
STERG
SOLAR THERMAL ENERGY
RESEARCH GROUP

The Techno-Economic Optimization of a 100MW$_e$ CSP-Desalination Plant in Arandis, Namibia

E.P. Dall, J.E. Hoffmann

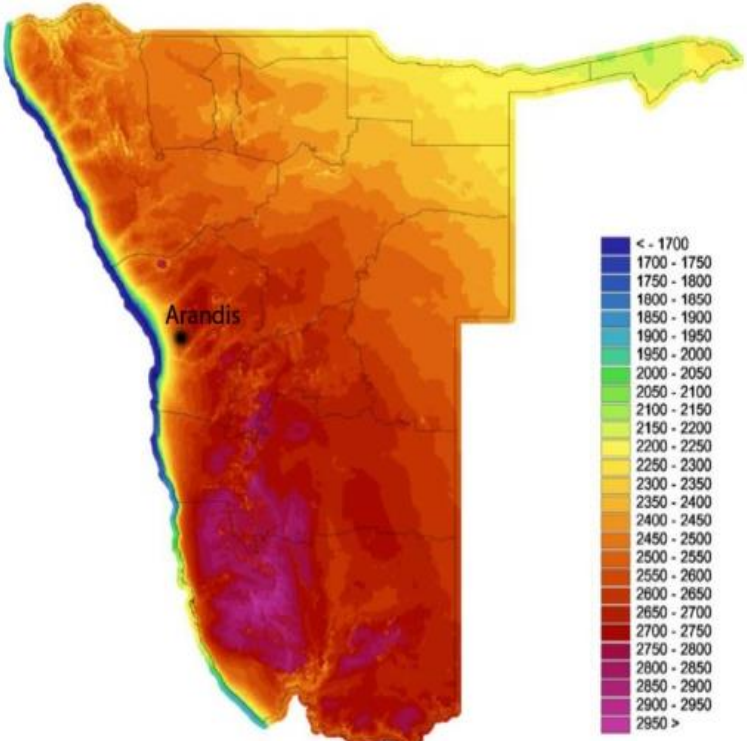
Solar Thermal Energy Research Group (STERG),
University of Stellenbosch

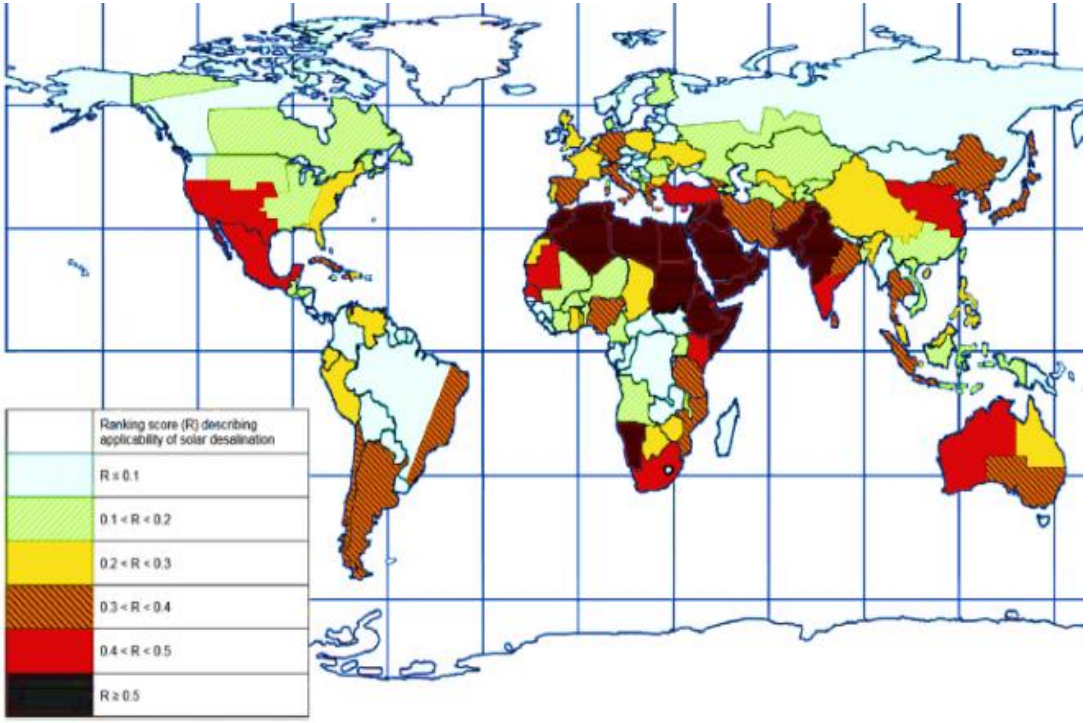
Overview

- Background
- Approach
- Modelling
- Results
- Conclusion

Desalination

Why cogeneration with CSP?

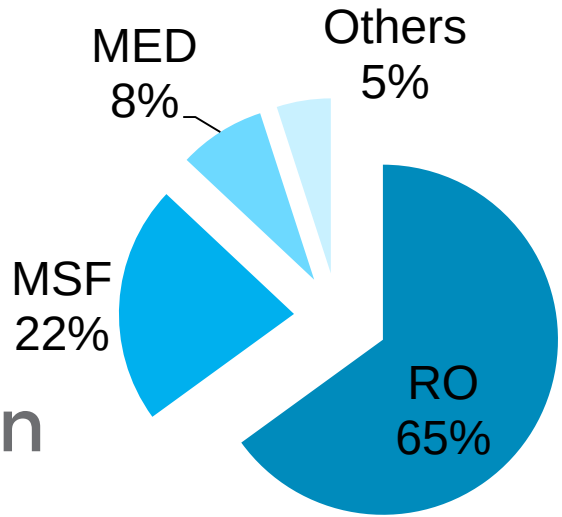




Global installed capacity

Commercial technology

- Reverse osmosis
- Multi-stage flash
- Multiple-effect distillation



Desalination with solar

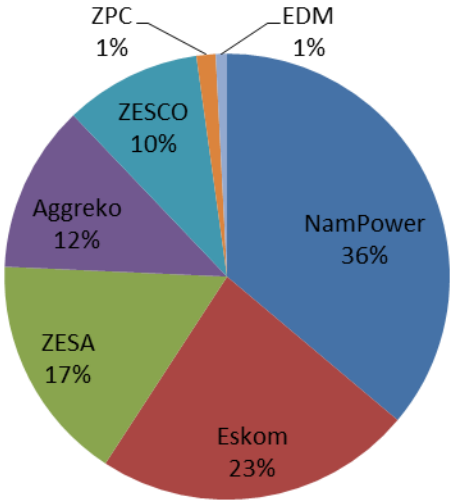
RO vs. MED/MES

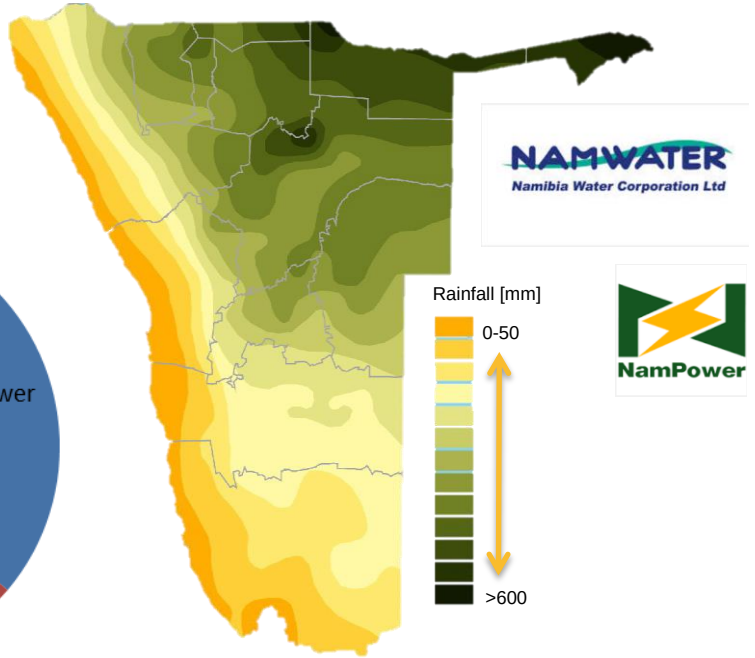
Desalination technology	Operating temperature $[°C]$	Thermal energy requirement $[kWh/m^3]$	Electrical energy requirement $[kWh/m^3]$
MSF	90-110	80.6	2.5-3.5
MED	70-55	80.6	1.0-2.5
RO	n/a	n/a	3-10

Background

Namibia's electricity and water situation

- Peak demand - 524MW
- Annual rainfall – 250 mm





Case study

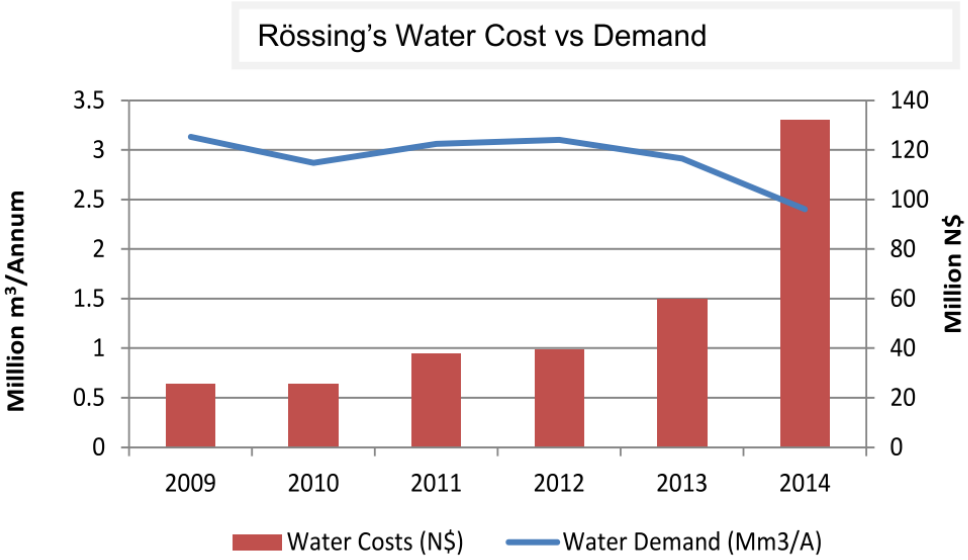
Erongo region, Arandis

- DNI – 2528 kWh/m²
- Omdel aquifer
- Desalination plant (RO)
- Uranium (Rössing/Husab)
- 50 km's from coastline

Cost of desalinated water

Rössing Uranium

- 13 N$/m³ (2012)
- 54 N$/m³ (2014)

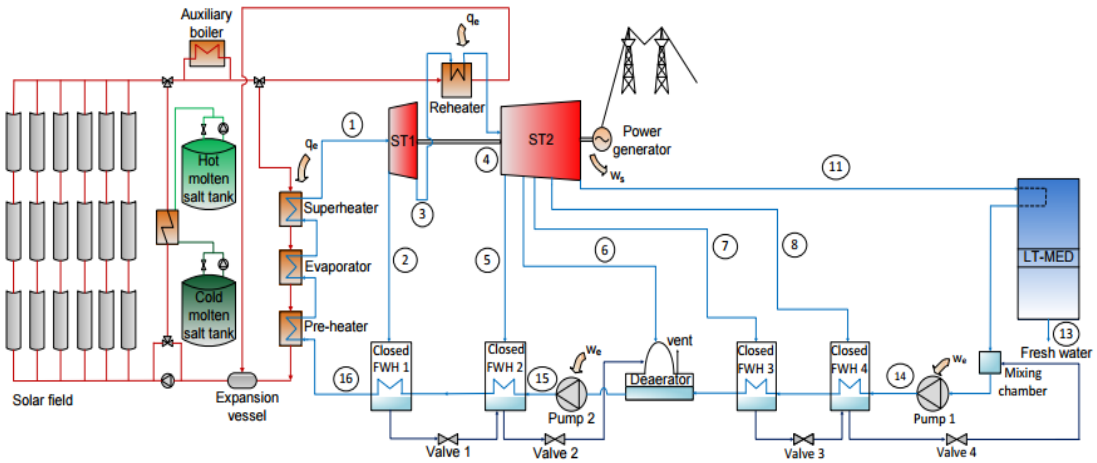


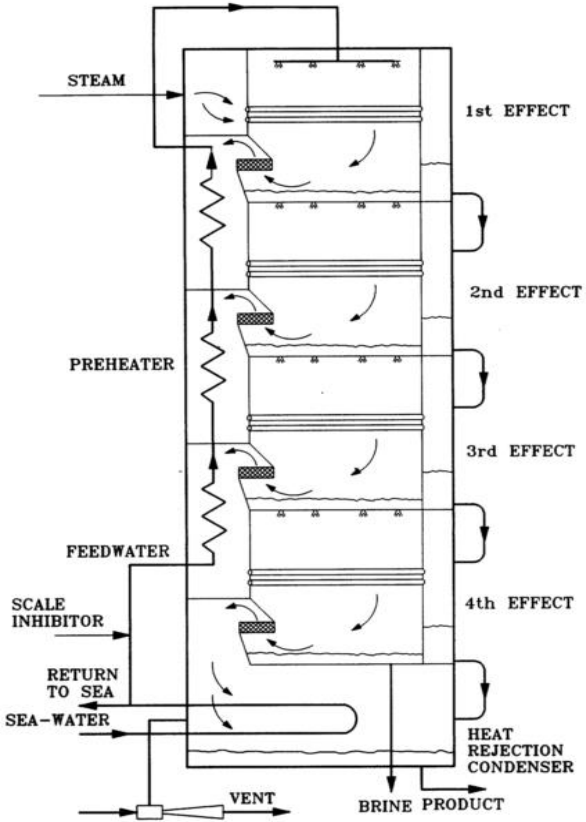
Approach

CSP tower + MES

- CSP Dry-cooled ref.
- CSP + MES (different TBT's)
- Pipeline pumping
- LCOE + LCOW
- Limitations

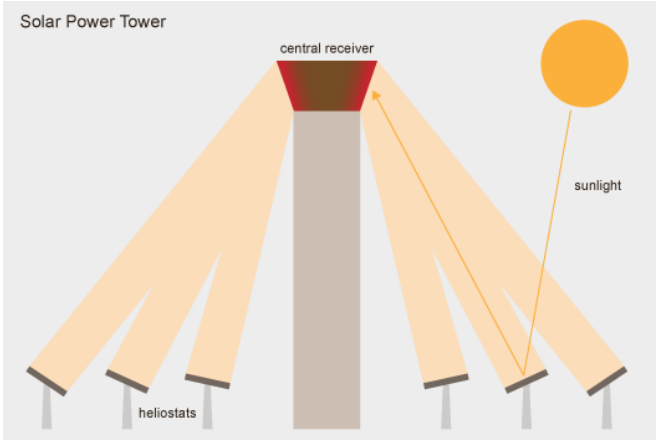
Modelling


Auxiliary boiler
Reheater
ST1
ST2
Power generator
Hot molten salt tank
Cold molten salt tank
Superheater
Evaporator
Pre-heater
Solar field
Expansion vessel
Closed FWH 1
Closed FWH 2
Closed FWH 3
Closed FWH 4
Deaerator
vent
Pump 2
Pump 1
Valve 1
Valve 2
Valve 3
Valve 4
LT-MED
Mixing chamber
Fresh water


STEAM
1st EFFECT
2nd EFFECT
PREHEATER
3rd EFFECT
FEEDWATER
4th EFFECT
SCALE INHIBITOR
RETURN TO SEA
SEA-WATER
HEAT REJECTION CONDENSER
VENT
BRINE PRODUCT

CSP Tower Plant

Heliostat field and receiver



Function of zenith angle

$$\eta_{opt} = 0.425\theta^6 - 1.148\theta^5 + 0.3507\theta^4 + 0.755\theta^3 - 0.5918\theta^2 + 0.0816\theta + 0.832$$

Convection + radiation losses

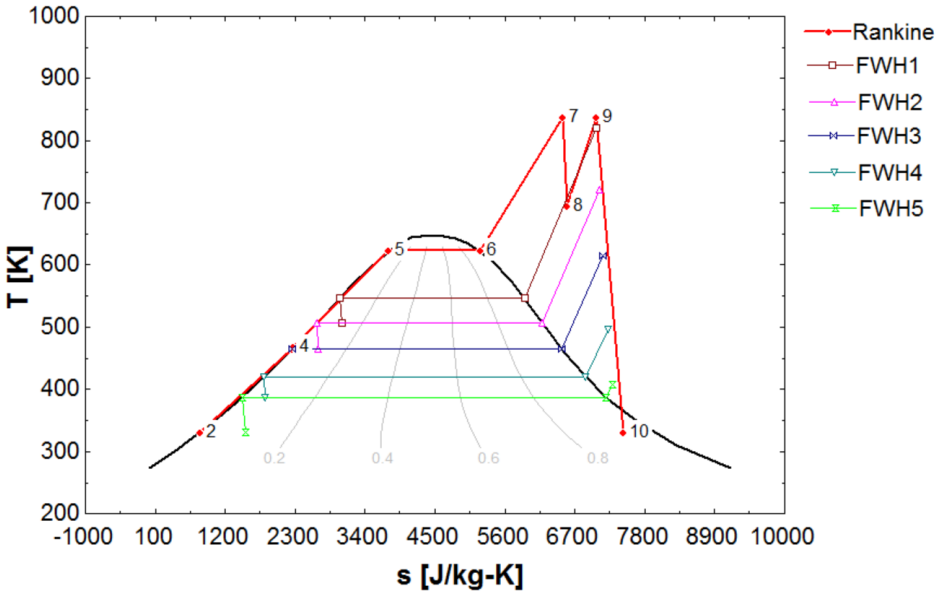
$$\eta_{rec} = \frac{Q_{in} - Q_{loss}}{Q_{in}} = \frac{\alpha Q_{in} - \varepsilon\sigma A(T_{wall}^4) - hA(T_{wall} - T_{amb})}{Q_{in}}$$

CSP Tower Plant

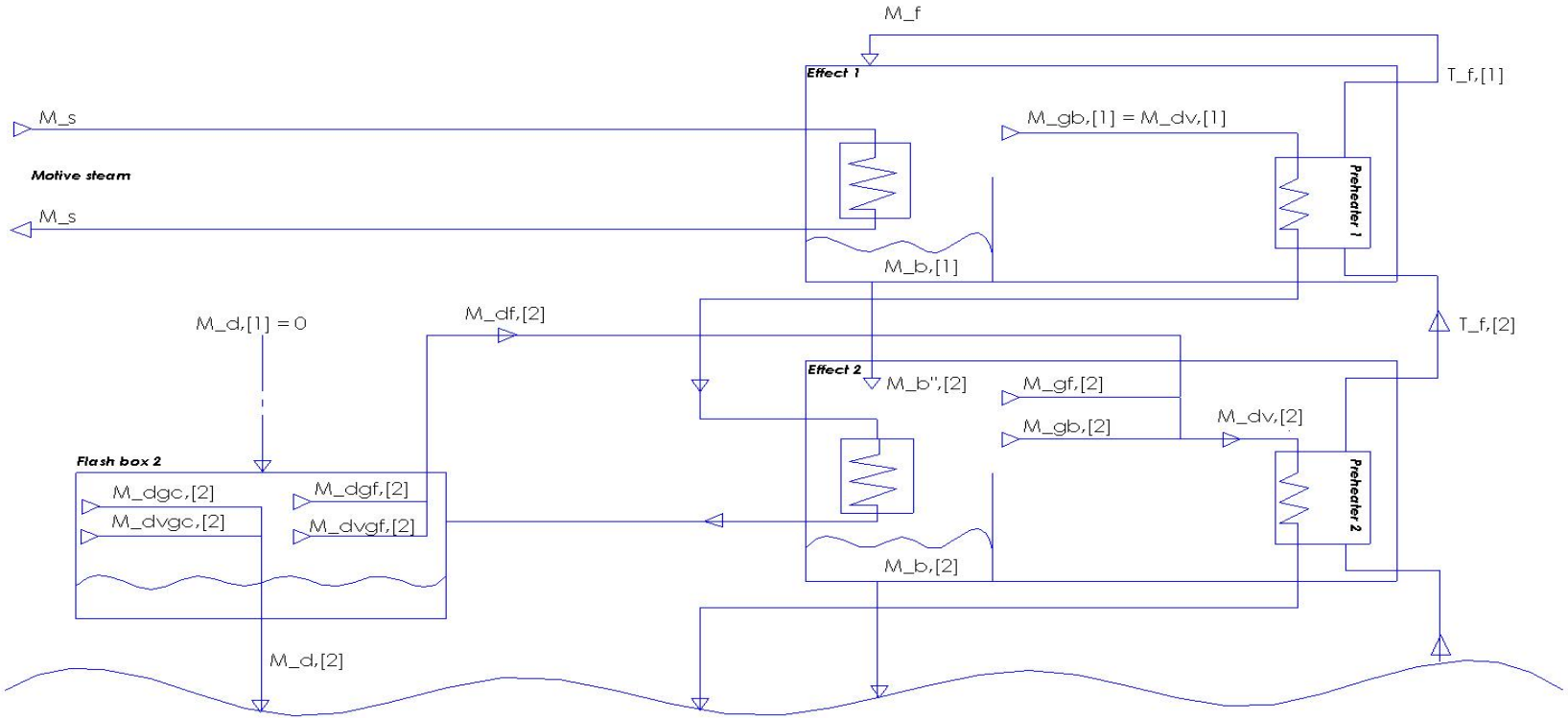
Power block

- Condensing temp.
  - MES (TBT + TTD)
  - Dry-cooled (DB+ITD)

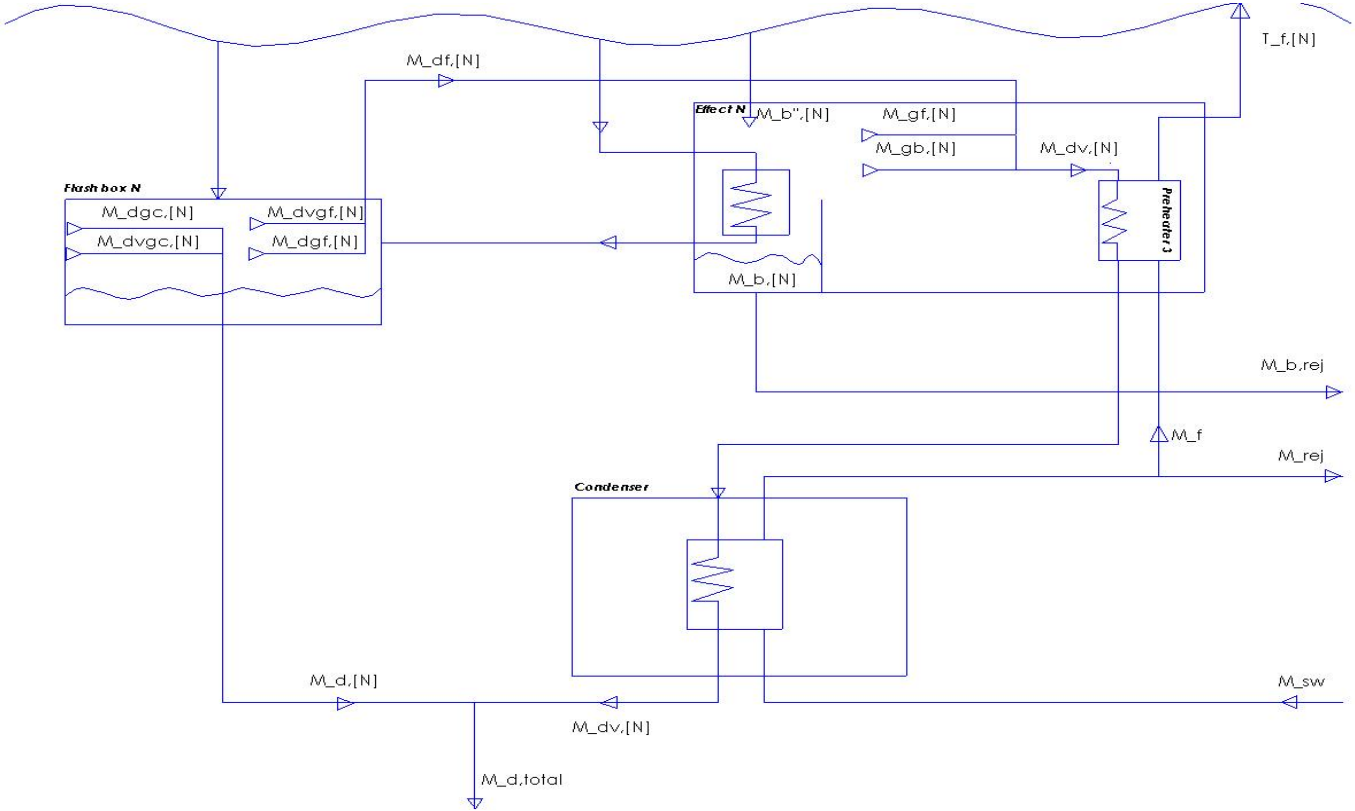
- T_{max} 565°C
- P_{max} 16.5 Mpa



MES Desalination Plant



MES Desalination Plant



Solving MES system

Analytical solution (EES)

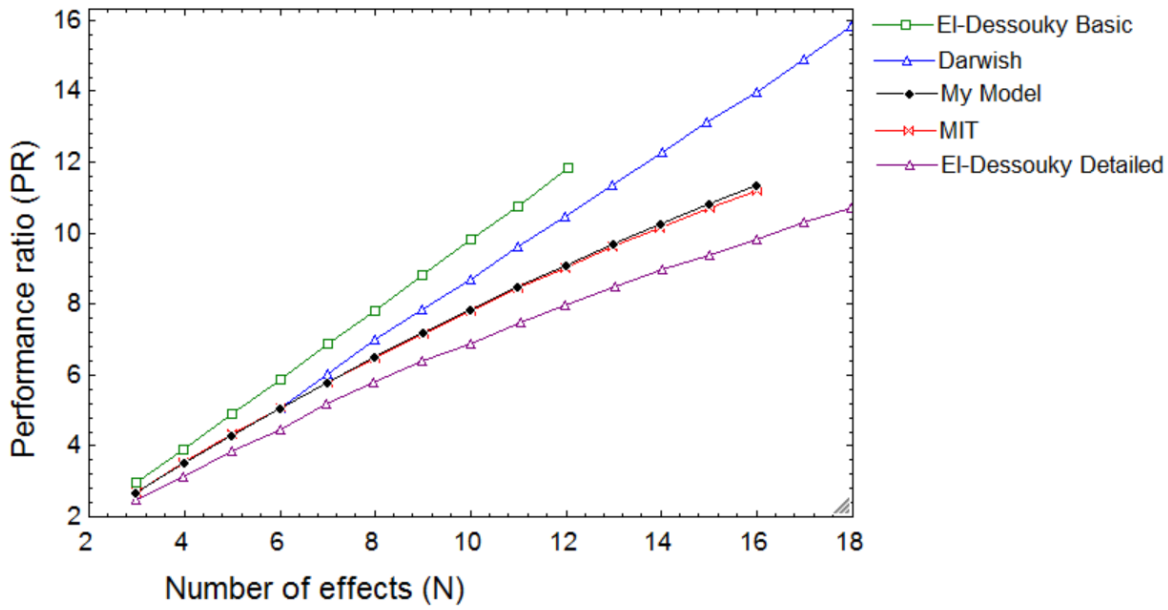
- Mass flow balances
- Energy balances
- Salt balances

- Heat transfer coefficient

$$U = 1617.5 + 0.1537T_{dc} + 0.1825T_{dc}^{2} - 0.00008026T_{dc}^{3}$$

Comparison to literature

Performance ratio (PR)



MES Desalination Plant

Assumptions and design considerations

Constraint	Value	Units
Salinity of seawater	35	[g/kg]
Salinity of brine at N^{th} effect	60	[g/kg]
Seawater temperature	15	[°C]
Min TTD between steam and 1st effect	2.5	[°C]
Min TTD of preheaters	5	[°C]
Brine temperature of N^{th} effect	40	[°C]
Spec. el. consumption	1	[kWh/m^3]

Levelized product costs

Electricity and water

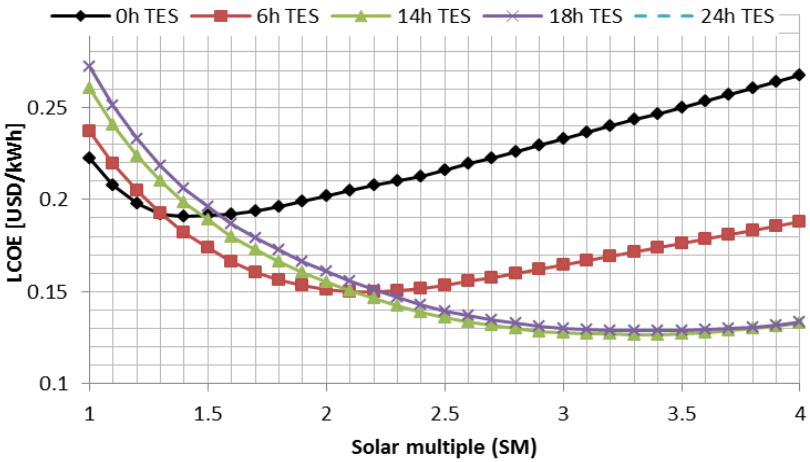
- Simplified IEA method
  - 25 year period

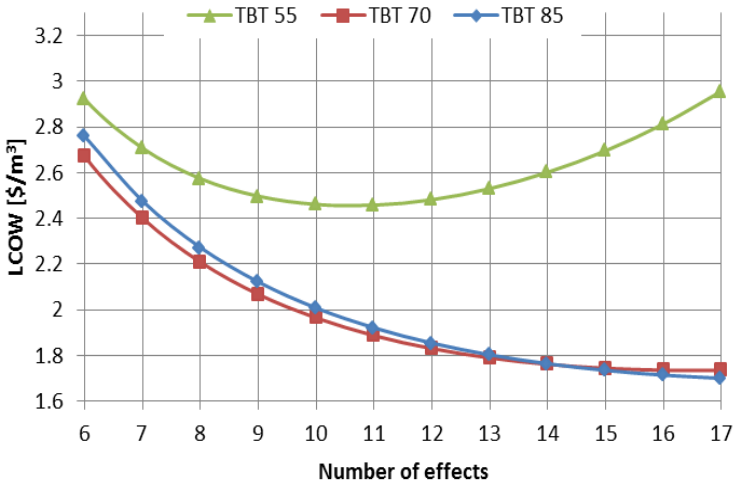
$$LCOE = \frac{CRF \cdot K_{invest} + K_{O\&M}}{E_{net}}$$

$$CRF = \frac{k_d (1+k_d)^n}{(1+k_d)^n - 1} + k_{insurance}$$

Results

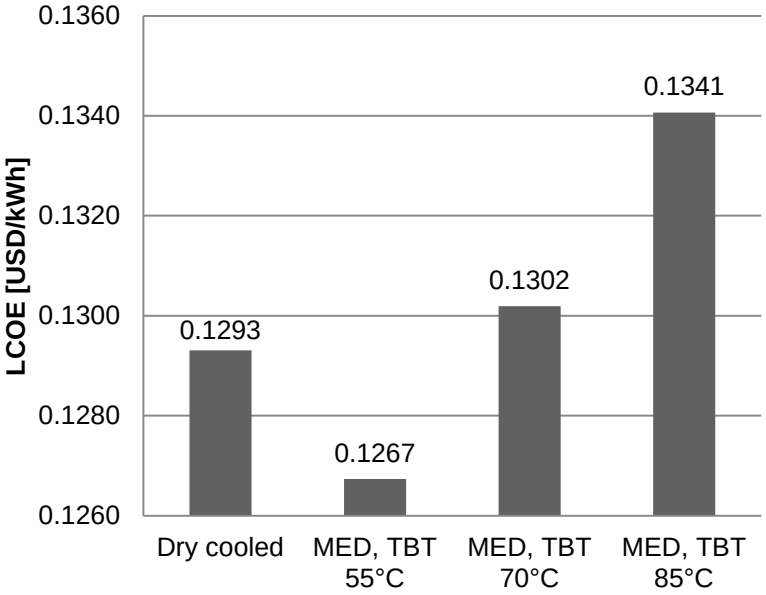
Parametric study

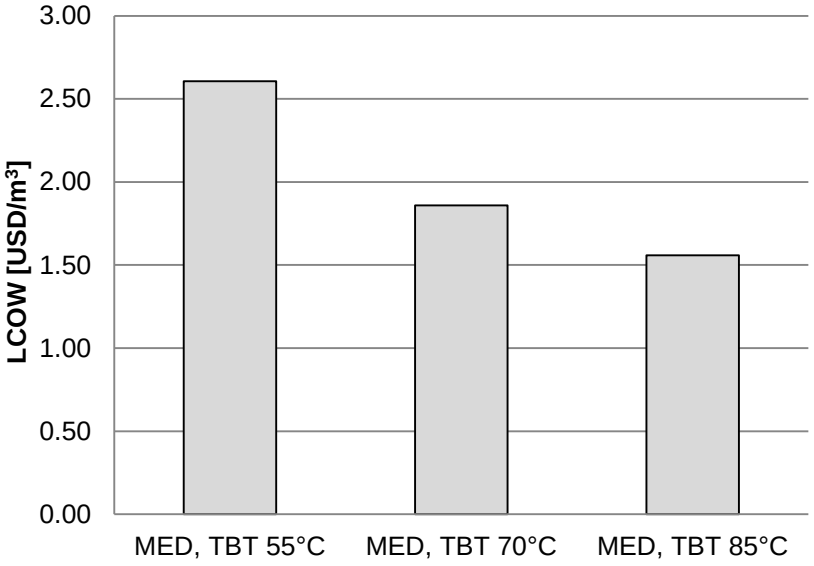




Results

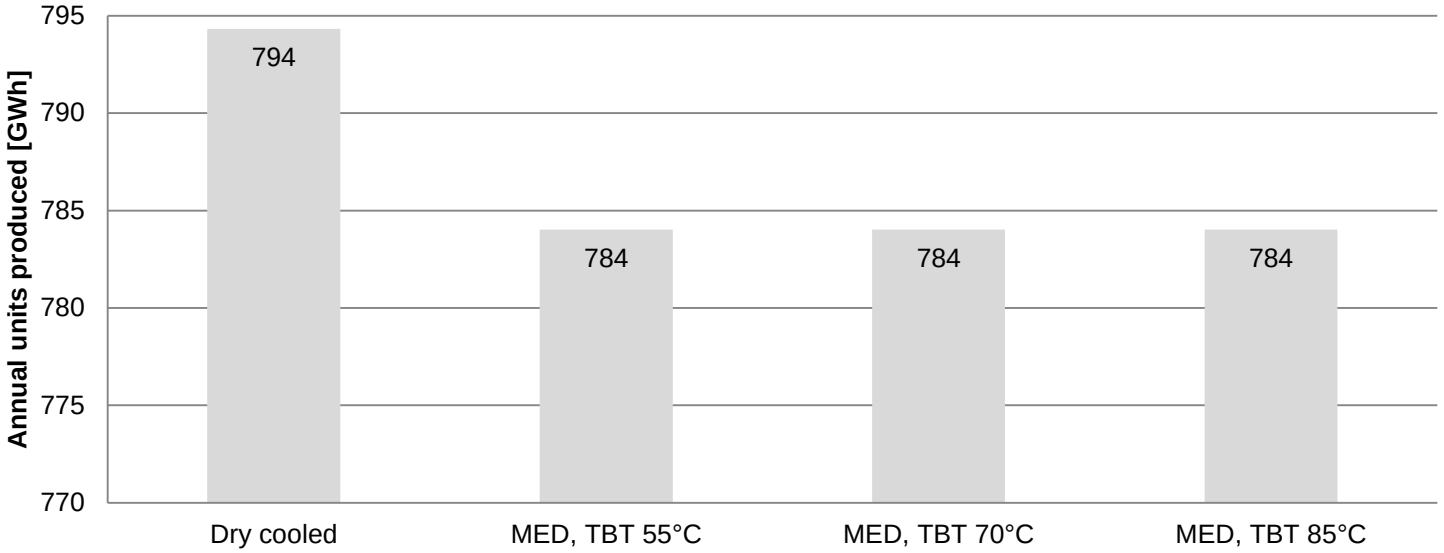
LCOE and LCOW





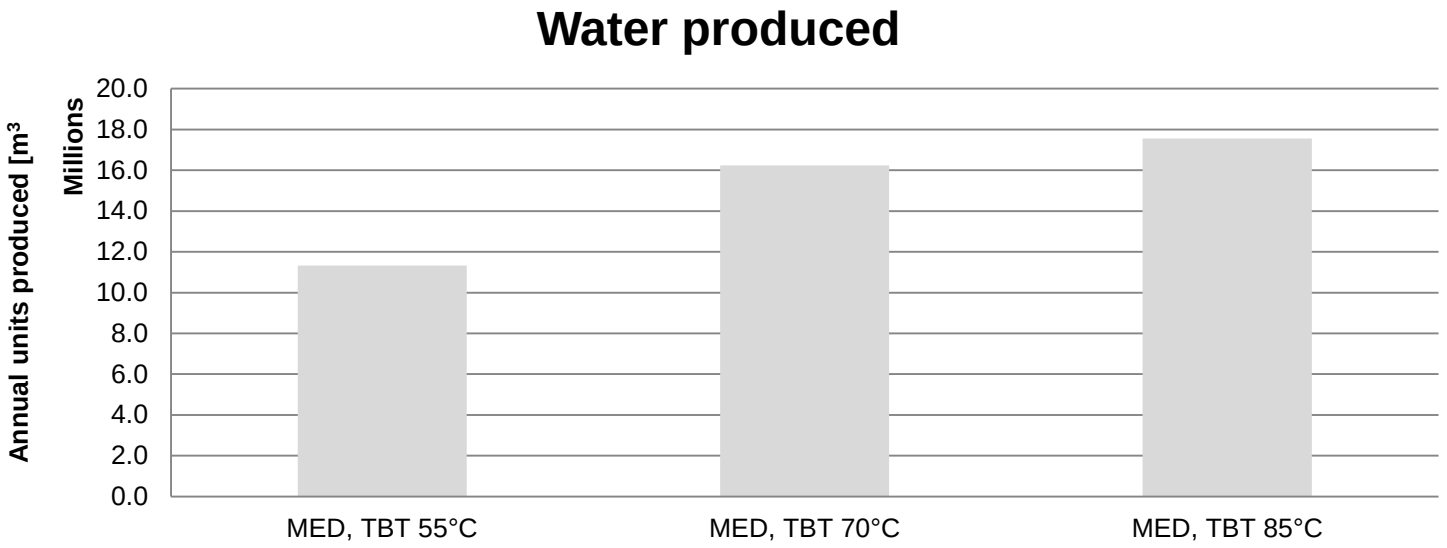
Annual production

Electricity



Annual production

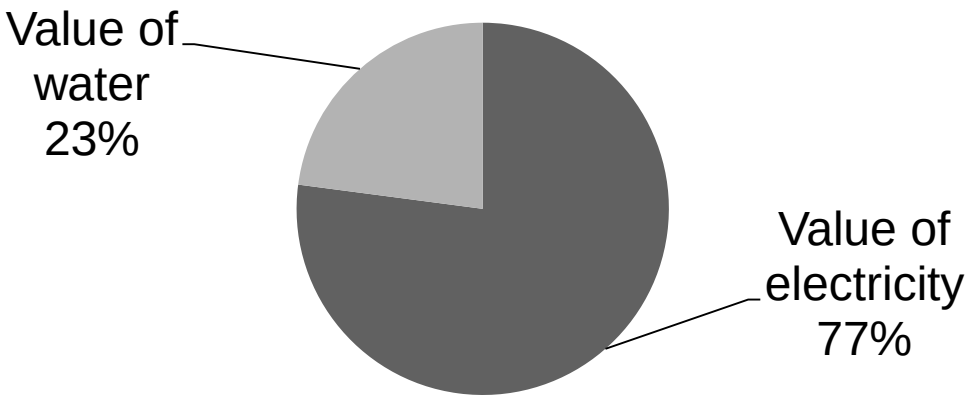
Water



Product value

In terms of levelized cost

- Value = LCO(E/W)*Units produced



Conclusion

Economic feasibility

- Namibian CSP tariff structure
- Reduction in MES capital costs
- Cycle sustainability
  - Rejection of brine

Thank you!

ACKNOWLEDGEMENTS:

STERG
CRSES

CONTACT DETAILS:

Ernest Dall
Solar Thermal Energy Research Group (STERG)
Stellenbosch University
South Africa

STERG@sun.ac.za
+27 (0)21 808 4024

visit us: concentrating.sun.ac.za