

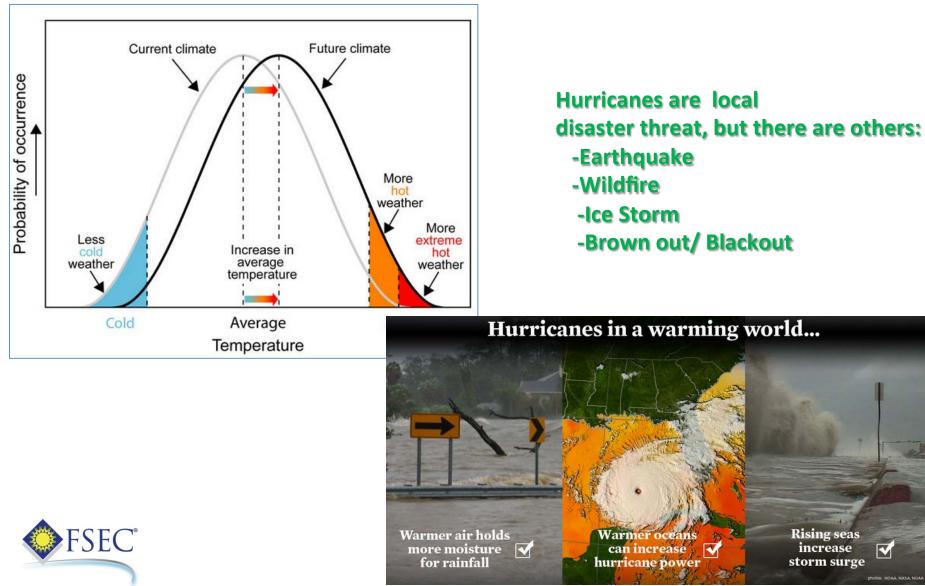
Experience with Residential Solar & Electrical Storage after a Hurricane

Danny Parker, Florida Solar Energy Center November 2019



A Research Institute of the University of Central Florida

Predicted future weather shift from IPCC Report:



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



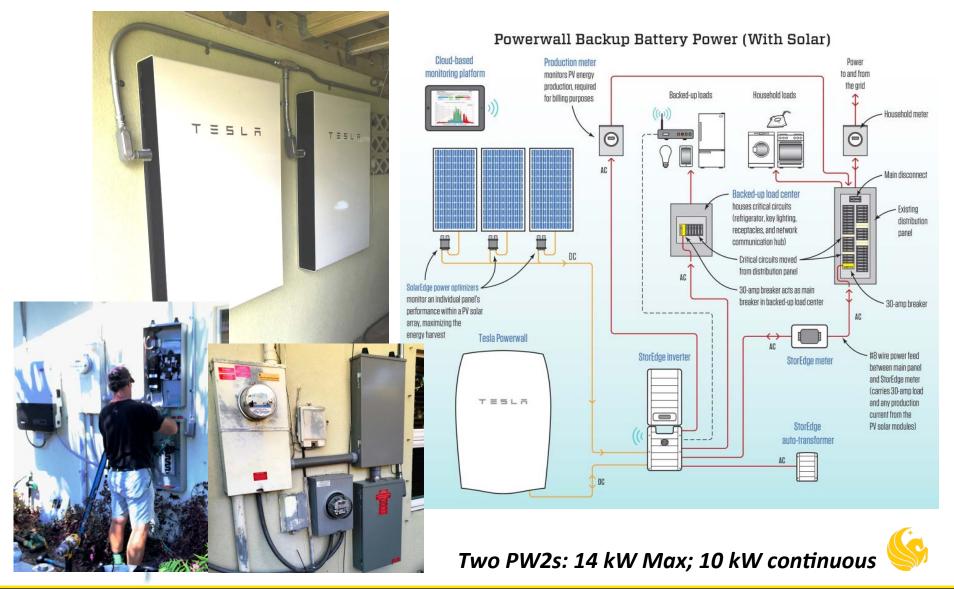
Installation of two Tesla Powerwall 2s on 22 May 2019 13.5 kWh ea. = 27 kWh Storage







What is Powerwall installation?



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

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- Whole house generator cost: \$7-\$15K <u>installed</u>
 - 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 us

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

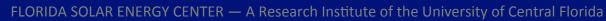


Home Standby Generators

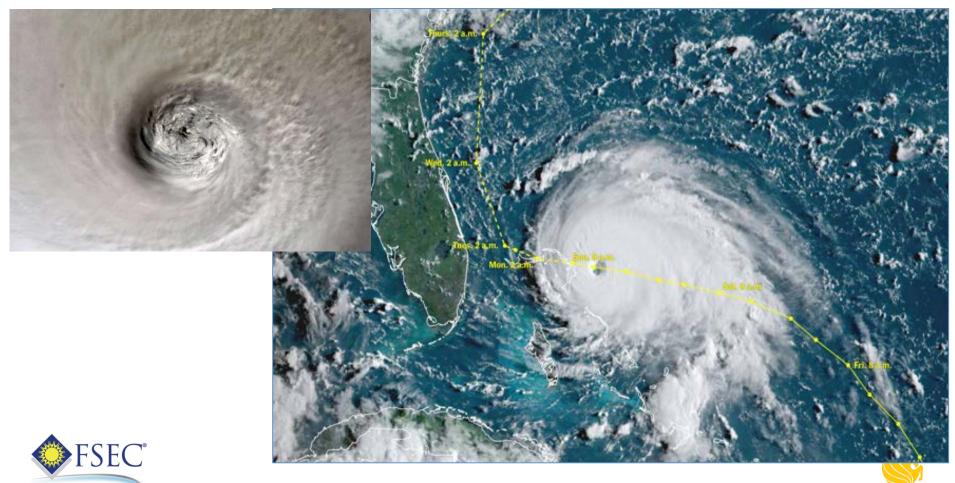
Reliable, worry-free operation, control kick-in within seconds of losing power

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

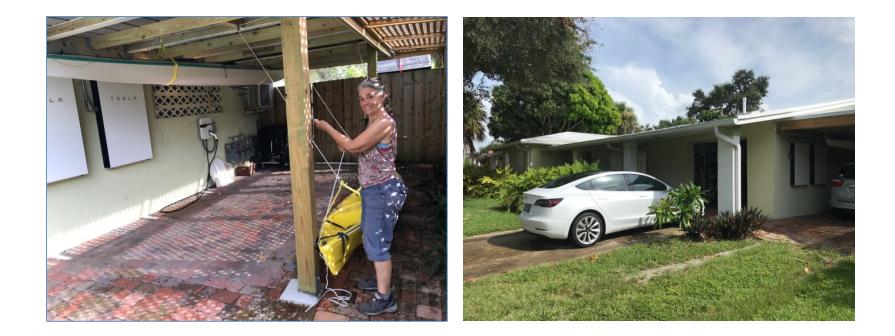




Wanted tropical depression to test, not Category 5 Dorian!



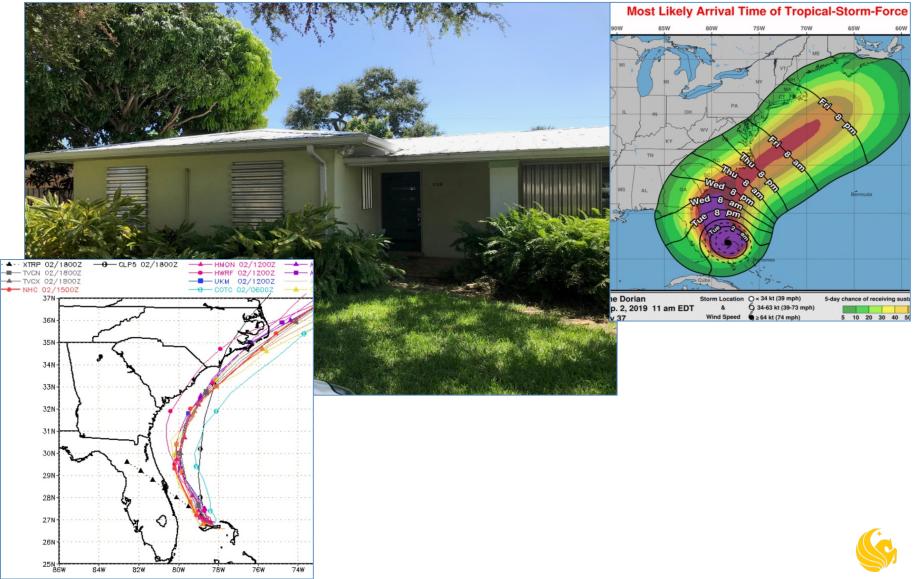
Lisa ties down her boats in the carport with the Tesla Power walls. She drives a Ford Cmax Energi with 20 miles of battery range (Level 2 Charger on the wall)



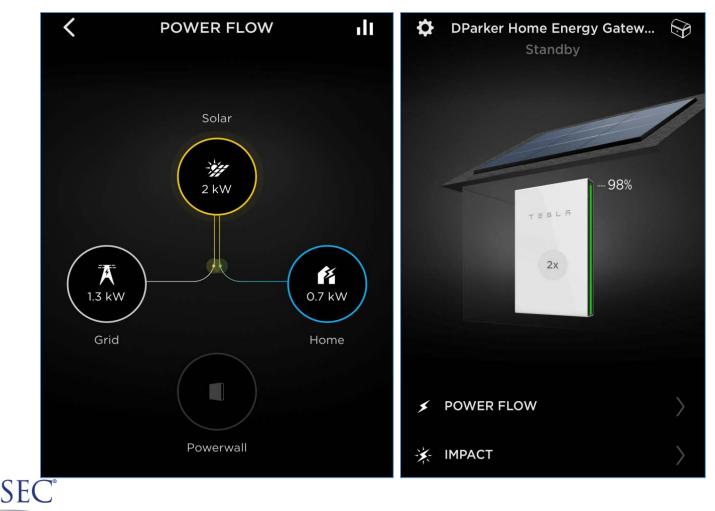




Our home all shuttered: September 3rd, 2019



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





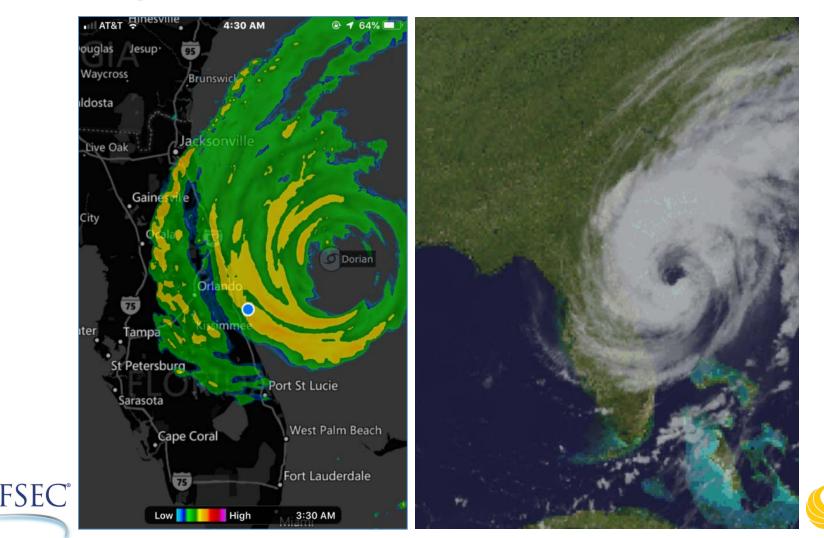
Performance of solar, grid, storage and home energy systems on 3 September as hurricane approached

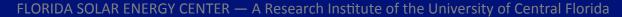




SEC°

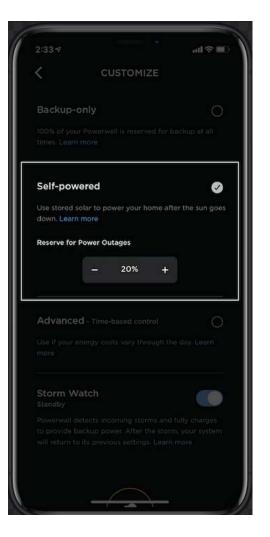
Hurricane Dorian passes by the East Coast of Florida on 4 September 2019. Blue dot marks our location





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

myac										
DP_weather										
5-in-1 Weather Station										
Wind ~	24 Hour ~									
Wind Speed 47 km/h High 5:25 AM	Wind Speed 37 km/h Avg 4:25 AM									
	09/03/2019 - 09/04/2019									
50										
40										
30										
20										
	50 PM 2:50 AM 8:50 AM 9/03 09/04 09/04									





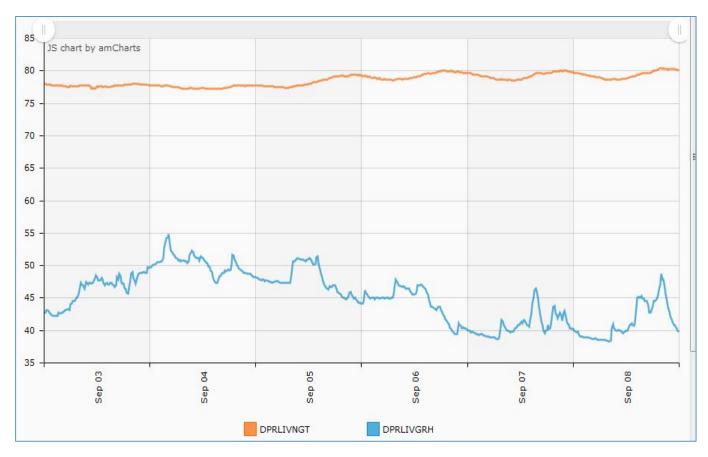
4 Sept. 2019: Performance of solar & Powerwall system during Hurricane Dorian. Closest approach at 4 AM





FSEC°

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





SEC°

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

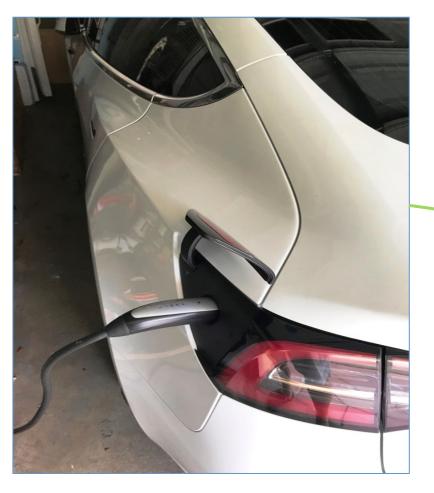
Sept <u>Date</u>	Home <u>kWh</u>	Solar <u>kWh</u>	Powerwall	kWh	Grid kWh	
			<u>From</u>	<u>To</u>	From	<u>To</u>
3	21.7	13.4	0	0.6	14.2	5.3
4	12.7	6.5	3.4	13.2	4.1	0.1
5	21.6	21.5	8.9	14.4	0.2	0.1
6	25.1	24.4	9.8	9.1	0.2	0.2
7	21.5	24.9	11.0	8.5	0.1	0.5
8	23.7	24.5	12.3	1.1	0.1	0.1

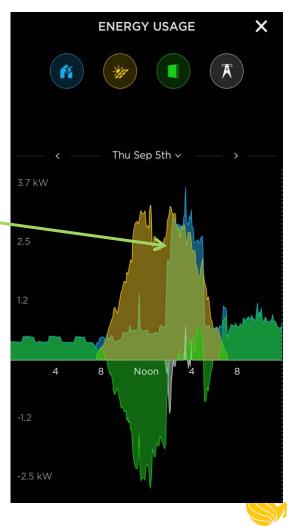




Using a Level 1 charger with solar the day after Hurricane Dorian to add range to an Electric Car

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





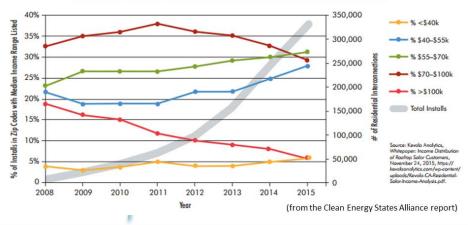


Solar & storage: equity issues

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



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





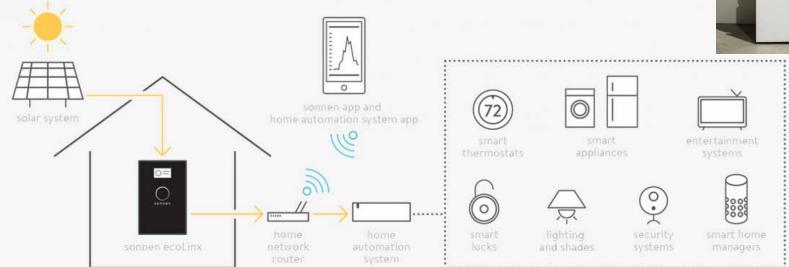


Other Electrical Storage Systems

33

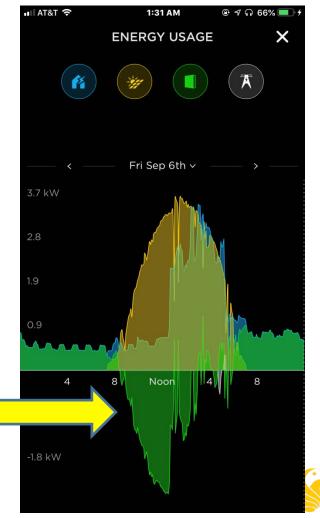
75,

- 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 selfconsumption of solar





Economics: How do Options Compare?

Estimating the Ten Year Cost of Emergency Household Electric Generation

System	Initial Cost	Annual	Gasoline	LPG	Gasoline	LPG	Electric	Period	Total Optio	on Analysis & System		
Description	\$	0&M \$	Gal	Gal	\$Cost	\$cost	\$Savings	\$0&M	\$Costs	Parameters		
										Analysis period (yrs)	10	
Portable Gas Generator	\$750									Hurricane Events Frequency	3	
Transfer Switch	\$500									Period of Interruption (Days)	5	
(6) 5 gallon gas cans	\$150									\$Gas/gallon	\$2.50	
Total	\$1,400	\$25	833	0	\$2,083	\$0	0	\$250	\$3,733	\$LGP/gallon	\$4.25	
										\$/kWh/electricity	\$0.12	
Inverter Generator	\$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											
Total	\$2,125	\$50	667	0	\$1,667	\$0	0	\$500	\$4,292	1 1		
										6 kW dc PV system w/Storage+ MSHP		
20 kW Whole House Generator	\$5,300									-		
30 gallon LPG Tank	\$450									6 kW dc PV system w/Storage		
Installation	\$3,700											
Total	\$9,450	\$250	0	967	\$0	\$4,108	. 0	\$2,500	\$16,058			
										20 kW Whole House Generator		
6 kW dc PV system w/Storage	\$12,000									-		
27 kWh Battery Storage	\$18,000									Inverter Generator		
Subtotal	\$30,000											
Less Tax Credit	\$9,000.0									Portable Gas Generator		
Final Cost	\$21,000.0	\$75	0	0	\$0	\$0	(\$11,820)	\$750	\$9,930	Portable Gas Generator		
										\$0 \$4.0	00 69 000	\$12,000 \$16,000
6 kW dc PV system w/Storage+ MSHP	\$12,000									\$0 \$4,0	00 \$8,000	\$12,000 \$10,000
27 kWh Battery Storage	\$18,000											
Subtotal	\$30,000											GENERA
less Tax Credit	\$9,000											Portable Generato
Supplemental Mini-SplitHPump (MSHP	\$3,500											Versatile power for the ho
Final Cost	\$24,500	\$75	0	0	\$0	\$0	(\$14,700)	\$750	\$10,550			emergency backup Primary Use: Emergency, Job S









outdoor projects or Fuel Type: Gasoline, Propane Surge Watts: 1.000 - 30.000 ated Watts: 3,000 - 10,000

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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)
 - <u>One sizes fits one</u>
- Emergency use of car battery (Vehicle-to-House)
- Utility programs to address equity issues



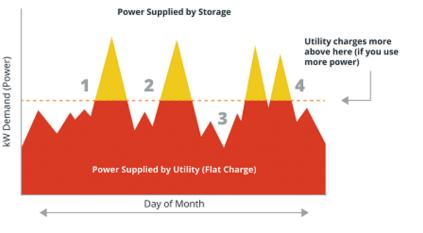




Solar & Electrical Storage: Value

DEMAND CHARGE AND STORAGE

Flat demand charge (same no matter how much power your 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.

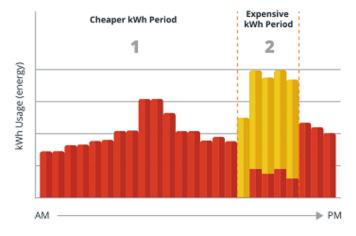
FSEC[®]

- 4 You ran the dryer, your microwave, your oven, and you blow dryer all at once.
- Demand Charges
- Time of Use (TOU) rates

TIME OF USE AND STORAGE



kWh Supplied by Your Battery

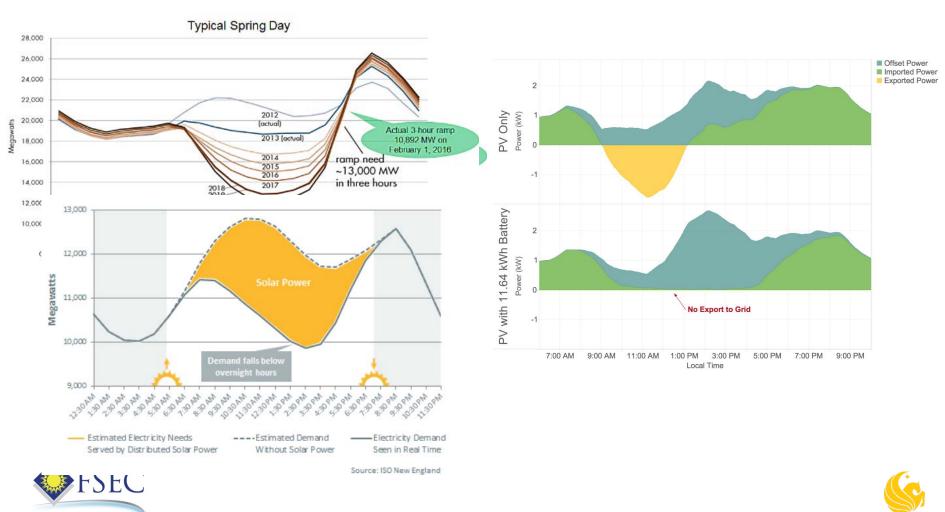


1 Your are getting ready for work in the morning.

2 Your are home from work, making dinner, kids are watching TV, and you just turned your AC back on.

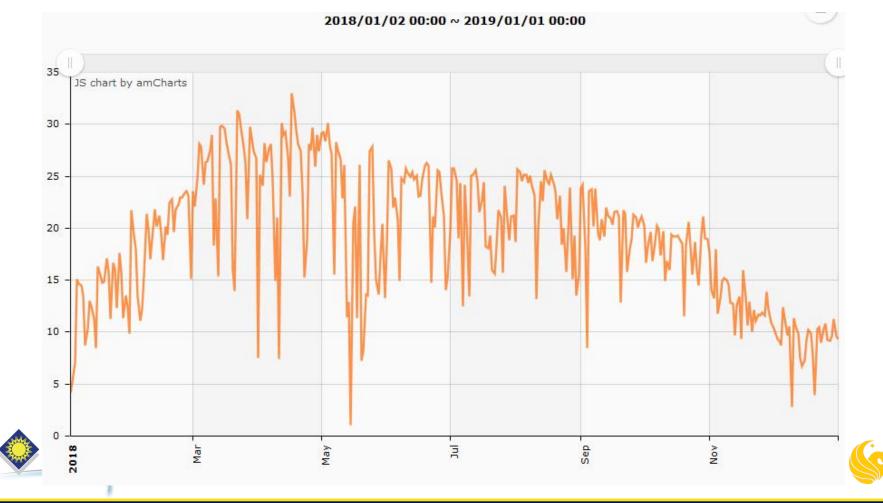


What Duck Curve? Self Consumption Mode

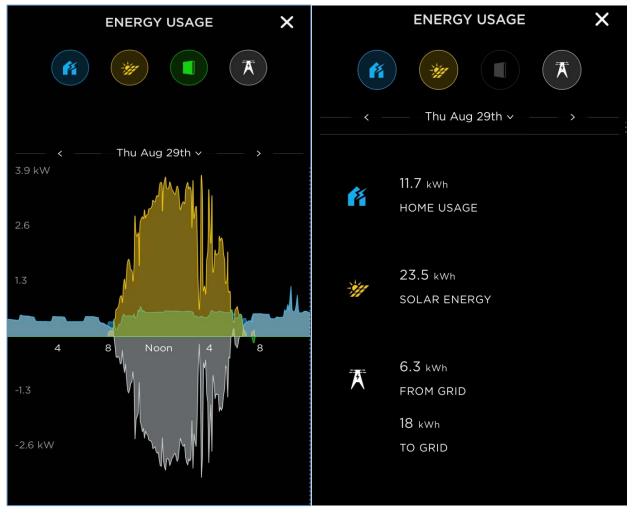


How Much Solar Each Day?

~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

