Cost and Performance Solar Advisor Model for All Solar Technologies

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INTRODUCTION

The US Department of Energy's Solar Energy Technologies Program (SETP) has adopted a systems driven approach (SDA) to program planning across all the solar technologies. According to the DOE Solar Program website [1], "A systems-driven approach, if applied correctly, offers clear advantages once market requirements are defined and understood. By clearly establishing the connection between market requirements and R&D efforts (and how specific R&D improvements contribute to the overall system cost and performance), the SDA approach will allow managers to allocate resources more efficiently." The data and metrics coming from SDA analysis will provide a more credible story regarding the impact of R&D on levelized energy costs for solar energy. Additionally, the SDA approach will promote the use of a consistent methodology in analysis regarding the impact of R&D activities and non-R&D activities on the costs and performance of solar technologies.

One aspect of the systems driven approach is the creation of analysis tools that promote this consistent methodology analysis across all solar technologies. The subject of this document is one tool known as the "Solar Advisor" model. In order to capture the goals of the SDA as described above, this tool is able to integrate the financing, costing and performance of systems. Additionally, it must be possible to apply consistent financing and cost assumptions across all solar technologies. Therefore, Solar Advisor is able to smoothly handle several types of financing – from residential to utility-scale - and a variety of technology-specific cost models for several - eventually all - SETP technologies. The SETP technologies currently represented in Solar Advisor include concentrating solar power (CSP) and photovoltaic (PV) technologies. Eventually, other technologies will be added including solar heating (primarily solar residential hot water) and solar hybrid lighting.

GRAPHICAL USER INTERFACE

The graphical user interface (GUI) has been designed with several goals. One primary goal is the ability to efficiently do complex sensitivity analysis. One aspect of the GUI that enables sensitivity analysis is the ability to have multiple "cases" within a project (Fig. 1). This is very similar in concept to Microsoft Excel allowing the user to have multiple worksheets within a workbook. Each case contains a specific technology system and inputs for the related performance, cost and financing parameters. A case may be created by duplicating (or copying) an existing case or, in future versions, from a series of pre-existing templates. For example, a user may want to construct a case and then duplicate it several times to look at the impact of changing a system configuration parameter or even changing to a different solar technology.

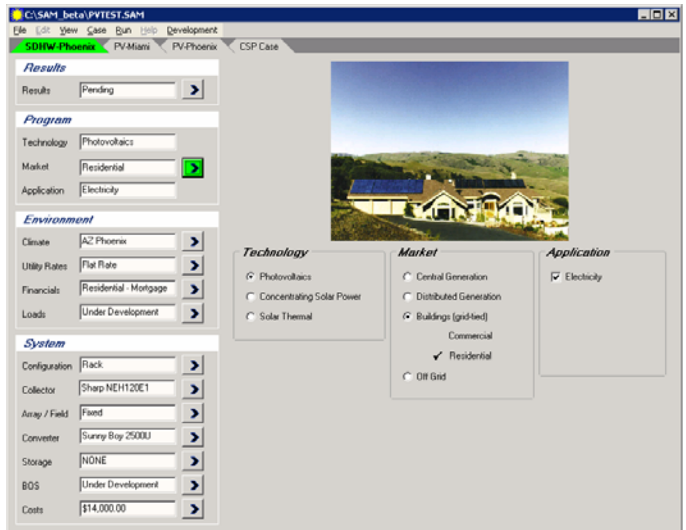

Figure 1: Solar Advisor GUI demonstrating multiple cases and program selection

In addition to multiple cases, another feature is the ability to construct complex parametric analysis within each case. Each variable available to the user within the GUI – financial, cost or performance – can be parameterized. These parametric values can be created using an equation or typed in individually or "linked" from another parameterized variable. A "linked parametric" is typically used when a relationship between variable values should be maintained for all parametric cases. For example, if the size of the PV array is parameterized, the user would want to make sure that an appropriately sized inverter is used in each parametric run. Therefore, the inverter size should be "linked" to the PV array size. Of course, it is possible to parameterize two or more variables independently of each other and do all combinations of these parametric values. Figure 3 illustrates the results screen from Solar Advisor to demonstrate a sample result of the impact on annual energy output due to varying both array tilt and array azimuth orientation.

Another method for doing sensitivity analysis is by using the "slider" bars on the results screen (Fig. 3). Because the data in the graphs is dynamic and tied to the current inputs, the user can obtain near-instant graphical feedback on the impact of varying the slider values. Typically, the user would vary financial items such as the inflation rate to observe the sensitivity of the results.

Figure 3: Results page and tilt vs. azimuth parametric results

Another goal of the GUI design is user-friendliness. In order to be useful to DOE, policy analysts, researchers with expertise in different solar technologies and solar industry analysts, the program should be both detailed but easy to obtain high-level results as well. To accomplish this, extensive pre-development testing of GUI concepts with potential users was conducted. The current GUI format –navigation buttons down the left, opening input or results windows to the right – was an outcome of this testing. Although not all technologies have currently been implemented, the structure of the GUI will be able to accommodate all technologies using the current configuration. More importantly, every variable and setting comes with an appropriate default value. This is powerful in that the user can use default values if they are not an expert on a particular technology. For example, if a PV analyst is interested in making comparisons to an CSP system, they can create a case using CSP technology and the associated default values.

FINANCIAL MODEL

The financial model within Solar Advisor uses values from the performance model and the cost model along with specific financial inputs to determine the appropriate financial output metrics. The calculated financial metrics include annual cashflow throughout the project life, the levelized cost of energy for the system (LCOE), tax payments, the net present value of the system, and the internal rate of return. The results calculated depend on the financing scenario used. The financial engine allows for a variety of standard financing scenarios eventually allowing for residential, commercial and utility-scale IPP and IOU project financing.

The most recent feature added to SAM is the ability to do complex financial incentive analysis for federal, state or even utility-sponsored incentives. The incentives available in the model include investment tax credits, production tax credits, investment based incentives, capacity based incentives and production based incentives.

COST MODEL

The simple cost model currently implemented allows for only a simple cost breakdown including collector first cost, converter first cost, storage, installation, marketing, balance of system and annual O&M costs (see Figure 4). Only the O&M cost is a recurring cost through the project lifetime. Both the collector cost and the converter cost can be input either as a constant or a function of the size of the collector or converter. This simple structure allows for a variety of cost and financial analysis. However, most solar analysts at national labs or at the DOE use complex spreadsheets as cost models. The GUI allows for linking with Excel to pass values back and forth between the GUI and spreadsheet. In the future, an "open architecture" approach will be adopted allowing even greater communication with external models in spreadsheets and other programs. The goal is to reduce the amount of recoding necessary and to allow the analysts to continue updating and improving their external models independently of the GUI. However, this does not mean that each user is forced to create their own cost model because standard cost models with appropriate default values will be included with Solar Advisor. The user will have the ability to modify the cost model or replace it with one of their own. Standard cost models will be available for PV, CSP and SDHW initially and more options and detail will be added by individual users.

PERFORMANCE MODEL

The performance model within Solar Advisor performs an hourly transient simulation as defined in the GUI. Because of the extensive existing content and existing validation of individual components, the TRNSYS program [2] was chosen as the performance engine for Solar Advisor. For example, methods for modeling PV, CSP and SDHW systems as well as the peripheral activities (such as reading weather data and outputting results) exist. The performance model works completely in the background and the user doesn't need to know anything about TRNSYS. The systems are pre-constructed and integrated into the Solar Advisor GUI. The number of times the performance model is run depends on the type and number of parametrics. For example, if ten different array sizes are chosen, then ten different runs of the performance model would need to be completed.

Currently, there are two methods for modeling photovoltaic modules. Existing modules, which have been tested by researchers at Sandia National Laboratory [3], can be modeled with the performance map created by that testing. Additionally, a simple single-point efficiency model has also been implemented which allows for more high level "what if" scenarios for which an appropriate commercial module does not exist yet.

Additional PV systems (including battery-based systems), CSP systems and other SETP technologies are currently being constructed and integrated into the GUI.

REFERENCES

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[2] Klein et al., 2000. TRNSYS 15, A Transient Simulation Program. Solar Energy Laboratory, University of Wisconsin, Madison, Wisconsin, WI.
[3] King et al., "Photovoltaic Array Performance Model," SAND2004-3535, Sandia National Laboratory, Albuquerque NM