UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

SOLAR THERMAL ENERGY RESEARCH GROUP

Scenarios for a South African peaking CSP system in a short term

Cebo Silinga

Supervisor: Paul Gauché

18 July 2013

Fakulteit Ingenieurswese
•
Faculty of Engineering

SOLAR THERMAL ENERGY
RESEARCH GROUP

Agenda

- Objective
- Rationale
- Methodology
- Load demand
- Scenario 1: peaking OCGT system
- Scenario 2: peaking CSP system and grid energy
- Scenario 3 peaking CSP system combined with OCGT

Background

Objective

- To investigate the feasibility of utilizing the CSP plants as peaking stations in South Africa

Rationale

- IRP 2010 – 2030 states that future peak load will be met by OCGT which operate using diesel and represents an allocation of 4,930 MW
- IRP does not identify the CSP as a potential peaking solution and allocates 1,200 MW
- CSP system with TES is a dispatchable source of electricity

Validity

- Competitive energy generation costs
- Guarantee of electricity to the grid

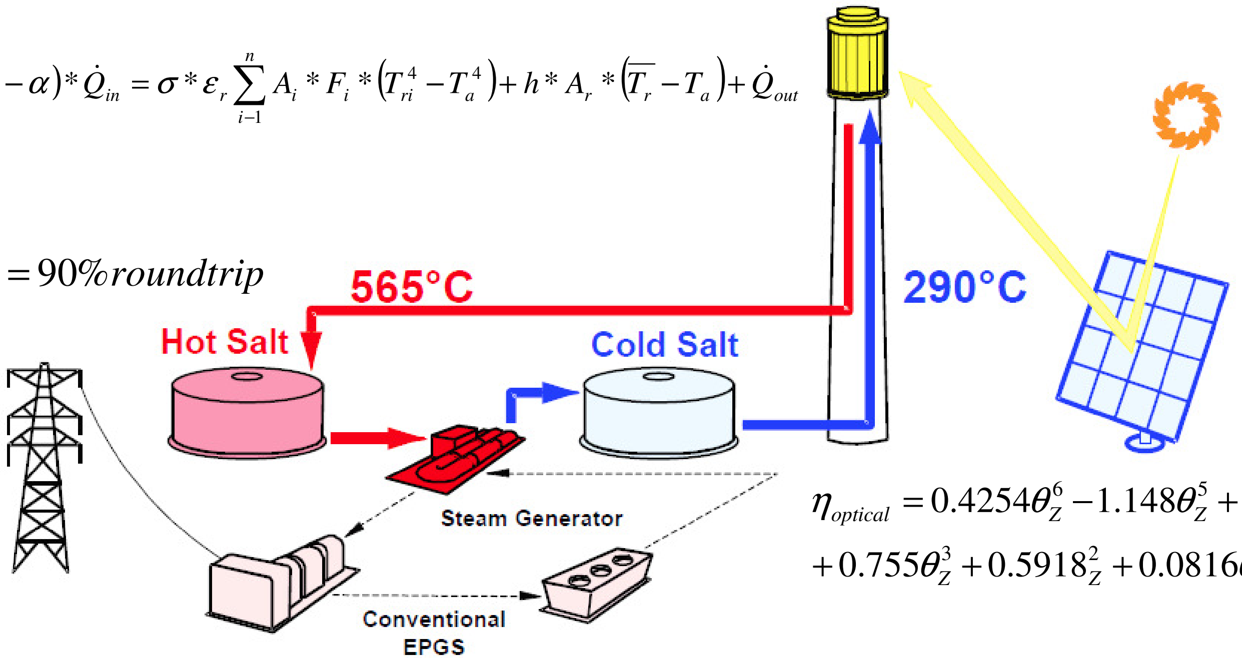
Methodology

Technology type

- Commercially available central receiver (Gemasolar CSP plant is used as the reference plant to obtain operating parameters

$$(1-\alpha)*\dot{Q}_{in} = \sigma*\varepsilon_r \sum_{i-1}^{n} A_i * F_i * \left(T_{ri}^4 - T_a^4\right) + h * A_r * \left(\overline{T_r} - T_a\right) + \dot{Q}_{out}$$

$$\eta_{TES} = 90\% roundtrip$$



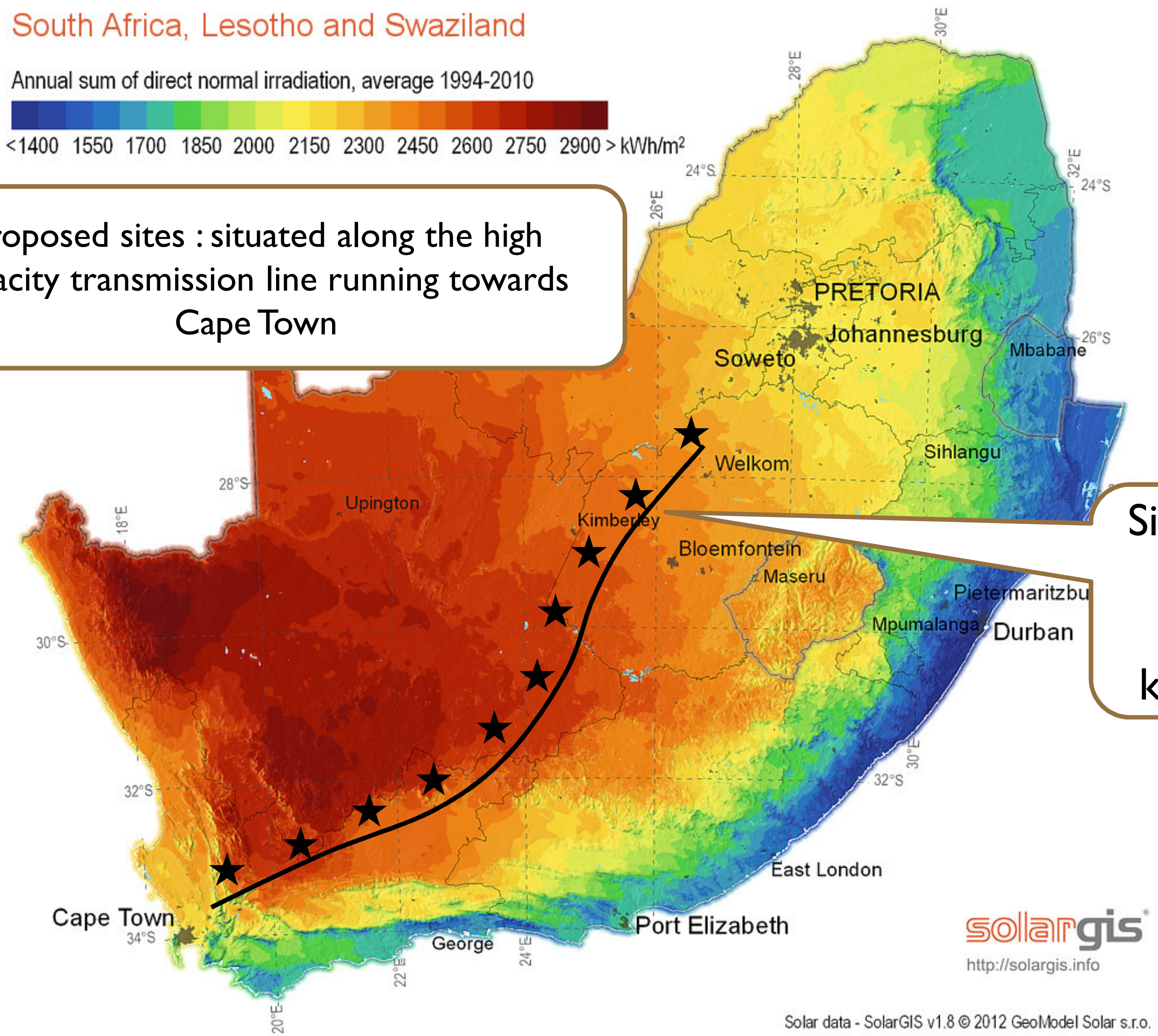
$$\eta_{optical} = 0.4254\theta_Z^6 - 1.148\theta_Z^5 + 0.3507\theta_Z^4 + 0.755\theta_Z^3 + 0.5918_Z^2 + 0.0816\theta_Z + 0.832$$

$$\eta_{th} = 1 - \sqrt{\frac{T_L}{T_H}}$$

SOLAR THERMAL ENERGY
RESEARCH GROUP

CSP scenario: peaking power fuel saver

Proposed sites : situated along the high capacity transmission line running towards Cape Town



Site average DNI: 2,636.43 kWh/m2/a

SOLAR THERMAL ENERGY RESEARCH GROUP

Dispatch model

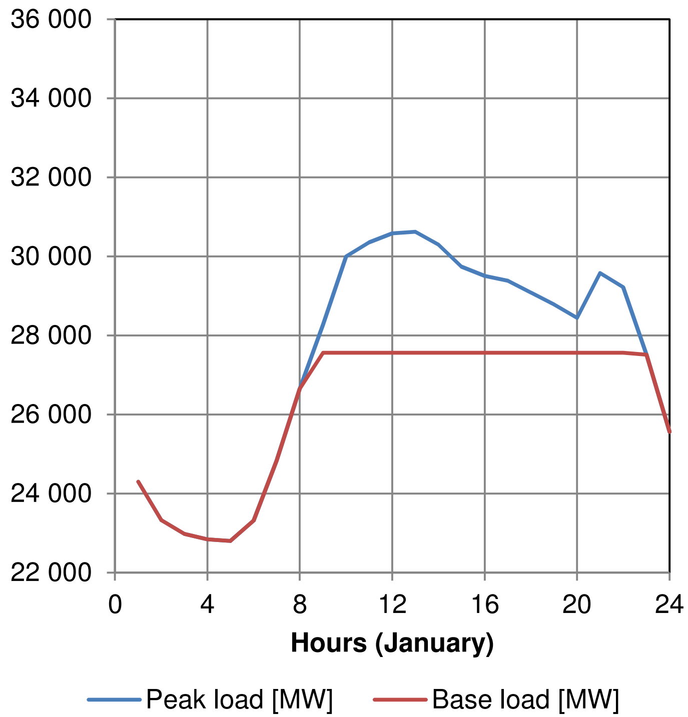
Step	Plant 1	Plant 2	Plant 3	Plant 4	…	Plant n
Begin hour: Rank storage	E.g. 50% R=2	E.g. 40% R=3	E.g. 60% R=1	E.g. 5% R=n		E.g. 10% R=n-1
For hour: Run full energy balance	Adds to storage if DNI threshold OK					
Determine dispatch demand for hour	NA					
Dispatch that hour	Dispatch if R1 full load < demand	Dispatch if R1+R1 < demand	Dispatch up to full load	Etc.	Etc.	Etc.
Deplete storage end of hour	Based on dispatch					

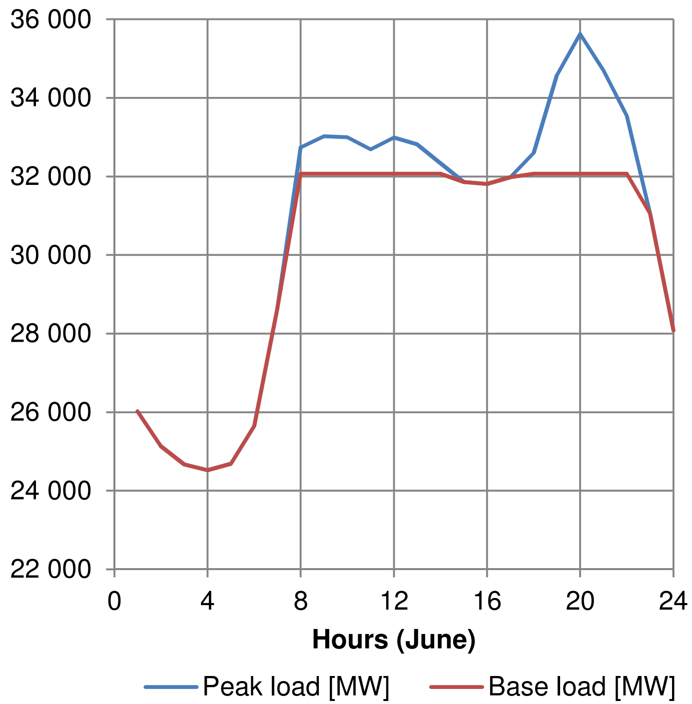
A dispatch model that always tries to keep some storage in highest number of plants in event demand capacity increases

SOLAR THERMAL ENERGY RESEARCH GROUP

Load demand

- Take 90% of the maximum hourly demand in each day as the daily baseload limit

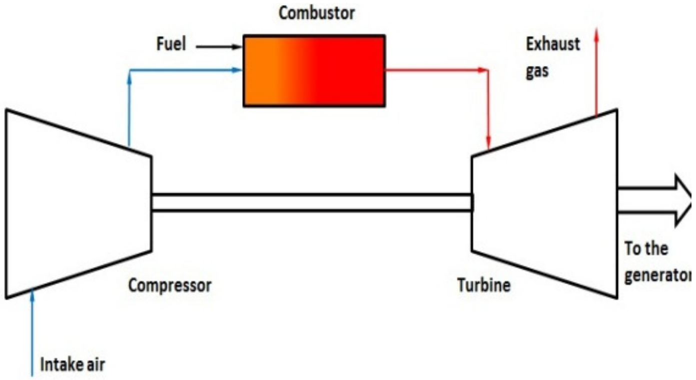




SOLAR THERMAL ENERGY RESEARCH GROUP

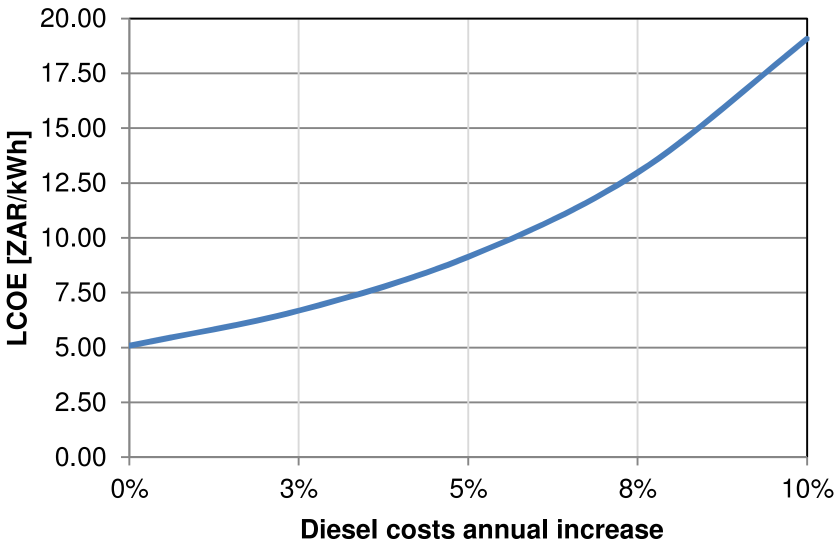
Scenario 1: OCGT energy supply

- The OCGT is used to meet the peak load
- The current capacity of OCGT is increased according to the IRP requirements



- Capacity OCGT = 5,000 MW
- OCGT_LCOE = 5.08 ZAR/kWh

- The OCGT is highly dependent on fossil fuel
- Prediction based on current SA conditions: fuel will likely increase



Scenario 2: CSP system and grid energy

CSP system is used to meet the peak load and the grid energy is used to meet the gap load that the CSP is unable to meet the gap load that the CSP is unable to meet

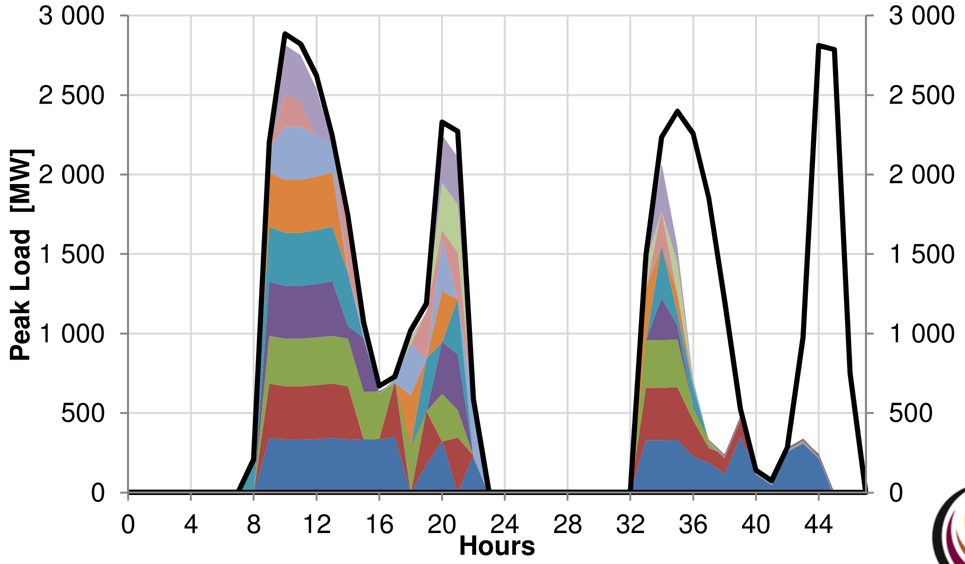
CSP Capacity = 3,300 MW

LCOE_CSP = 1.89 ZAR/kWh

Curtailment coefficient = 0.06

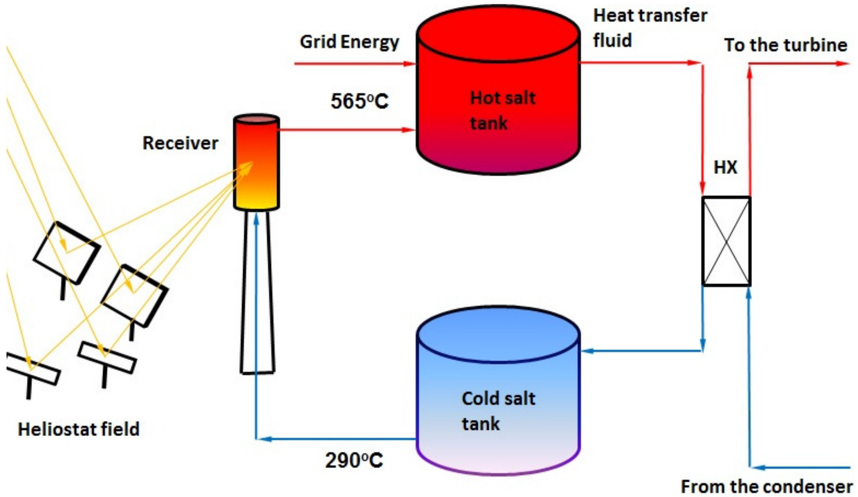
Fulfilment coefficient CSP = 0.82

- Grid energy is used to supply the gap demand



SOLAR THERMAL ENERGY RESEARCH GROUP

Scenario 2: CSP system and grid energy



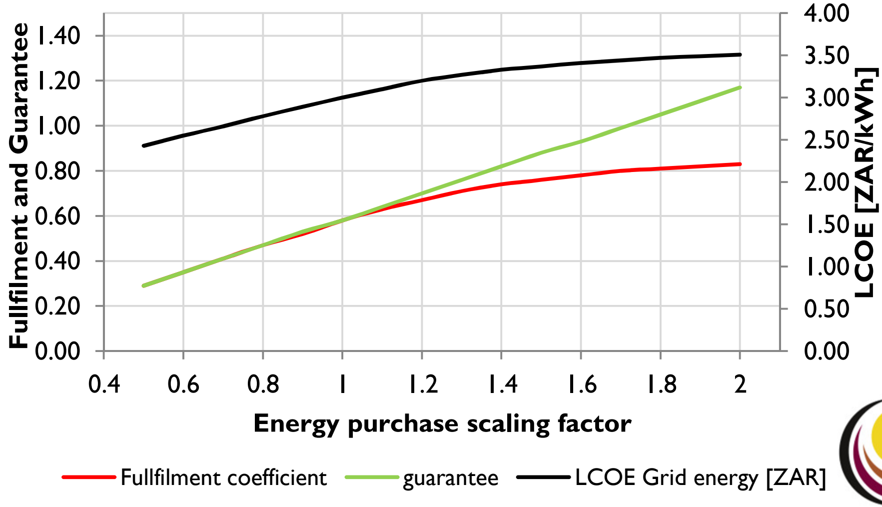
- Grid energy is used to charge the HTF in the hot tank
- The energy purchase is based on the weather prediction model

Demand gap fullfilment = 0.58

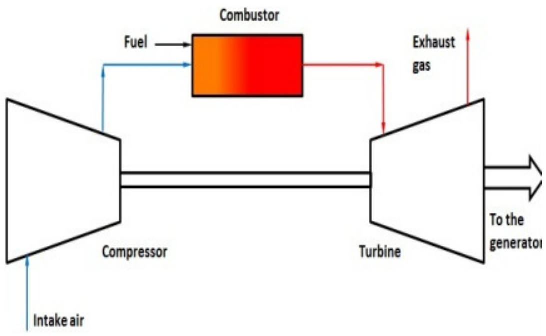
Energy purchase scaling factor = 1

LCOE combined = 3.00 ZAR/kWh

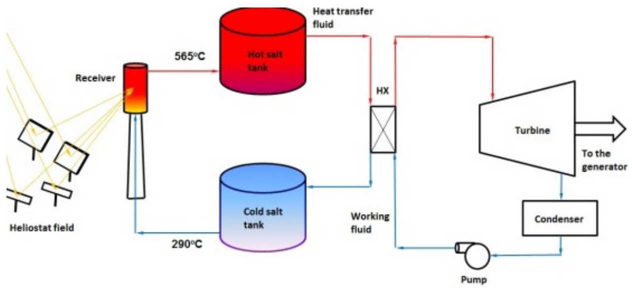
Fulfilment coefficient total = 0.92



Scenario 3: CSP system and OCGT system



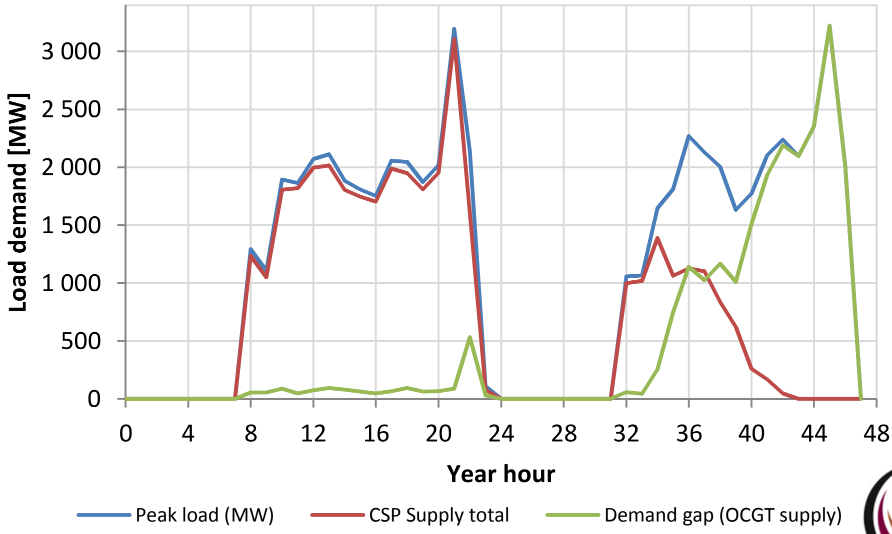
Capacity = 5,000 MW



Capacity = 3,300 MW

OCGT is used to supply the gap energy demand

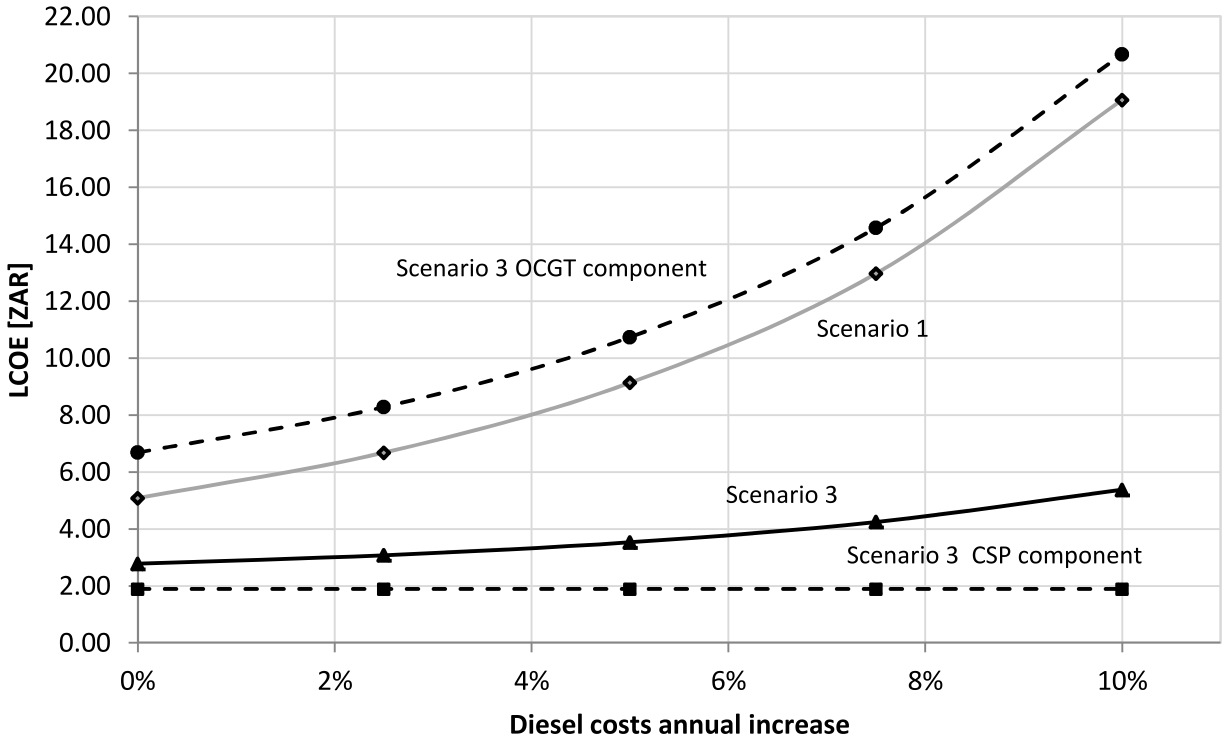
LCOE_OCGT = 6.67 ZAR/kWh (15% more than the scenario 1 LCOE)



SOLAR THERMAL ENERGY RESEARCH GROUP

Scenario 3: CSP system and OCGT system

- LCOE combined = 2.78 ZAR/kWh
- Fullfilment coefficient = 1



SOLAR THERMAL ENERGY RESEARCH GROUP

Conclusion

- Scenario 1: OCGT only = 5.08 ZAR/kWh + fluctuation vulnerability
- Scenario 2: CSP only = 1.89 ZAR/kWh + does not fullfil the demand
- Scenario 2: CSP and grid electricity = 3.00 ZAR/kWh + does not fullfil the energy demand
- Scenario 3: CSP system with the OCGT = lowest LCOE of 2.78 ZAR/kWh + guarantees electricity generation
- For implementation, a fleet of distributed CSP optimized to operate with the OCGT drop the net cost of electricity and show impressive resilience to fuel price fluctuations

Scenario 3 (CSP + OCGT as virtual hybrid peaking system) adds over 3,000 MW CSP without subsidy in the IRP horizon

SOLAR THERMAL ENERGY RESEARCH GROUP