



# 2008 Solar Annual Review Meeting

## Solar Advisor Model

Session: Modeling and Analysis

National Renewable Energy Laboratory



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**NREL** National Renewable Energy Laboratory

*Innovation for Our Energy Future*

# Budget and Solar America Initiative Alignment



| <b><i>National Renewable Energy Laboratory</i></b> |                    |                    |                     |
|--|--------------------|--------------------|---------------------|
| <b>Project Beginning Date</b>                      | <b>FY07 Budget</b> | <b>FY08 Budget</b> | <b>Total Budget</b> |
| FY03   | \$732k             | \$850k             | \$1582k             |

- This project supports the Solar America Initiative by:
  - Provide a consistent framework for analyzing and comparing power system costs and performance across the range of solar technologies and markets
    - PV, solar heating systems, CSP
    - Residential, commercial and utility markets
  - Developing and validating performance models to enable accurate calculation of Levelized Cost of Energy (LCOE)
  - Providing a consistent modeling platform for all TPP's
  - Supporting implementation and usage of cost models



# Project Overview: SAM (Solar Advisor Model) Concept

- Original Vision (For DOE Multi-Year Planning by Lab analysts)
  - Combine all solar technologies in one modeling environment
    - concentrating solar power (CSP)
    - photovoltaics (PV)
    - solar heating (solar hot water, industrial process heat, etc.)
    - solar hybrid lighting
  - Model performance, costs and financing consistently across technologies for appropriate comparisons.
  - Calculate impact of R&D technology improvements on LCOE, NPV, etc. in various markets.
  - Extensive sensitivity analysis and output/ plotting capabilities
  - Do not reinvent the wheel (existing models when possible)
- Current Vision
  - Robust simulation tool that industry, the labs and DOE will use
  - Implementation of best performance models (Sandia PV module, NREL parabolic trough model, Sandia Inverter, 5-Parameter PV module via UW-Madison and CEC)
  - Policy, Markets and Technology Analysis
  - Siting Tool (especially with detailed Google-Maps solar satellite data)
  - Easy to Use interface with detailed analysis capabilities
  - Solar Hybrid lighting and Solar Heating are currently on hold

# Current User Demographics



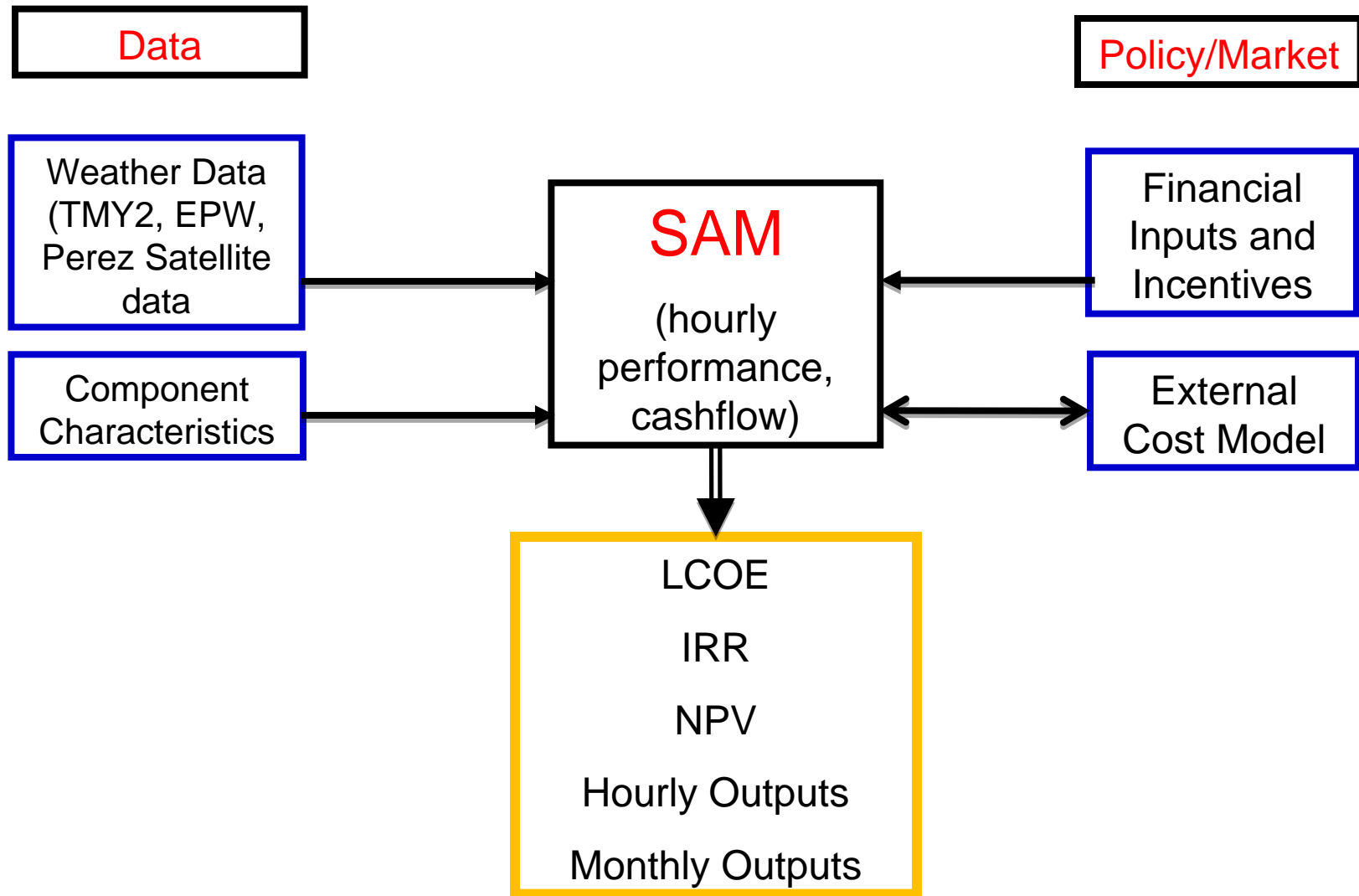
We currently have 1492 separate emails that have downloaded one or more versions of the software. Of those:

- Recognizable participants include Worley Parsons, Konarka, EPRI, GE, Dow, Solo Power, Evergreen Solar, GT Solar, Chevron, Nanosolar, Boeing, Sun Edison, UPC Solar, Alcoa, RWBeck, CH2MHill, Solfocus, APS, SunPower Corp., SkyFuel, Raytheon, HeliVolt, Solaria, Miasole, Siemens, SolucarPower, Strategen, Invenergy, McKinsey, Johnson Controls, Honeywell, FPL, Duke Energy, Constellation, Acciona, United, Sempra, Navigant Consulting, Black and Veatch

Other anecdotal examples of SAM use:

- Clean Energy Advocates
  - Encouraging NJ Clean Energy Program to adopt as standard.
- Alcoa
  - using SAM to investigate costs and finance options for CSP.
- Arizona Public Service
  - evaluate CSP and PV – want to use own weather data
- Federal Energy Management Program (FEMP)
  - Using SAM for feasibility of PV and CSP projects on federal lands
- PowerLight
  - using SAM's IPP financial analysis, apparently as a check on their internal calculations
- DOW
  - using the SAM model to validate various commercial installation options for roof mount, BIPV, and field mount PV systems around the world.

# SAM Block Diagram



# Download and use recent solar satellite data



The screenshot displays a GIS web application interface. On the left is a 'Layers' panel with a tree view of GIS Layers. The main area is a 'Map' showing a solar resource map with a color scale from red (high) to yellow (low). A 'Download Window' is open on the right, allowing users to select formats and years. At the bottom of the map, there is a 'Display Month' slider set to 'APR'.

**Layers Panel:**

- GIS Layers
  - Solar Resources
    - Average DNI (1998 - 2005)
  - Resource Classes
  - Slope Filters
  - Infrastructure
    - Transportation
      - Interstates
      - US Highways
      - Rails
  - Hydrology
  - Land Ownership
  - Boundaries
  - Base Data
    - Shaded Relief
    - Satellite Imagery
  - Download
    - Download Grid

**Map Panel:**

Zoom Box Pan Query **Download** Clear

Map

Display Month: APR

**Download Window:**

1. Select Formats:

- TMY Format
- CSV Format

2. Select Years

| Available | Selected |
|-----------|----------|
| 1998      | 2001     |
| 1999      | 2005     |
| 2000      | TDY      |
| 2002      |          |
| 2003      |          |
| 2004      |          |

Submit Close



# Finance Model

- Detailed Cashflow model
- Output
  - LCOE, NPV, IRR, Revenue, Taxes, etc.
- Residential
  - Cash, Loan or Mortgage
- Commercial
  - Cash, Loan or 3<sup>rd</sup> Party Owner
- Utility Scale
  - IPP (at right) or IOU

Type of Financing

**General**

Analysis Period  years

Inflation Rate  %

Real Discount Rate  %

**Taxes and Insurance**

Federal Tax  %/year

State Tax  %/year

Property Tax  %/year

Sales Tax  %

Insurance  %

**Power Purchase Agreement (PPA)**

PPA Escalation Rate  %

Optimize PPA escalation rate to minimize LCOE.

**Constraining Assumptions**

Specify minimum equity Internal Rate of Return (IRR) and minimum Debt Service Coverage Ratio (DSCR) and Positive Cashflow requirement

Minimum Required IRR  %

Minimum Required DSCR

Positive Cashflow

**Loan**

Amount

Term  years

Rate  %/year

Loan (Debt) Fraction  %

Optimize debt fraction to minimize LCOE.

**Federal Depreciation**

No Depreciation

MACRS Mid-Quarter Convention

MACRS Half-Year Convention

Straight Line  years

**State Depreciation**

No Depreciation

MACRS Mid-Quarter Convention

MACRS Half-Year Convention

Straight Line  years



# Financial Incentives

- Detailed Incentives available
- Separate possible entries
  - Federal
  - State
  - Utility
  - Other
- Variable Tax Implications
- Incentives
  - Tax Credits
    - Investment
    - Production
  - Investment Based Incentives (Buy-Downs)
  - Capacity Based Incentive
  - Production Based Incentive

Show Tax Details

|   |         | Taxable Incentive                   |                                   | Incentive Reduces ITC Basis         |                                     | Incentive Reduces Depreciation Basis |                          |
|---|---------|-------------------------------------|-----------------------------------|-------------------------------------|-------------------------------------|--------------------------------------|--------------------------|
|   |         | Federal                             | State                             | Federal                             | State                               | Federal                              | State                    |
| <b>- Investment Tax Credit (ITC)</b>      |         |                                     |                                   |                                     |                                     |                                      |                          |
|   |         | Amount (\$)                         |                                   |                                     |                                     |                                      |                          |
| <input type="checkbox"/>                  | Federal | <input type="text" value="0"/>      |                                   | n/a                                 | no                                  | n/a                                  | n/a                      |
| <input type="checkbox"/>                  | State   | <input type="text" value="0"/>      |                                   | no                                  | n/a                                 | n/a                                  | n/a                      |
|   |         | %                      Maximum (\$) |                                   |                                     |                                     |                                      |                          |
| <input checked="" type="checkbox"/>       | Federal | <input type="text" value="10"/>     | <input type="text" value="1E99"/> | n/a                                 | no                                  | n/a                                  | n/a                      |
| <input type="checkbox"/>                  | State   | <input type="text" value="0"/>      | <input type="text" value="1E99"/> | no                                  | n/a                                 | n/a                                  | n/a                      |
| <b>+ Production Tax Credit (PTC)</b>      |         |                                     |                                   |                                     |                                     |                                      |                          |
| <b>- Investment Based Incentive (IBI)</b> |         |                                     |                                   |                                     |                                     |                                      |                          |
|   |         | Amount (\$)                         |                                   |                                     |                                     |                                      |                          |
| <input type="checkbox"/>                  | Federal | <input type="text" value="0"/>      |                                   | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
| <input type="checkbox"/>                  | State   | <input type="text" value="0"/>      |                                   | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
| <input type="checkbox"/>                  | Utility | <input type="text" value="0"/>      |                                   | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
| <input type="checkbox"/>                  | Other   | <input type="text" value="0"/>      |                                   | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
|   |         | %                      Maximum (\$) |                                   |                                     |                                     |                                      |                          |
| <input type="checkbox"/>                  | Federal | <input type="text" value="0"/>      | <input type="text" value="1E99"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
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| <input type="checkbox"/>                  | Other   | <input type="text" value="0"/>      | <input type="text" value="1E99"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/>             | <input type="checkbox"/> |
| <b>+ Capacity Based Incentive (CBI)</b>   |         |                                     |                                   |                                     |                                     |                                      |                          |
| <b>+ Production Based Incentive (PBI)</b> |         |                                     |                                   |                                     |                                     |                                      |                          |



# SAM Solar Performance Models



- PV Modules
  - Single-point efficiency with single temperature coefficient
  - Sandia PV Array Performance Model
  - CEC/Wisc 5-parameter model
- Inverters
  - Single-point efficiency inverter model
  - Sandia Inverter Performance Model
- CSP
  - Parabolic Trough (based on NREL's Excelergy model)
- Generic
  - Very simple capacity \* capacity factor model for comparison with non-solar technologies
  - Able to run with externally calculated performance to take advantage of financing, incentives and parametric capabilities

# SAM Strength – Parametric Analyses



**Define Parametric for 100 MW Baseline - Parameterized Storage**

**Independent Parameters**

- Add Variable
- Delete Variable
- Edit Values

**Combination Parameters**

- Add Variable
- Delete Variable
- Edit Combo
- Delete Combo

**Combination Parameters 1**

- Equiv. Full Load Hours c
- Solar Multiple

**Combination Parameters 2**

**Linkages**

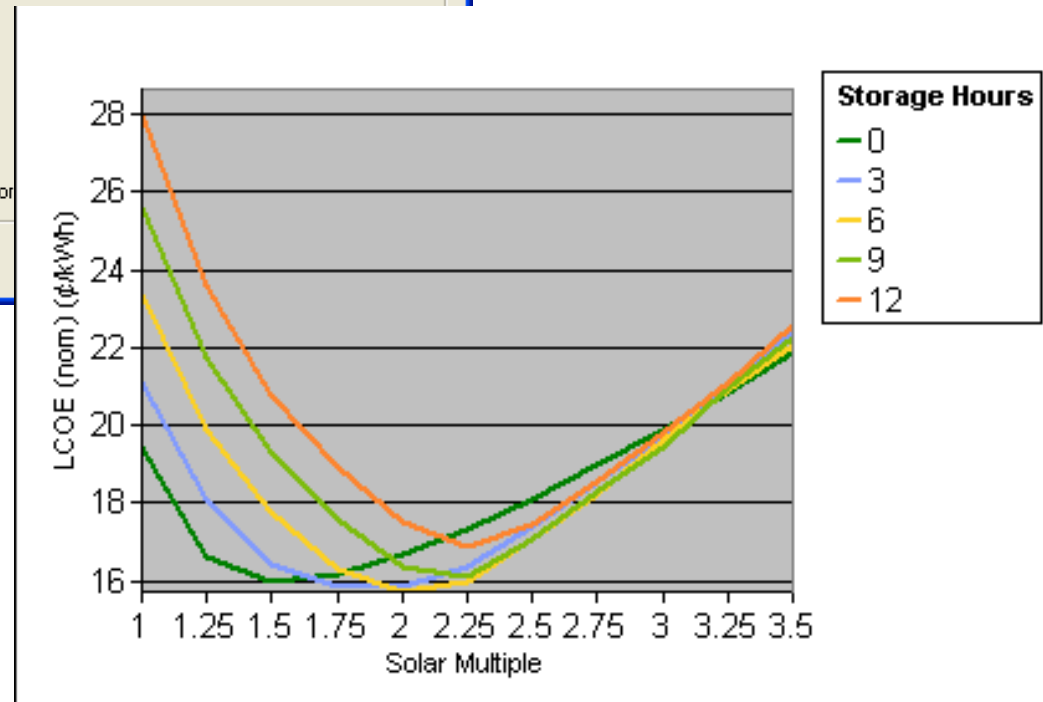
- Add Variable
- Delete Variable
- Edit Linkage
- Delete Linkage

**Linkage 1**

- Equiv. Full Load Hours c
- Tank Heat Losses

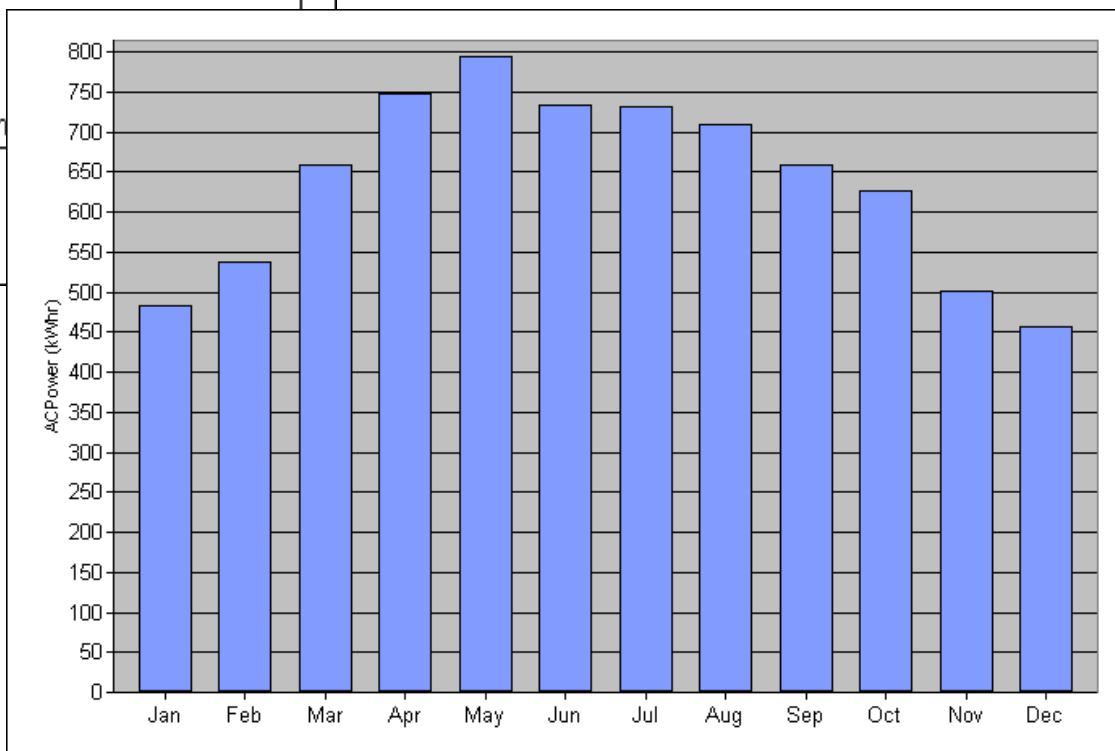
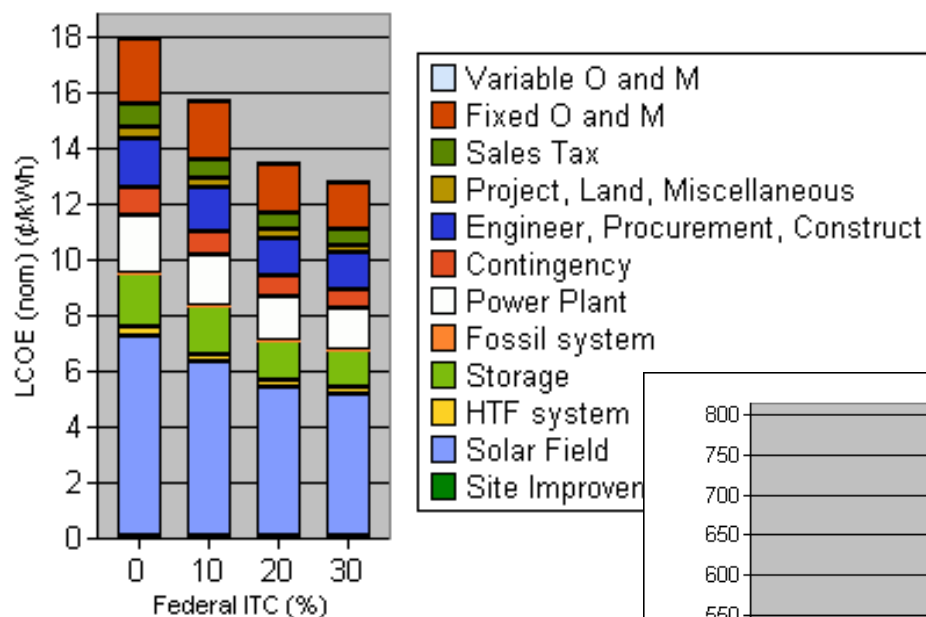
**Linkage 2**

NOTE: Linkages apply to all Independent Parameters and Combination Parameters for





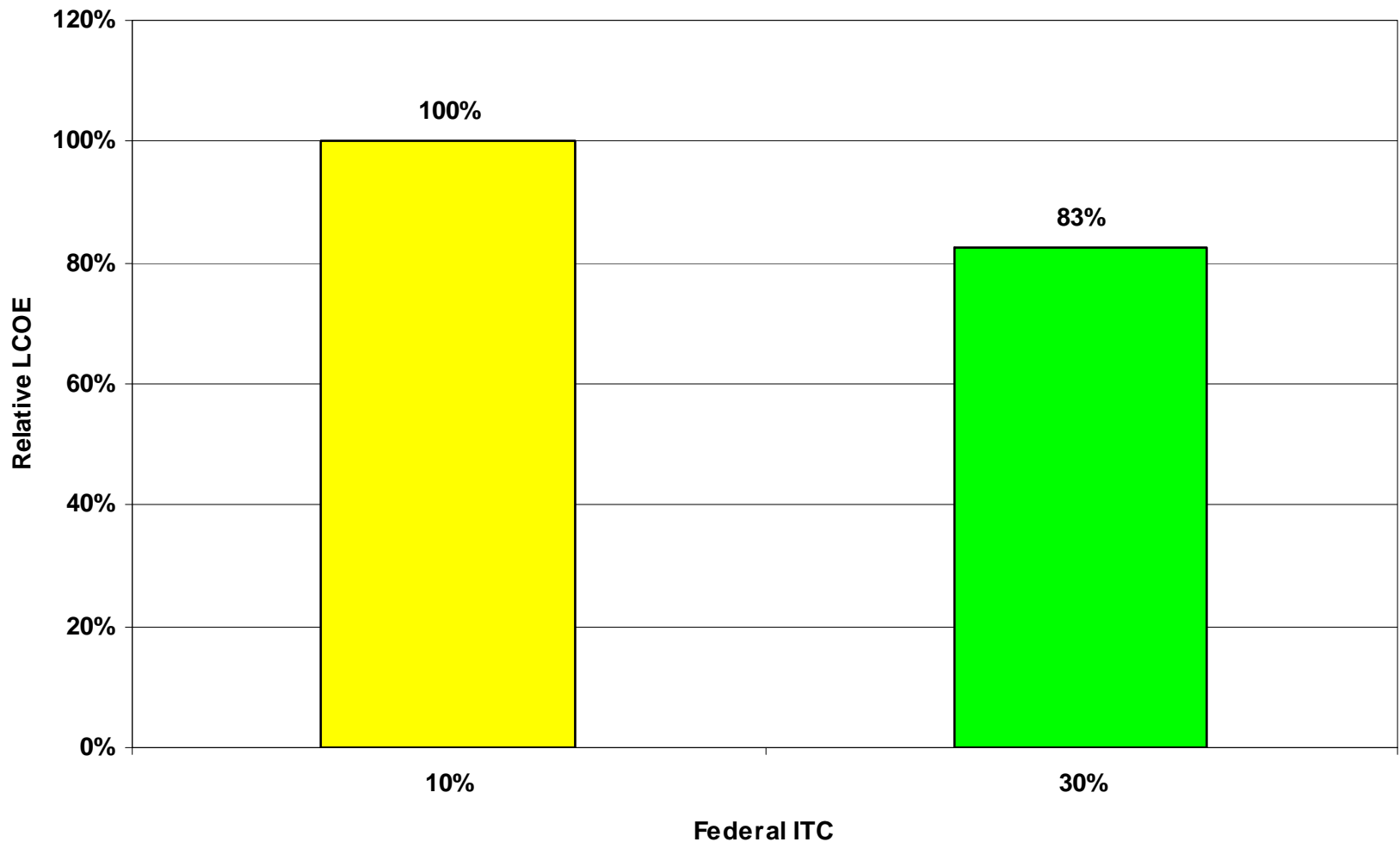
## CSP System LCOE vs. Fed. ITC (%)



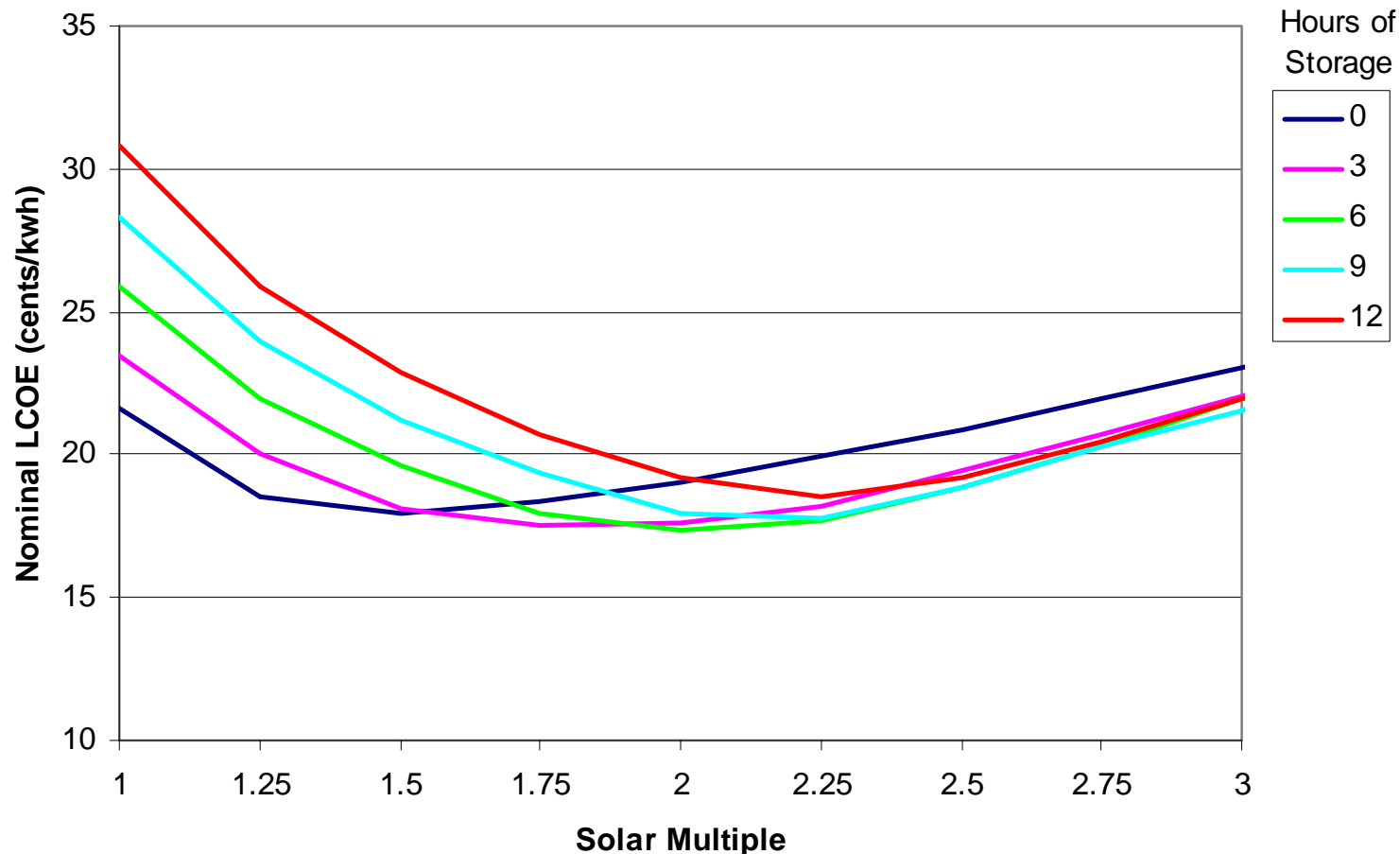
## Monthly PV System Output

# Policy Impacts

## Federal Investment Tax Credit



# CSP Plant & Storage Optimized to Minimize LCOE



- Solar Multiple is non-dimensional solar field term (1 = solar-only design point)
- 6-hours TES and solar multiple of 2.0 results in minimum LCOE

# Project Update



Past

Future

| Planned Work Since Last Program Review  | Expected date (mm/yy)  |
|---|------------------------|
| Release SAM version with additional weather file type support   | 12/07                  |
| User forum and user interactivity   | 2/08 (delayed to 5/08) |
| Release SAM version with: <ul style="list-style-type: none"> <li>•major update of user manual with perf model documentation</li> <li>•improved PV performance algorithms</li> <li>•capability of using latest CEC and Sandia module and inverter databases</li> <li>•detailed yearly O&amp;M inputs (annual \$, \$/MW, \$/MWh options)</li> </ul> | 4/08                   |
| First Modeling Workshop Held concurrent with ASES   | 5/08                   |
| Publish subcontractor report on financial model validation  | 6/08 (delayed to 7/08) |
| Release SAM version with: <ul style="list-style-type: none"> <li>•dish Stirling CSP models included</li> <li>•enhanced GUI and greater graphical output capability</li> <li>•time-of-use rates</li> </ul>   | 8/08                   |

# Obstacle Discussion



- Keeping up with addition of new components and technologies
- Estimating PV derate factors
- Credible, current cost data for general users
- Difficulty in hiring junior staff member to help with coding and support of SAM as funded.
- Due to lack of hiring, programming support still main bottleneck
- Varying customer base (including lab analysts, DOE, industry developers, investors, ...) and how to tailor the program to each