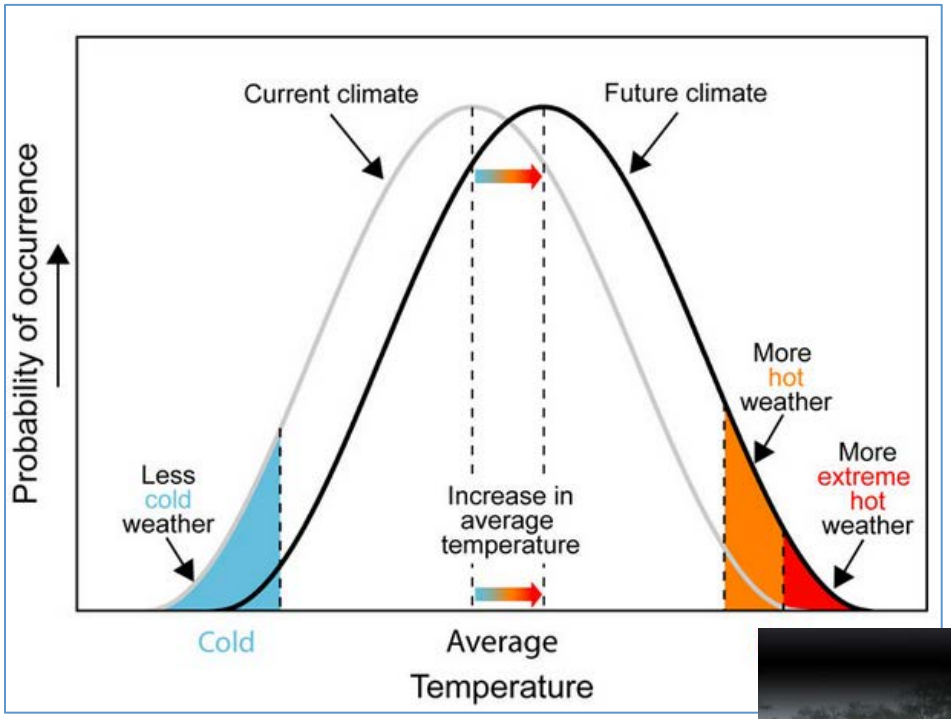
FLORIDA SOLAR ENERGY CENTER®

Creating Energy Independence

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**

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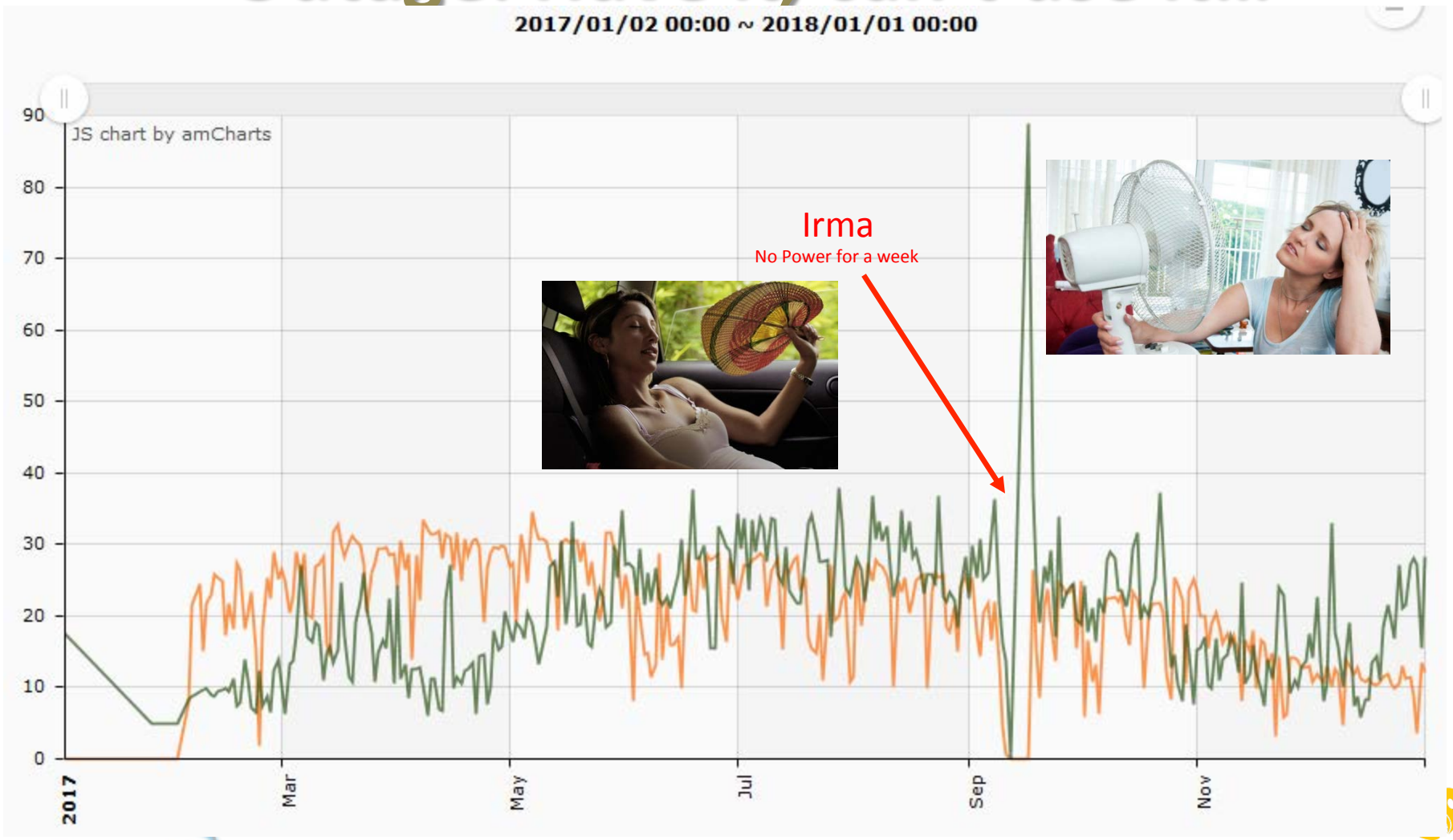
Our home in Cocoa Beach: White roof, Solar hot water, PV-pumped pool and 6 kW PV system

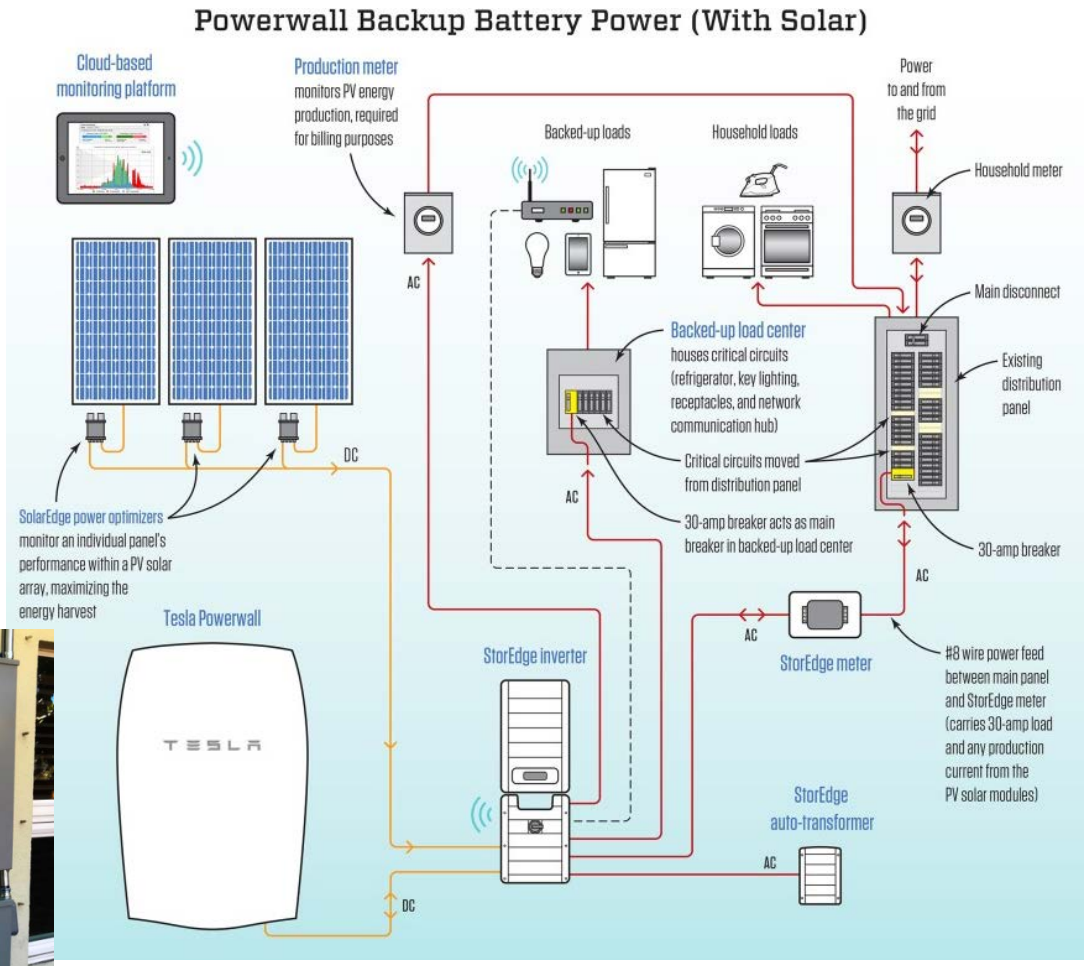
Daily Solar vs. Consumption: 2017
Outage: Have it, can't use it…



Problems & Headaches

Installation of two Tesla Powerwall 2s on 22 May 2019
13.5 kWh ea. = 27 kWh Storage

What is Powerwall installation?



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

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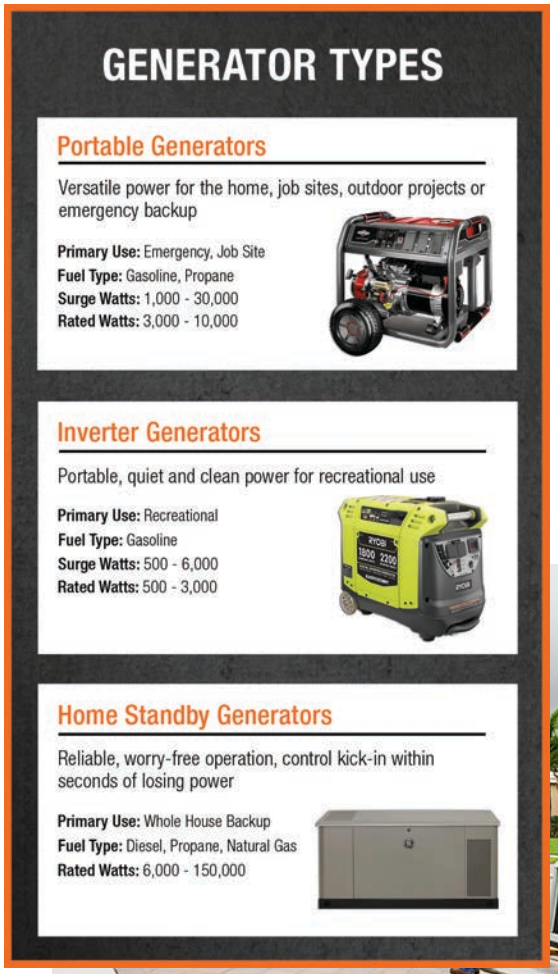
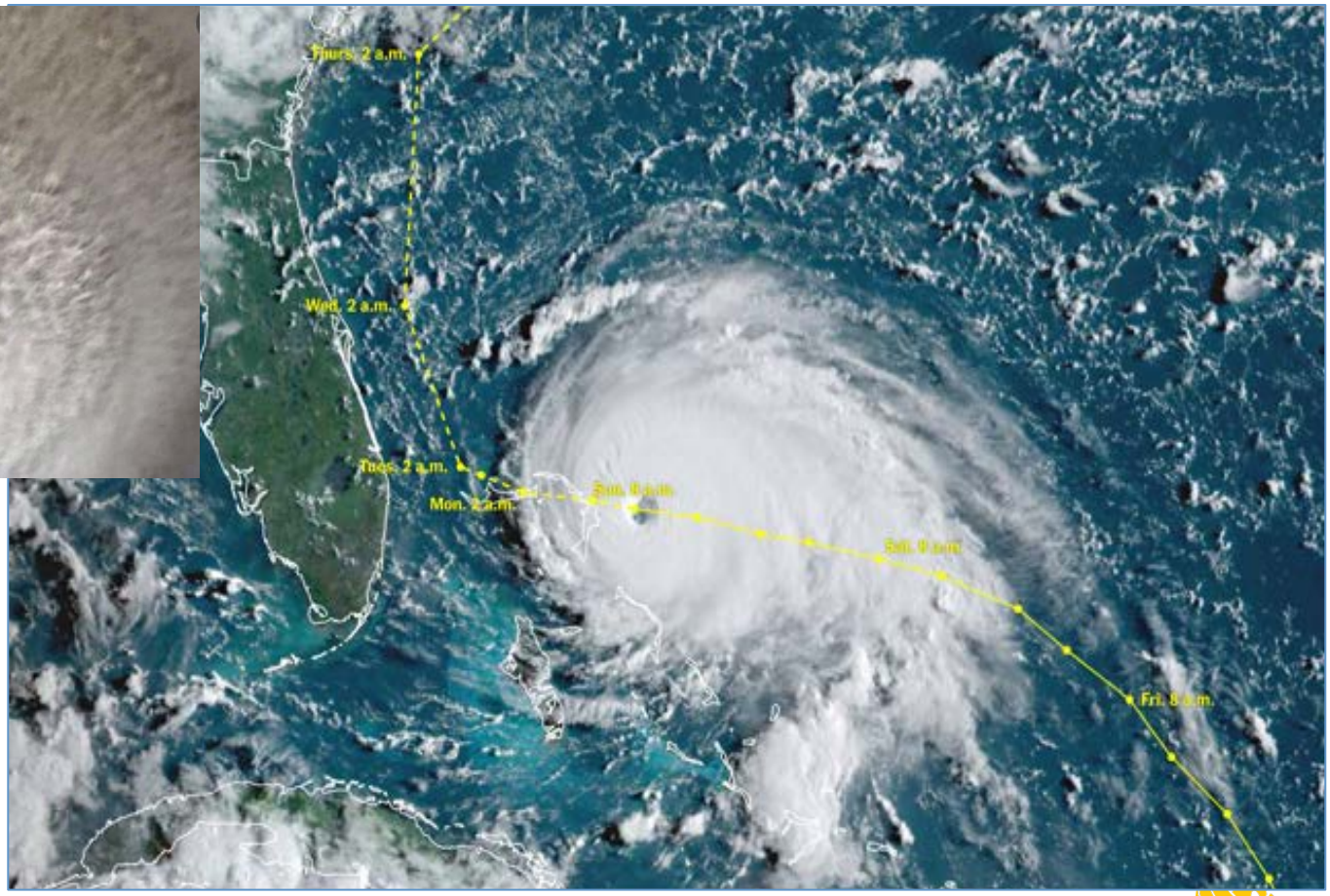
No Power: Conventional Options?

- 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 - 6000W 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!



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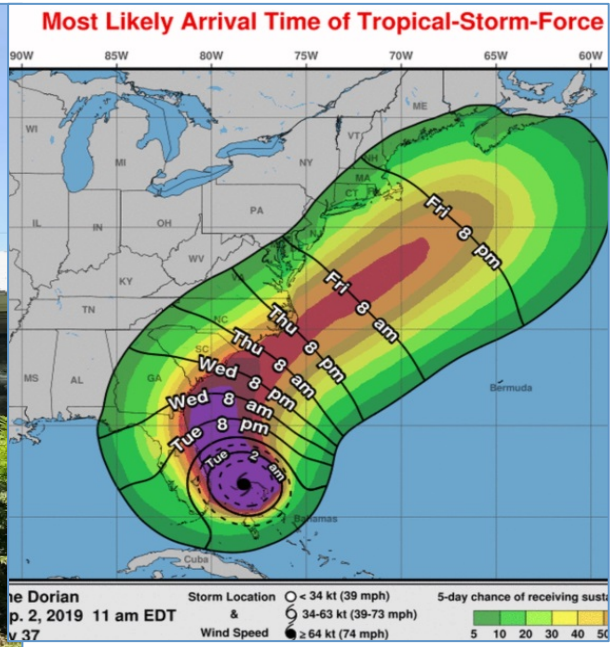
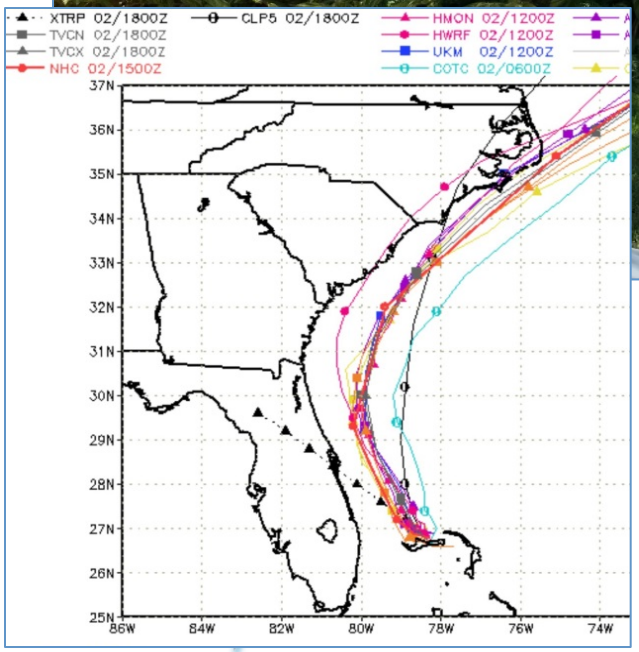
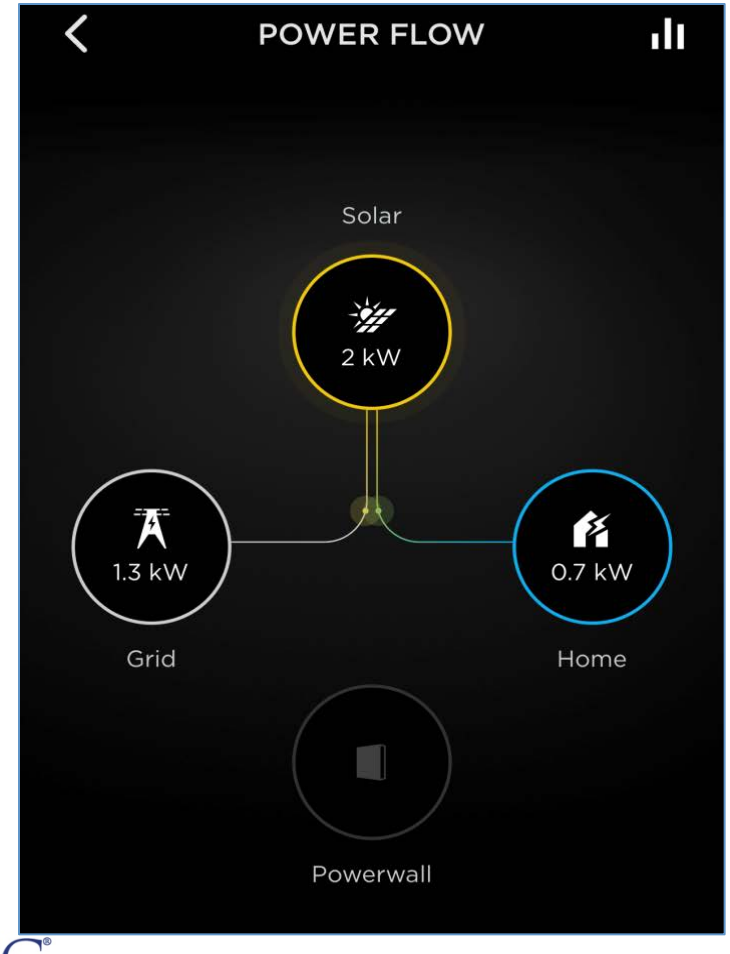
Lisa ties down her boats in the carport with the Tesla Power walls. She drives a Ford Cmax Energi with 20 miles of battery range (Level 2 Charger on the wall)

Our home all shuttered: September 3rd, 2019

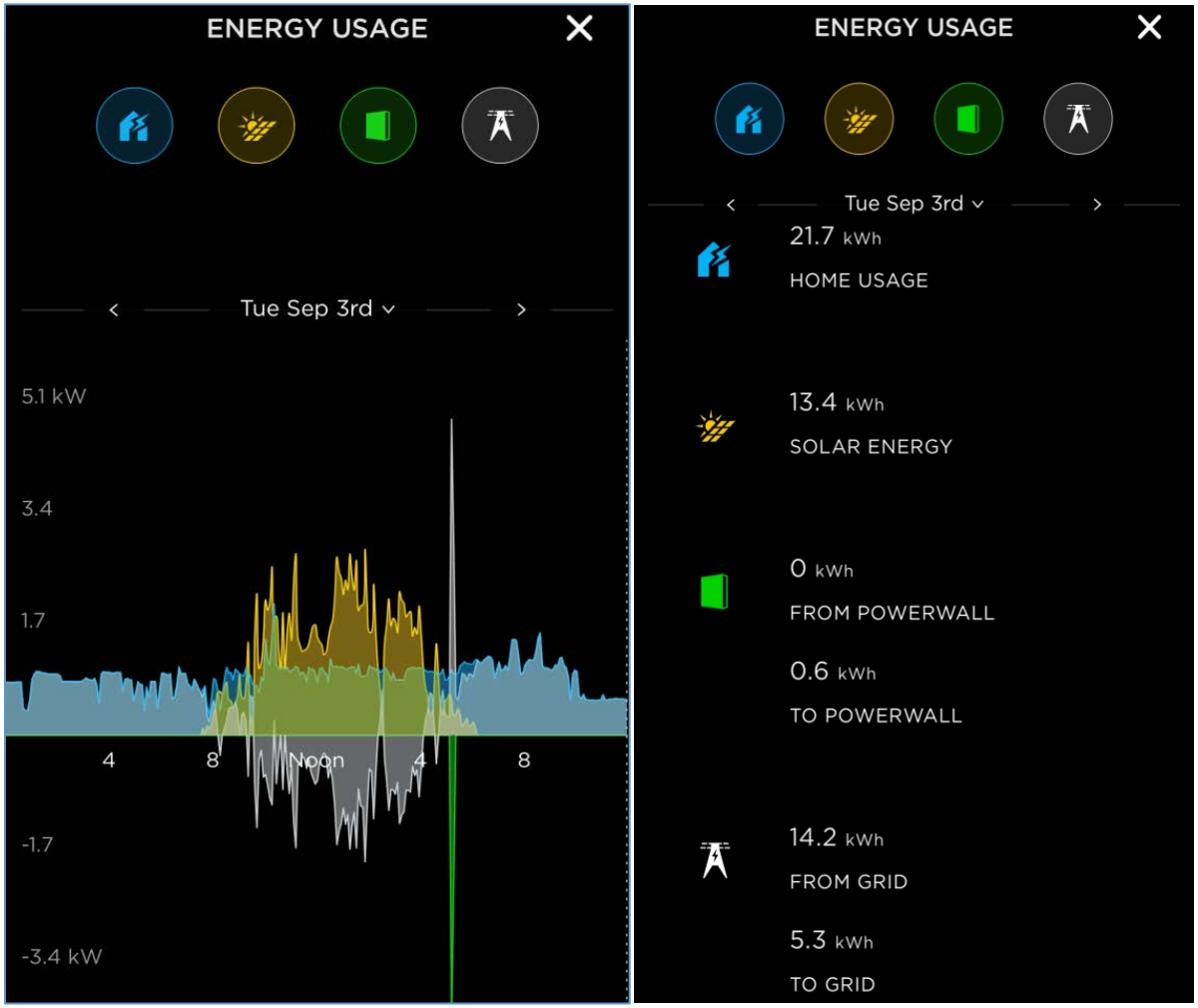




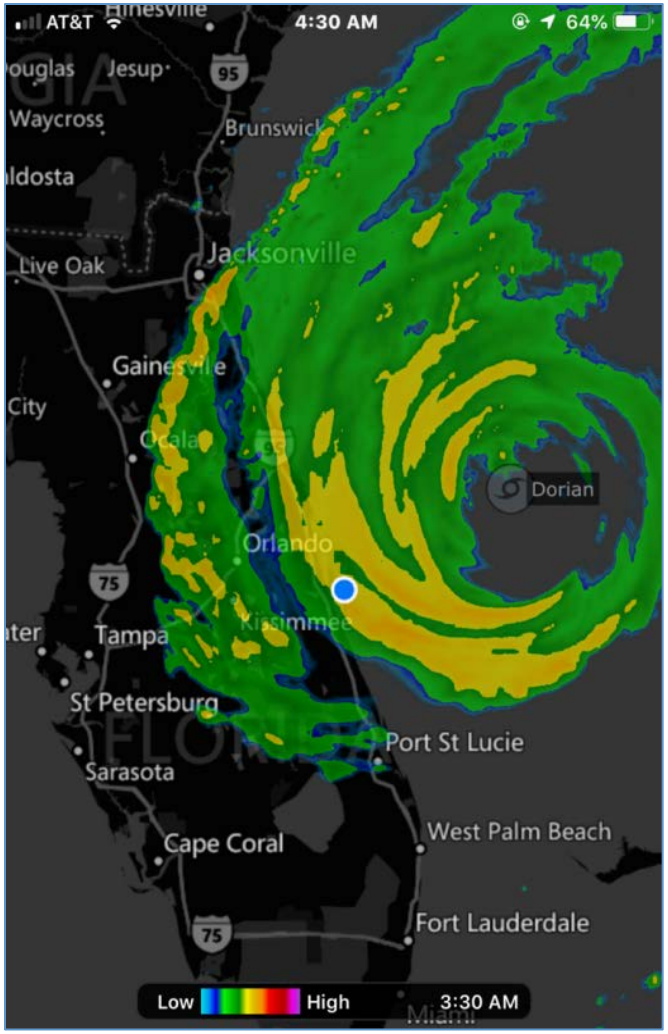
Powerwall App showing 2kW being produced by solar; 1.3 kW going to grid and the house electric load at 0.7 kW

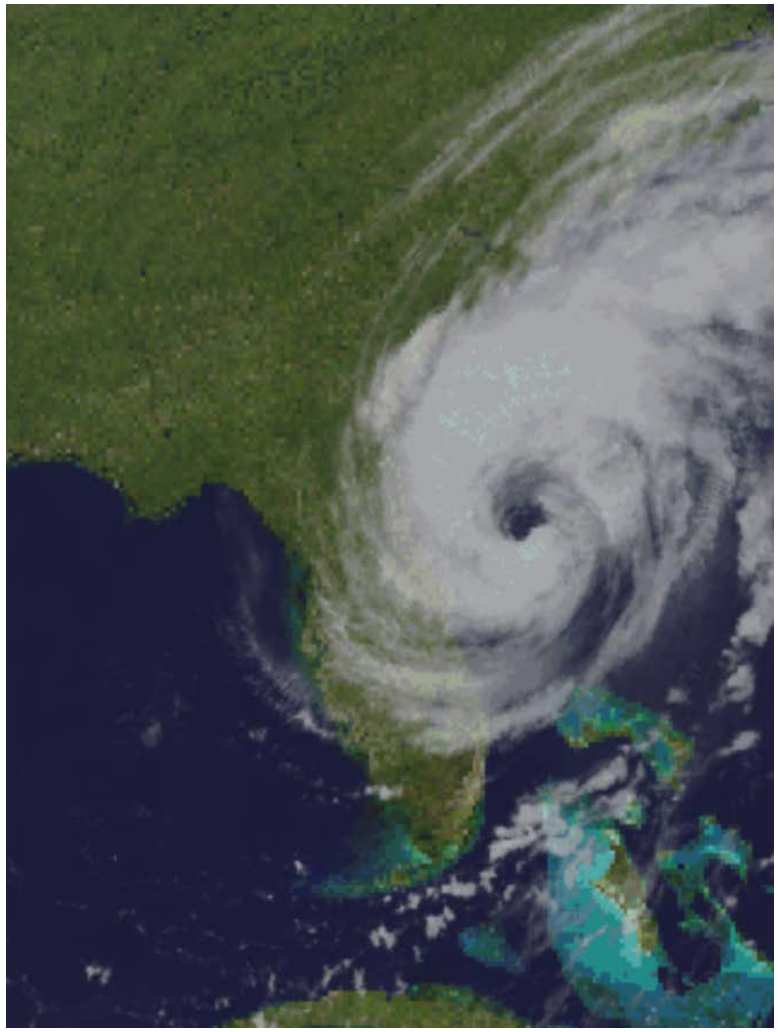


Performance of solar, grid, storage and home energy systems on 3 September as hurricane approached

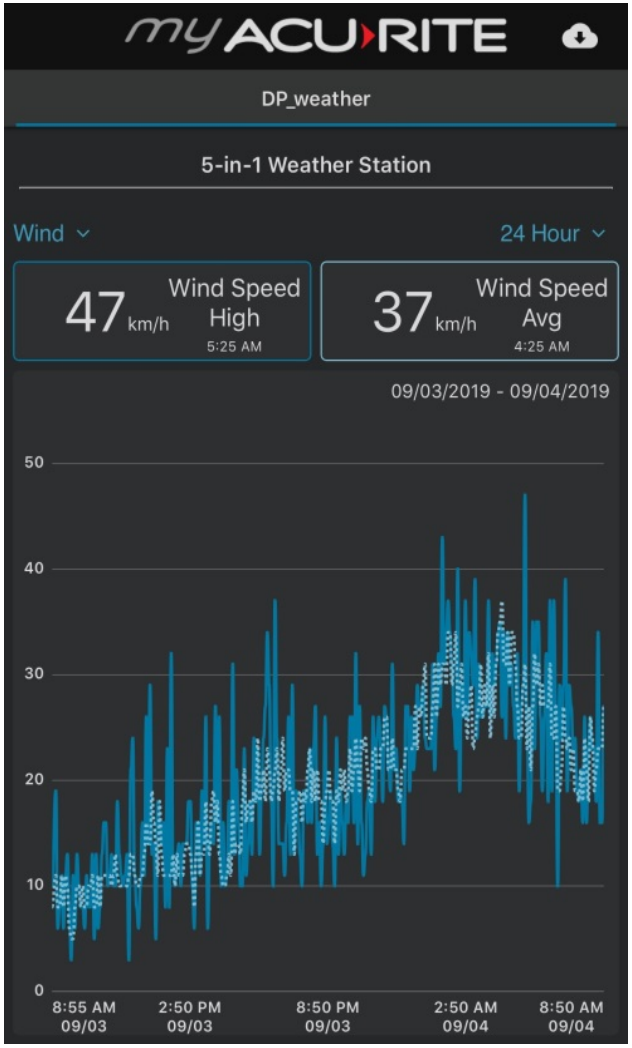


Hurricane Dorian passes by the East Coast of Florida on 4 September 2019. Blue dot marks our location

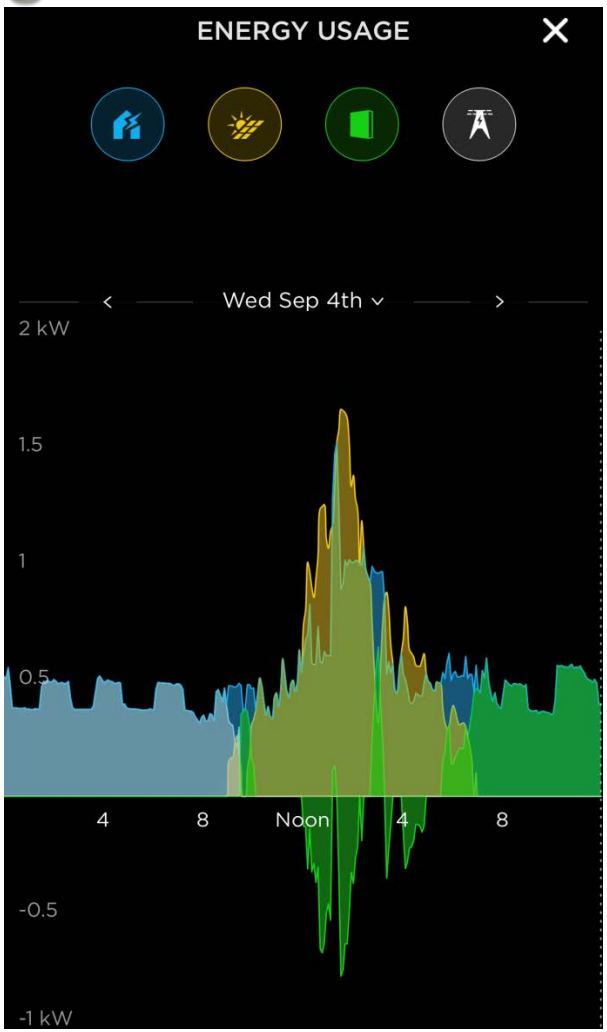


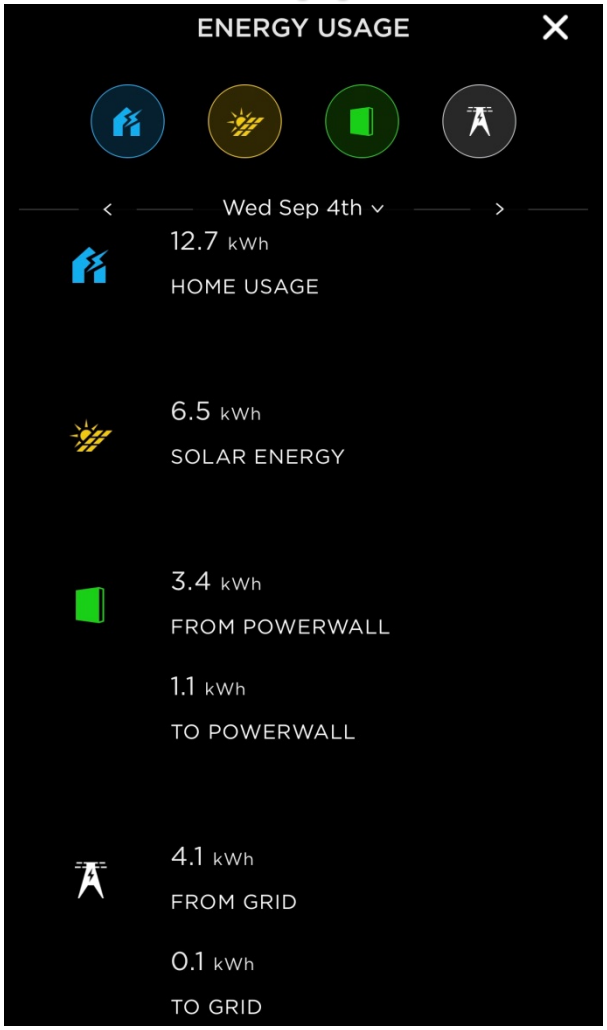


Measured rooftop wind speed on Sept 3-4 as Hurricane Dorian approaches

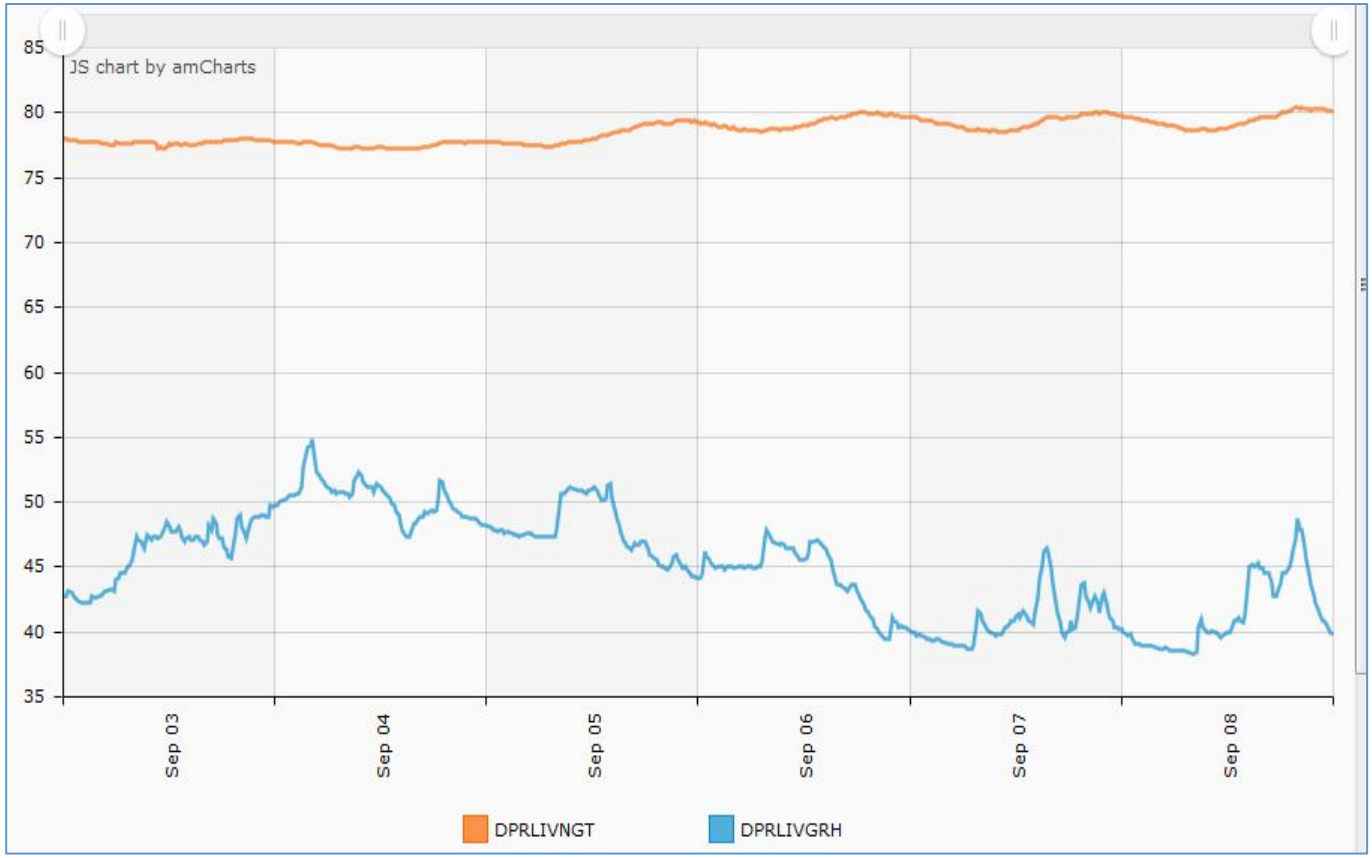


4 Sept. 2019: Performance of solar & Powerwall system during Hurricane Dorian. Closest approach at 4 AM

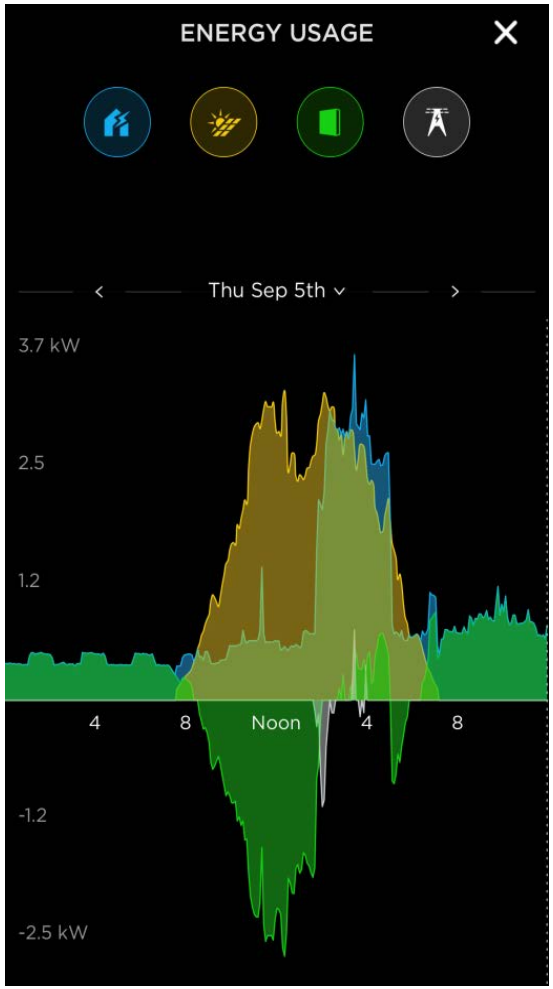


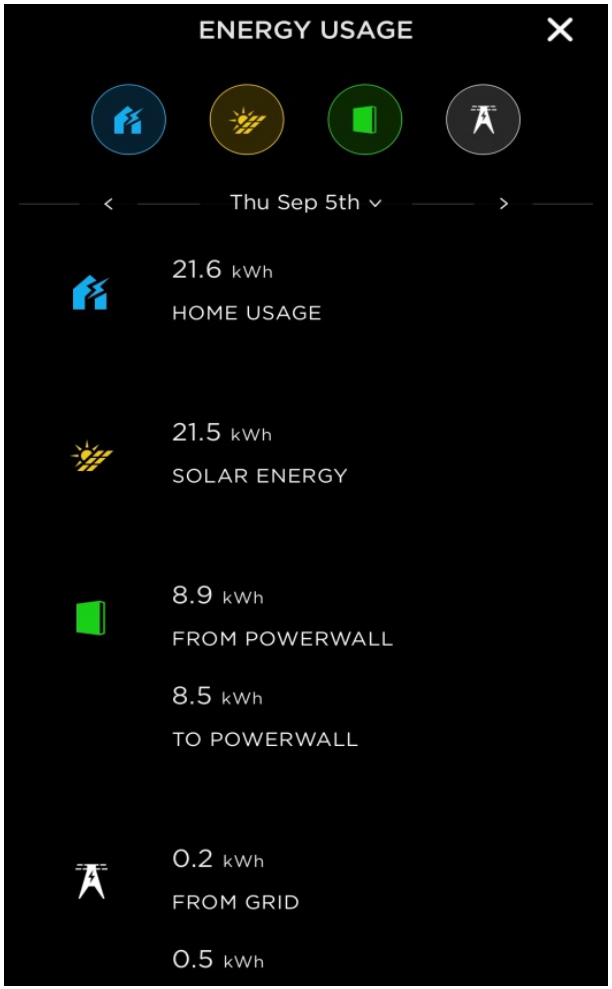


Interior temperature (orange) and relative humidity (blue) inside home from Sept-3rd - 9th, 2019



Performance of solar system, home and Powerwall after storm: September 5th



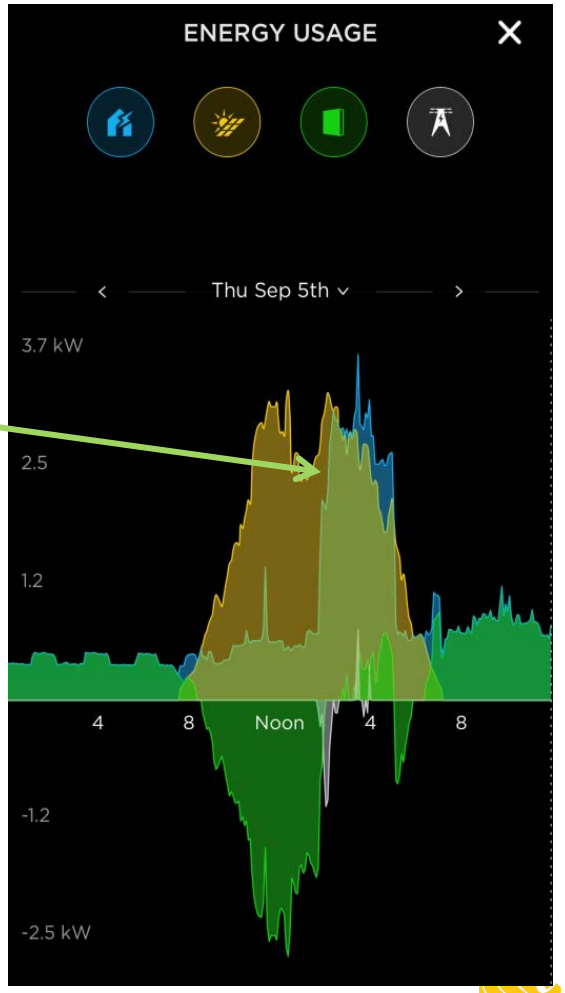


Home, Solar and Powerwall Performance from September 3-8, 2019

Sept Date	Home kWh	Solar kWh	Powerwall kWh		Grid kWh	
			From	To	From	To
3	21.7	13.4	0	0.6	14.2	5.3
4	12.7	6.5	3.4	13.2	4.1	0.1
5	21.6	21.5	8.9	14.4	0.2	0.1
6	25.1	24.4	9.8	9.1	0.2	0.2
7	21.5	24.9	11.0	8.5	0.1	0.5
8	23.7	24.5	12.3	1.1	0.1	0.1

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 nightime cooling
- Helped by efficiency
  - Heat pump water heaters
  - Good windows and insulation= low cooling
- Possible to operate indefinitely by controlling loads

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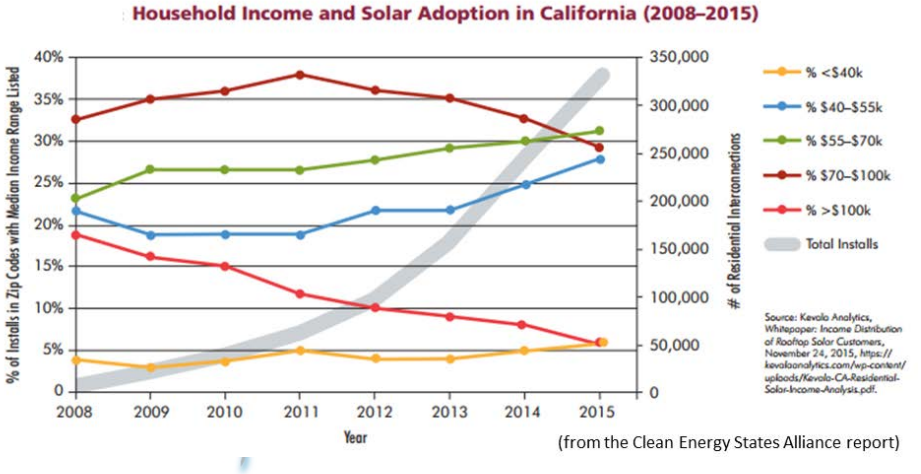
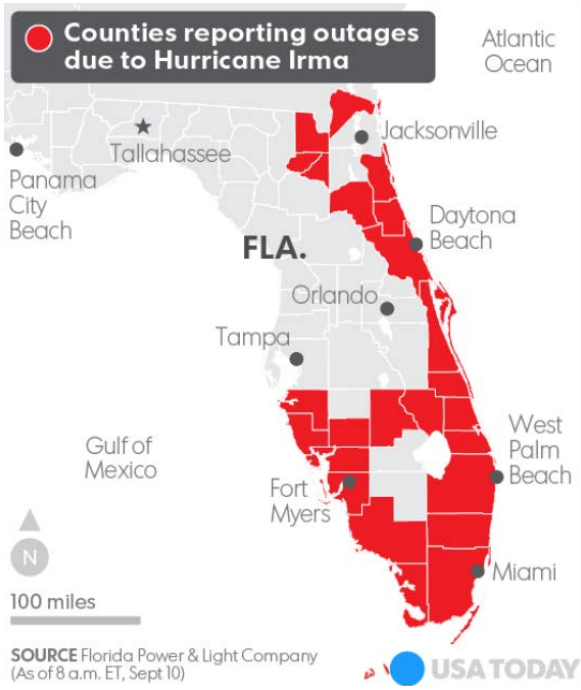
Solar & storage: equity issues

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

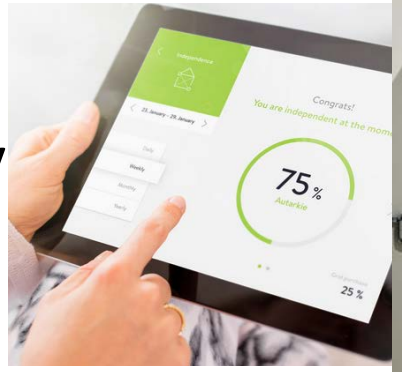


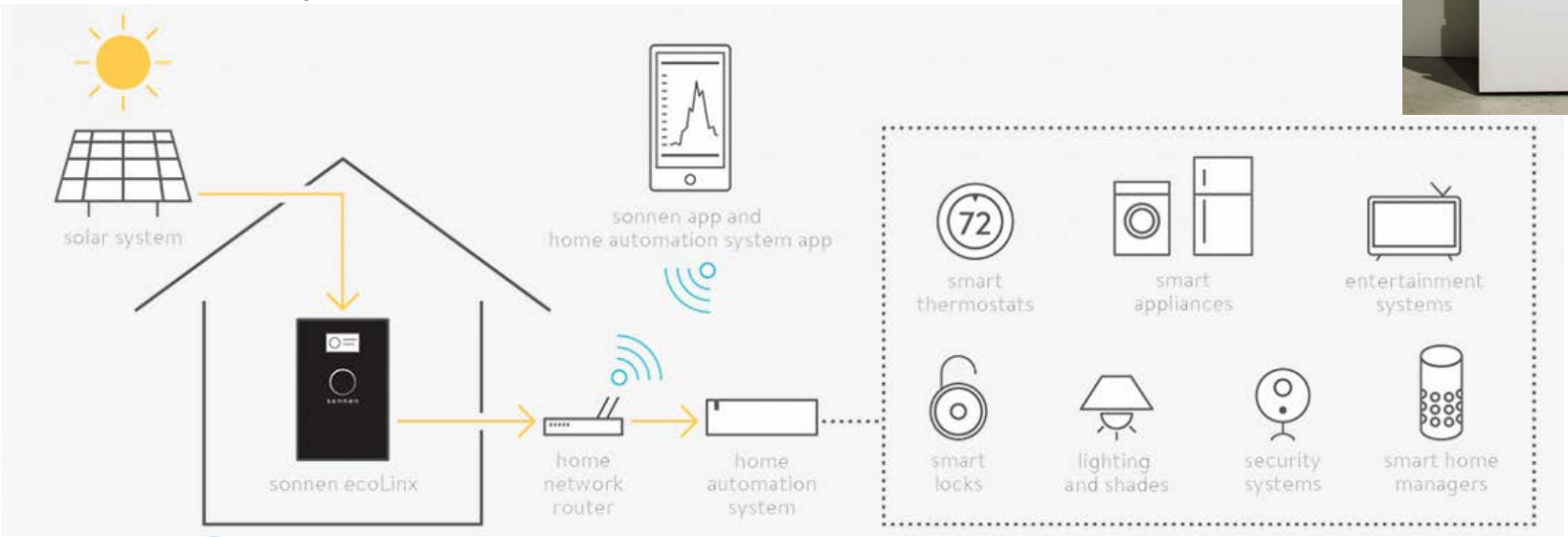
(from the Clean Energy States Alliance report)



Other Electrical Storage Systems

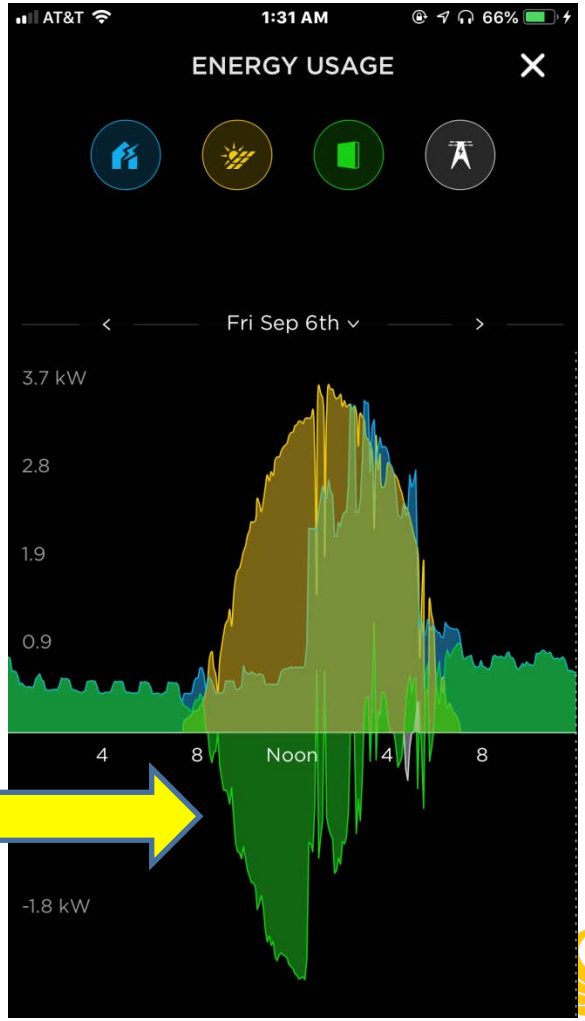
- Other manufacturers & battery chemistries
- Outback: Lead-acid/Li-ion
- *Sonnen*: (*LiFePO4* battery chemistry
  - Crestone & Control4 EMS
- 16 kWh: $22.8K





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

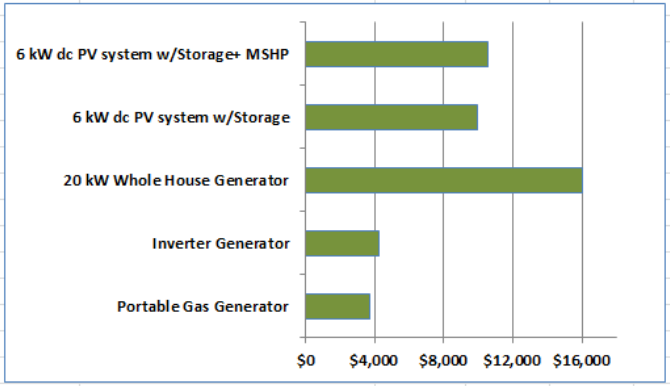


Economics: How do Options Compare?

Estimating the Ten Year Cost of Emergency Household Electric Generation

System Description	Initial Cost $	Annual O&M $	Gasoline Gal	LPG Gal	Gasoline $Cost	LPG $cost	Electric $Savings	Period $O&M	Total Option $Costs
Portable Gas Generator	$750								
Transfer Switch	$500								
(6) 5 gallon gas cans	$150								
Total	**$1,400**	**$25**	**833**	**0**	**$2,083**	**$0**	**0**	$250	**$3,733**
Inverter Generator	$1,500								
Transfer Switch	$500								
(5) 5 gallon gas cans	$125								
Total	**$2,125**	**$50**	**667**	**0**	**$1,667**	**$0**	**0**	**$500**	**$4,292**
20 kW Whole House Generator	$5,300								
30 gallon LPG Tank	$450								
Installation	$3,700								
Total	**$9,450**	**$250**	**0**	**967**	**$0**	**$4,108**	**0**	**$2,500**	**$16,058**
6 kW dc PV system w/Storage	$12,000								
27 kWh Battery Storage	$18,000								
Subtotal	$30,000								
Less Tax Credit	$9,000.0								
Final Cost	**$21,000.0**	**$75**	**0**	**0**	**$0**	**$0**	**($11,820)**	**$750**	**$9,930**
6 kW dc PV system w/Storage+ MSHP	$12,000								
27 kWh Battery Storage	$18,000								
Subtotal	$30,000								
Less Tax Credit	$9,000								
Supplemental Mini-SplitHPump (MSHP)	$3,500								
Final Cost	**$24,500**	**$75**	**0**	**0**	**$0**	**$0**	**($14,700)**	**$750**	**$10,550**

Analysis & System Parameters	
Analysis period (yrs)	10
Hurricane Events Frequency	3
Period of Interruption (Days)	5
$Gas/gallon	$2.50
$LGP/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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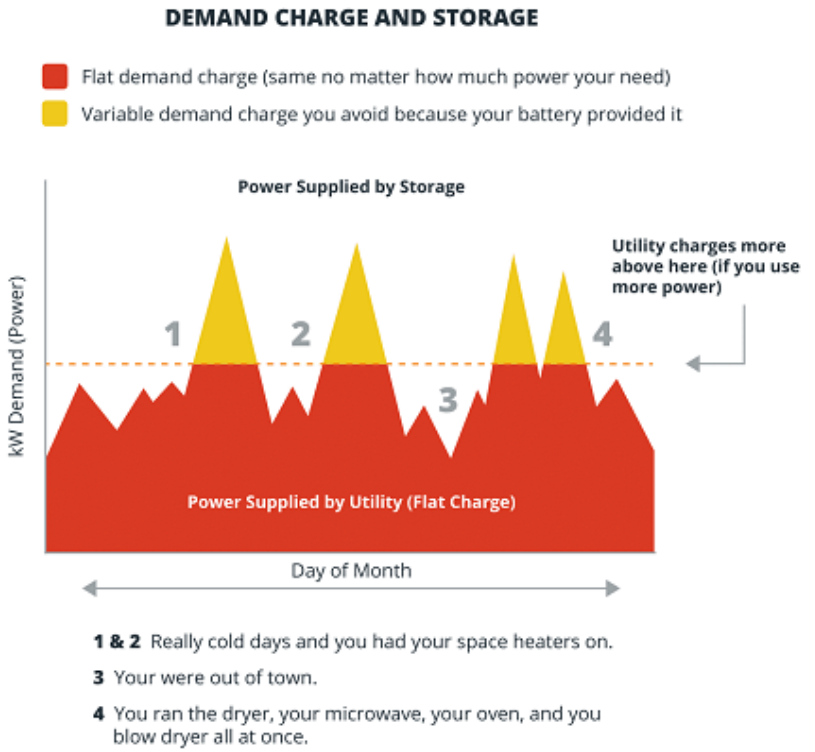
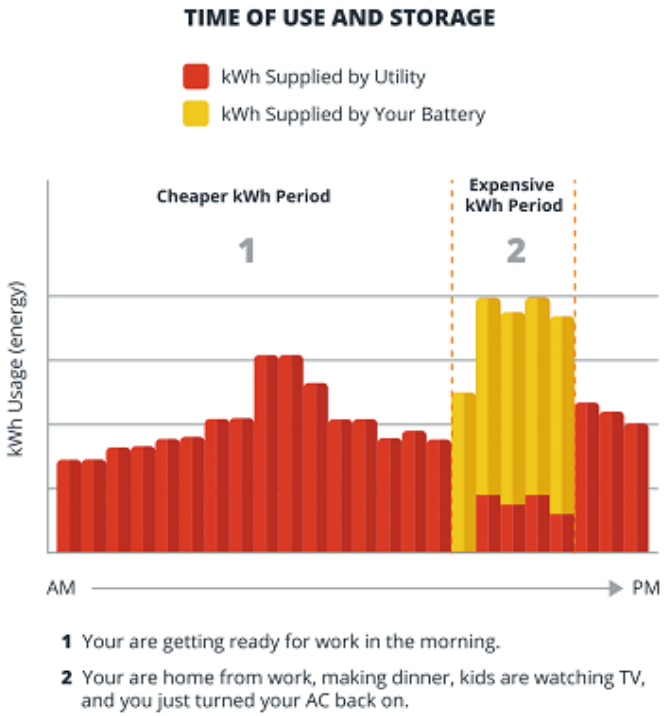
What's Needed Going Ahead?

- Storage costs to fall significantly, but fixed install costs hi ((~$3-4K)
  - Complex electrical challenge (sub-panel)
  - *One sizes fits one*
- Emergency use of car battery (*Vehicle-to-House)*
- Utility programs to address equity issues

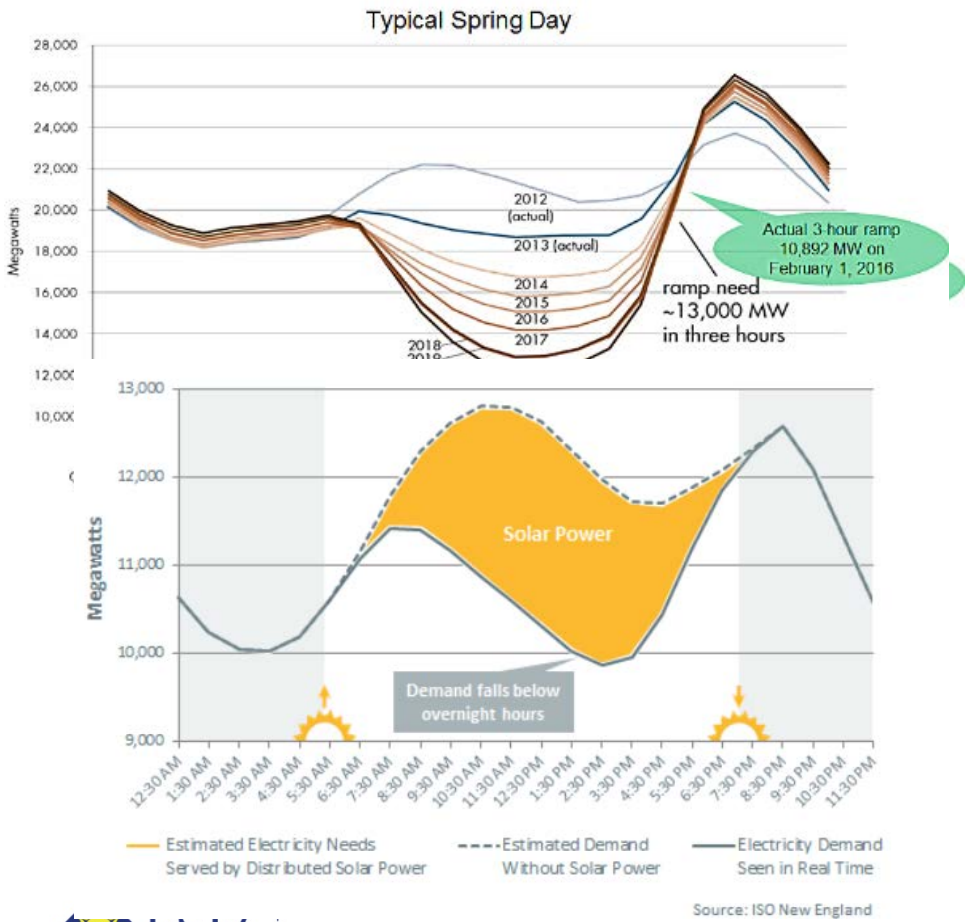
Solar & Electrical Storage: Value

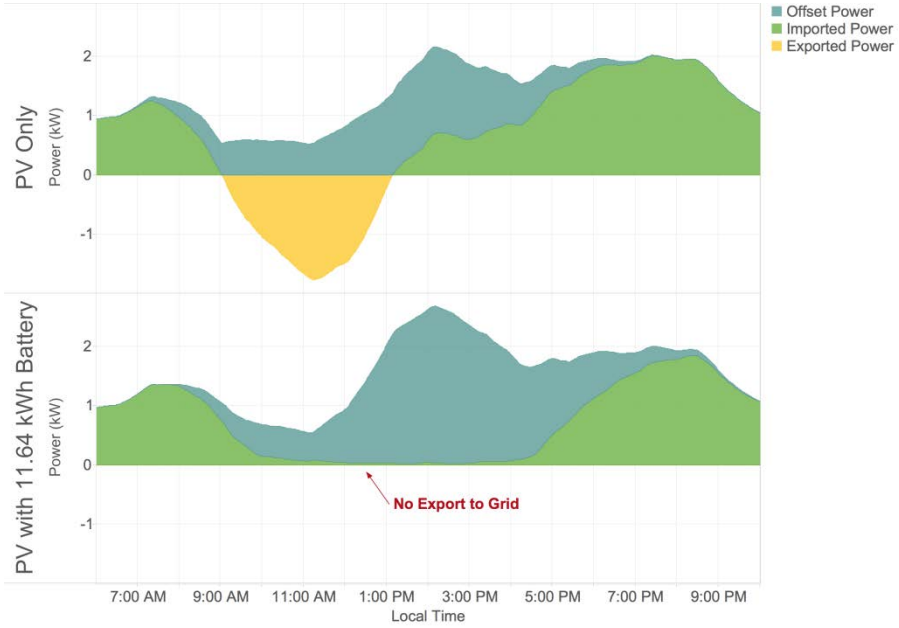




- Demand Charges
- Time of Use (TOU) rates

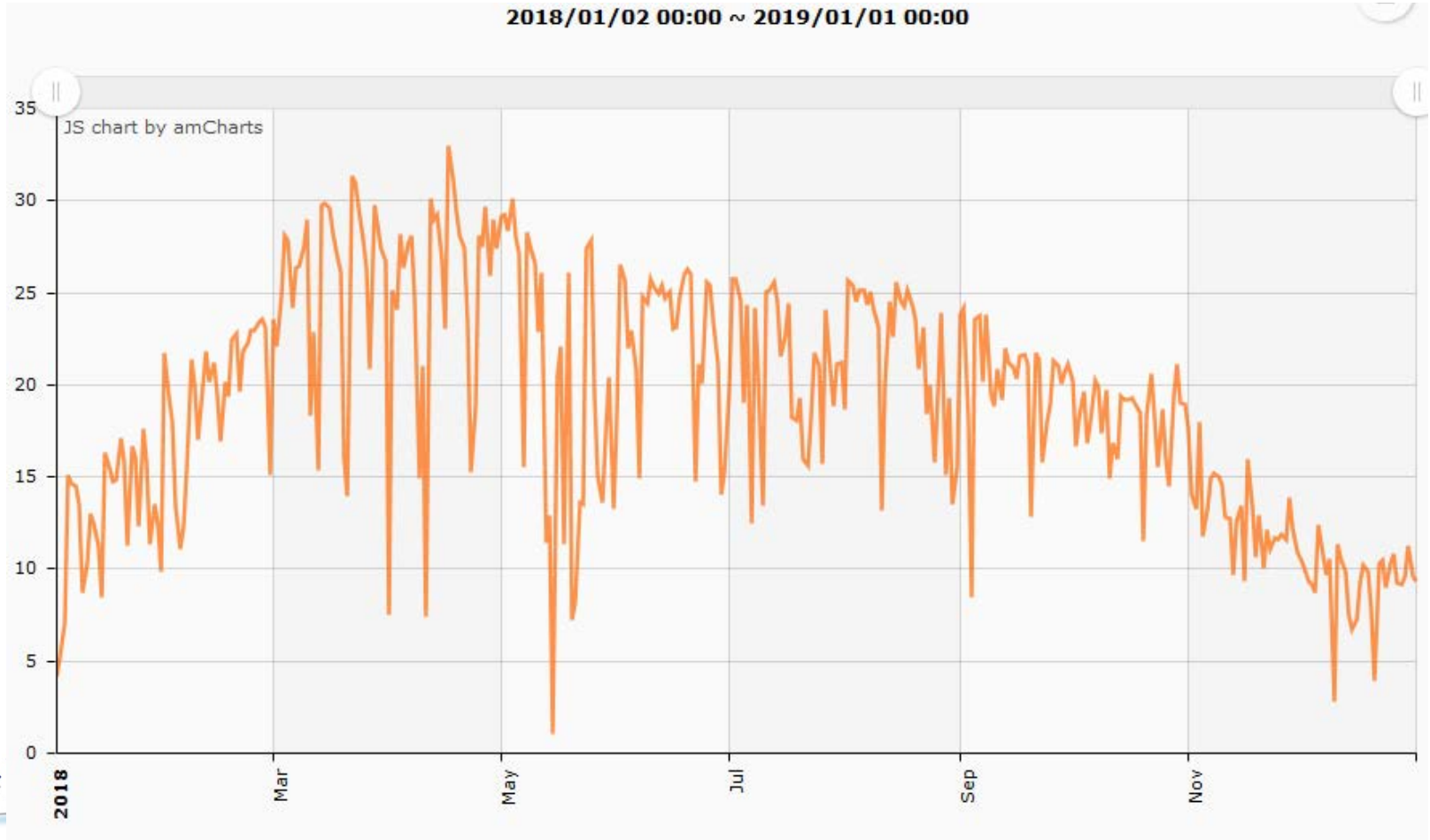
What Duck Curve?
Self Consumption Mode



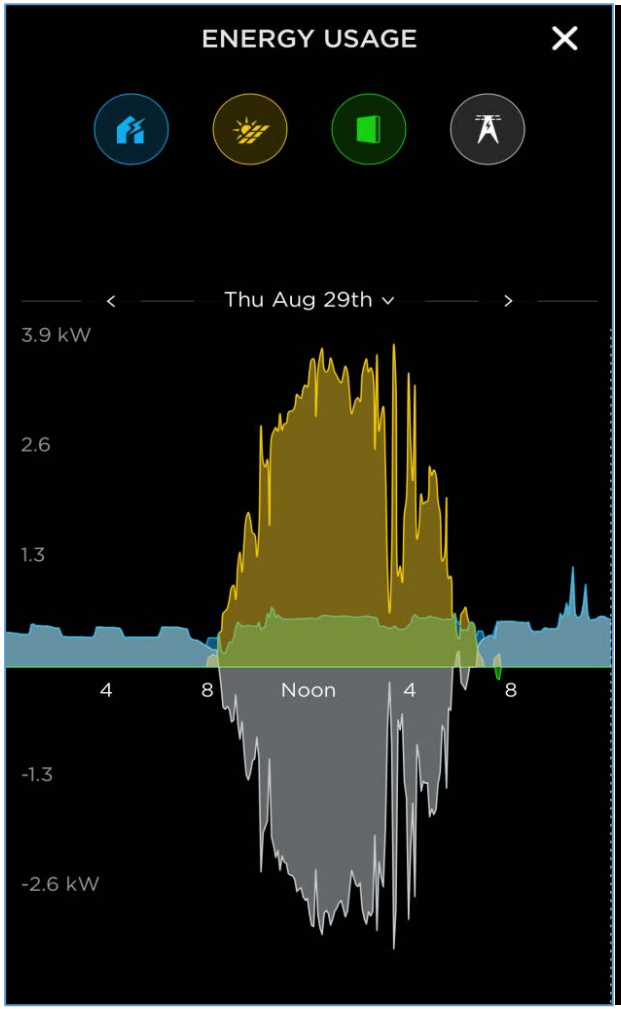


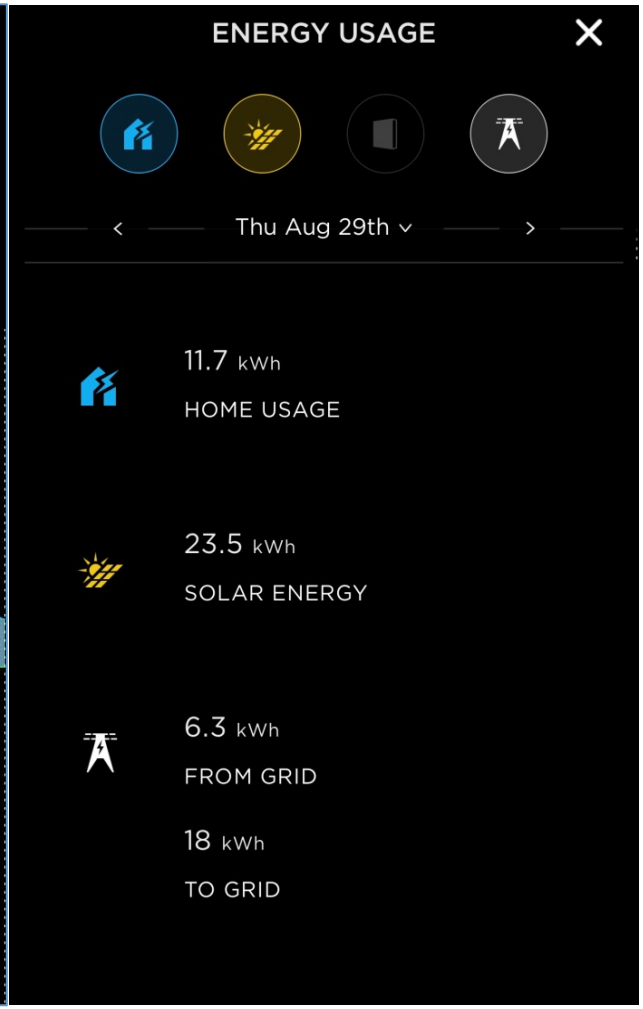
How Much Solar Each Day?

- ~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