Concentrated Solar Power
Modular Power Tower

November 7, 2012
Today’s agenda

• GE & eSolar
• Our scalable approach
• Direct steam experience
• Hybrid power plants
• Thermal storage development
• Summary
GE alliance with eSolar
Integrated solar combined cycle and concentrated solar plants

- Leading-edge GT technology
- 100+ year ST experience
- Strategic equity investment

- Proven solar technology
- Unique modular, scalable design
- Rapid installation
- Advanced control/optimization software

Working to deliver integrated technology solutions
Modular CSP
Tower Technology
eSolar CSP Technology – Overview

1. Solar Collection System (SCS) – Two sub-fields of dual axis heliostats (~25,000/ tower)
2. Solar Receiving System (SRS) – collects energy from SCS to generate superheated steam in receiver on 65m tower
3. Steam turbine generator or combined cycle power island
4. Cooling towers or air cooled condensers
5. Control & Optimization System “SPECTRA”
50MWe reference field layout

For 2400 Annual DNI/ 1.1 solar multiple

- 2 subfields of 84 rows, 133 heliostats per row
- 22,340 heliostats per tower
- 10m perimeter around field
- 18.3 acres (7.4 hectares) per tower
- 10 towers
- 223,400 total heliostats
- 183 acres (74 hectares)
- 3.7 acres/MWe
Differentiating features

Modular tower technology

- **Scalability** ... single module size for multiple configurations
  - Capacity factor (20 - 30%)
  - Solar multiple (1.0 - 1.3)
  - Overall plant size (up to ~100MW)

- **Lower tower heights** (versus single tower plants)

- **Fault tolerance** (no single point tower failure)

- **Standardized design** ... reduces project specific engineering cost/risk
Large heliostats ... high material & construction cost requirements

- Large heliostats can be greater than 100m$^2$
- Size drives higher wind loads ... requires robust structure and foundation
- Large, powerful actuators required for aiming accuracy
- Heavy lifts in the field required to set heliostats
Smaller profile heliostats ... lower costs

eSolar uses small, flat mirrors about the size of a flat screen TV

Heliostats are small and low to the ground ... much lower wind forces result in less steel and complexity

Actuator designed for reliable, accurate operation and cost
Heliostat Technology

- Low profile installation (requiring much less steel & no ground penetration)
- Rapid field deployment (one subfield in ~2-3 weeks w/o heavy equipment)
- Breakthrough software control of mirror calibration and tracking
- Semi-automated cleaning
External direct steam steam receiver

- 11’x11’x20’, 45 tons
- Factory assembled, lifted in one piece
- Natural circulation vertical drum
- 440°C, 60bar outlet steam
Operating eSolar Technology
5MWe Sierra Plant

- Proven technology demonstrated at scale
- On-line since 2009 in Lancaster, CA.
Acme Bikaner, India Project

- Located approximately 40km north of Bikaner, Rajasthan
- Construction began early in 2010 ... Commissioning completed in April of 2011
Integrated Solar Combined Cycle
Modular tower CSP offering ... application flexibility

**ISCC**
- Initial offerings 10%-15% of plant rating ... driving for greater solar fraction
- ~8% increase in fuel efficiency with solar contribution

**Hybrid Fossil**
- Initial offerings 10%-15% of plant rating ... driving for greater solar fraction
- Solar integrated into feedwater heating
- ~8% increase in fuel efficiency

**Stand Alone**
- Direct steam without storage available today
- 100MWe maximum per power block
- Molten Salt storage available for strategic pilot

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Integrated Solar Power Plants ... hybrid approach

- Stronger financial viability ... leverages capex investment in power block
- Mitigates concerns over generation volatility of solar
- Complex technical integration ... requires deep equipment/plant expertise
- Enhances fuel efficiency of host plant when solar is available

Projects drive volume on standard components ... cost maturity
Thermal Storage
Modular Molten Salt Technology

Thermal module
- 92,568 heliostats in a hexagonal field
- 100m monopole tower
- 50 MW, shippable molten salt receiver generating 565°C steam

Reference 100-MW plant
- 10 to 14 thermal modules (depending on desired Capacity Factor)
- Two 39m by 17m tanks to store up to 13 hours of hot and cold salt
- 275 MWt steam generator powered by hot salt to drive a conventional 100MW steam turbine, when power is needed

10 vs. 14 towers
50 vs. 75% capacity factor

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Localization Opportunity
CSP localization considerations

- **Material/components**
  - Heliostat Frame
  - Cables/general electronics
  - Receiver towers
  - Mirrors- would require significant volume and possibly a vendor JV

- **Construction and assembly labor**
  - EPC scope/installation/civil work
  - On-site reflector assembly (mirrors adhered to frames in controlled environment)

- **Localization- needs to be cost competitive or factored into evaluation**

- **Volume of projects is essential**
  - Sustainable pipeline needed to support localized vendors
Summary

- Ready to serve growing demand for solar generation
- GE & eSolar bring a unique, scalable, modular solution to the CSP industry
- Hybrid solar plants ... a catalyst for the CSP deployment
- Components support strong localization potential
Thank You!

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