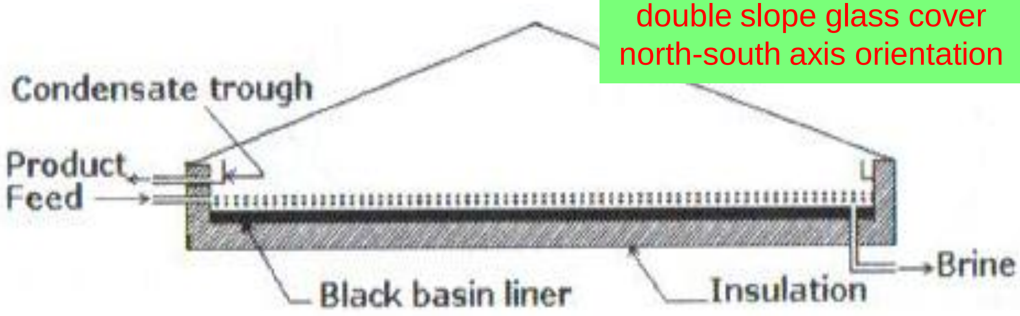
Operating Pressure Range: max. 7 bar

Reactor Material: Stainless Steel

Cost (without PV power generator):
up to 600 US$ (version for 12 V DC)
+ regular replacement of cartridges & lamp

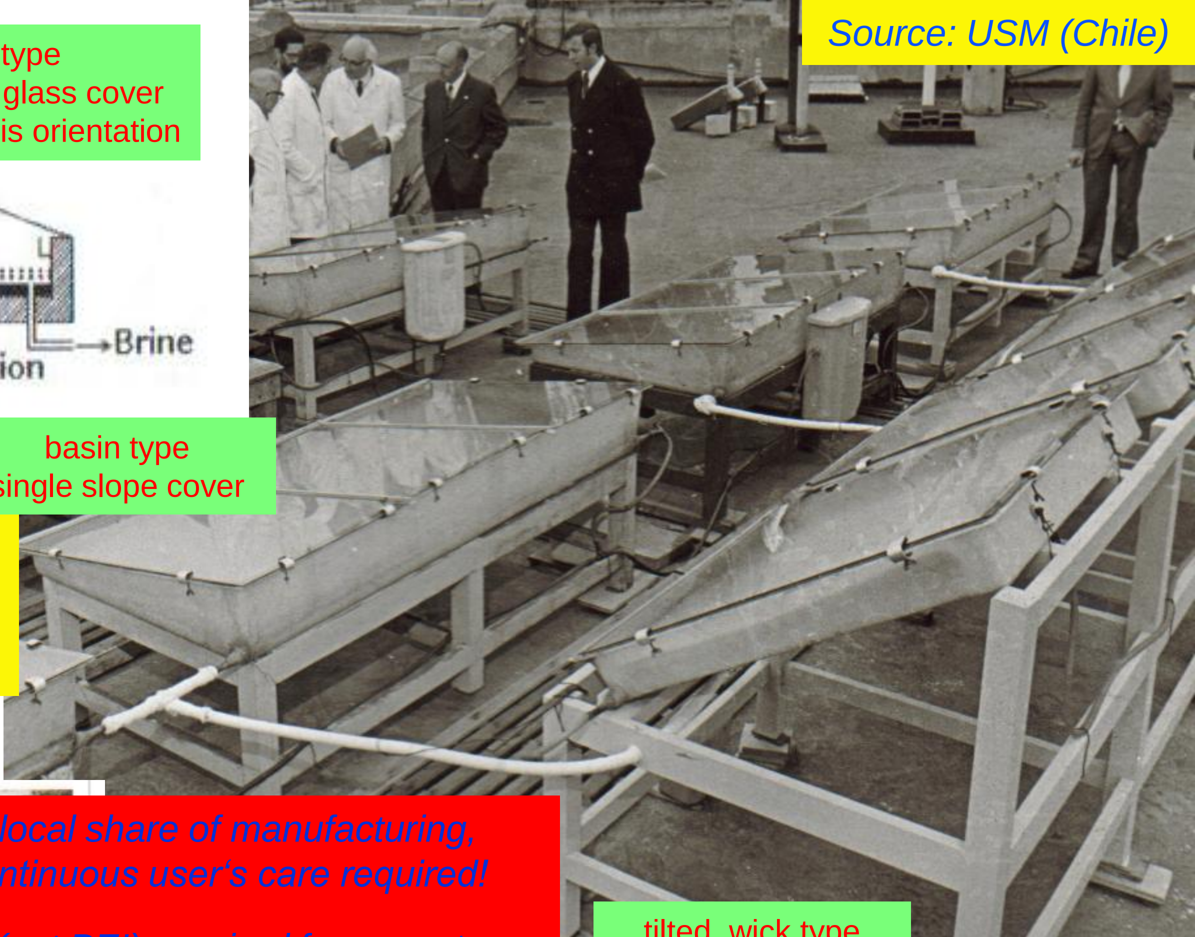
Source: Bio-Logic

Source: Chaibi and El-Nashar



basin type
double slope glass cover
north-south axis orientation

Source: USM (Chile)



basin type
single slope cover

Solar Still (one effect)

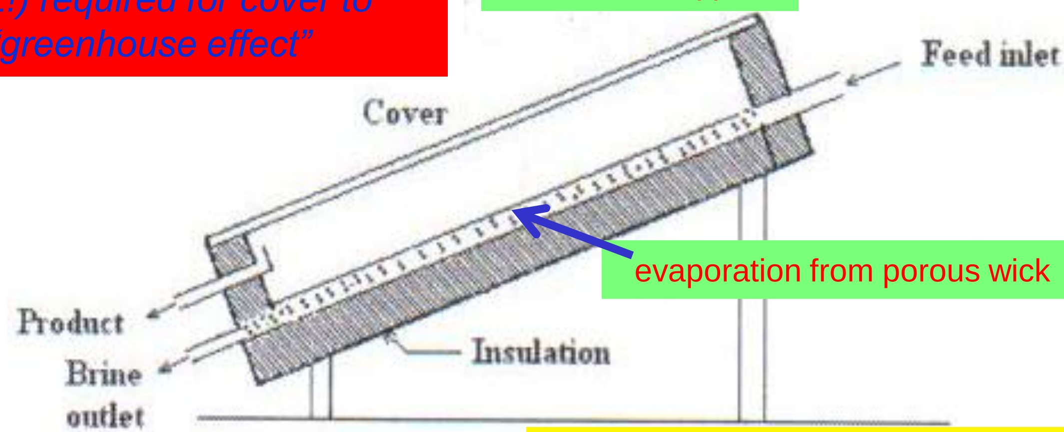
up to 6 liters/m²/day

1872 first plant in northern Chile for 22 m³/day
40 years of operation at mining site

large local share of manufacturing, but continuous user's care required!

glass (not PE!) required for cover to achieve "greenhouse effect"

tilted wick type



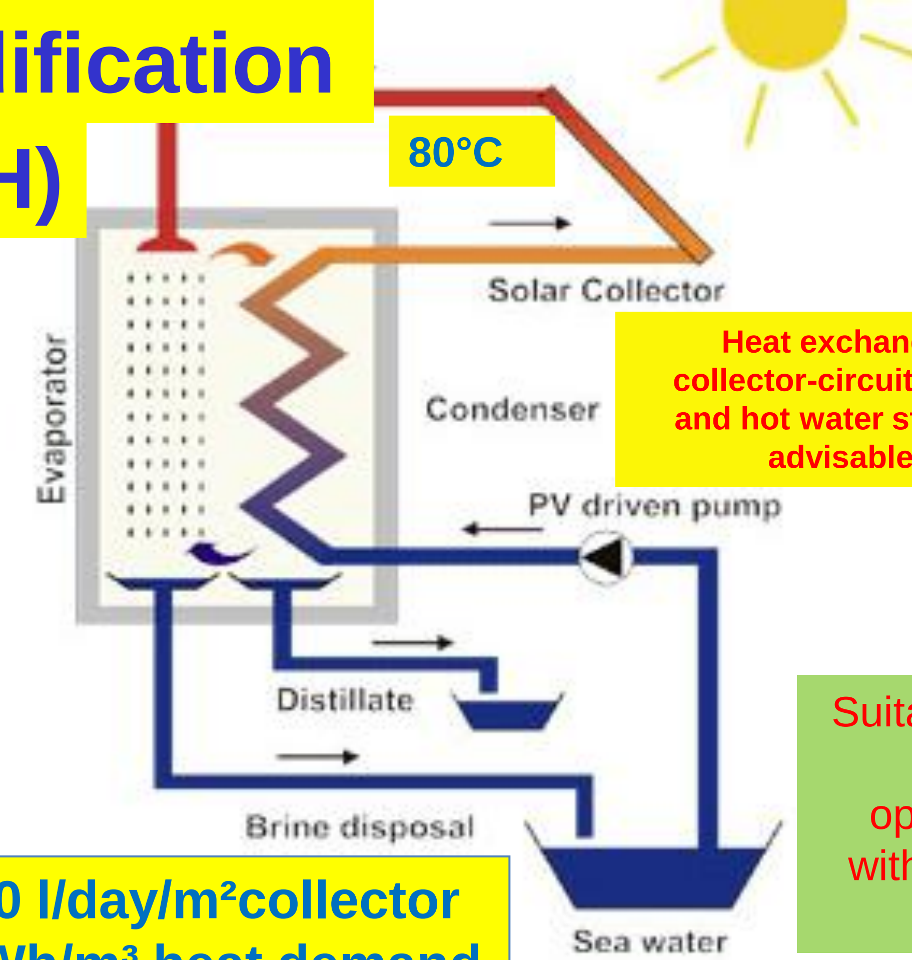
evaporation from porous wick

Source: USM (Chile)

Source: Chaibi and El-Nashar

Humidification-Dehumidification (HDH)

Pilot plant Oman - 1 m³/day



80°C

Heat exchanger collector-circuit / brine and hot water storage advisable

Suitable for hybrid operation with waste heat

up to 30 l/day/m²collector
~ 120 kWh/m³ heat demand

Source: MAGE Water Management GmbH

PV for power

Flat plate collectors for heat

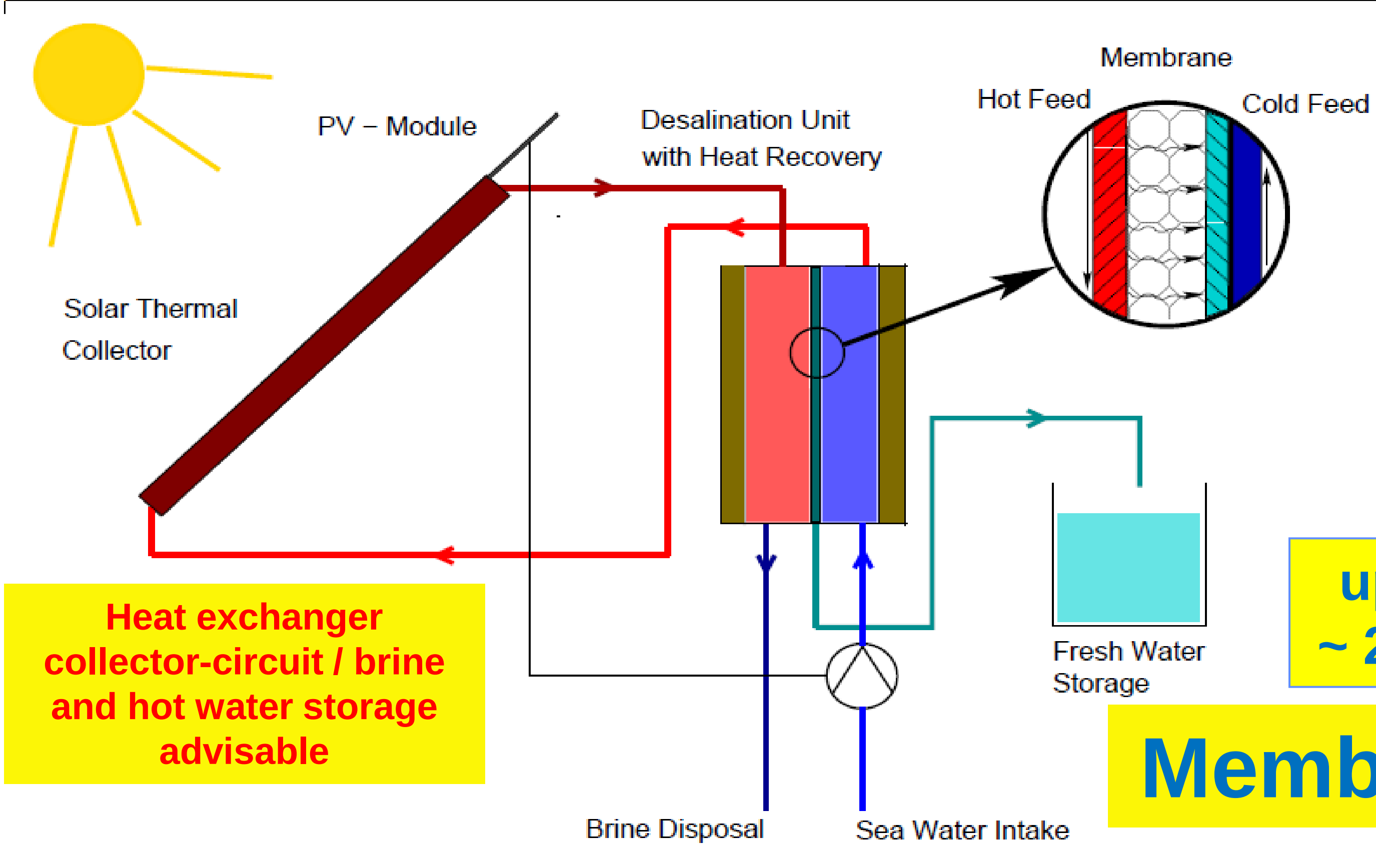
Commercial plant - 5 m³/day

Membrane Distillation (MD)

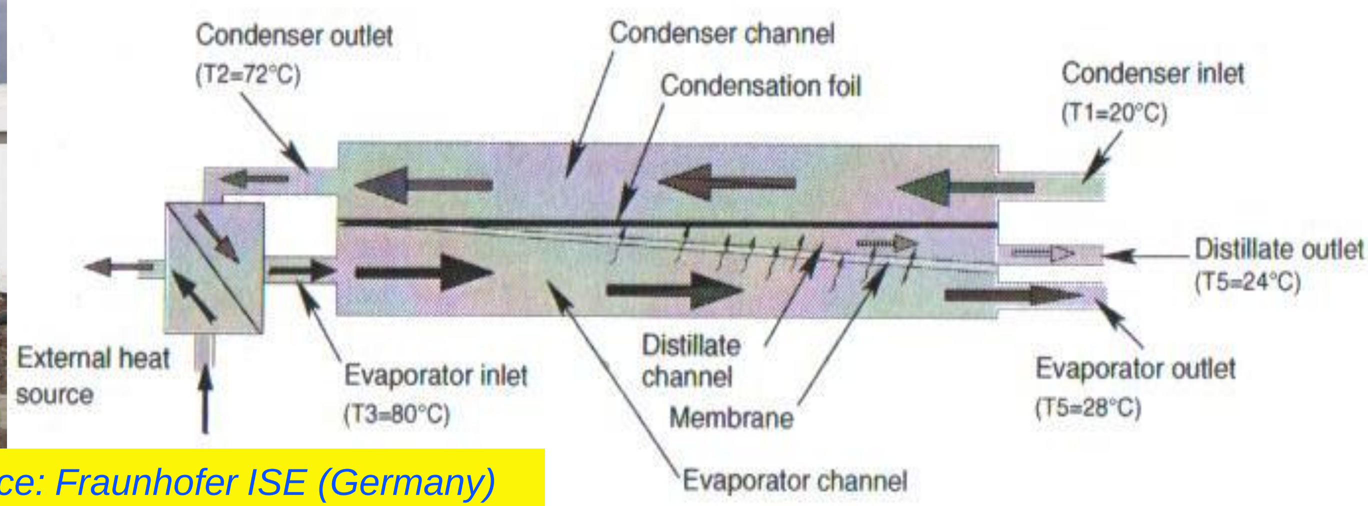
Pilot plants up to 2 m³/day in operation

Suitable for hybrid operation with waste heat

up to 20 l/day/m²collector
~ 200 kWh/m³ heat demand



Heat exchanger collector-circuit / brine and hot water storage advisable



Source: Fraunhofer ISE (Germany)

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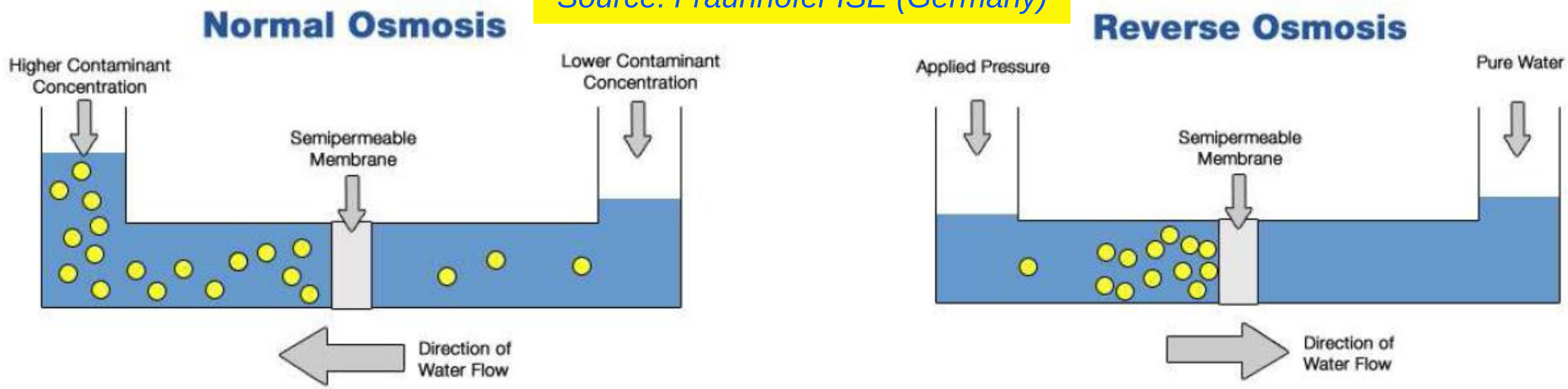
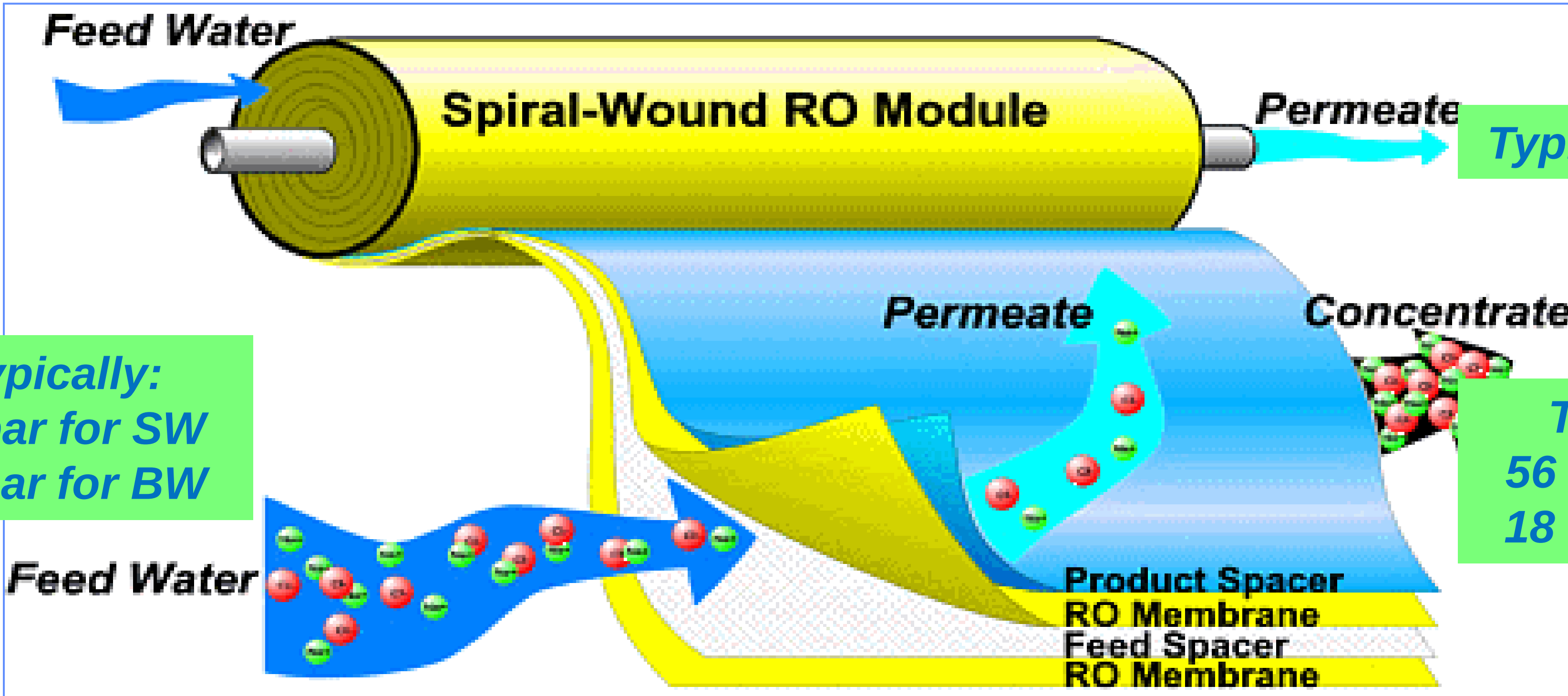


Reverse Osmosis (RO)

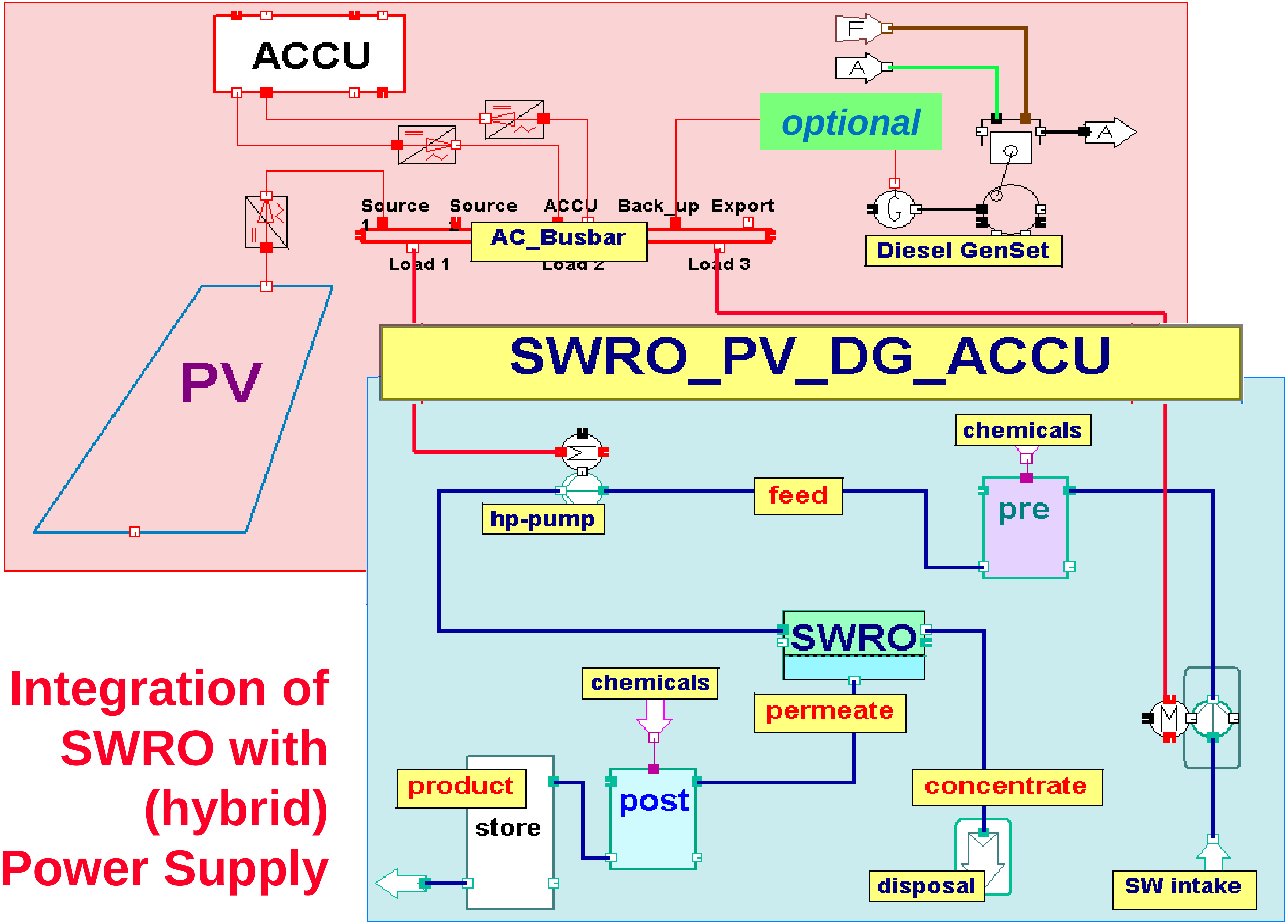


Typically: 2 bar

Typically:
60 bar for SW
20 bar for BW

Typically:
56 bar for SW
18 bar for BW

Source: IONICS (USA)



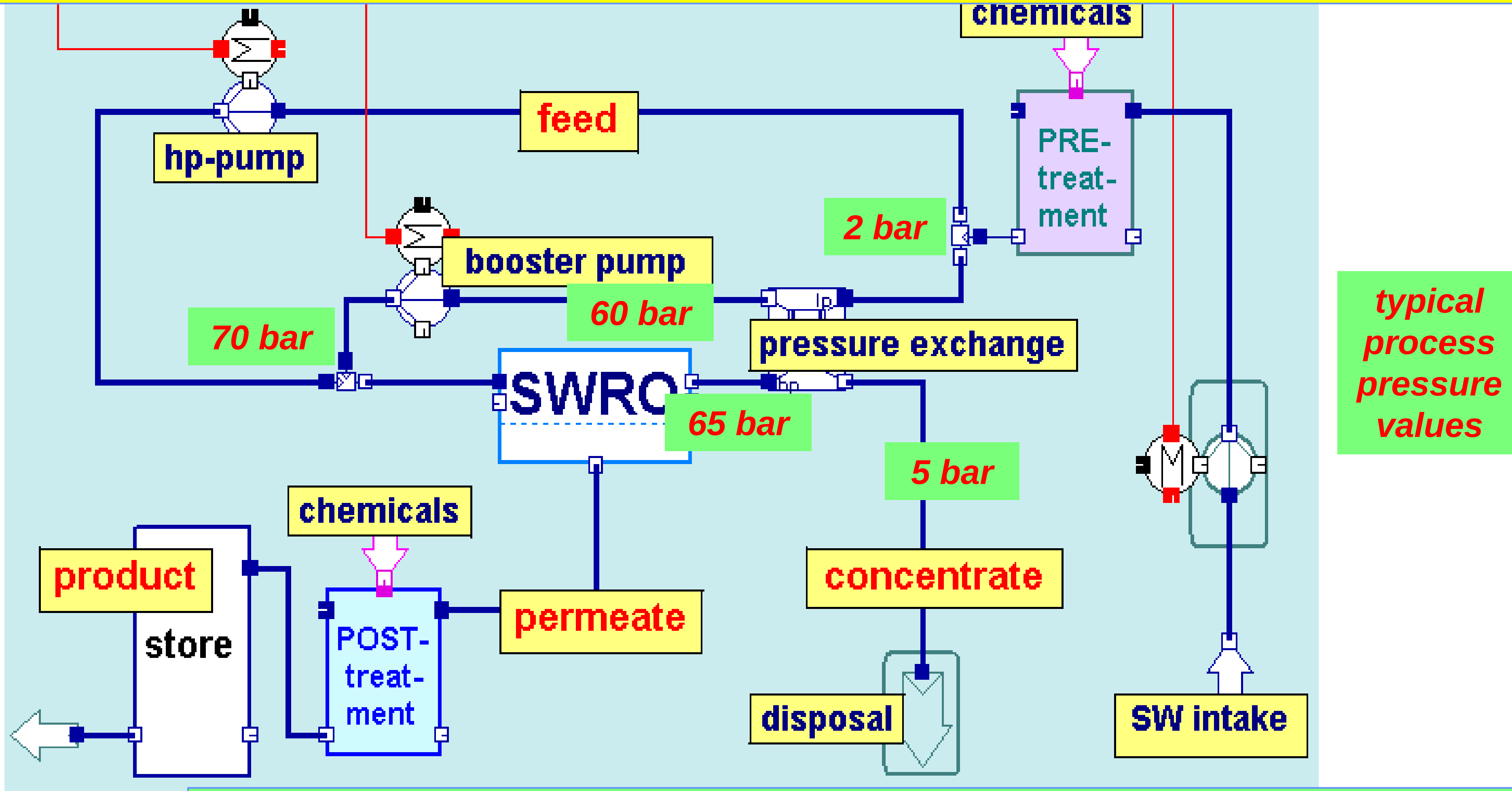
Integration of SWRO with (hybrid) Power Supply

PV for BWRO at Aqaba (Jordan)

50 m³/day
PV+Grid

Source: NERC (Jordan)

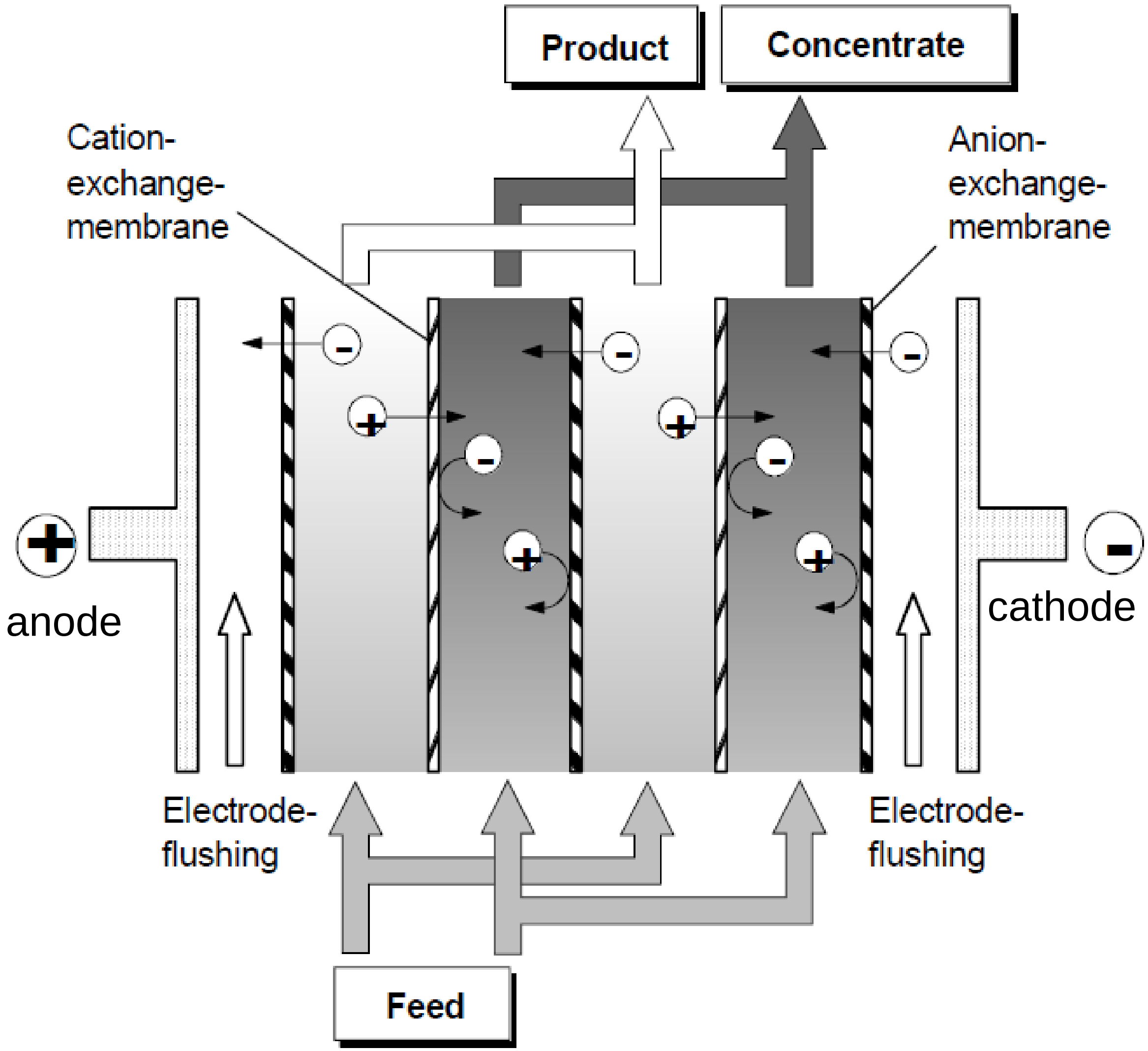
SWRO: Power Recovery from Concentrate



With SWRO reduction of power demand by 30 to 60% through:

- ***Pelton turbine on HP-pump shaft (>10 m³/h), conventional)***
- ***Pressure Exchanger (>2 m³/h), ERI, ENERCON a.o.)***
- ***Axial Piston Motor (>0.2 m³/h), Danfoss A/S***
- ***Pressure Intensifier (>0.03 m³/h), "Clark pump"***

Electrodialysis Reversal (EDR)



Source: MEDRC report 97-AS-006a

driven by <u>DC power</u> ➔ PV

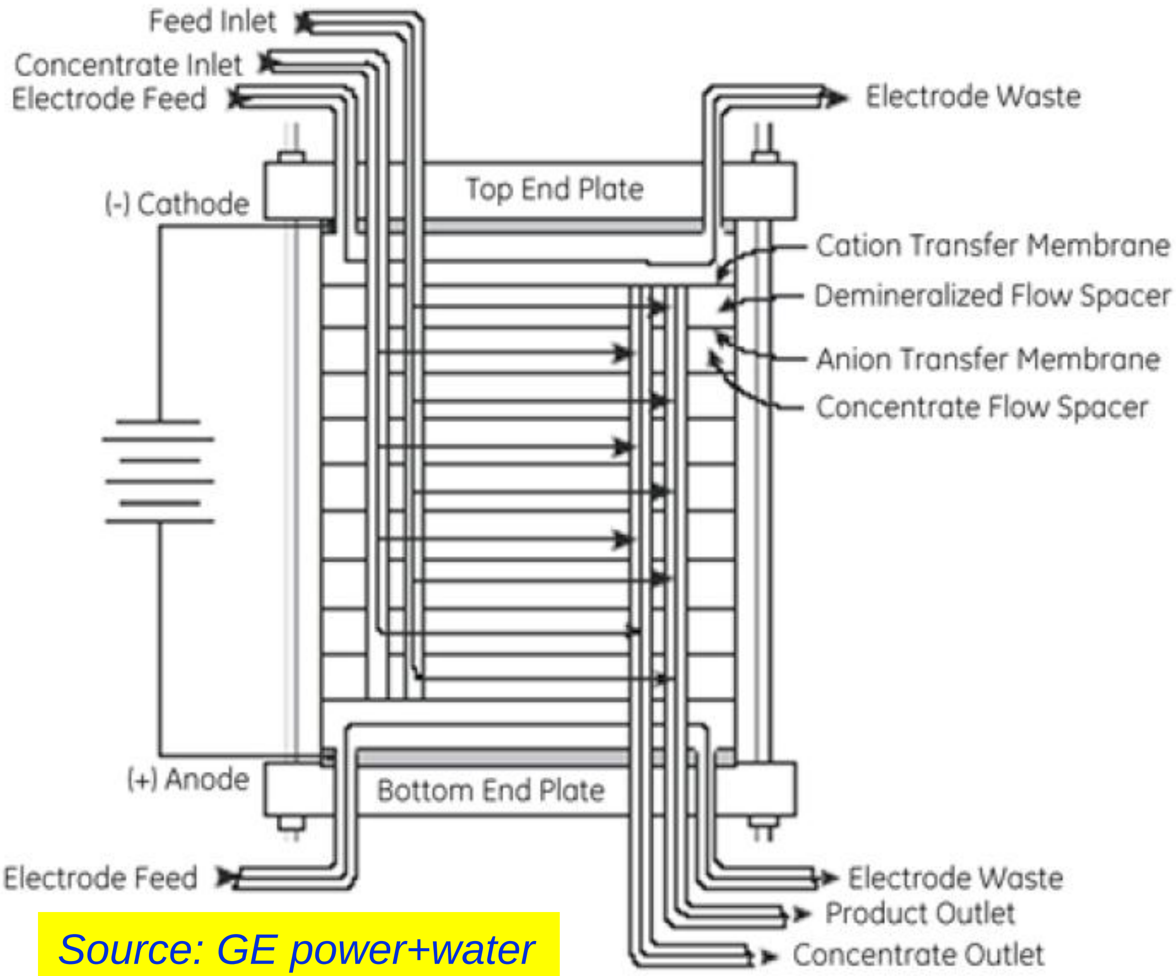
Power demand rises with salinity ➔ <u>brackish water</u> only

Germs are not removed ➔ <u>„clean“ BW</u> only

<u>Reversal of polarity</u> and exchange of product / concentrate paths ➔ reduction of scaling on membranes

Typical dissolved ions:
anions (charge -): Cl, NO_3, SO_4
cations (charge +): Na, K, Ca

EDR - Stack



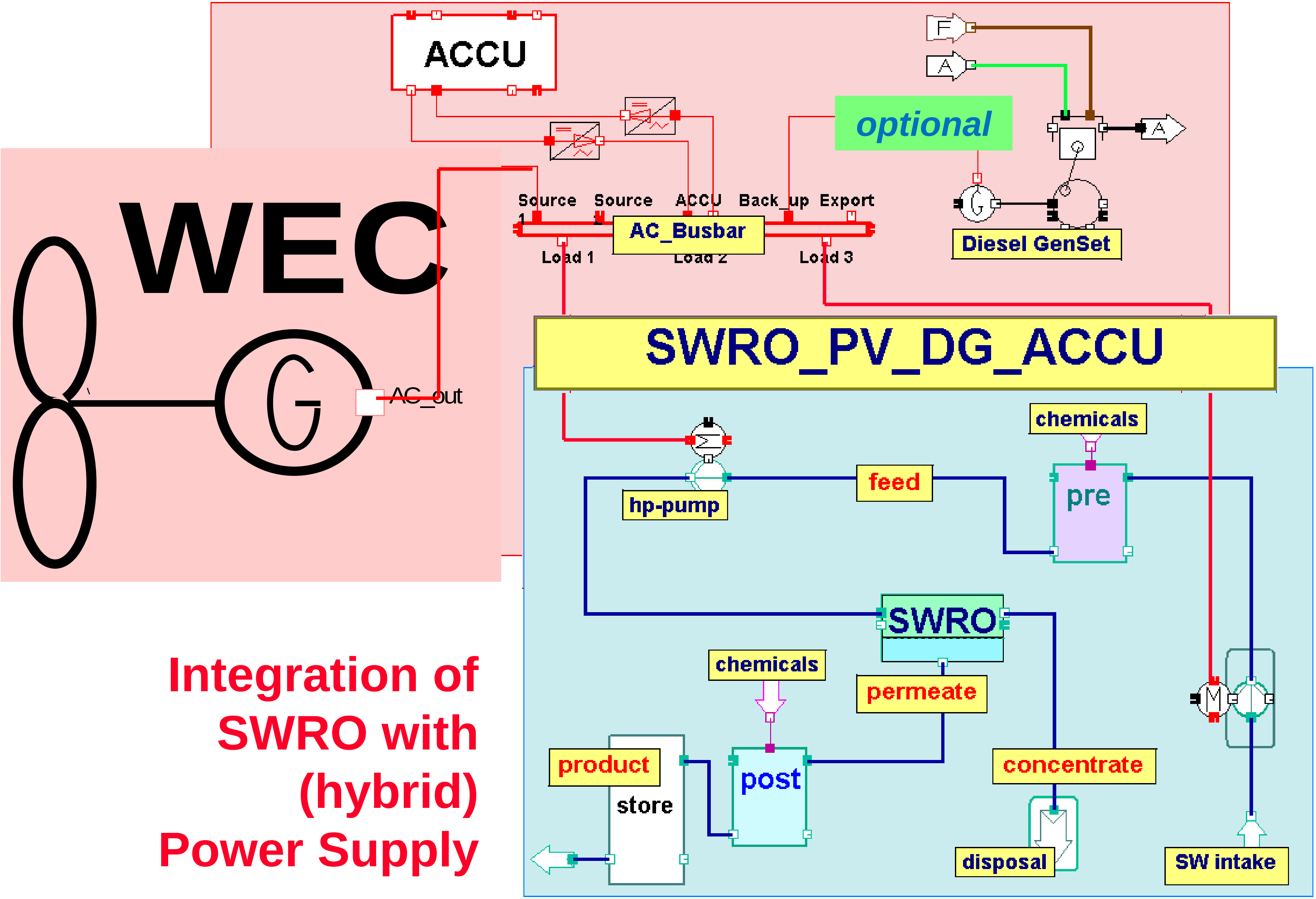
Source: GE power+water

Source: pca-GmbH

Source: ARCADIS G&M Inc

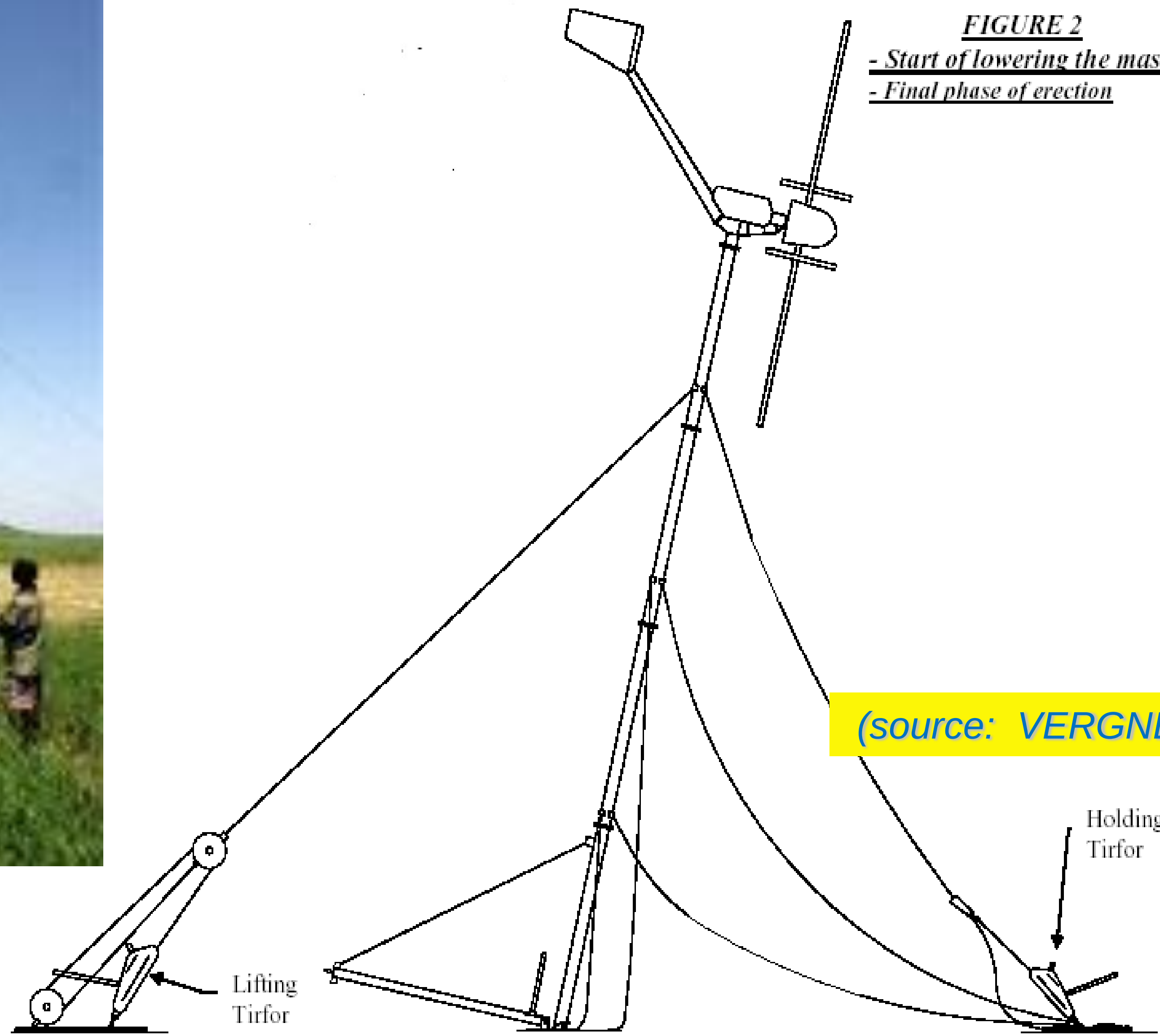
DC power ~ 3 kWh/m^3 (10,000 ppm TDS)

Integration of SWRO with (hybrid) Power Supply



Erection and Lowering of WEC without Large Crane

(source : GTZ)



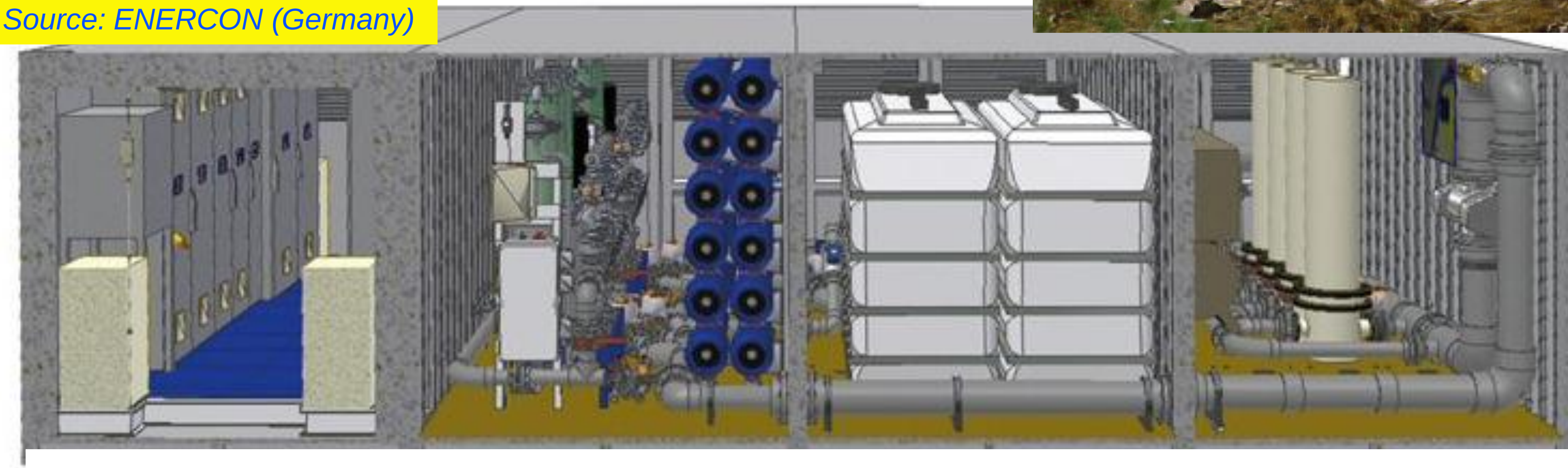
(source: VERGNET)

Source: Canary Islands Institute of Technology

Small PV – wind RO plant all in one container and autonomous

Modular Design of RO Plant

Source: ENERCON (Germany)

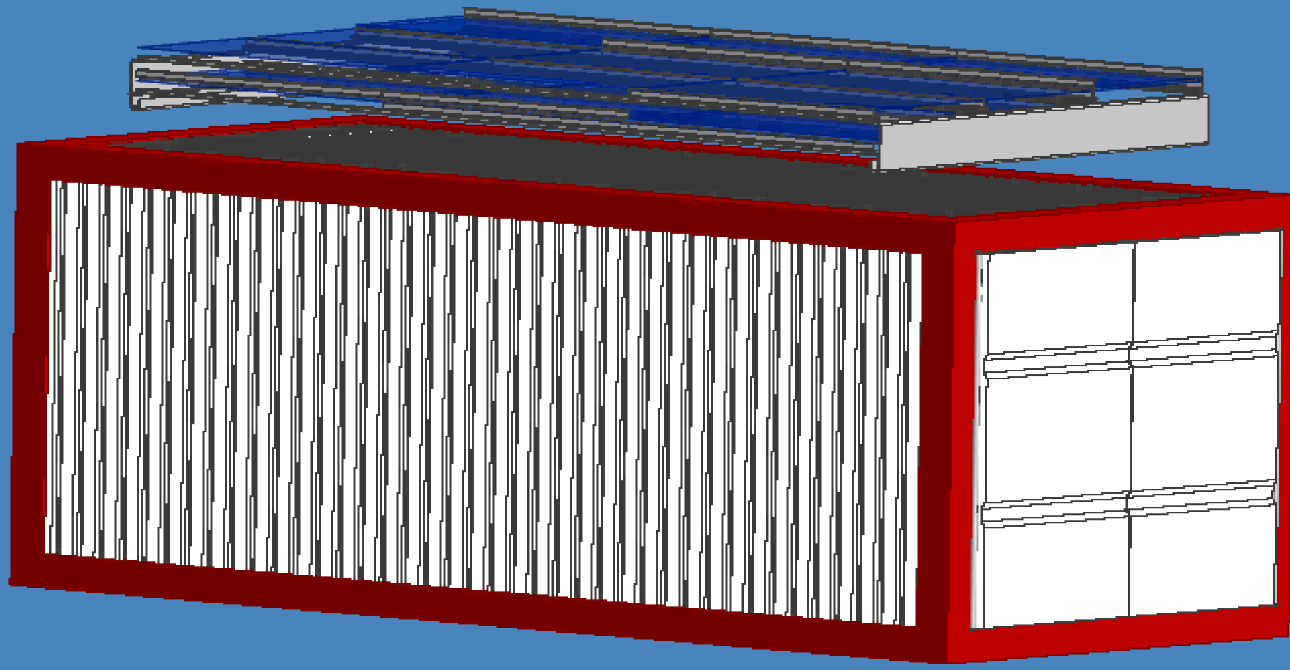


Summary: Renewable Energy for Desalination

	TYPICAL CAPACITY	ENERGY DEMAND	WATER GENERATION COST	TECHNICAL DEVELOPMENT STAGE
SOLAR STILL	< 0.1 m³/d *> 0.1 m³/d feasible*	solar passive *thermal: ~700 kWh/m³*	1–5 €/m³ *Owner's labor not included !*	applications
SOLAR MEH *=Humidification-Dehumidification*	1–100 m³/d	thermal: 100 kWh/m³ electrical: 1.5 kWh/m³	2–5 €/m³ *Owner's labor not included !*	applications/ advanced R&D
SOLAR MD	0.15–10 m³/d	thermal: 150–200 kWh/m³	8–15 €/m³	advanced R&D
PV-RO	< 100 m³/d	electrical: BW: 0.5–1.5 kWh/m³ SW: 4–5 kWh/m³	BW: 5–7 €/m³ SW: 9–12 €/m³	applications/ advanced R&D
PV-EDR	< 100 m³/d	electrical: only BW: 3–4 kWh/m³	BW: 8–9 €/m³	advanced R&D
WIND-RO	50–2,000 m³/d *< 50 m³/d feasible*	electrical: BW: 0.5–1.5 kWh/m³ SW: 4–5 kWh/m³	units under 100 m³/d BW: 3–5 €/m³ SW: 5–7 €/m³ about 1,000 m³/d 1.5–4 €/m³	applications/ advanced R&D

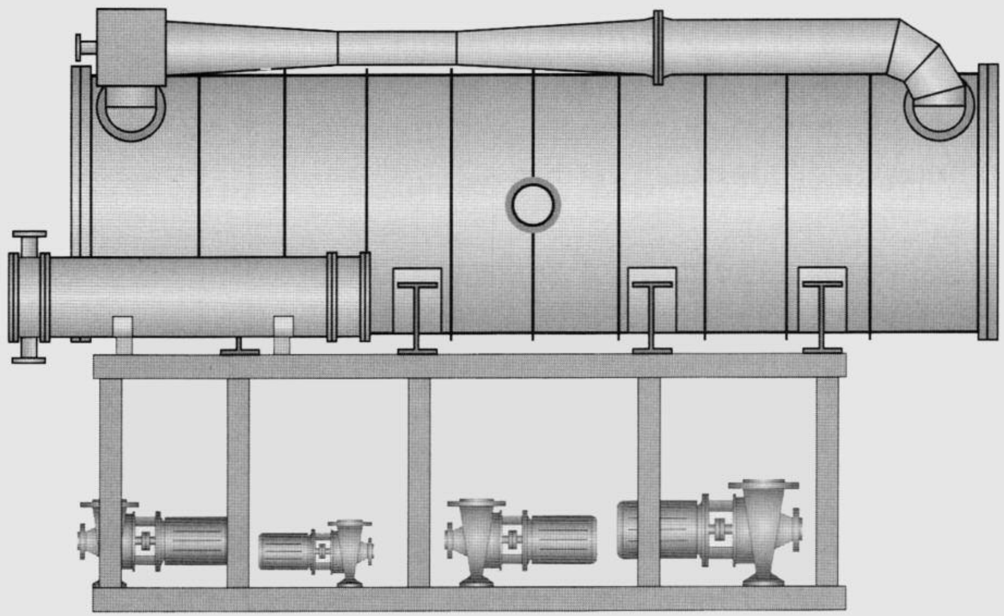
Source: PRODES – Roadmap 2010 (EU) – without remarks in red

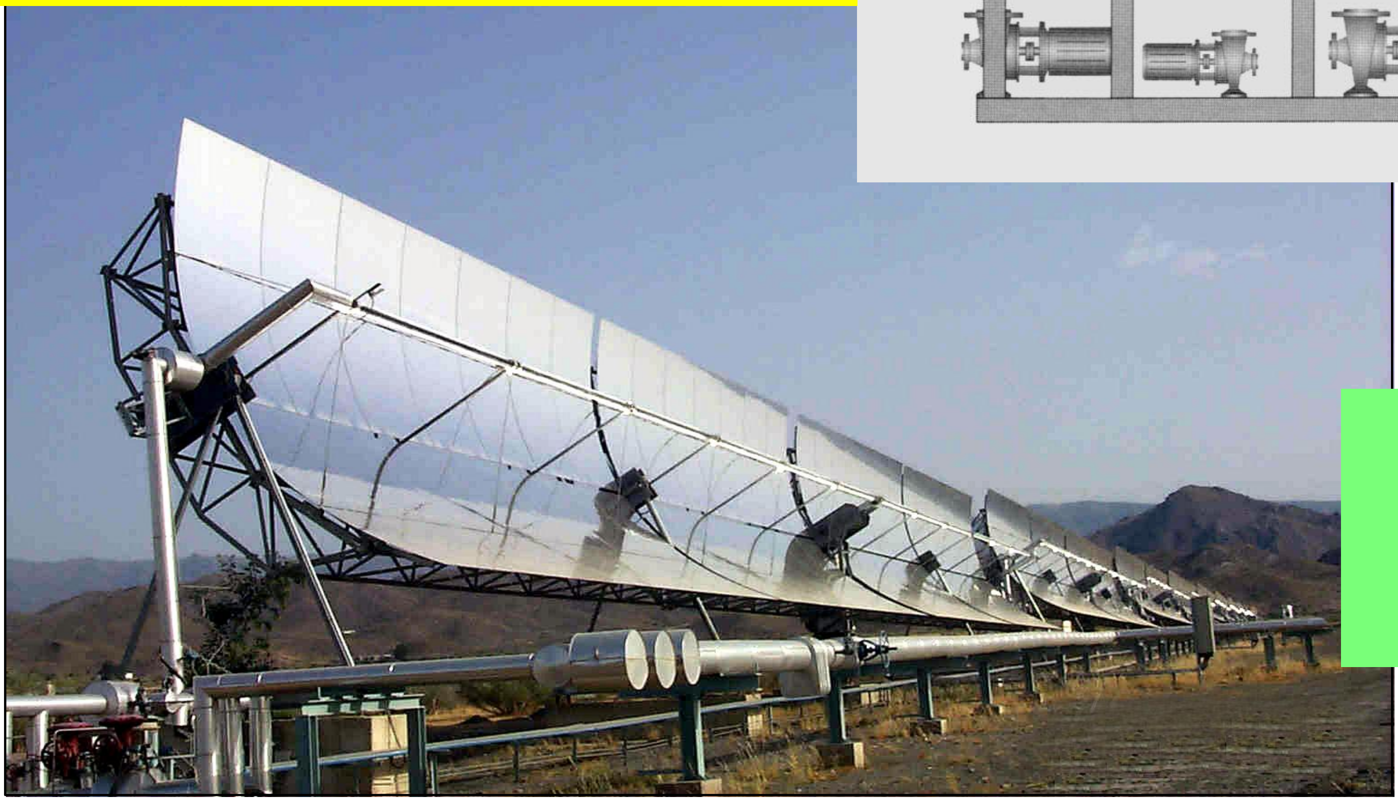
Thank You for Your Attention!



Thermal Vapor Compression Driven by Steam from Solar Parabolic Trough Collectors

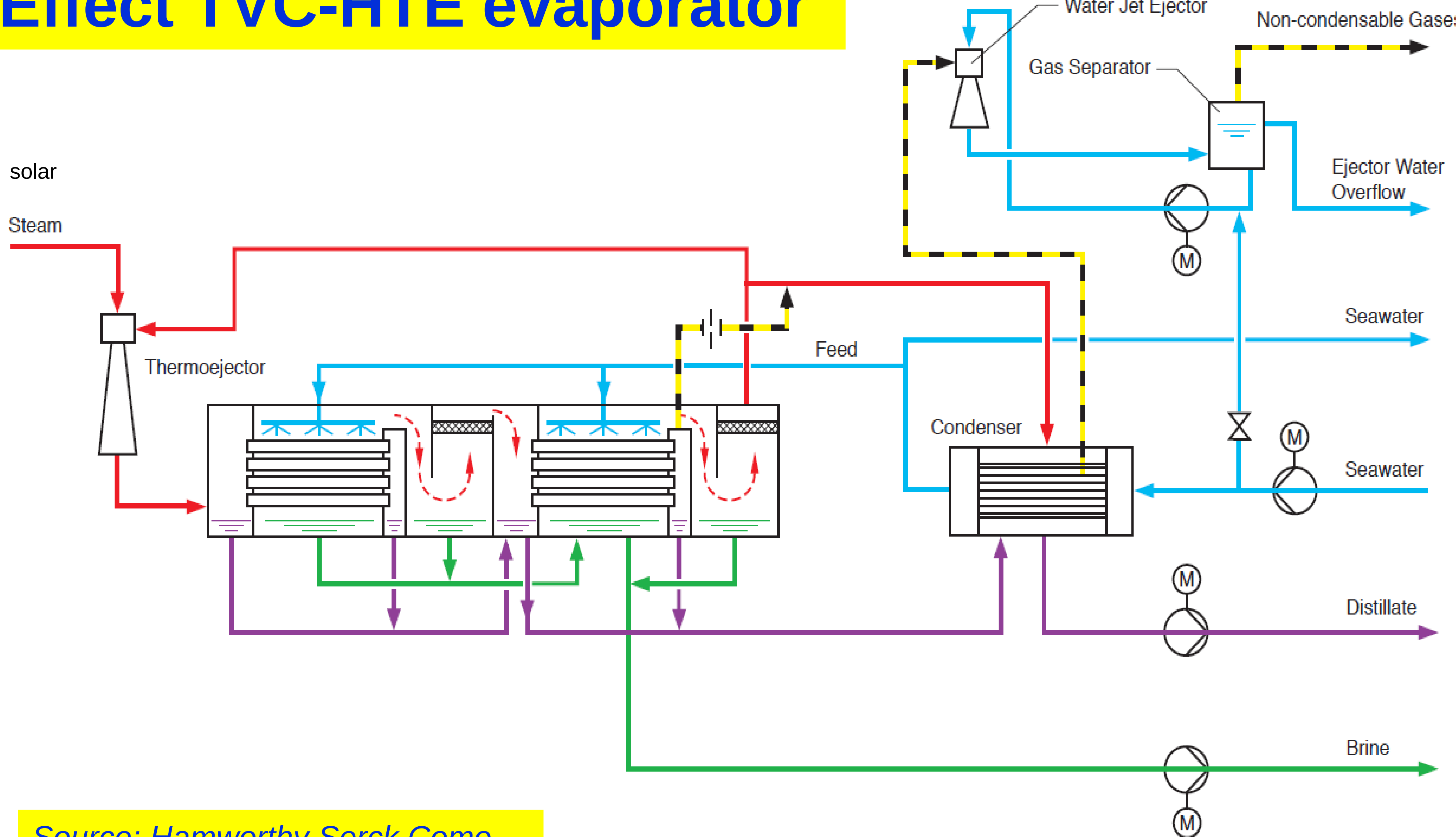
Source: Hamworthy Serck Como





Direct Solar Steam Generation on Plataforma Solar de Almería (Spain)

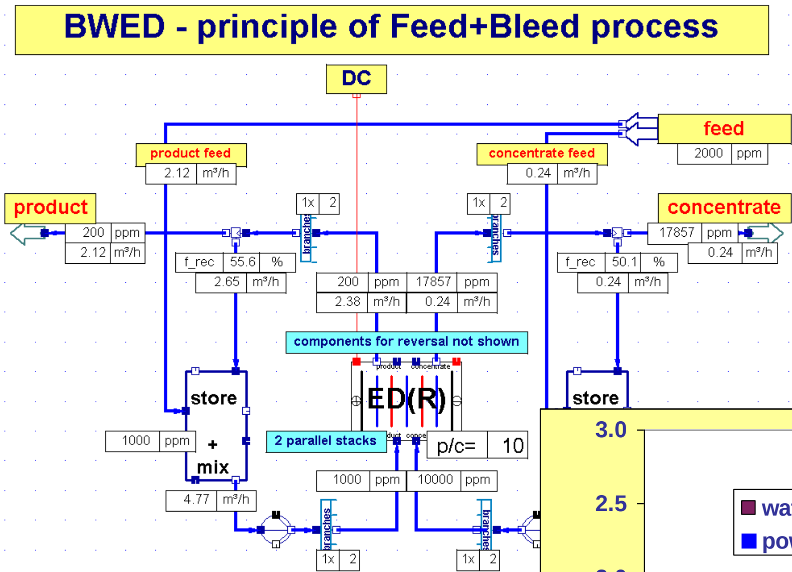
Process flow diagram of 2 Effect TVC-HTE evaporator



Source: Hamworthy Serck Como

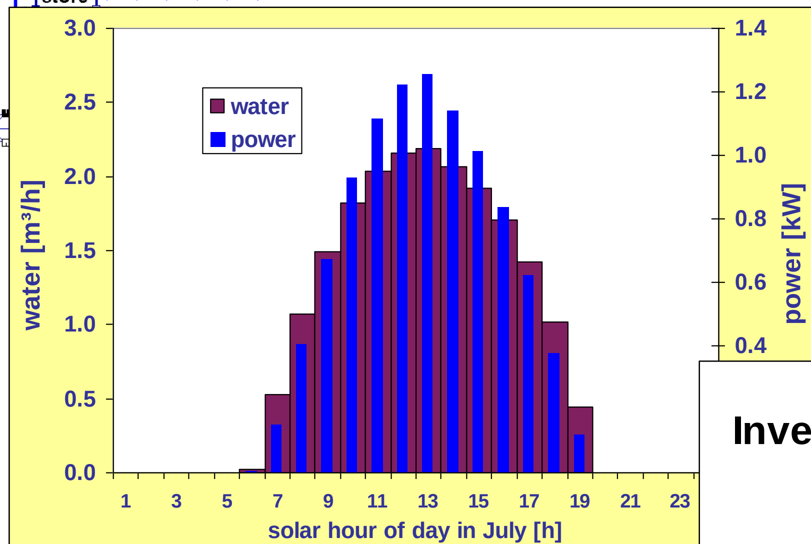
Systems Analysis Environment

RESYSproDESAL



***IPSEpro*:**

Design, Analysis, Optimisation



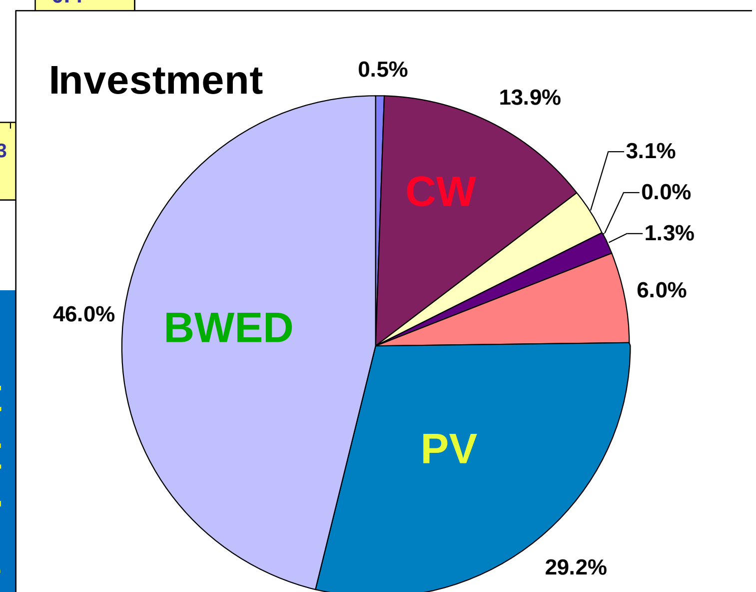
***PSExcel*:**

Day, Month, Year

Balances

Fractions of RES

Emissions



***PSEconomy*:**

Life Cycle Cost

Present Value of Project

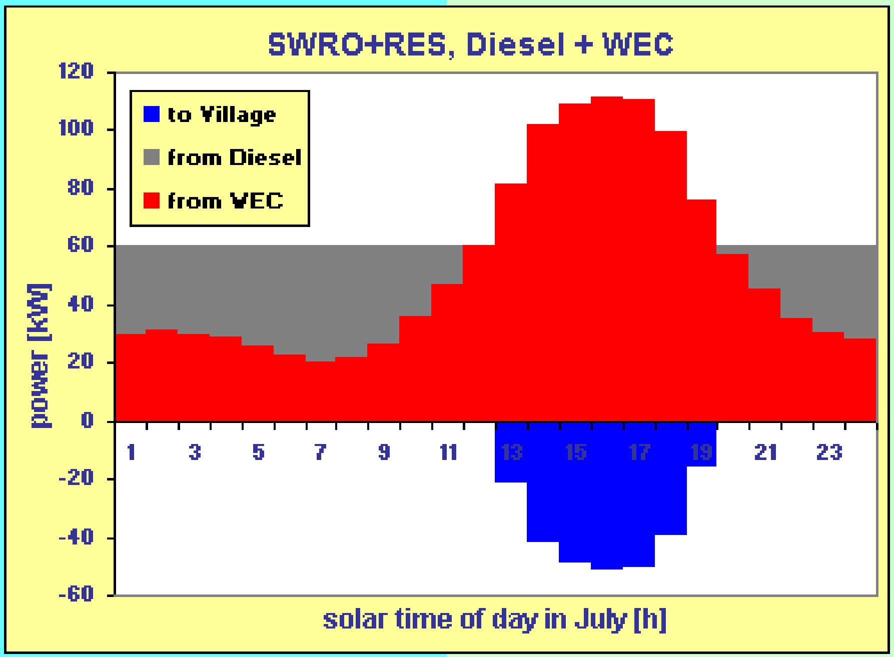
Levelised Costs of Power and Water

Cost of CO_2-Avoidance

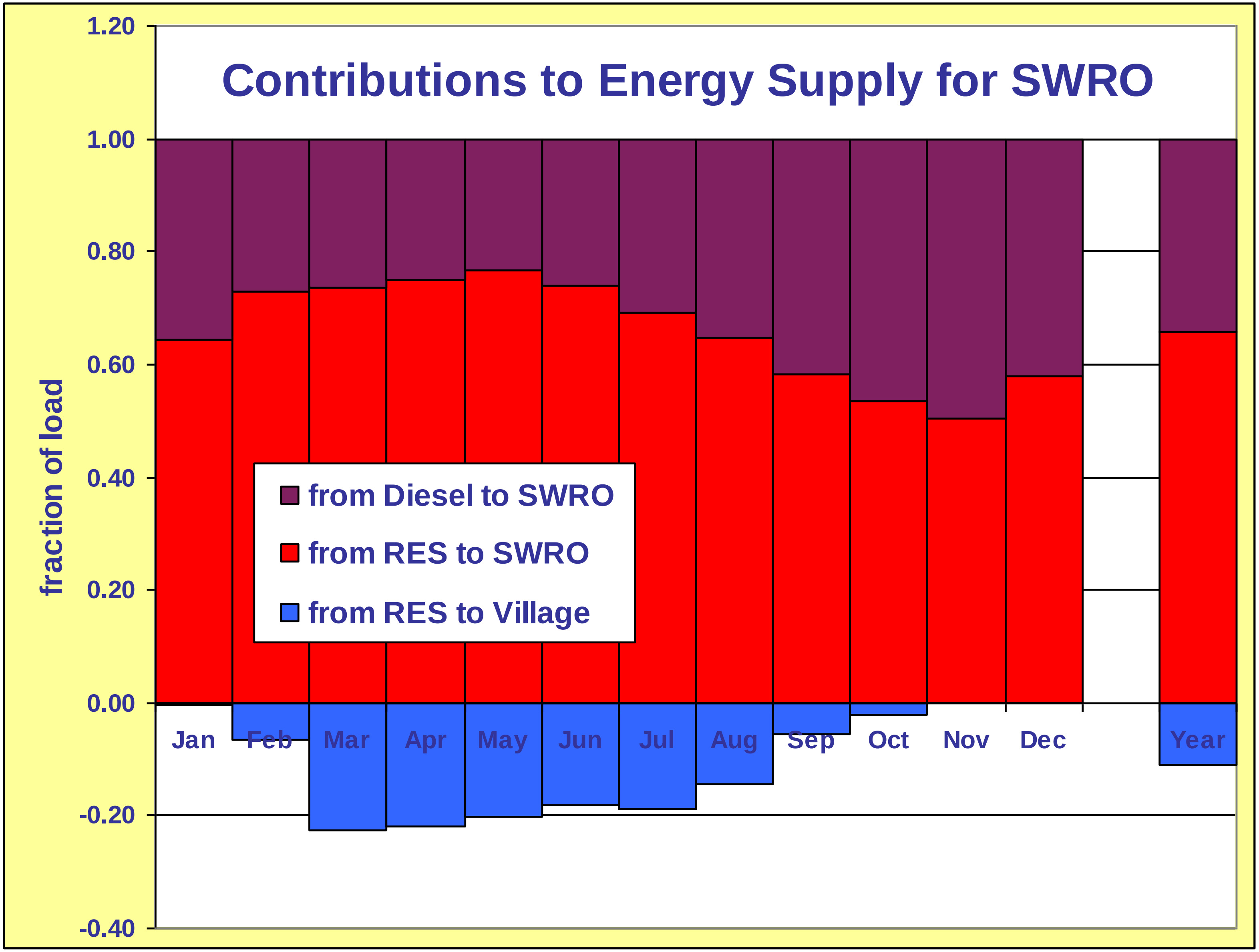
Time Series Simulation of Power Supply

Example: Performance of WEC on Typical Day of July

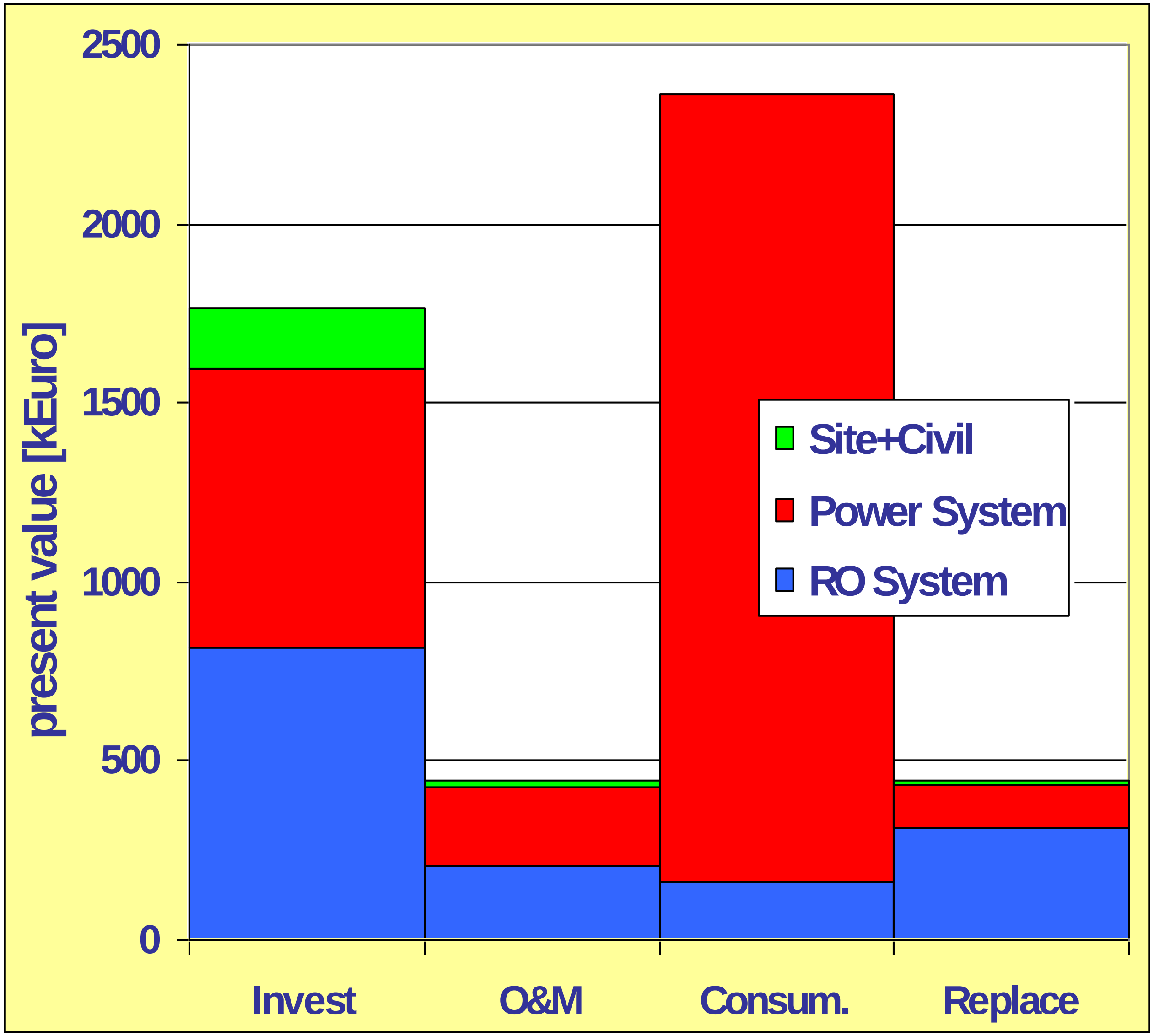
	July	21st	31	4848														
hour(s)	t_amb	V_Wind	Irradiance	WEC P/P0	perm_1	perm_2	HP_p_1	HP_p_2	sal._1	recov_1	sal._2	recov_2	P_RO_tot	P_RO_1	P_RO_2	P_aux.	P_PV	P_wind
	°C	m/s	kW/m²	---	g/s per ves:	0	bar	bar	ppm	---	ppm	---	kW(AC)	kW(AC)	kW(AC)	kW(AC)	kW(AC)	kW(AC)
1	24.6	4.61	0.000	0.13	0.87	0.87	77.07	77.07	376	0.57	376	0.57	60.0	25.8	25.78	8.44	0.00	30.00
2	24.5	4.70	0.000	0.13									60.0	25.8	25.78	8.44	0.00	31.40
3	24.5	4.59	0.000	0.12									60.0	25.8	25.78	8.44	0.00	29.58
4	24.5	4.54	0.000	0.12									60.0	25.8	25.78	8.44	0.00	28.83
5	24.3	4.35	0.000	0.10									60.0	25.8	25.78	8.44	0.00	25.78
6	24.9	4.15	0.014	0.09									60.0	25.8	25.78	8.44	0.00	22.55
7	25.6	4.02	0.080	0.08									60.0	25.8	25.78	8.44	0.00	20.48
8	26.5	4.12	0.258	0.09									60.0	25.8	25.78	8.44	0.00	22.04
9	27.5	4.40	0.454	0.11									60.0	25.8	25.78	8.44	0.00	26.53
10	28.7	4.95	0.644	0.16									60.0	25.8	25.78	8.44	0.00	35.60
11	29.8	5.53	0.792	0.23									60.0	25.8	25.78	8.44	0.00	46.53
12	30.5	6.10	0.881	0.28									60.0	25.8	25.78	8.44	0.00	60.14
13	31.0	6.76	0.910	0.36									60.0	25.8	25.78	8.44	0.00	81.63
14	30.9	7.28	0.823	0.44									60.0	25.8	25.78	8.44	0.00	101.68
15	30.5	7.45	0.720	0.46									60.0	25.8	25.78	8.44	0.00	108.61
16	29.6	7.52	0.584	0.45									60.0	25.8	25.78	8.44	0.00	111.43
17	28.5	7.50	0.425	0.43									60.0	25.8	25.78	8.44	0.00	110.38
18	27.4	7.22	0.244	0.39									60.0	25.8	25.78	8.44	0.00	99.28
19	26.3	6.61	0.075	0.35									60.0	25.8	25.78	8.44	0.00	76.33
20	25.7	5.99	0.000	0.28									60.0	25.8	25.78	8.44	0.00	57.38
21	25.3	5.46	0.000	0.21									60.0	25.8	25.78	8.44	0.00	45.05
22	25.0	4.93	0.000	0.15									60.0	25.8	25.78	8.44	0.00	35.26
23	24.7	4.66	0.000	0.13									60.0	25.8	25.78	8.44	0.00	30.73
24	24.7	4.50	0.000	0.12	0.87	0.87	77.07	77.07	376	0.57	376	0.57	60.0	25.8	25.78	8.44	0.00	28.18
maxima:	31.0	7.5	0.9	0.46	0.87	0.87	77.07	77.07	376	0.57		0.6	60.0	25.8	25.8	8.4	0.0	111.4
daily sum:		132	6.90	5	75	75							1440	619	619	202	0	1265
monthly sum:		4090	214	168	2325	2325							44642	19182	19182	6277	0	39227
unit;fraction:		m/s*h	kWh/m²	---	m³	m³							kWh	0.43	0.43	0.14	**0.00**	**0.88**



Monthly Contributions to Energy Supply



Breakdown of Present Value of Cost for Total Water and Power Supply to Village



An internet version of the
Systems Analysis Environment

RESYSproDESAL

is accessible
- free of charge -
via:

www.RESYSpro.net#

offering:

several reference configurations,
RO, ED and HDH integrated with
PV, WEC, SOT, Diesel and Grid,
on-line pre-feasibility studies.

the development of *RESYSproDESAL_WEB* was supported by the Middle East Desalination Research Center (MEDRC) and by the Commission of the European Community (CEC)