Beyond eSolar’s Direct Steam Technology

- 12 field/receiver/tower modules for 30% capacity factor
- B&W shippable external receiver
- No storage
Our Molten Salt Development Program

In partnership with B&W, supported by DOE “Baseload FOA”

– 100-MW plant; 75% capacity factor; Daggett weather
– No water restriction; 15% fossil contribution allowed
– 8 to 9 ¢/kWh by 2020 (in 2009$ with SAM assumptions)

• **Phase I:** System feasibility study & conceptual design
  – Performance estimates, system optimization and trade studies

• **Phase II:** Engineering design
  – Apr 2011 – Jun 2012
  – Preliminary design of major systems

• **Phase III:** Demonstration
  – Timing and duration TBD, depending on concept
  – Detailed engineering, site selection, procurement
  – Construction, startup, and commissioning, test and evaluation

• **Continuing** technology and project development
  – Not part of DOE program
**eSolar’s Modular Molten Salt Plant**

**DOE 100-MW Baseload Configuration**

- Fourteen 50-MW thermal modules on 530 hectares total land area
- Central power block
  - 13 hours thermal storage
  - $275 \text{ MW}_t$ steam generator
  - 115 MW gross turbine generator
- Capacity factor: 75% (dry cooled (design basis)), 78% (wet-cooled)
- No hybridization
50-\(\text{MW}_t\) Module Configuration

- Hexagonal heliostat field with 105,000 m\(^2\) mirror area
- 50-\(\text{MW}_t\) B&W receiver on 100-m monopole tower

Heliostat evolution from:

SCS3 heliostats

To:

Next-generation SCS5 heliostats
Solar Collector System

• 14 hexagonal field modules
  – 92,000 1.1 m² SCS3 heliostats per module
  – 1.3 million heliostats total
  – Small north field bias
• SCS/SRS solar multiple: ~1.2
B&W 50-MW\textsubscript{t} Molten Salt Receiver

- External, salt-in-tube configuration
  - Vertical tube panels, serpentine flow
  - Fully drainable (30s), fast startup capability

- Factory assembled, truck shippable for rapid field installation

- Leverages Solar Two and Sierra lessons learned

Geometrically similar Babcock & Wilcox 10-MW\textsubscript{t} direct steam receiver in operation at eSolar’s Sierra plant
Solar Receiver System

- 100-m tower
  - Wind turbine-type monopole, 5 sections

- Cold pumps
  - Three 50%, long-shafted, vertical turbine, suspended in tanks

- SRS/SGS solar multiple: ~2.5
DOE Baseload Configuration
Field Piping Details

• 10,500 m cold piping (carbon steel)
• 11,200 m hot piping (stainless steel)
• Heat traced, insulated, and drainable
DOE Baseload Configuration
Power Block Systems

• Thermal storage system
• Steam generation system
• 100-MW steam turbine w/ reheat
DOE Baseload Configuration
Thermal Storage System (TSS)

• Rated capacity
  – 3500 MWh\(_t\) (13.1 hours)
  – 36,500 metric tons of salt

• Hot and cold tanks
  – 39-m diameter
  – 17.5-m height
275-MW$_t$ Steam Generation System

- Preheater, Evaporator, Superheater, & Reheater vessels
- Natural-circulation Evaporator design
- Detailed transient and dynamic analyses
- Leverages Solar Two lessons learned
Power Generation and Plant Controls

- **Power generation system (PGS)**
  - 100-MW Rankine-cycle reheat turbine generator
  - Gross thermal-to-electric efficiency: 42%
  - Air-cooled condenser

- **Plant Control System (PCS)**
  - Designed for automated operation
    - No manual control required for daily functions
  - Total IO count: ~8100
Alternative Configurations

- **Single module** (possible ISCC integration or demo)
- **4-modules**
  - 50-MW, 40% capacity factor
  - 100-MW, 20% CF peaker
- **10-modules**
  - 100-MW, 50% CF

- **All configurations utilize**
  - Identical modules (heliostat field, receiver, tower)
  - Similar, scaled SGS and TSS components
Commercial System Configuration

- Plant rating: 100 MW
- Number of fields/towers: 10 towers
- Hours of storage: 6 hours
- Solar multiple: 1.8
- Capacity factor: 50%
- Dry cooling, no hybridization
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On-Going Work (Beyond DOE Contract)

- Risk assessment and mitigation
- Receiver design refinement
- Materials testing
- Heliostat development
- Project development
Risk Assessment and Mitigation

- Based on likelihood and consequences of various failure modes, top receiver risks and other risks identified and ranked

- Range of mitigation options considered
  - Additional design and analysis beyond DOE Phase 2
  - Component testing
  - Receiver panel test
  - Full-scale module test
  - Multi-module plant
  - Full-scale commercial plant

![Risk Assessment and Mitigation Table]
Receiver Design Refinement

• Dynamic modeling
• Transient stress analysis
• Tube-to-header design optimization
• Tube bend testing
• Tube panel optimization for weld access
• Electric heat trace system refinement
• Weld development
Materials Testing

- Receiver material fatigue testing (ORNL & SNL)
  - Tube and bar stock materials
  - Isothermal and thermomechanical fatigue
  - w/ and w/o hold times and salt contact

- Corrosion testing
  - Electrochemical
  - Stress corrosion cracking
  - Salt immersion tests (SNL)

- Receiver tube paint testing
  - Adhesion
  - Aging (3000 hr)
  - Thermal Cycling
eSolar’s New 2-m² SCS5 Heliostat
eSolar’s New SCS5 Heliostat

- SCS5 design optimized around molten salt module
  - Higher performance and reliability
  - Simplified electrical and networking systems
  - Parts count reduction and environmental sealing
  - Significantly reduced all-in cost
  - Utilizes eSolar’s proven Spectra control system

- Heliostat field layout similar to SCS3 layout
Next Steps

• Investigating
  – Project opportunities
  – First-of-a-kind build strategies

• Full-scale module
• Multi-module plant
• Full-scale commercial plant

• Prefer staged approach of an “Expandable Peaker”
  – Best of multi-module and full-scale plant options combined in a first plant
Our Vision:
Changing the world by making solar power competitive with fossil fuels