



Geothermal energy and thermal storage

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Geothermal energy and thermal storage - summary

- Why storage?

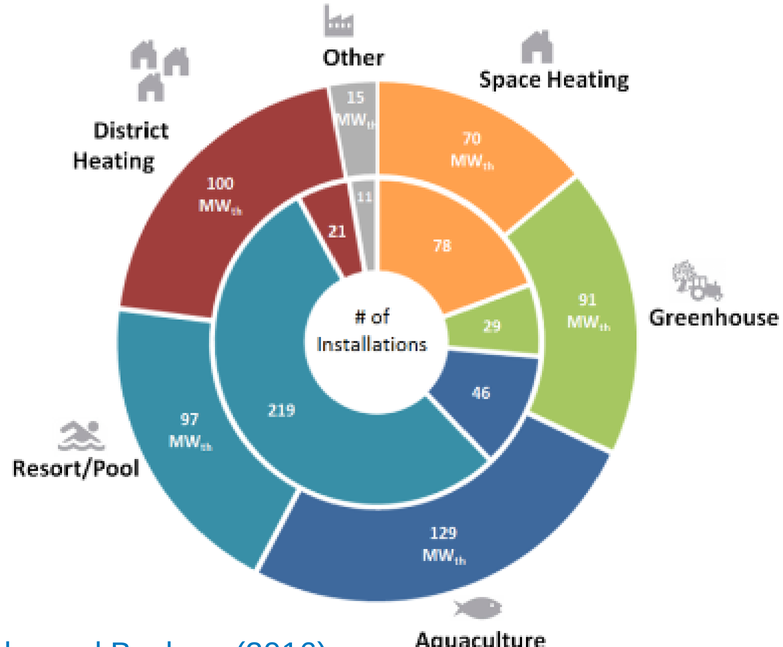
- "Deep Direct Use" project
  - The direct use of geothermal heat
  - Use heat to run absorption chiller (cooling) applications
  - Benefit of 'turbine inlet cooling' in a power plant
  - Case study

- Solar-geothermal hybrid
  - Declining geothermal resource
  - Integration of concentrating solar power and storage
  - Preliminary results

DDU Proposal Summary

- Geothermal DDU: Turbine inlet cooling in East Texas

- Objectives:
- Target large-scale integration (~50 MW_{th}) into industrial application
- Decouple 24/7 geothermal heat use from varying demand
- Generate high-value product (electricity) from low-temperature geothermal resource
- Tap resource outside of traditional hydrothermal-use regions



U.S. direct-use geothermal, Snyder and Beckers (2016).

Project Scope

Focus on geothermal-driven absorption chillers for turbine inlet cooling at Eastman Chemical's combined-cycle cogen plant.

Tasks:

1. Evaluate geothermal resource, local regulations, and other site-specific issues
2. Model integration options to quantify efficiency benefits
3. Assess overall economics by cost and sensitivity to geothermal resource temperature, well depth, and well-to-plant distance

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TAS economic. clean. energy.

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EASTMAN Eastman Chemical Company

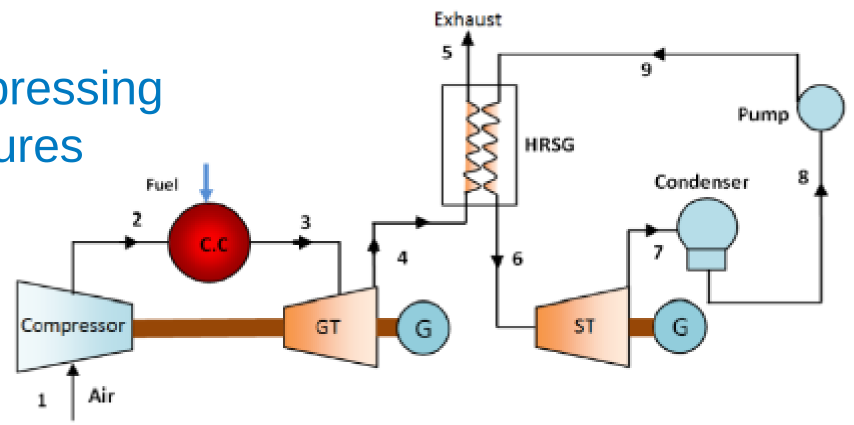
Eastman Chemical, Longview, TX

- 6000 acre site established 1952
- 2-ethylhexanol, propylene, ethylene and >40 other major chemical and polymer products
- ~1500 employees
- 468 MW_e cogen combined-cycle plant

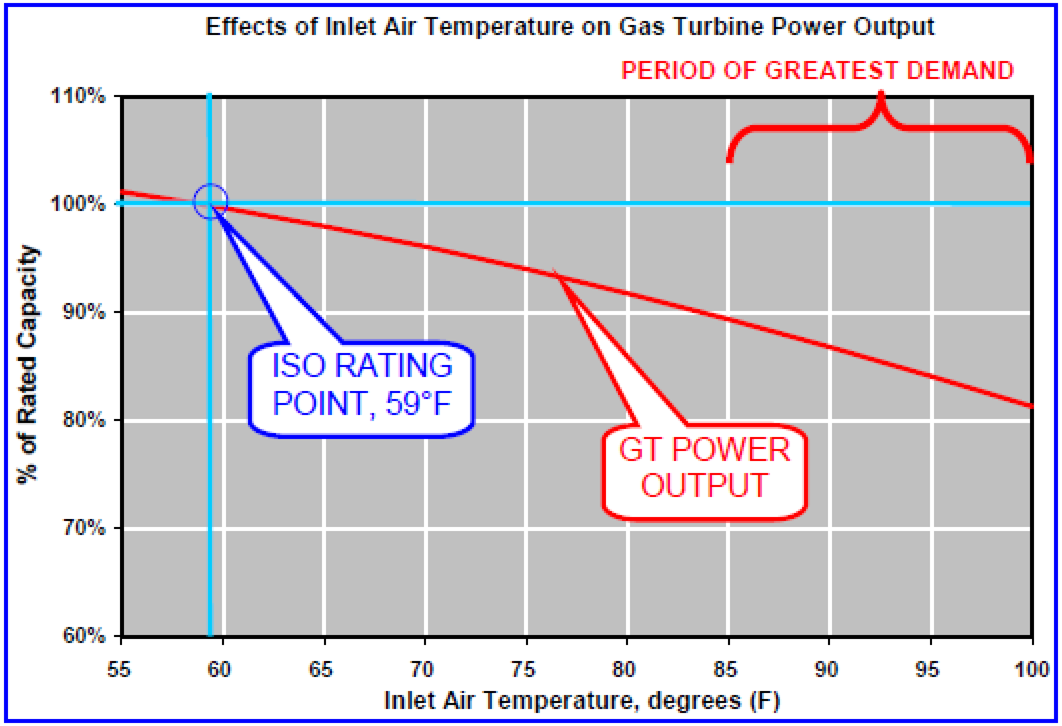
- Highlights:
- Ships nearly 10 million pounds of chemical products per day
- One of the largest employers in East Texas
- Recipient of American Chemistry Council's Responsible Care® Energy Efficiency Award (2011-2012)
- Recognized for pollution prevention programs and communications with the public; awarded the 2012 "Sustained Excellence in Caring for Texas Award"
- Improved energy intensity by 25% in past 10 years

Why Turbine Inlet Cooling?

The first step of a gas turbine is compressing ambient air. Altitude or high temperatures decrease compressor efficiency.

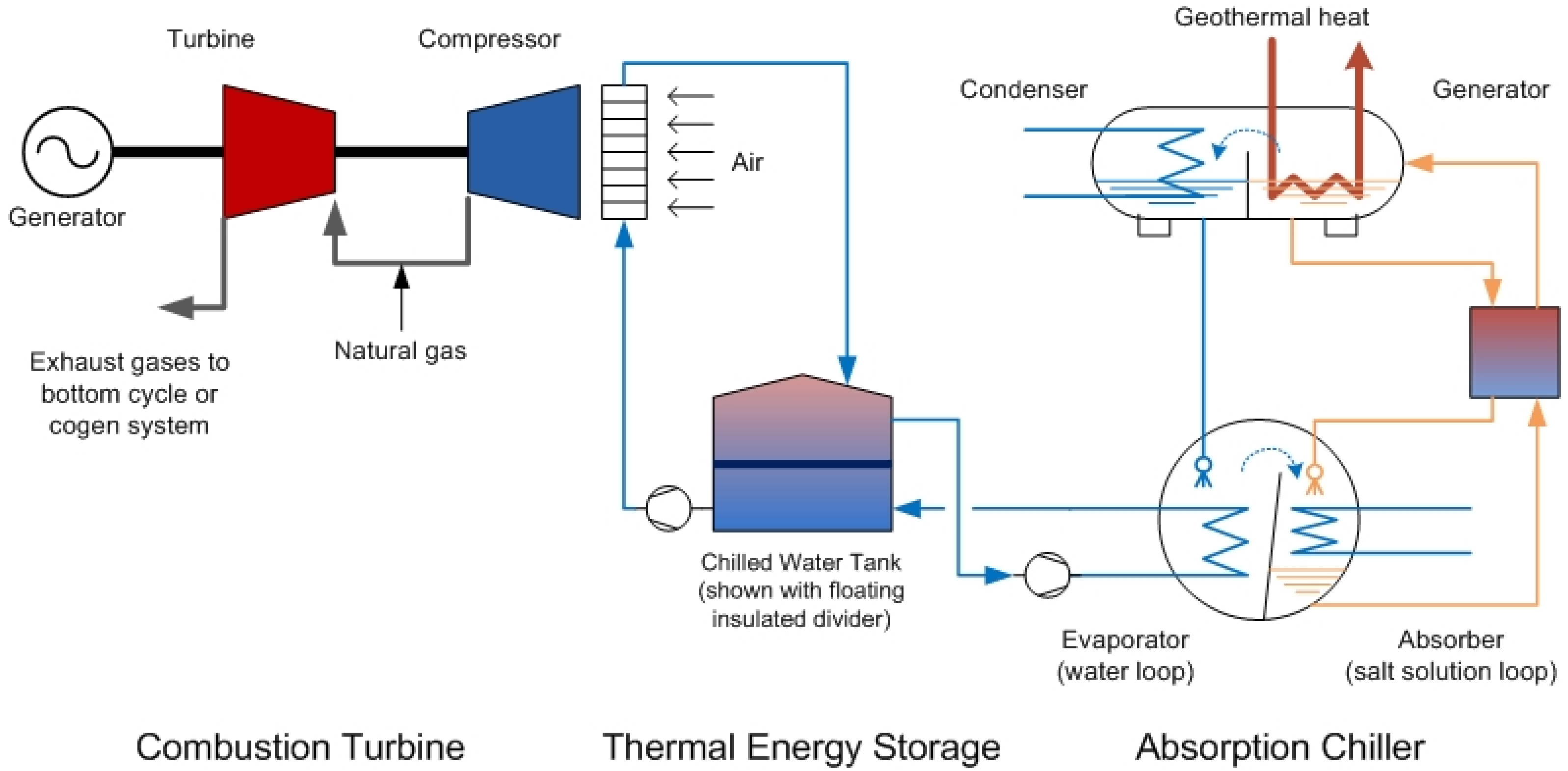


Standard gas turbine rating is estimated at 15°C (59°F). Turbine performance drops with increasing air temperature.



Tillman, "Weather-Rated Economics of Gas Turbine Installations," Turbine Air Systems, 2005.

Integration with Turbine Inlet Cooling



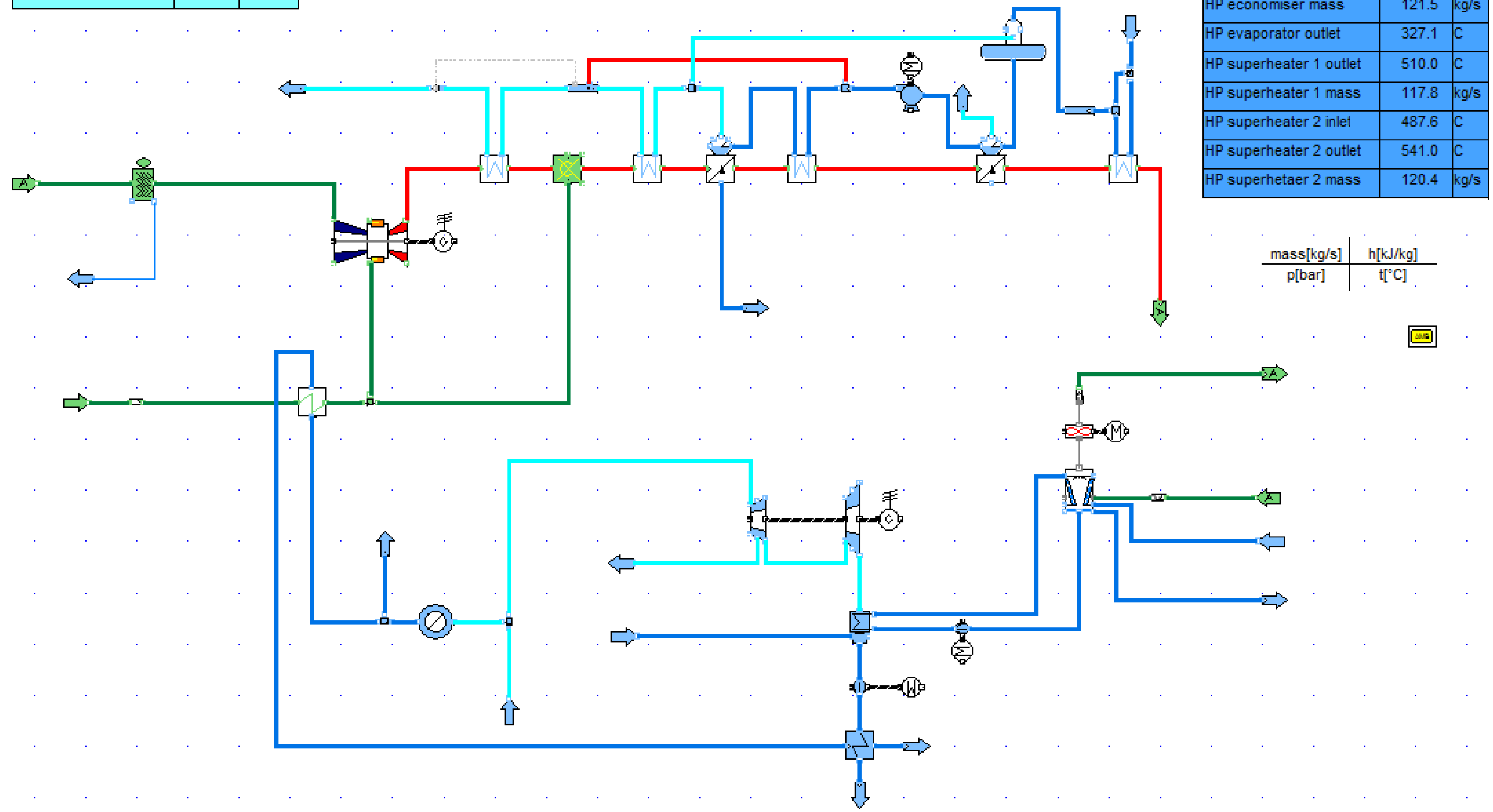
Modelling of the co-gen plant - IPSEpro

Steam temperature	537.8	C
Steam pressure	109.0	bar
HP steam mass flow	156.0	kg/s
LP steam mass flow	97.1	kg/s
Gross power output	126.6	MWe
Pumping power	2.2	MWe
Exhaust temperature	44.0	C
Efficiency	37.3	%

GT power	167.5	MWe
Heat rate	9963.0	kJ/kWh
Exhaust temp	604.9	C
Exhaust mass flow	445.9	kg/s
Efficiency	36.1	%

Exhaust	604.9	C
Superheater 1 exit	572.0	C
Burner exit	798.0	C
Superheater 2 exit	647.0	C
HP evaporator exit	337.1	C
HP economiser exit	131.6	C
LP economiser exit	127.6	C
Preheater exit	74.8	C

Inlet water	56.0	C
Inlet mass	122.5	kg/s
Preheater exit	105.0	C
LP evaporator inlet	115.6	C
LP evaporator outlet	115.6	C
LP evaporator mass	125.0	kg/s
Pump outlet	117.0	C
HP economiser outlet	298.0	C
HP economiser mass	121.5	kg/s
HP evaporator outlet	327.1	C
HP superheater 1 outlet	510.0	C
HP superheater 1 mass	117.8	kg/s
HP superheater 2 inlet	487.6	C
HP superheater 2 outlet	541.0	C
HP superhetaer 2 mass	120.4	kg/s



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Retrofitting a Geothermal Plant with Solar and Storage to Increase Power Generation

Josh McTigue, Jose Castro, Greg Mungas, Nick Kramer, John King, Craig Turchi, Guangdong Zhu

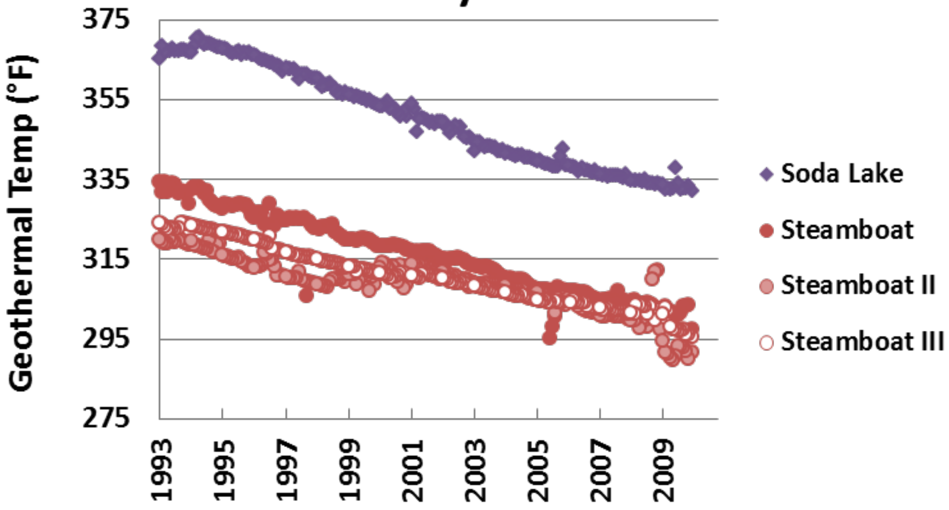
GRC Annual Meeting, #41

October 3rd , 2017

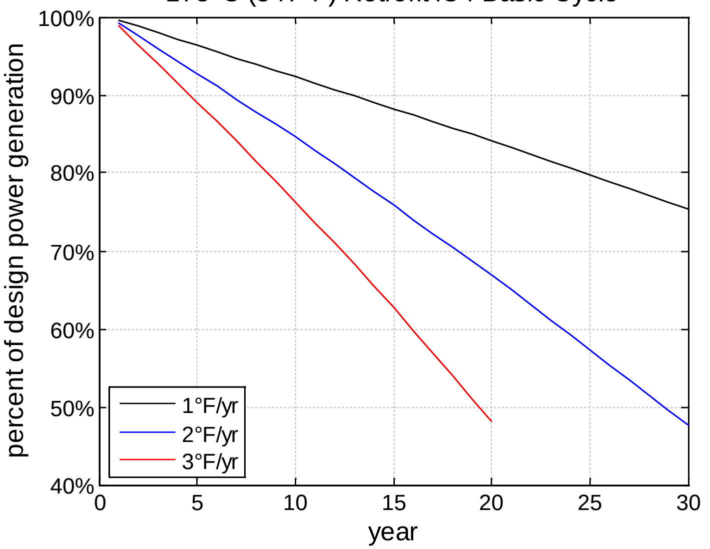
Summary

- Motivation: off-design geothermal power plants
- Hybrid geothermal-CSP plants
- Annual simulations
- Economic analysis

Off-design geothermal plant behavior

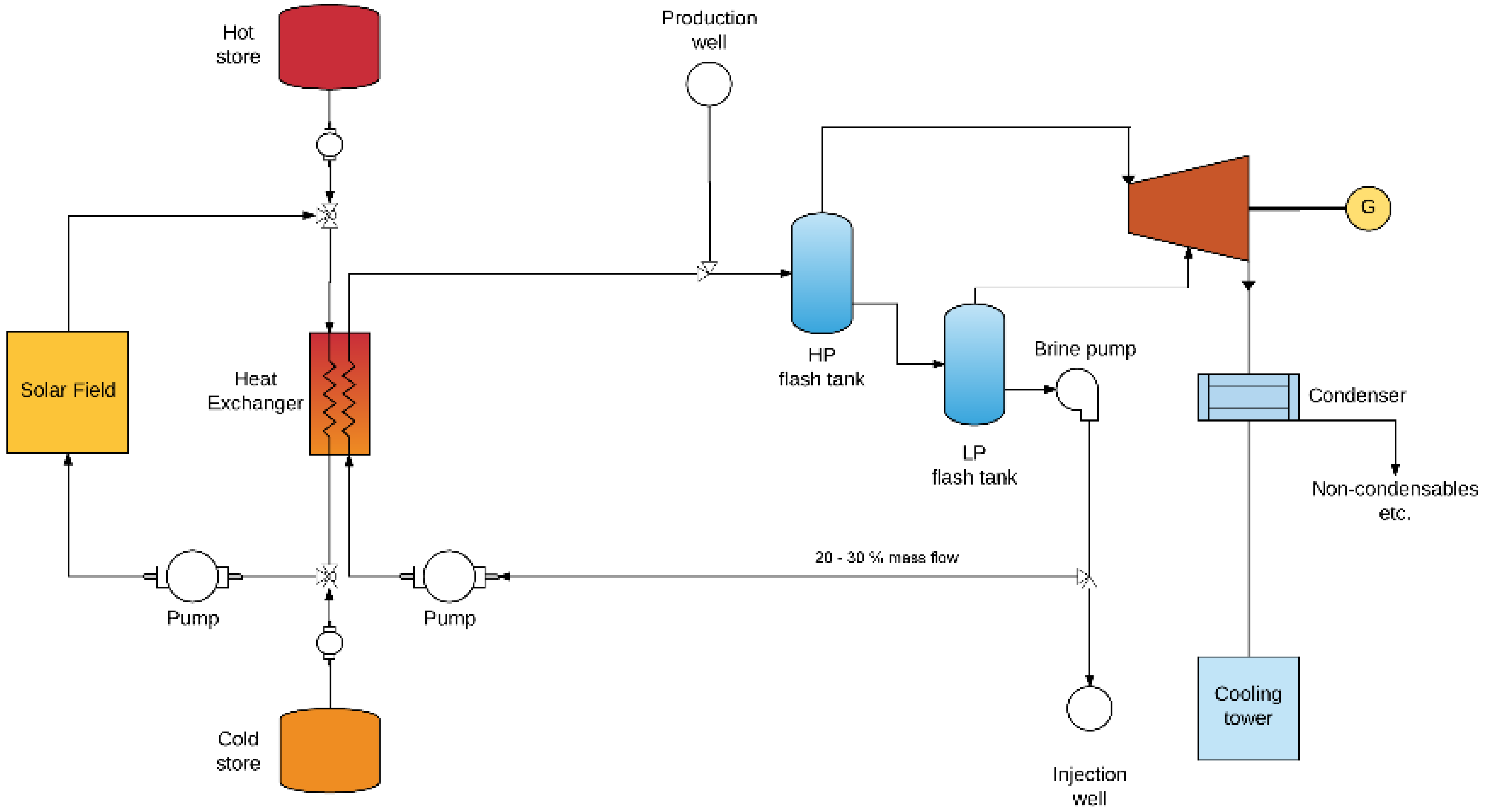


Simulated effect of temperature decline on air-cooled binary plant performance



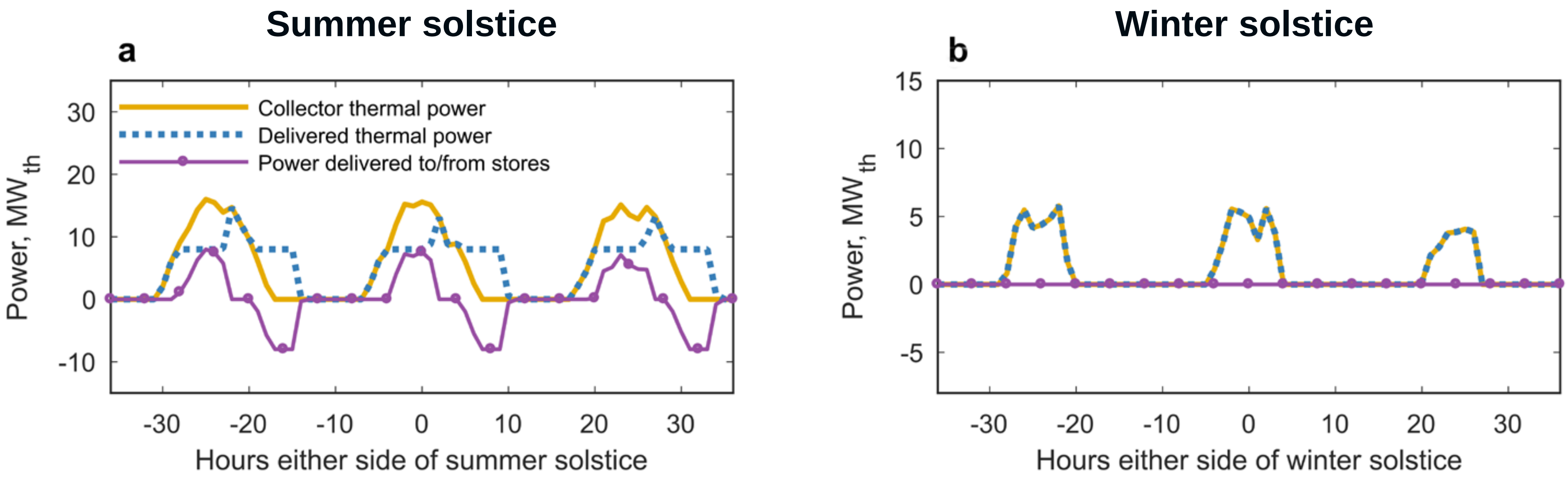
Wendt & Mines, "Use of a Geothermal-Solar Retrofit Hybrid Power Plant to Mitigate Declines in Geothermal Resource Productivity", GRC Transactions, 38, 2014

Hybrid geothermal-CSP power plants



McTigue et al. “Retrofitting a geothermal plant with solar and storage to enhance power production”, GRC Transactions, 41, 2017

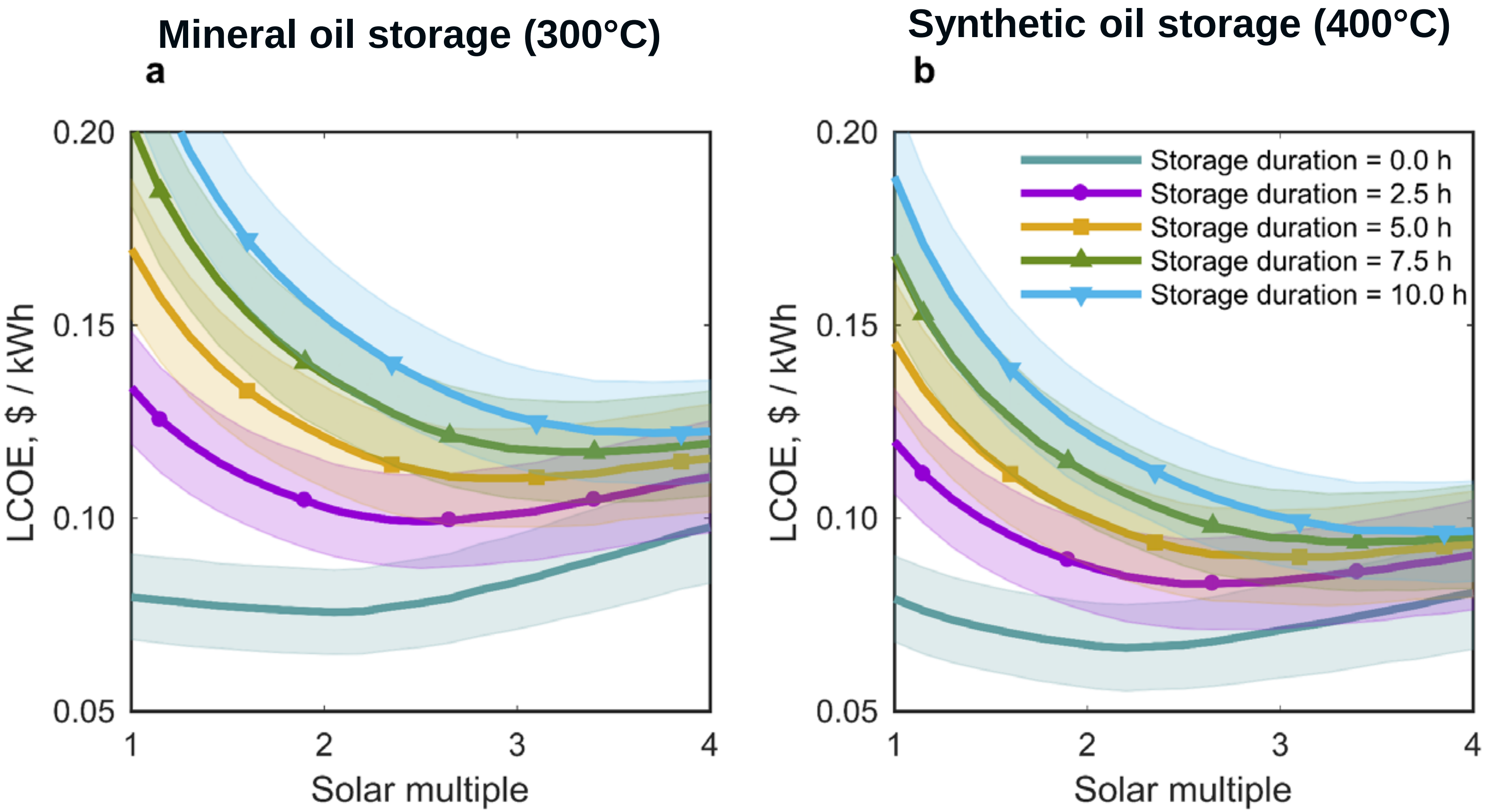
Yearly calculations – storage and economics



- If stores aren't large enough in the summer then power may be curtailed
- Stores are unused in the winter

McTigue et al. "A hybrid power plant combining geothermal, concentrating solar, and thermal energy storage provides dispatchability and increased power production", manuscript in preparation

Economic analysis – levelized cost of electricity



- Is LCOE the most suitable metric?
- Results are comparable with PV + BES

McTigue et al. “A hybrid power plant combining geothermal, concentrating solar, and thermal energy storage provides dispatchability and increased power production”, manuscript in preparation

Summary

- A range of thermal storage tech is available
- Provides value to the grid in various ways
- Can be integrated into geothermal plants without turning the plant off
- Need to evaluate with appropriate metrics

Acknowledgements to:

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DOE Geothermal Technology Office
DOE Solar Technology Office
Navy Geothermal Program Office

www.nrel.gov

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