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Performance of a SUNDISC cycle CSP plant for off-grid baseload applications

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Outline

Background for CSP in Chile

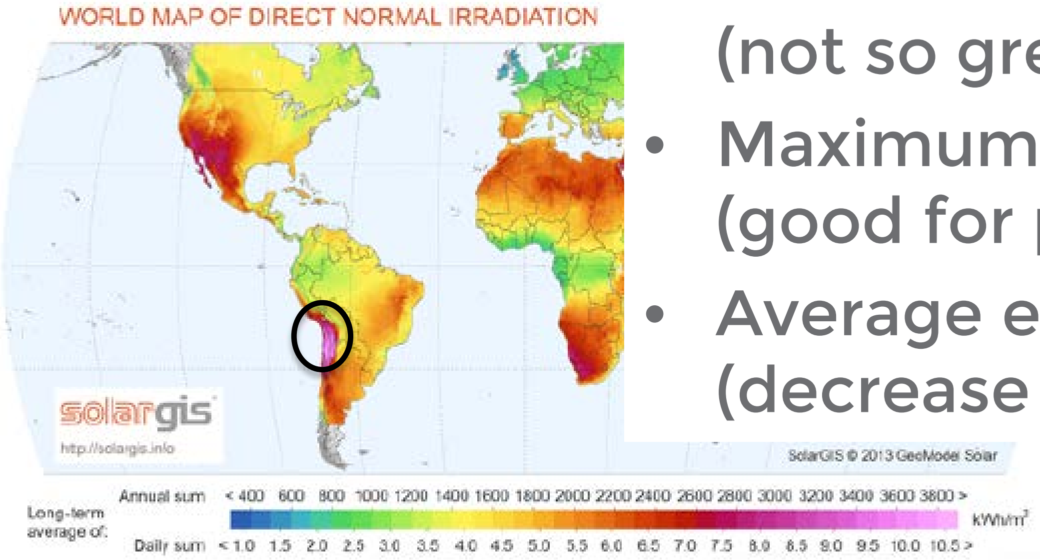
Modeling of the SUNDISC cycle

Simulation results

Conclusions

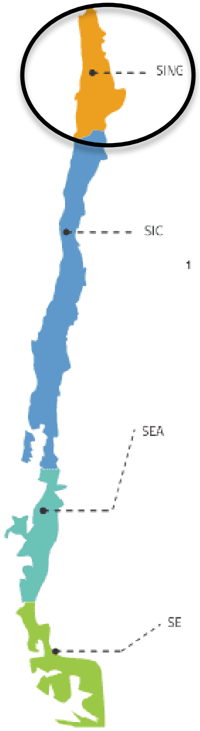
The Atacama desert

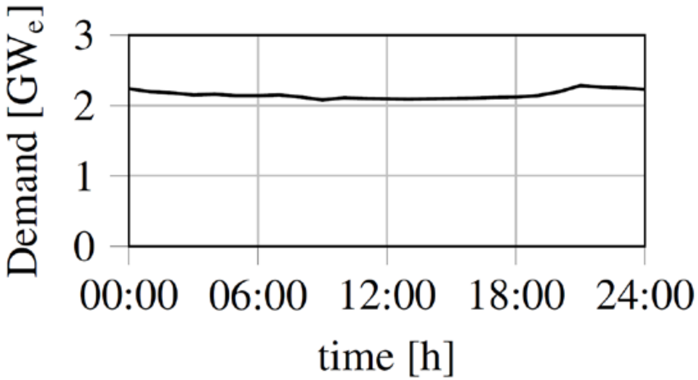
- Highest annual DNI (great)
- one of the driest places on earth (not so great)
- Maximum temperature ~25 °C (good for power block efficiency)
- Average elevation > 2000 m a.s.l. (decrease in gas turbine output)



Electricity in Chile

- Currently disconnected northern grid (SING)
  - 85 % of consumption in SING is caused by mines
  - Mines commonly require *constant, reliable* output throughout the year





(left) Chilean electricity grid distribution; (top) SING average hourly gross generation at times of highest fluctuation

Fossil resources in Chile

- Chile has no noteworthy fossil fuel deposits
  - Dependency on expensive coal, Diesel and LNG imports
  - 95 % of generation in SING is from fossil fuels

Conclusion on CSP in Chile

- Mostly favorable conditions in northern Chile
- Need for reliable, continuous generation (baseload)
  - PV and wind mostly not suitable
- High costs of fossil competition (especially off-grid)

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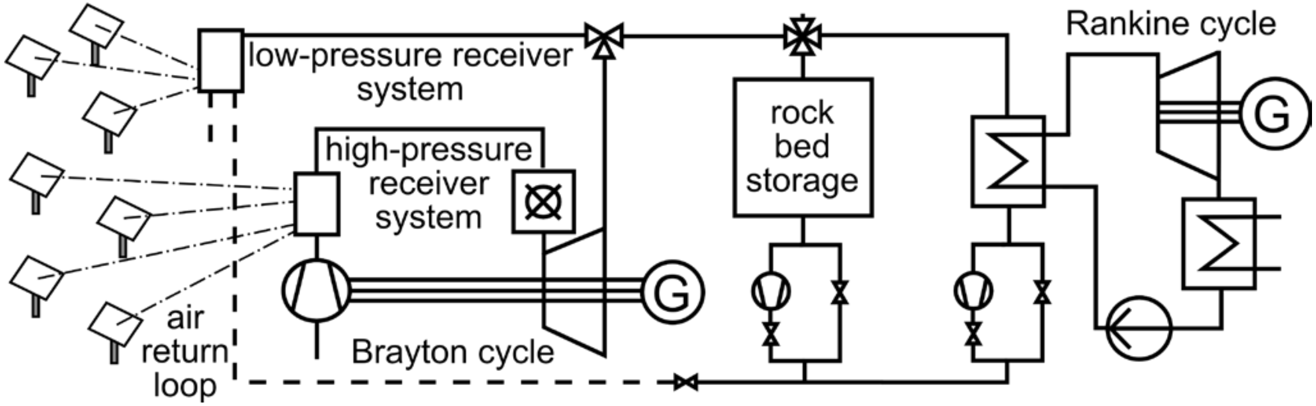
The SUNDISC cycle



- Combined cycle → high efficiency
- Brayton cycle
- Rankine cycle operates mainly at night

} → low water consumption

- Cost-effective long-term storage
- Simple, high-efficiency co-firing

} → baseload characteristics

SUNDISC cycle plant model

- Annual, hourly model with greatly simplified Rankine cycle and receiver models (details: Heller et al., 2017)
- Cost model as below; fuel costs and ambient conditions adapted for northern Chile

Component	Cost	Unit	Relative to
TES system	12	USD/kW_th	TES capacity
HPRS	190	USD/kW_t	HPRS nominal rating
Brayton cycle	570	USD/kW_e	GTU nominal rating
Adaption of GT	970	10^3 USD	absolute
Rankine cycle	830	USD/kW_e	cycle nominal rating
Solar field	100	USD/m^2	mirror surface area
Tower	440	10^3 USD	constant in equation
Control	550	10^3 USD	absolute
Annual O&M	63	USD/kW_e	installed total rating

These estimates are for first of its kind plants built today.

There is significant cost-saving potential, mainly for air receivers and the Brayton cycle.

Simulations

- Parametric study with variable TES and SF sizes
- Two fuel hybridization schemes
  - Low: co-firing only used to assist the HPRS
  - High: co-firing also employed when TES completely discharged -> 8760 h annual power generation

- Performance indicators:
  - *LCOE* – levelized cost of electricity [USD/kW_e h]
  - $TNPG_a$ – annual time of no power generation [h]
  - f_{fossil} – fuel co-firing fraction = (1-solar share) [%]

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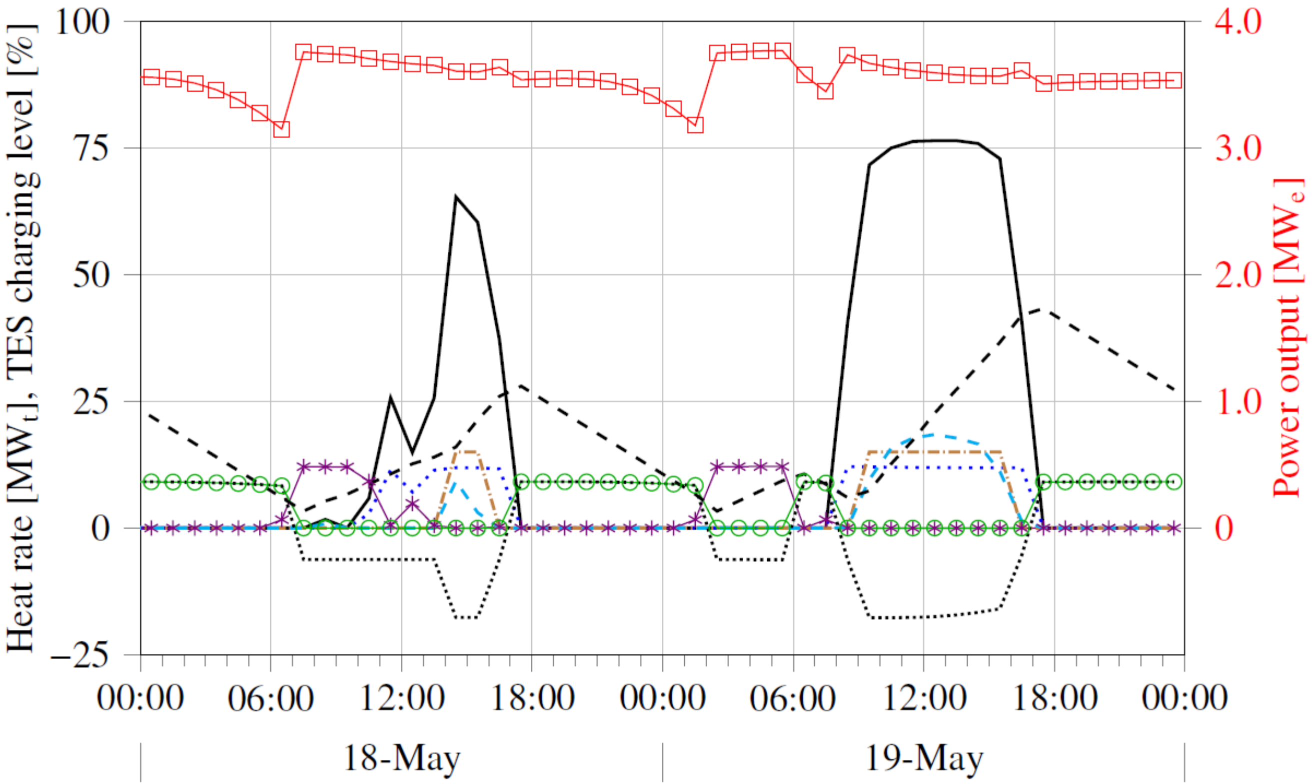
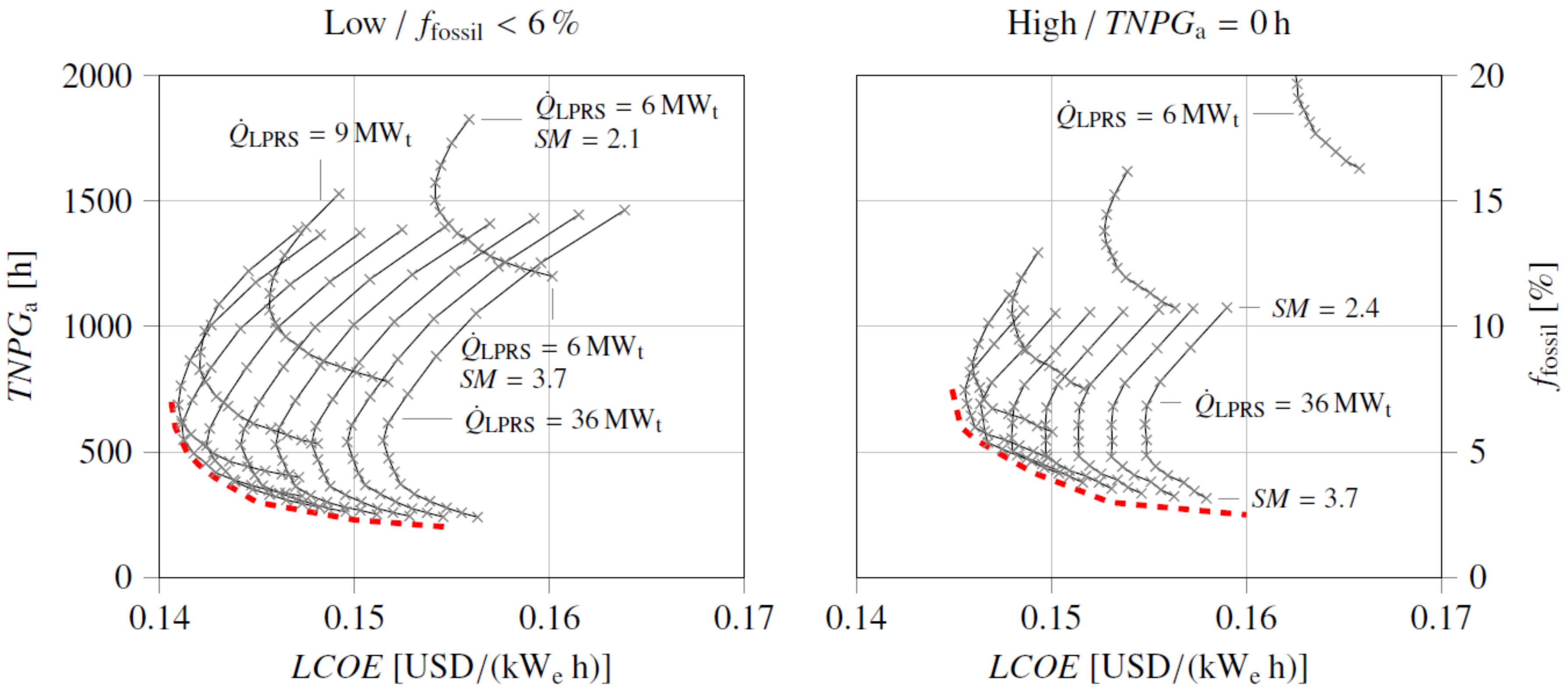
Hourly performance



"High" co-firing

Pareto frontiers



Results

- Lowest LCOE for a plant with "Low" co-firing is achieved with approximately 700 h annual TNPG.
  - 250 h can be achieved with little extra cost.
- 8760 h of power generation is most economical at solar fractions above 93 % (!)
  - 97 % solar fraction can be achieved at 5 % higher LCOE

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Comparison

- At a current Diesel price of 0.78 USD/L (and a higher LNG price), the SUNDISC cycle plant has considerably lower costs than the fuel only (!) of these competing small generators.
- The marginal electricity price in the SING grid has dropped significantly in recent years. At the moment, grid generated electricity is cheaper than the lowest LCOE calculated for a SUNDISC cycle plant. However, if grid connection costs for mines are taken into consideration this should tip the scale in CSP's favor. Furthermore, the dependence on energy price volatility can be lowered.

Conclusion

- A 3.5 MW_e SUNDISC cycle plant is predicted to reliably supply a constant output to an off-grid application at lower costs than competing technologies and with negligible co-firing rates. For a grid-connected location, electricity supply from the grid is currently cheaper according to the conservative cost model.
- Further steps include the investigation of non-baseload demand profiles (e.g. 3-tier tariff) and a sensitivity analysis to costs.
- In the future, a refinement of the techno-economic model is planned.

Thanks!

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