Low-Cost Thermal Energy Storage for Dispatchable CSP (MacroTES)

CEC EPIC Symposium

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SoCalGas: Ron Kent

Hyperlight Energy: John King

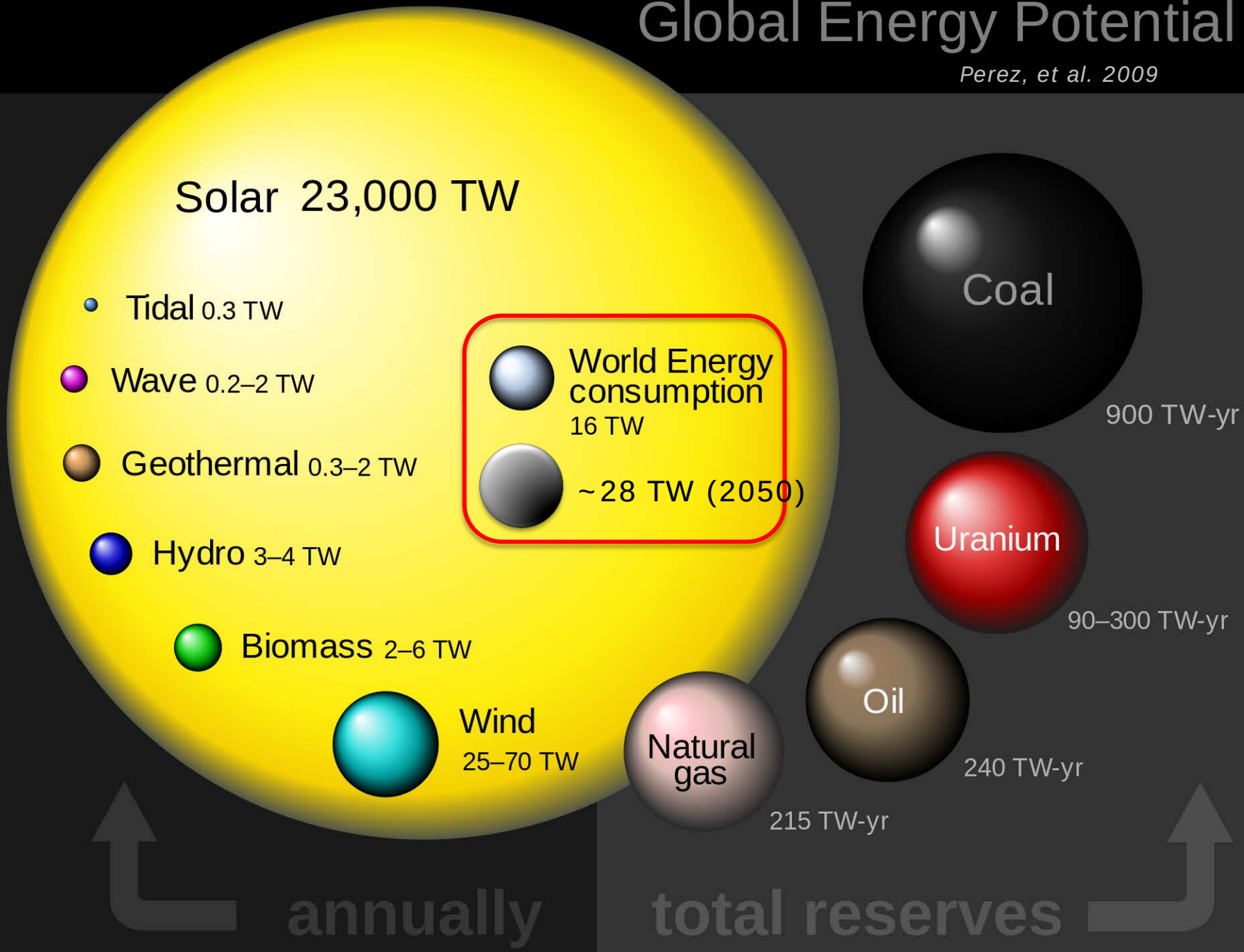
UCLA

University of California

Los Angeles, CA

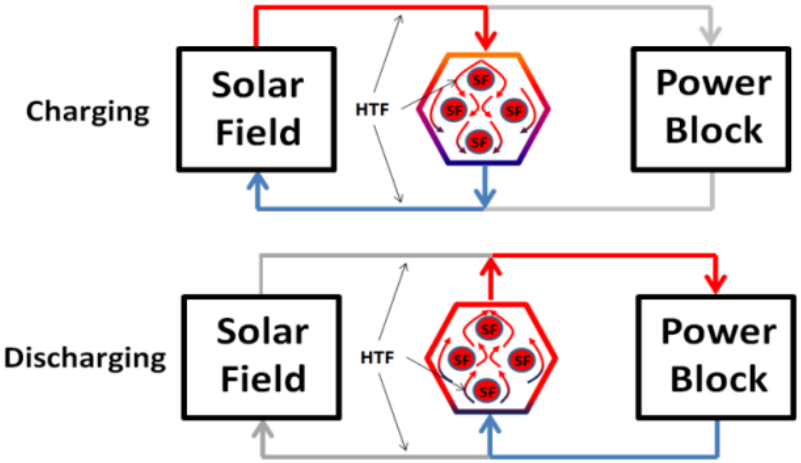
Global Energy Potential

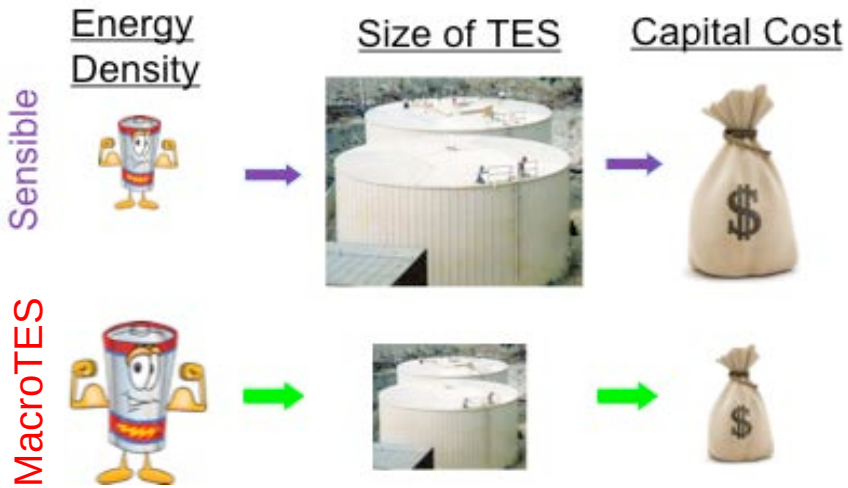
Perez, et al. 2009

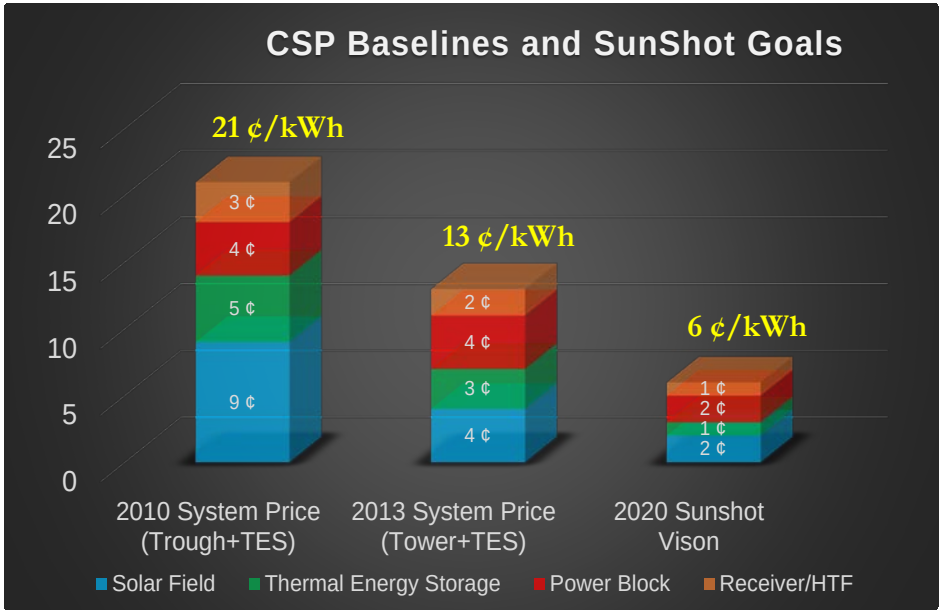


Background

- Thermal energy storage is a distinguishing feature of Concentrating Solar Power (CSP)
- Development of novel low cost, high energy density thermal storage is necessary to decrease the levelized cost of electricity to 6¢/kWh and increase the efficiency of a CSP plant.

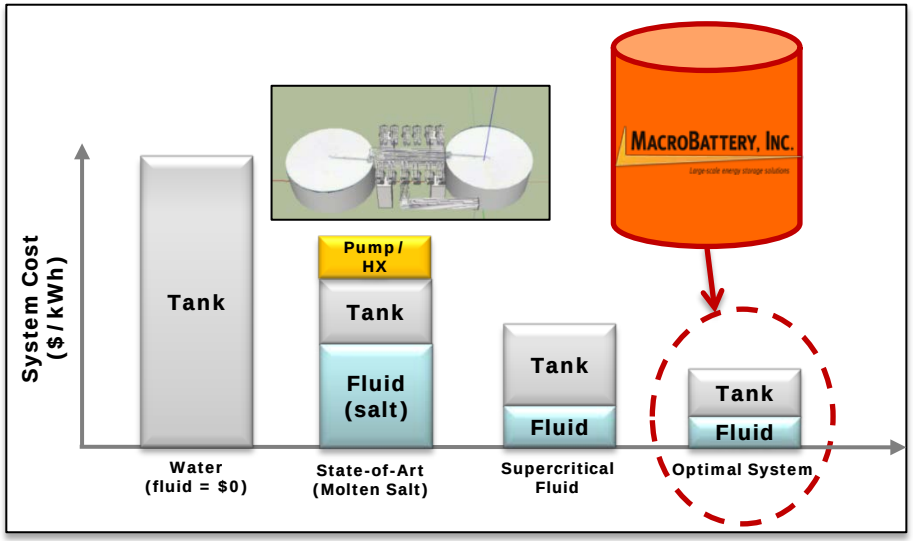




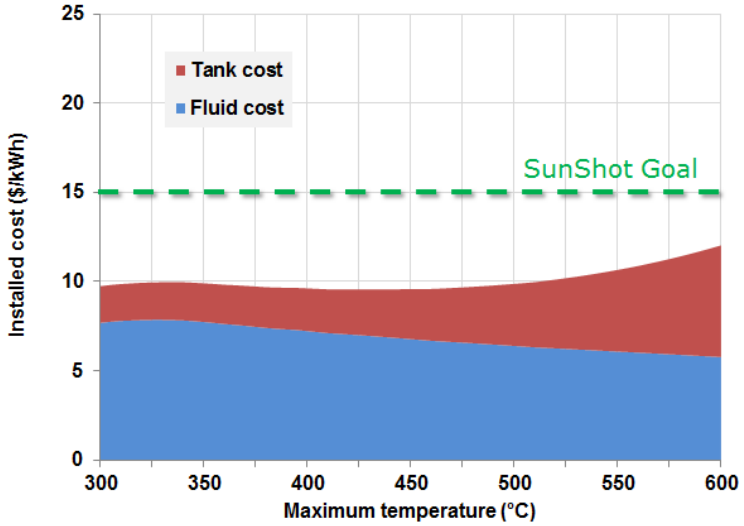


Issues Addressed

- **State-of-the-art: thermal energy storage (TES) systems**
  - Molten salt mixtures (KNO_3 and $NaNO_3$) as storage medium
    - low vapor pressure, good specific heat, chemical stability
  - Cost prohibitive
    - >$15/kWh$_t$ for utility-scale dispatchable CSP

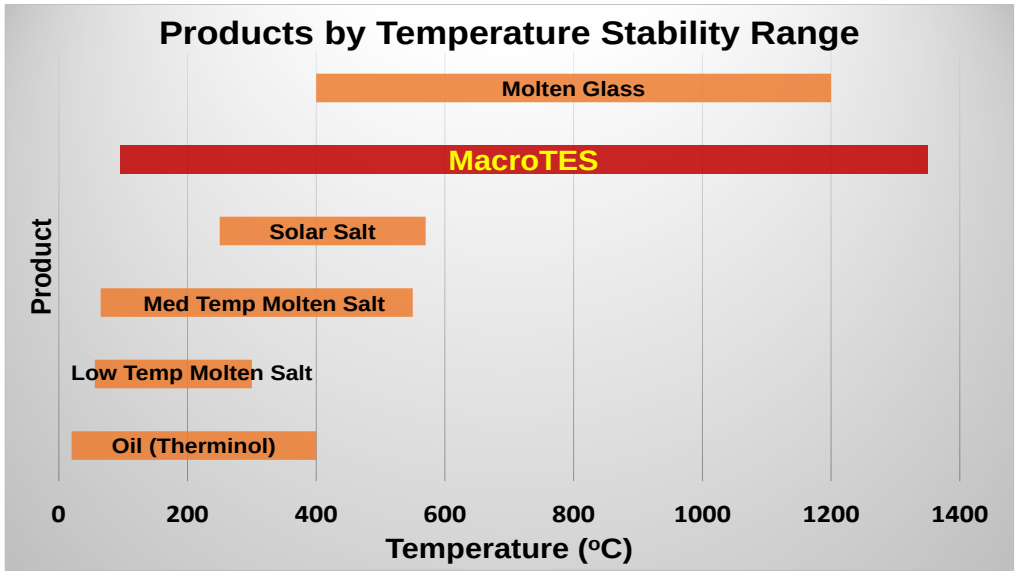


- **MacroTES Solution**
  - Best practice uses an extremely low-cost fluid with modest vapor pressure to minimize storage vessel costs
  - Cost-optimal solution for TES
    - **MacroTES = $10-12/kWh installed cost**
    - **Beats SunShot goal ($15/kWh)**

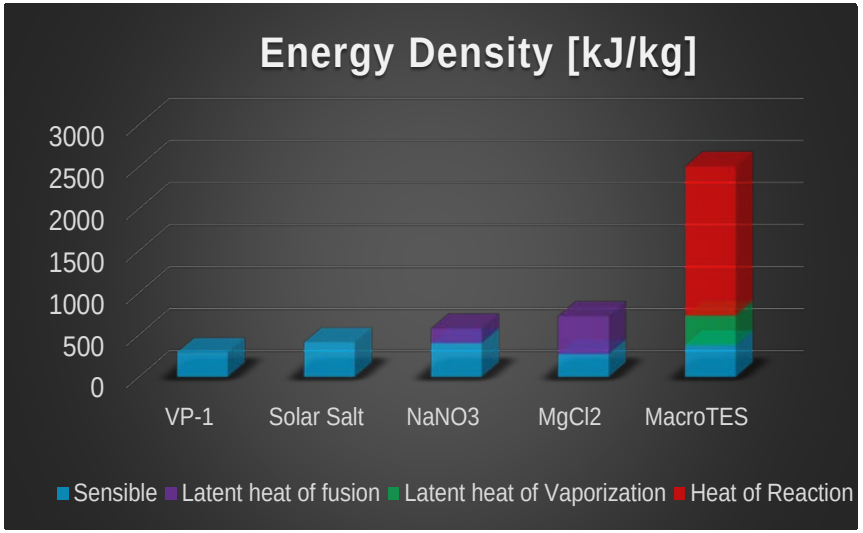


Issues Addressed (Contd.)

- **Temperature Range**
  - MacroTES covers all temperature ranges
  - Other products need to be specifically designed for a temperature range



- **Energy Density**
  - Sensible+Latent+Thermochem = High Energy Density

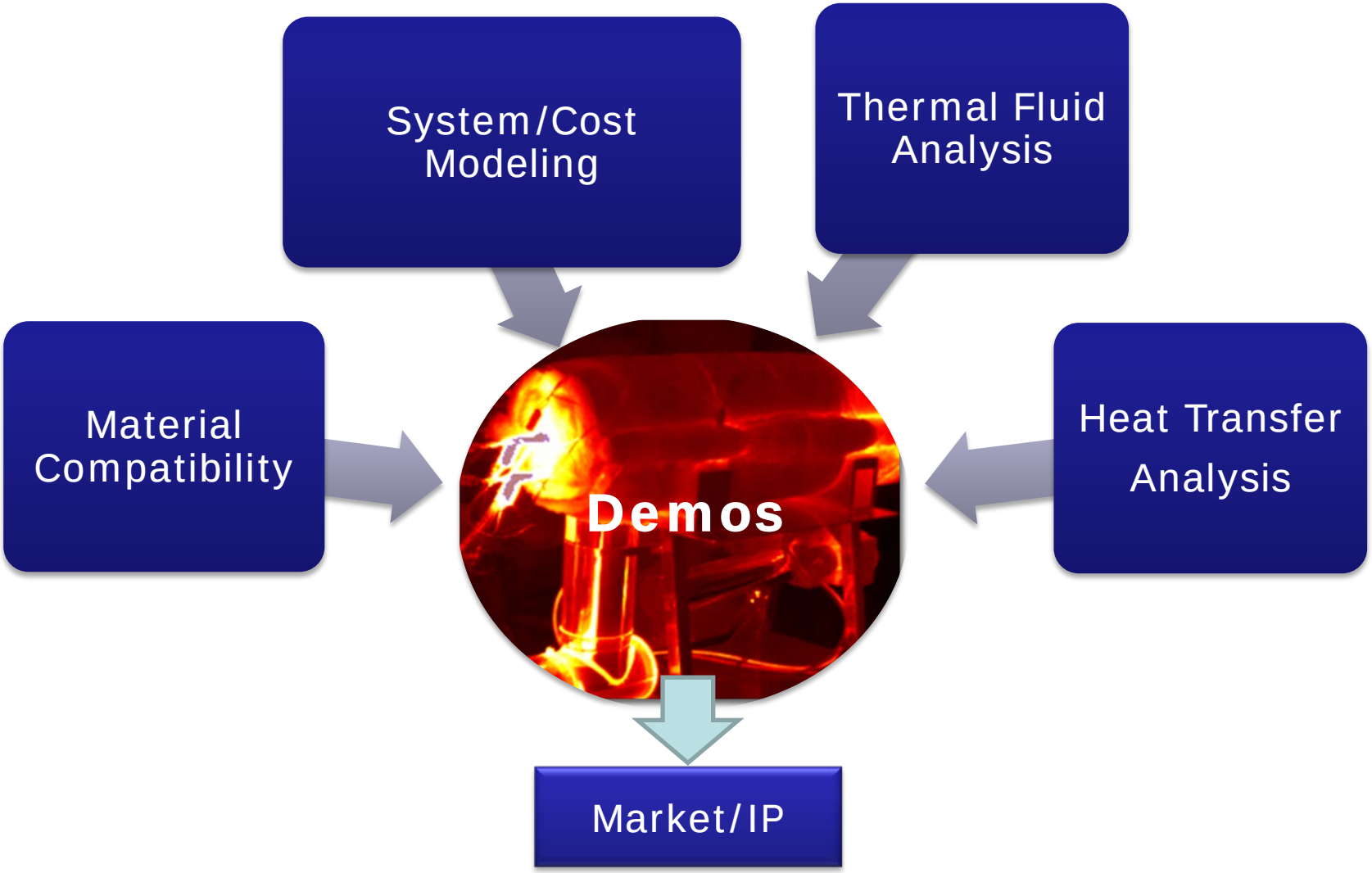


Project Goals and Objectives

- **Primary Objectives**
  - Develop an innovative and low-cost TES system for CSP systems using low-cost fluid
    - Along with a system/cost model for system and market analyses
  - Perform on-sun pilot-scale demonstration of a modular single-tank TES design
    - Along with laboratory and computational analyses to validate long-term component life and performance
  - Develop a market strategy and IP portfolio for the proposed TES system and single-tank thermal battery designs

- **Technological and Scientific Advancements:**
  - Develop a theoretical model for fluid species equilibria
  - Assess heat transfer behavior, particularly as it applies to charge discharge rates, for a wide range of CSP operating temperatures

Project Scope



Team

Concept

UCLA
- Engineering
- Chemistry
- Material Science

Engineering Technology (CPP)

Hyperlight® Energy

UCLA Office of Tech Transfer

Southern California Gas Company®
A Sempra Energy™ company

Market

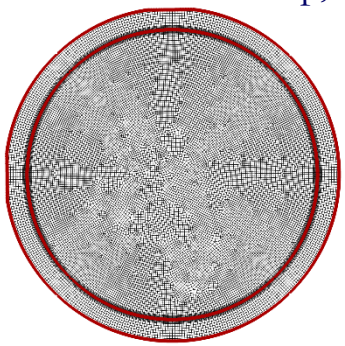
MACROBATTERY, INC.
Large-scale energy storage solutions

- **UCLA**
  - **Mechanical/Thermal** Prof. Richard Wirz, Prof. Adrienne Lavine, Prof. Pirouz Kavehpour, Dr. Amey Barde, Dr. Karthik Nithyanandam
  - **Chemistry** Prof. Miguel Garcia-Garibay: Fluid and material selection
  - **Students:** Louis Tse, Gaby Bran, Parker Wells, Mitchell Shinn, Ahmed Momtaz, Kaiyuan Jin
  - **Tech Transfer:** Scott Davis, Parker Wells
- **SoCalGas**
  - Ron Kent, Advanced Technologies, Strategy & Development
- **Hyperlight Energy**
  - John King, CEO
- **CPP**
  - Prof. Reza Baghaei-Lakeh

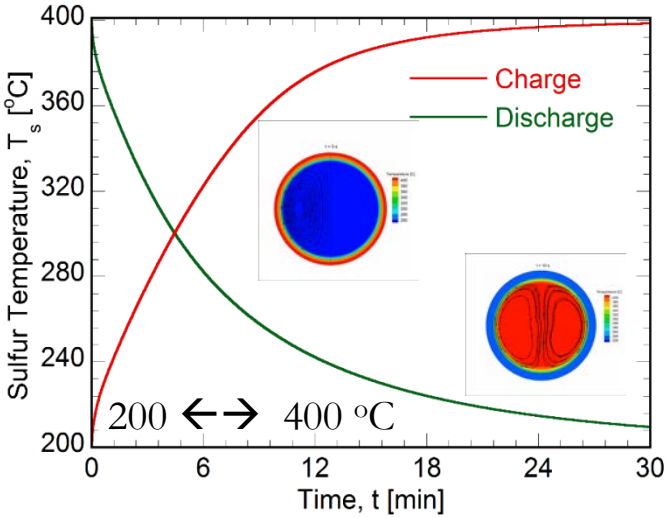
Preliminary Heat Transfer Results

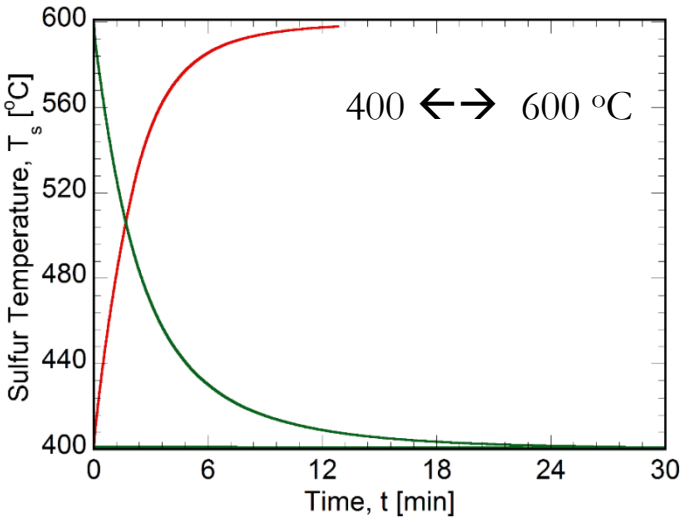
Boundary Cond

Constant Wall Temp, T_w

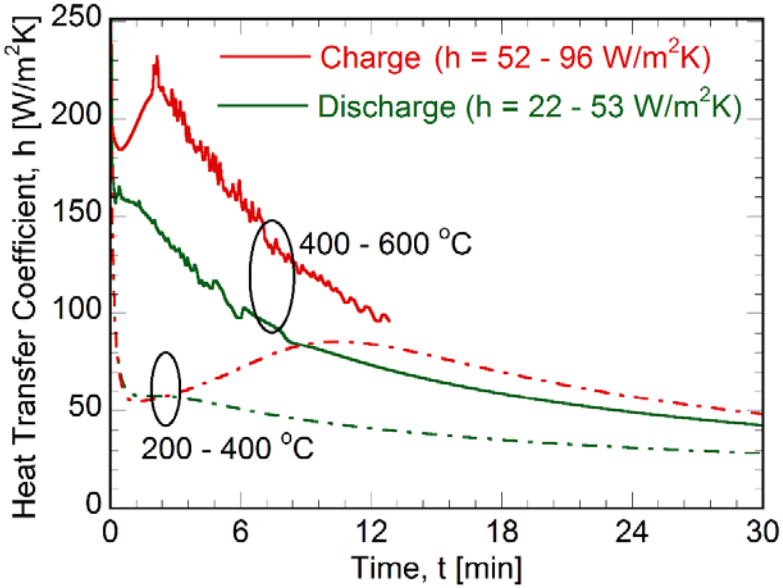


SS 316, 2" NPS, 40 Sch.





- Discharge heat transfer rate much higher than PCM based thermal storage system being explored (h~ 6 – 8 W/m^{2}K)[1,2]



[1] Nithyanandam, K., & Pitchumani, R. (2013). Computational studies on a latent thermal energy storage system with integral heat pipes for concentrating solar power. *Applied Energy*, *103*, 400-415.

[2] Robak, C. W., et al. (2011). Enhancement of latent heat energy storage using embedded heat pipes. *IJHMT*, *54*(15), 3476-3484.

Core Innovation: Levelized cost of energy

	Molten Salt (Trough, 2015)	MacroTES (Trough, 2015)	MacroTES (Tower, 2020)
Design assumptions			
Solar multiple	2.0	2.0	3.0
TES capacity (h)	12	12	14
Power cycle eff.	0.37 (Rankine)	0.37 (Rankine)	0.55 (sCO2)
Cost assumptions			
Solar field ($/m^2)	245	245	120
Power block ($/kW)	875	875	880
TES ($/kWht)	30	14	12
LCOE (cents/kWhe)	**19.40** [1]	**12.20**	**5.45**

Key point: MacroTES cost significantly lower in state-of-art and future plants.

[1] DOE, US. "Sunshot vision study." *US DOE, Washington, DC* (2012).

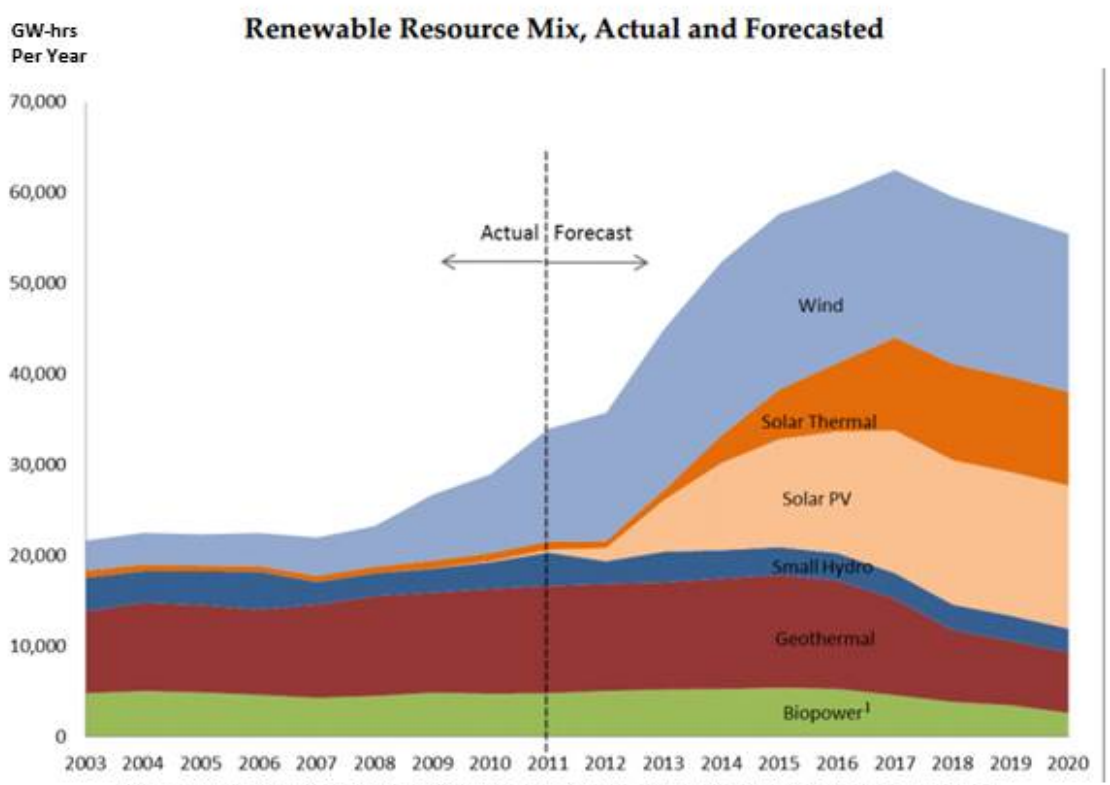
Core Innovation: How big is the system?

50 MW_e plant with 6h TES	Volume (m^3)	
Medium	Trough (390°C-290°C)	Tower (565°C-290°C)
MacroTES	**11,000**	**6,700**
HiTec (2-tank)	29,000	17,660
Concrete	50,000	30,450

Power tower plants have even less available real estate for TES – energy density is increasingly important.

Benefits to Ongoing State Proceedings

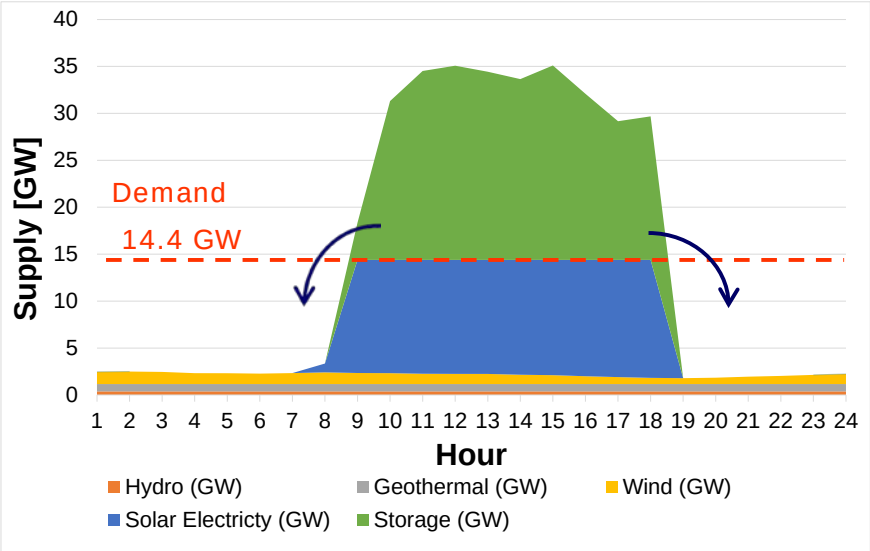
- **The California Global Warming Solutions Act of 2006 (AB 32)**
  - Reduction of greenhouse gas emissions
    - 2791 ton/MW of CO_2 , 37 ton/MW of SO_2,5 ton/MW of NO_x, 2.4 ton of CO
- **Renewable Portfolio Standard (SBx1-2) & Go Solar California (SB 1)**
  - MacroTES provides dispatchability and increases CSP plant efficiency.
- **Governor's Clean Energy Job Plan:**
  - Creation of ~950 job-years
    - Based on NREL job and Economic Development Impact Model
- **Water Conservation Act (SBx7-7):**
  - Load shifting from day to night provides ~3 ton/MW of water savings.



(from the California Public Utilities Commission 2012 RPS Program Status Report)

Benefits to Ongoing State Proceedings

Supply Scenario (LA 2050)



Source	% of Total Supply
Wind	7.1 %
Geothermal	5.4 %
Hydro	2.7 %
Solar	**84.8 %** **(50 - 55% to storage)**

- Solar is by far the biggest resource for LA energy sustainability
- Solar requires both CSP and PV

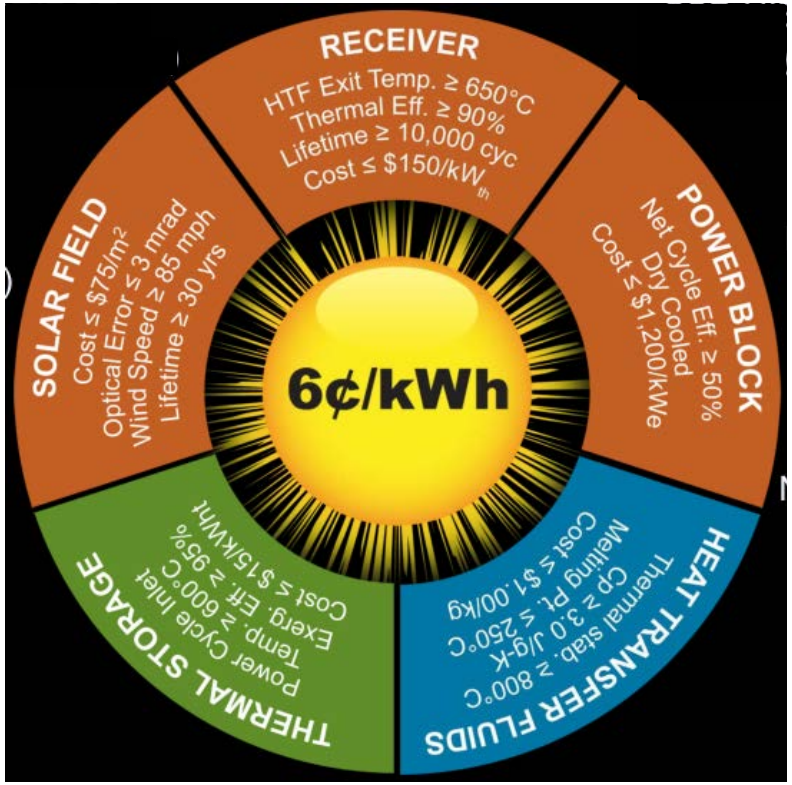
Wirz et al., 100% Renewable Energy for Los Angeles - A Preliminary Assessment, *LA Grand Challenge, UCLA 2015*.

MacroTES benefits for California RPS*

1. Cost-effective energy storage
2. Match power production to need/usage
3. MacroTES+CSP = Dispatchable power generation

*RPS = Renewable Portfolio Standard

Future Research Recommendations



SunShot Review Program, 2013.

- **Collectors**
  - Reduction in collector structure weight and material
  - High optical accuracy and highly efficient tracking technology
- **Receivers**
  - High temperature receiver corrosion and heat transfer fluid stability
  - High temperature solar selective coatings
- **Power block**
  - High temperature and high efficiency power cycles such supercritical-CO_2

- **Research and development to achieve the technical and economic targets for different CSP component technologies.**

THANK YOU!

QUESTIONS?

UCLA Energy Innovation Lab

www.UCLAEnergyInnovation.com

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