Achieving 100 Percent Residential Renewables in Hawaii with Solar+Multi-Storage

August 2, 2017

By John Borland, Takahiro Tanaka, Harumi McClure, Jay Moore and Corpuz Poncho

At the 44th IEEE Photovoltaic Specialty Conference (PVSC-44) on June 29 in Washington, D.C., we presented a paper on our case study based on field data for the past 14 months starting from the June 1, 2016 installation of a 7-kWh solar PV system with a 5.5-kWh inverter from Tabuchi Electric and 10-kWh Li-ion battery. Those components were integrated and tied to the grid in a post-NEM, self-supply mode with no export/selling of excess rooftop solar PV energy back to the utility grid.

Future growth in the residential solar market for customer self-supply in a post-NEM world will be driven by shortest ROI economics requiring lower price packaging of properly sized solar PV systems integrated with multiple energy storage options, such as electrical battery storage, solar hot water thermal storage and solar PV-A/C (air conditioner) cold thermal

storage with optimized energy time-of-use (TOU) of key household appliances. This will minimize excess PV energy dumping and reduce grid-buy electricity from the utility in a post-NEM world.

The Tabuchi Electric software control system in the post-NEM mode prevents export/sell back to the grid, controls the PV generation to meet the daytime demand loads, controls charging or discharging of the battery and controls grid-buy when additional power is needed beyond the available renewable energy sources. Additionally, two solar thermal hot water panels with 120 gallons of thermal storage capacity were also installed as an additional alternative renewable energy source to reduce grid-buy since electrical hot water heating in Hawaii can account for 40 percent of the residential electricity bill.

After the first month of solar system with storage operation, the grid-buy monthly bill from Hawaiian Electric (HECO) was reduced by ~53 percent going from 47 kWh/day for April 2016 to 22 kWh/day for June 2016, as shown in Figure 1. That reduction would provide a 13-year return on investment (ROI) for the $3.20/W solar PV and $0.71/W battery storage system in agreement with the 12-year ROI reported May 22, 2017 in *Renewable Energy World* by Barry Cinnamon, which is well beyond the 10-year battery warranty — so as he stated, a poor economic investment.

Using the National Renewable Energy Laboratory's System Advisor Model simulation results for the island of Oahu, we estimate the monthly excess solar PV power dumping was ~30 percent (~8-kWh/day) due to post-NEM with no export/selling of excess PV energy back to the grid. In a post-NEM world, the key to economic cost savings and shortest ROI is reducing the monthly home electric bill by reducing grid-buy from the utility as opposed to maximum solar PV generation for excess sell back to the grid to reduce monthly electrical bill.

So, starting in July 2016, we spent the next 10 months figuring out how best to operate (integrate and optimize) the rooftop solar PV system with solar thermal hot water to achieve 94.5 percent reduction in grid-buy electricity going from 47-kWh/day for April 2016 to 2.6-kWh/day for April 2017, as shown in Figure 1.

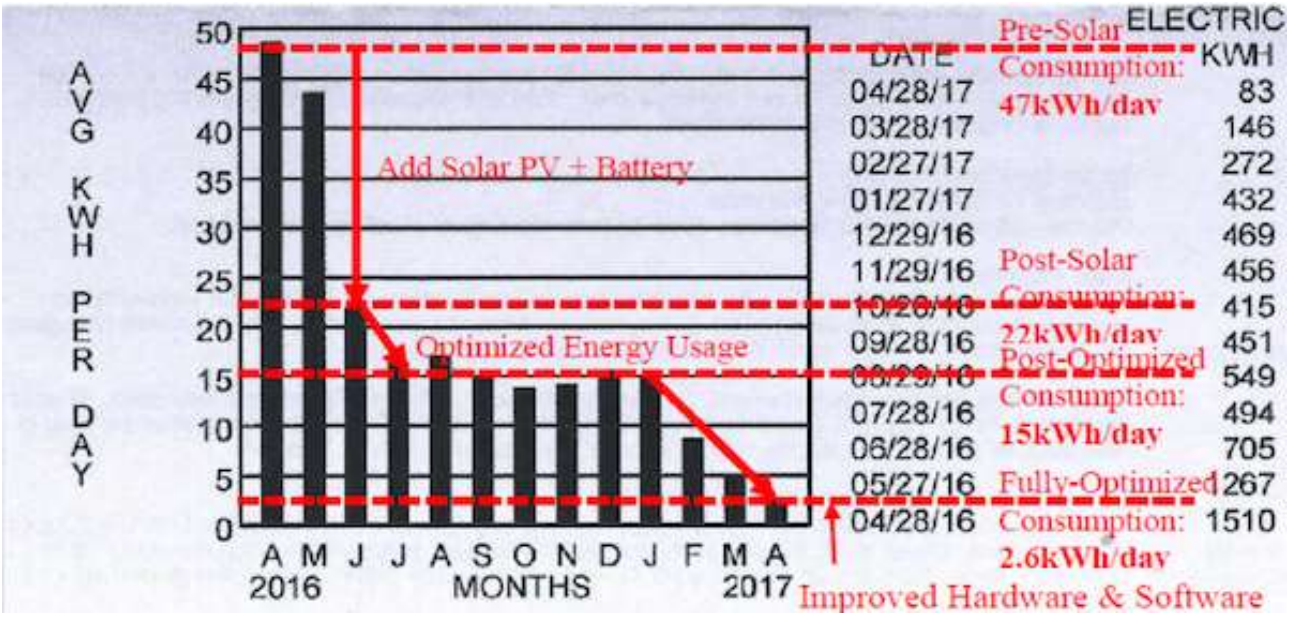

Fig.1: grid-buy electricity from April 2016 to April 2017.

As shown in Figure 2, 12 days were at zero grid-buy, achieving a new milestone of 100 percent renewable energy. This reduced ROI to seven years or three years if we include the full state of Hawaii and federal tax credits.

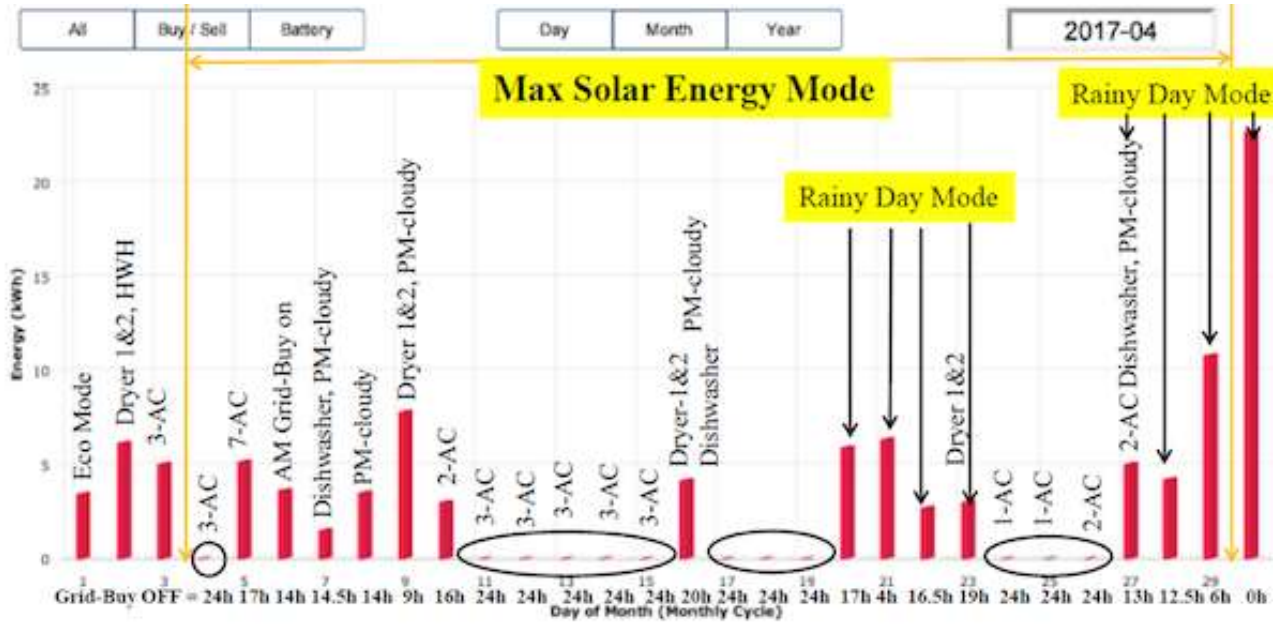

Fig.2: April 2017 daily grid-buy energy usage showing 12 days with 100 percent Renewables (Zero grid-buy).

To achieve this, we needed better monitoring of daily energy usage to look for areas to

further reduce grid-buy by optimizing TOU of key household appliances and identifying the root cause of each energy spike so we could find a renewable energy alternative.

We used:

- Three different energy monitoring systems with three seconds to one hour data collection resolution
- Tabuchi Electric remote wall real-time monitor with three-second resolution
- Laplace Solarlink website/App with both one-hour and one-minute off-line monitoring
- Hawaii's Blue Planet Foundation Bidgely website/App with five-minute real-time monitor

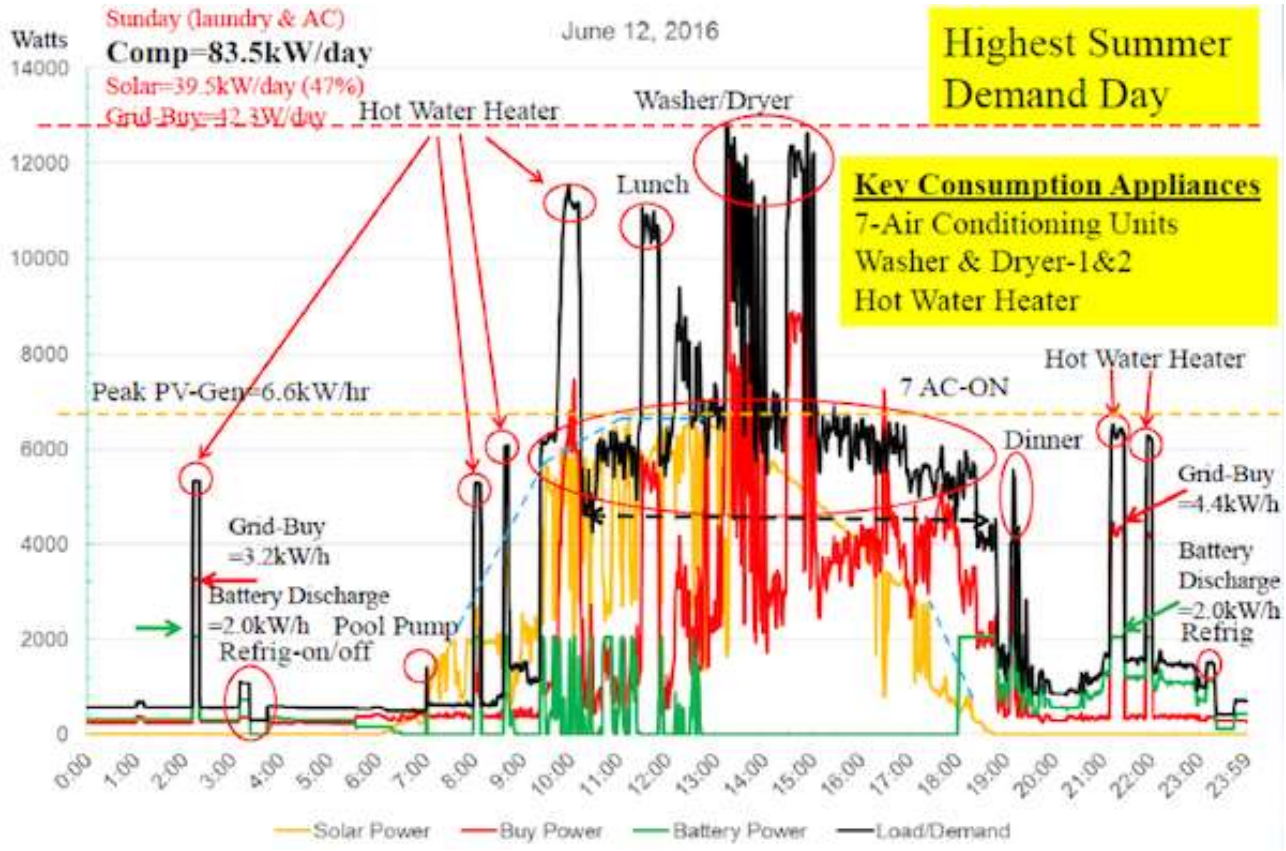

Fig.3: Summer time sunny day home energy usage.

Figure 3 shows summer time energy usage for a hot sunny day (6/12/16), and Figure 4 for winter time energy usage for a rainy day (11/7/16). Figure 5 shows the flat grid-buy for 1/19/17 and the elimination of duck curve morning and evening grid-buy energy peaks/spikes. From the Pareto analysis:

- The top energy usage appliance was A/C at ~40 kWh/day (+6 kW/hour)

- No. 2 was the hot water heater element at ~16 kWh/day (+4.5 kW/hour)
- No. 3 was Sunday's laundry (washer/dryer) at ~12 kWh/day (+5.5 kW/h)
- No. 4 was refrigerator at 7.2 kWh/day (+0.3 kW/hour)
- No. 5 was pool pump at 6.5 kWh/day (+0.5 kW/hour)
- No. 6 was Christmas lights at 2.9 kWh/day
- No. 7 was the night lights at 2 kWh/day

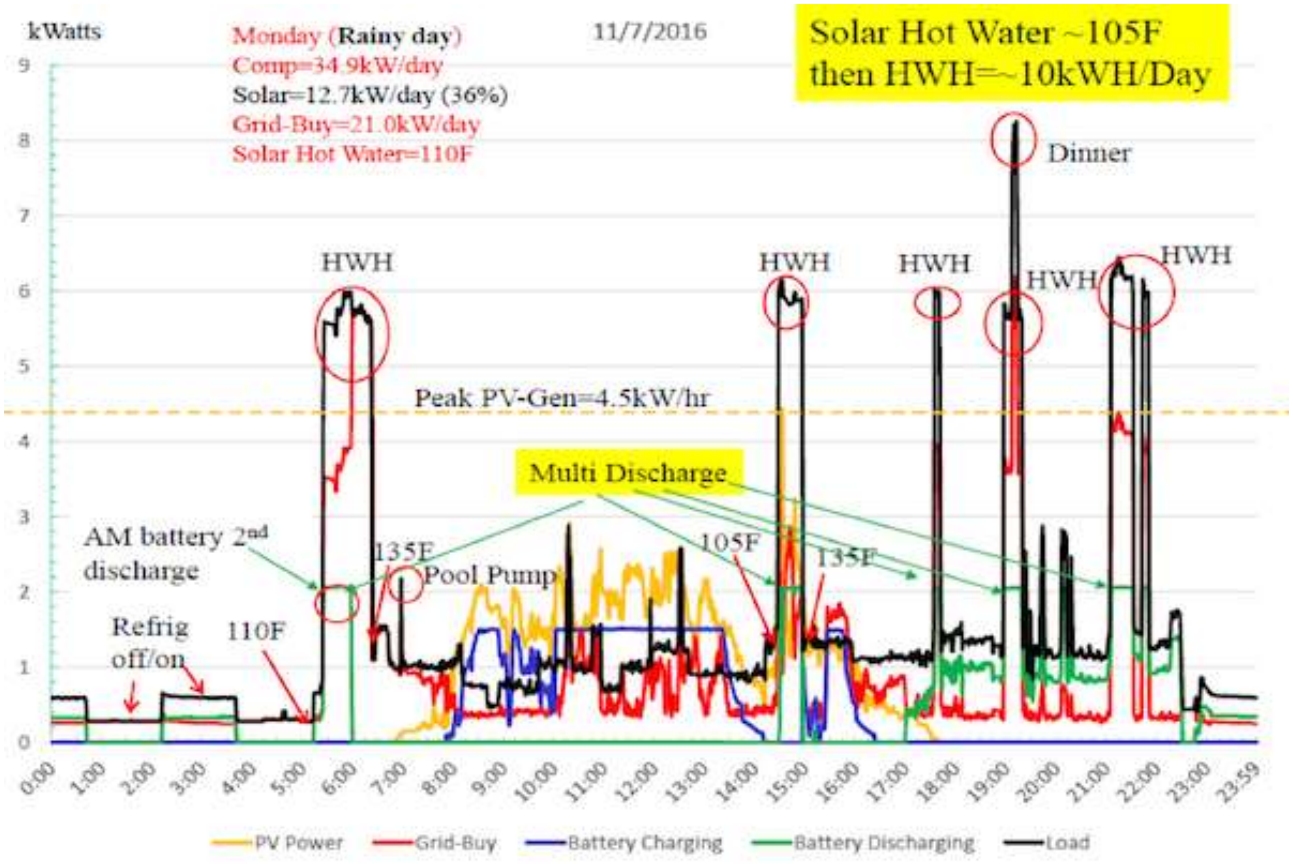

Fig.4: Winter time rainy day home energy usage.

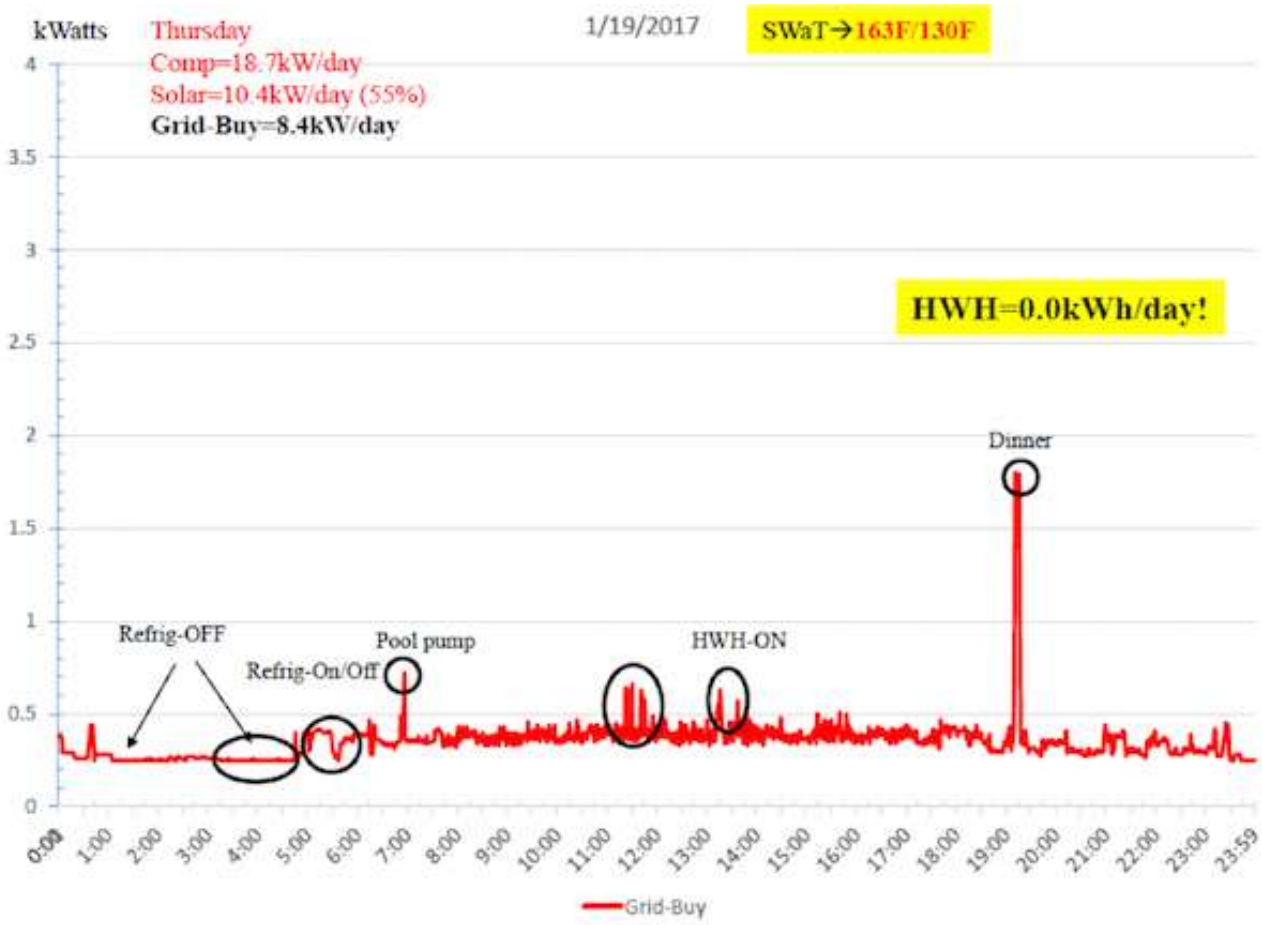

Fig.5: Elimination of duck curve morning and evening grid-buy energy peaks/spikes.

We also did some hardware modification for battery optimized discharge (BOD) at the end of January 2017 to give ~16 kWh/day equivalent stored solar thermal energy. The Tabuchi Electric control system software was upgraded in mid-Feb 2017 to reduce grid-buy by another 5 kWh/day, and the benefits for these resulted in the continued drop in grid-buy from February 2017 to April 2017, achieving 2.6 kWh/day shown in Figure 1. Also critical was the HEMS (home energy management system) integration of solar energy with multiple storage and optimized TOU for key appliances to realize these economic beneficial values with shortest ROI.

Authors

John Borland (see below), J.O.B. Technologies, Aiea, Hawaii

Takahiro Tanaka, Tabuchi Electric, San Jose, California

Harumi McClure, Tabuchi Electric, San Jose, California

Jay Moore, Poncho's Solar, Honolulu, Hawaii

Corpuz Poncho, Poncho's Solar, Honolulu, Hawaii

John Ogawa Borland received his BS and MS degrees from MIT completing his BS thesis research at Hughes Malibu Research Labs and MS thesis research at Nippon Telegraph and Telephone Musashino Labs in Japan. He has published over 140 technical and invited papers around the world in the areas of advanced semiconductor device manufacturing techniques and high efficiency c-Si solar cells and has been awarded 6 patents. Currently he is President of J.O.B. Technologies a strategic technical marketing consulting company he founded in 2003 providing service to the semiconductor device manufacturing, equipment and metrology companies in the area of advanced front end of line process technology with the current focus on 7nm and 5nm technology for next generation smartphones. He is a senior member of IEEE, the IEEE Hawaii section chair, the chairs of the Hawaii joint EDS/SSCS chapter and PES chapter, and on the advisory committee for the IEEE International Workshop on Junction Technology (2008-present). He is also a member of the Electrochemical Society (ECS) and co-organized several ECS technical conferences/symposiums.
