Using SAM to Re-calibrate Estimated Energy Production from Solar PV Array Based on Actual Electrical Energy Data

Kenneth Anderson, PE
The Energy Gleaners
Lake Oswego, Oregon

Objective

Present a method for calibrating a SAM PV System model to:

- 1. Help SAM modelers to improve their inputs so they better estimate electricity production
- 2. Improve the overall estimate of PV electricity production

TriMet South Terminus Station PV System

TriMet's PV system has 255 Solar World panels rated at 60.7 kWdc and seven SMA America SB inverters rated at 63 kWac.

TriMet is Portland, Oregon's bus and train mass transit system.

Original Estimate Compared to Actual Electricity Production

Original model has been lost but production was estimated at 64,300 kWh per year.

Actual production on average is 59,587 kWh/year

http://live.deckmonitoring.com/?id=tri_met_south_terminus

February 14, 2012 to June 11, 2015 from AlsoEnergy (Deck Monitoring)							
2/14/2012	6/11/2015	1197	days	195,413	kWh	Estimated Energy	
				163	kWh/day		
		365	days/yr	**59,587**	kWh/year	64,360	**92.6%**

SAM Calibration Process

Create an as-built SAM using actual conditions and TMY3 weather to see how close it fits actual production

Calibrate SAM:

1. Actual weather 2013 and 2014
2. Further calibration adjusting losses

Steps to Calibrate an As-built Model

As-built Steps

1. Verify the installed equipment
2. Verify the system configuration and wiring
3. Enter the actual equipment and system data into SAM's PV model
4. Estimate the other inputs as possible
5. Gather electrical energy delivered for particular year
6. Run SAM with TMY3 weather and compare results to actual production

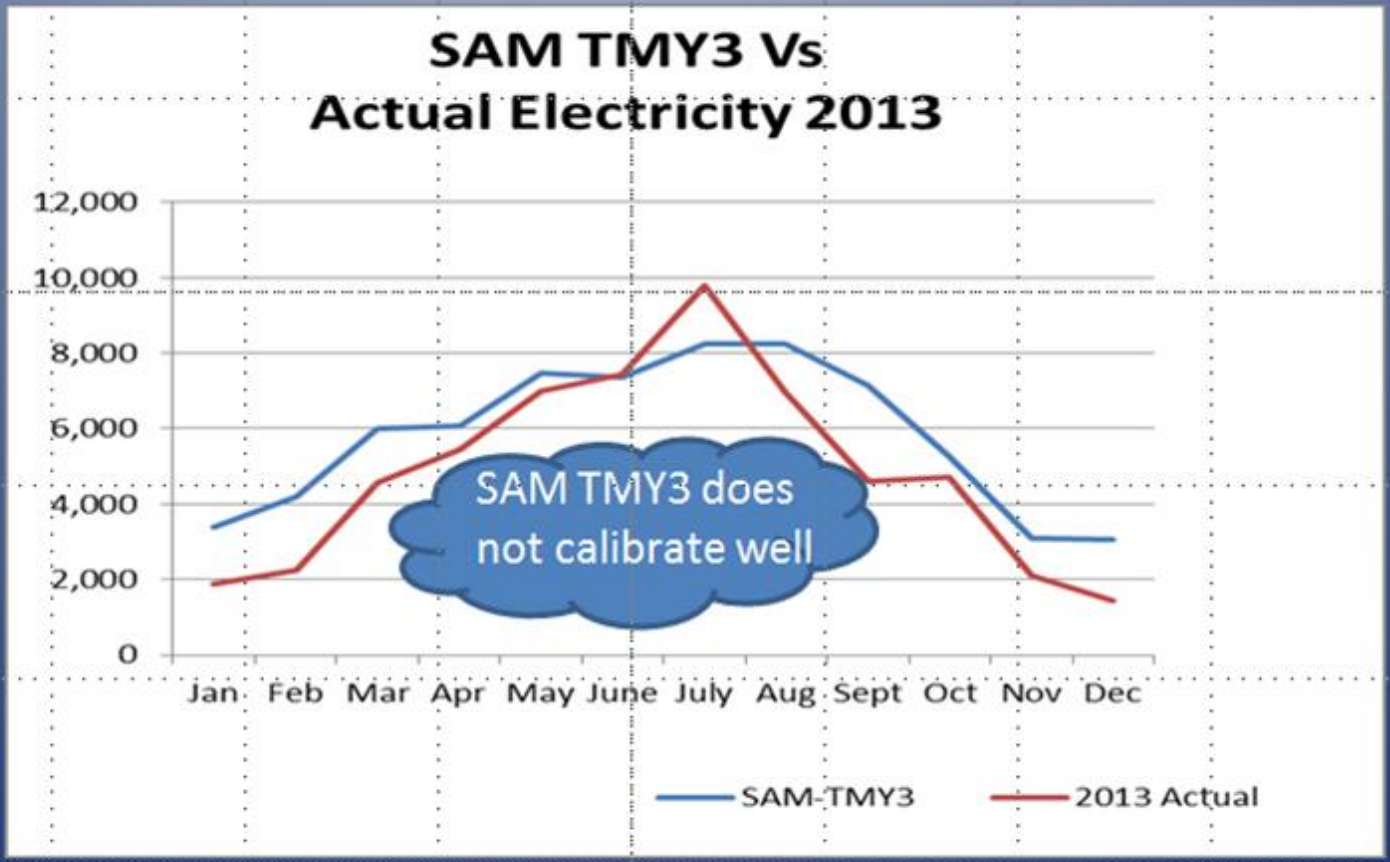
Component	Actual	SAM Inputs	SAM Calibrated
Weather Data	Actual	TMY3	Actual 2013 & 2014
Panel type	Solar World Sunmodule SW-240 polycrystalline	Same	Same as SAM Inputs
Panel Number	255	252	Same
Subarrays	7 or more	4 & Voltage Mismatch Calculated (table below)	Same
Inverter type	SMA America 4-SB8000TL & 3- SB8000TL	SMA America 7-SB8000TL	Same
Shading	Minimal	None	Same
DC Losses		Same all subarrays	Same
Panel Soiling	Unknown	5%	Same
Mismatch	Unknown	2%	Same
Diodes & connections	Unknown	0.5%	Same
Total DC power loss	Unknown	4.44%	Same
AC Losses			
AC wiring	Unknown	1%	Same
Step-up transformer	Unknown	0%	Same
Total AC Power Loss	Unknown	1%	Same
Curtailment & Availability	Unknown	0%	Annual 17% & Hourly

SAM Inputs	Strings	Tilt (deg)	Azimuth (deg)
Subarray 1	6	55	180
Subarray 2	5	55	190
Subarray 3	5	55	200
Subarray 4	5	55	215
Voltage mismatch calculated			

Annual Results of As-built SAM TMY3

Object

Annual Electricity Production				
Actual	Original Estimate		SAM TMY3	
59,587	64,360	108%	69,542	117%



Calibrate SAM with Actual Weather

- Global irradiance - GHI (W/m2)
- Beam irradiance - DNI (W/m2)
- Diffuse irradiance - DHI (W/m2)
- Wind speed (m/s)
- Wind direction (deg)
- Dry bulb temp (C)
- Wet bulb temp (C)
- Dew point temp (C)
- Relative humidity (%)
- Pressure (millibar)
- Snow depth (cm)
- Albedo (fraction)

Weather calibration Steps

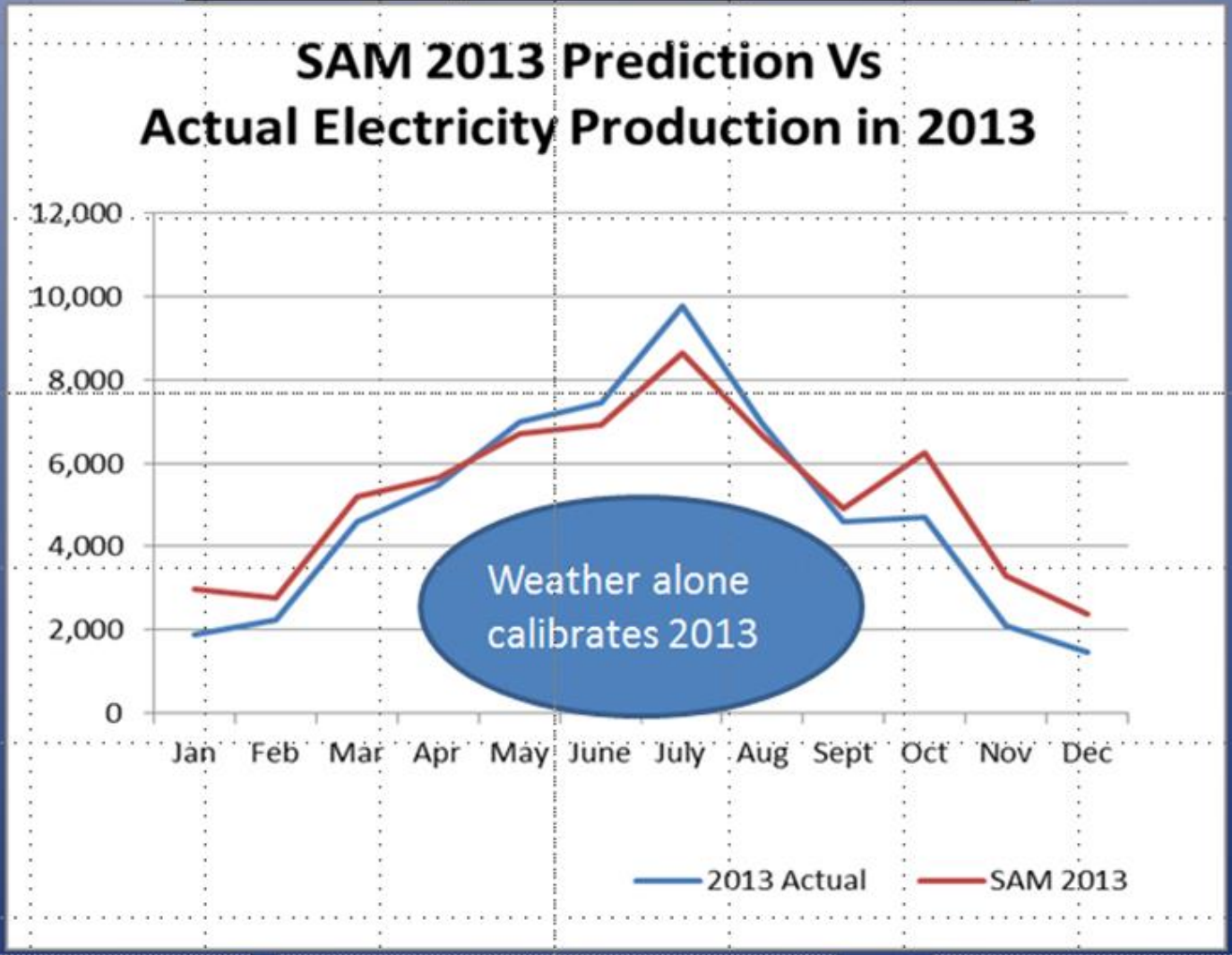
1. Identify good quality weather station close to the site

2. Gather hourly solar, wind & temperature data

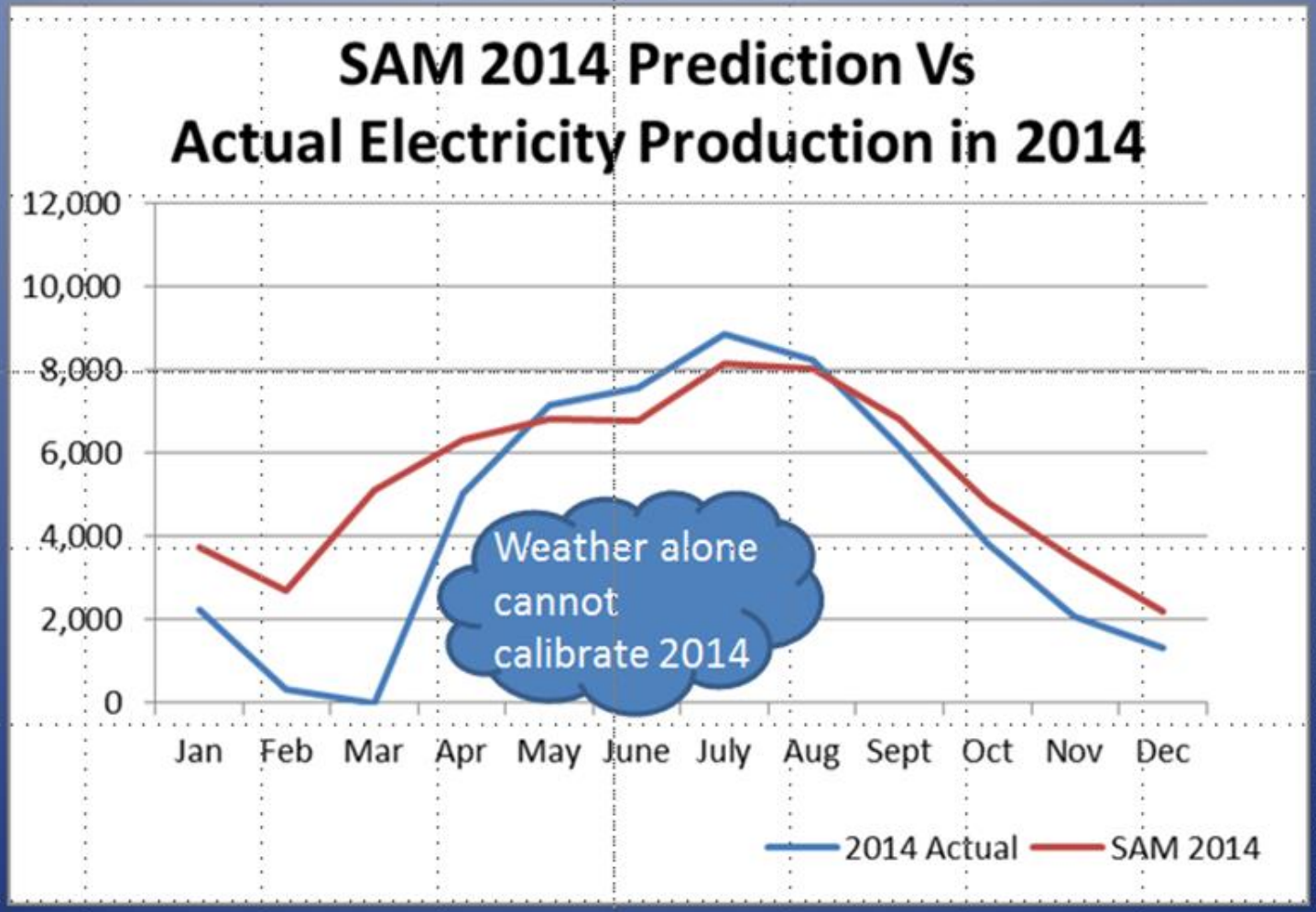
3. Be sure the actual weather data matches the SAM weather data units and file format.

4. Open existing weather file with Excel, load actual data, & save with a new csv filename in the SAM solar_resource folder

2013 Electricity Production		
Actual	SAM 2013	Difference
58,205	62,425	107%



2014 Electricity Production		
Actual	SAM 2014	Difference
52,690	64,835	123%



Steps for Further Calibration of SAM

Further Calibration Steps

7. Evaluate actual production data to see if there is a reason for production being lower or higher than expected

8. Identify non-weather inputs that can be adjusted

Looking at the graph and table of monthly actual production data, we see that February and March actual production is way too low. Looking deeper we see that there were 62 days with zero production as the PV array was off-line.

Actual Electricity, 2014			
	2014 Actual	SAM 2014	SAM/Act
Jan	2,228	3,715	167%
Feb	331	2,704	818%
Mar	0	5,105	#DIV/0!
Apr	5,006	6,312	126%
May	7,130	6,806	95%
June	7,560	6,771	90%
July	8,845	8,154	92%
Aug	8,209	8,010	98%
Sept	6,131	6,792	111%
Oct	3,821	4,817	126%
Nov	2,089	3,446	165%
Dec	1,340	2,203	164%

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Further calibration with SAM's losses to account for actual curtailment

There are two ways this can be done

1. Annual Loss
2. Hourly losses with custom periods.

To calibrate with 2014 only we could use the actual curtailment period

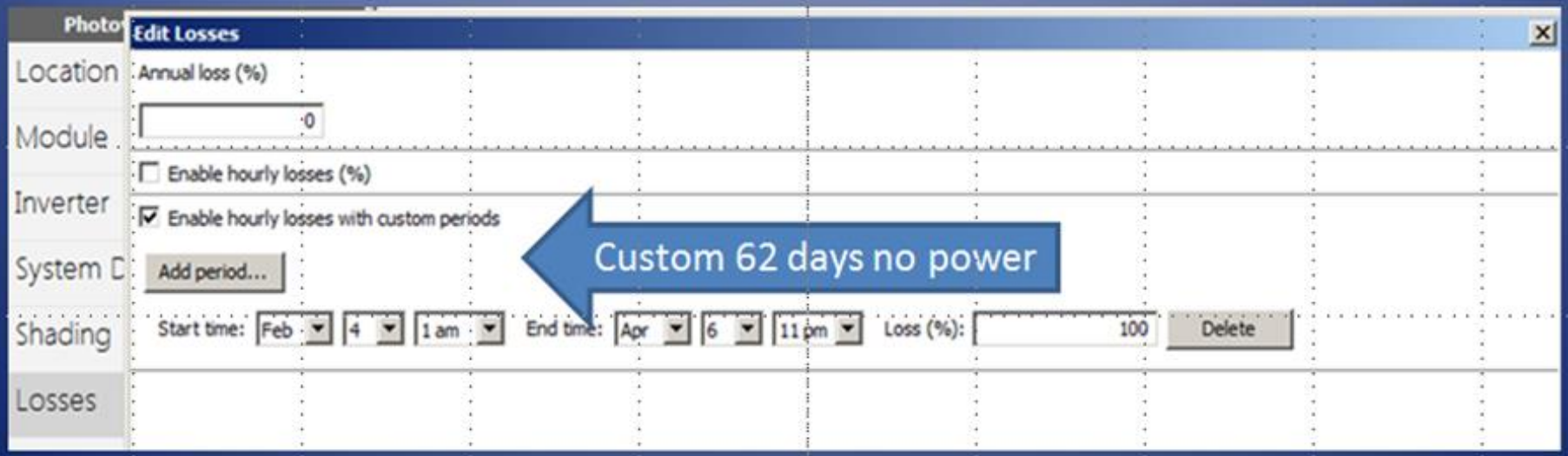
However, other years will not have the same curtailment. For example 2013 had no curtailment.

Therefore, to represent all future years a more generic loss allowance such as the annual loss would be a better calibration.

Calibration for 2014 only

For the annual loss 62 days of 365 is about 17% of the year.

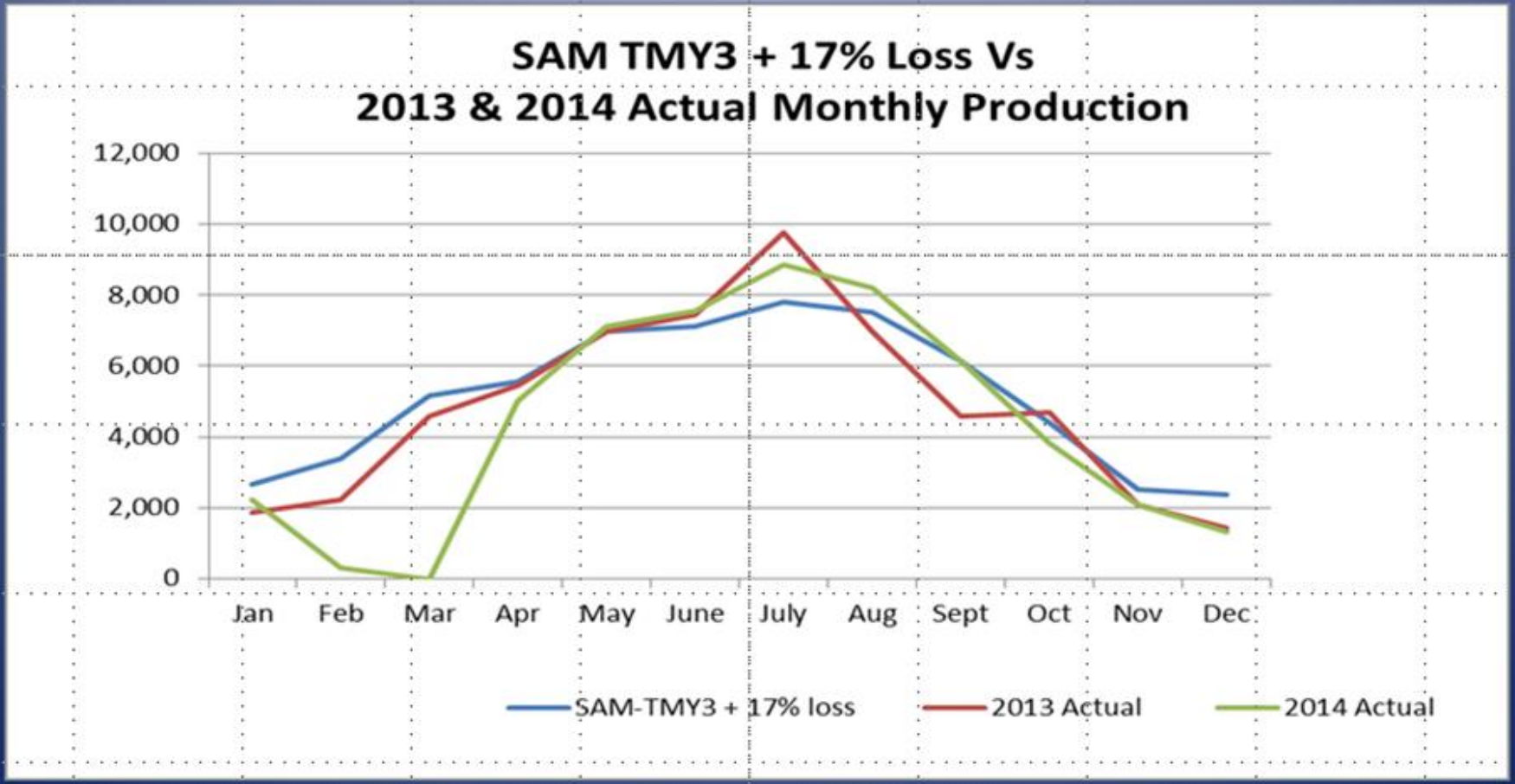
Actual 2014		52,690	
SAM 2014 &	Annual 17%	53,813	102%
Curtailment	Custom	56,716	108%



Results with Calibrated SAM

SAM-TMY3 + 17% loss	2013 Actual	2014 Actual	Long Term Actual
61,658	58,205	52,690	59,587
	106%	117%	103%

The calibrated SAM is predicting within 3% of the actual long-term (3.25 years) production; but it is too high for 2013 and 2014 likely due to poor weather conditions.



Recommendations

1. The calibrated SAM TMY is still over predicting the annual electricity production. A larger annual loss, perhaps 20%, would provide a better fit.

2. The monthly graph of the calibrated SAM TMY with 2013 and 2014 actual production shows that SAM is consistently over predicting winter and under predicting summer electricity production.

3. This suggests that some further calibration on a seasonal basis would benefit SAM TMY . One way to create a seasonal calibration would use hourly losses with custom periods, larger losses in the winter and smaller losses in the summer months. This same adjustment could improve SAM TMY's annual energy prediction as well.

Possible SAM Issues

1. SAM's four sub-arrays were not really sufficient to approximate the multiple different azimuth angles used by the TriMet PV system designer to create an artistic curve.

2. SAM requires that each string have the same number of panels (252 panels = 21 strings of 12 panels) or (260 = 20 strings of 13 panels); the actual number of panels was 255, but SAM TMY had to use 252.

3. SAM allows only one type of inverter; the actual system has two different inverter sizes. SAM TMY assumed that all seven inverters are SMA America SB8000TL-US-12.

4. SAM's "Curtailment and Availability" losses are reflected in the Annual energy of the Metric box. However, the "Monthly Array and System Production" graph is not adjusted for losses, so the monthly data exported to Excel is not correct.

Acknowledgements

System Advisor Model (SAM), Version 2015.1.30, Run on 64 bit PC with Windows 7 (build 7601, Service Pack 1), 64-bit edition

Owner: TriMet, Portland, Oregon http://trimet.org/news/releases/feb21-solar.htm

Contractor: REC Solar Inc. http://www.recsolar.com/education-and-municipalities-case-studies-overview

Module Manufacturer: Solar World http://www.solarworld-usa.com

Inverter Manufacturer: http://www.sma-america.com

Data Acquisition Firm: AlsoEnergy (Deck Monitoring) Portland, Oregon, (866) 303-5668 http://www.deckmonitoring.com TriMet data posted at http://live.deckmonitoring.com/?id=tri_met_south_terminus

Weather Data Source: University of Oregon Solar Radiation Monitoring Laboratory, Site Portland PV; http://solardat.uoregon.edu/cgi-bin/ShowArchivalFiles.cgi

The Energy Gleaners, Lake Oswego, Oregon (503) 481-0444 http://www.TheEnergyGleaners@Comcast.net.com