U.S. House of Representatives

COMMITTIE ON SCIENCE AND TECHNOLOGY

Subcommittee on Energy and Environment

"Technology Research and Development Efforts Related to the Energy and Water Linkage"

Testimony of Terry Murphy, President and Founder of SolarReserve: July 9th, 2009

Good Morning Chairman Gordon and members of the Committee.

Thank you for this opportunity to appear before you this morning to discuss the linkage between Energy and Water. My name is Terry Murphy and I'm the President and Founder of SolarReserve.

I co-founded SolarReserve, along with US Renewables Group, after a twenty-seven year career at Rocketdyne, where I was the Director of Advanced Programs. My executive responsibilities at Rocketdyne covered a wide range of advanced power systems for both space and terrestrial applications. My business unit generated over 40 patents which leveraged aerospace technologies into clean and renewable terrestrial energy projects, so I appreciate the opportunity to offer my perspective on water usage in the generation of electricity.

Solar Reserve is a US company, based in Santa Monica, California, which is leveraging US technology, DOE investments and local manufacturing to address our energy security and energy related environmental concerns. SolarReserve has the exclusive worldwide rights to the United Technologies, Pratt & Whitney Rocketdyne molten salt power tower technology that was thoroughly validated by the Department of Energy at the Solar Two pilot plant in Barstow, California from 1995 to 1999.

United Technologies, a Fortune 30 company, is standing behind this technology by guaranteeing the performance of the system, which is key enabler to successful project finance.

The critical components in this facility are engineered by the same team at Pratt & Whitney Rocketdyne that designed and built the International Space Station solar power systems, the Space Shuttle Main Engines, and the Apollo moon rocket propulsion systems. This is world-class American technology generating American jobs, erecting critical, desperately needed infrastructure and establishing a foothold to our permanent energy independence.

Our unique, molten salt, solar power technology solves a key fundamental challenge of renewable energy: ***storage***. Wind only has a 2% correlation with electrical energy demand in California, so while building a wind farm may satisfy the Renewable Portfolio Standards (RPS), it does very little to satisfy customer requirements.

Conventional solar, the rooftop photovoltaic (PV) that we are all familiar with is more coincident with demand, but intermittent cloud cover can cause it to drop off in milliseconds; and what's worse, turn right back on just as quickly. While these systems have minimal water use and are great for distributed rooftops, Utility scale deployment of PV could introduce problems with grid stability and reliability due to a rapid and unpredictable intermittent generation profile.

Conversely, a SolarReserve power plant generates electricity from the sun's heat; this type of solar energy is known as Concentrated Solar Power (CSP). These power plants capture the sun's thermal energy by focusing thousands of heliostats (or mirrors) on to a central receiver, converting and storing that energy in molten salt and then transforming that energy into steam, which in turn drives turbines. Unlike a photovoltaic power system, however, the molten salt CSP technology allows electricity to be generated on demand and controlled like any conventional power generator. These load following power plants operate on a highly predictable and dependable fuel supply, the sun! They have zero price volatility, zero fuel costs, and can provide reasonably-priced renewable electricity for generations to come. The technology does not require toxic operational fluids and last, but not least, SolarReserve technology does not require natural gas or other fossil fuels.

Like any power plant technology using a conventional steam turbine, our system can be Air-Cooled, reducing overall plant water consumption significantly relative to any water-cooled plant, particularly older plants which use less efficient technologies or water-saving designs. We believe, however, that we need appropriate public policy and economic incentives to realize this opportunity in the competitive marketplace since, relative to conventionally water-cooled generators, air-cooled technologies have a significant impact on electricity production efficiency and cost of electricity. In addition, SolarReserve encourages collaborative research with the Department of Energy into technologies that could further reduce our water consumption and increase our plant performance, thereby putting us on track to build the "Ideal Power Plant".

SolarReserve Power Towers can't solve all of our energy problems, but I believe that they do represent the best utility scale renewable energy system for the American Southwest. Because SolarReserve Power Towers operate on demand, they are perfectly suited to replace the aging coal-fired power plants that are currently operating in the Southwest. SolarReserve already has fifteen projects in various stages of development, with the first project in the United States slated for Tonopah, Nevada. This system will provide 500,000,000 kW-hr per year of clean, emission free, renewable energy and would abate over 500,000 tons of CO_2 when compared to a coal fired power plant over its operating life.

Our $700 million dollar Tonopah facility is scheduled to begin construction in 2010. Solar Reserve hopes that this committee will support our efforts to expedite the federal review and approval process by working directly with the Department of Defense, the Federal Aviation Administration and the Bureau of Land Management, so that this project can avoid further costly delays. SolarReserve will employ nearly 500 people during the two year construction period and will operate with 50 permanent positions. In addition to Tonopah, SolarReserve has significant development activities in California, Arizona, New Mexico, Colorado, Utah, and several international efforts, including two projects is in Spain.

I look forward to answering your questions this morning and hope that our brief exchange of ideas, along with my written testimony will provide you with a more comprehensive analysis and awareness of water usage in power plants and the true potential of Concentrated Solar Power technologies.

Energy & Water Linkage

U.S. House of Representatives Subcommittee on Energy and Environment

Terry Murphy

Congressional Testimony

July 9th, 2009

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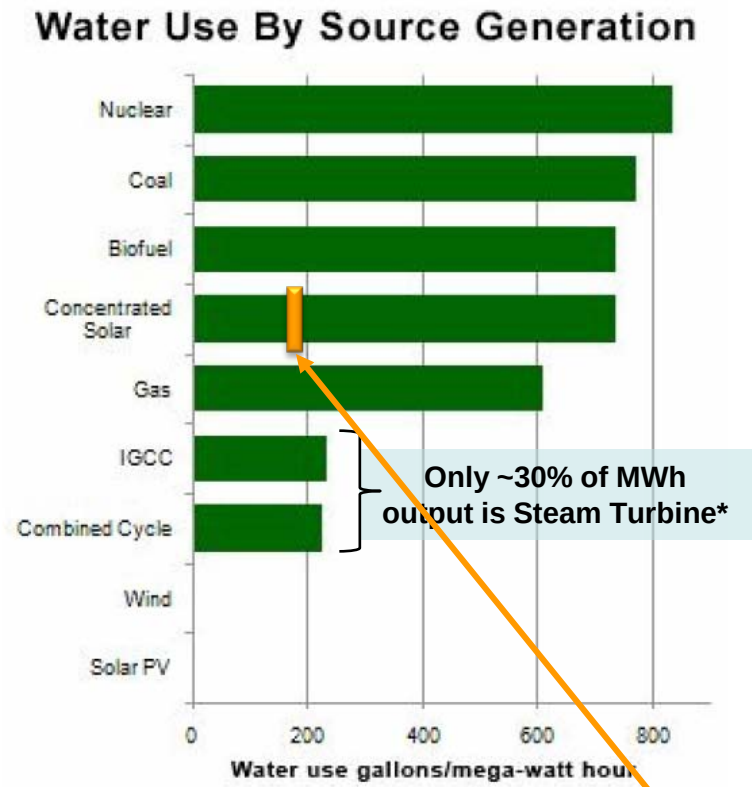
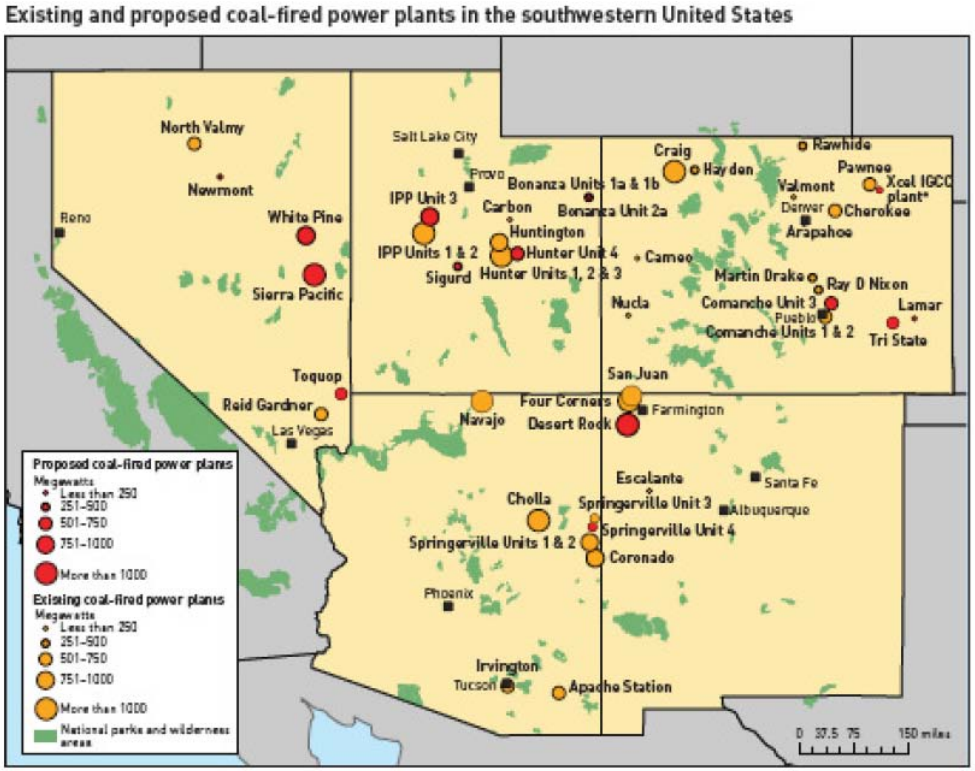
Power Plants need to Address Water Usage



*Steam turbines using wet-cooled configuration



100% MWh Output is from Steam Turbines*

SolarReserve power plant with Hybrid Cooling
80% less water consumption than current systems

Clean Air Task Force and The Land and Water Fund of the Rockies
Power plants in Nevada average 600 gallons of water withdrawn and consumed per Megawatt Hour in 2000.[2]

[2] ***"The adverse effects of coal power plants on water resources."*** **Report by the office of Sen. Harry Reid (D-NV)**

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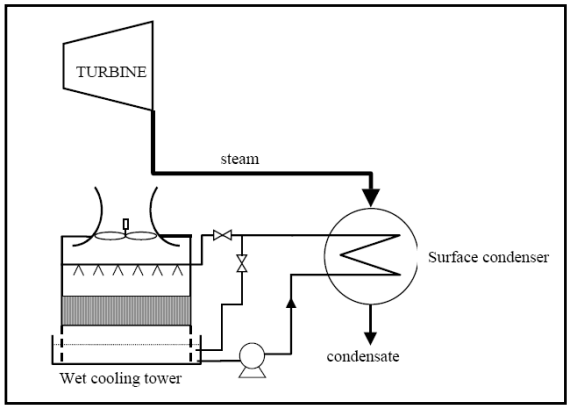
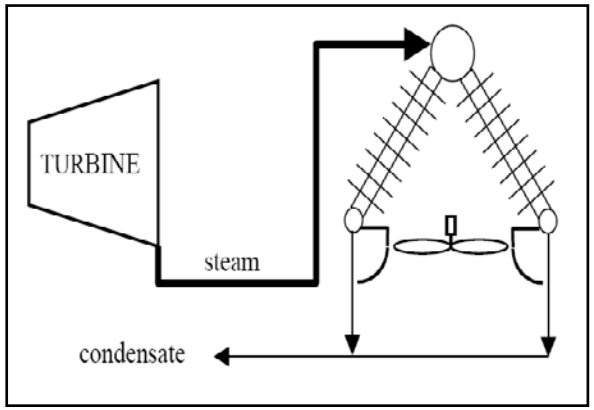
Steam Turbine Exhaust Cooling Options

Wet Cooling Tower



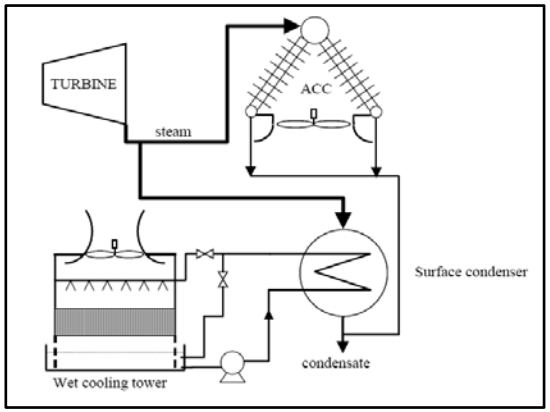
- Lowest Capital Cost
- Highest Performance
- Most Water Usage

Air Cooled Condenser



- Higher Capital Cost
- High Power Consumption
- Lowest Performance
- Least Water Usage

Hybrid Cooling System



- Highest Capital Cost
- Highest Maintenance
- Good Performance
- Best Water Usage

- Steam Turbine output efficiency is highly dependent on external temperature conditions
  - Power Plants yield the lowest output during the highest external temperatures
  - Dry cooling options very sensitive to external ambient temperatures
    - Water is a scarce resource in most CSP territories

All Plants are Site Specific and Require Detailed Technical and Economical Analysis

Rankine Cycle Cooling Options, Babul Patel, Nexant, July 1, 2009

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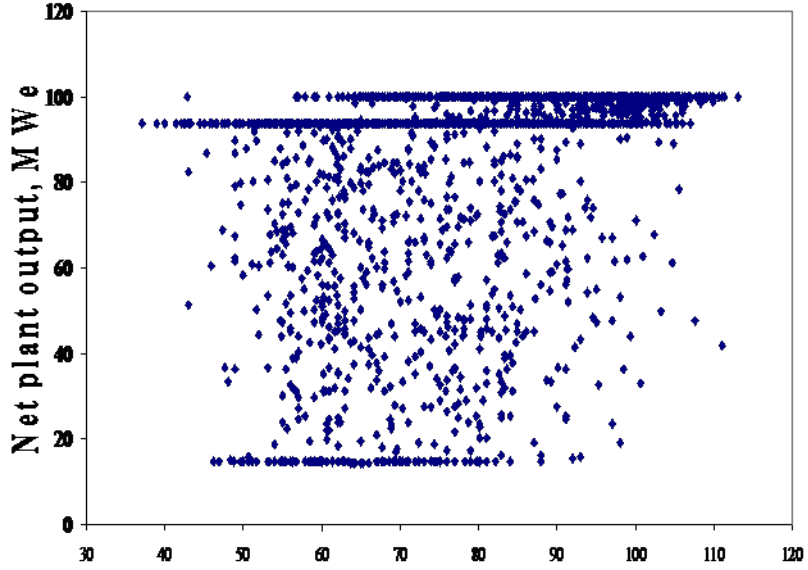
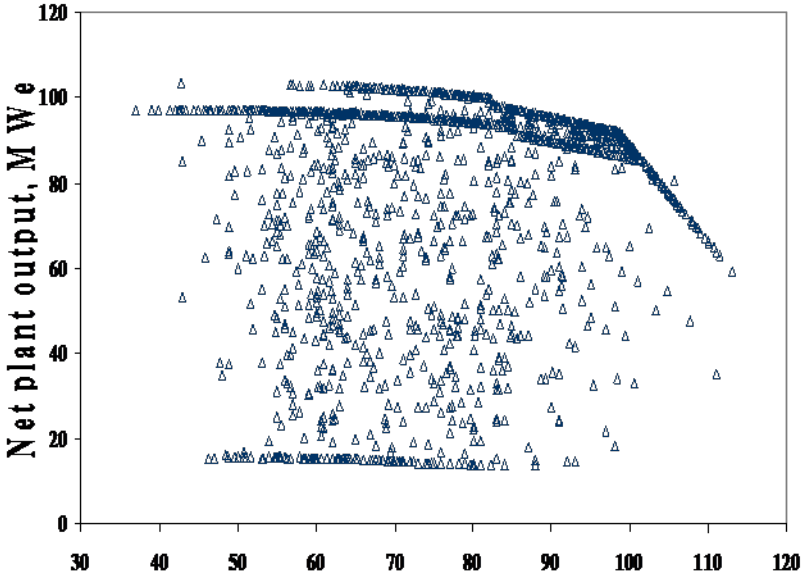
Fossil Fuel vs. CSP Power Plants

Fossil Wet Cooling



CSP Dry Cooling



Fossil Fuel Plant

- Operates Day & Night, all year-long
- Analysis can be based on *Yearly* average

<0.5% Difference between Wet and Dry

CSP Plant

- Operations coincident with the Sun
- Analysis must be based on *Hourly* average

<6% Difference between Wet and Dry

Air Cooled Systems can adversely Impact CSP Financials

Rankine Cycle Cooling Options, Babul Patel, Nexant, July 1, 2009

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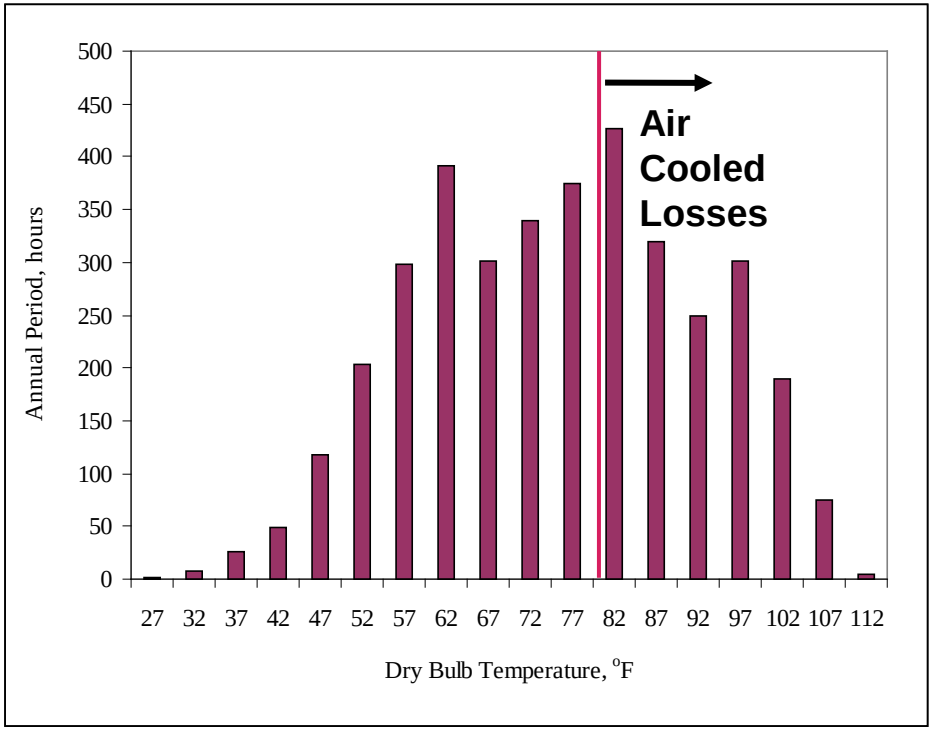
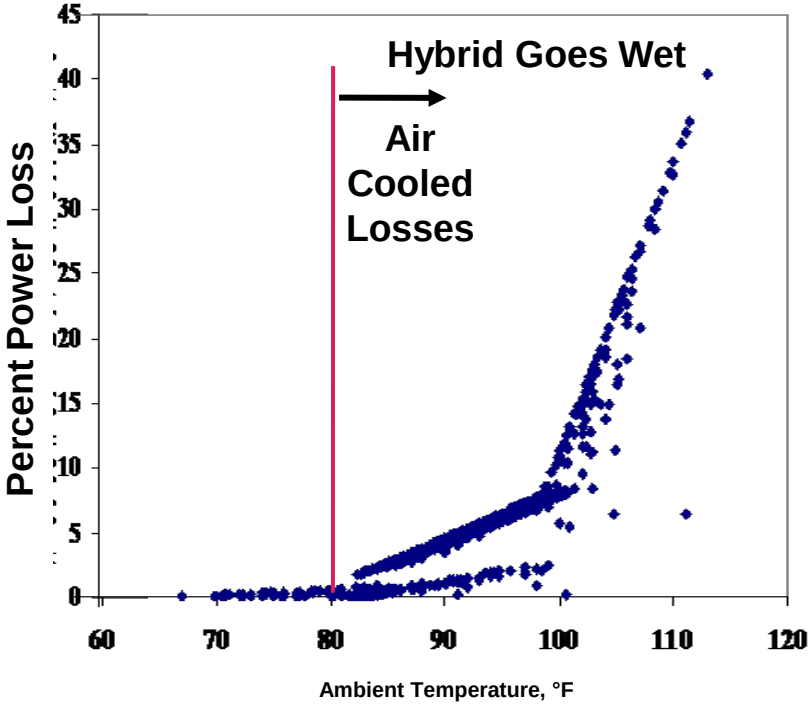
Dry Cooling Impacts on Steam Turbines

Typical Temperature Distribution



Typical Performance Degradation



- **Dry Cooling Losses are Greatest on the Hottest Days**
- ***30+ % Losses at the Worst Possible Time – True for all Steam Turbines***

Hybrid Systems minimize Water and keep Performance – Capital Cost is High

Rankine Cycle Cooling Options, Babul Patel, Nexant, July 1, 2009

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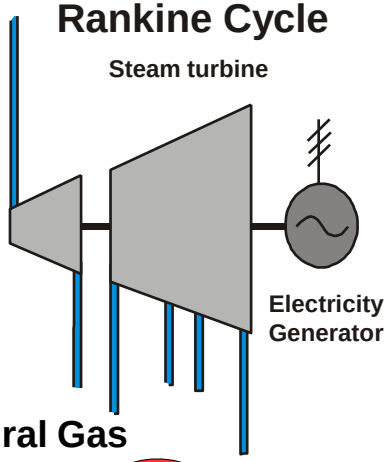
Turbine Comparison

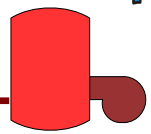
Trough

"Solar" Turbine
36% Efficiency

Rankine Cycle



Natural Gas *Boiler Required*

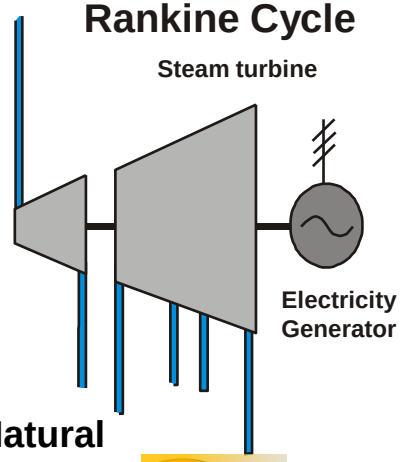


Saturated Steam 675°F

Tower

"Utility" Turbine
40% Efficiency

Rankine Cycle



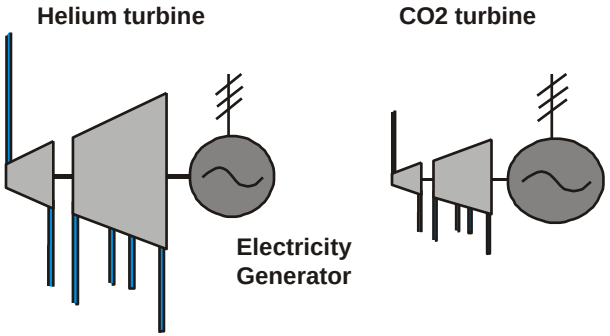
Natural Gas *Not Required*

Superheated Steam 1030°F

Advanced Tower

"Advanced" Turbine
45- 50% Efficiency

Closed Loop Brayton Cycle



- **Potential for:**
  - **Lower Recurring Costs**
  - **Higher Performance**
  - **Less Water in Cooling**

MultiReheat Helium or CO_2 1300°F- 1500°F

Increased Temperature Improves Performance and Reduces Dependency on Wet Cooling

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Water Impacts on CSP

- **Air Cooled: Expensive and Big Performance Hit on Hot Days**
  - **Very Common in Western NGCC Systems – Path of Least Resistance**
    - **Only 30% Power is Steam Generated – Marginal Impact**
  - **Significant Performance Impact on CSP plants**
    - **100% power from Steam**
    - **Deliberately located in High Heat Zones**
    - **System Operation is Coincident with Hottest Time-of-Day**
      - **Storage can shift Operation, but not Demand**

- **Wet Cooled: Cheapest and Most Efficient**
  - **Consider Water Allocation "Set-Aside"**
    - **Hottest Days are the Most Productive = Maximum Energy Production**
    - **Lowest Cost Electricity**
  - **Site-by-Site Analysis warranted; Potential reuse on "Gray-Water"**

- **Hybrid Cooling: Most Expensive**
  - **Big Water Savings, but essentially two systems: Wet and Dry**
  - **Wet only used 20% of the Time, but during the Driest Months**
  - **Adequate Solution for CSP, but Increases Cost**
  - **Could Block CSP Entry into the Marketplace**

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"Ideal" Power Plant

- Low Cost Electricity
  - Zero Price Volatility
  - Zero Fuel Costs
  - Highly Predictable / Dependable Fuel Supply
    - 100% Dispatchable, Load Following
    - Turn-down, spinning reserve potential
- Limited Environmental Impact
  - Zero Air Emissions
  - Minimal Water Usage
  - No fossil fueled auxiliary systems
  - Inert materials:
    - Construction, Operation to Decommission

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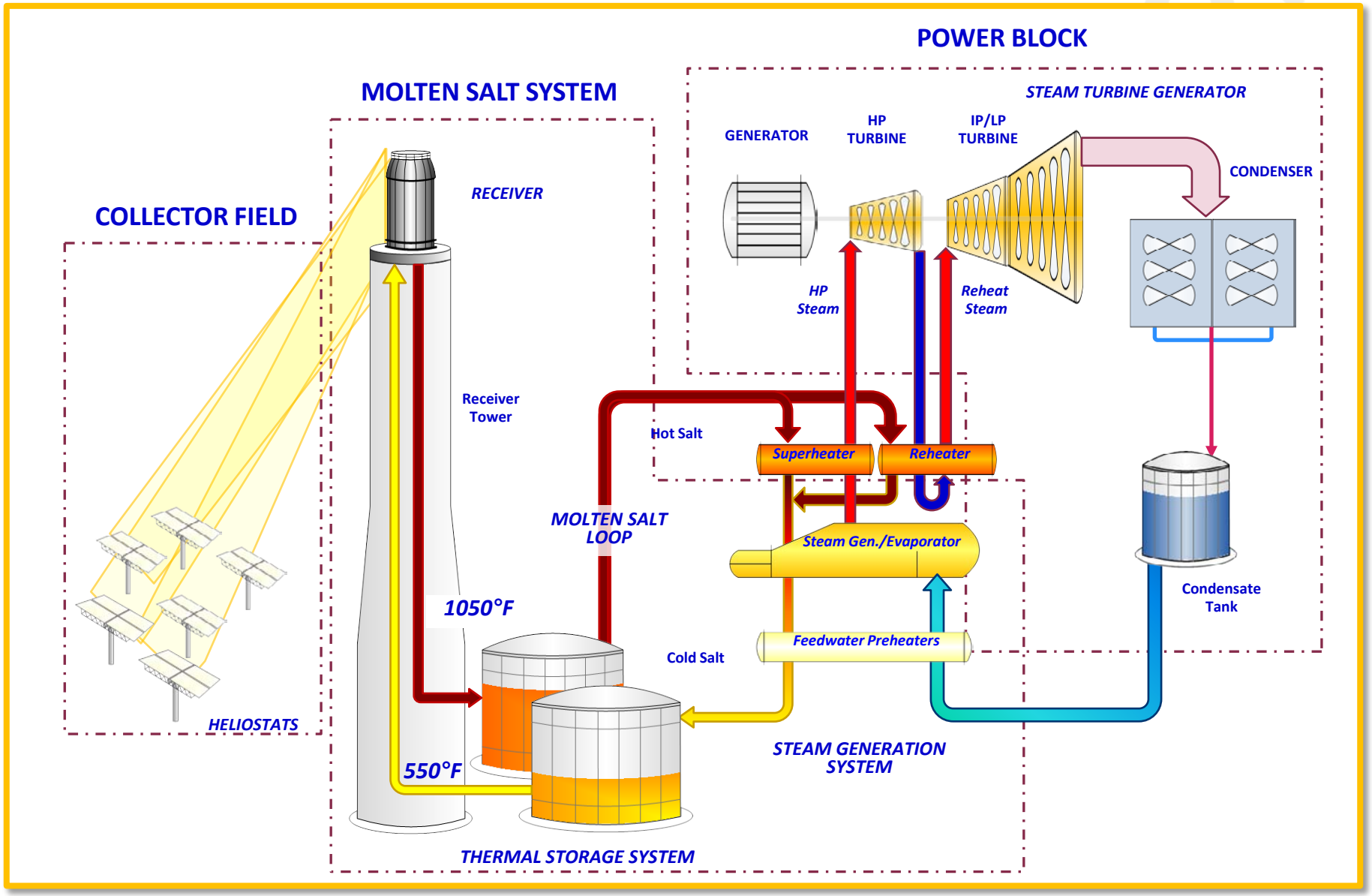
Energy Storage can Enable Dry Cooling



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Hoover Dam – 2 billion kWh/year (avg)

4 SolarReserve Towers are Equivalent to Hoover Dam

Hoover Dam + Lake Mead

157,900 acres or 247 square miles

SolarReserve Park (4 towers)

6,400 acres or 10 square miles

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Solid Support to Project Development

Original Partner

US RENEWABLES GROUP

- Entrepreneurial Structure
- Energy Expertise
- Operating Capital

United Technologies

Rocketdyne

- Technology License
- Guarantee/Warranty
- Engineering Investment

$140M Series "B" Financing

Sustainable Development Investments
Citi Alternative Investments

citi

Good Energies
POWER FOR A BETTER WORLD

NAZARIAN enterprises

ARGONAUT PRIVATE EQUITY

PCG ASSET MANAGEMENT

CREDIT SUISSE

SolarReserve has the Exclusive Worldwide Rights to the Rocketdyne Power Tower Technology

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UTC Guarantees Performance

United Technologies

$60B Revenue

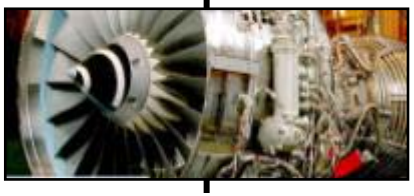
Sikorsky

Otis

Carrier

UTC Fire & Security

Hamilton Sundstrand



Pratt & Whitney

UTC Power

Research Center

Space Station Power System

Shuttle Engines

Solar Two Receiver

Rocketdyne

3,500 Employees

1,300Technical Degrees

SOLARRESERVE

$100+ Million DOE Investment

Rocketdyne

Designed, Developed and Built

Liquid Rocket Engines - *1585 Launches*

Space Station Power System

Liquid Metal Systems

Competencies

High Heat Flux

Systems Engineering

Molten Salt

Mission

Leveraged Know-How

Solar Two

10 MWe Demonstration Plant

Technology Validated

Dispatchability
Demonstrated 24 hrs/day
Exceeded performance targets
Met all test objectives