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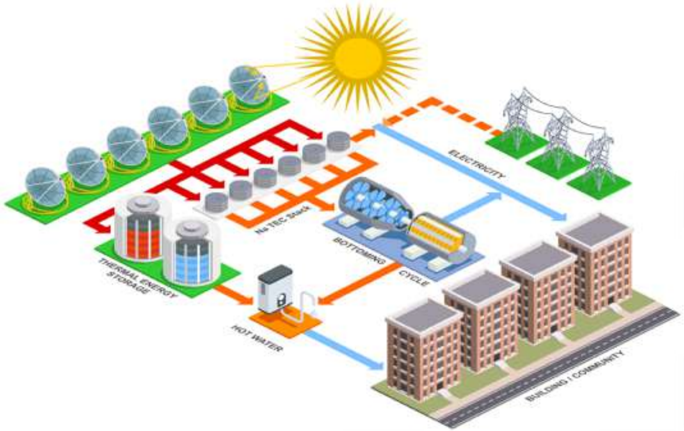
SOLAR ENERGY TECHNOLOGIES OFFICE

SETO CSP Program Summit 2019

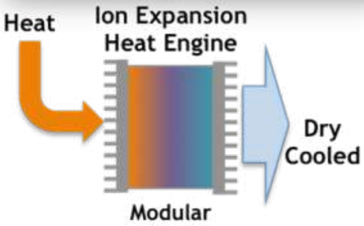


Sodium Thermal Electrochemical Converter (Na-TEC) Power Block for Distributed CSP

Shannon K. Yee, Assistant Professor
Georgia Institute of Technology

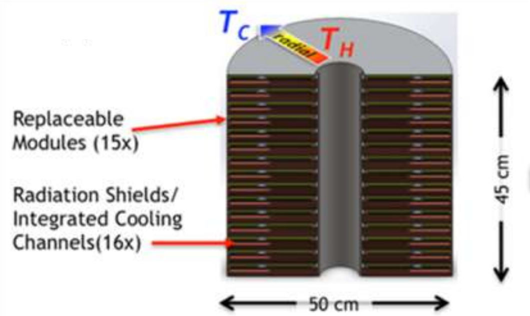
Project Summary

Goal: Develop a ***dual-stage modular*** sodium thermal electrochemical converter (Na-TEC) heat engine power block with an estimated efficiency (η_T) of ***51.3%***, which can be potentially integrated with either a ***small-scale dish solar*** or ***large-scale heliostats and parabolic trough CSP***.

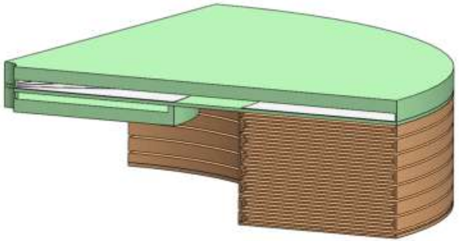


Key Advantages

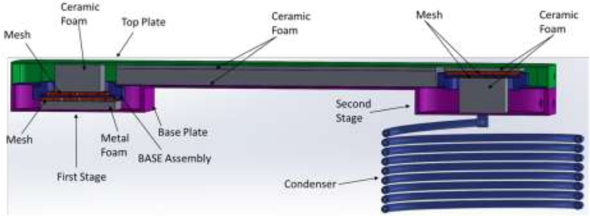
1. High second law efficiency (>90% of the Carnot limit)
2. High specific power (up to 0.2 kW/kg)
3. Closed system operation with no moving parts
4. Scalable to multiple power levels (100 W -10 kW)
5. Amenable to cogeneration using rejected heat



Year 1



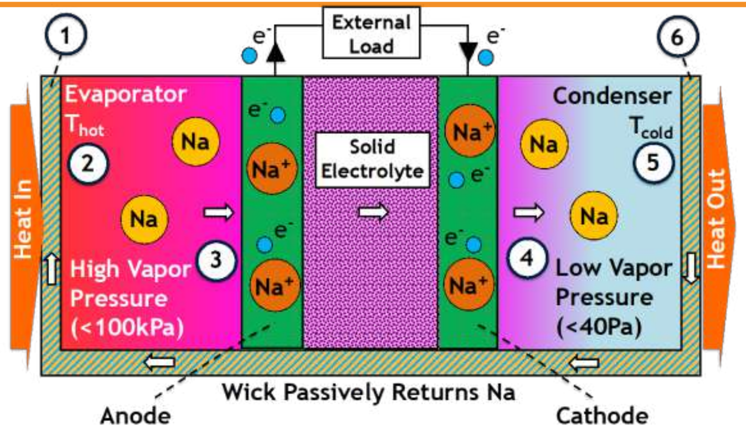
Year 2



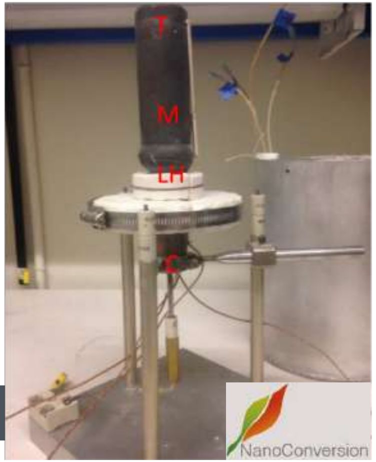
Year 3

Operation of Na-TEC: Single- *vs.* Dual-stage

Single-stage

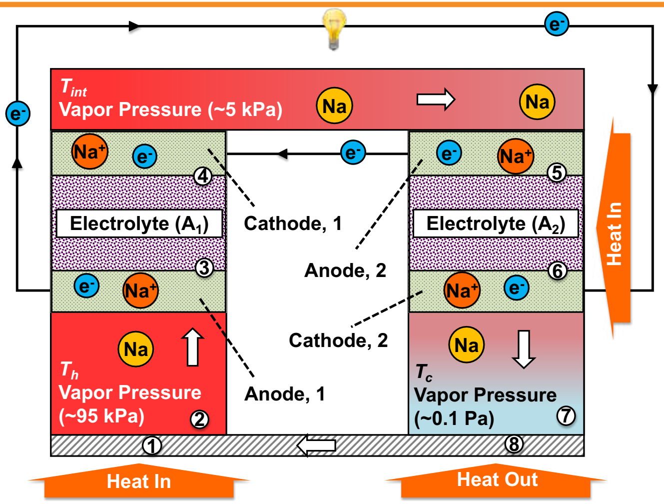


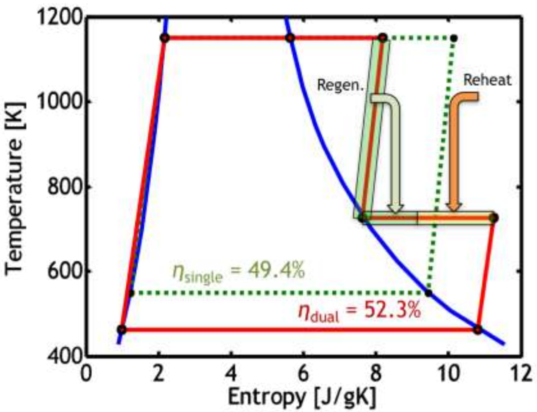
Single-stage Heat Engine



The performance of the dual-stage device will be compared against a single-stage Na-TEC

Dual-stage





Limia et al., J. Power Sources (2017)

Key Technical Challenges and Solutions

1. Beta''-Alumina Solid Electrolyte (BASE) fabrication

2. Metal to Ceramic joint

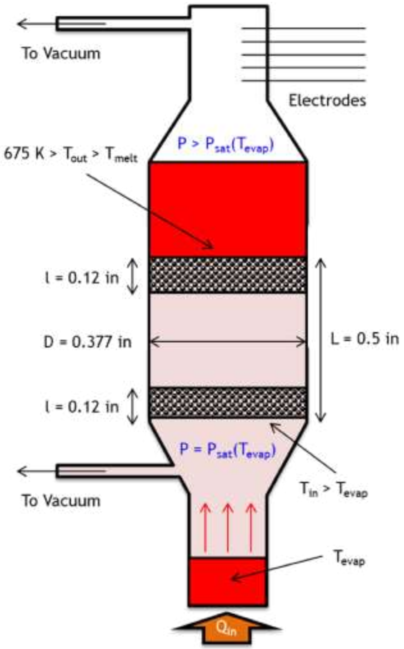
Partnered with Ionotec, Ltd. (United Kingdom) They have expertise in BASE fabrication and metal to Ceramic join using thermocompression bonding process.

SS 253 MA

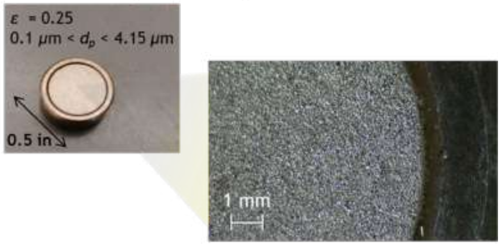
Alpha-Alumina

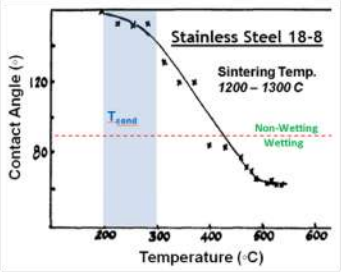
Key Technical Challenges and Solutions (cont'd)

3. Passive pumping demonstration

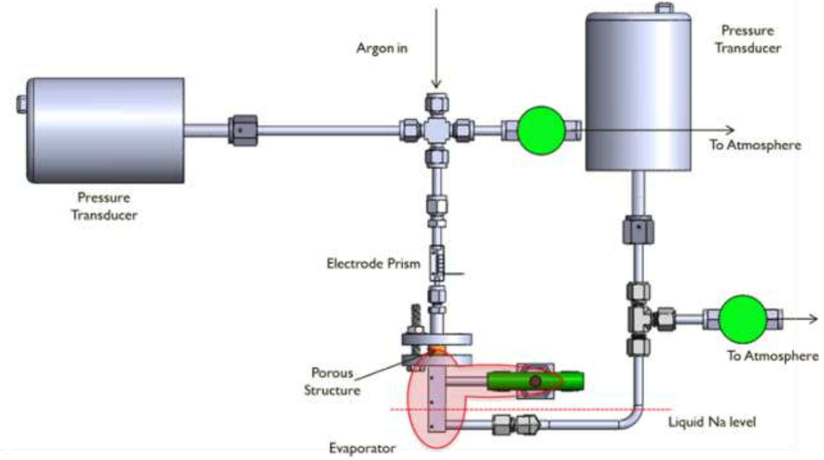


SS316 thermally pressed inside cylinder





Taylor & Ford, *U.K. Atomic Energy Authority Report*, 1955

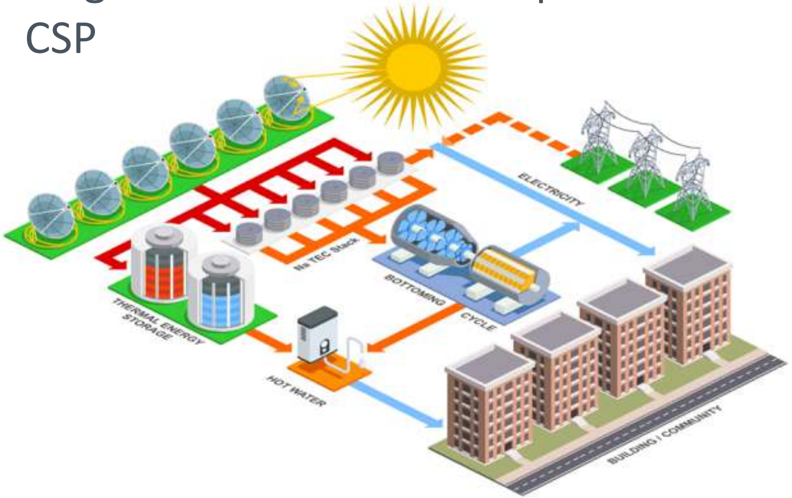


Test rig for demonstration

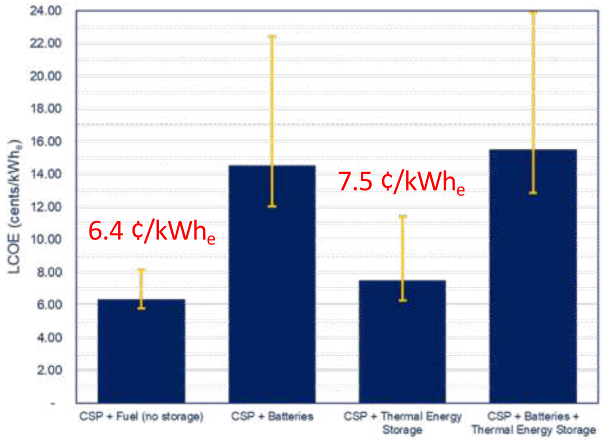
Experiments are currently in progress to demonstrate passive pumping concept

Four Potential Impacts

- This power block can be deployed for both:
  - ✓ Small-scale dish solar (displacing dish Stirling)
  - ✓ Large-scale heliostats and parabolic trough CSP



- Lower costs (6 cents/kWh-target depending on the region, at an estimated cost of < $900 for kW_e unit



- Cogeneration of heat and power: Suitable for CHP applications
- This technology is well suited for dry air-cooling

Project Team & Facilities

- Alexander Limia (Grad student)
- Jong Ha (Grad student)
- Abhishek K. Singh (Postdoctoral Fellow)
- Peter A. Kottke (Sr. Research Engineer)
- Andrey Gunawan (Research Engineer II)
- Andrei G. Fedorov (Co-PI)
- Seung Woo Lee (Co-PI)
- Shannon K. Yee (PI)
- Scalable Thermal Energy Engineering Laboratory
- Heat Lab (heat.gatech.edu)







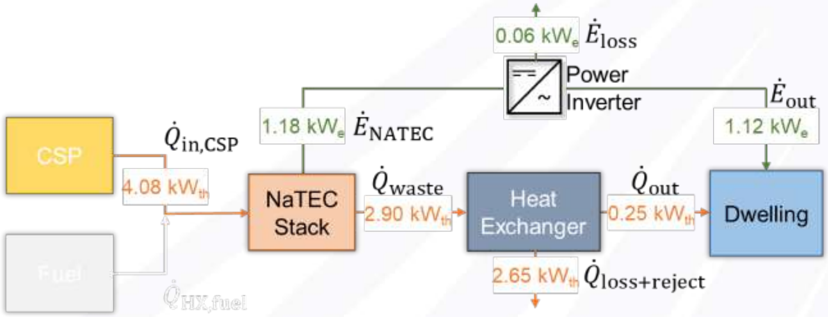

HEAT LAB

Additional slides

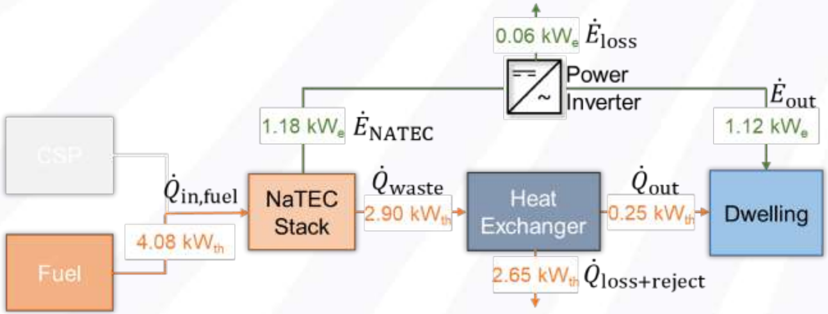
Scenario 1: CSP + Na-TEC + Fuel

$\eta \sim 34\ \%$

On Sun



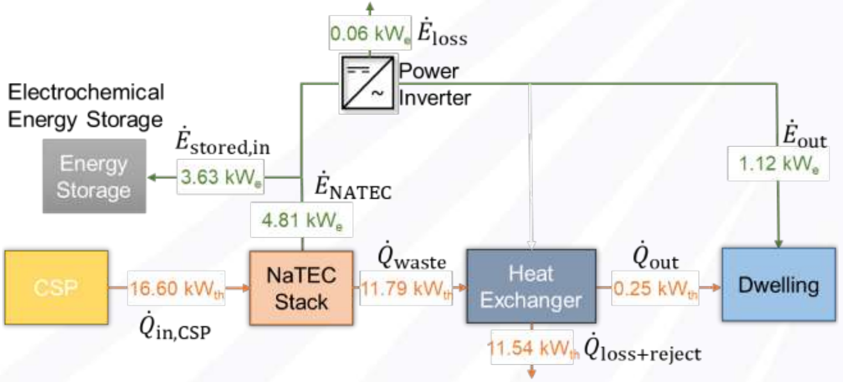
Off Sun



Scenario 2: CSP + Na-TEC + Batteries

$\eta \sim 25\ \%$

On Sun



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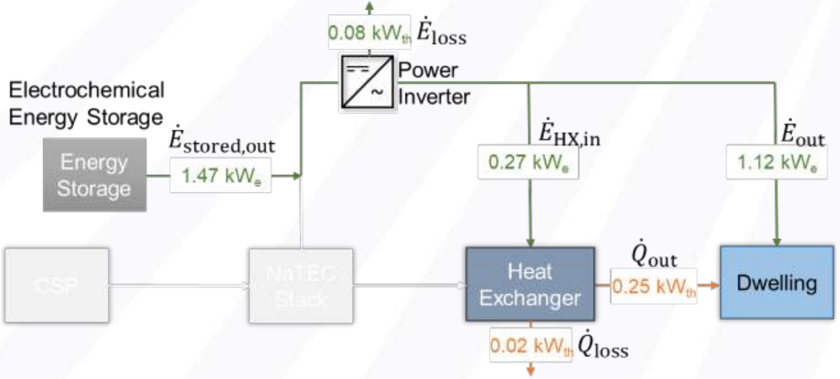
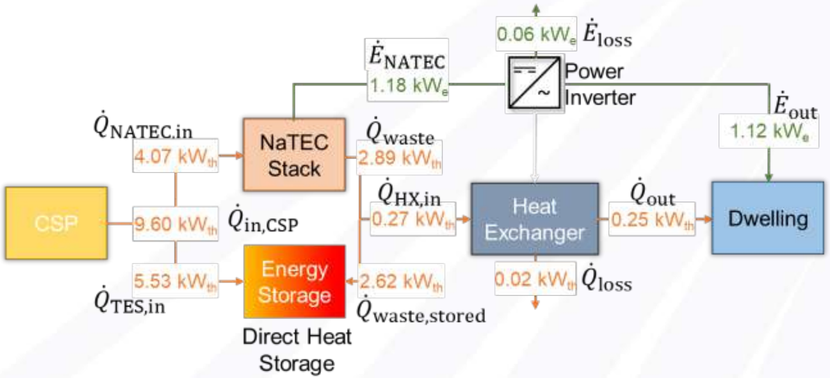


Scenario 3: CSP + Na-TEC + Direct Heat Storage

$\eta \sim 43\ \%$

On Sun



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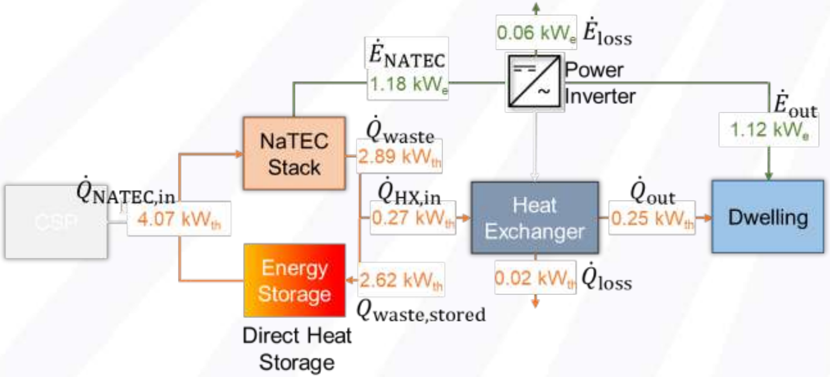
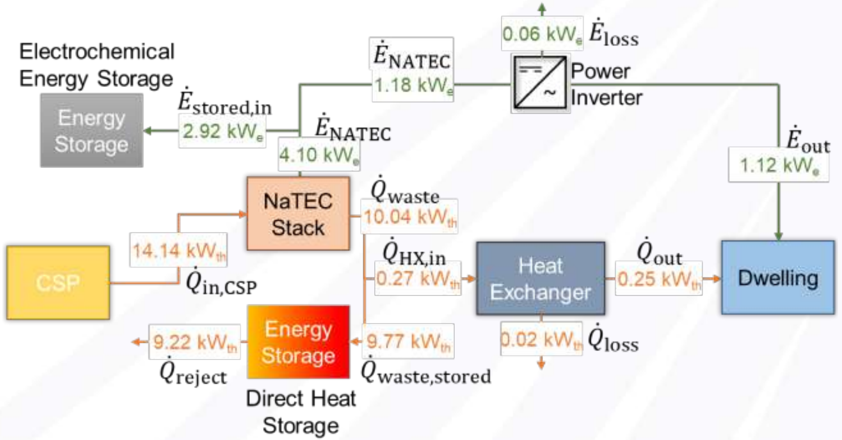


Scenario 4: CSP + Na-TEC + Hybrid Storages

$\eta \sim 29\ \%$

On Sun



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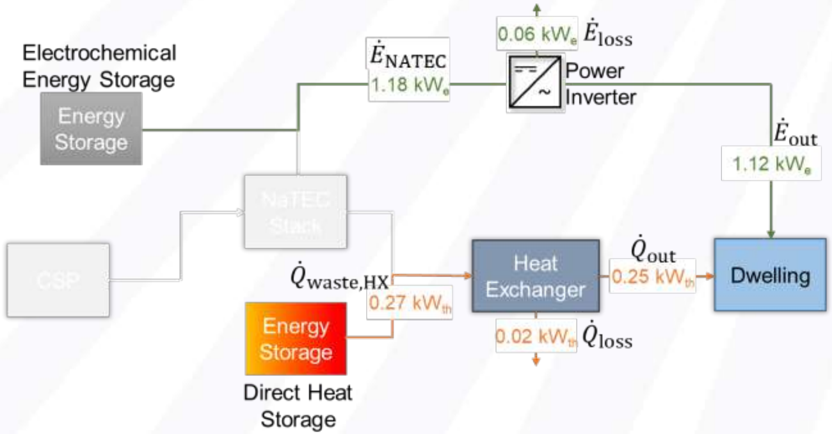
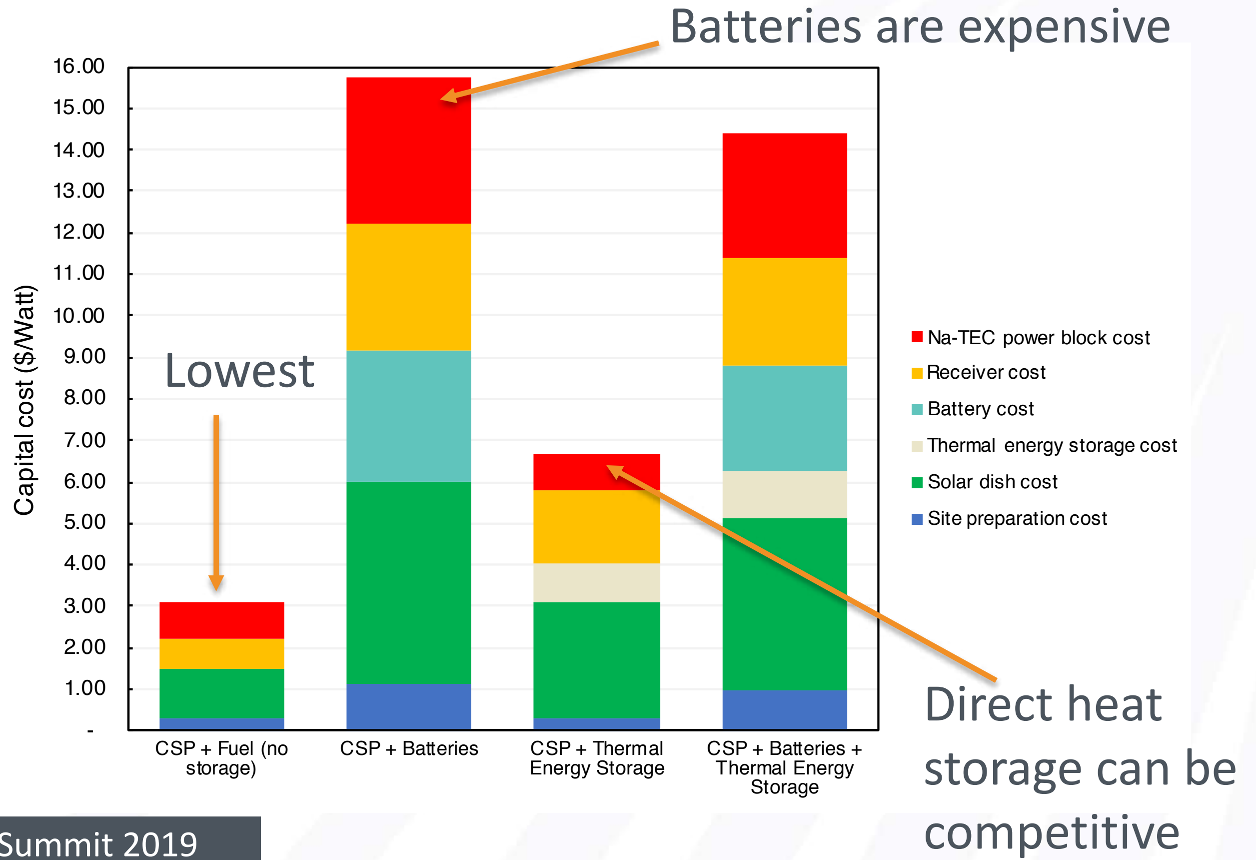
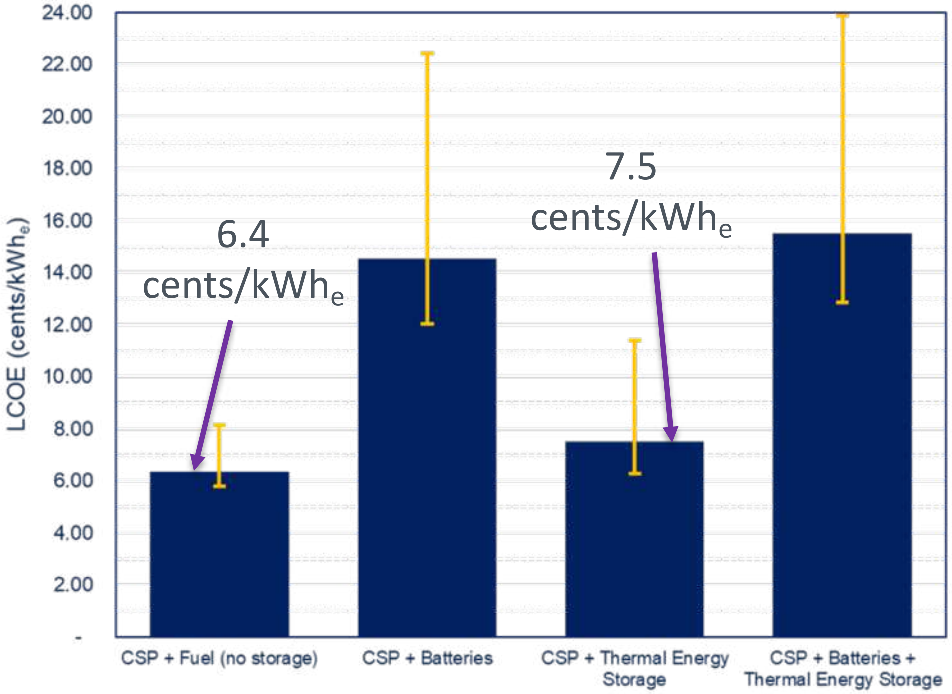


Capital Cost of CSP–Na-TEC Systems in Four Scenarios



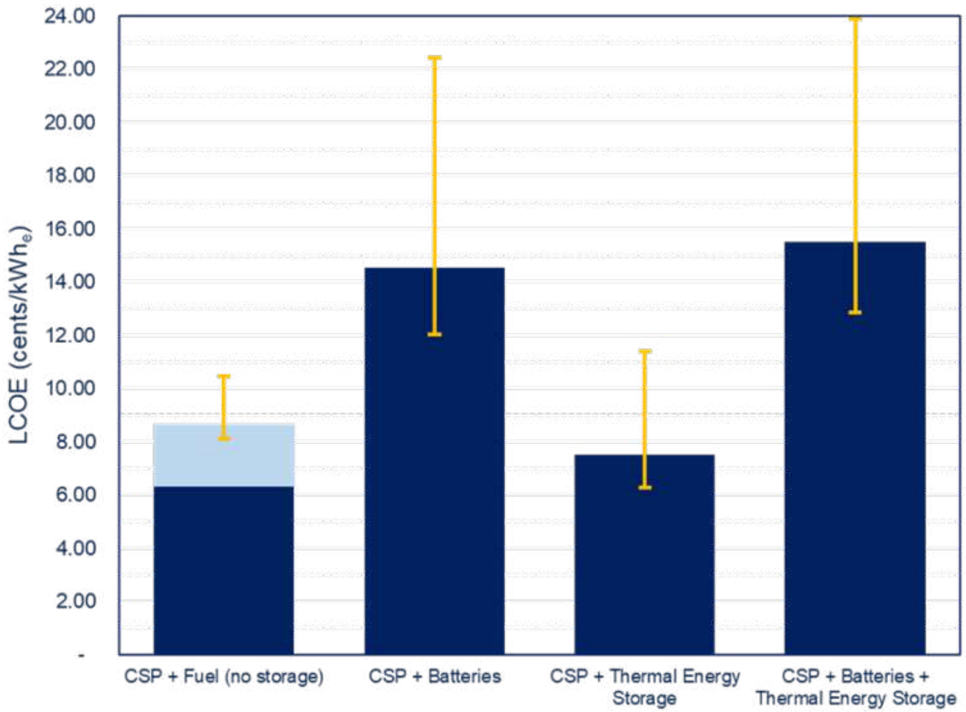
LCOE Comparison

- LCOE comparison of 4 considered scenarios
- Current fuel price – 1 cents/kWh
- Discount rate variability – 3 to 10%
- Fuel is having lowest LCOE but direct heat storage is also prices competitive



LCOE Comparison – including future fuel price

- LCOE comparison of 4 considered scenarios
- Current fuel price – 1 cents/kWh
- Discount rate variability – 3 to 10%
- Fuel is having lowest LCOE but direct heat storage is also prices competitive



For future fuel prices – similar LCOE between the scenarios of using fuel and direct heat storage