Solar Power Tower Technologies for Algeria

Scott Jones

Sandia National Laboratories

Oct 23, 2003

Sandia National Laboratories

CONCENTRATING•SOLAR• POWER
Sun•Lab
Sandia National Laboratories, Albuquerque, NM
National Renewable Energy Laboratory, Golden CO
Operated for the United States Department of Energy

NREL

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000

Power Tower Technology

- Electricity production
  - Dispatchable through storage or hybridization
  - Molten-salt power towers
    - Thermal storage reduces levelized cost & increases value
  - Atmospheric pressure volumetric air & Rankine
  - Pressurized air & gas turbine
- Chemistry & fuel production
  - Thermochemical hydrogen
  - Industrial processes (e.g. lime for concrete)

Concentrating Solar Power - Tower

The Solar Two Demonstration

- After 10-15 years of salt development work
- Consortium of 8 utilities, EPRI, CEC, DOE, SunLab
- Solar Two Objectives
  1. Validate technical characteristics
  2. Improve accuracy of economic projections
  3. Simulate design of 100 MWe plant
  4. Collect, evaluate and distribute knowledge gained
  5. Stimulate consortium capable of building commercial plants

All Objectives Were Met

- Retrofit of Solar One reduced costs
  - Receiver, storage, SGS replaced
  - Solar field slightly refurbished/modified to simulate 100 MWe plant
  - Like a SEGS I plant, but built partially with surplus parts

Impact of Thermal Storage on Cost

- Excellent solar sites provide an ~25% capacity factor resource
- CSP plant Capacity Factor (CF) set by design, cannot be changed
- Solar Multiple (SM) = Solar Output/EPGS input at design point

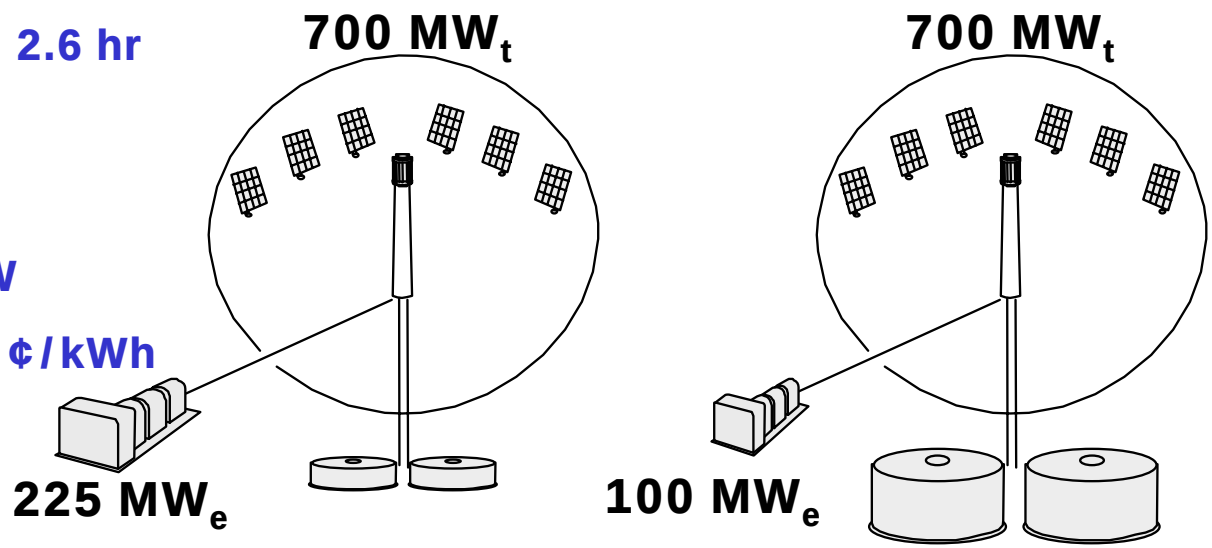
Storage = 2.6 hr

SM = 1.2

32% CF

$1600/kW

LEC = 5.7 ¢/kWh



Storage = 13 hr

SM = 2.7

73% CF

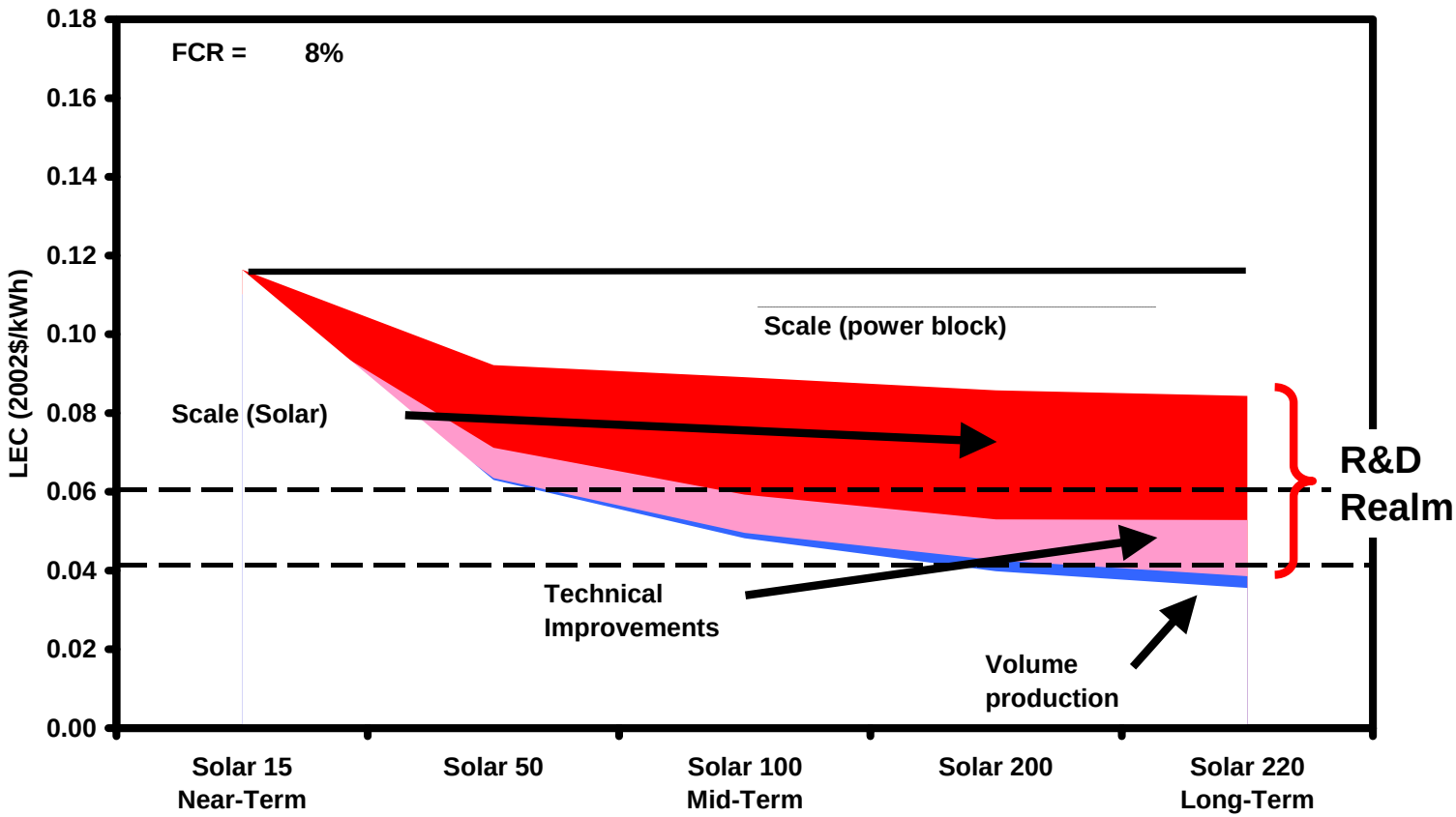
$3500/kW

LEC = 5 ¢/kWh

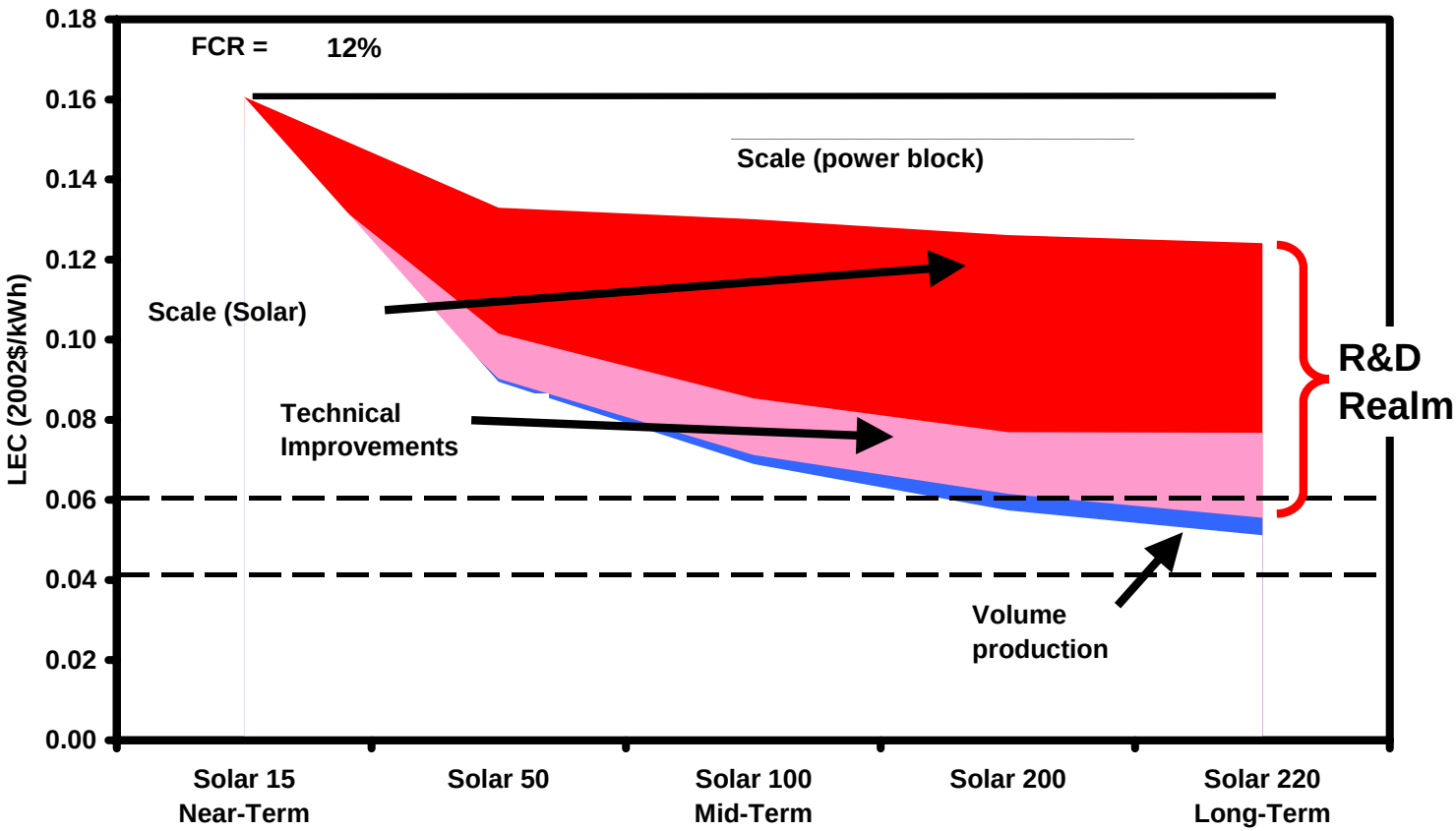
Hybrid Options

- Commercial-ready tower technology best suited to operating temperature of Rankine (steam) cycles
  - Gas hybridization of Rankine no problem
  - Not many gas Rankine built today (CC instead)
  - Higher temperatures than needed for ISCCS
  - Solar share in ISCCS limited to 5-15%
- Prototype-scale (~250 kW) demonstration of solar-hybrid gas turbine system achieved this summer. More work needed to be commercial ready.

Salt Tower LEC Projections



Salt Tower LEC Projections



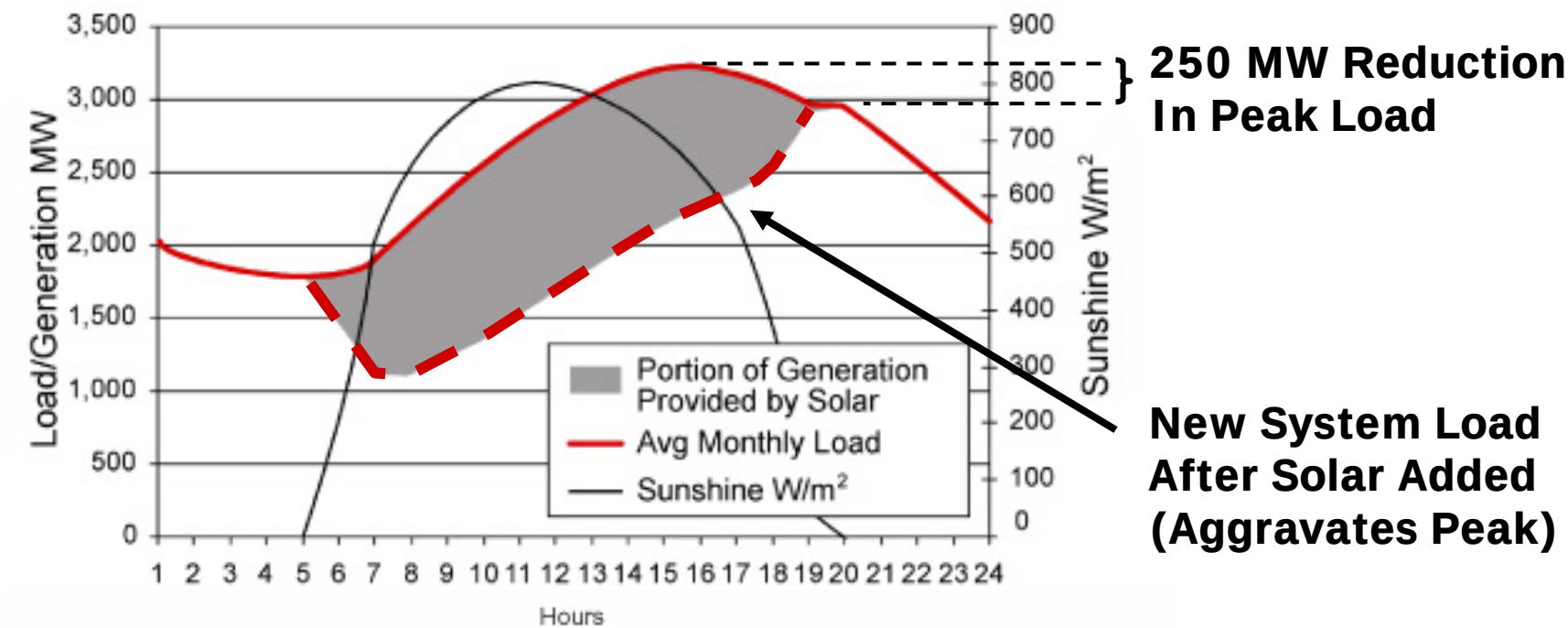
Conclusions

- Molten-salt towers are a near-term option w/ storage
  - Storage reduces cost & increases value w/ dispatchability
  - Demo plant successful, now need a commercial plant
  - Scale-up provides very fast cost reduction
  - 100 MWe plant has potential to be cost-competitive
  - How to handle financial, technology risk?
- High-temperature future options for power & fuels
- Financial terms critical, so risk reduction important

Appendix

Solar Plants w/o Storage

1250 MW Solar Plant
No Thermal Storage

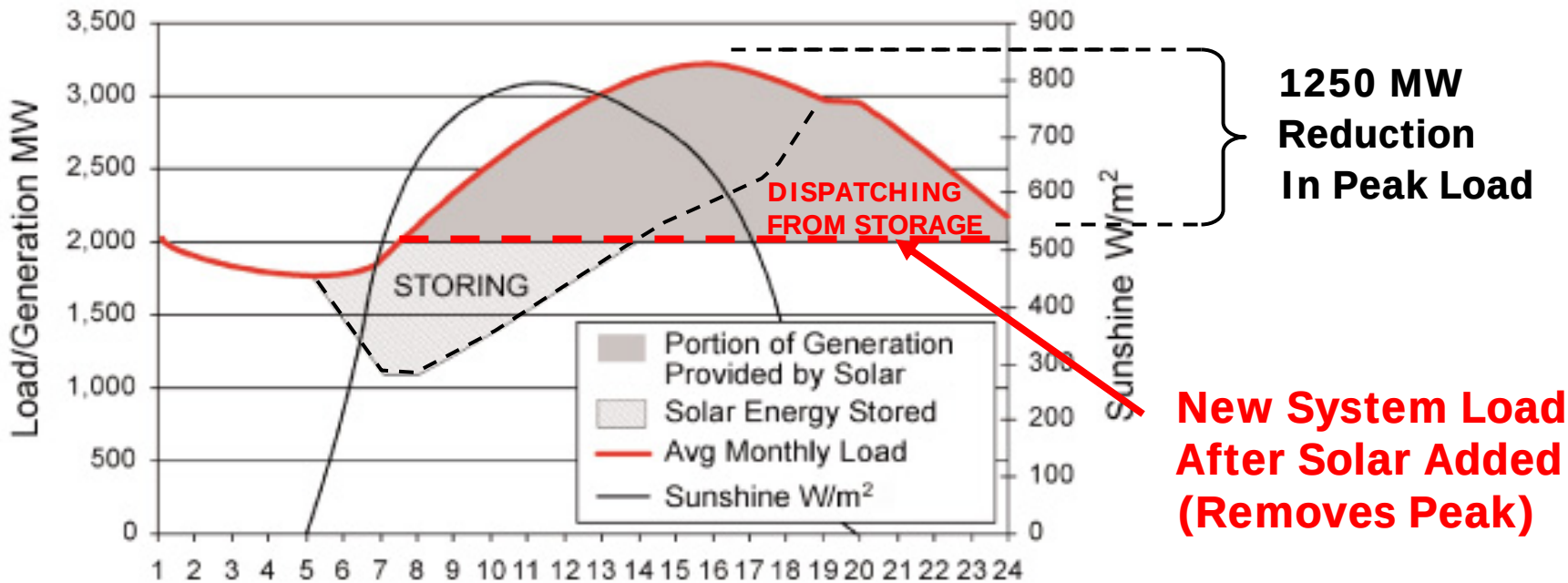


Nevada Power

Source: Platts Research and Consulting

Solar Plants w/ Storage

Exhibit 27: Generation of 1,250 MW of Solar with 3.5 Hours of Storage During Nevada Power's Summer Peak Month (August)



Source: RDI Consulting

Source: Platts Research and Consulting

Avenues for Improvement

$$LEC = \frac{CC(\$) \times FCR + O\&M_{fixed}(\$)}{AnnualEnergy(kWh)} + \cancelto{0}{O\&M_{variable/fuel}(\$/kWh)}$$

- **Consider all aspects of LEC**
  - **Capital cost**
  - **Financial**
  - **O&M**
  - **Performance**

Categorization of Tower Avenues

- Power cycle scale ($MW_{electric}$)
- Solar system scale ($MW_{thermal}$)
  - Heliostat size (95 m^2, 148 m^2), number of heliostats
  - Tower height, receiver rating
- Technology advancements
  - Receiver flux limits, absorptivity
  - Heliostat optimization, reflectivity, cleanliness,
  - Operational cost and efficiency
  - Advanced heliostat and supercritical Rankine cycle
- Volume production effects