SYSTEM ADVISOR MODEL (SAM) CASE STUDY:

IDEAL HOMES' ZERO-ENERGY HOME

OKLAHOMA CITY, OKLAHOMA

Abstract

The Zero-Energy Home in Oklahoma City, Oklahoma features a roof-mounted 5.3 kW PV array which serves as the energy source for the building. The residential PV system began generating energy in November 2005. System performance data and building load data were provided from authors of previous NREL reports for all of 2006. With this data, in combination with satellite climate data from the same time period, we were able to create a thorough model of the system. The SAM model shows good agreement at the monthly level for most of the year, except for a few months where there were various issues with the system.

Figure 1: PV array on the roof of Ideal Homes' Zero-Energy Home in Oklahoma City, OK [1]

System Description

The PV modules on the Zero-Energy Home are Sanyo HIP-190BA3 and cover a total area of 33 m². The array is arranged with 4 modules in series per string and 7 strings in parallel. The modules are mounted on the roof such that they have a 23° tilt, the same tilt as the slope of the roof and an azimuth of 0° (due south). Power from the array is delivered to a Fronius IG-5100 grid-tied inverter.

Data Acquisition

This study used proprietary Perez satellite climate data from 2006 for Oklahoma City, Oklahoma (Lat: 35.35°, Long: 97.55°) that was acquired from internal NREL datasets. We used SAM's TMY3 creator to compile the weather data in a useable format in SAM. The array layout and specifications were obtained from a previous NREL report on the Zero-Energy Home PV system [2]. We found system performance and building load data from the same dataset that was used for the NREL report, but it is reserved only for NREL internal use.

SAM Inputs

The SAM technology for this system is Component-based Photovoltaics. The market and associated financing is Residential. We selected the Sanyo HIP-190BA3 from the Sandia module model drop-down list on the module page and then chose the Fronius IG5100 NEG from the list of Sandia inverter models on the inverter page. We started with the default inputs and then made a few changes to fit the system specifications.

Table 1: SAM performance inputs that differ from the default values for the Zero-Energy Home PV system

Page	Variable	Default Value	Zero-Energy Home
Climate	Location	Phoenix, AZ (TMY2)	Custom (Perez/satellite)
Array	Modules per String	9	4
	Strings in Parallel	2	7
	Tilt	0°	23°

Next, we added the hourly electric load data by selecting "User entered data", clicking the "Edit data" button and then pasted in the average power at a one hour time step. To find the utility rate, we used the OpenEI Utility Rate Database that is built into SAM. We decided to use Oklahoma Gas & Electric Co. as the utility, because they are the major utility company in the Oklahoma City area. Then we selected the Residential Time of Use Rate and downloaded it (checking the "Enable TOU Rates" box and unchecking the "Enable Flat Rates" box). If the simulation was run with a flat rate instead, one would notice a difference in the net present value. We had to estimate some of the variables on the financial side of the model because we did not have explicit financing or cost data. We found the total installed cost of similar sized (3-7 kW) systems throughout the U.S. that were installed around the same time that the Zero-Energy Home system was installed (July-December 2005) on NREL's Open PV Project Database [3]. After calculating the cost per watt, we took the average for these systems, which gave us a total installed cost per capacity of $8.30/W. We ended up changing the module cost from $2.15/W to $4.63/W in order to achieve a total installed cost per capacity of $8.30/W. We left the rest of the financing and cost inputs as the default values and then ran the simulation.

Results and Discussion

The SAM metrics table is shown in Table 2. As mentioned above, these values should be interpreted with caution. They are based primarily on default values and are not necessarily representative of the system.

Table 2: SAM metrics table

Metric	SAM value
Net Annual Energy	8,758 kWh

LCOE Nominal	31.06 ¢/kWh
LCOE Real	24.73 ¢/kWh
First Year Revenue without System	$ -1,180.39
First Year Revenue with System	$ -683.00
First Year Net Revenue	$ 497.39
After-tax NPV	$ -17,313.95
Payback Period	1e+099 years
DC-to-AC Capacity Factor	18.8 %
First year kWhac/kWdc	1,646
System Performance Factor	0.81
Total Land Area	0.02 acres

The SAM graphs are very useful in visualizing the financial aspects of the system. Though we did not have accurate cost data, it is still interesting to see the cost breakdown of the $8.30 total installed cost per watt value (using the average of the OpenEI data and the default inputs) in Figure 2.

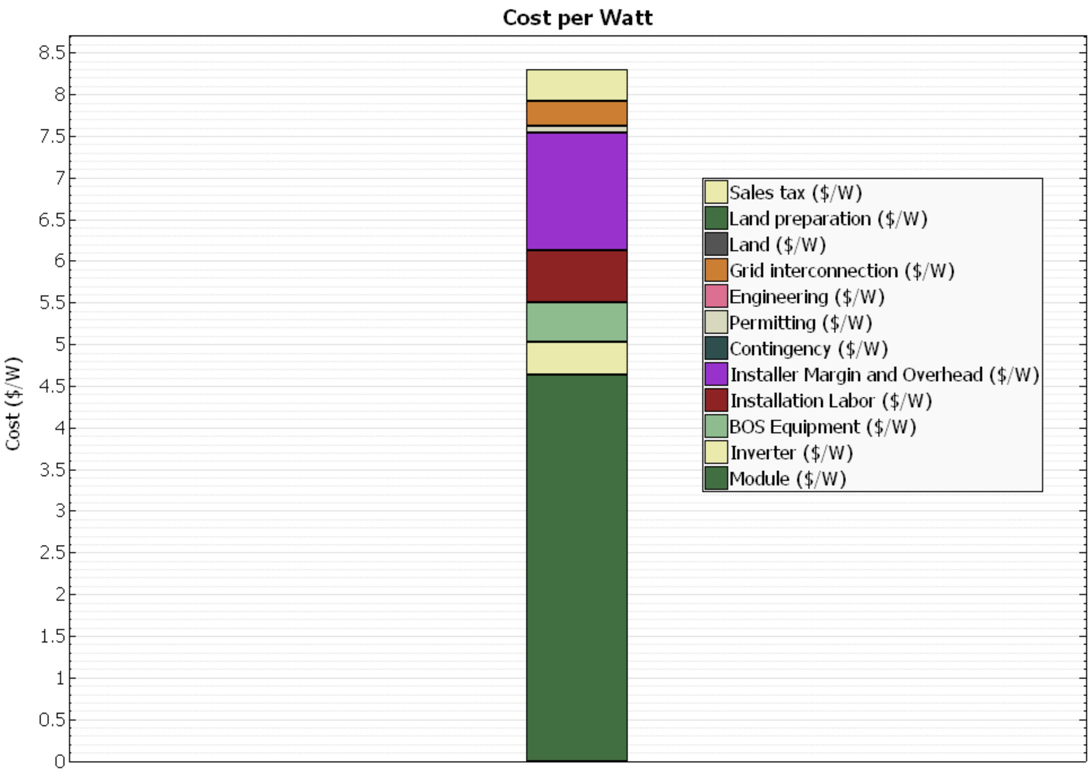

Figure 2: Breakdown of costs that make up the total installed cost per watt, including the $4.63/W module cost from OpenEI

Because we had system performance data from 2006, we had the opportunity to see how accurately this SAM case represents the actual system. Figure 3 shows the monthly output comparison between the SAM estimates and the measured data for each month in 2006.

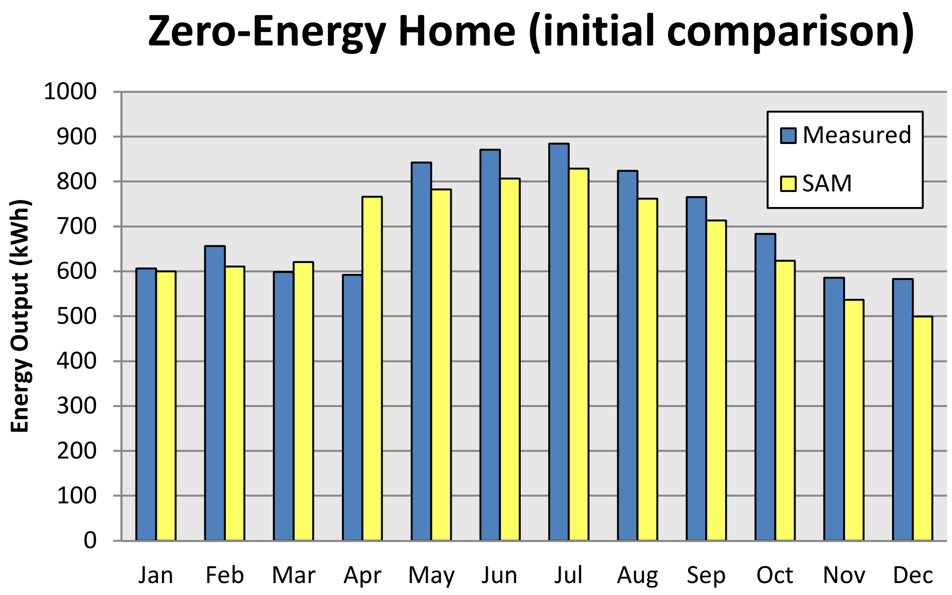

Figure 3: Initial comparison of measured output (blue) to SAM estimates (red)

There is clearly significant disagreement between the modeled SAM energy output estimates and measured output data in Figure 3. However, aside from a few months, there does seem to be a distinct trend. In order to analyze this trend in a more precise manner, we can look at the percent difference between the modeled and measured outputs in Figure 4.

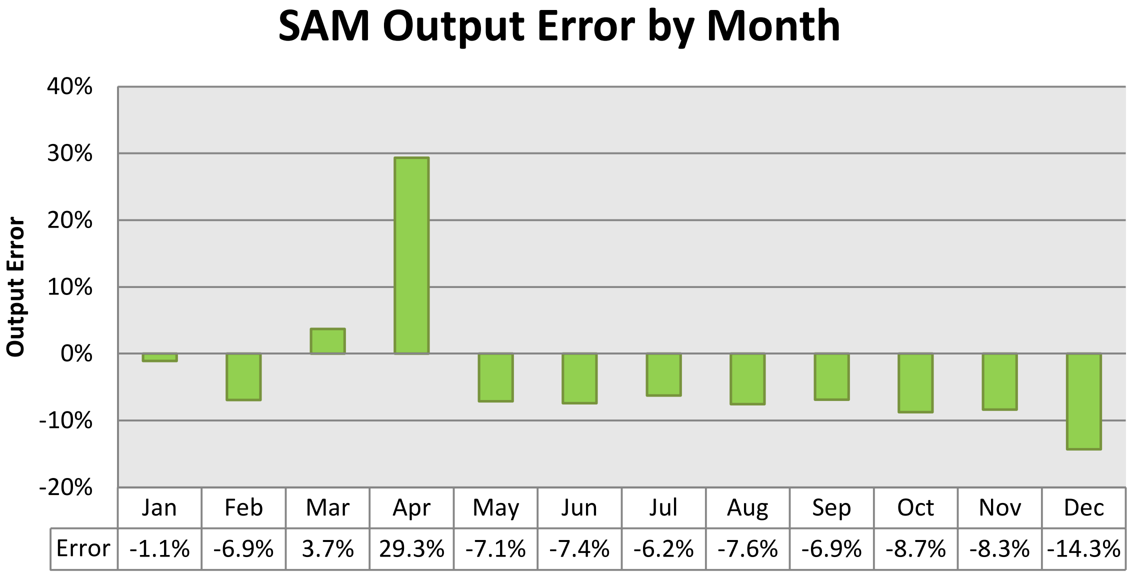

Figure 4: Shows the percent difference between the SAM estimations and the measured output data

Except for January, March, April and December, SAM is consistently underestimating at the monthly level by roughly the same amount. After examining the dataset in detail, we found considerable significant issues with the array's performance in each of the four months that did not fit the trend. For example, for the first two and a half weeks in April, the system output data was highlighted in blue, denoting that the array was "known to be impaired". The cause of the impairment was not disclosed; however it is likely that it is the major reason that the SAM overestimated by 29% in April. The last few days of March were also highlighted in blue, presumably from the same malfunction, explaining why the model overestimated in March as well. In January, the array was disconnected for testing for a few days. Had the array been generating power for those days, it would have increased the output error, and therefore matched the trend better. The reason that December diverged from the trend is not as evident. However, it was noted for several days in December that some of the values were "approximated data because no direct measurement was available". It is possible that these approximations may not have been accurate; if they overestimated the actual value, it could explain why SAM underestimated by more in December than the other months. In the eight other months, SAM underestimated fairly consistently, by an average of 7.4%. The most probable rationale for this would be that the derate factor was not calibrated for the system. This is an issue for most systems because derates are inherently imprecise and vary from system to system even if they are laid out the same way with the same specifications. Ignoring the months where the array was impaired or the data was flawed, we adjusted the derate factor in order to account for the consistent model underestimation. The default total derate factor is set at 85.4% so we changed the nameplate derate (from 95% to 99%) and soiling derate (from 95% to 98%) to get a total derate factor of 91.8%, thereby enhancing the output by 7.4% and matching the average output error. After the derate calibration, we made a final comparison between the modeled and measured data, shown in Figure 5. In the eight months that do not have data or array performance issues, the SAM output estimates are within 1.9% for each month.

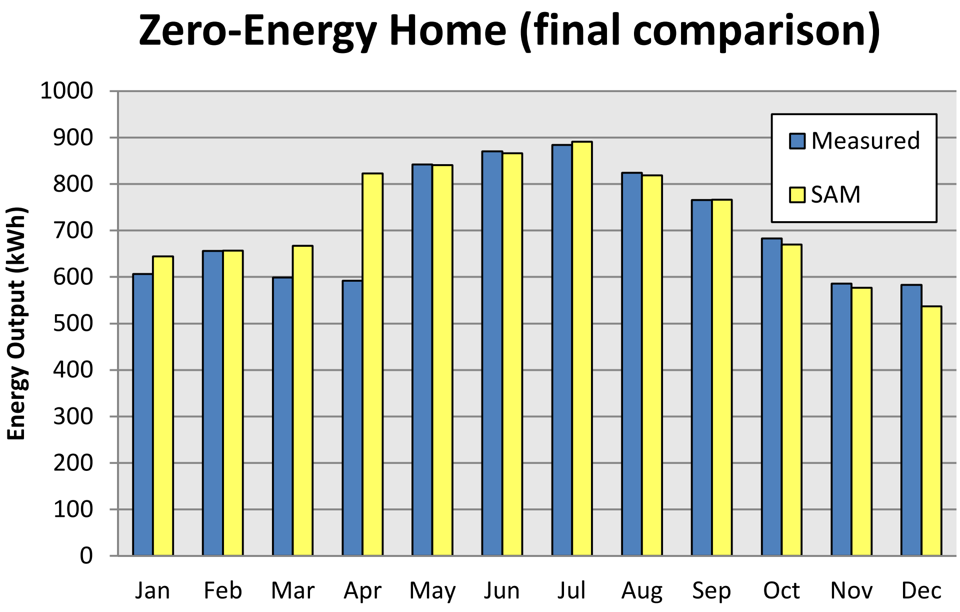

Figure 5: Final comparison between the measured data (blue) and SAM estimates (yellow) after derate factor calibration

Conclusions

This case study used SAM to model the residential PV array on the Zero-Energy Home in Oklahoma City. Using Perez satellite data and building load data we were able to model the system with few changes to the default values. After calibrating the derate value to fit the system, we were able to get within 1.9% of the measured system output for each of the 8 months that did not include flawed data or array performance issues. This case study is a good example of a residential PV system that includes building load data. The SAM file associated with this case study is located in the SAM samples folder.

References

[1] Sen, I. "Oklahoma's First 'Zero-Energy' Home". *EcoFriend Online Gallery*. 17 May 2006. <http://www.ecofriend.com/entry/oklahomas-first-zero-energy-home/>

[2] Barker, G. "Report on PV System Performance." NREL Subcontract # LAX-1-30480-02. 24 April 2006.

[3] PV system cost data available at: http://openpv.nrel.gov/