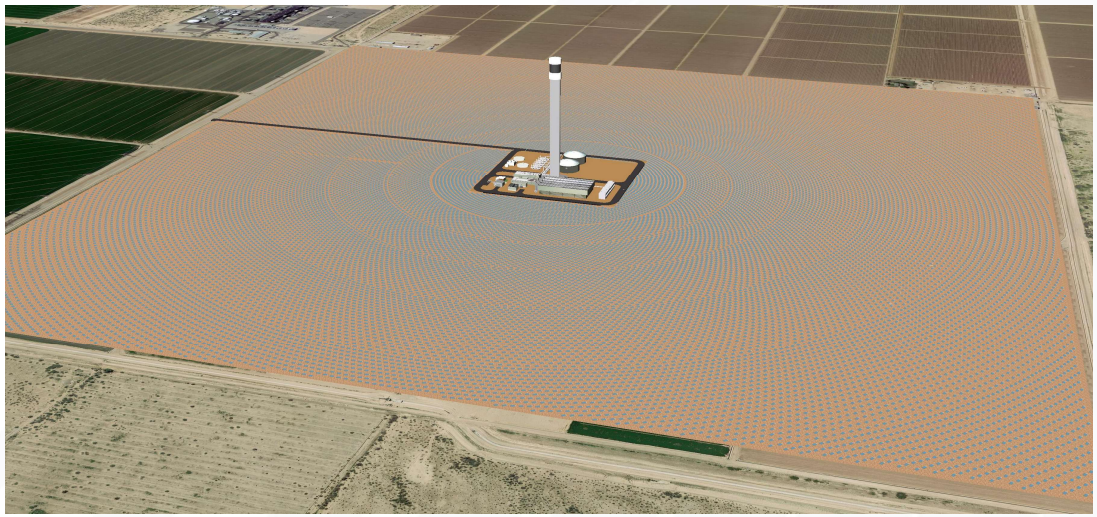
SolarDynamics



Dispatchable Solar Power

Adapting CSP to modern grid and off-taker needs

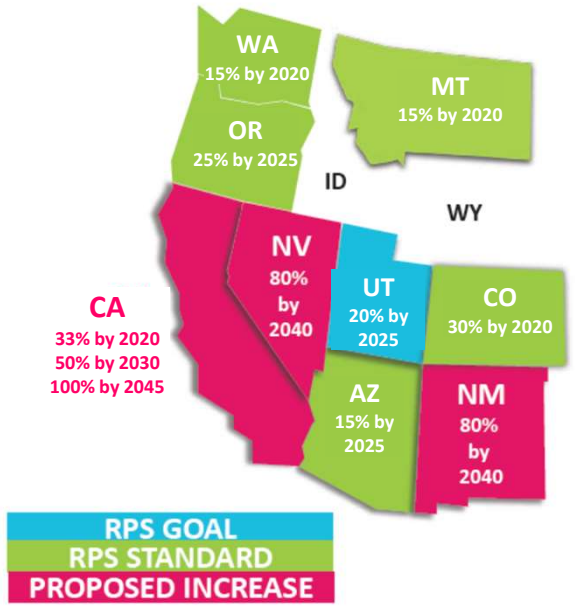
Hank Price, Managing Director, hank.price@SolarDynLLC.com
Solar Dynamics LLC

Flexible Generation Needed

SolarDynamics

- The CAISO “Duck Curve” is a sign of success.
- Managing the Duck is one of the key challenges to moving to higher renewable contributions on the grid.
- Utilities are responding by:
  - Reducing procurement of utility scale solar.
  - Closing baseload plants.
  - Adding flexible or “Peaking” natural gas resources.
- Western states proposing more aggressive RPS targets
  - California 100% by 2045
  - Nevada 80% by 2040
  - New Mexico 80% by 2040
  - Colorado, Arizona ?

FIGURE ES-8. PROPOSED RENEWABLE PORTFOLIO STANDARD (RPS) INCREASES



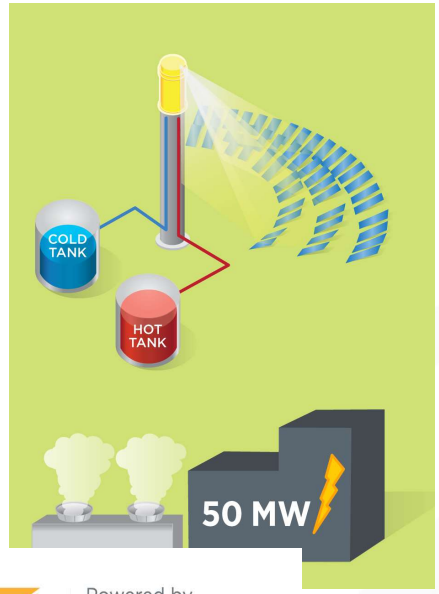
Source: SNL – S&P Global Market Intelligence

Can a dispatchable CSP plant fill the need for flexible peaking capacity?

CSP: Flexible Designs for an Evolving Grid

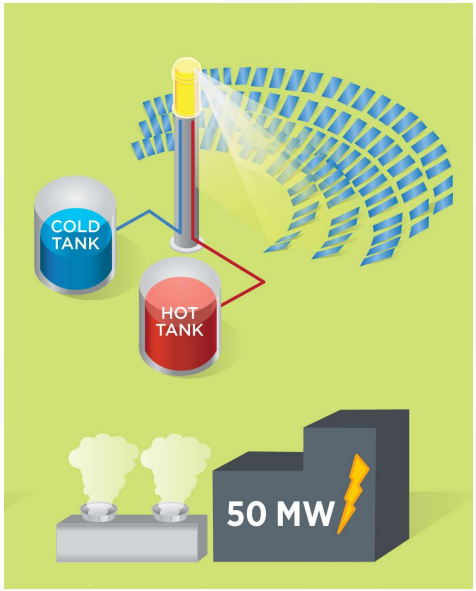
‘Peaker’

4 to 6 hours of storage
Capacity Factor <20%



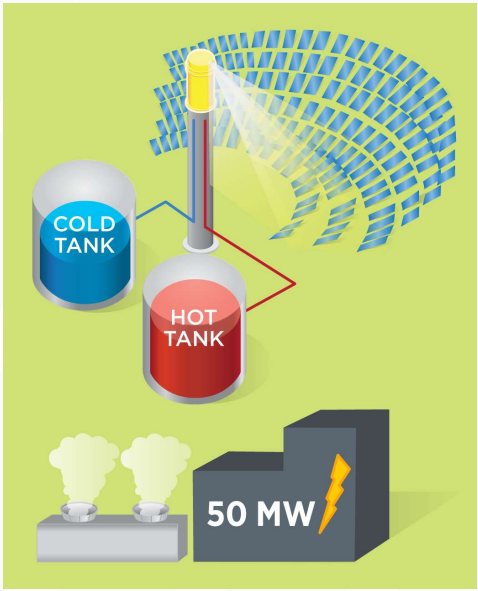
‘Intermediate’

6 to 9 hours of storage
Capacity Factor 30 to 50%



‘Baseload’

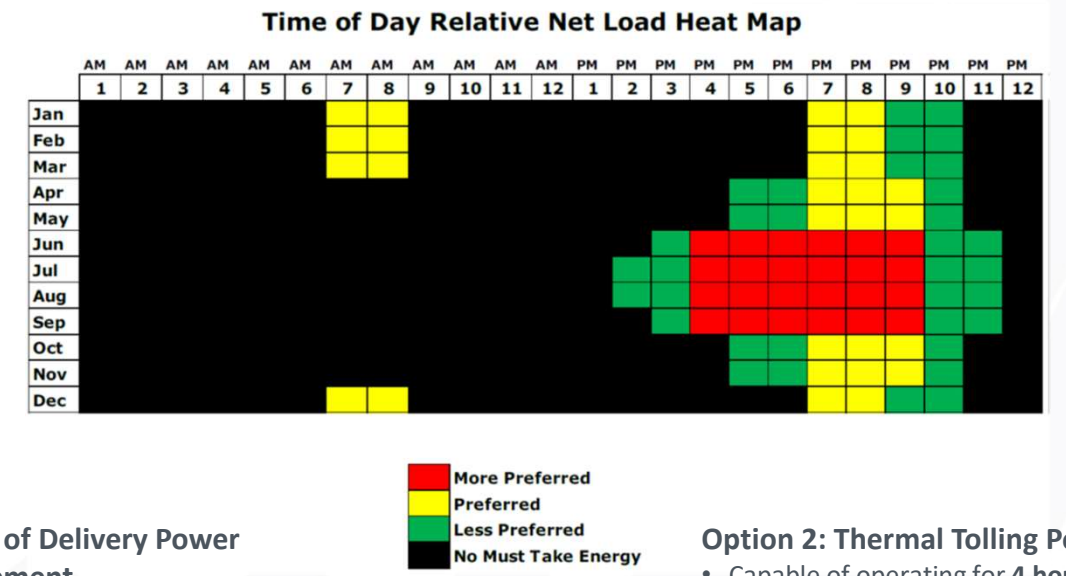
≥12 hours of storage
Capacity Factor >50%



Powered by SunShot
U.S. Department of Energy

Arizona Public Service 2017 Peaking Capacity RFP

SolarDynamics



Option 1: Time of Delivery Power Purchase Agreement

- Preferred = 3X Less Preferred
- More Preferred = 9x Less Preferred
- No power during "No Must Take Energy

Option 2: Thermal Tolling Power Purchase Agreement

- Capable of operating for **4 hours at 46°C** at 100% contract capacity.
- Dispatchable by APS with AGC (load following capability)
- Stable operation at a 25% loading.
- Capable of at least 2 starts per day.
- Faster starts and ramp rates are better

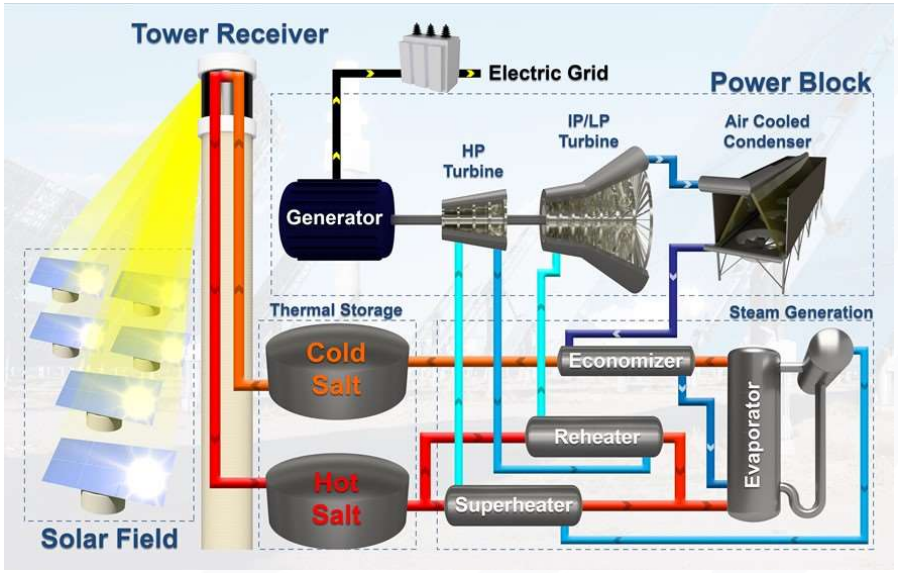
U.S. DOE SunShot: Dispatchable Solar Power Plant

Tech 2 Market

SolarDynamics

Dispatchable Solar Power (DSP) Plant

Uses Conventional Molten-Salt Tower Technology



- Market Assessment
- DSP Operational Requirements
  - Fast Starts & Ramps
  - Store solar energy during the day
  - Dispatch power anytime during next 24 hrs
- Cost Reduction
  - Standardized design
  - Power Parks
  - Compressed EPC schedule
- Commercialization
  - Conceptual engineering design and EPC cost estimate
  - Vendors identified for all key equipment
  - Address tower sensitive development issues
  - Outreach to Developers, EPCs, Utilities

Powered by SunShot U.S. Department of Energy

Sargent & Lundy

Morse Associates

BlüNebü

K&A

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Dispatchable Solar Power Plant Design

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DSP Configuration

	Summer On-Peak 5 hours
Turbine Nominal Gross Power	**250 MW_e**
Turbine Nominal Net Power	230 MW_e
Power cycle gross thermal efficiency	44%
Power cycle cooling system	hybrid
Power cycle design ambient temperature	115°F
Solar Receiver design duty	**400 MW_t**
Solar Multiple	**0.65**
Tower Optical Height	560 ft
Total Heliostat Area	700,000 m^2
Solar Field Area	640 acres
Storage Capacity (MWh electric)	1,150 MWh_e
Storage Capacity (hrs of turbine op.)	**5 hrs**
Annual Solar Resource	2,685 kWh/m^2
Annual Gross Capacity Factor	**16.5%**
1st year Net Generation	**334.2 GWh_e**

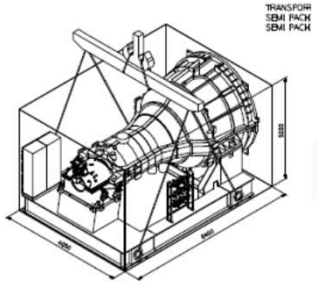
DSP Plant Design

- Large power plant mated to small solar field
- Produces 4 hrs/day on average
  - Compared to Solana 10 hrs/day
- 5 hours of thermal storage
  - Stores energy during the day to dispatch at night
- Design optimized to produce full power during hot AZ summer afternoons.
  - Uses hybrid cooling to minimize water use.
- Designed to fit on square mile plot of land to simplify development.

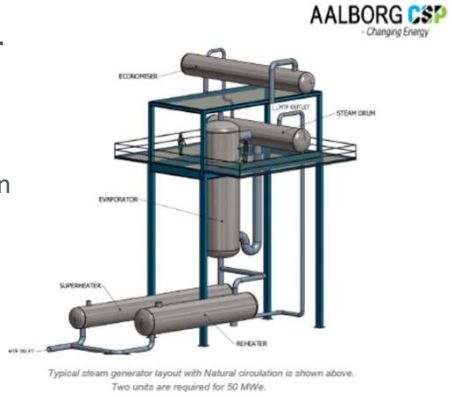
Fast Start Power Cycle

SolarDynamics

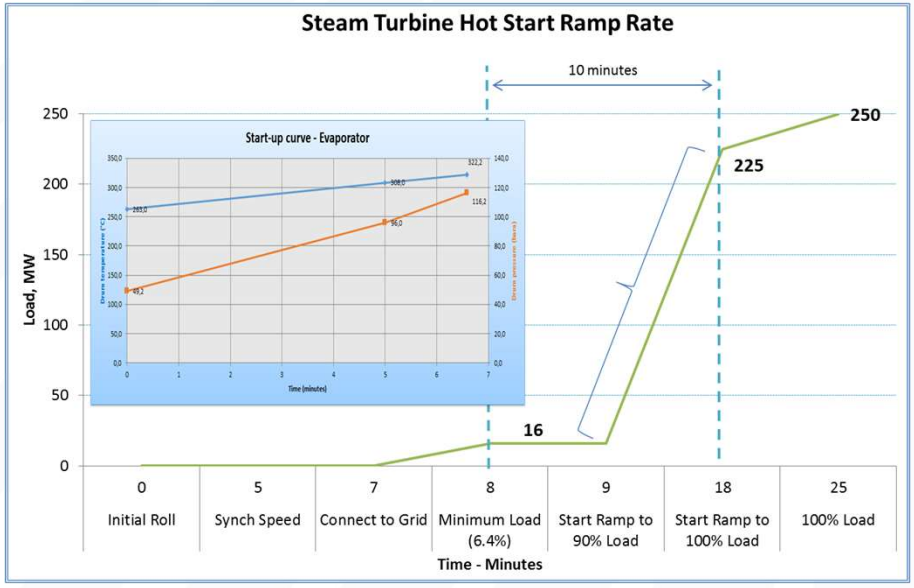
- **Siemens SST900 Steam Turbine**
  - Up to 250 MW
  - Fast Start & Ramp
  - Automated Start-up
  - Ships in 3 pieces
  - 30 years with daily starts



- **Aalborg Steam Generator**
  - Header Coil HX
  - Allows 5x temperature gradients
  - Starts up in under 10 min
  - Modular design
  - Passive circulation
  - Salt drains back.



Typical steam generator layout with Natural circulation is shown above.
Two units are required for 50 MWe.



400 MWth Molten-salt Receiver

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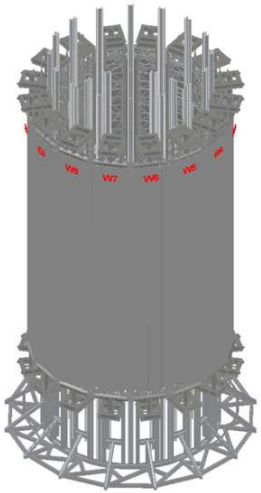
Aalborg CSP



GE Alstom

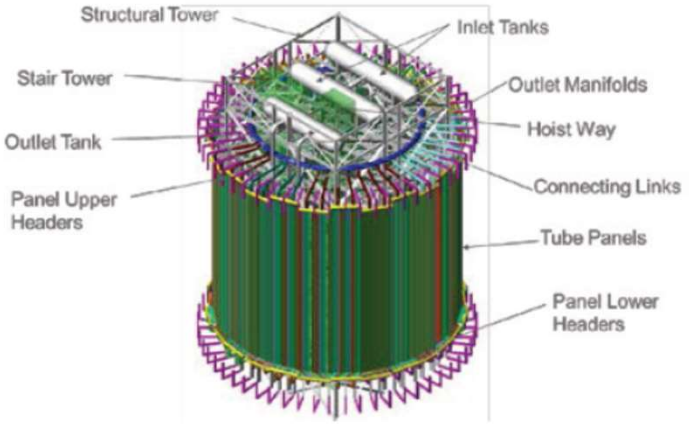


Fig 4: MSCR Isometric View with Major Equipment and Subsystem Identification

Heliostat Technology

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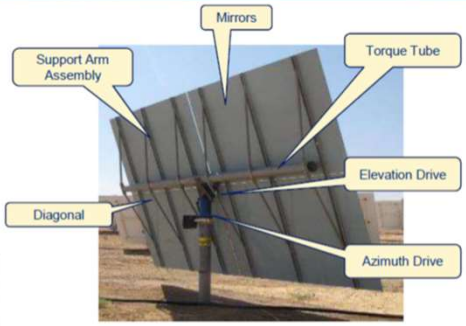
Commercial Heliostat

Heliostat — **Bright Source Energy**

- **Highly Engineered:**
  - Accuracy (static and tracking)
  - Light Weight & Low Cost
  - **Sustain:**
    - High Winds
    - Earthquakes
    - Floods
    - Climatic Conditions
    - Zero Maintenance
- Power & Control Module: WHC* & PV charger



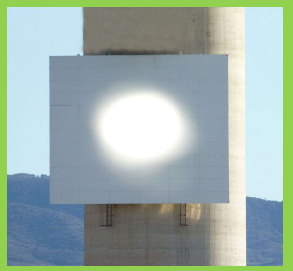
Heliostat Parameter	Dimensions
Net heliostat mirror area [m²]	24.99
Mirror Thickness	4 mm
Mirror Reflectivity	92 – 93 %

* WHC: wireless heliostat control

14

New Low Cost Heliostats

Stellio Heliostat



Stellio Image on Tower

Solar Dynamics DROP-C Heliostat

DSP Plant Output for APS TOD Schedule

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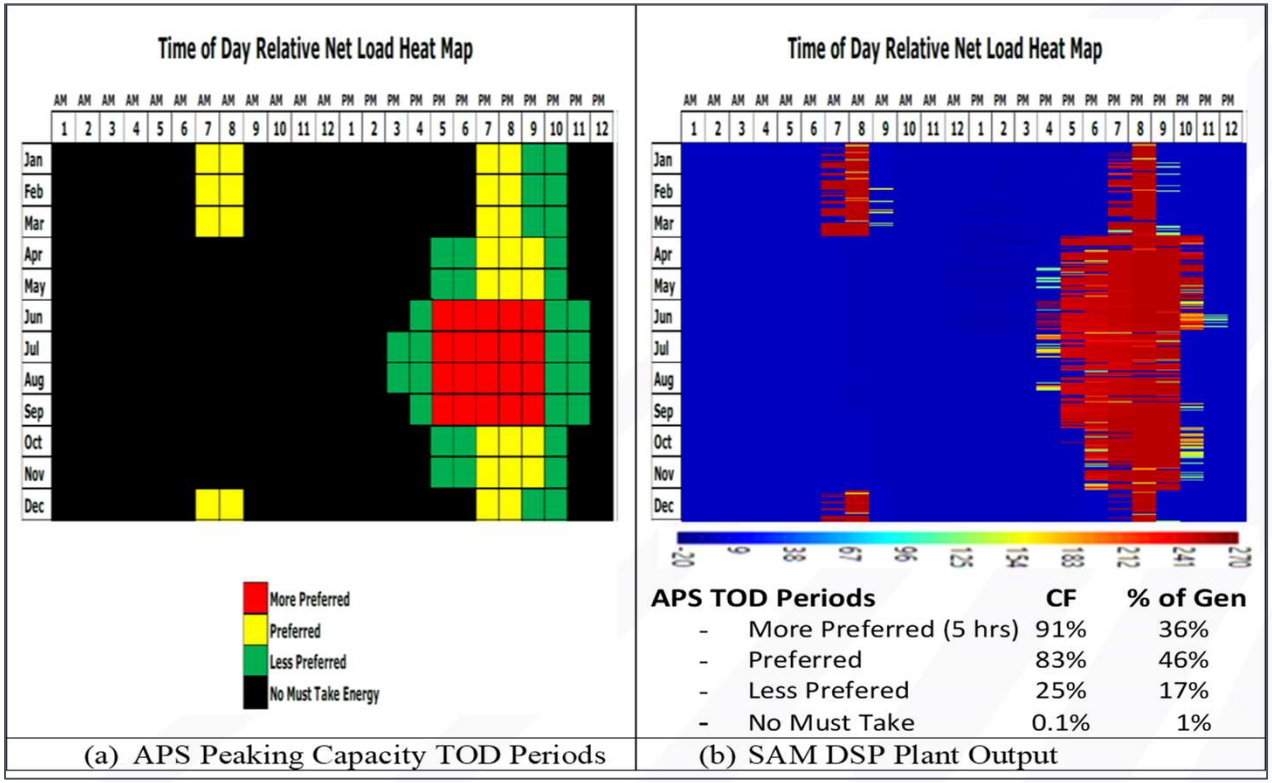


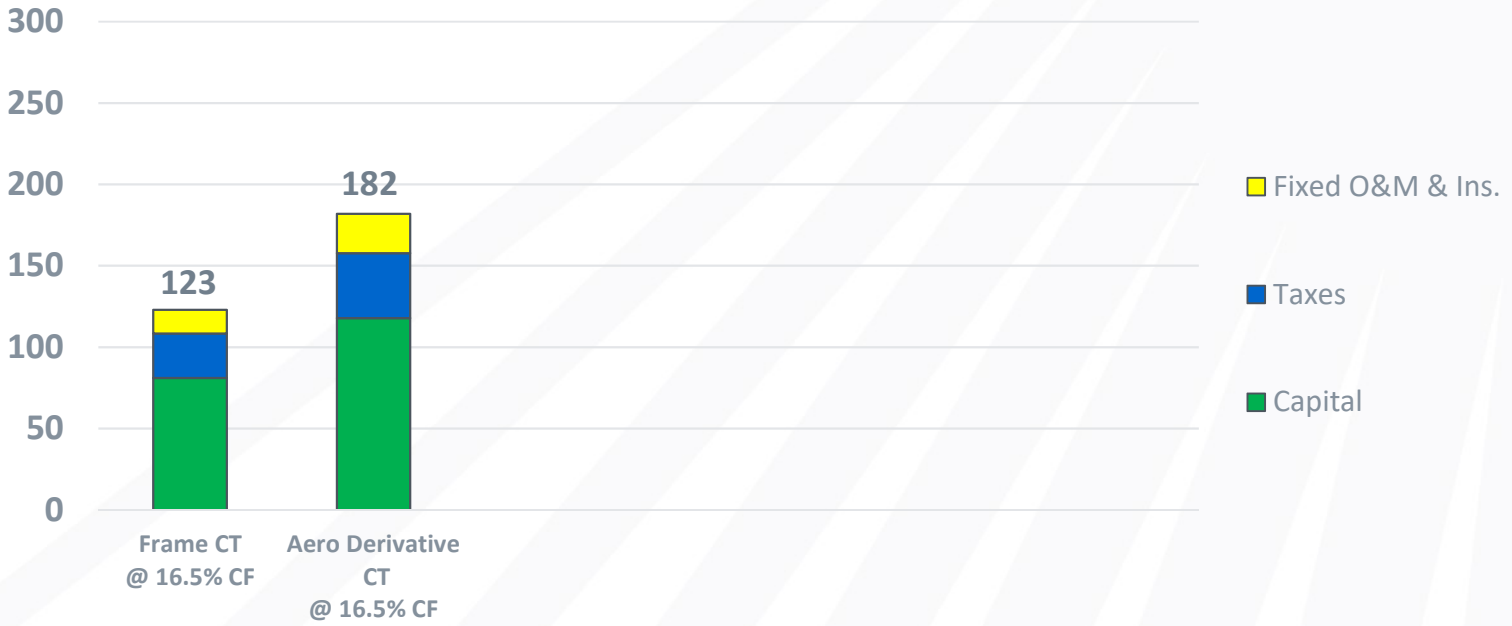
This shows the modeled output of a DSP plant optimized for a specific TOD schedule requested by Arizona Public Service (APS).

- The plant achieves high capacity factors during the more preferred and preferred TOD periods **91% & 83%.**
- Approximately **82%** of the total energy from the plant is delivered during these periods.

DSP Plant vs. Combustion Turbine in Arizona

SolarDynamics

Capacity Cost [$/kW-yr]



DSP Plant vs. Combustion Turbine in Arizona

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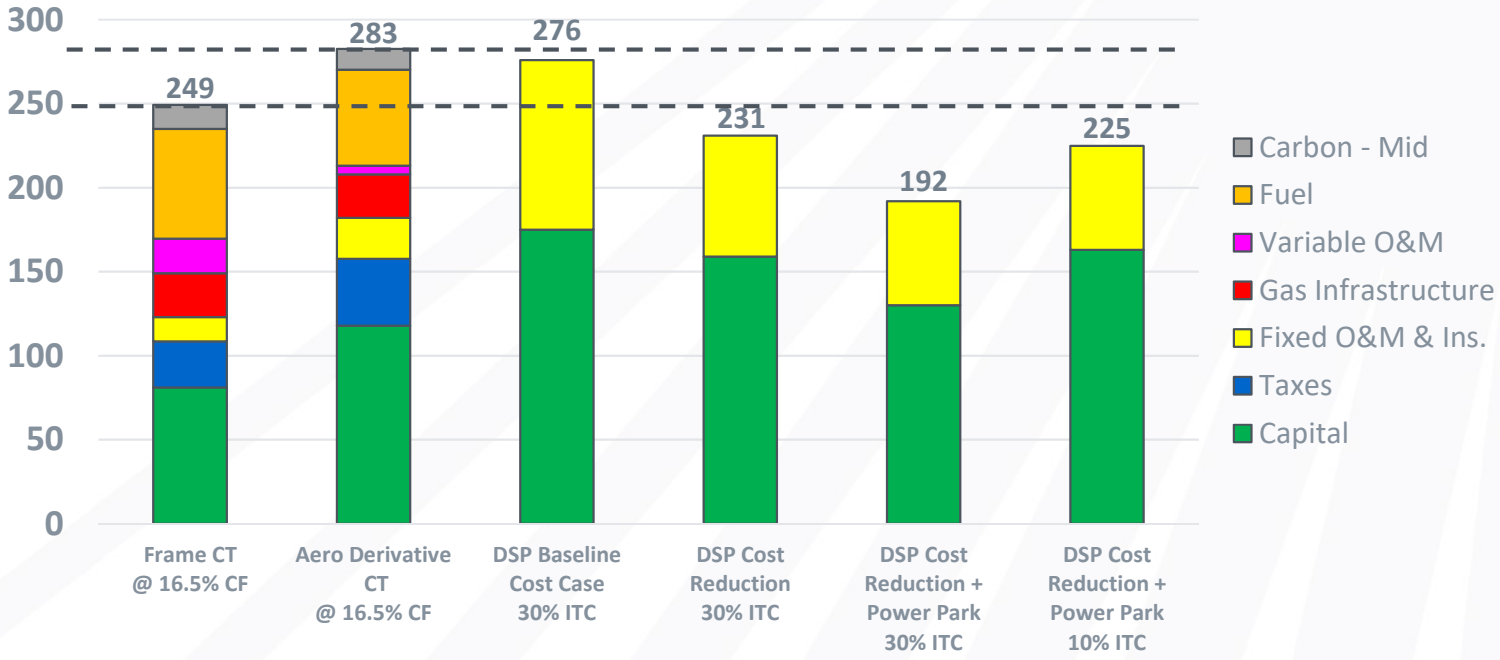
All-In Capacity Cost [$/kW-yr]



Sargent & Lundy

Morse Associates

BlüNebü

K&A

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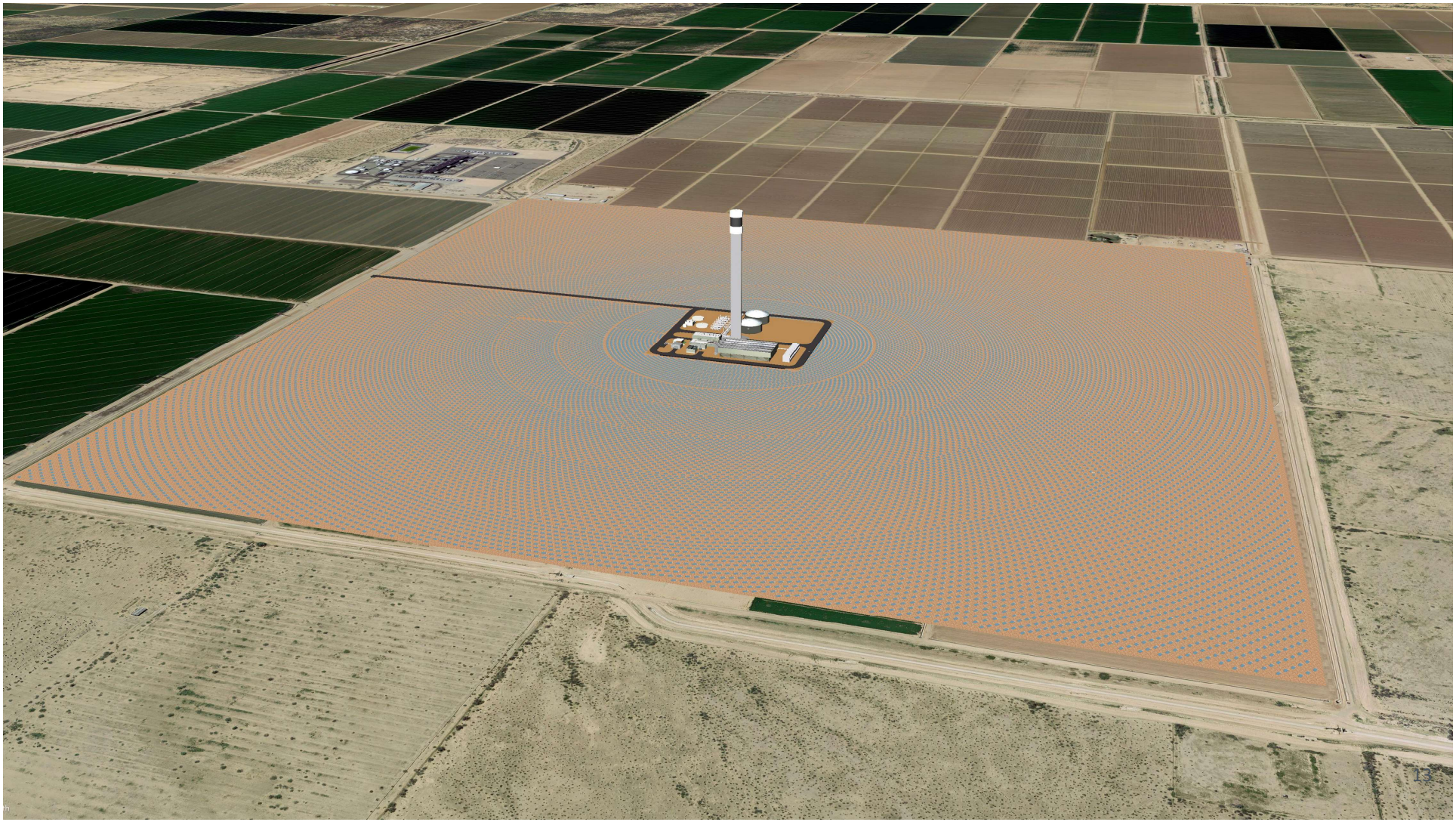

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Dispatchable Solar Power Plant - Final Report
https://www.osti.gov/biblio/1418902-dispatchable-solar-power-plant-project