



**FLORIDA SOLAR ENERGY CENTER\***

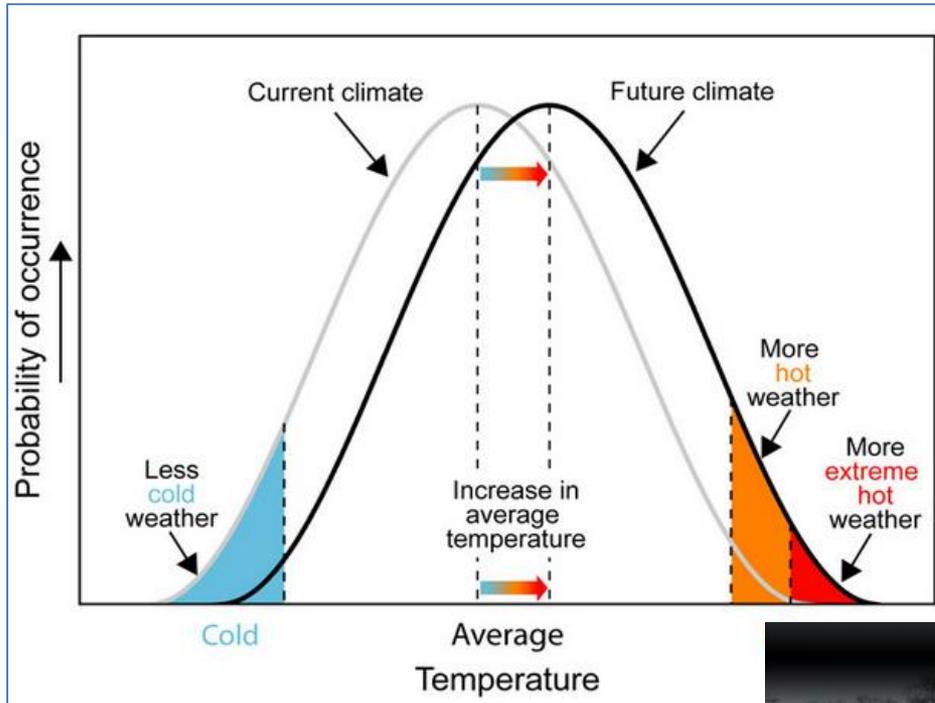
*Creating Energy Independence*

# **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

## Hurricanes in a warming world...



# 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



# Problems & Headaches



# Installation of two Tesla Powerwall 2s on 22 May 2019

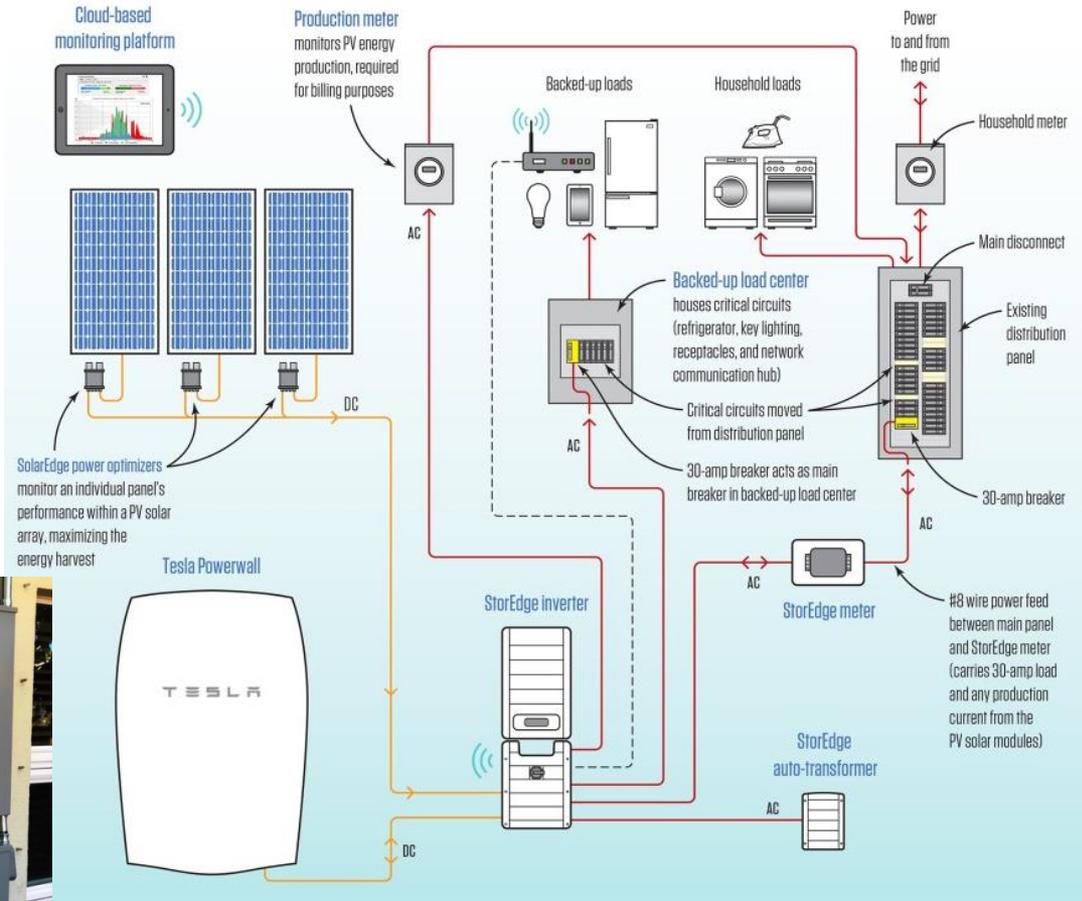
## 13.5 kWh ea. = 27 kWh Storage



# 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 - 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

## GENERATOR TYPES

### Portable Generators

Versatile power for the home, job sites, outdoor projects or emergency backup

**Primary Use:** Emergency, Job Site  
**Fuel Type:** Gasoline, Propane  
**Surge Watts:** 1,000 - 30,000  
**Rated Watts:** 3,000 - 10,000



### Inverter Generators

Portable, quiet and clean power for recreational use

**Primary Use:** Recreational  
**Fuel Type:** Gasoline  
**Surge Watts:** 500 - 6,000  
**Rated Watts:** 500 - 3,000



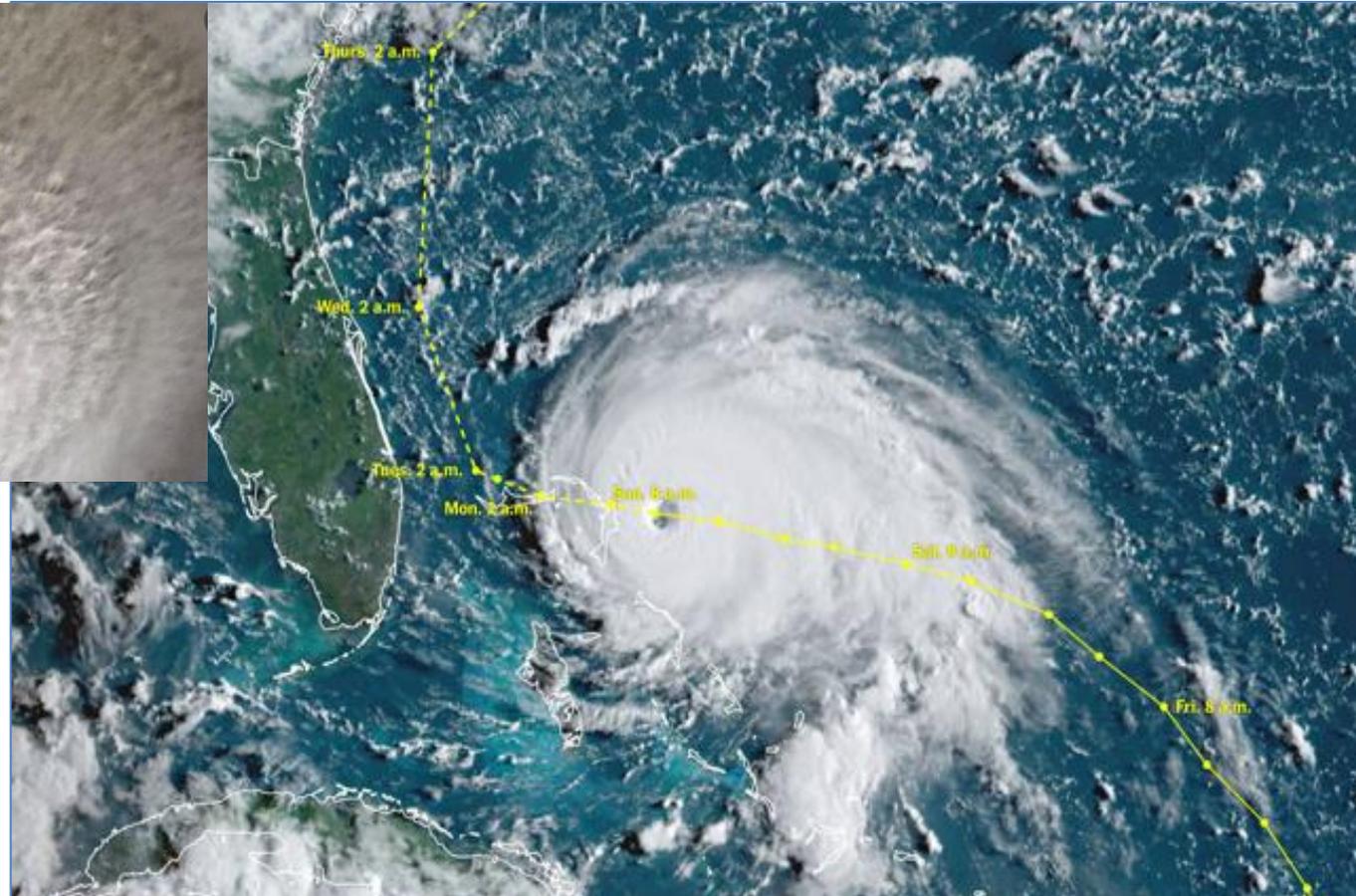
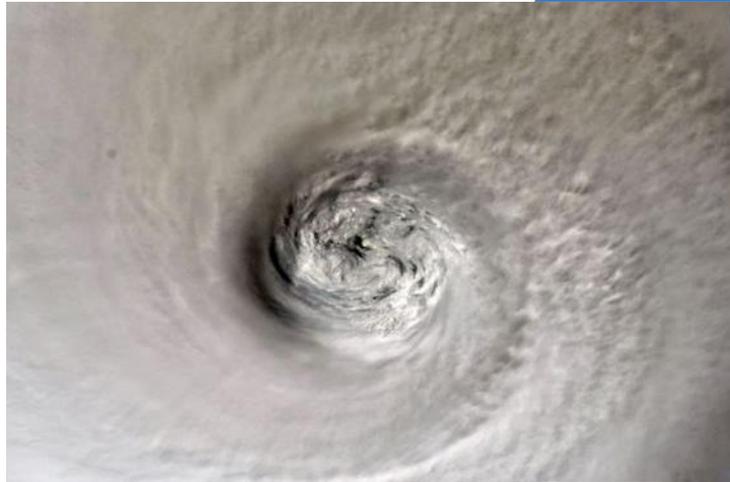
### Home Standby Generators

Reliable, worry-free operation, control kick-in within seconds of losing power

**Primary Use:** Whole House Backup  
**Fuel Type:** Diesel, Propane, Natural Gas  
**Rated Watts:** 6,000 - 150,000



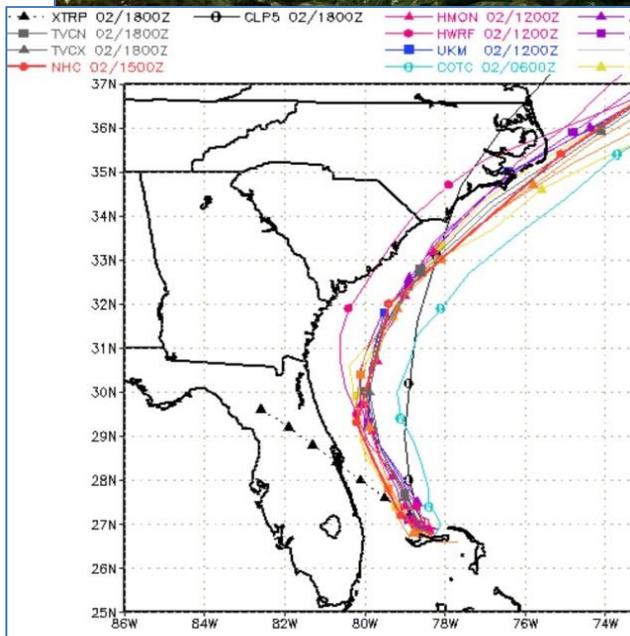
# Wanted tropical depression to test, not Category 5 Dorian!



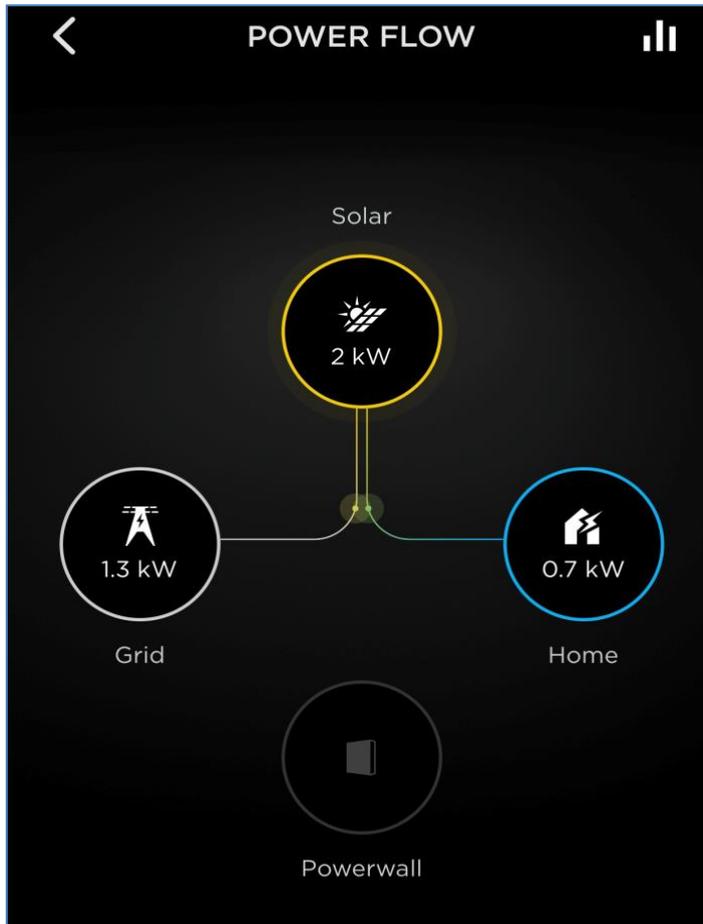
**Lisa ties down her boats in the carport with the Tesla Power walls. She drives a Ford Cmax Energi with 20 miles of battery range (Level 2 Charger on the wall)**



# Our home all shuttered: September 3<sup>rd</sup>, 2019



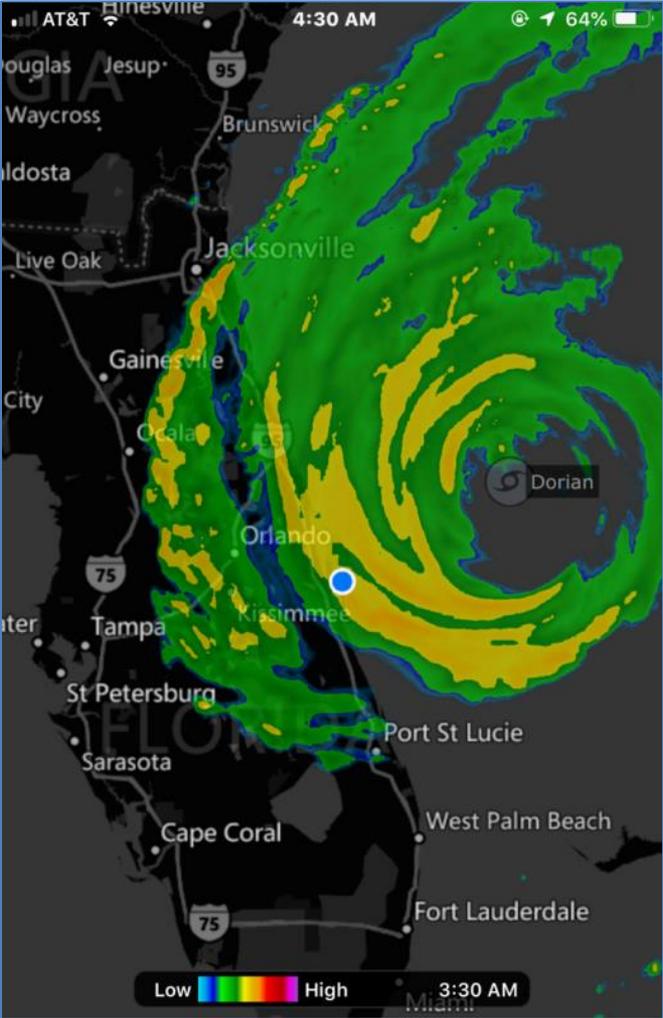
# Powerwall App showing 2kW being produced by solar; 1.3 kW going to grid and the house electric load at 0.7 kW



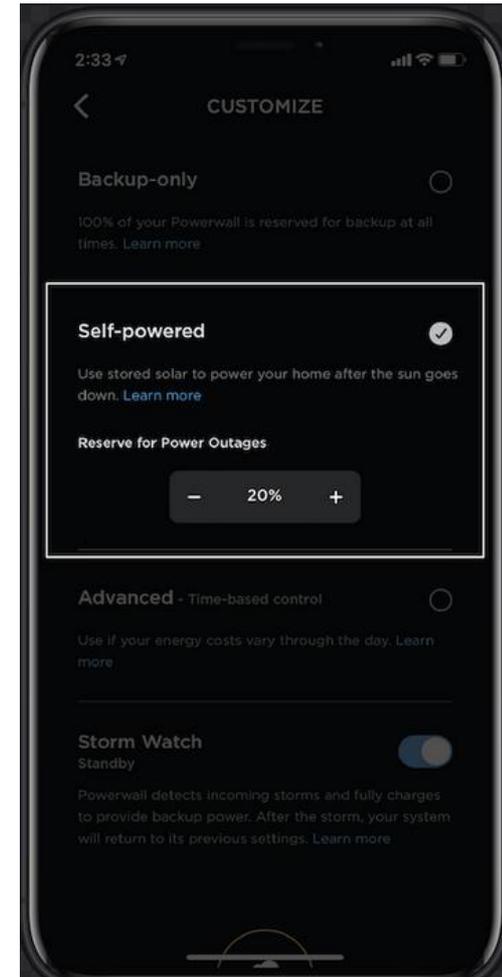
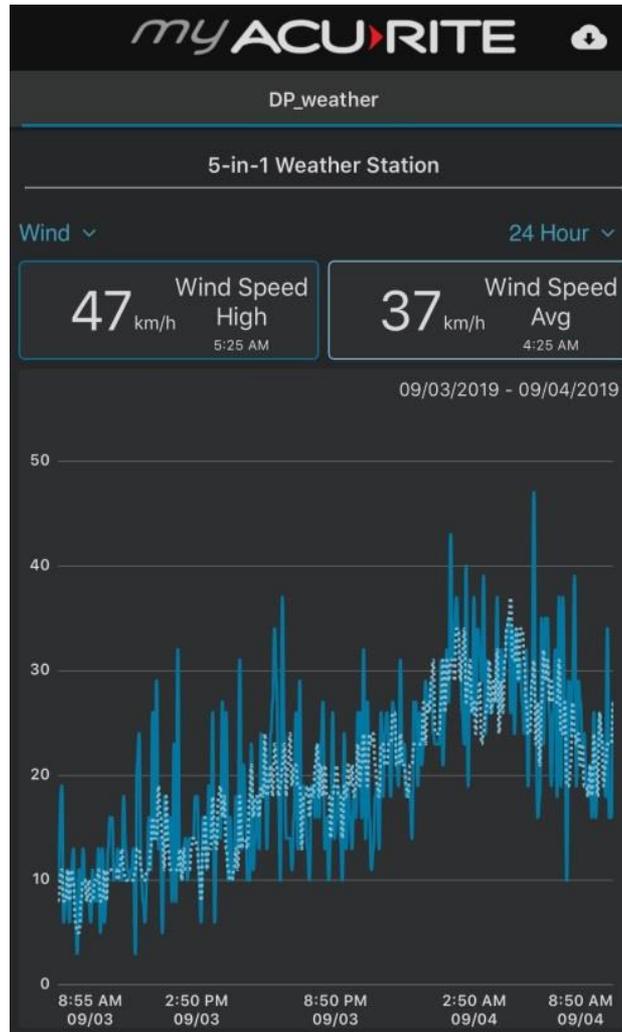
# Performance of solar, grid, storage and home energy systems on 3 September as hurricane approached



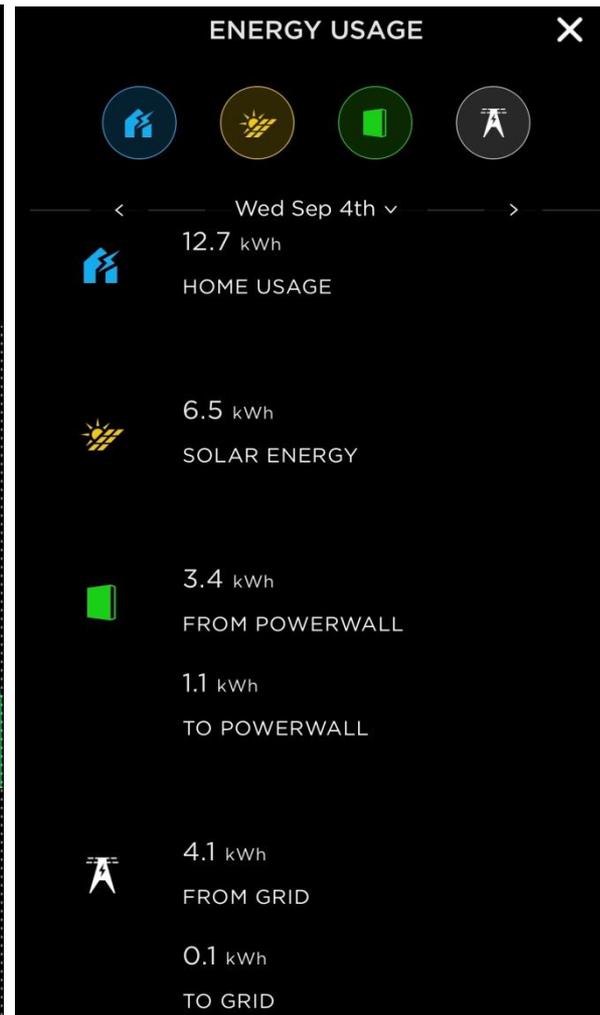
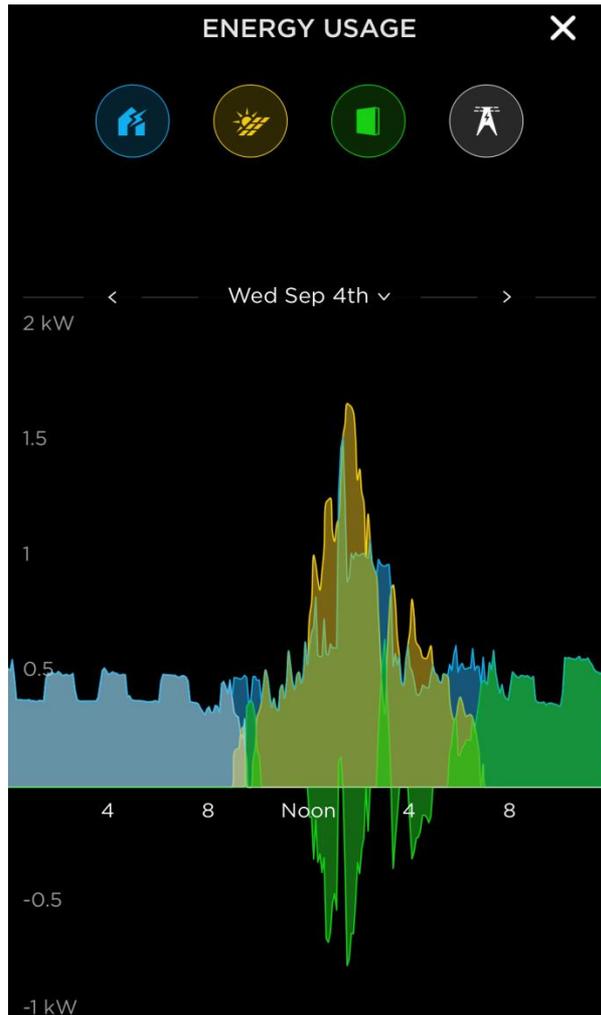
# Hurricane Dorian passes by the East Coast of Florida on 4 September 2019. Blue dot marks our location



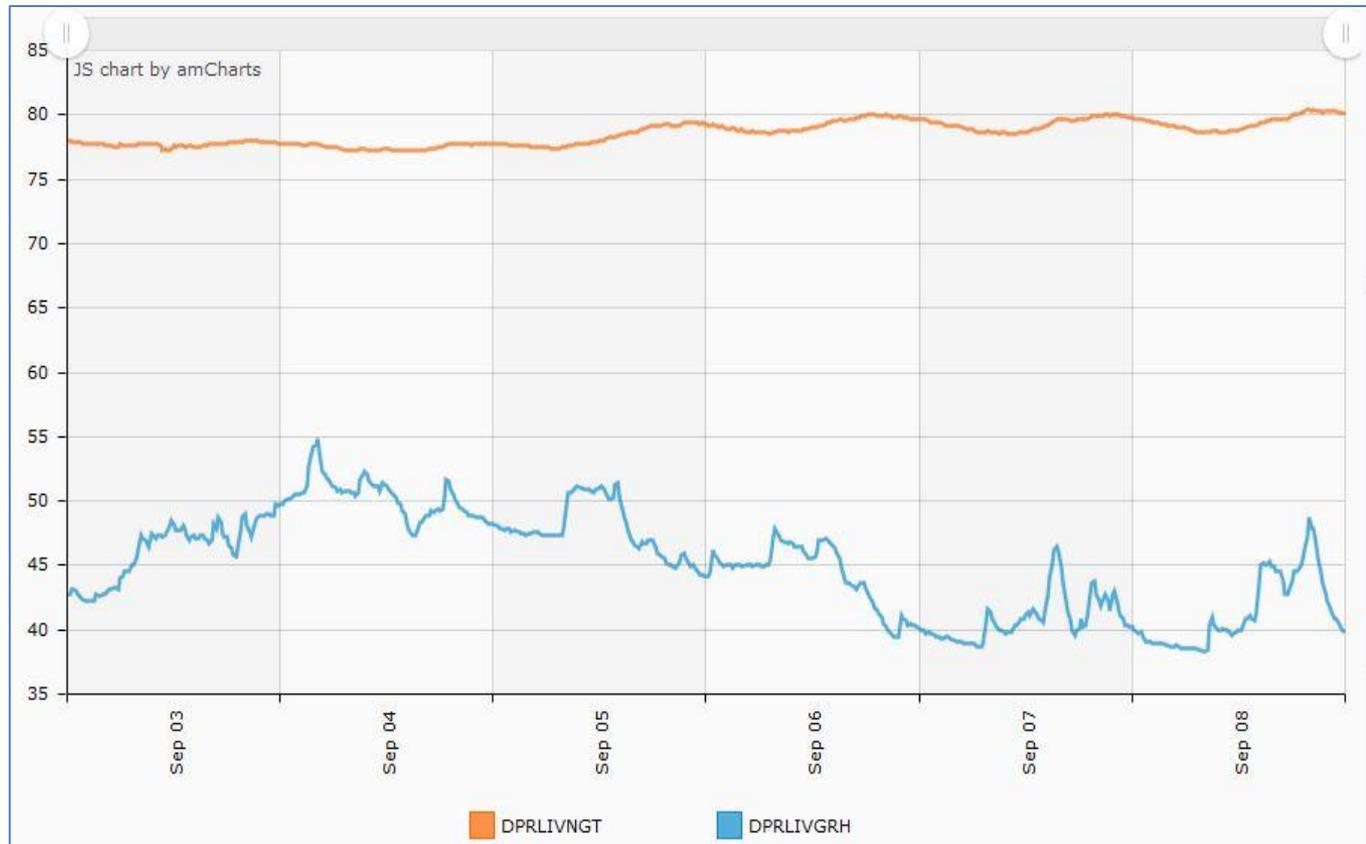
# Measured rooftop wind speed on Sept 3-4 as Hurricane Dorian approaches



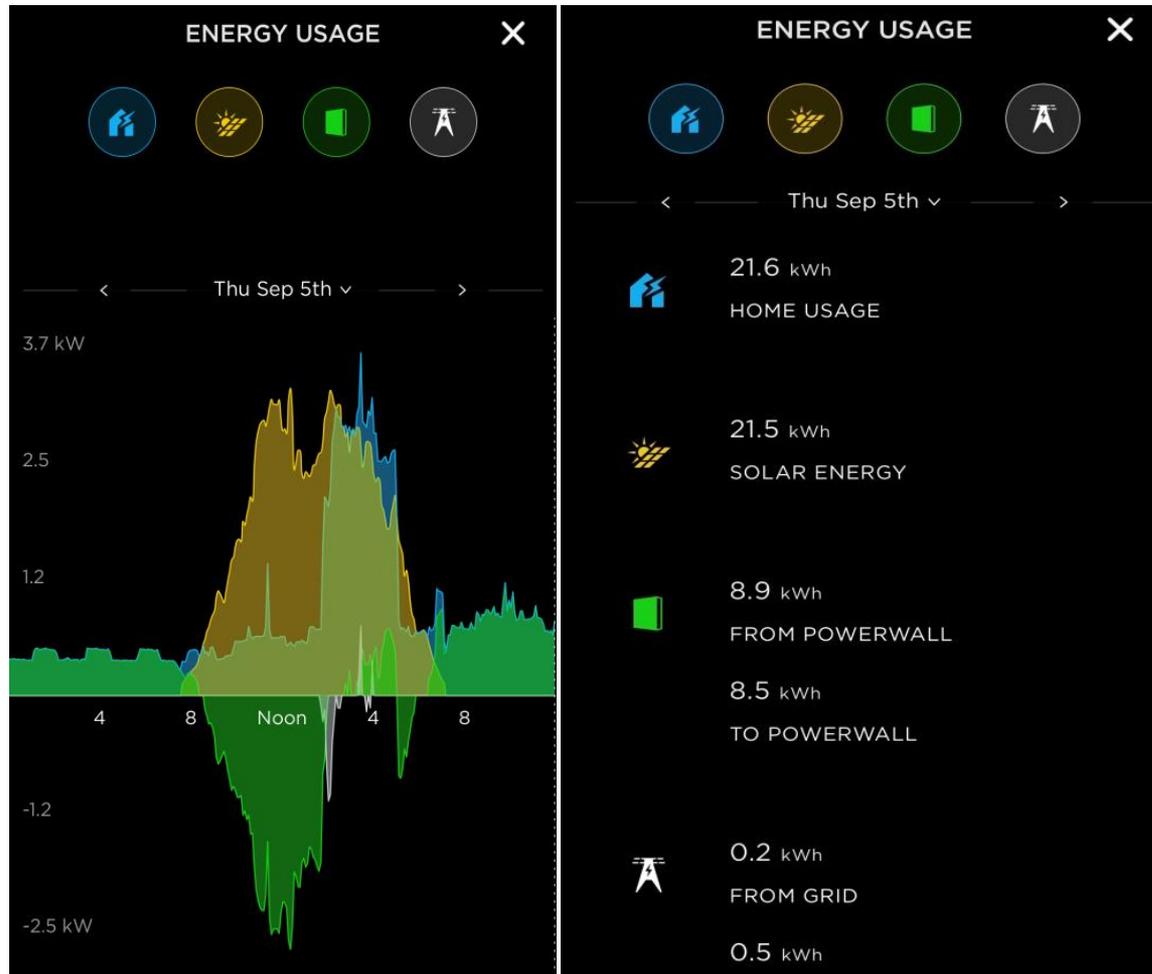
# 4 Sept. 2019: Performance of solar & Powerwall system during Hurricane Dorian. Closest approach at 4 AM



# 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



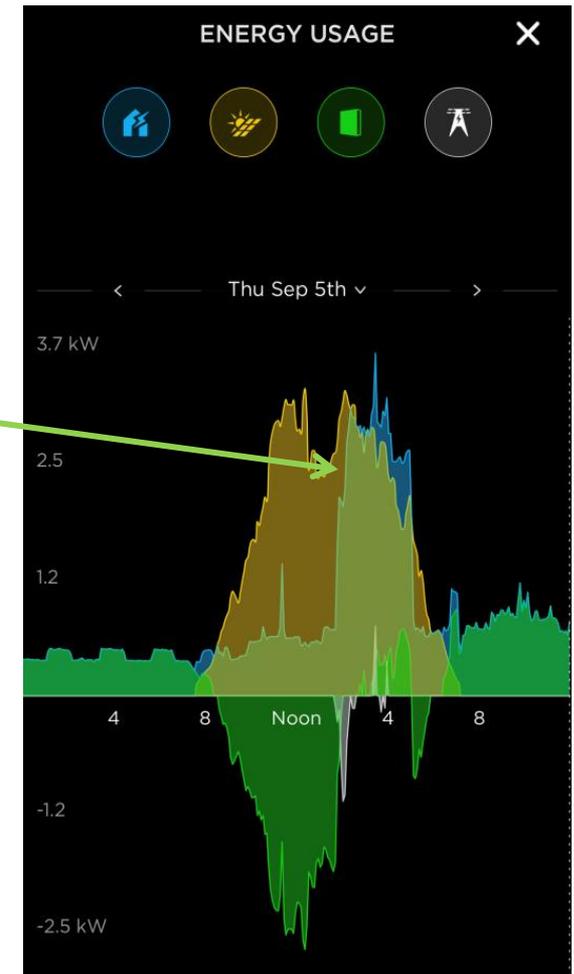
# Home, Solar and Powerwall Performance from September 3-8, 2019

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 + 2<sup>nd</sup>  
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

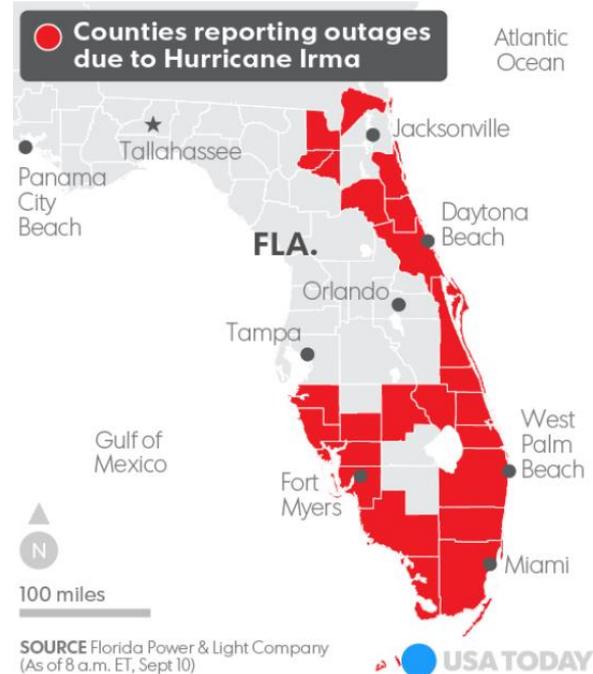
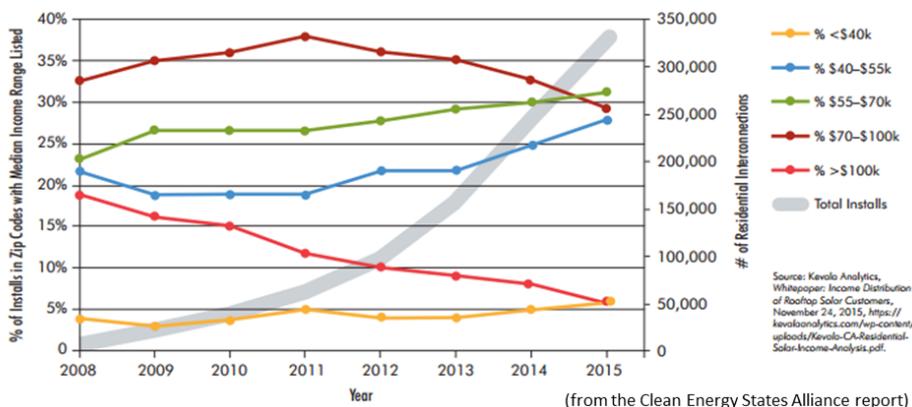


# Solar & storage: equity issues

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

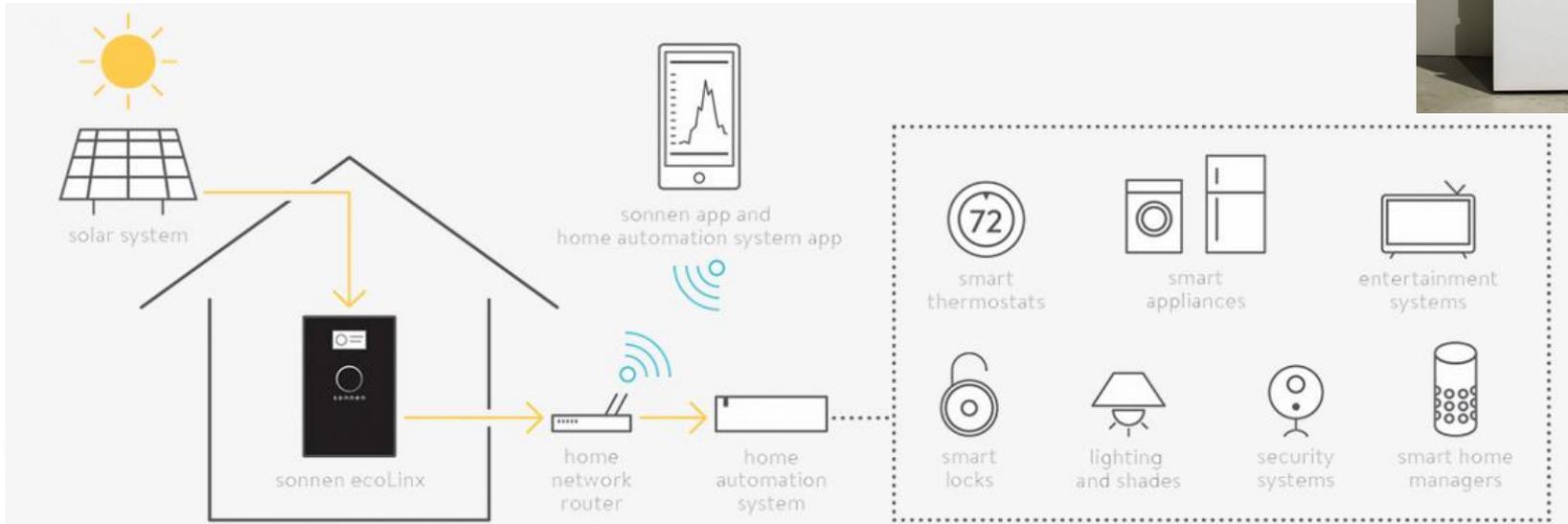


Household Income and Solar Adoption in California (2008–2015)



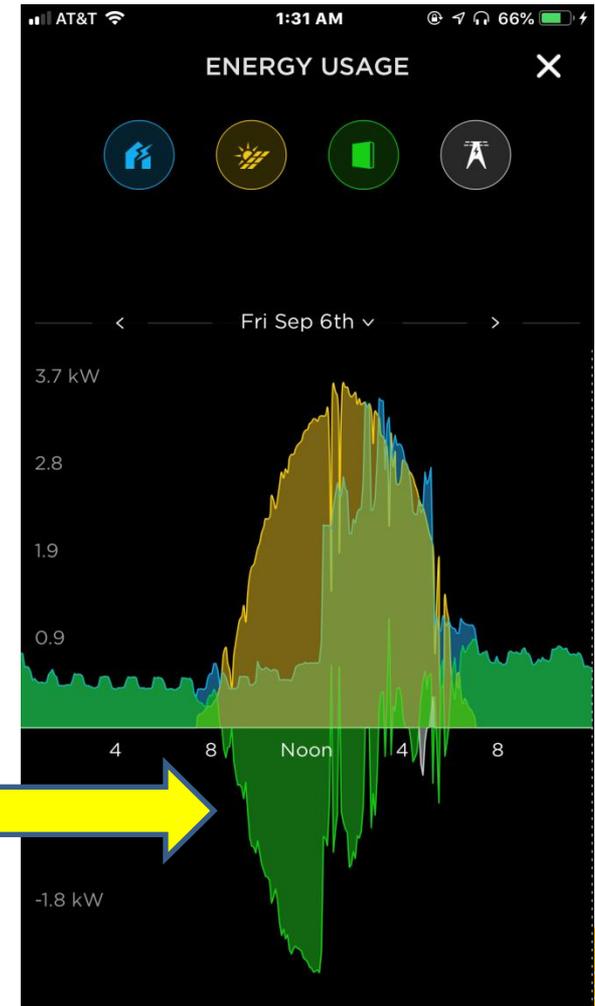
# Other Electrical Storage Systems

- Other manufacturers & battery chemistries
- Outback: Lead-acid/Li-ion
- *Sonnen*: (LiFePO<sub>4</sub> battery chemistry)
  - Crestone & Control4 EMS
- 16 kWh: \$22.8K



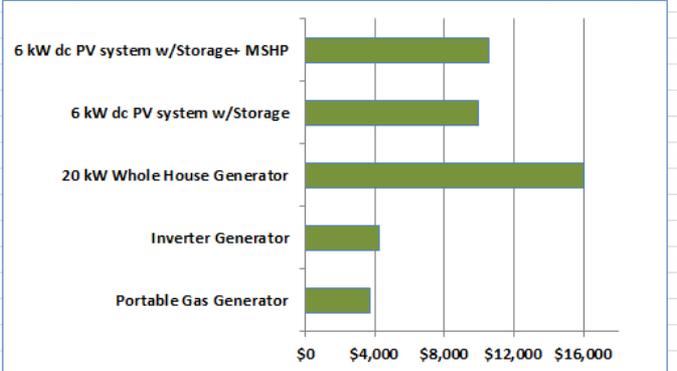
# Solar & Electrical Storage: Reduced Net Metering Compensation

- 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	Analysis & System Parameters
<b>Portable Gas Generator</b>	\$750									Analysis period (yrs) 10
Transfer Switch	\$500									Hurricane Events Frequency 3
(6) 5 gallon gas cans	\$150									Period of Interruption (Days) 5
<b>Total</b>	<b>\$1,400</b>	<b>\$25</b>	<b>833</b>	<b>0</b>	<b>\$2,083</b>	<b>\$0</b>	<b>0</b>	<b>\$250</b>	<b>\$3,733</b>	\$Gas/gallon \$2.50
										\$LGP/gallon \$4.25
										\$/kWh/electricity \$0.12
<b>Inverter Generator</b>	\$1,500									Ann. electricity PV system (kWh) 9,850
Transfer Switch	\$500									Ann. electricity savings MSHP (kWh) 2,400
(5) 5 gallon gas cans	\$125									
<b>Total</b>	<b>\$2,125</b>	<b>\$50</b>	<b>667</b>	<b>0</b>	<b>\$1,667</b>	<b>\$0</b>	<b>0</b>	<b>\$500</b>	<b>\$4,292</b>	
<b>20 kW Whole House Generator</b>	\$5,300									
30 gallon LPG Tank	\$450									
Installation	\$3,700									
<b>Total</b>	<b>\$9,450</b>	<b>\$250</b>	<b>0</b>	<b>967</b>	<b>\$0</b>	<b>\$4,108</b>	<b>0</b>	<b>\$2,500</b>	<b>\$16,058</b>	
<b>6 kW dc PV system w/Storage</b>	\$12,000									
27 kWh Battery Storage	\$18,000									
Subtotal	\$30,000									
Less Tax Credit	\$9,000.0									
<b>Final Cost</b>	<b>\$21,000.0</b>	<b>\$75</b>	<b>0</b>	<b>0</b>	<b>\$0</b>	<b>\$0</b>	<b>(\$11,820)</b>	<b>\$750</b>	<b>\$9,930</b>	
<b>6 kW dc PV system w/Storage+ MSHP</b>	\$12,000									
27 kWh Battery Storage	\$18,000									
Subtotal	\$30,000									
Less Tax Credit	\$9,000									
Supplemental Mini-SplitHPump (MSHP)	\$3,500									
<b>Final Cost</b>	<b>\$24,500</b>	<b>\$75</b>	<b>0</b>	<b>0</b>	<b>\$0</b>	<b>\$0</b>	<b>(\$14,700)</b>	<b>\$750</b>	<b>\$10,550</b>	



### GENERATOR TYPES

**Portable Generators**  
Versatile power for the home, job sites, outdoor projects or emergency backup.  
Primary Use: Emergency, Job Site  
Fuel Type: Gasoline, Propane  
Surge Watts: 1,000 - 50,000  
Rated Watts: 500 - 12,000

**Inverter Generators**  
Portable, quiet and clean power for recreational use.  
Primary Use: Recreational  
Fuel Type: Gasoline  
Surge Watts: 200 - 8,000  
Rated Watts: 500 - 3,000

**Home Standby Generators**  
Reliable, worry-free operation, control kick-in within seconds of losing power.  
Primary Use: Whole House Backup  
Fuel Type: Propane, Natural Gas  
Rated Watts: 6,000 - 120,000

# What's Needed Going Ahead?

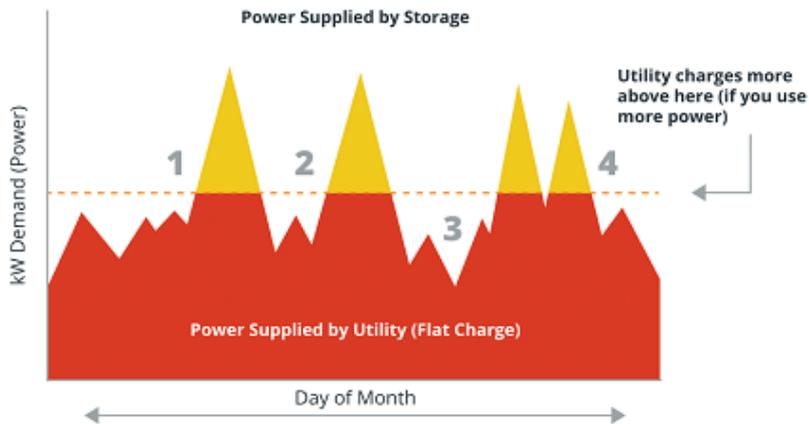
- Storage costs to fall significantly, but fixed install costs hi ((~\$3-4K)
  - Complex electrical challenge (sub-panel)
  - One sizes fits one
- Emergency use of car battery (*Vehicle-to-House*)
- Utility programs to address equity issues



# Solar & Electrical Storage: Value

## DEMAND CHARGE AND STORAGE

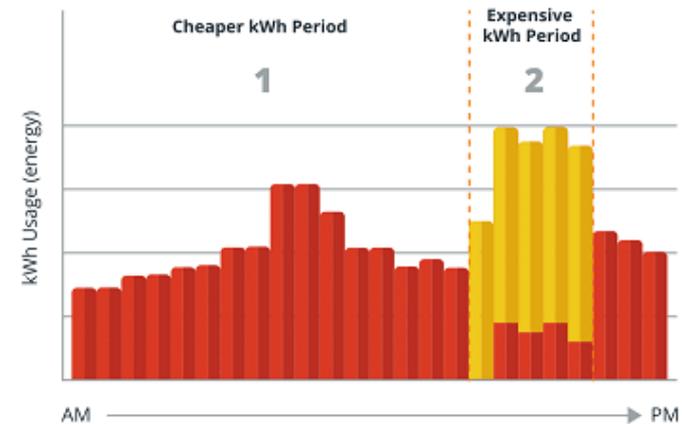
- Flat demand charge (same no matter how much power you need)
- Variable demand charge you avoid because your battery provided it



- 1 & 2 Really cold days and you had your space heaters on.
- 3 Your were out of town.
- 4 You ran the dryer, your microwave, your oven, and you blow dryer all at once.

## TIME OF USE AND STORAGE

- kWh Supplied by Utility
- kWh Supplied by Your Battery



- 1 Your are getting ready for work in the morning.
- 2 Your are home from work, making dinner, kids are watching TV, and you just turned your AC back on.

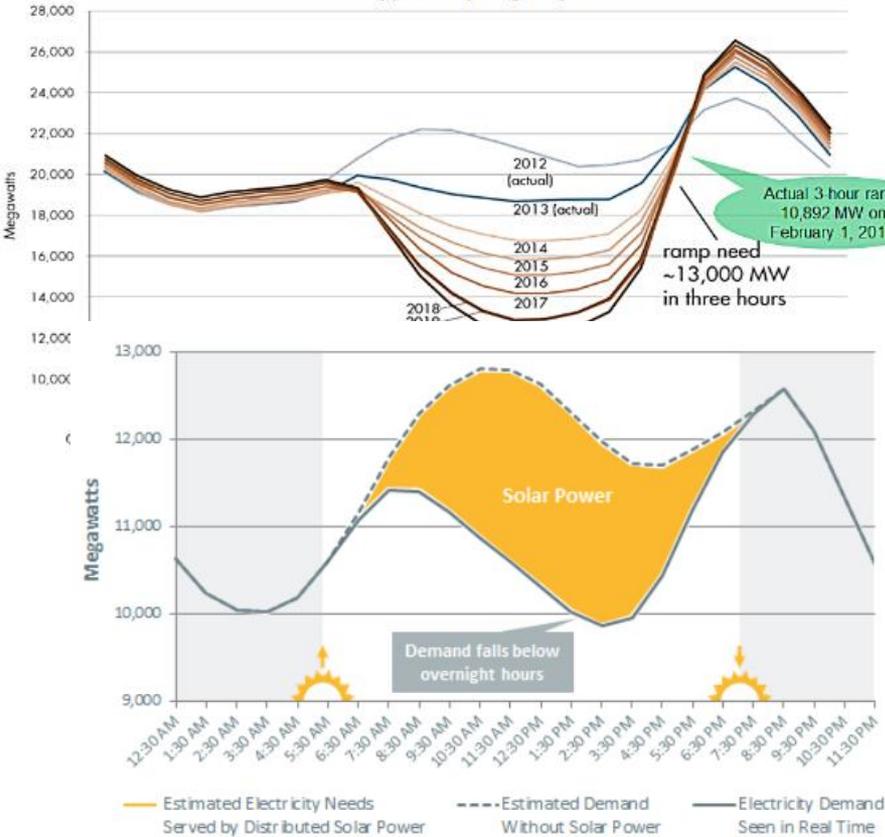
- Demand Charges
- Time of Use (TOU) rates



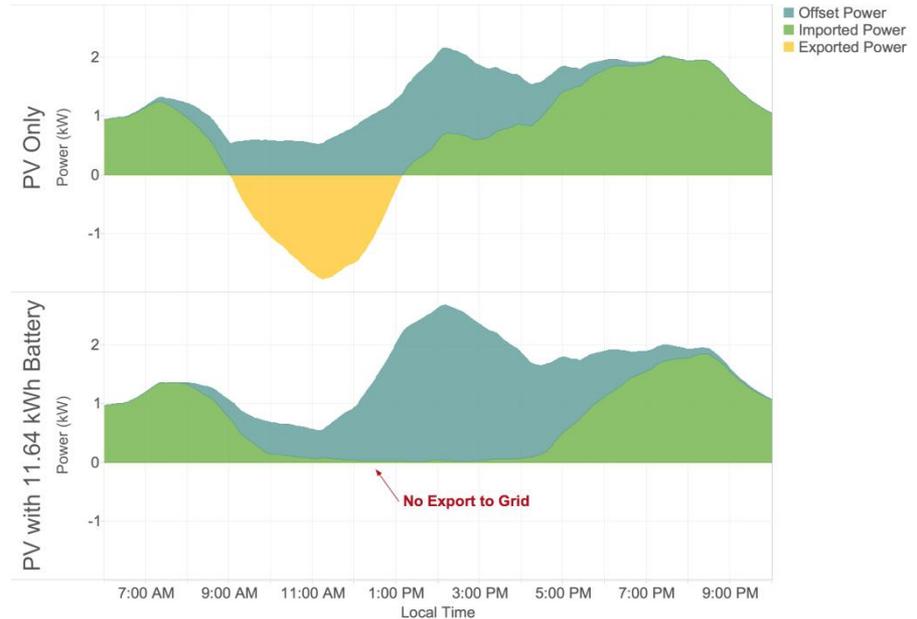
# What Duck Curve?

## Self Consumption Mode

Typical Spring Day



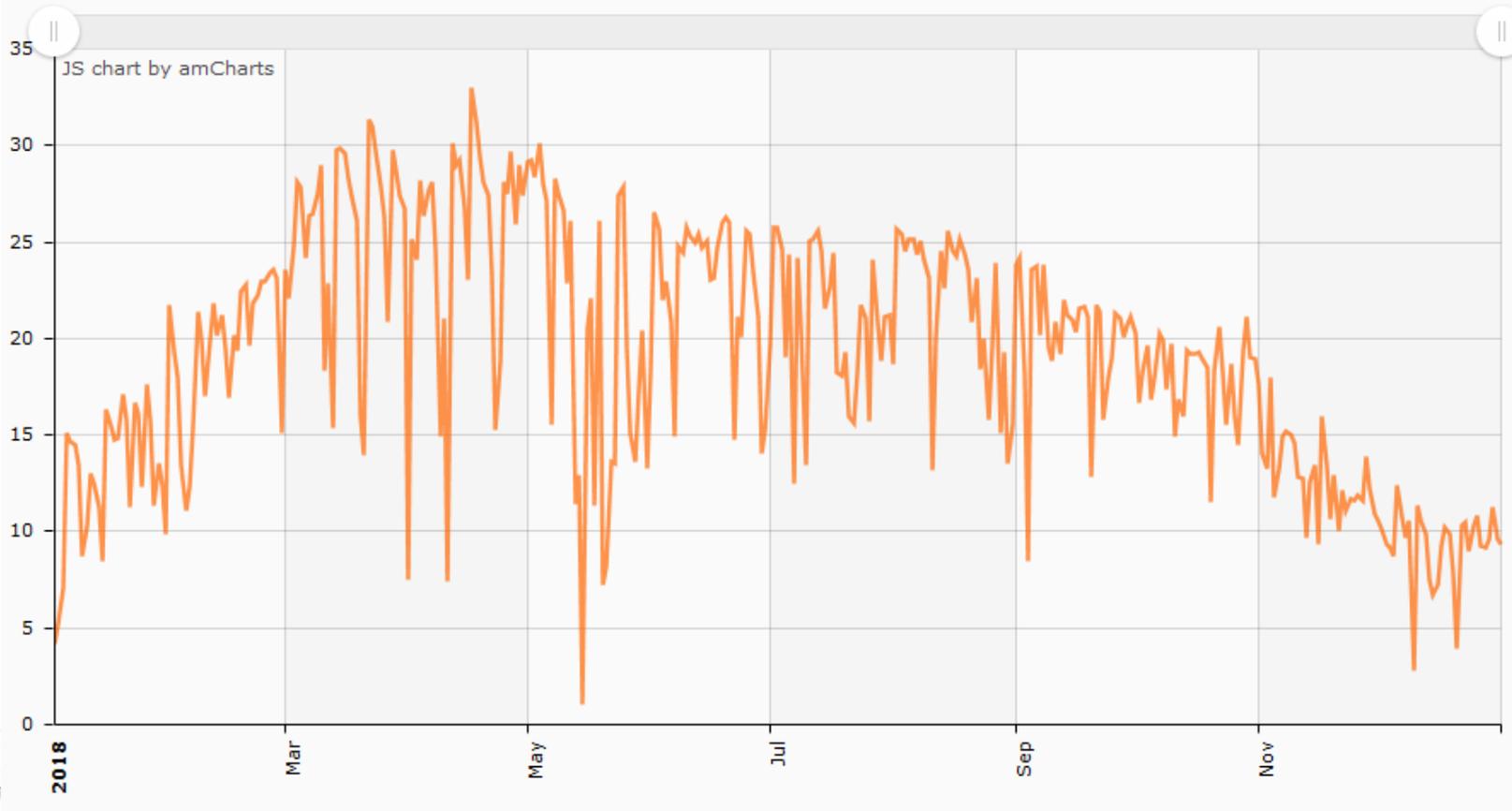
Source: ISO New England



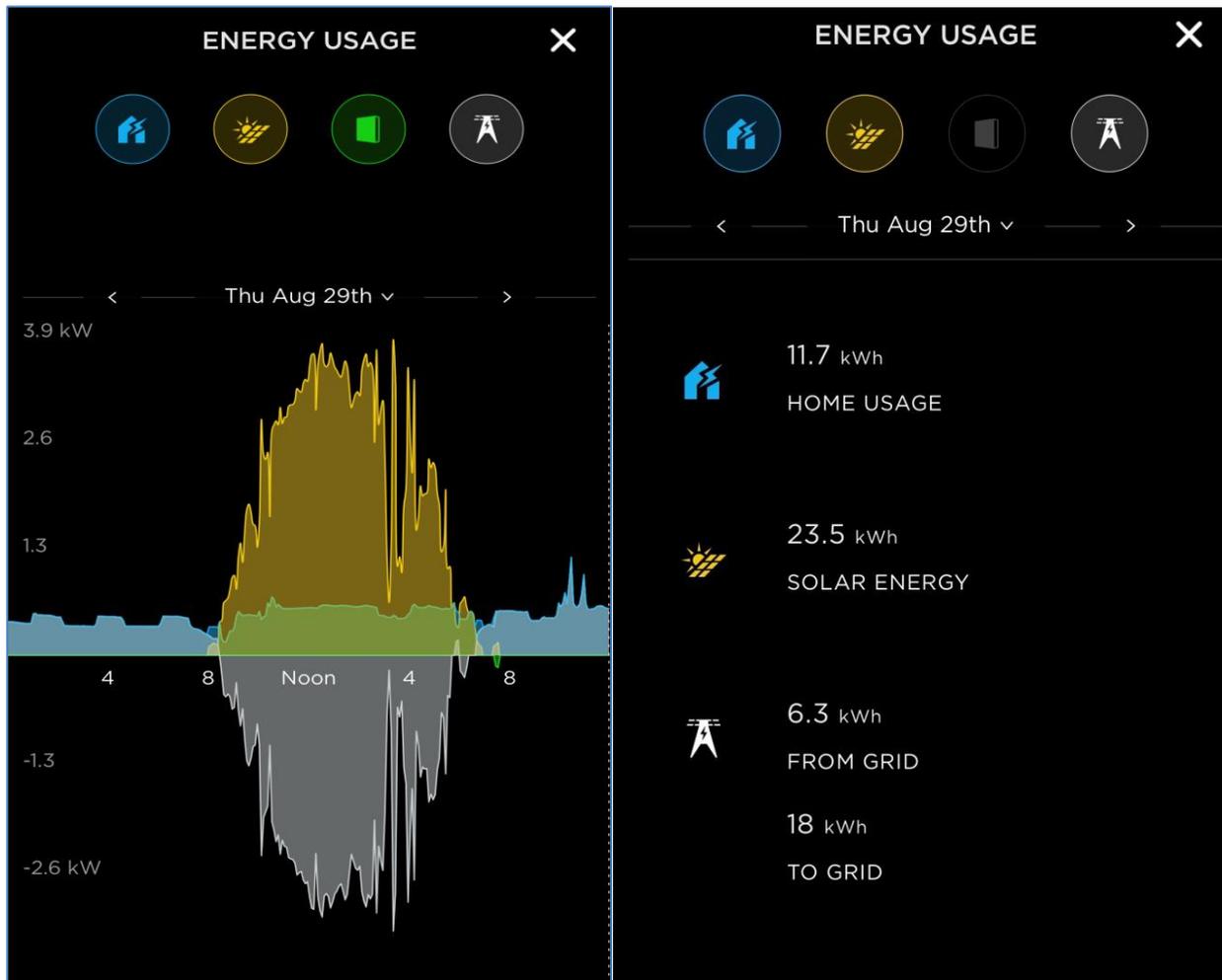
# How Much Solar Each Day?

- ~23 kWh per day

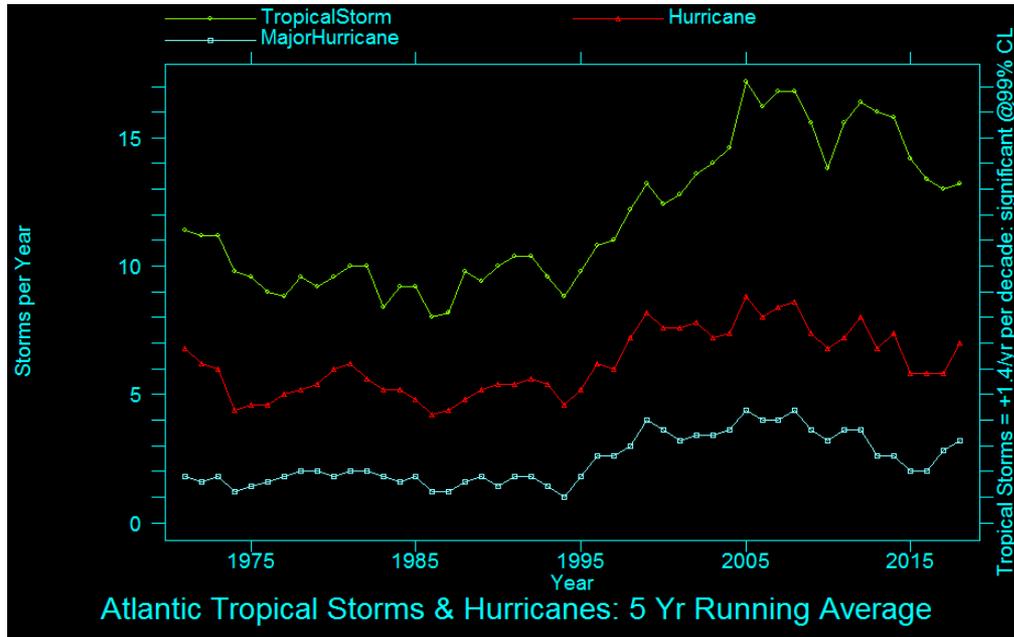
2018/01/02 00:00 ~ 2019/01/01 00:00



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



Number of Atlantic Hurricanes of Each Strength Since the Satellite Era

