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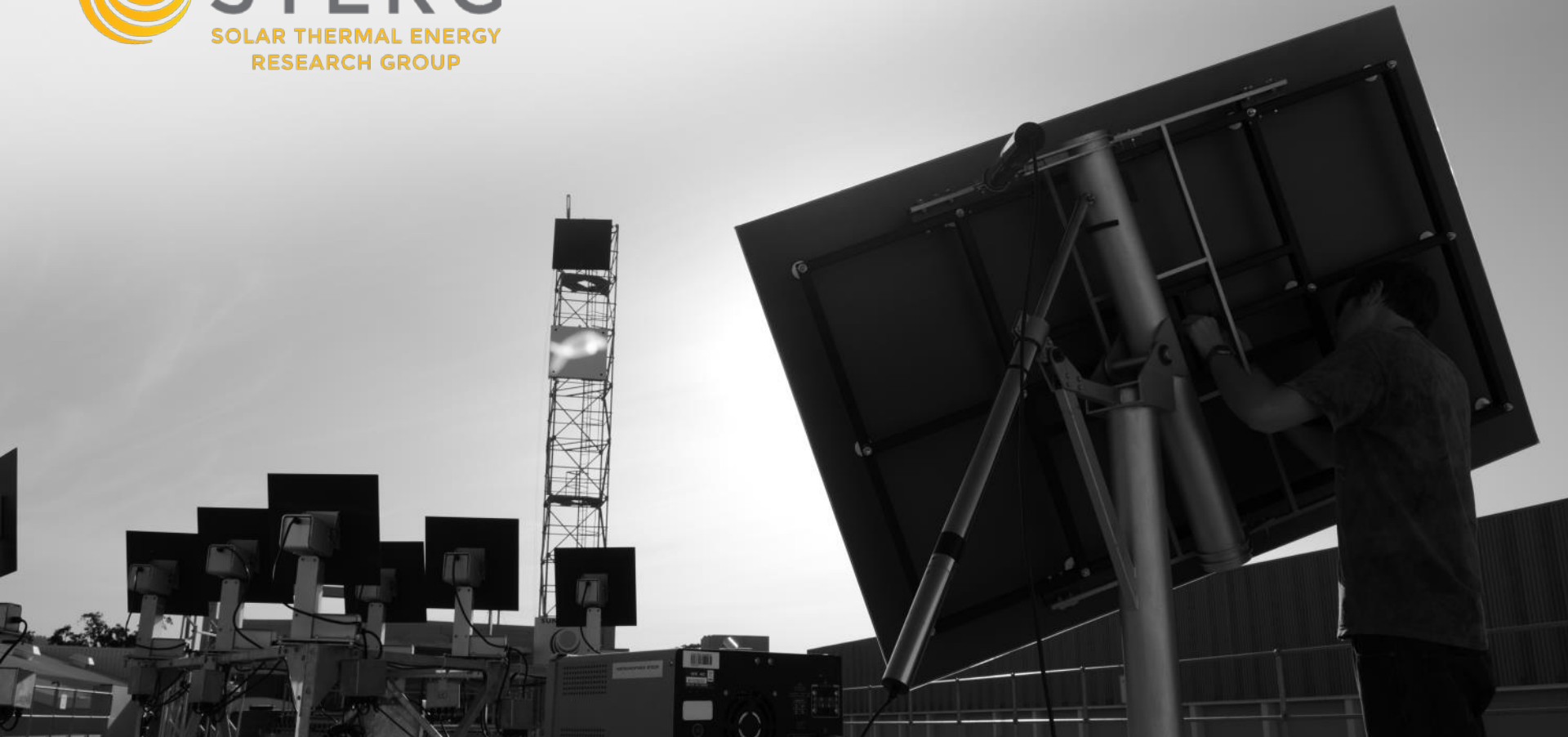

Identification of optimum molten salts for use as heat transfer fluids in parabolic trough plants. A techno-economic comparative optimization

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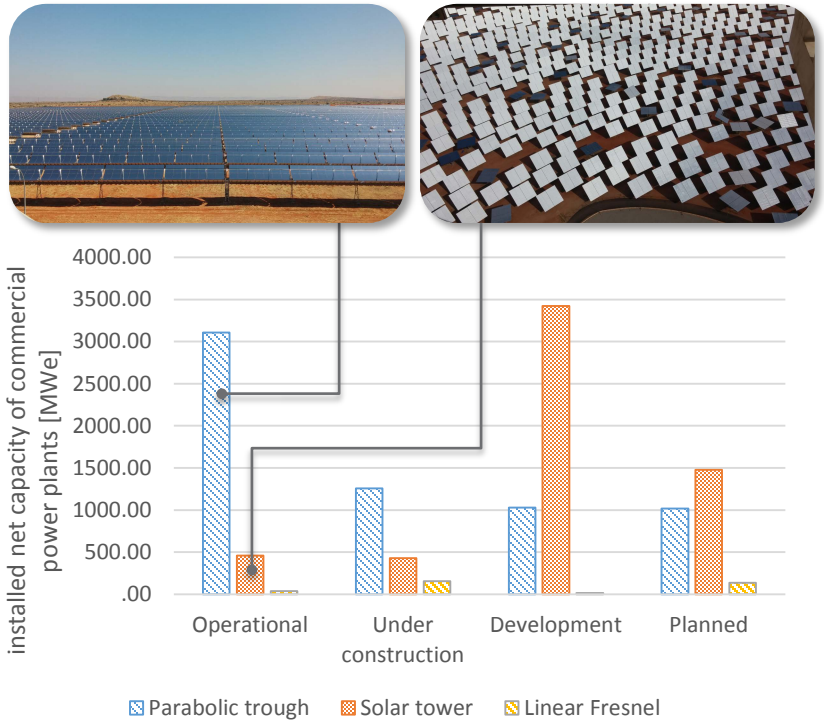
Contents

Introduction

- PT most mature and bankable CSP technology
- Towers are catching up
- Increase competitiveness of PT by reducing LCOE
- Higher cycle efficiency through larger cycle temperature difference needed
- Molten salt linked to challenges
- New opportunities for CSP in Southern Africa



Source: CSP World, 2017

Background

- LCOE reduction by switching from thermal oil to molten salt
  - 12.1% (Dersch *et al.*, 2014)
  - 16.4 % (Boukelia *et al.*, 2015)
  - 20 % (Ruegamer *et al.*, 2014)

  } large variations caused by different assumptions and locations (Abu Dhabi, Béchar, Daggett)

- LCOE reduction by using different molten salts
  - 3 to 5 % (Ruegamer *et al.*, 2014)

  } small variations but still significant

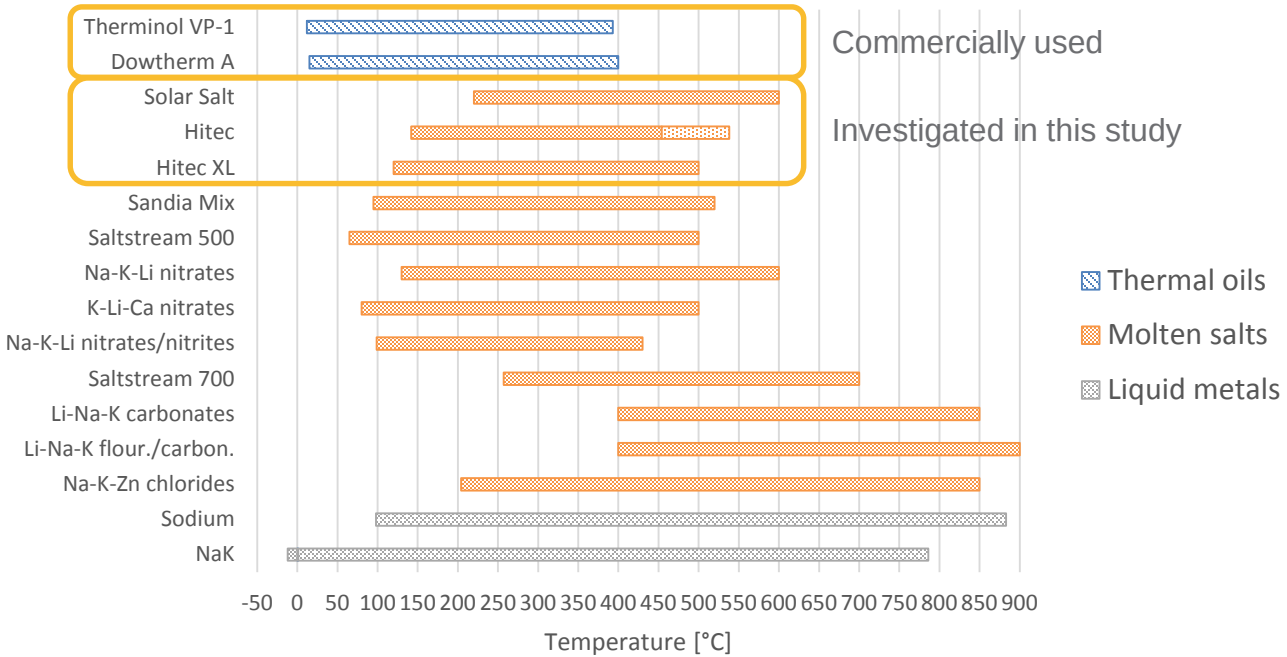
- LCOE variations in literature
  - 7.59 to 23.6 $cent/ kWh_e

- Studies only look at one power plant configuration and compare it with other fluids, but what about different configurations?

Research question

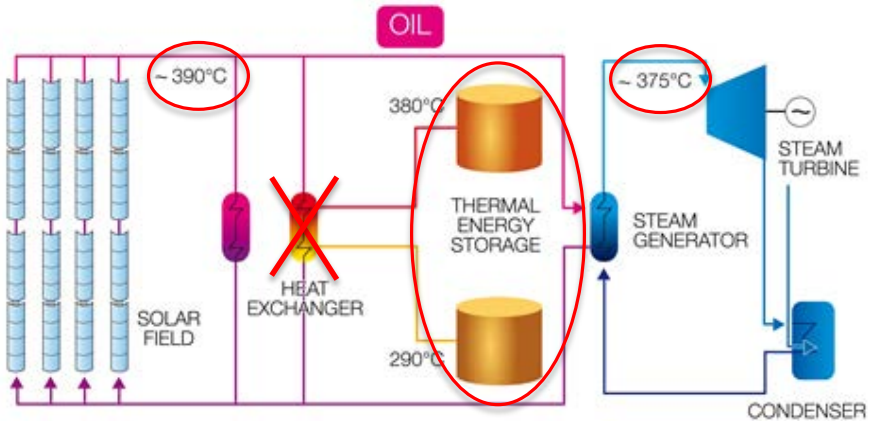
- Which molten salt as heat transfer fluid (HTF) is most suitable to improve the performance of a parabolic trough power plant from a techno-economic standpoint for a variety of configurations and locations?

Heat transfer fluids

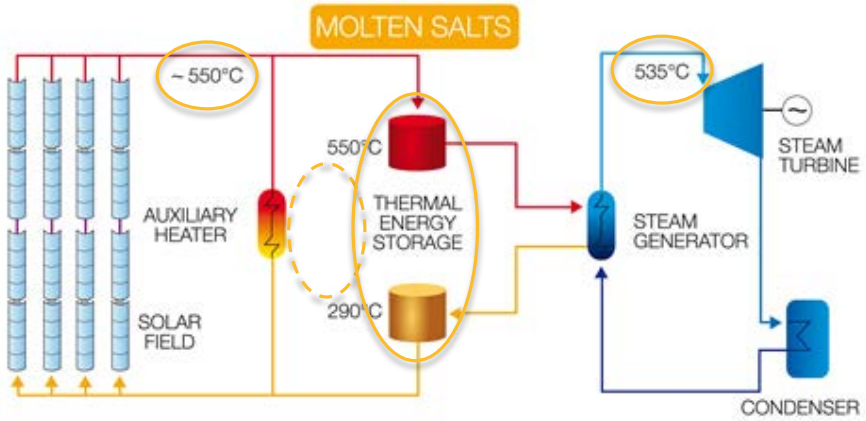


Sources: Dow Chemical Company, 2001; Bradshaw & Siegel, 2008; Vignarooban et al., 2015

Advantages of molten salts



Cycle efficiency up to 38 %



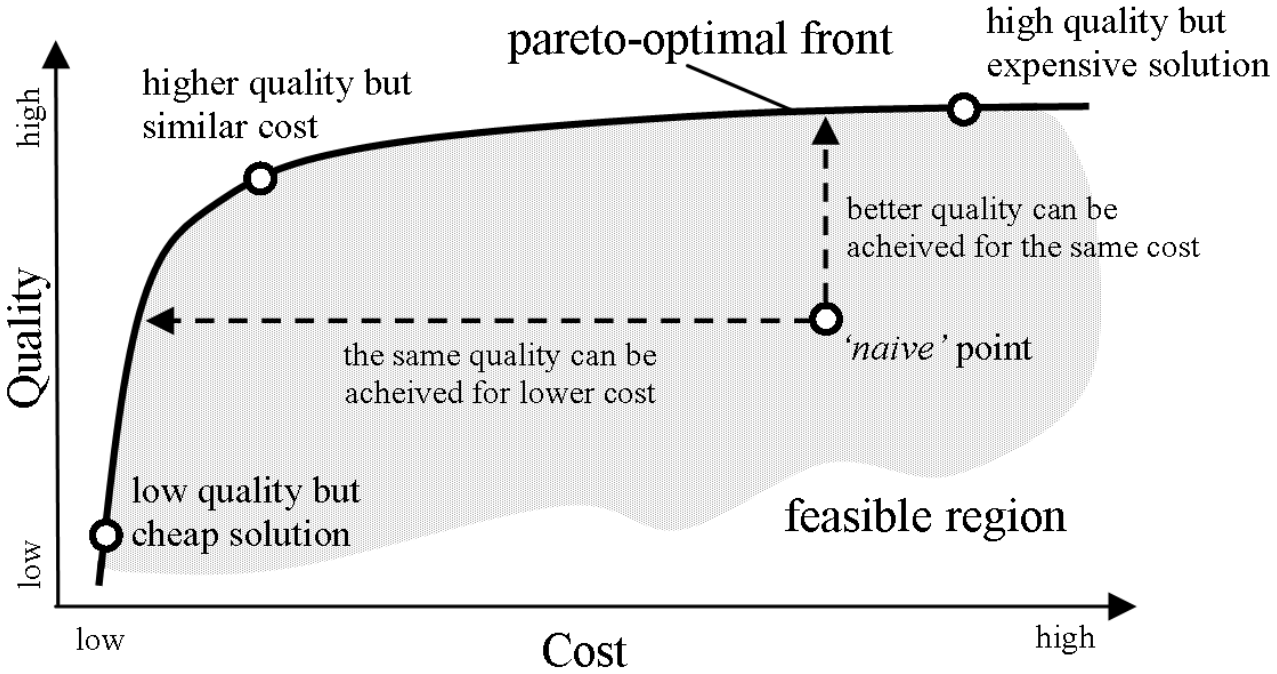
Cycle efficiency over 40 %

Adapted from: Archimede Solar Energy, 2016

Techno-economic optimization

- Optimization of technical and financial indicators
  - LCOE
  - CAPEX
  - IRR
- Identification of optimal HTF for
  - various component sizes (TES, solar field, turbine capacity, etc.)
  - various operating strategies (base load or peaking)
  - various location-based framework conditions (solar resource, feed in tariff, financial parameters)
- Population based evolutionary algorithm
- Range of solutions that are optimal
- Compromise between cost and quality

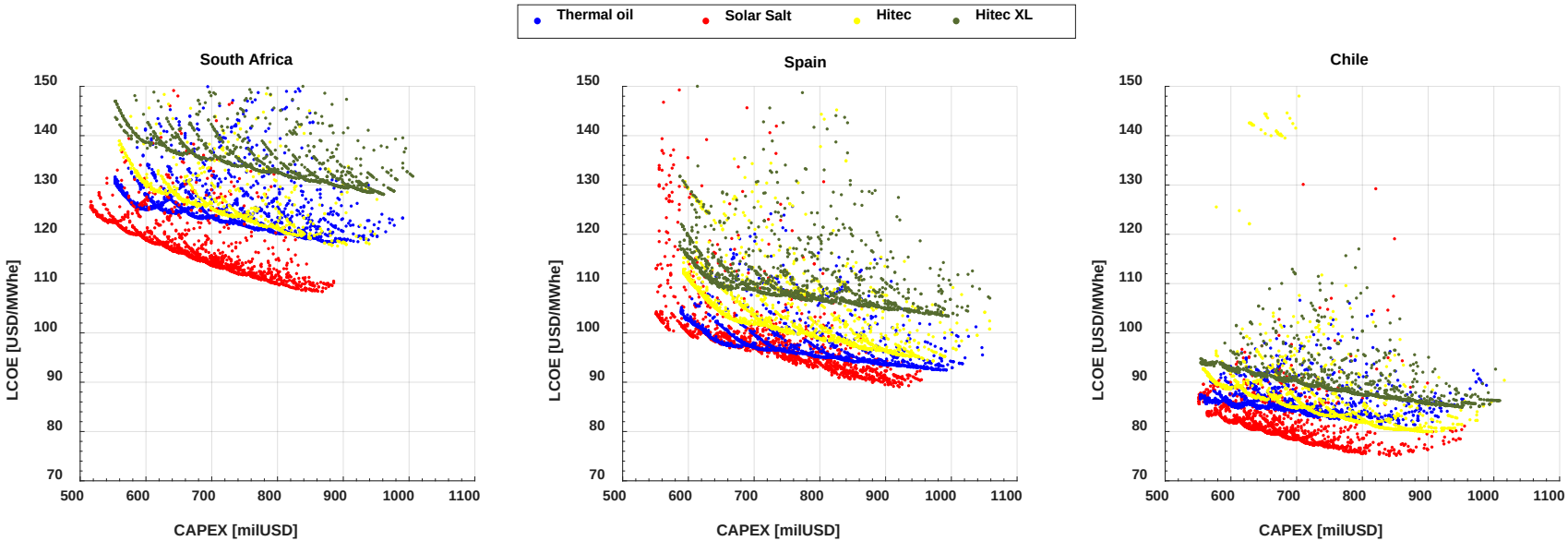
Techno-economic optimization



Source: Spelling, 2013

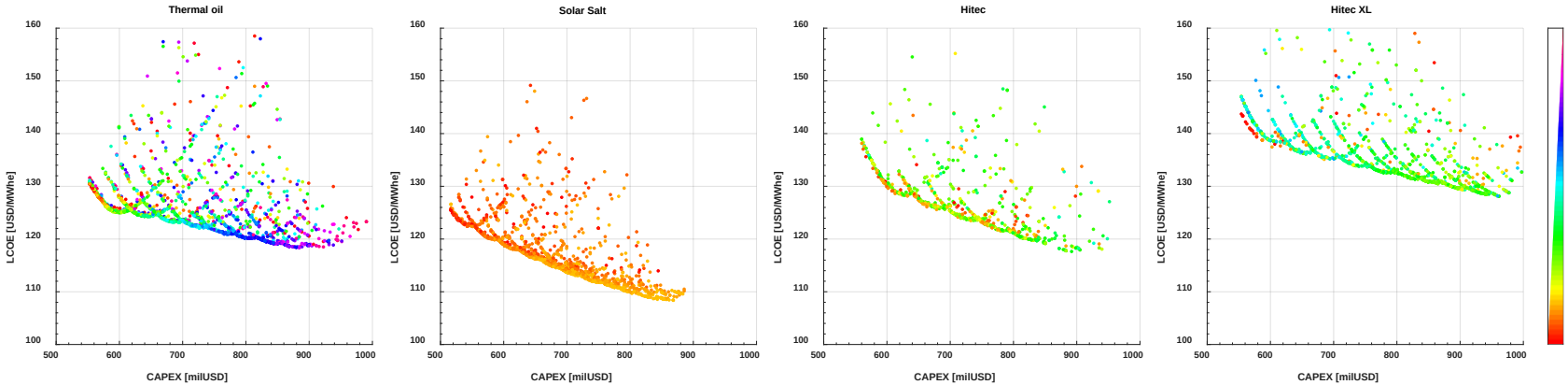
Results– LCOE vs. CAPEX at various locations

- Choice of HTF is dependent on DNI and system size
- Solar Salt offers lowest LCOE



Results – freeze alert temperature

- Freeze alert temperature variation in South Africa
- Set point should be close to solar field outlet temperature for small systems
- Temperature can be lowered significantly in large systems



Next steps

- Vary other parameters (turbine capacity, location)
- Analyze different operating strategies (base load, peaking)
- Optimize IRR, capacity factor
- Future applications of optimization
  - TES technology (direct storage, thermocline)
  - Water consumption
  - Steam generator (ramp-up rates, pinch points)

Conclusion

- Optimal HTF dependent on system size and DNI
- Freeze alert temperature has significant impact on plant economics
- Model can be used to find optimal power plant configuration in terms of
  - location
  - operating strategy
  - feed in tariff
  - costs
- New salt mixtures needed
  - cheaper
  - wider operating temperature range
- Increase competitiveness of parabolic trough
- Support for policy makers, developers and plant operators
- Technology promotion & development opportunities in Southern Africa

References

- Archimede Solar Energy. 2016. Molten salts vs Oil. [Online], Available: http://www.archimedesolarenergy.it/molten_salt_vs_oil.htm [2017, January 13].
- Boukelia, T.E., Mecibah, M.S., Meriche, I.E. & Belgroun, Z. 2015. Comparative study of parabolic trough power plant with integrated TES and BS using synthetic oil and molten salt. In Tlemcen, Algeria: IEEE 3rd International Conference on Control, Engineering & Information Technology (CEIT).
- CSP World. 2017. CSP World Map. [Online], Available: http://www.cspworld.org/cspworldmap [2017, January 12].
- Dersch, J., Vogel, T., Polklas, T. & Tümmers, C. 2014. Solar-only Parabolic Trough Plants with High Steam Parameters. Energy Procedia. 49:1117–1126.
- Dow Chemical Company. 2001. *DOWTHERM A - Synthetic Organic Heat Transfer Fluid - Liquid and Vapor Phase Data*. [Online], Available: http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_097a/0901b8038097ad39.pdf?filepath=heattrans/pdfs/noreg/176-01463.pdf&fromPage=GetDoc [2017, January 12].
- Ruegamer, T., Kamp, H., Kuckelkorn, T., Schiel, W., Weinrebe, G., Nava, P., Riffelmann, K. & Richert, T. 2014. Molten Salt for Parabolic Trough Applications: System Simulation and Scale Effects. Energy Procedia. 49:1523–1532.
- Spelling, J.D. 2013. Hybrid Solar Gas-Turbine Power Plants: A Thermoeconomic Analysis. PhD Thesis, KTH Royal Institute of Technology. Stockholm, Sweden.
- Vignarooban, K., Xu, X., Arvay, A., Hsu, K. & Kannan, A.M. 2015. Heat transfer fluids for concentrating solar power systems – A review. *Applied Energy*. 146:383–396.

Thank you

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