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SAM Technical Review Committee Final Report

Summary and Key Recommendations from the Onsite TRC Meeting Held April 22-23, 2013

N. Blair, A. Dobos, S. Janzou, P. Gilman,
J. Freeman, and L. Kaffine

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Milestone Report
NREL/TP-6A20-58785
August 2013

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Foreword

The System Advisor Model (SAM) is a broad and robust set of models and frameworks for analyzing both system performance and system financing. It does this across a range of technologies dominated by solar technologies including photovoltaics (PV) and concentrated solar power (CSP).

The U.S. Department of Energy (DOE) Solar Energy Technology Program requested the SAM development team to review the photovoltaic performance modeling with the development community and specifically, with the independent engineering community. The report summarizes the major effort for this technical review committee (TRC).

Acknowledgments

The authors would like to thank the appropriate parties for the onsite TRC meeting. Particularly, this includes the following committee members (external to DOE):

Industry

- Ben Bourne (SunPower Corporation)
- Jeff Newmiller (DNV KEMA Energy & Sustainability)
- Monali Joshi (Black & Veatch Corporation)
- Drew McMahan (Luminate)
- Walt Novash (Johnson Controls, Inc.)
- Charlie Dearie (McCalmont Engineering)
- Tim Pfannenstiel (AWS Truepower)

National Laboratories

- Josh Stein (Sandia National Laboratories).

Executive Summary

In 2012, the DOE Solar program and NREL completed a plan for the Laboratory's next three years of research, development, and deployment for system modeling. The overall goal is to improve system modeling accuracy and risk assessment via research into improved data and algorithms. The systems modeling activity aims to make robust models available to various audiences, thereby improving the industry characterization of risk and improving bankability across all markets (residential, commercial, and utility).

In April 2013, the systems modeling team at NREL hosted an onsite technical review committee (TRC) to invite discussion and guidance from the industry on how to best prioritize research and development in PV systems modeling with a focus on improving the flagship System Advisor Model (SAM) tool. The full day meeting revealed general agreement regarding several key areas for improvement to the tool. These categories of SAM enhancements are highlighted and briefly explained below, with an indication of how they might be achieved with DOE support through modified and expanded agreement deliverables and milestones.

Some aspects of the current research and development (R&D) agreement were thought by the TRC to be of limited value, and although these are listed , they are likely to be deemphasized going forward. It is worth noting that numerous key improvements suggested by the TRC were already in the three-year development plan, but a reprioritization is suggested to reflect the current needs of the community.

Six key areas of improvement were identified:

1. Integrated 3D shading modeling and visualization
2. Module model enhancements and ability to integrate measured module performance data directly from test measurements
3. Inverter model flexibility
4. Weather data input flexibility and associated tools
5. Validation reports, PV technical documentation, and loss tree improvements
6. PVWatts documentation and usage guidance

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1 Introduction

In 2012, the DOE Solar program and NREL completed a plan for the Laboratory's next three years of research, development, and deployment for system modeling. The overall goal is to improve system modeling accuracy and risk assessment via research into improved data and algorithms. The systems modeling activity aims to make robust models available to various audiences, thereby improving the industry characterization of risk and improving bankability across all markets (residential, commercial, and utility). The proposal is divided into three parts (in decreasing level of resources required to complete these enhancements):

1) **Validation of System Advisor Model (SAM)/PVWatts and related Web services** to improve acceptance by the solar industry and gather valuable insights to improve and interact with a technical review committee of users and potential users
2) **Transfer R&D results from across systems integration to the solar analysis community** via development of the successful DOE-sponsored SAM tool
3) Refactor simple system algorithms to **better inform the risk and improve the bankability of residential systems** and provide technical updates to the PVWatts system model.

Within the validation task (Task 1), a description of the use and value of a technical review committee (TRC) for SAM was noted, including the following language:

Create a TRC made up of independent engineers, other lab modelers (from Sandia in particular), the solar finance community, and utility engineers.

- This TRC will meet in person with the SAM team annually (starting in the early second quarter of year one); several shorter Web-based meetings will also be held
- The TRC will have several outcomes for the SAM team:
    - Education of the TRC members on the current and planned capabilities of SAM
    - Development of what members would consider as convincing "validation" of SAM and "bankability" of SAM results
    - Impart to the SAM team the reasons that other tools (specifically PVSyst) are considered more "trustworthy" than SAM
    - Assistance for the SAM team in feedback on the model
- The TRC will reconvene annually in person and more than once per year via Web to re-evaluate progress toward SAM improvements to meet their needs and the needs of the larger industry
- Integrate the TRC with Sandia's modeling workshop (if logistically possible) which has been pushed to FY13 and reports the outputs of the TRC to the PV Modeling Collaborative website.

Unfortunately, due to staffing issues and delays from FY12 milestones, the first TRC meeting was not held until April 2013. However, the goals described in the planning document text above should be achieved going forward.

1.1 TRC Participants

The TRC provided very useful feedback with participation from all individuals invited. In person contributions were particularly helpful in the discussion.

Industry

- Ben Bourne (SunPower Corporation)
- Jeff Newmiller (DNV KEMA Energy & Sustainability)
- Monali Joshi (Black & Veatch Corporation)
- Drew McMahan (Luminate)
- Walt Novash (Johnson Controls, Inc.)
- Charlie Dearie (McCalmont Engineering)
- Tim Pfannenstiel (AWS Truepower)

Sandia National Laboratories

- Josh Stein

NREL

- Nate Blair
- Aron Dobos
- Steven Janzou
- Paul Gilman
- Leah Kaffine
- Janine Freeman
- Sarah Kurtz
- Pam Gray-Hann (logistics)

1.2 Agenda

The goal of the SAM TRC was to receive structured feedback on a variety of SAM topics of greatest interest to this particular audience. The TRC was queried in advance to identify those areas and topics of most interested. The organizers received a response from most members and adjusted the final schedule accordingly (noted below). In response, the agenda dedicated more time to priority topics. For example, items with 15 minutes on the agenda received either 1 or 0 votes from the TRC committee members. For example, we could assume that this audience

would not be interested in utility rates, while for other users that capability represents a key value in using SAM.

Agenda for SAM TRC

Monday Afternoon

11:30-12:00 PM	Lunch and introductions
12:00-12:30 PM	SAM Team introduction, planned updates and improvements
12:30- 1:15 PM	PVWATTS new version demo, planned work, and feedback
1:15 to 5:00 PM	Specific topics for feedback
1:15- 1:45 PM	General user interface
1:45- 2:15 PM	Resource inputs
2:15 – 2:30	Break
2:30- 3:30 PM	Derates, performance adjustments
3:30- 3:45 PM	Utility rates and electric load
3:45- 4:15 PM	Simulation options (p50/p90, stochastic, parametrics)
4:15- 4:30 PM	Simulation, results, and outputs options (plots, cashflows, loss trees)
4:30- 4:45 PM	Financing, incentives, depreciation, costs
4:45-5:15 PM	Documentation/help, user support, training, SAM API, SAM SDK

Tuesday Morning

8:00- 10:15 AM	PV System design needs not being met • Layout options • Shading options/models • Module/inverter models
10:15-10:30 AM	Break
10:30- 11:15 AM	SAM validation needs (What would make users more confident?)
11:15- 11:30 AM	CSP and CPV modeling feedback
11:30- 12:30 PM	Prioritization of improvements and wrap-up

2 Key Outcomes and Recommendations

This section categorizes and describes the primary TRC recommendations for SAM and PVWatts modeling efforts at NREL.

2.1 Integrated 3D Shading Scene Modeling and Visualization

- **Ability to define a 3D scene of buildings, trees, and other obstructions, and estimate shading impacts on a PV array over the course of a year**
- **Ability to properly model row-to-row self-shading in one-axis tracked arrays, including diffuse light degradation on some backtracked arrays**

Historically, the SAM team has avoided integrating 3D shading scene modeling capabilities into the tool under the assumption that this could be done with other tools, even if that effort was cumbersome. However, discussion with the TRC and at the subsequent Sandia PV modeling workshop in Santa Clara indicated very broad support for the integration of such capabilities into SAM. Several industry stakeholders showed how their use of 3D visualization tools helped them estimate shading impacts, allow interactive visual review of a proposed system design, and have an iterative check throughout the modeling process. There was strong general agreement that current tools and methods were inadequate and were a significant stumbling block for efficiently developing project proposals.

Several approaches are possible for 3D visualization of a PV system installation and calculation of the shade. It is recommended that the Lab consider partnering with commercial software vendors that have similar tools and investigating what levels of integration might be possible with SAM. Additionally, the SAM team will investigate the techniques for implementing such a capability from scratch with SAM using standard, well documented methodologies for 3D shade calculations. The actual path will be chosen based on cost, performance and integration with SAM. Either path reflects a potentially major effort, but the feedback was very clear that improvement in this area was *critically important for SAM to be more broadly accepted*.

In a related area, one-axis tracking in SAM currently does not derate the diffuse light due to row-to-row shading effects. Furthermore, if backtracking is disabled, SAM assumes that the rows are far enough apart to avoid shading altogether. This is typically an invalid assumption as more developers may tolerate some level of shading to increase system packing factors. Consequently, SAM must be modified to enable self-shading calculations for one-axis tracking to really make the back-tracking feature work as desired. The TRC indicated that these values would be important, and that this aspect be approached using a straightforward, area-weighted approach.

2.2 Module Model Enhancements and Integration of Measured Module Performance Data

- **Ability to edit module performance parameters directly and easily**
- **Ability to tune the module model given measured IV curves and related data**
- **Ability to automatically import IEC-61853 test matrix data and calibrate the module models**

- **Ability to import or otherwise manipulate .pan files used by PVSyst**
- **Continue to maintain a current module database**

The most important piece of any photovoltaics modeling software is how the module itself is modeled. While SAM provides several best-in-class module models and frequently updates its module databases for the CEC and Sandia models, the TRC members agreed that a key area for improvement is the ability for users to enter module performance parameters directly into the tool. This involves being able to take measured specifications from a third-party performance test and tune the SAM module models to accurately reflect the measured performance across the whole irradiance-temperature performance space. In addition, new modules used in large scale systems frequently do not appear in the module databases immediately, so there is a need to be able to manually enter performance specifications.

The TRC expressed that there is generally "standardization" in the industry to accept the IEC-61853 test matrix for PV modules. The recommendation is to augment the single-diode model representation in SAM to be flexible enough to accurately characterize measured module performance. This requires a research effort to determine which additional parameters are required in the model to enable it to match specifications. A mix of physical parameters and non-dimensional tuning parameters may be required.

Given additional module model flexibility, there is a need to be able to automatically and accurately estimate model parameters from the given data. The concept is for SAM to automatically calibrate its module model to the set of measured performance data provided; if only one or two IV curves are available, SAM would know how to best utilize those to predict overall performance. If the IEC-61853 test matrix results are available, SAM would know how to import those results and automatically calibrate the model. Currently it is not possible to do this with either module model (CEC, Sandia) in the SAM tool. An extension of this would be to interpret PVsyst .pan files that appear to be common in the industry; however, it is not proposed to make a PVsyst-specific import option because that would imply that the underlying models are identical, which could not be guaranteed.

The SAM team had identified some of these issues and has several aspects of these features on the current plan, and proposed to augment and shift milestones based on TRC feedback to best address the stated needs in a timely and robust fashion.

2.3 Inverter Model Flexibility

- **Ability to manually edit Sandia inverter performance parameters directly and easily**
- **Ability to manually enter inverter efficiency curves based on measurements**
- **Ability to import or otherwise manipulate .ond files used by PVsyst**
- **Continue to maintain a current inverter database**

General agreement existed among TRC members that the SAM inverter model implementation was not flexible enough to accommodate many usage scenarios. Frequently, a specific inverter was not included in the default Sandia model database, and the single point efficiency model was insufficient to properly characterize system performance.

The SAM team proposes to augment the current Sandia model to allow users to easily enter their own performance parameters, as well as add a new inverter model based on a piece-wise linear or spline-fitted efficiency curve derived from measured part-load efficiency data points provided by the user. This general purpose inverter model method will deliver much greater flexibility. The inverter-related enhancements agreed to in the three-year project plan regarding staging and other large system effects were not considered to be a high priority among TRC members.

2.4 Weather and Solar Data Input Flexibility

- **Ability to import sub-hourly data and select what timescale at which the SAM model runs**
- **Ability to enter measured plane-of-array (POA) data directly into the model**
- **Ability to enter solar and weather data in CSV column-data formats rather than be required to use TMY2 or TMY3 file formats, especially when the data itself is not a TMY specification**
- **Built-in tool with capability to analyze, visualize, merge, and backfill measured data streams for producing SAM-capable input files**

Extended options and additional flexibility for entering solar and meteorological resource data into SAM was a consistent theme among TRC members. In particular, the ability to directly enter measured plane-of-array (POA) resource data was a highly sought-after capability that comes with several challenges due to the nature of the PV models that were designed to utilize multiple irradiance components. This represents a research opportunity to determine the best technique for entering POA data into SAM consistently across all PV module models.

A sub-hourly data input capability was also requested, along with the ability to run SAM at a timestep different from the data input. For example, a user could enter one-minute data, but have SAM run simulations at five- or ten-minute steps, and aggregate accordingly for the multitude of hourly output data vectors. The SAM project plan included this idea of but will likely be accelerating it at least via the interface more immediately. A key aspect of this extension would require designing a flexible standard SAM data input file format that: 1) is minimalistic, 2) is easy to edit with Excel, 3) works across all time step inputs, 4) is well documented, and 5) has integrated tools in SAM for manipulating, visualizing, and automatically backfilling missing data. This solar resource data analysis tool could be similar to the capabilities available to the wind program via the commercial Windographer tool.

2.5 Validation Reports, Documentation, and Loss Diagram Improvements

- **Augment validation reports against measured system performance data with inter-model comparisons**
- **Provide detailed technical manuals for the PV performance models**
- **Enhance the loss tree reporting system in SAM to show more details similar to PVsyst**

The TRC indicated that the SAM validation reports in progress under Task 1 were valuable contributions to the knowledge base and would help SAM gain acceptance for PV systems modeling. Interestingly, the group had not found similar documentation and validation reporting

for PVsyst, but that did not diminish its use. Regardless, the TRC suggested that inter-model comparisons, particularly to PVsyst for the same validation datasets, would be a useful outcome.

In addition to the SAM validation reports, a comprehensive PV Modeling Technical Manual for SAM was suggested as an important step toward achieving full transparency and subsequent acceptance of the SAM model implementation. The SAM team has already started on this work, and it intends to add its completion as a project milestone for year two.

The primary guidance with regards to the visual loss tree was that to be accepted, the loss tree in SAM needs to be much more detailed. Several TRC members described how the PVSyst loss tree is used as a design tool as well as a final document to include in reports. The SAM team will implement the outcome of the efforts of Sandia and others to define standard terminology for the losses and system derates. However, in the interim, the SAM team will attempt to modify their work structure to replicate the PVSyst loss terminology for better consistency. It should be noted that calculating the losses appropriately will require reformulating significant parts of the PV performance models to enable the calculations to be made during the simulation process.

2.6 PVWatts Documentation and Usage Guidance

The TRC was generally very pleased with the demonstration of the updated PVWatts online tool. However, the main concerns were that users were not adequately warned of PVWatts limitations and the level of uncertainty in its predictions. Suggestions included having more comprehensive documentation of the tool as well as the underlying calculations, and adding disclaimers and caveats on the results pages. In particular, adding a watermark or similar cautionary text to the final PVWatts report would help educate users as to the appropriateness of a PVWatts calculation for a particular purpose. Moreover, the proposed work in year two to add P50/P90 inter-annual variability analysis to PVWatts was a much welcomed capability. The PVWatts team will also provide additional links and guidance to SAM and non-DOE tools to encourage enterprising PVWatts users to migrate to more sophisticated tools in situations where detailed systems performance analysis is warranted.

3 Detailed PVWatts Feedback

The new beta version of the online tool for PVWatts, which is available at http://pvwattsbeta.nrel.gov was also demonstrated at this event, with several screen captures of that demonstration provided below. The TRC provided feedback even though they aren't necessarily the key PVWatts user group (even though all members were familiar with it).

The comments received are listed in Appendix 2. There was a consistent theme in the suggestions: *providing the user with more understanding of the limitations of PVWatts.* The team had already included some of this thinking in the three-year plan. However, the response from the SAM TRC encouraged the team to raise this in priority. Specifically, they suggested or supported current plans for:

- **Generally including uncertainty in the output values**
- **Outputting a range of production values, giving guidance as to how to achieve the higher end of the range, and explaining how to access SAM for more in-depth analysis**
- **How to avoid implying that impossible configurations are possible on a roof**
- **Disregarding module power coefficients**
- **Warnings when system sizes exceed the assumptions used in the model**

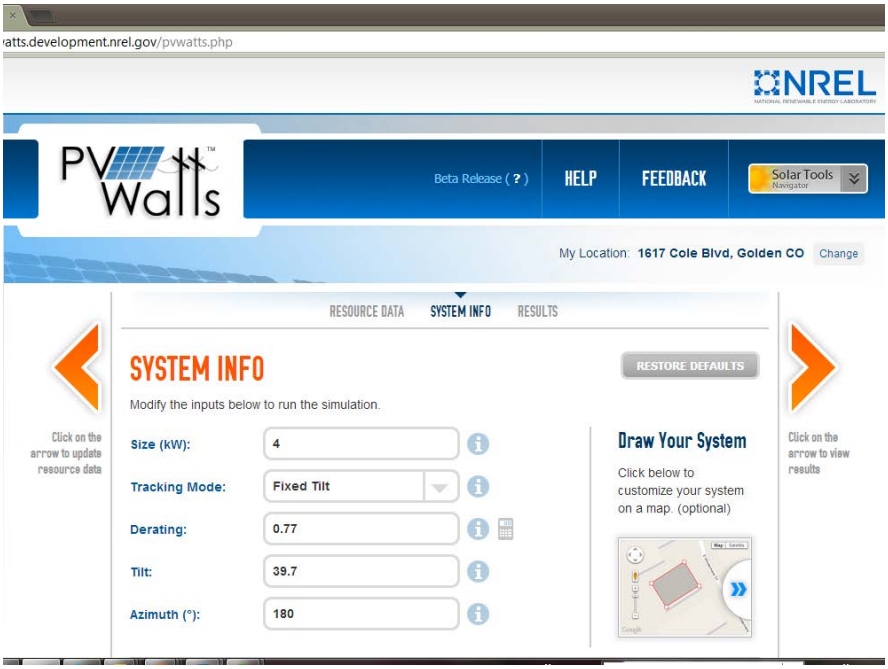

Figure 1. PVWatts beta system information input page

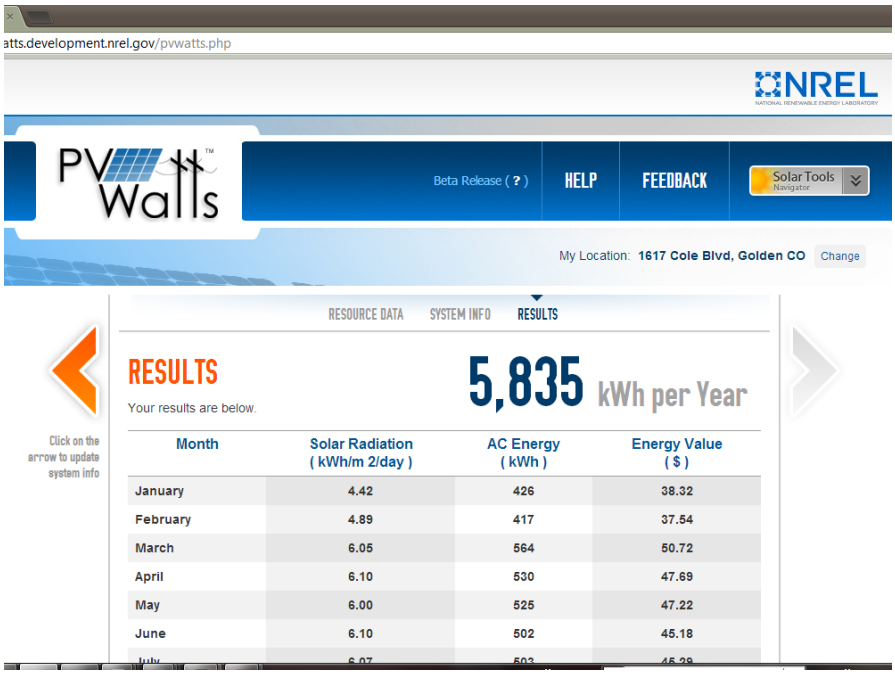

Figure 2. New PVWatts beta results view

4 Detailed SAM Feedback

The team received high-level and detailed feedback from the TRC in a number of areas. To make this discussion more structured for the reader, the authors have summarized the results by agenda area as much as possible. Certain items cross into other areas, so the entire set should be reviewed collectively. For each recommendation, the team has initially indicated how this would impact the three-year work plan. A separate document and spreadsheet will indicate to DOE proposed changes to milestone language and language in the LPDP technical narrative document. The expectation is that a broader audience might be interested in this feedback.

4.1 General User Interface

The agenda began with basic user interface feedback, which is generally easy to provide and also allows the SAM team to ascertain where the TRC was likely to focus their interest when reviewing the user interface.

The SAM team started this section by describing the concern that the SAM user (for PV) is almost immediately faced with the choice of selecting a "PV module model" which can be problematic. The TRC generally agreed that can be confusing and supported the plan to let the user select an existing module name and allow SAM to select the best module model for that module name.

There were other comments on how to make SAM more streamlined. The approach used by TurboTax came up as a related idea to indicate which inputs had deviated from the default values for the project. Finally, the discussion centered around the suggestion to make common inputs more prominent by pushing seldom-used inputs to options chosen by selecting an "advanced' button and/or adding text to the UI indicating "this isn't very common" or "this is rare".

In general, the TRC liked the fact that SAM has great visualization options and can do parametric analysis easily.

As the idea of streamlining the module/inverter modeling interface was in the existing work plan, pursuing these ideas likely would not lead to modifications of milestones. The team will investigate indicators for when the SAM inputs have been changed from the default values.

4.2 Resource Inputs

There was a robust conversation about resource data, reflective of the TRC makeup as well as the changing world of PV project development. Several of the key highlighted ideas (ranked highly by individual TRC members at the end) were grouped into this category. Additionally, this same area of discussion came up several times in the subsequent Sandia Modeling Workshop in California.

Specific requests in this area include:

- Sub-hourly data capability
- As already addressed in the SAM multi-year plan, the use of sub-hourly data with SAM. While this could go down to rates in seconds, the goal here is to modify SAM to include

existing sub-hourly data and, more importantly, allow SAM to run with sub-hourly time steps and handle the various output values correctly

- As stated above, the existing project plan included this idea but will likely be accelerating it, at least via the interface, more immediately
- Greater flexibility in irradiance input options for all models (i.e., SAM use of POA). Here, the primary and immediate driving issue is the use of POA data. This is how data is typically measured and is critical if the team intends to use Locus Energy as a near-term validation partner.
- More flexibility with resource input; possibly a standard SAM PV input file with reduced variables. The key idea is to input sub-hourly data at various time levels and minimize useless data streams. The current SAM PV models use only a third or less of the available data within a TMY3 file
- Ability to input one's own long-term or multiple resource datasets for P50/P90 analysis. This can already be done in SAM but likely could have improved access and/or documentation
- Nomenclature: "TMY3" is being used where not appropriate because the "format" of the file often gets confused with the content. A user can create a TMY3-formatted file that has a specific year's worth of data. Creating a SAM-specific solar data format would be one way to improve this.

4.3 Derates, Performance Adjustments

This area is a primary research effort area for both NREL and Sandia. The SAM team eventually intends to incorporate the output of several other NREL projects, including those being led by Sarah Kurtz. Additionally, Sandia is also working extensively on the bankability/rate issue.

The Sandia-organized PV modeling workshop in also focused heavily on this topic, with a special half-day session at the end of their meeting.

From the SAM TRC, the primary guidance was that to be accepted, the loss tree in SAM needs to be much more complex. The SAM team learned that the PVSyst loss tree is used as a design tool as well as a final document to be included.

The SAM team will implement the resulting efforts of Sandia and others to define standard terminology for the losses/derates. However, in the interim, the SAM team will likely modify their work structure to more significantly replicate the PVSyst loss terminology for better consistency.

Of the items listed below, a number of them are relatively easy and the SAM team will make have made progress on several of these by the next release. The most difficult issue will be the calculation of these values within the SAM construct and the calculation of snow and soiling based on available data.

- Nomenclature: "Snow & Soiling" loss?
- More intuitive snow cover input- number of days (Summary NOAA data: x days with >5")

- Single curtailment input (MW)
- Apply degradation to capacity vs. performance
- Nomenclature- losses & efficiencies on scale of 100% versus coefficients
- Availability gets distributed over entire year- this is a problem for comparison on a monthly or hourly basis
- Soiling: Provide Addie. Kimber's original and follow-up papers, link to references in interface. Basically, allow users to easily access collective wisdom about soiling.

4.4 Utility Rates & Electric Load

For this section, the SAM team described the various options available and how SAM accesses these items within the interface. These features were new to the TRC, as few of them had used them from within SAM for their work. The SAM team will continue to work with other stakeholders that use these capabilities extensively to perform analysis at NREL and for universities.

4.5 Simulation Options (p50/p90, Stochastic, Parametrics)

In this area, the team rolled out some of our general plans, notably the idea of combining stochastic SAM capabilities with the idea of doing p50/p90. This approach was well received and the team was able to educate them more broadly on the issue.

4.6 Simulation, Results, and Outputs Options (Plots, Cash Flows, Loss Trees)

Related to derates and general PV improvements, the TRC indicated that they used the standard outputs and that they used the standard reports. They typically use other financial tools but like having the option to use this as a first cut.

4.7 Financing, Incentives, Depreciation, Costs

For this section, the SAM team described the various options available and how SAM accesses these items within the interface. The TRC members learned how to utilize these SAM capabilities for their work. The SAM team will continue to work with other stakeholders that use these capabilities extensively to perform analysis at NREL and for universities.

4.8 Documentation/Help, User Support, Training, SAM API, SAM SDK

The SAM team reviewed the current plan and activities related to these topics. Several organizations were very interested in the SAM SDK and hadn't yet known about it. Almost everyone said they had used the online videos to get started on SAM. They all felt that, while there was a lot of information in the documentation, it would be helpful to pull it out separately for a specific audience. The SAM team asked if the current plan to provide a relatively high-level PV technical manual would be helpful, and that was strongly encouraged. Key suggestions for these areas included:

- Links to whitepapers and other references at the relevant location in the SAM interface
- PV technical user guide

- Additional granularity in pop-up help menus to indicate the location on the page
- SAM SDK webinar
- (From the Sandia modeling workshop, a related suggestion) make the libraries of information available within SAM more readily available, such as the Sandia Module model coefficient library

The SAM team has already added an SDK webinar to the plan and has started the process of modifying the SAM website to make it easier for users to download related data items like the libraries separately from the main SAM tool. The team will continue to provide technical support through a variety of mechanisms.

4.9 PV system design needs not being met - particularly in the areas of layout options, shading options/models, and module/inverter models

This section of the agenda received a majority of votes from the TRC members before the meeting and they were very interested in providing feedback in this area. Again, the team started by describing current plans for improving module and inverter models and system layout. Several of those were embraced and several were discouraged. The items that were most desired and those currently planned that received the least support are highlighted below.

Major Suggestions (in terms of likely effort)

- **Visualization & 3D shading calculations**
    - **Ability to display shading at a given date/time**
    - **Inter-row shading for backtracking (i.e., First Solar)**

Comment: this is a new request for the SAM team, but it received very broad support. The use of this visualization as a first cut at shading, for a visual review of the design, and as an iterative view throughout the modeling process was not something we had fully grasped. A valid question is "how best to do this?" Initially, partnering with programs that have existing tools and then reviewing any standards in the literature for appropriateness (for example, export formats from AutoCAD) will likely be helpful. The team also will investigate the options for constructing our own tool. Both of these seem like potentially major efforts, but the feedback was very clear that this was critically important to allow SAM to be generally accepted.

Backtracking in SAM currently has the issue that diffuse light isn't degraded if there is shading from other modules. Additionally, if backtracking is turned off, SAM assumes that the rows are far enough apart not to have shading. This is a poor assumption as more developers forgo using backtracking. SAM uses a similar assumption for two-axis tracking as well. The team would need to add self-shading to at least one-axis tracking to really make the backtracking feature work as desired. The TRC indicated that these values would be important and could be approached in a more simplistic area-weighted approach, as done by PVSyst.

- **Module model enhancements to utilize other module data directly and represent performance across the performance space better**
- **Ability to "read in" PAN files used by PVSyst**
- **Ability to edit module coefficients/information directly and easily**
- **Ability to input one's own module based on efficiency curves, user data, etc.**
- **Methods to integrate 61853 test data**
- **Maintain a current module database**
- **Selection by PV module vs. model, but maintain option to switch to other model**

Comment: The team plans to modify and simplify the SAM PV interface so that users (especially new users) aren't immediately faced with the decision of which module model to use. This enhancement will present a list of modules or the option to import or construct custom modules. This plan was received positively even though TRC members would like the ability to change the option back from, for example, Sandia to CEC.

- **Light induced degradation loss option and/or modifying existing models to include light induced degradation more directly.**

Comment: This issue and the related modeling have also arisen at the recent Sandia Modeling Workshop in California.

Minor Suggestions (in terms of likely effort)

Comment: Each of these items will not be commented on individually, but instead be reviewed for difficulty and implemented based on efficiency. The most complex item on this list is probably focusing SAM on enabling design via several smaller changes. However, all of the suggestions can readily improve someone's user experience and so they are worthy of consideration.

- **Monthly albedo values (hourly is too refined, but annual is not flexible enough)**
- **Generally modifying SAM with a focus on enabling design rather than just energy estimation. An example of this would be improved AC/DC sizing feedback/guidelines**
- **No one uses isotropic model - remove or hide**
- **Separate thermal models from module models and evaluate which thermal models to have**
- **No one uses NOCT - hide it**
- **Visual representation of which defaults have been changed**
- **Visual representation of which sections a user has visited**
- **Backtracking inputs - module width and tracker center-to-center versus current inputs**
- **PV subarrays - when tracking options are highlighted, tilt and azimuth should be grayed out**

Currently planned items that were discouraged:

- Building on the current FY12 capability to have multiple sub-arrays within a SAM system feeding a single inverter, allowing the **SAM user to have multiple sub-arrays feeding either a single inverter or a bank of staged inverters.**

Comment: It seemed that this particular activity wasn't very highly valued by the TRC given that they aren't sure the data is readily available and the use of this system topology was not very commonly used. A modular structure for large systems was much more typical than staged inverters.

4.10 SAM Validation Needs (What would make users more confident?)

Again, here the team reviewed our current validation efforts and asked specifically what kinds of graphs/charts/metrics they would like to see that would validate SAM. The TRC responded with several comments:

- Specifically, they were interested in seeing more inter-model comparisons as well as comparisons to real data. They felt that comparisons between SAM and PVSyst would be an important step. This in the plan already, but it was good to hear it was considered valuable.
- The idea of documenting the primary steps that SAM goes through to model a PV system would be important.

4.11 CSP and CPV Modeling Feedback

This discussion, while short, was generally illuminating. Some members of the TRC felt quite strongly that CPV wouldn't likely be a widely deployed commercial technology in the near future, and so we should focus less effort there in the near term.

On the topic of CSP, two reviewers indicated that SAM was the premier solar modeling tool available for CSP. No one seemed to make concrete suggestions for CSP.

Appendix A. SAM TRC Feedback and Prioritization Notes from the White Board/Paper Sheets

The following bulleted list contains a summary of the final TRC meeting section, the prioritization of suggested improvements by the committee members. All improvements that were suggested during the two-day meeting are listed, grouped by category. In the final section of the TRC meeting, participants were asked to rank their top five priorities. The highlighted bullet points indicate the top priorities as ranked by the participants. Green highlighting indicates that the item received multiple votes in the number one or two spot, and yellow highlighting indicates the rest of the items that received a top five priority by the TRC.

PV Watts

- Improve user understanding of limitations of PVWatts
    - Output a range of production values and give guidance for how to achieve higher end of range; link to SAM for more in-depth analysis
    - How not to imply that impossible configurations are possible on a roof
    - Module power coefficients not taken into account
    - Warnings when system sizes exceed the assumptions used in the model
- Improved PVWatts default assumptions for tilt angle- not based on latitude? (consult Dunlop)
- Check ohmic effects in PVWatts (reference Jeff Newmiller)
- Ability to input a two slope array on a roof.

Resource Inputs

- Sub-hourly data capability
- Greater flexibility in irradiance input options for all models (i.e., SAM use POA)
- More flexibility with resource input, possibly a standard SAM PV input file with reduced variables
- Input individual long-term or multiple resource datasets for P50/P90 analysis
- Ability of SAM to evaluate timestamps

Results/Outputs

- Update output report with more information, specifically improved loss tree
    - Break out module losses
    - Specify gain from transposition
    - Break out inverter losses: clipping, temperature, threshold
- Probabilities of Exceedance
    - P50/P90 analysis using global NASA dataset
    - Variable uncertainty (P75,P90,P99, etc.) ability

- Evaluate just on resource AND on combination resource/energy

- Ability to filter hourly modeled data by a given parameter
- Parametric analysis: highlight large differences or outliers

Support/Documentation

- Validation activities
  - Inter-model (i.e., compare to PVSyst, etc.)
  - Work with Sandia validation algorithm
  - Model "edge" cases as well as normal cases
- Links to whitepapers and other references at the relevant location in SAM
- Target development one sector at a time (i.e., residential, then commercial, then utility)
- PV technical user guide
- Additional granularity in pop-up help menus telling users where they are on the page.

Models & Algorithms

- Visualization & 3D shading calculations
- Module/Inverter files
  - Ability to use PAN and OND files
  - Ability to edit module/inverter files
  - Ability to input one's own inverter based on efficiency curves, user data, etc.
  - Implement piecewise inverter curve calculation
- Tool to fit 61853 test curves
- Maintain a current module/inverter database
- Apply degradation to capacity vs. performance
- Bring back the "No financing" option
- Soiling: Provide Addie. Kimber's original and follow-up papers, link to references in interface. Basically, allow users to easily access collective wisdom about soiling.
- Combine Monte Carlo and probability of exceedance analyses
- Ability to handle SMA "above nameplate" inverters
- Inter-row shading for backtracking (i.e., First Solar)
- Monthly albedo values
- Separate thermal models from module models and evaluate which thermal models to include
  - No one uses NOCT, hide it
- Availability gets distributed over an entire year; this is a problem for comparison on a monthly or hourly basis

- Tilt angle optimization tool (with options based on what optimizing for)
- Backtracking algorithm doesn't work.

PV Design Interface

- Simplify: reduce options, hide advanced settings to make more user friendly (designate tasks for the "super user" or functions that might be considered rare)
- Ability to display shading at a given date/time
- Improvements in using SAM as a PV design tool (not just evaluation)
    - Example: AC wiring calculations
    - Example: Separate inverter/transformer specifications and losses
- Improved AC/DC sizing feedback/guidelines
- Selection by PV module vs. model, but maintain option to switch to other model
- Fix confusing SAM layout
- Visual representation of which defaults have been changed
- Visual representation of which sections have been visited
- Single curtailment input (MW)
- Mechanism for users to provide feedback as to what's missing
- Nomenclature- "TMY3" being used where not appropriate
- Nomenclature- losses and efficiencies on scale of 100% versus coefficients
- Light induced degradation loss option
- Date updated should display for OpenEI data in SAM
- Backtracking inputs- module width and tracker center-to-center vs. current inputs
- PV subarrays- when tracking options highlighted, tilt and azimuth should be grayed out
- Nomenclature: "Snow and Soiling" loss?
- More intuitive snow cover input- number of days (Summary NOAA data: x days with >5")
- Isotropic model rarely used - remove or hide.