Experience with Residential Solar & Electrical Storage after a Hurricane

Danny Parker,
Florida Solar Energy Center
November 2019
Predicted future weather shift from IPCC Report:

- Hurricanes are local disaster threat, but there are others:
  - Earthquake
  - Wildfire
  - Ice Storm
  - Brown out/ Blackout

Hurricanes in a warming world...

- Warmer air holds more moisture for rainfall
- Warmer oceans can increase hurricane power
- Rising seas increase storm surge
Our home in Cocoa Beach: White roof, Solar hot water, PV-pumped pool and 6 kW PV system
Daily Solar vs. Consumption: 2017
Outage: Have it, can’t use it...

2017/01/02 00:00 ~ 2018/01/01 00:00

Irma
No Power for a week
Problems & Headaches
Installation of two Tesla Powerwall 2s on 22 May 2019
13.5 kWh ea. = 27 kWh Storage
What is Powerwall installation?

Powerwall Backup Battery Power (With Solar)

Two PW2s: 14 kW Max; 10 kW continuous
Cost of Powerwall 2

• Cost: $6,700 ea + $1,100 gateway
• Cost of two Powerwalls:
  – $18,100 turnkey
  – Would have been $10,600 for single Powerwall
  – Install costs= $3-4K+
• 6 kW PV + Powerwall=$30K: $21K after tax credit
  – Saves $1000 a year
  – Reduces emissions
• Context:
  – Whole house generator can cost $15K installed
  – Saves nothing, needs annual time & maintenance, costs to operate, increases emissions
No Power: Conventional Options?

- **Portable Generator:** $500-$1000
  - Up to 4000 W out
  - Refrigerator, lights, chargers
  - 5 gallons of gas/24 hours
  - Noisy, uses a lot of fuel

- **Inverter Generator:** $1000-$2000
  - 2000 - 6000 W out
  - Refrigerators, lights/chargers
  - 3-5 gallons of fuel/24 hrs
  - Quieter, cleaner power, less fuel

- **Danger:** Carbon monoxide

- **Whole house generator cost:** $7- $15K *installed*
  - Natural gas, propane or diesel fuel
  - Require large tank for diesel
  - Expensive and require maintenance
    - E.g. Diesel fuel useless after 2 years
Wanted tropical depression to test, not Category 5 Dorian!
Lisa ties down her boats in the carport with the Tesla Power walls. She drives a Ford Cmax Energi with 20 miles of battery range (Level 2 Charger on the wall)
Our home all shuttered: September 3rd, 2019
Powerwall App showing 2kW being produced by solar; 1.3 kW going to grid and the house electric load at 0.7 kW
Performance of solar, grid, storage and home energy systems on 3 September as hurricane approached.
Hurricane Dorian passes by the East Coast of Florida on 4 September 2019. Blue dot marks our location.
Measured rooftop wind speed on Sept 3-4 as Hurricane Dorian approaches

[Graph showing wind speed data with a high of 47 km/h and average of 37 km/h]
4 Sept. 2019: Performance of solar & Powerwall system during Hurricane Dorian. Closest approach at 4 AM
Interior temperature (orange) and relative humidity (blue) inside home from Sept-3rd - 9th, 2019
Performance of solar system, home and Powerwall after storm: September 5th

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Home Usage</th>
<th>Solar Energy</th>
<th>From Powerwall</th>
<th>To Powerwall</th>
<th>From Grid</th>
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<tbody>
<tr>
<td>4-8</td>
<td>3.7 kW</td>
<td>21.6 kWh</td>
<td>8.9 kWh</td>
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<td>Noon</td>
<td>1.2 kW</td>
<td>21.5 kWh</td>
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<td>4-8</td>
<td>1.2 kW</td>
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-1.2 kW
-2.5 kW
# Home, Solar and Powerwall Performance from September 3-8, 2019

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<tr>
<th>Sept Date</th>
<th>Home kWh</th>
<th>Solar kWh</th>
<th>Powerwall kWh</th>
<th>Grid kWh</th>
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Using a Level 1 charger with solar the day after Hurricane Dorian to add range to an Electric Car

Level 1 Charger
Adds 5 miles range
Per hour with excess solar + 2nd Air conditioner, Laundry & dishwasher
Disaster? Solar + Batteries Work

- PV + batteries work
- Cost of storage = $11-$18K
- Whole house backup power costs $5 - $15K + need fuel
- Key is home efficiency
- With low power mini-split heat pumps: cool entire home
- Key: minimize night loads: LED lighting, low nighttime cooling
- Helped by efficiency
  - Heat pump water heaters
  - Good windows and insulation = low cooling
- Possible to operate indefinitely by controlling loads
Solar & storage: equity issues

- Disaster affects everyone
- Affording solar/storage?
- Utilities provide income dependent rebates?

**LOW-INCOME HOUSEHOLDS SPEND AN AVERAGE OF 8.8% OF THEIR INCOME ON ELECTRICITY, WHILE THE AVERAGE FOR ALL AMERICANS IS ONLY 2.9%.**

(from the Clean Energy States Alliance report)
Other Electrical Storage Systems

- Other manufacturers & battery chemistries
- Outback: Lead-acid/Li-ion
- **Sonnen**: (LiFePO4 battery chemistry)
  - Crestone & Control4 EMS
- 16 kWh: $22.8K
Solar & Electrical Storage: Reduced Net Metering Compensation

- Most net metering in FL
  - Retail rate
- Changes: Jacksonville Electric Authority (JEA)
  - Net metering was at retail rate
    - $0.105/kWh
    - Now incremental fuel cost $0.0325/kWh
- $2000 incentive to install storage with solar
- Real incentive to increase self-consumption of solar
### Economics: How do Options Compare?

#### Estimating the Ten Year Cost of Emergency Household Electric Generation

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<tr>
<th>System Description</th>
<th>Initial Cost</th>
<th>Annual O&amp;M</th>
<th>Gasoline Gal</th>
<th>LPG Gal</th>
<th>Gasoline $/Cost</th>
<th>LPG $/Cost</th>
<th>Electric $/Savings</th>
<th>Period $/O&amp;M</th>
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#### Analysis & System Parameters
- Analysis period (yrs): 10
- Hurricane Events Frequency: 3
- Period of Interruption (Days): 5
- $/Gas/gallon: $2.50
- $/LPG/gallon: $4.25
- $/kWh/electricity: $0.12
- Ann. electricity PV system (kWh): 9,850
- Ann. electricity savings MSHP (kWh): 2,400

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**Generator Types**

- **Portable Generators**: Variable power for the home, job site, outdoor projects or emergency backup.
  - Primary Fuel: Gasoline
  - Power Range: 1,000 - 10,000 Watt
  - Retail Costs: $2,000 - 10,000

- **Inverter Generators**: Portable, quick-ship power for recreational use.
  - Primary Fuel: Diesel
  - Power Range: 200 - 4,000 Watt
  - Retail Costs: $1,600 - 1,800

- **Home Standby Generators**: Reliable, year-round operation, control kicks in within seconds of loss of power.
  - Primary Fuel: Natural Gas
  - Power Range: 10,000 - 40,000 Watt
  - Retail Costs: $10,000 - 50,000
What’s Needed Going Ahead?

• Storage costs to fall significantly, but fixed install costs high (~$3-4K)
  – Complex electrical challenge (sub-panel)
  – *One size fits one*

• Emergency use of car battery (*Vehicle-to-House*)

• Utility programs to address equity issues
Solar & Electrical Storage: Value

- Demand Charges
- Time of Use (TOU) rates
What Duck Curve?
Self Consumption Mode
How Much Solar Each Day?

- ~23 kWh per day
Measured house total loads on Thursday, August 29th. Blue is house loads in kW, white to grid, green to Powerwall, yellow is solar output. (The recurrent square-waves in house power is the home main refrigerator cycling)
Increasing Number of Major Hurricanes

Atlantic Tropical Storms & Hurricanes: 5 Yr Running Average

Number of Atlantic Hurricanes of Each Strength Since the Satellite Era

- Category 1
- Category 2
- Category 3
- Category 4
- Category 5