

# *Molten Salt Power Towers*

**DOE Program Review,  
Austin, Texas, 23 April 2008**

**Bill Gould  
Chief Technical Officer  
Solar Reserve, LLC**

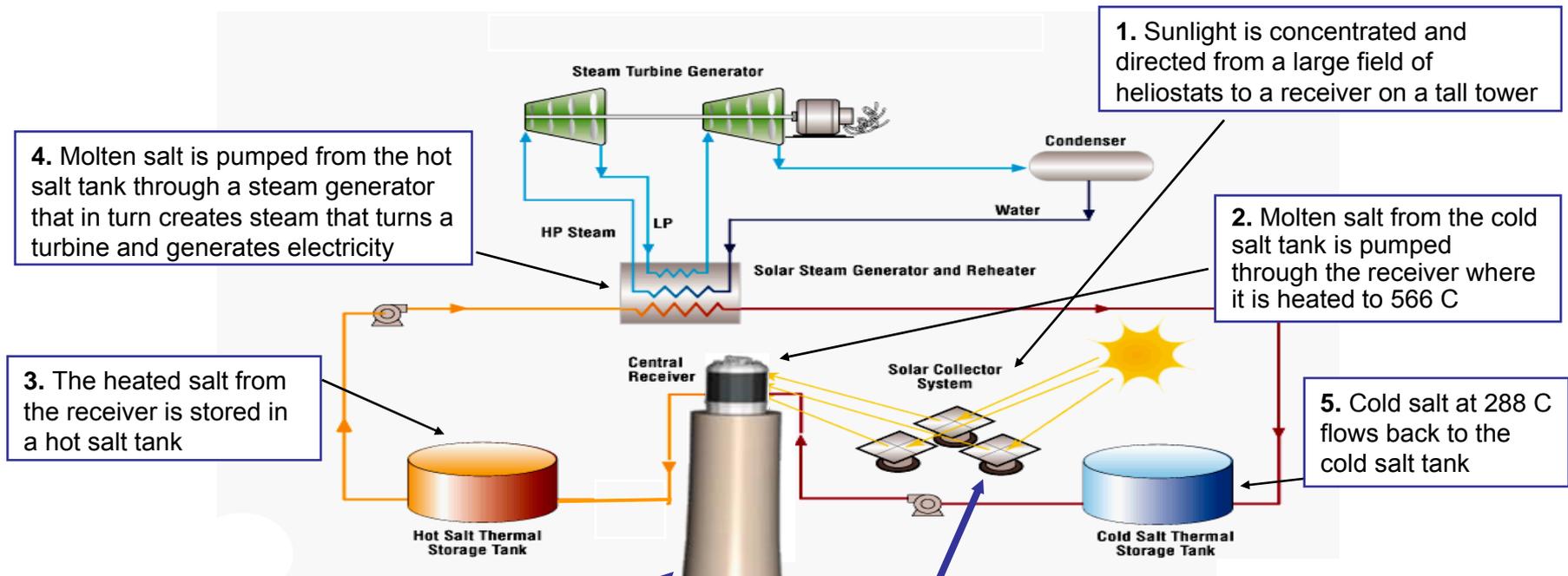


*Bill Gould, Chief Technology Officer, Solar Reserve  
Formerly Bechtel's Project Manager at Solar Two.*

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- **Discussion:**
  - **Who is Solar Reserve?**
  - **Why is Solar Reserve commercializing the Solar Two, power tower concept?**
  - **Why is Solar Reserve using molten salt instead of direct steam generation?**

# Solar Power Tower with Energy Storage



Central Receiver



Power Tower



Heliostat



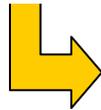
Storage Tanks

# *Solar Reserve Enables Project Development*



**United Technologies**

- Technology License
- Guarantee/Warranty
- Engineering Investment



**US RENEWABLES GROUP**

- Capital for Detailed Design
- Operating (Seed) Capital
- Project Development



# SolarReserve - Overview

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- **United Technologies Corporation** - a \$65 billion company. UTC's subsidiary, HS Rocketdyne, designs and manufactures the solar components. **UTC offers a full performance guarantee.**
- **US Renewables Group, LLC** - a \$575 million private equity firm manages renewable power and clean-fuel assets.
- **SolarReserve** is a developer, and owner of Solar projects. **SR has the exclusive license to market Rocketdyne's projects.**

# 50 Years of Rocketdyne Engines

1585 Launches

ACTIVE

										
Redstone 85	Navaho 11	Jupiter 46	Thor 380	Atlas I/II 568	Saturn I/1B 19	Saturn V 13	Space Shuttle 120	Delta I/II/III 321	Atlas III/IV 17	Delta IV 8

# Space Shuttle Main Engine

*First and Only Large Reusable Liquid Hydrogen / Oxygen Engine*



- High performance, Human rated
  - 1.5 Million pounds of thrust
  - >1,000,000 seconds of maturity
  - SSMEs operate for 8 1/2 minutes

	2007	2008	2009	2010
• Shuttle Flights	4	5	4	3
• 120 Launches – 360 Engine Flights				
• 100% engine mission success				

# *Solar Two Molten Salt Demonstration Plant*



- Daggett, California
- 1926 heliostats
- 42 MWt receiver
- 10 MWe turbine
- 3 hrs molten salt storage
- 300 ft tall tower (top)
- 1994-1999

# *Solar Two Molten Salt Demonstration Plant*

Solar Two was shut down in April,  
1999.

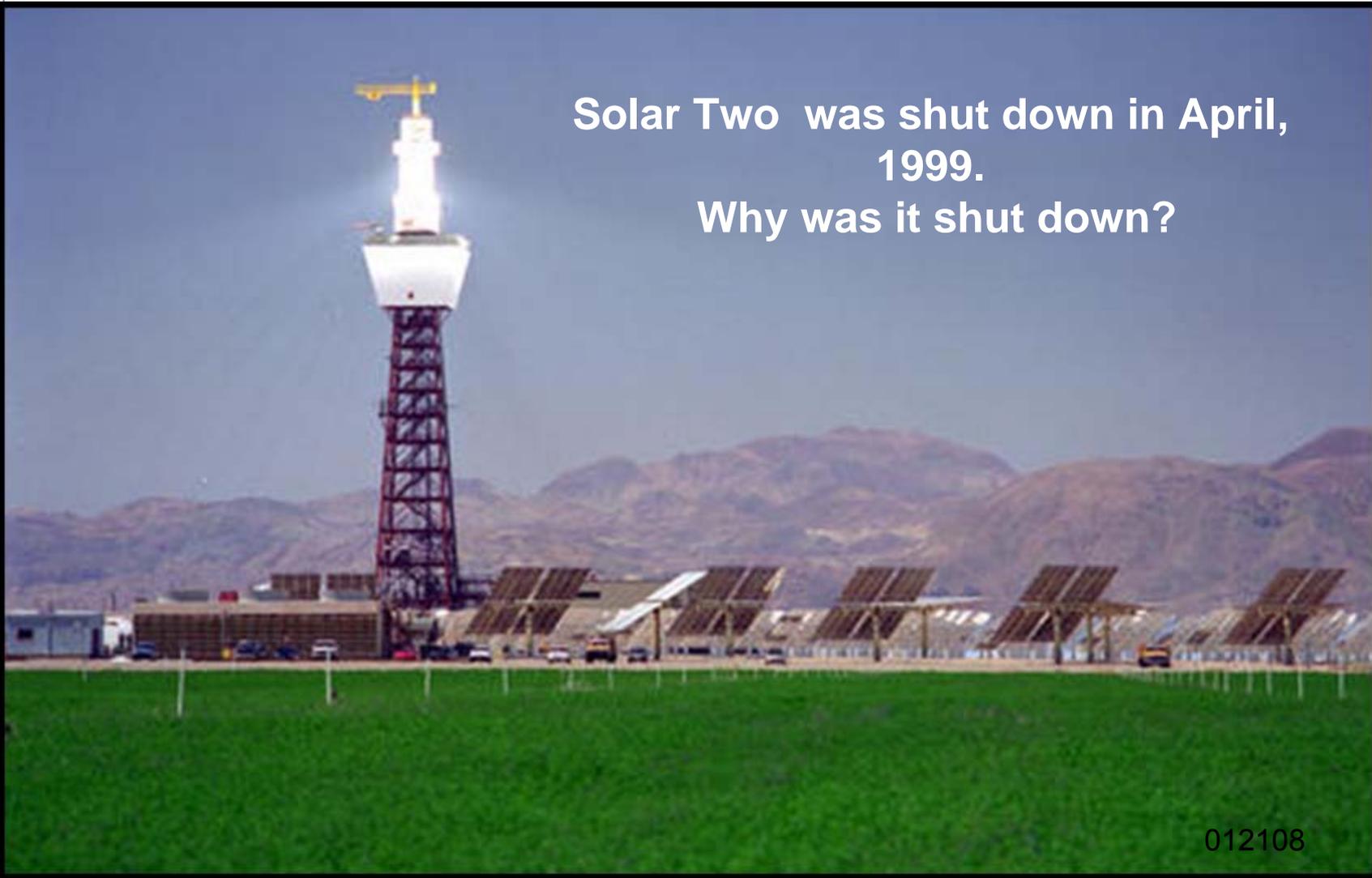


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## *Solar Two Molten Salt Demonstration Plant*

Solar Two was shut down in April,  
1999.

Why was it shut down?

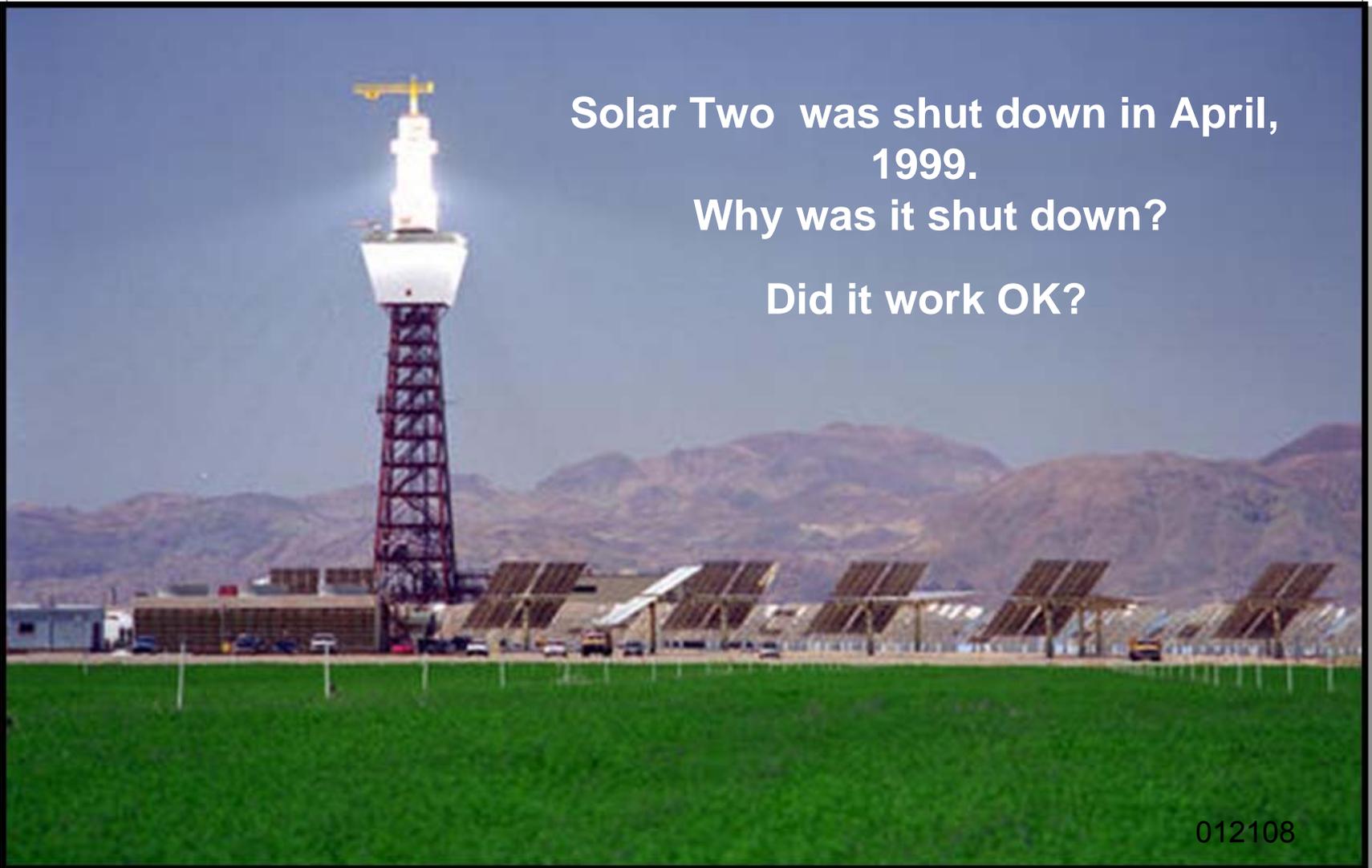


# *Solar Two Molten Salt Demonstration Plant*

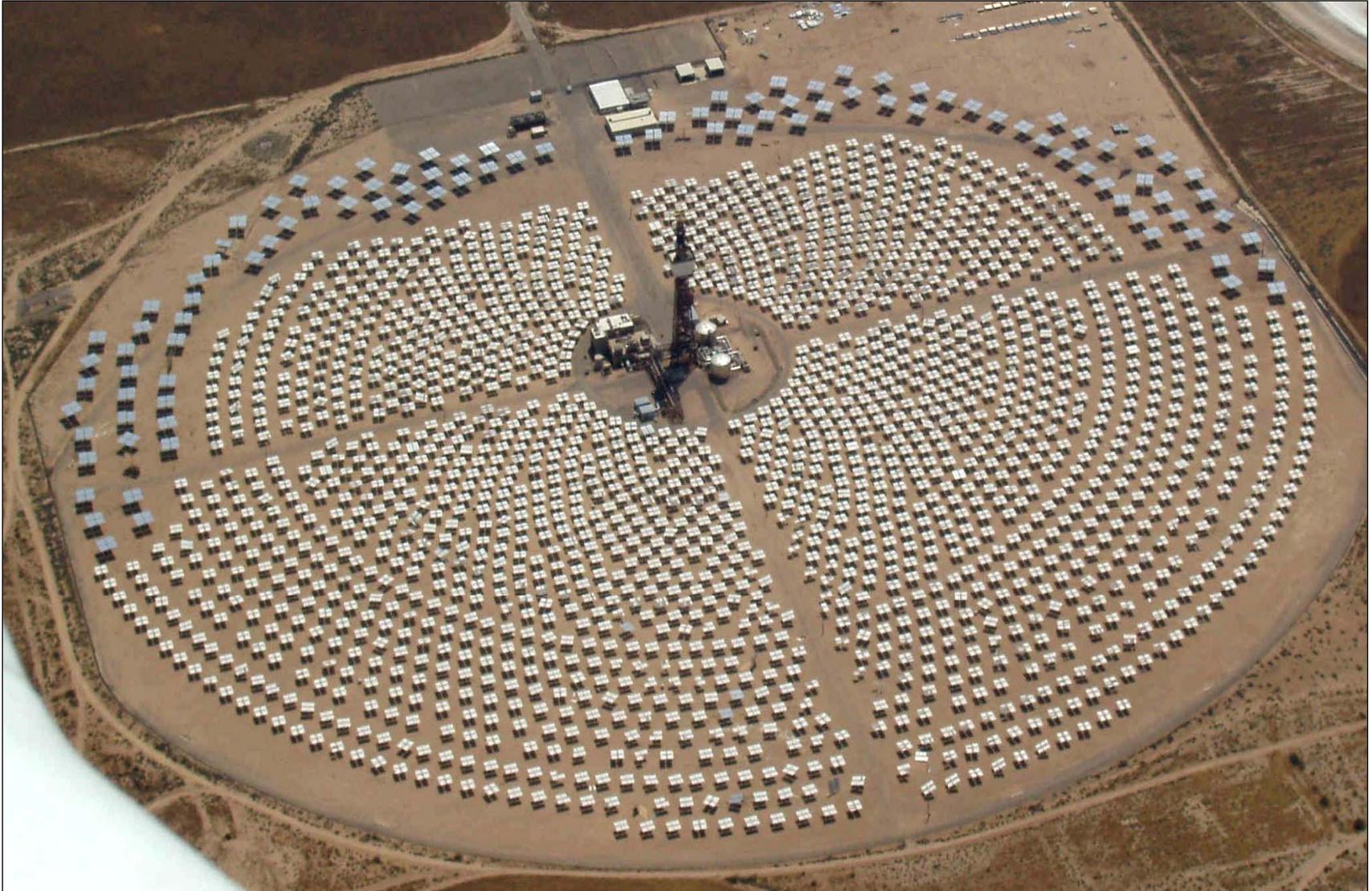
Solar Two was shut down in April,  
1999.

Why was it shut down?

Did it work OK?



# *DOE-Utility Consortium Collector Fields were Demonstration Only*



## ***Solar Two Demonstrates Clean Power for the Future***

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

“The 10 Megawatt Solar Two power tower pilot plant near Barstow, California, successfully completed operations in April, 1999, having met essentially all of its objectives.”

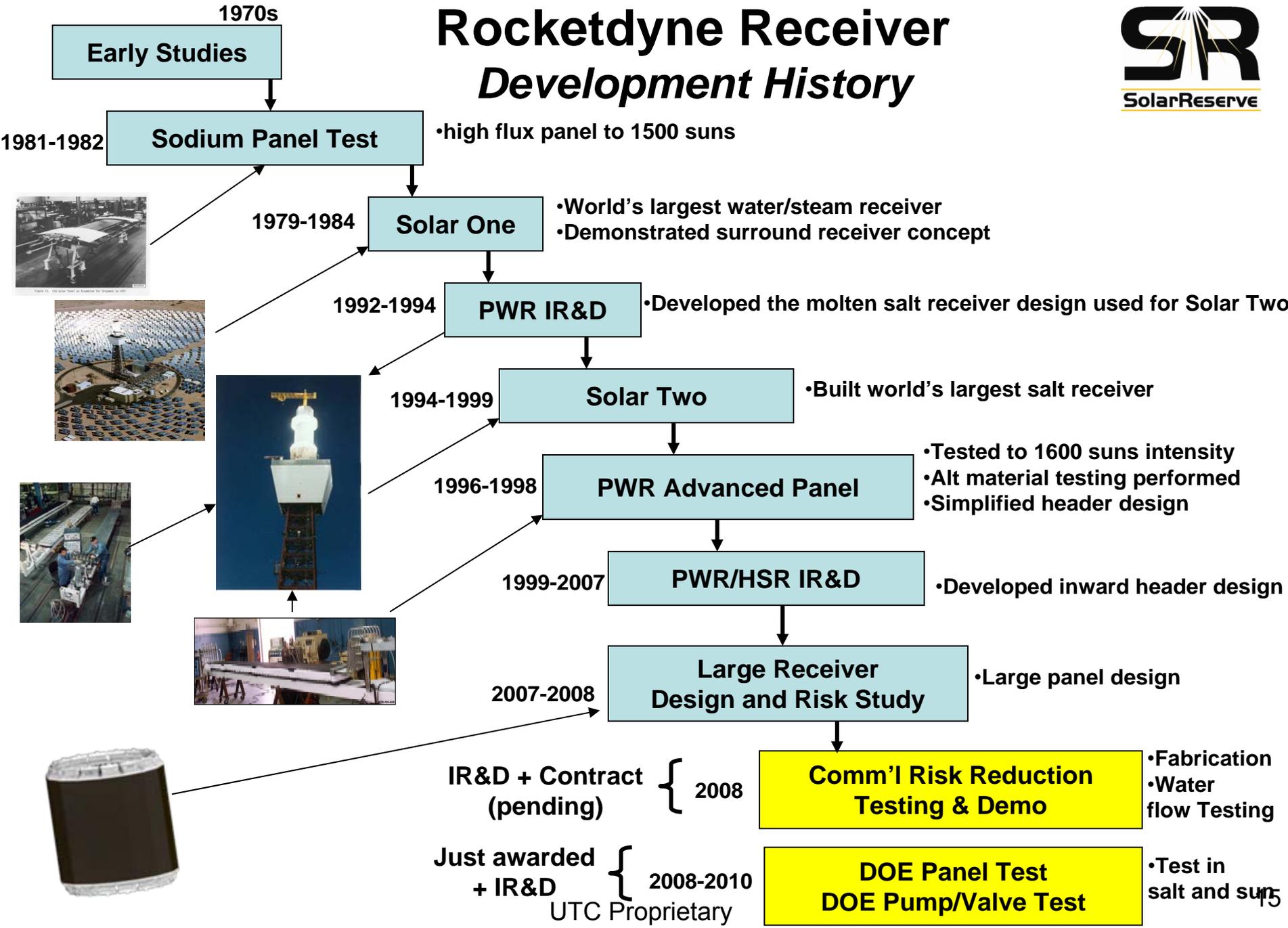
Sunlab Snapshot, SAND2000-613, March, 2000

## ***Market Conditions Were Not Favorable in 1999***

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- **Fossil fuels were cheap,**
- **No solar premiums were available,**
- **Boeing would not provide a performance guarantee,**
- **Non-recourse loans could not be obtained for a power tower without a guarantee.**

# Rocketdyne Receiver Development History



## *Direct Steam Versus Molten Salt*

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- **Rocketdyne is one of the few companies who can say they have tried both direct steam and molten salt.**
- **Solar One – 1979 – 1984**
- **Solar Two – 1994-1999**

## *Direct Steam Versus Molten Salt*

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- Rocketdyne is one of the few companies who can say they have tried both direct steam and molten salt.
- Solar One – 1979 – 1984
- Solar Two – 1994-1999

A bright green, cloud-like graphic with a blue outline, containing the text 'Direct Steam' in white, bold, sans-serif font.

**Direct Steam**

## *Direct Steam Versus Molten Salt*

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- Rocketdyne is one of the few companies who can say they have tried both direct steam and molten salt.

- Solar One – 1979 – 1984

- Solar Two – 1994-1999

A green, cloud-like graphic with a white outline, containing the text 'Direct Steam' in white.

**Direct Steam**

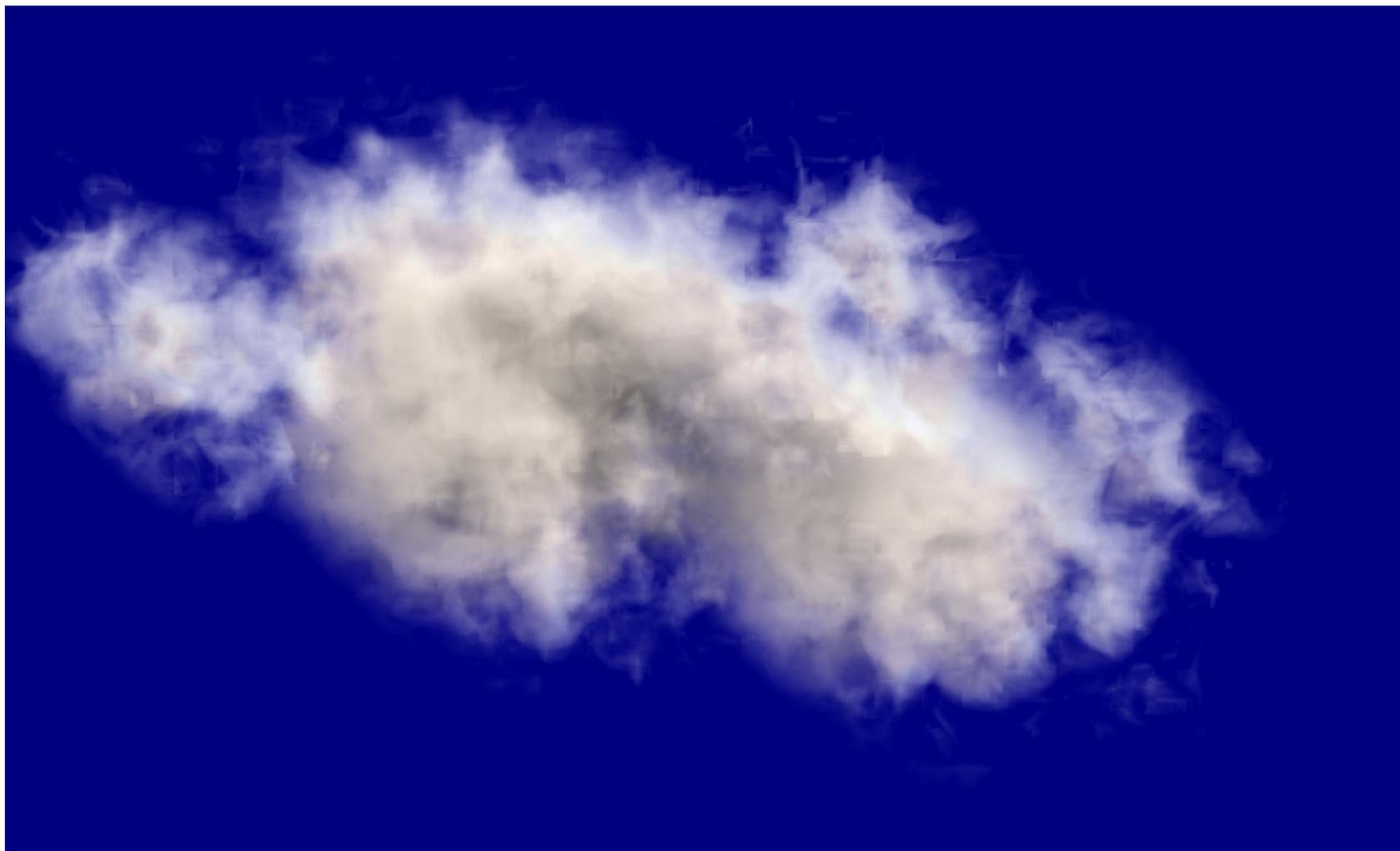
An orange, cloud-like graphic with a white outline, containing the text 'SALT' in white.

**SALT**

- Which fluid was best? Why?

# *Just a Little White Cloud*

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# *Solar Two Thermal Storage Tanks*



~ 35 ft diam. and 30 ft tall each

"Cold"

Hot

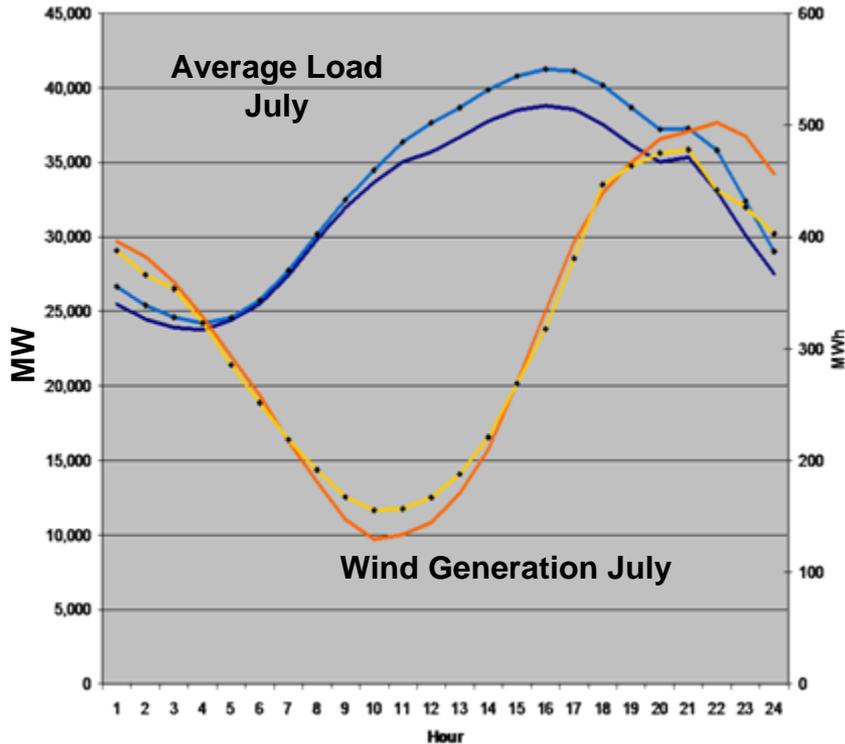
## *Direct Steam Requires Thicker Pipe Walls*



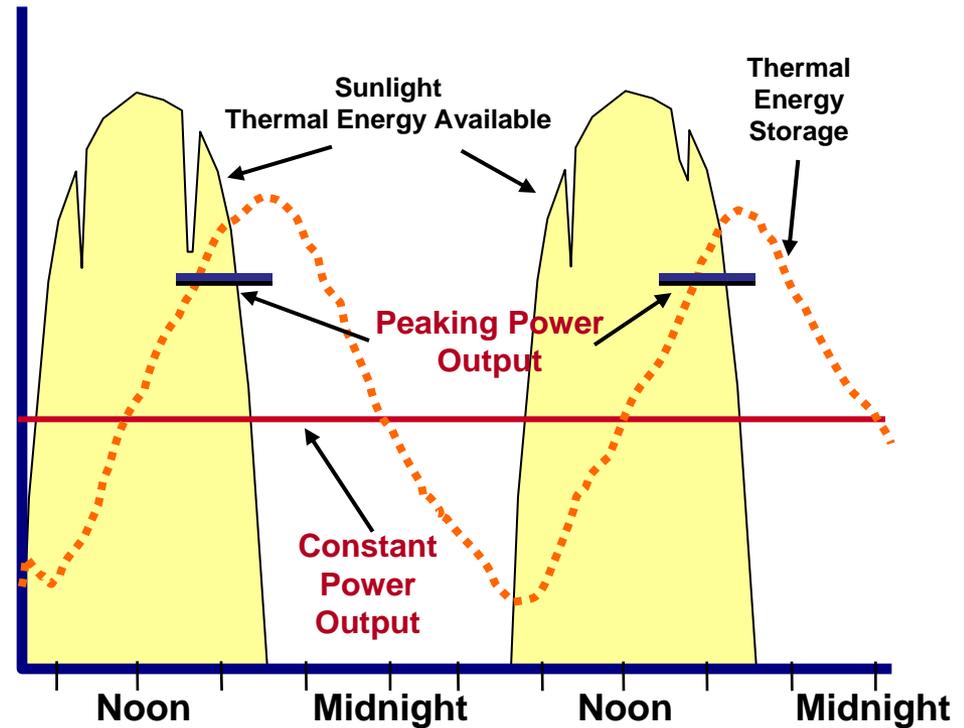
# Highly Efficient Molten Salt Storage

INTERMITTENCY LIMITS LONG-TERM VALUE

## Wind “Out-of-Phase” with Demand



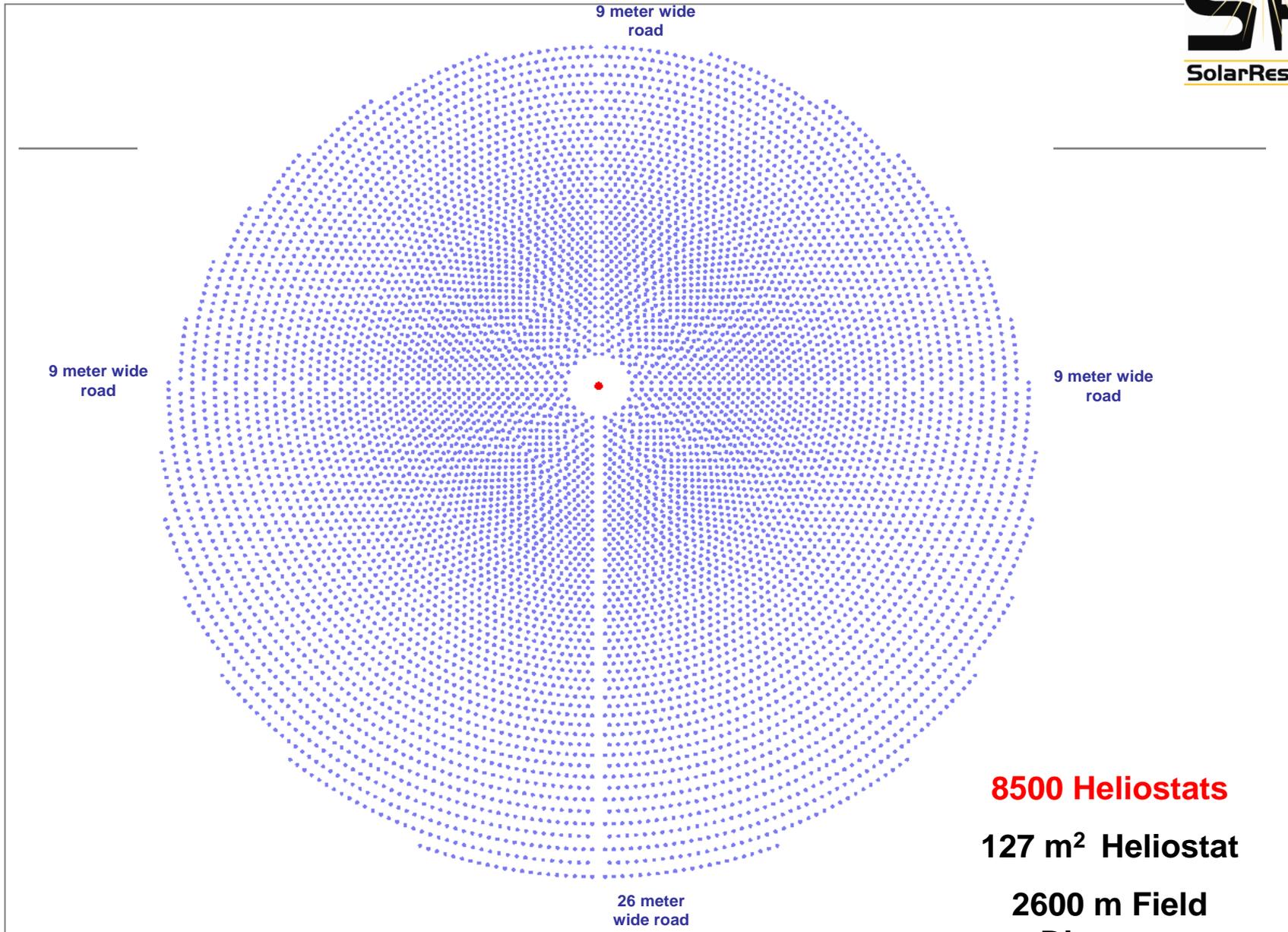
## Power Towers Offer Firm Dispatchable Power



## *Design Innovations From the Solar Two Design*

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- **Salt circuit metallurgy**
- **Salt valve type and packing strategy,**
- **Steam generator internals and steam drum,**
- **Salt pumps suspended in the salt tanks,**
- **Eliminated pump sump tanks,**
- **Slip formed concrete tower,**
- **High Performance Heliostat,**
- **Third generation (3G) receiver with many proprietary changes.**



9 meter wide road

9 meter wide road

9 meter wide road

26 meter wide road

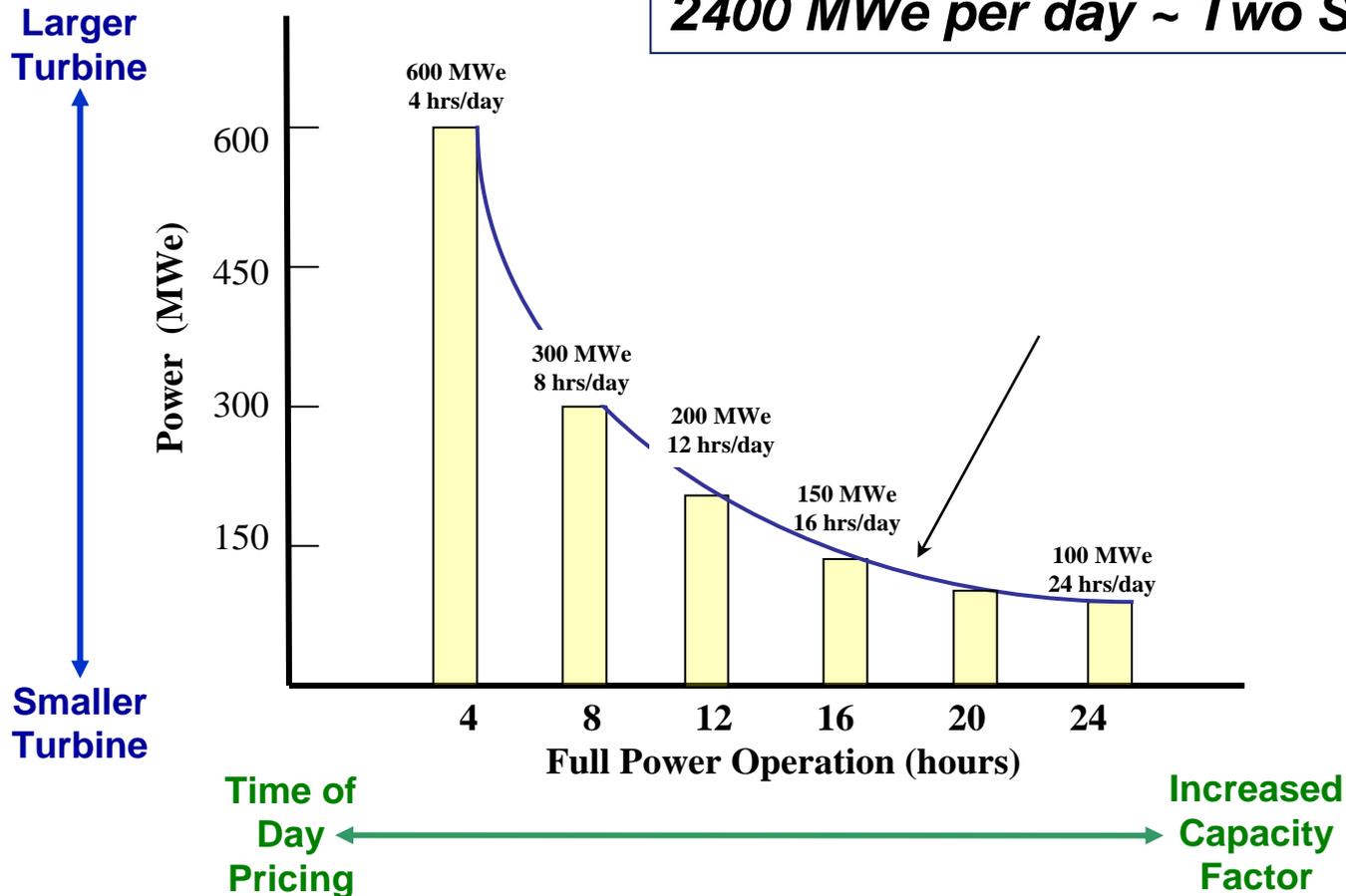
**8500 Heliostats**

**127 m<sup>2</sup> Heliostat**

**2600 m Field Diameter**

# Storage and Turbine Sized to Customer Needs

**2400 MWe per day ~ Two Sq Miles**



## *Power Towers are Ready Now*

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- **Molten Salt Power Towers is game-changing technology**
  - 500+ MW<sub>t</sub> Receiver under design
  - Can be tailored for time-of-day pricing
    - Peaking or 24/7 Capability
  - High power quality - steady vs. fluctuations (Wind)
  - 100% renewable energy - No natural gas required
- **Power Tower technology and performance fully demonstrated**
- **Performance Guaranteed / Warranted by United Technologies**
- **Pricing Competitive and Stable**
  - More competitive with increased size and TOD optimization



**SolarReserve has exclusive worldwide rights to the UTC design**