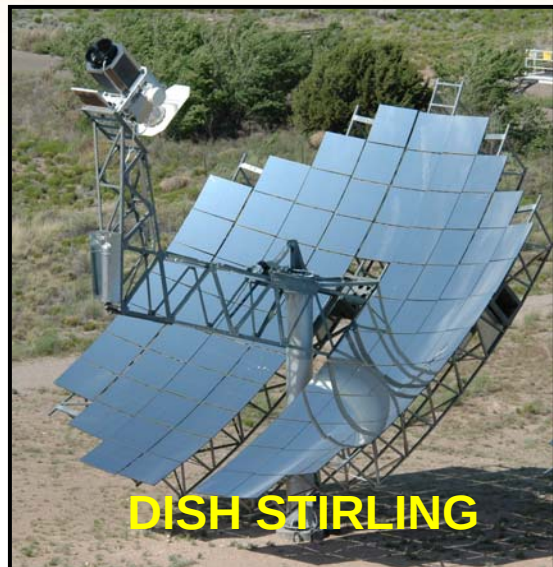


Concentrating Solar Power

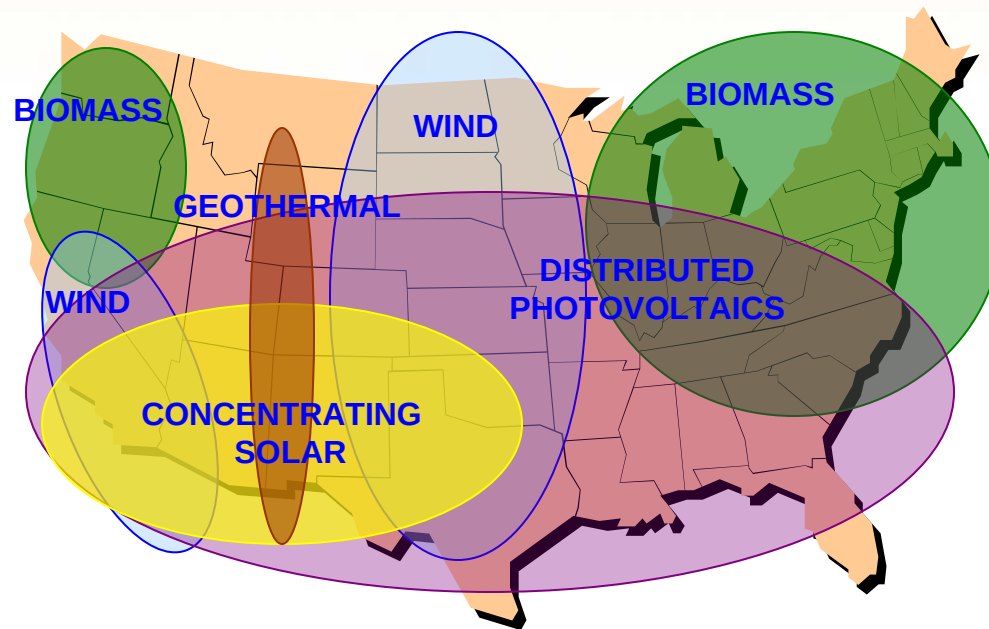


Tom Mancini
CSP Program Manager
Sandia National Laboratories
505.844.8643
trmanci@sandia.gov

Concentrating Solar Power (CSP) is also referred to as Solar Thermal Electric Power.



We need a 21st Century Renewable Energy “Marshall Plan”



- There is no “silver bullet”
- Utilize regional resources locally
- Establish a New National Electrical Transmission Grid
- Develop renewable/solar Energy to Transportation Fuel
- Explore advanced micro-grid infrastructure

Topics for Discussion

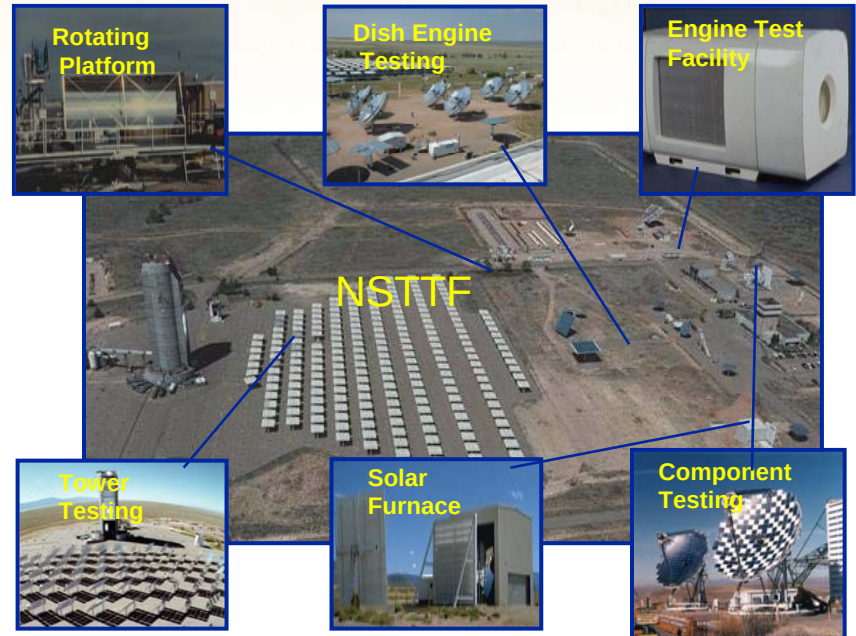
- What can CSP provide
- Brief Descriptions of technologies
- Importance of thermal storage
- Status of the technology
- Cost of the technology
- Potential in the Southwest
- Benefits of CSP

High Points of MY Message

- **Concentrating Solar Power is capable of and very close to making a major impact in Southwestern Power markets.**
 - More than 400 MW operating in CA and NV
 - More than 3,000 MW under development (known PPAs)
 - Current costs ~ 16¢/kWh
 - With as little as 3 to 5 GW of deployment estimated costs comparable to or less than coal with sequestration
- **What is needed are sustainable policies that enable projects to be planned and deployed.**

National Security Lab

Nuclear weapons
Nonproliferation and assessments
Military technologies and applications
Homeland security
Energy and infrastructure assurance
Working in CSP since 1975



National Solar Thermal Test Facility

Sandia is
Over 8,500 employees
Over 1,500 PhDs; over 2,500 MS/MA
Over 700 on-site contractors
\$2.7 billion FY07 operating budget

What is CSP?

CSP systems

- convert the sun's energy to heat and use that heat to power and engine/generator.
- are utility-scale solar power (> 100 MW).
- comprise three generic technologies: parabolic trough, power tower, and dish Stirling.
- have more than 140 plant-years of commercial operation (9 plants, 354 MW) in California desert.
- can provide dispatchable power for peaking and intermediate loads (with storage or hybridization).
- mostly utilize commodity items for manufacture (glass, steel, aluminum, piping, controls, etc.).

CSP Movie

**Power
Towers**

**Trough
Electric
Systems**

**Dish
Stirling
Systems**



Parabolic Troughs

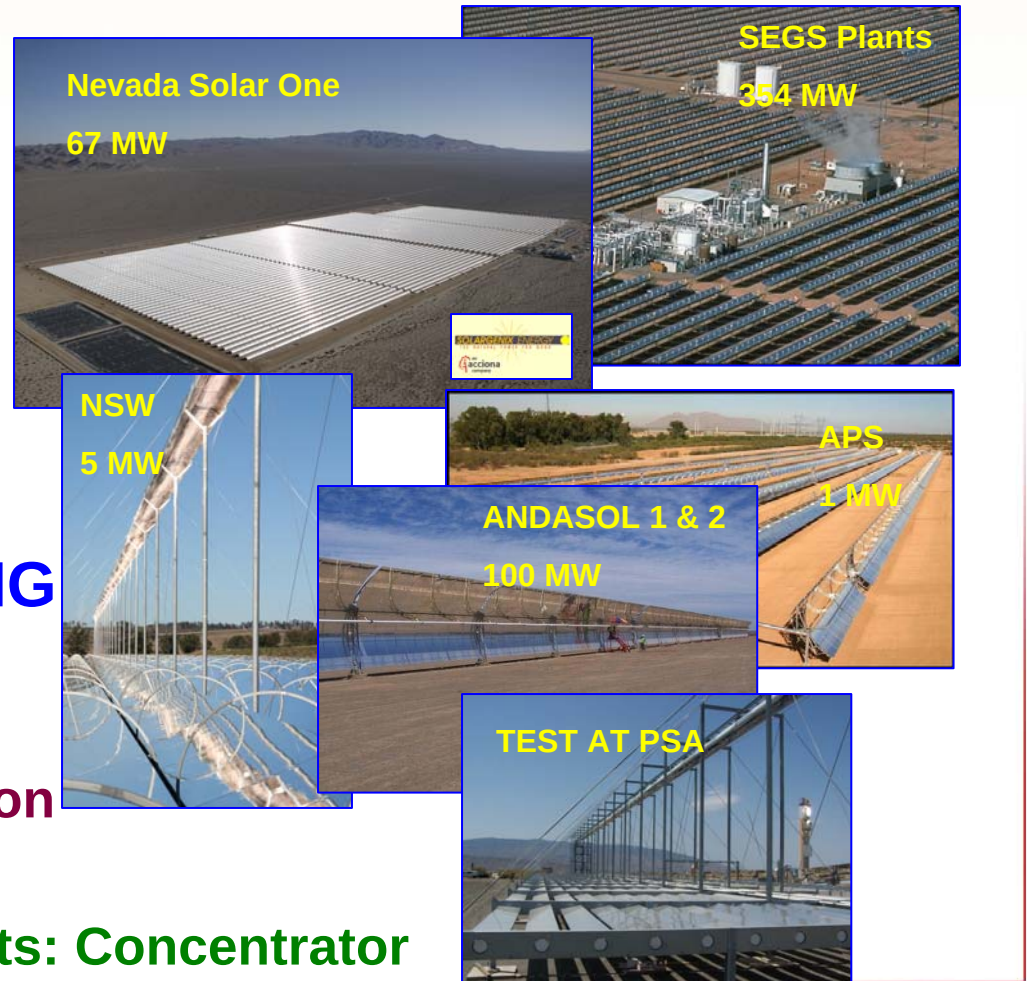
Line-focus technologies
State-of-the-art (SOA) is
parabolic trough

- Total annual average solar-to-electric efficiency at 12 - 14%.
- No thermal Storage
- Capacity ~ 29%
- Could be hybrid with NG

Emerging Technologies

- Thermal storage
- Higher Temperature Operation
- New low-cost designs

Key elements: Concentrator
and Receiver Tube



Power Towers

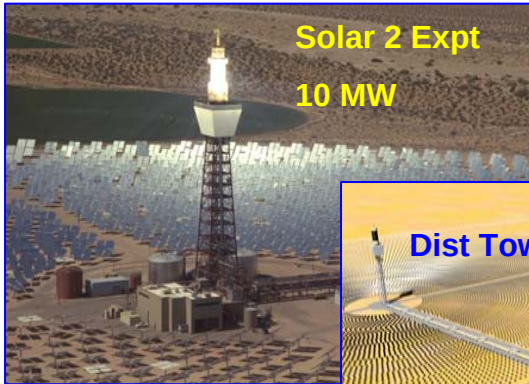
Point-focus technology

SOA is water/steam system

- Total annual average solar-to-electric efficiency ~ 12%.
- Minimal thermal Storage
- Capacity ~ 30%

Emerging Technologies

- Higher Temperature, molten salt operating fluid
- Integrated MS Thermal storage
- Higher Efficiency ~ 18 – 20%



**Key element: Heliostats and
Central Receiver**

Dish Stirling Systems

Point-focus technology

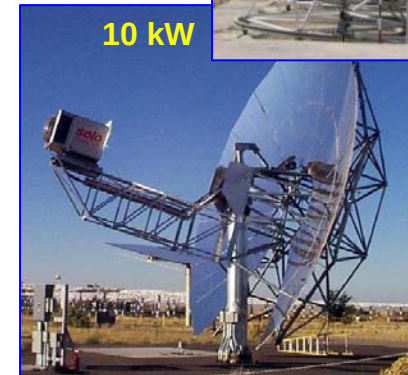
SOA 25 kW Dish Stirling

- Total annual average solar-to-electric efficiency ~ 22%.
- Does not accommodate thermal Storage
- Capacity ~ 30%

Emerging Technologies

- Alternative engines in development
- Limited mass production of engines required to reduce cost

Key element: Stirling engine
and dish concentrator

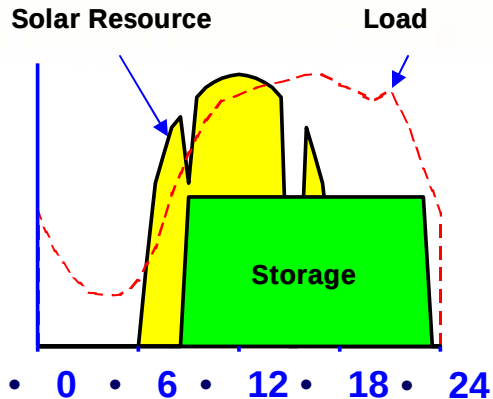


The Value of Storage: Dispatchable Power

Thermal Storage

- **uncouples** solar energy collection and generation.
- produces **higher value electricity** because power production can better match utility time-of-day needs.
- is high efficiency (~98% roundtrip)

Molten salt power towers utilize the salt as the working fluid and storage. Two trough systems are under construction in Spain to use the salt as storage.



Technology Status

- Solar-only parabolic trough is the most mature and commercially available of the three CSP technology.
- Dish Stirling technology is unique and may fill some near term solar applications.
- Some emerging technologies may provide lower costs.
- Thermal storage for trough systems is yet to be validated for performance and cost, but soon will be.
- Molten salt power tower (with storage, capacity factor 0.5 – 0.7) is attractive in mid term – 5 to 10 years.
- Long term – high performance power cycle (high T) with storage (capacity factor > 0.5).



CSP R&D Directions

DOE R&D Directions

- **Support near-term deployment of CSP Systems**
- **R&D to reduce collector/receiver/system costs**
- **Focus on Thermal Storage use in trough systems and long-term alternatives**

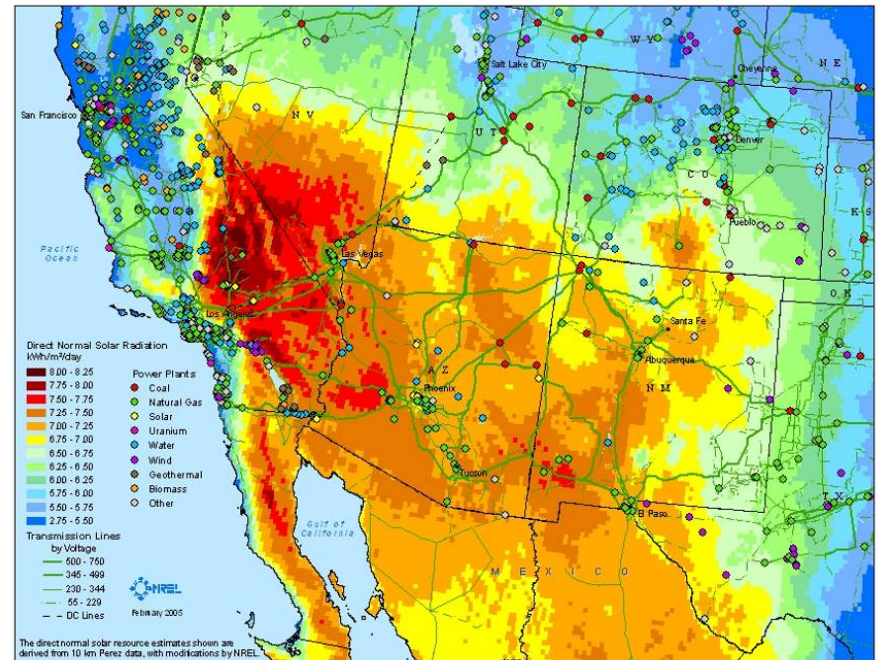
Future R&D Potential of CSP

- **High performance CSP power cycles (Brayton)**
- **Utilization of solar energy to produce transportation fuels**
- **CSP providing higher-capacity generation in energy micro grids**

DNI Solar Resource in the Southwest

Screening Approach

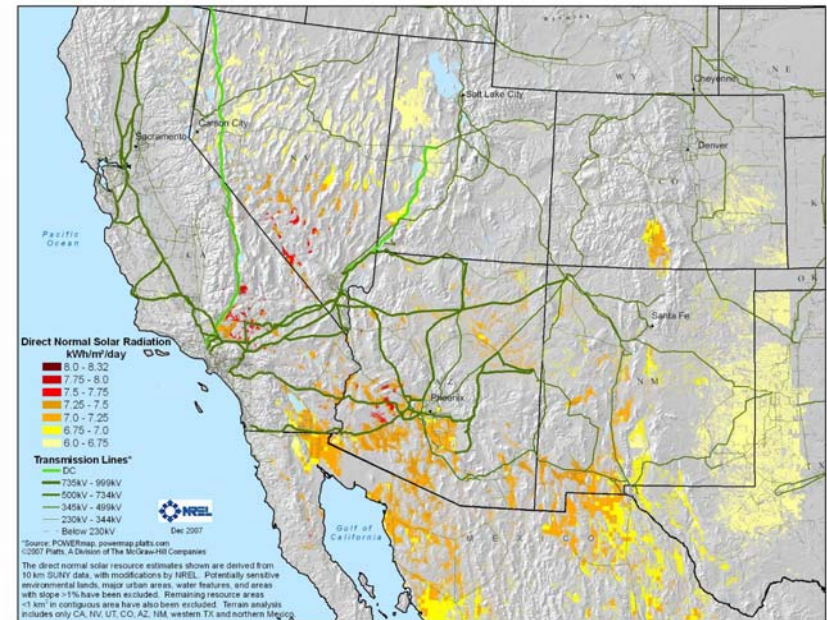
- Filters applied:
- Direct-normal solar resource.
- Sites > 6.0 kwh/m²/day.
- Exclude environmentally sensitive lands, major urban areas, etc.
- Remove land with slope > 1%.
- Only contiguous areas > 10 km²



Data and maps from the Renewable Resources Data Center at the National Renewable Energy Laboratory

CSP Resource Potential

State	Land Area (mi ²)	Solar Capacity (MW)	Solar Generation Capacity GWh
AZ	13,613	1,742,461	4,121,268
CA	6,278	803,647	1,900,786
CO	6,232	797,758	1,886,858
NV	11,090	1,419,480	3,357,355
NM	20,356	2,605,585	6,162,729
TX	6,374	815,880	1,929,719
UT	23,288	2,980,823	7,050,242
Total	87,232	11,165,633	26,408,956



**Current total nameplate capacity in the U.S. is
1,000,000 MW with an annual generation
of 4,000,000 GWh**

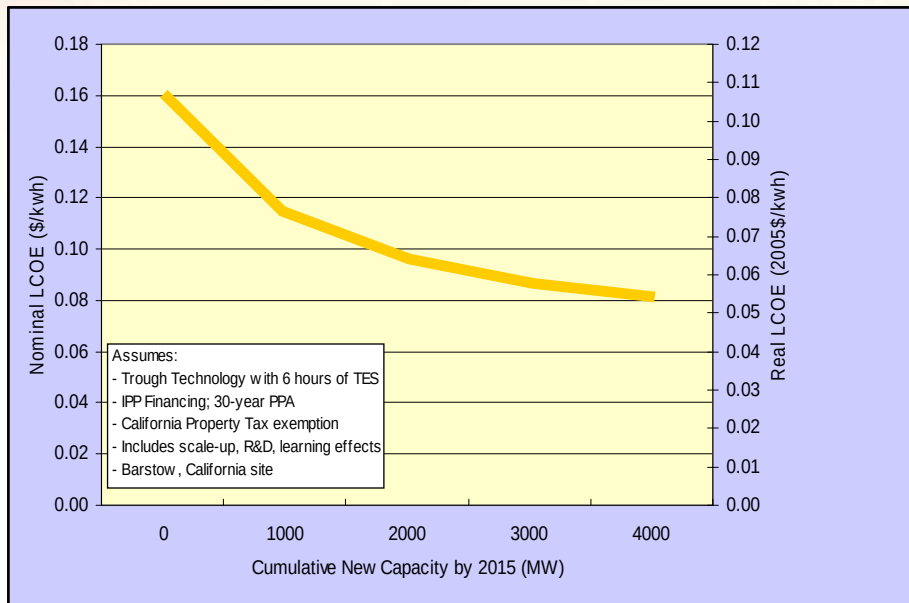


Energy Costs

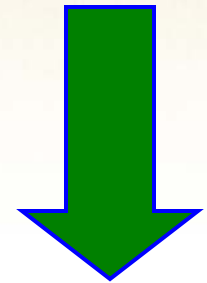
Levelized Energy Cost (LEC): The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Nominal Energy Cost: The cost of electricity at the time of service or the time of the transaction. Nominal costs are not adjusted to remove the effects of inflation; they reflect buying power in the year in which the transaction occurred. (Utilities typically use nominal costs brought back to present value.)

Cost of CSP-Generated Electricity

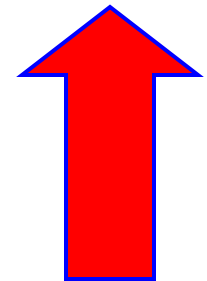


**Cost of CSP
Generation**



**CO₂
POLICY**

**Cost of Fossil
Generation**



Cost Reductions result from

- Increased Plant Size and Deployment
- Reduced Financial risk from proved performance
- Cost reductions from R&D

Source: WGA Solar Task Force Summary Report Jan 2006

More Than 3 GW Under Development

- 1 MW trough/ORC in Arizona (APS, Acciona) operating
- 64 MW trough electric project in Nevada (Nevada Power, Acciona) commissioned June 2007
- 500 (option to 850 MW) Dish Stirling plant in Southern California (SCE, SES, Aug 2005)
- 300 (option to 900 MW) of Dish Stirling plants in Southern CA (SDG&E, SES, Sep 2005)
- 553MW Trough plant (PG&E, Solel, July 2007)
- 177 MW Linear Fresnel Reflector (AUSRA, PG&E, Nov 2007)
- 280 MW Parabolic Trough with storage (Abengoa, APS, Feb. 2008)
- 250 MW Arizona PS Consortium RFP issued Dec 2007
- 250 MW Parabolic Trough (FPL Energy, AFC filed)
- 900 MW Power Tower (BrightSource, PG&E, April 2008)
- Other RFPs issued but not announced

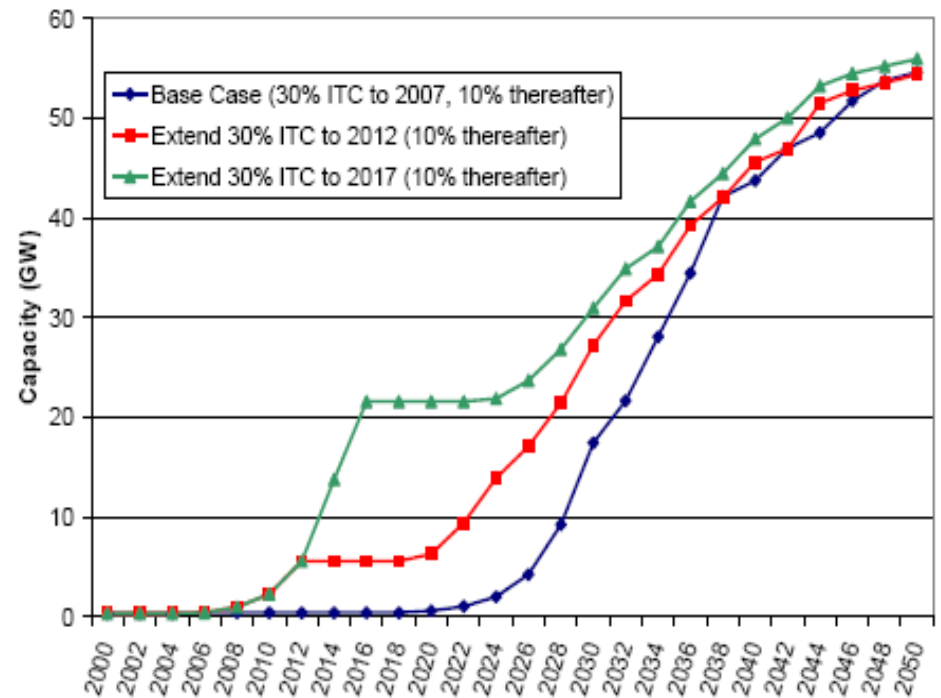


Figure 1-5. Investment Tax Credit Impact on CSP Capacity

CSP Reference Plant

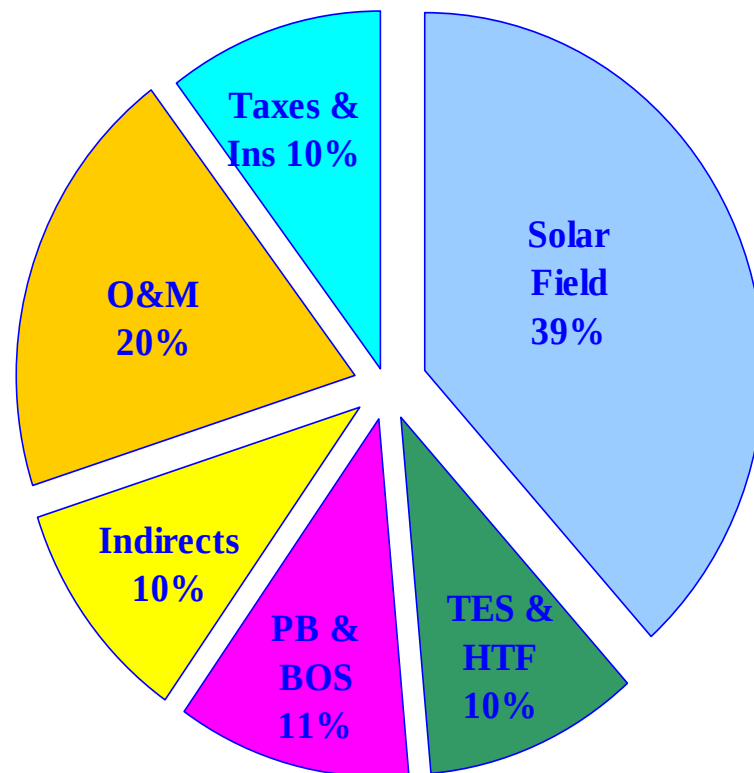
Parabolic Trough Technology Proxy for CSP

- Current solar technology
- Rankine cycle plants
- 6-hours of thermal energy storage

Finance Assumptions

- Based on IPP financing

Breakdown of LEC for 100 MWe Reference System



Benefits of CSP

Energy Benefits
Hedge against Natural Gas
price increases
Hedge against hydropower
fluctuations
Mitigate transmission
problems

Economic Benefits
Create new jobs
Increase capital
investment in the state
Increase state GSP

Environmental Benefits
Produce clean power
Reduce air pollution
Reduce greenhouse
gas emissions

References for Additional Information on CSP

The Department of Energy

<http://www1.eere.energy.gov/solar/csp.html>

The Western Governors' Association

<http://www.westgov.org/wga/publicat/CDEACReport07.pdf>

Sandia National Laboratories

<http://www.energylan.sandia.gov/sunlab/>

The National Renewable Energy Laboratory

<http://www.nrel.gov/>

SolarPACES International CSP activities

<http://www.solarpaces.org/>