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Subject: SOLARRESERVE COMMENTS ON IEPR WORKSHOP ON ENERGY STORAGE DOCKET NO. 09-IEP-1G

Enclosed for filing with the California Energy Commission is the original copy of **SOLARRESERVE COMMENTS ON IEPR WORKSHOP ON ENERGY STORAGE**, (09-IEP-1G).

Sincerely,

Scott Galati
Counsel to SolarReserve

SOLAR

CALIFORNIA ENERGY COMMISSION - DOCKET 09-IEP-1G

Comments on 2009 IEPR Workshop on Energy Storage Technologies 4-16-09

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SOLARRESERVE INTRODUCTION

About SolarReserve

- SolarReserve is a developer and owner of large-scale concentrated solar power (CSP) projects for sale of electricity to utilities
- SolarReserve is a well capitalized solar energy development company based in Santa Monica, California

Technology

- SolarReserve utilizes thermal storage technology allowing us to meet and follow utility peak demand requirements of electricity
- The technology was developed by United Technologies Corporation (UTC), a diversified US-based technology company and demonstrated at Solar Two in Barstow, CA

Financial Backing

- SolarReserve is Backed by a Consortium of Major Financial Partners: *U.S. Renewables Group (USRG); Good Energies ,Citi – Sustainable Development Investments (SDI) , Credit Suisse Customized Fund Investment Group ("CFIG") , Argonaut Private Equity, The PCG Clean Energy and Technology Fund, Nimes Capital, LLC*

SOLARRESERVE

SOLARRESERVE PROCESS DIAGRAM

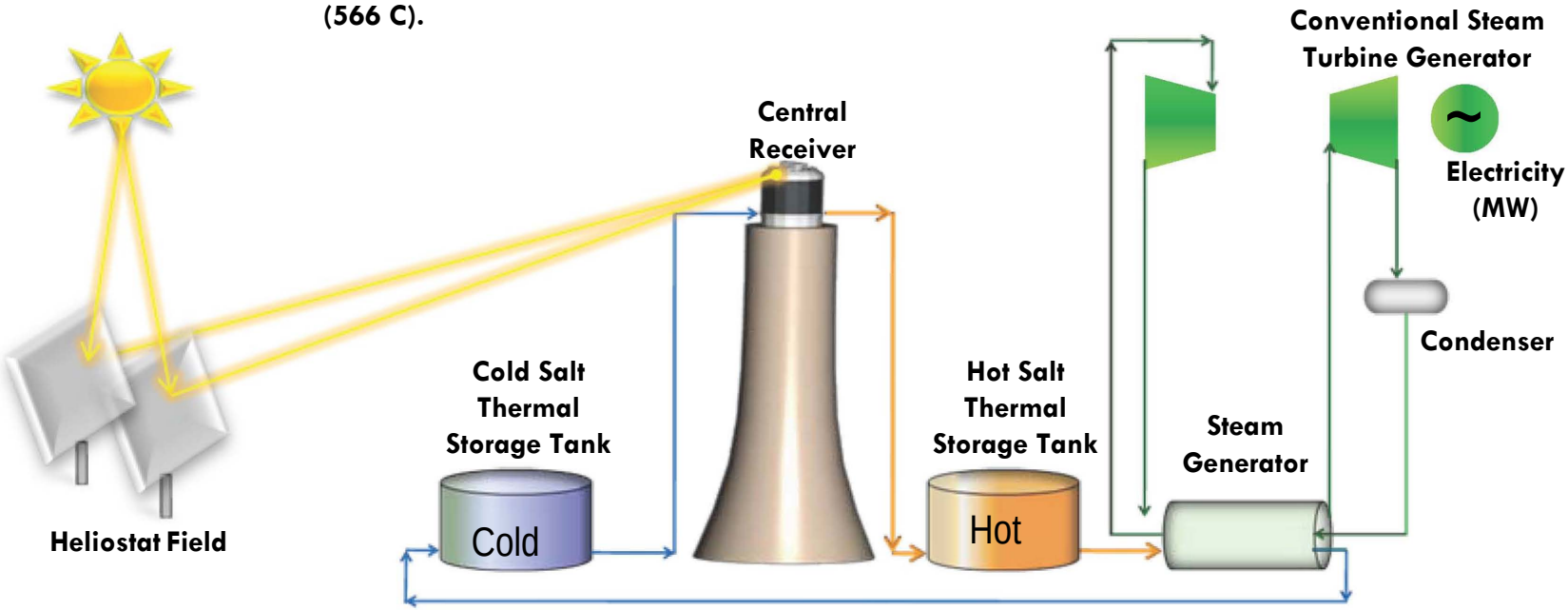
1
Sunlight is concentrated and directed from a large field of heliostats to a receiver on a tall tower.

2
Molten salt from the cold salt tank is pumped through the receiver where it is heated to 1050 F (566 C).

3
The heated salt from the receiver is stored in the hot salt tank.

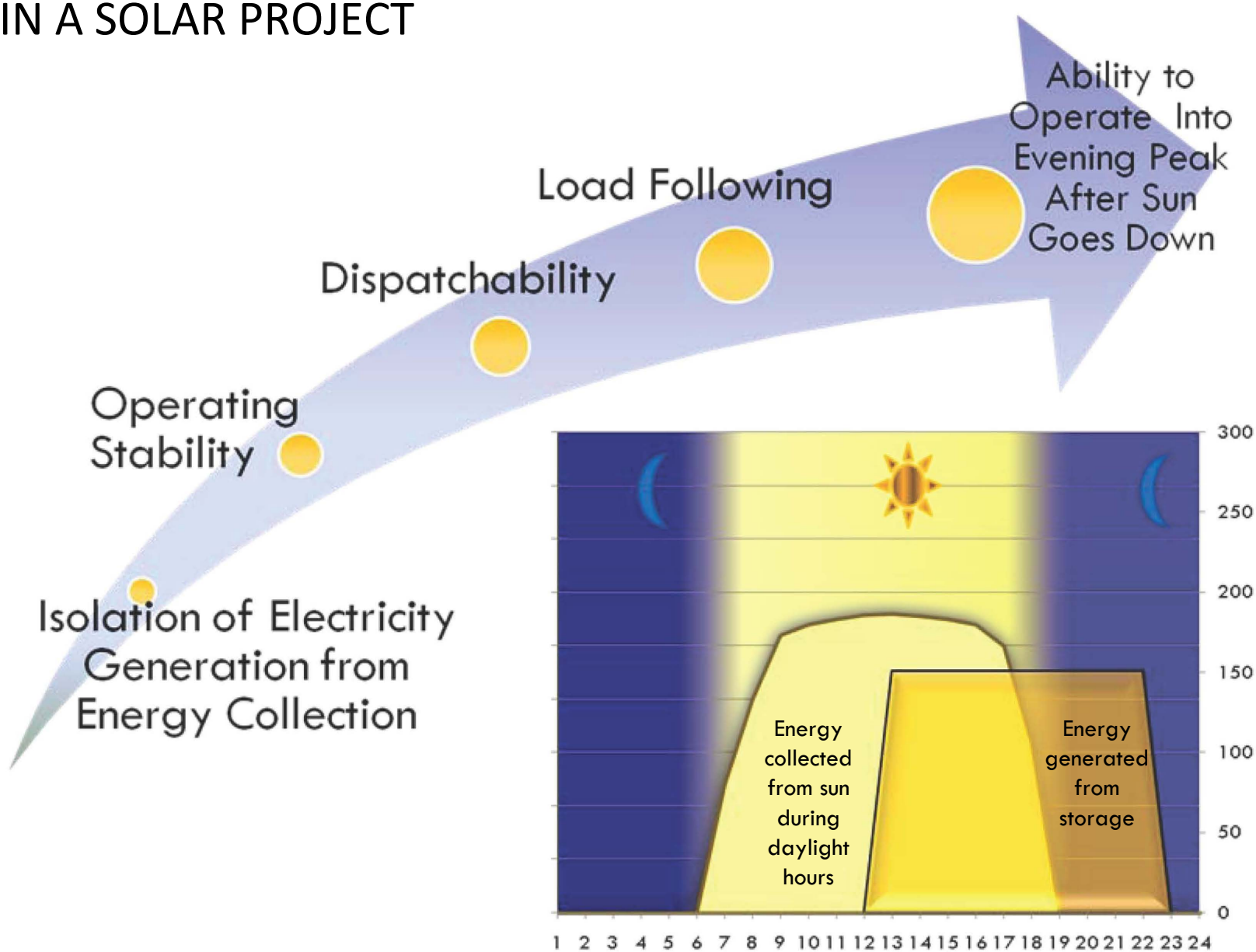
4
Molten salt is pumped from the hot salt tank through a steam generator that creates steam, which drives a steam turbine, generating electricity.

5
Cold salt at 525°F (288 °C) flows back to the cold salt tank.

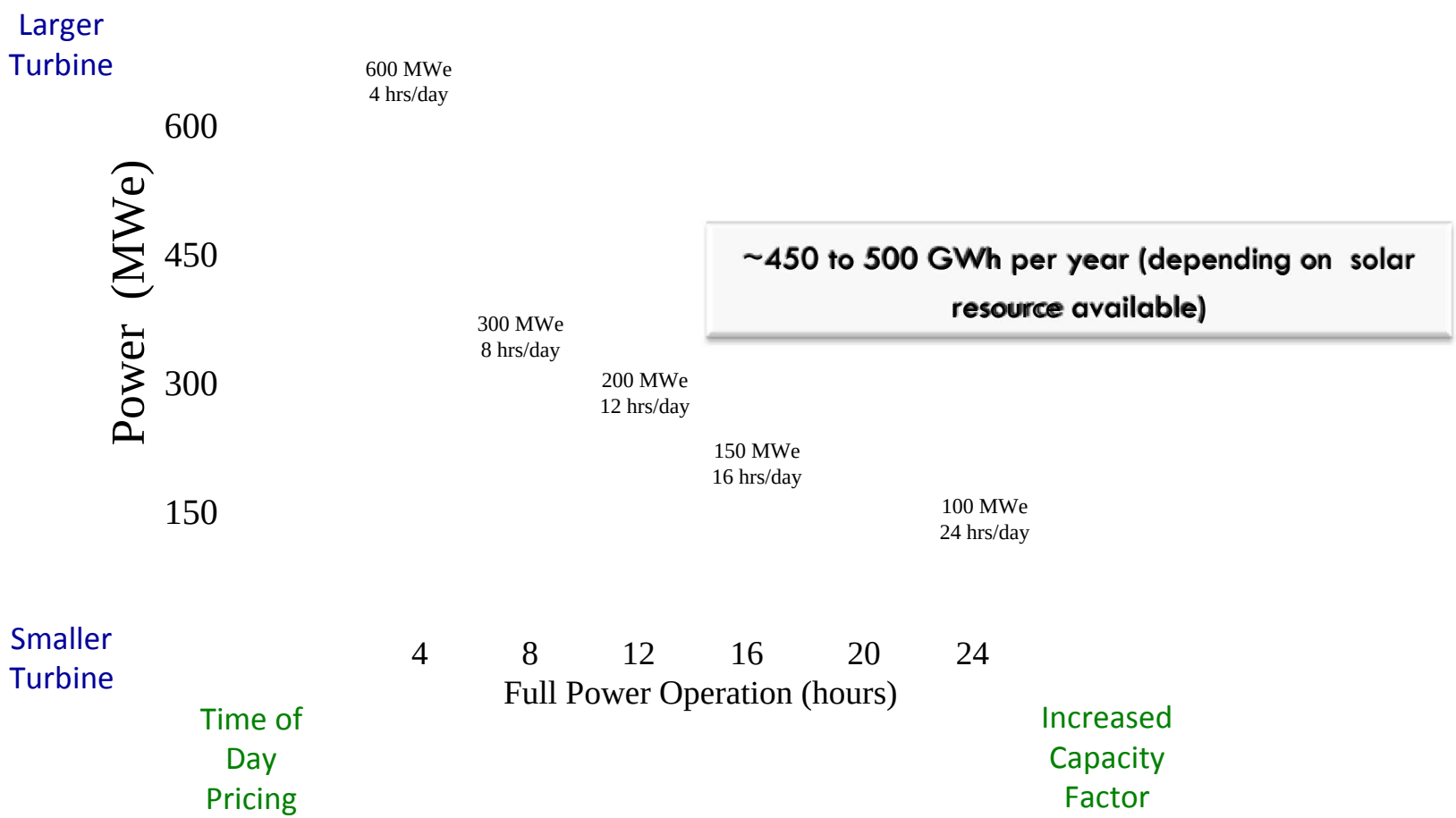


BENEFITS OF INTEGRAL THERMAL STORAGE IN A SOLAR PROJECT

SOLARRESERVE



FLEXIBILITY TO CUSTOMIZE STEAM TURBINE OUTPUT AND OPERATING PROFILE TO MEET NEEDS OF MARKET



BENEFITS OF CENTRAL TOWER TECHNOLOGY

- By focusing all of the sun's energy onto a central point, the heat transfer fluid can be heated and stored at high temperatures.
  - *Higher temperatures translate to more efficient steam cycles*
  - *Thermal storage at higher temperatures is more cost effective through reduced storage volume for a given amount of energy*
- Systems have a cost advantage by being able to benefit from economies of scale, reducing the cost to generate

TECHNOLOGY VALIDATION AT SOLAR TWO (DOE DEMONSTRATION PROJECT)

SOLARRESERVE

- Molten Salt Operations Characterized
- Demonstrated electric power 24 hr/day
- Exceeded Performance Targets
- Receiver Performance Exceeded Prediction (88% Efficiency)
- Pump Performance-Demonstrated Full-Flow at Design Pressures

10 MWe Pilot Plant
1997-1999

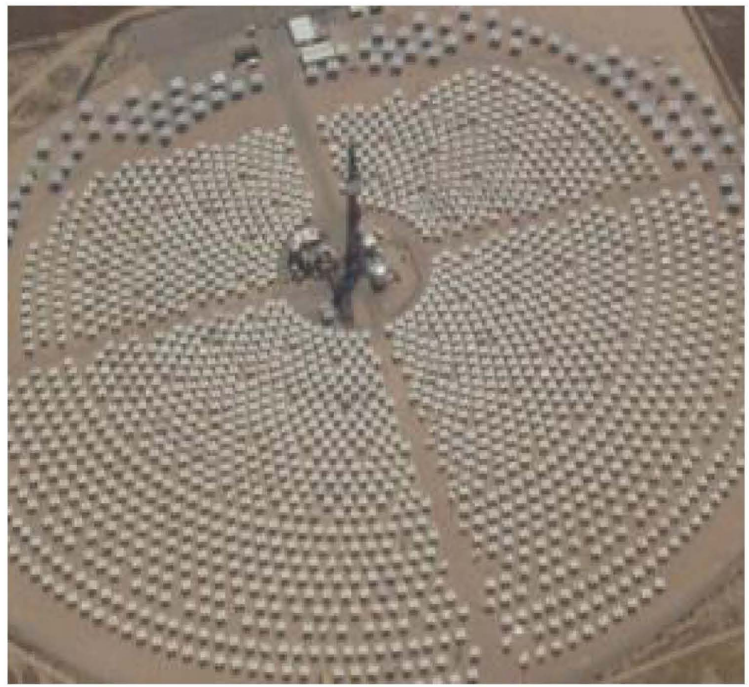
- **300 ft tall tower; 1926 heliostats**
- **42 MWt receiver; 10 MWe turbine**
- **3 hours molten salt storage**

"Over the three-year operating lifetime, daily operation of Solar Two became relatively routine, with various performance records broken on a fairly regular basis."

DOE SunLab Brochure, March 2000)

PICTURES OF SOLAR TWO (BARSTOW, CA)

SOLARRESERVE



OTHER SOLAR CONCEPTS BEING STUDIED BY MARKET

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- New lower freezing point heat transfer fluids
- Phase change materials
- Thermo-chemical storage
- Sand sifter
- Nano particles and nano tubes
- Graphite monoliths

OTHER DEPLOYABLE TECHNOLOGIES

- Steam in pressure vessels
- Compressed air – in tanks in underground caverns
- Pumped storage – using water
- Concrete monoliths
- Other Solids: ceramics, alumina, iron oxides, etc.
- Molten nitrate salts:
  - Single-Tank Thermocline
  - Two-Tank System

STORING STEAM IN LARGE PRESSURE VESSELS

- Can provide some operating stability through short cloud transients.

- Requires an ASME code stamped pressure vessel.

- Cannot support large scale:
  - Firm Dispatch (utility dispatch and curtail)
  - Dispatch through the night or through a long storm
  - Load Following – to fill in on wind transmission lines
  - Load Multiplying- for peaker duty
  - Cannot efficiently collect energy at various temperatures on hazy days or near sunset.

ASME PRESSURE VESSEL

Primarily useful to provide short term operating stability through short cloud transients.

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PUMPED STORAGE AND PRESSURIZED CAVERNS

Underground Salt Caverns requires the right geological features, plus development.

Pumped Storage Requires a mountain and two reservoirs. Concepts and costs are well understood.

Underground Cavern

Both Pumped Hydro and Compressed Air in Caverns work. Both require extensive offsite development.

SOLID MEDIA: CONCRETE, CERAMIC, ALUMINA MANGANESE OXIDE, IRON, ETC.

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- Concrete blocks and Solid Media containers might be paired with heated air, CO_2 or liquid heat transfer fluids.

- Concrete can be inexpensive, but there is concern about concrete separating from the HTF tube after many thermal cycles. Tests underway at DLR look promising.

- Cost is still a question for other solid media.

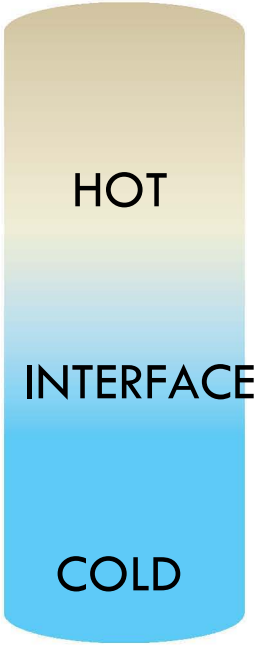
- These systems cannot efficiently utilize heat at various temperatures.

Concrete Block

Pipe Filled w. Solid Media

Single Tank Systems (Steam, Ceramic & Concrete) Cannot Capture Heat at Low Temperatures w/o Degrading the Hot Side Temperature.

THERMOCLINE THERMAL STORAGE SYSTEMS



- Thermoclines promise cost savings by using one tank instead of two.
- They can work well in small and moderate sizes
- Work best with tall, narrow cylinders (to keep the interface zone from growing to fill the entire volume. Tall and narrow is more expensive than short and wide.
- Does not scale to commercial sized plants which might use 50 to 75 million pounds of salt.
- A two tank system might use two tanks each ~40' tall by ~150' in dia.

HOT

COLD

Thermoclines' cost advantage does not scale.

BENEFITS OF TWO-TANK STORAGE SYSTEMS

- Firm Dispatch – Enabling Utility Dispatch & Curtail
- Grid Stability – Stable Output thru Cloud Transients
- Magnified Peaking Capacity
- Increased Annual Capacity Factor
- Low Insolation Collection – for Hazy Days
- Equipment Elimination
- Eliminates Startup Boiler
- Eliminates Supplemental Firing for Superheat

RESERVE

THERMAL STORAGE AS AN "ADD-ON" TO A CSP TROUGH SYSTEM

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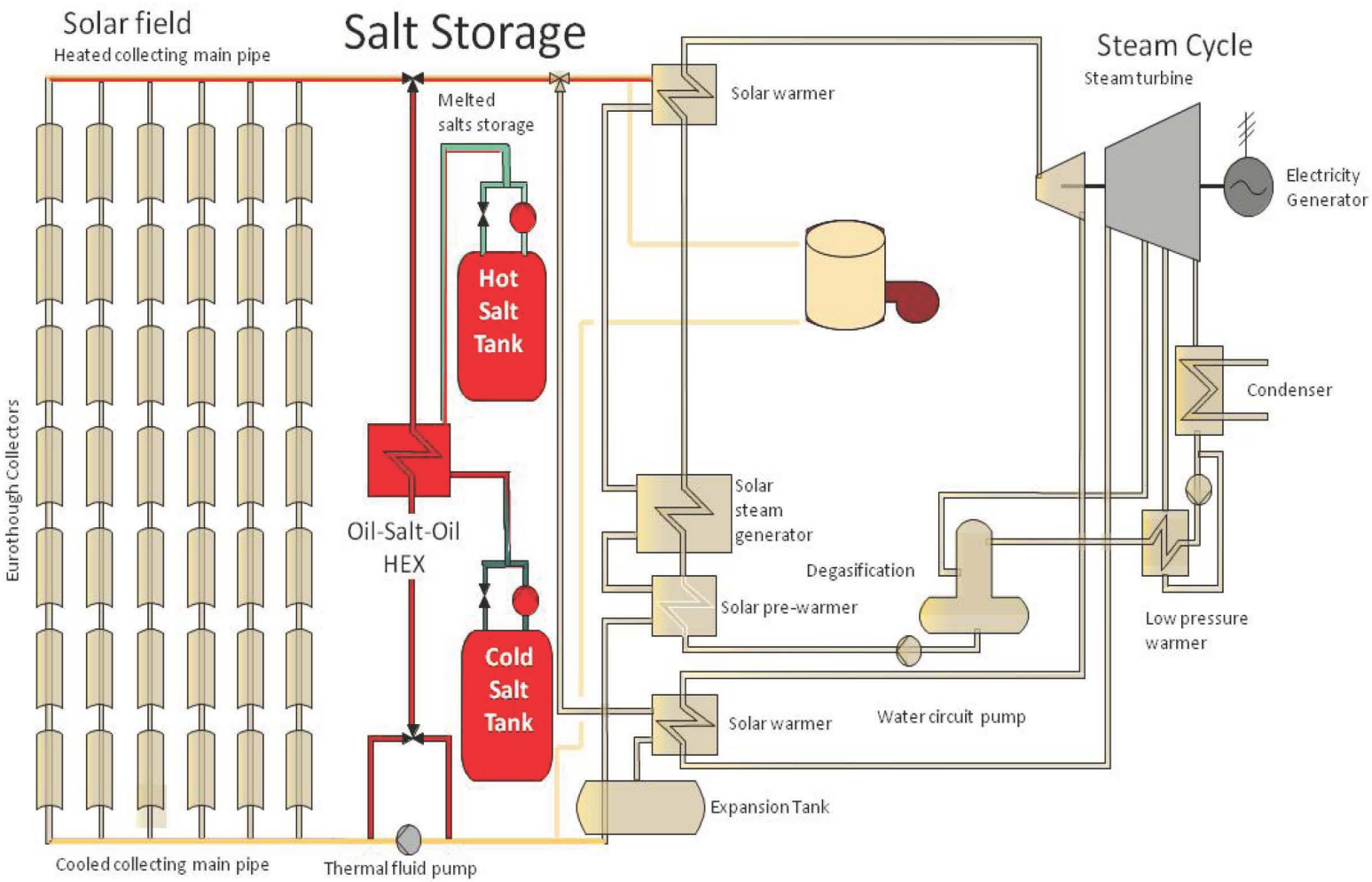

Addition of heat exchangers to cycle reduces efficiency and cost-effectiveness of storage in this application.

REMOVING BARRIERS TO WIDER DEPLOYMENT OF TECHNOLOGIES WITH THERMAL STORAGE

SOLARRESERVE

Suggestions:

- Establish permitting priority for projects equipped with thermal storage
- Provide enhanced RPS benefits for projects equipped with thermal storage
- Encourage the CPUC to consider valuation premiums for projects with thermal storage in utility procurement processes

Thank You

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