PROFITABILITY THRESHOLDS OF RESILIENT MICROGRIDS
(and how to exceed them)

Microgrid 2.0
Advancing Industry Growth

HARC

Baltimore, MD October 27th, 2018

Agenda

- About HARC
- Resilience and microgrids
- Microgrid Design Considerations with Uncertainty
- HARC Energy Planning for Microgrids
- HARC’s Microgrid Scenarios
- Conclusions & Next steps

About HARC

About HARC

- The Houston Advanced Research Center (HARC) is an independent research hub helping people thrive and nature flourish
- Founded by George P. Mitchell in 1982
- A 501(c)(3) organization located in The Woodlands
- We provide objective, unbiased, non-advocacy approach to finding scientific answers to complex questions
- A sustainability-focused company

HARC Mission & Programs

HARC

Mission: To provide independent analysis on energy, air, and water issues to people seeking scientific answers and to operate as a research hub finding solutions for a sustainable future.

ENERGY

Accelerating clean, efficient and sustainable energy

AIR

Improving air quality through research

WATER

Protecting water resources and ecosystems

RESILIENCE

Providing science-based resilience solutions to communities

HARC's Headquarters

Certified LEED Platinum & Energy Star (92/100)

- 18,500 SF office building
- 11.52 kW DC rooftop PV solar plant
- Geothermal field, high-efficiency heating and cooling
- LED lighting
- Uses 73% less energy than the average office building in the US.
- First monitored Net-Zero event – Feb. 19, 2018: 4,41 kWh/2h20m

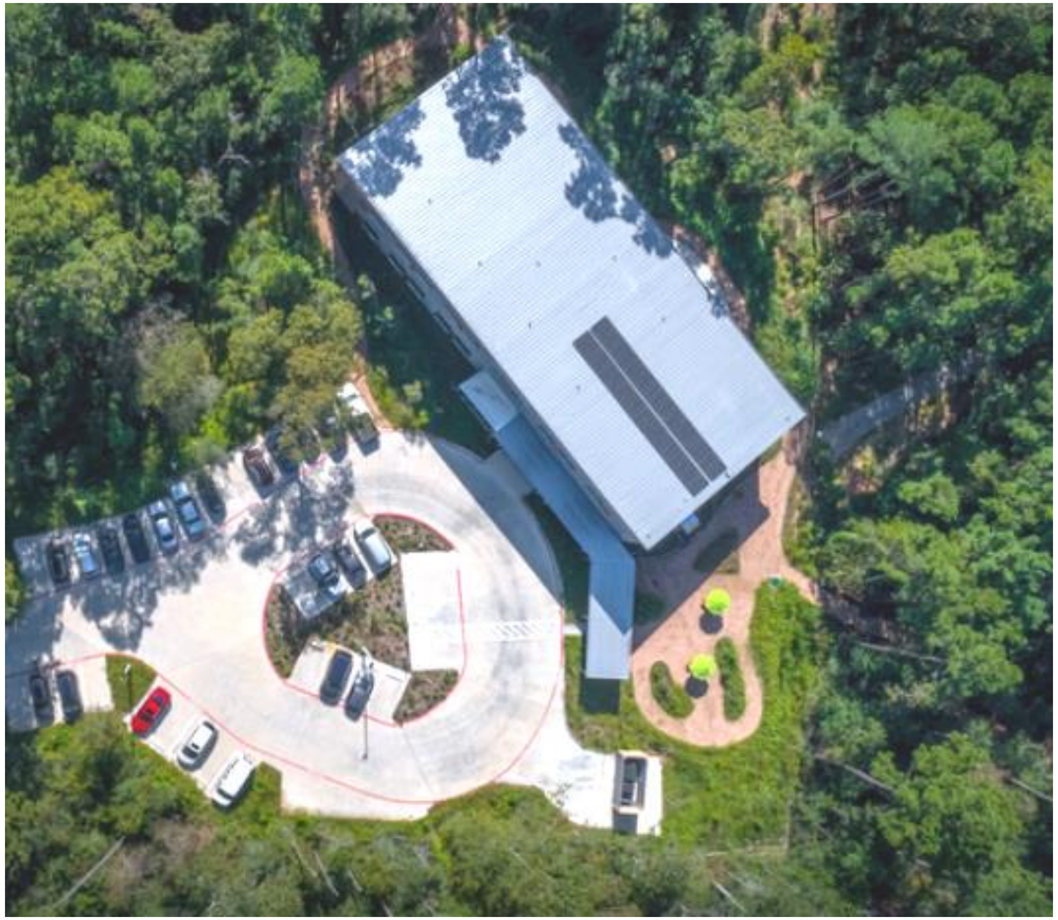
ENERGY STAR

U.S. GREEN BUILDING COUNCIL LEED PLATINUM USGBC

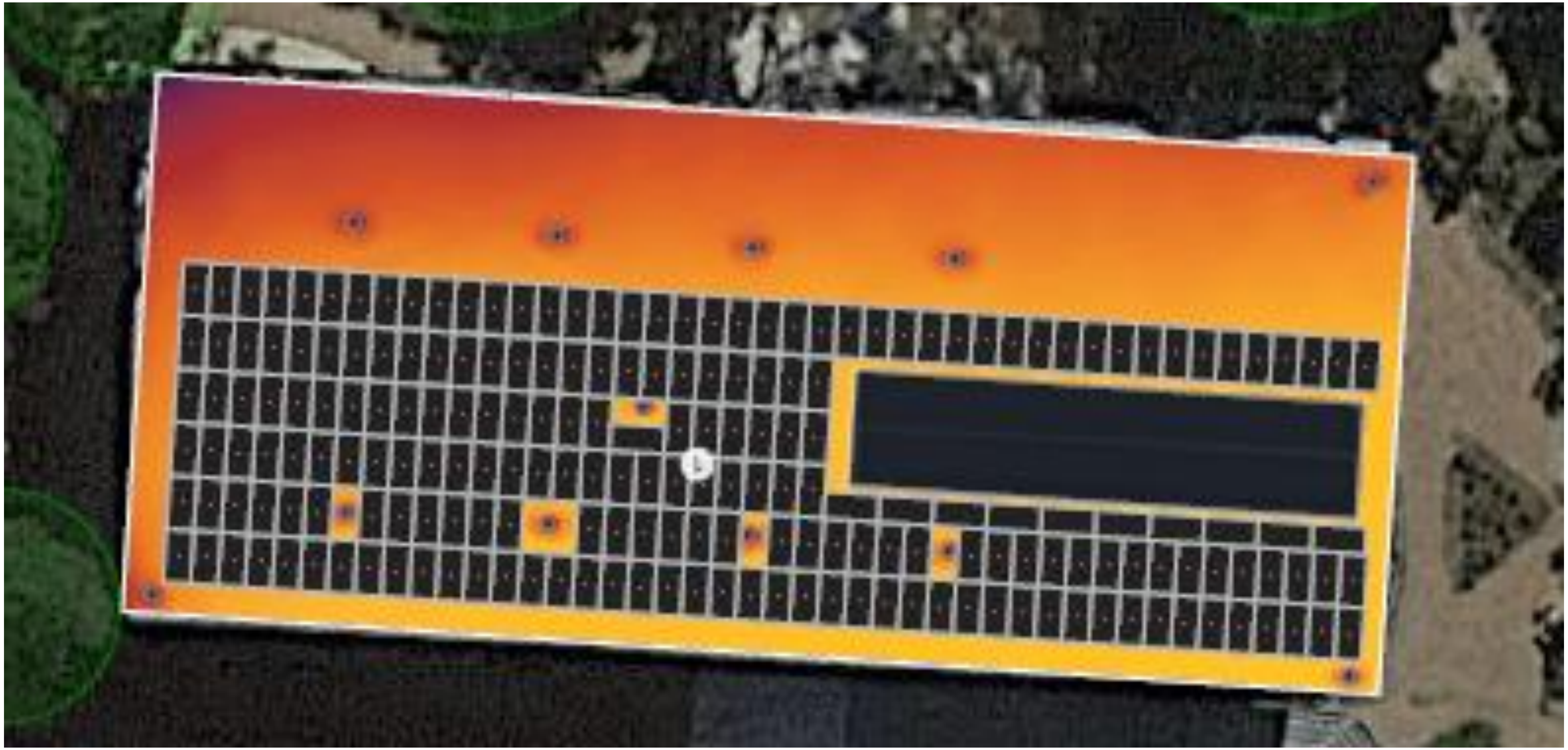
Road to Certified Zero Energy

Green Mountain Energy
SUN CLUB®

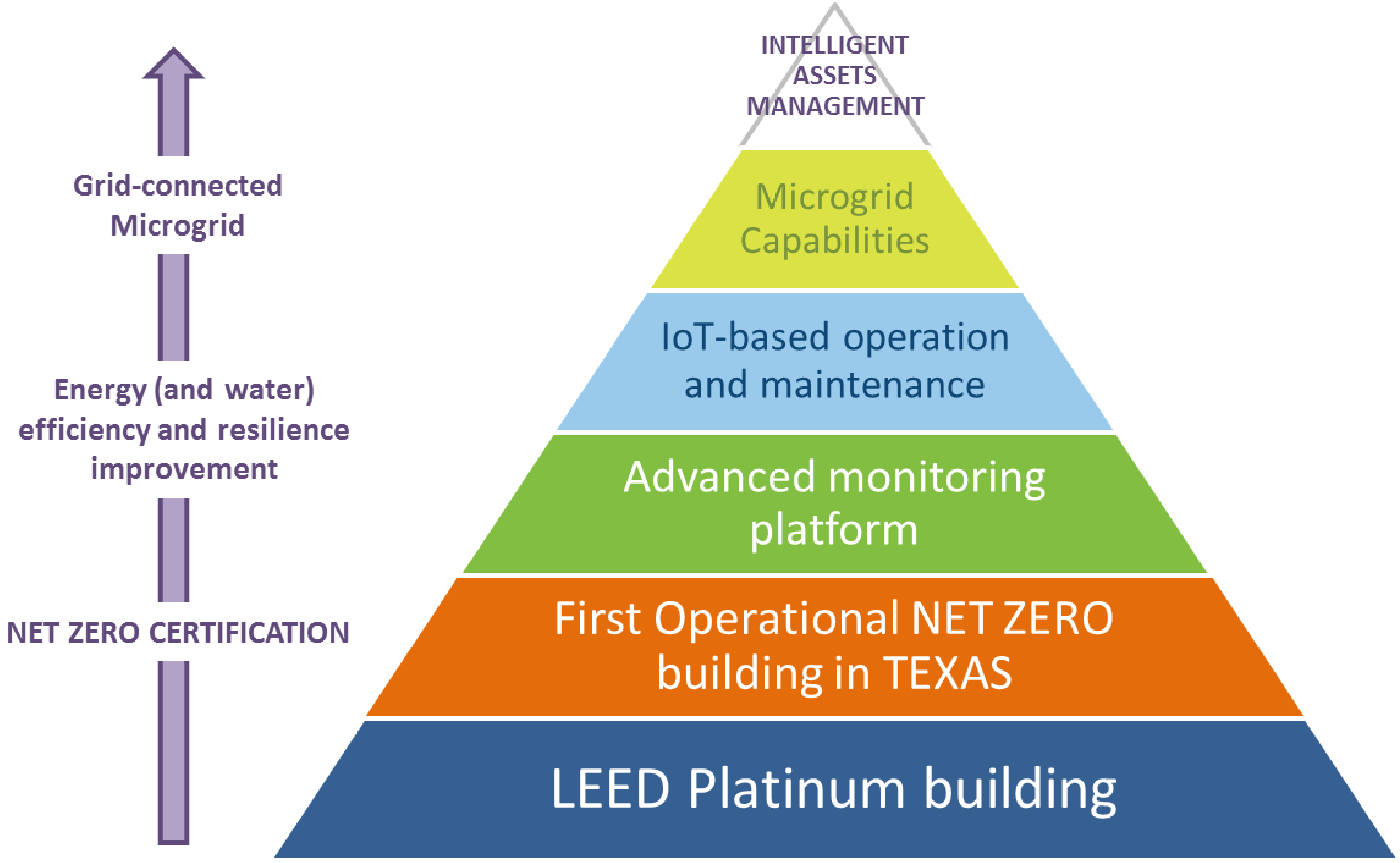
- Transition from intermittent net-zero events during the weekends to being one of the first certified commercial net-zero energy (NZE) buildings in Texas
- Financial support of the Green Mountain Energy Sun Club
  - 208 additional solar panels (about 75 kW DC) with the requisite inverters
  - Expected completion date: November 2018



Road to Certified Zero Energy



HARC Building Upgrade – Beyond Platinum

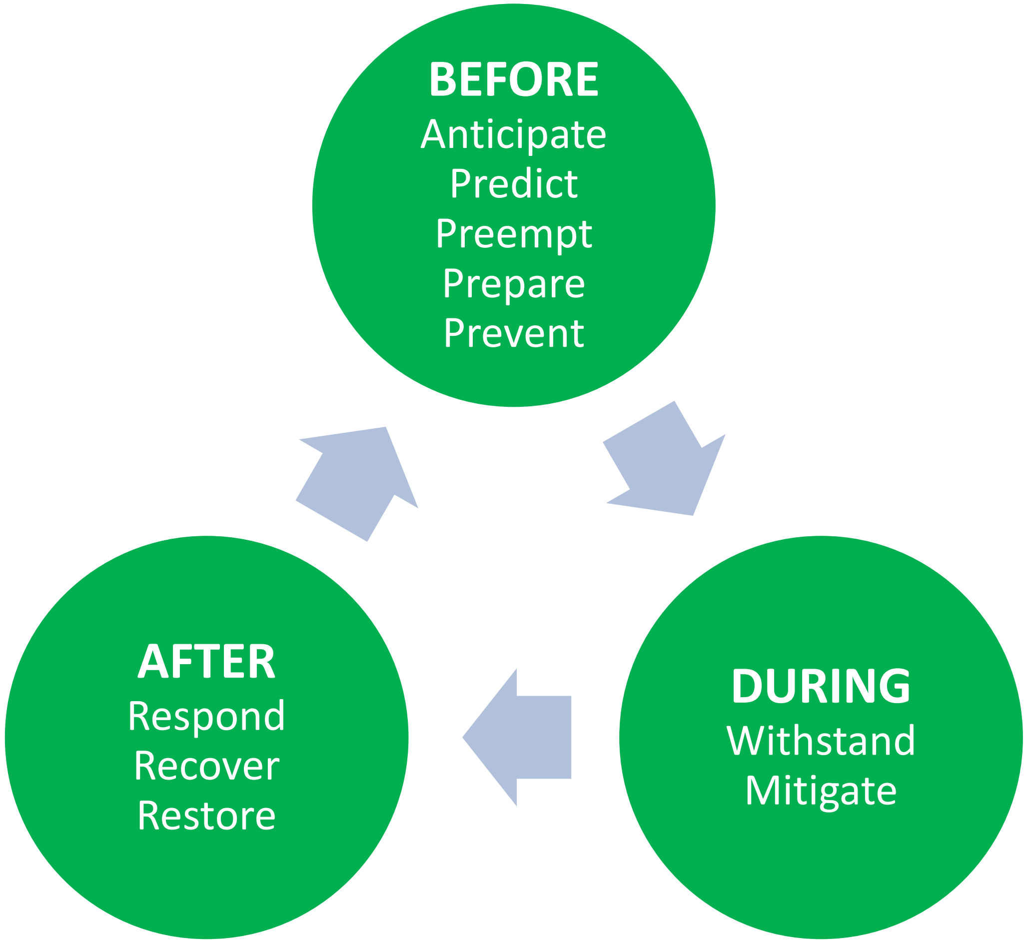


Resilience and Microgrids

Planning for Resilience

RESILIENCE is a key principle of disaster preparedness and planning

- ***Resilience (engineering)*** *is the ability to absorb or avoid damage without suffering complete failure.*
- ***Human resilience (psychology) is the capacity to make realistic plans and take steps to carry them out.***
- Ability to maintain operation despite a devastating event – business continuity



What kind of microgrid HARC wants?

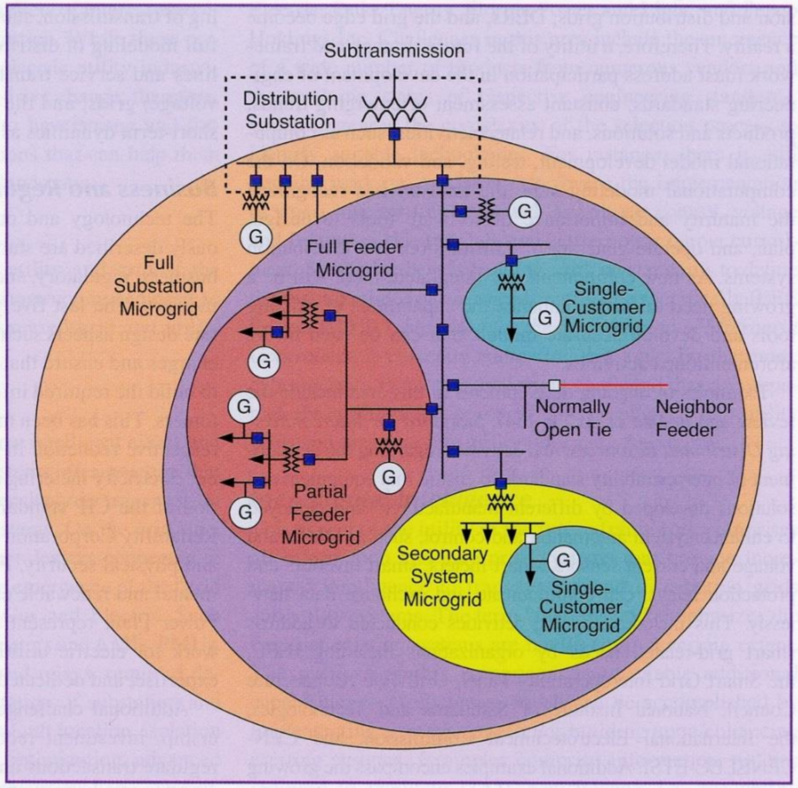


figure 3. This hierarchical microgrid is an example of the grid architectures being explored to enable the highly distributed grid concept and maximize reliability and resiliency under a wide variety of contingency conditions and locations as well as DER and load-balance scenarios. (Source: Sandia National Laboratory.)

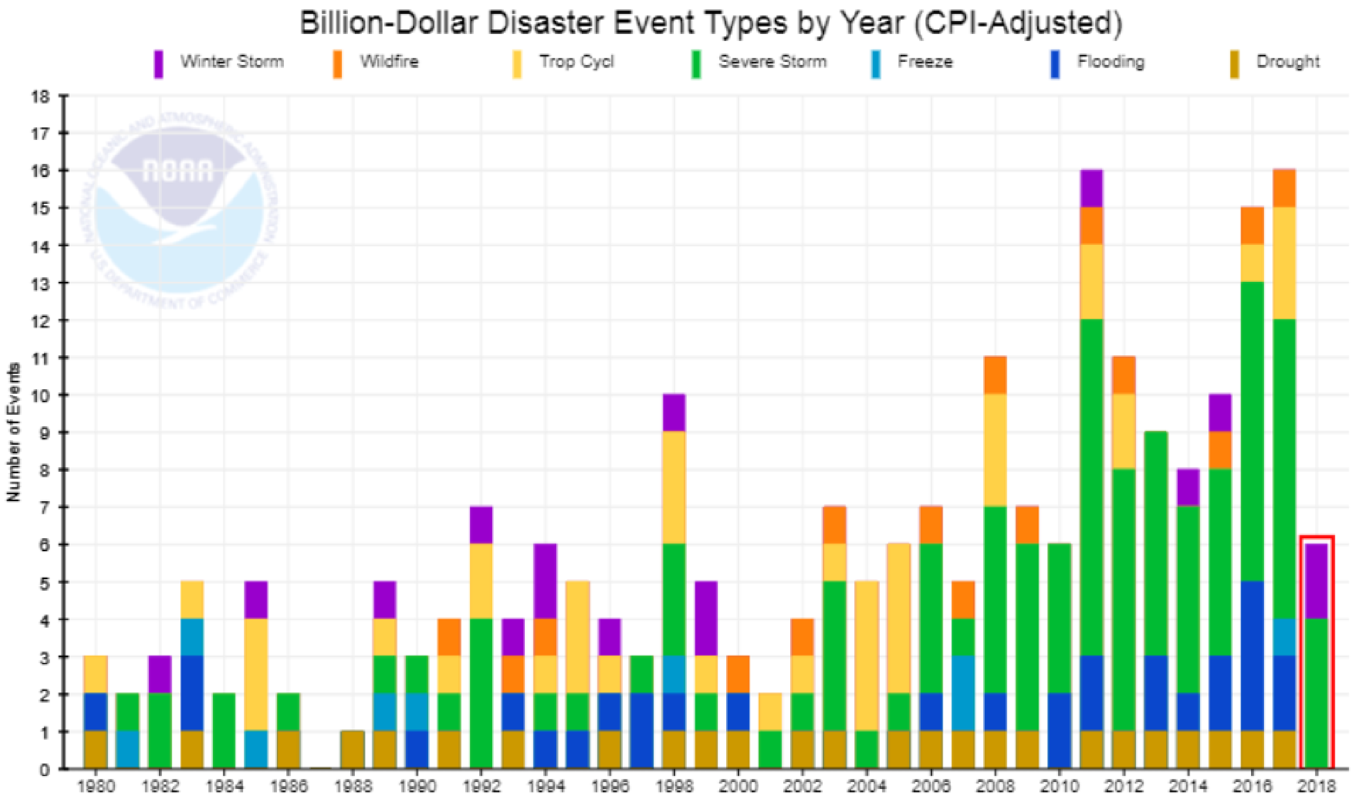
SOURCE: *IEEE POWER & ENERGY. Vol.*14, Number 5, September/October 2016

- Regarding the grid, power generators in a microgrid can :
  - **Coexist:** as individual power systems, using resources on both sides of the meter at a time.
  - **Compete:** as individual power systems using one or another.
  - **Cooperate:** provide services to other microgrids or to the distribution grid.

- Is there a microgrid for every company? YES
- Is it worth exploring your possibilities to have a MG? YES
- Make sense for every company to have their own microgrid? NO

Designing MGs for Resilience

How do we plan for uncertainties in a 20-year energy project?



Number of events as of July 9, 2018

- One estimate states that over $150 billion per year is lost by U.S. industries due to electric network reliability problems*
- Distributed generation systems designed for resilience will incur additional costs ($45 - $170/kW for CHP systems depending on complexity of system)*
- These additional costs however provide important reliability benefits to the site, and to the community at large

* Source: https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf

Designing MGs for Resilience

Distributed Energy Resources Disaster Matrix

Natural Disaster or Storm Events	Flooding	High Winds	Earthquakes	Wildfires	Snow/Ice	Extreme Temperature
Battery Storage	◒	○	◒	●	○	◒
Biomass/Biogas CHP	◒	◒	◒	●	○	○
Distributed Solar	○	◒	◒	●	◒	◒
Distributed Wind	○	◒	◒	◒	◒	◒
Natural Gas CHP	○	○	◒	◒	○	○
Standby Generators	◒	○	◒	●	◒	○

Ranking Criteria

Four basic criteria were used to estimate the vulnerability of a resource during each type of disaster event. They include the likelihood of experiencing:

1. *a fuel supply interruption,*
2. *damage to equipment,*
3. *performance limitations, or*
4. *a planned or forced shutdown*

○ *indicates the resource is unlikely to experience any impacts*

◒ *indicates the resource is likely to experience one, two, or three impacts*

● *indicates the resource is likely to experience all four impacts*

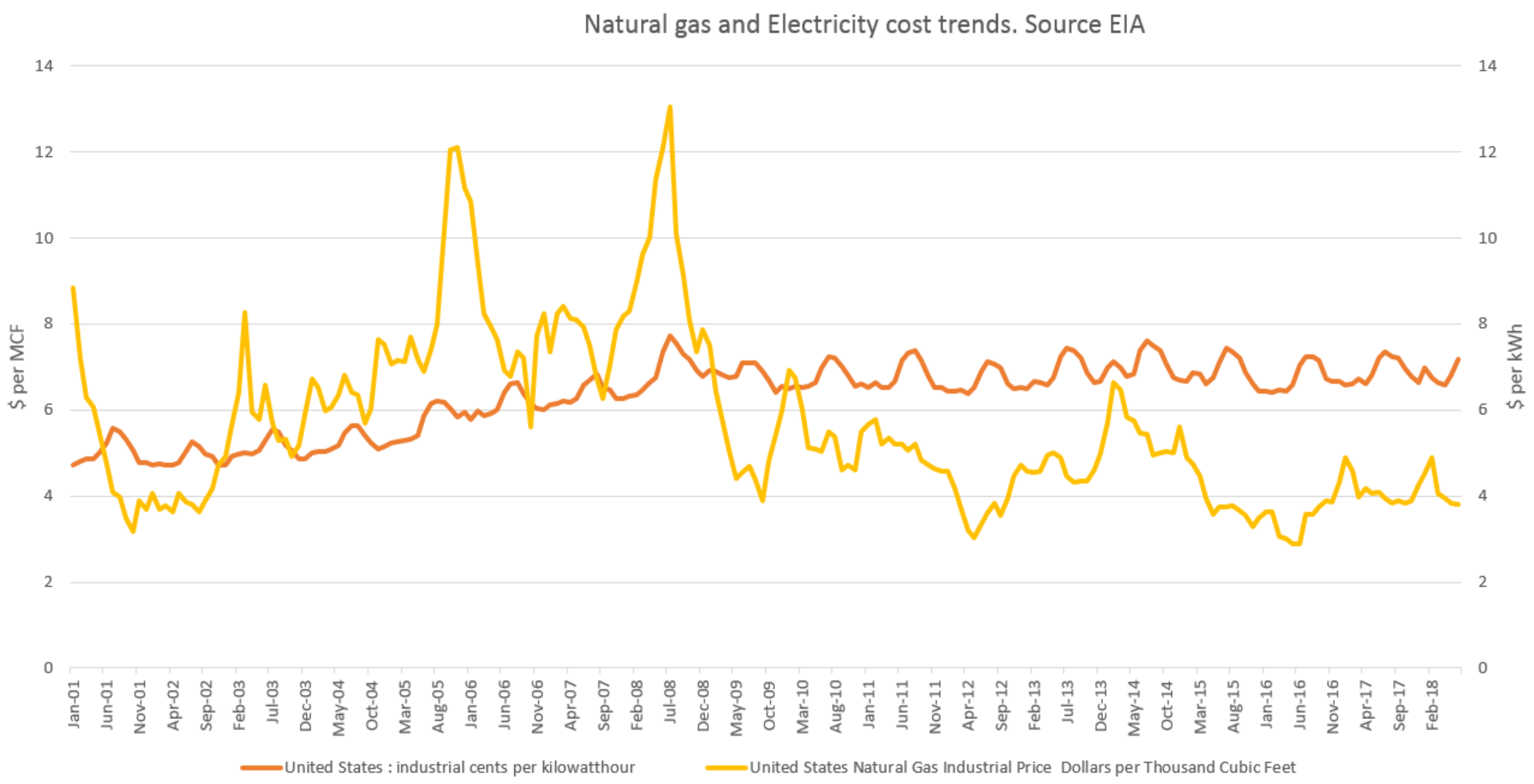
Source: DOE Better Buildings (2018). Issue Brief: Distributed Energy Resources Disaster Matrix

Designing MGs for Resilience

1. Identify potential events that can harm the performance of your facilities
2. Analyze historic values and duration of different events: power blackouts, hurricanes, floods, droughts, equipment breakdown, etc..
3. Define strategies to follow for each of those events
4. Define a frequency/probability for this events to occur
5. Estimate potential economic losses under different situations
6. Define how much money does your company want to spend on avoiding the potential consequences of these events (resilience)
7. Include the costs of the lack resilience in your microgrid's economic balance
8. Define the right microgrid for your facilities
9. Find a business model that fit your financial goals

Microgrid Design Considerations with Uncertainty

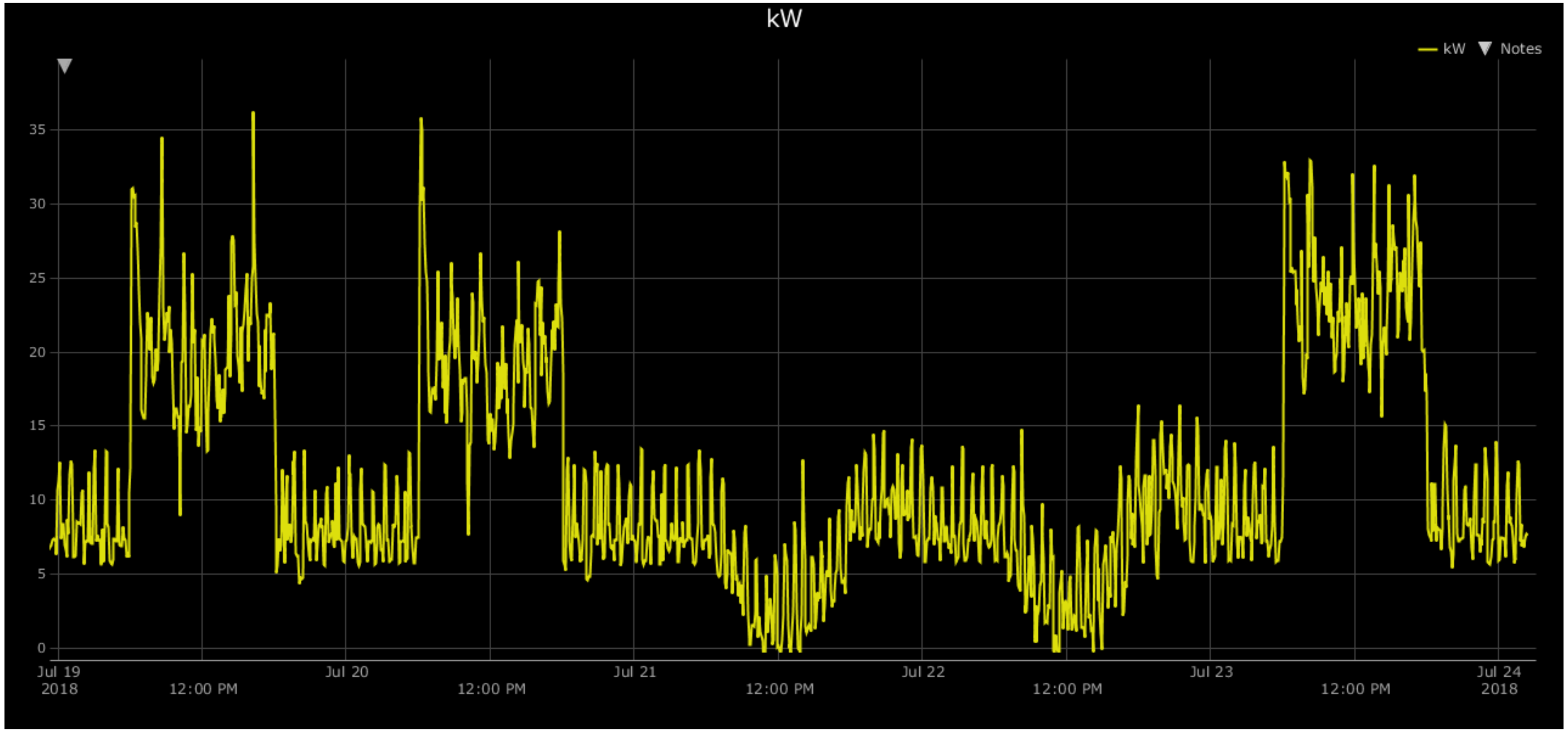
Uncertainty Sources: Energy Price



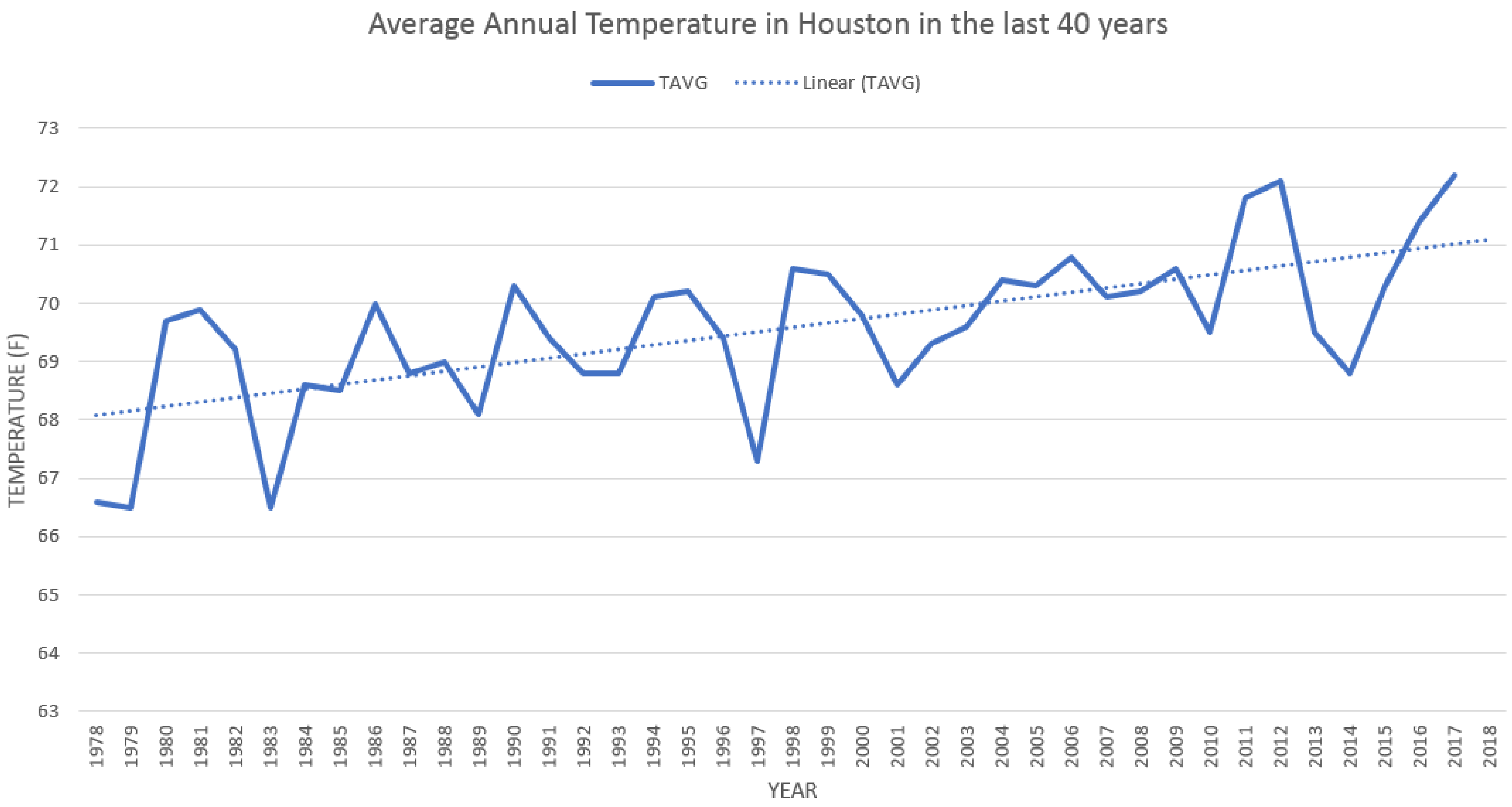
Uncertainty Sources: Energy Demand

Weekly Power Demand Curve (July 19th-July 24th)

- Power demand was between -1 and 17 kW during the weekend.



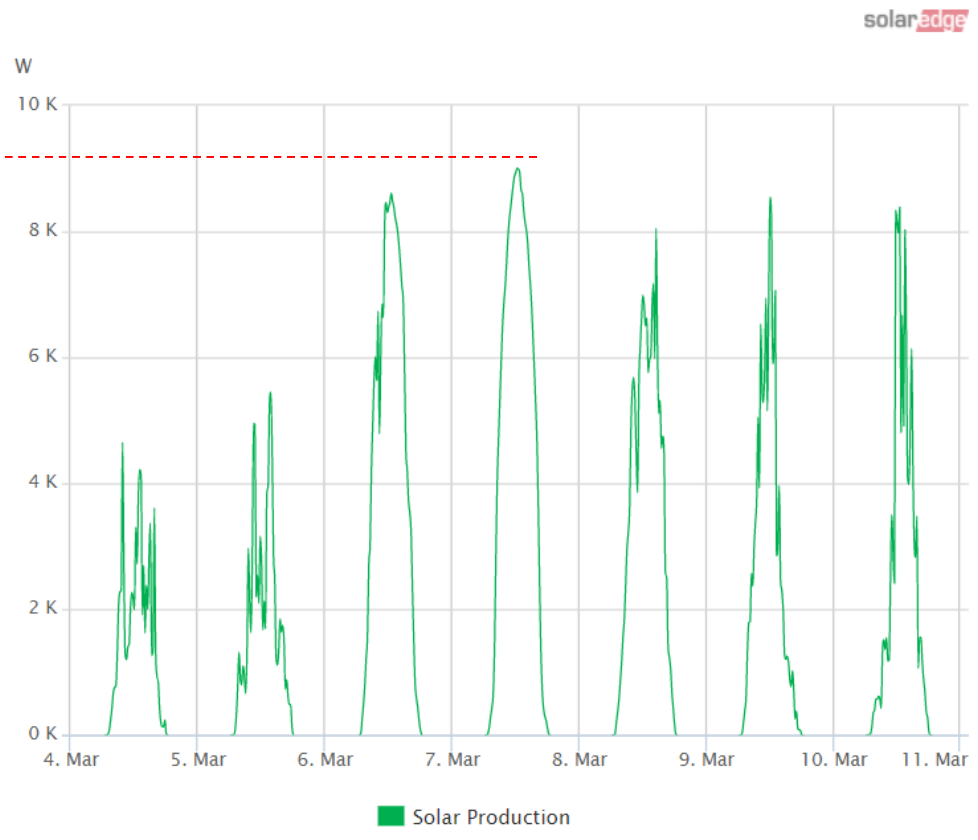
Uncertainty Sources: Temperatures



SOURCE: NOAA National Centers for Environmental Information (NCEI)

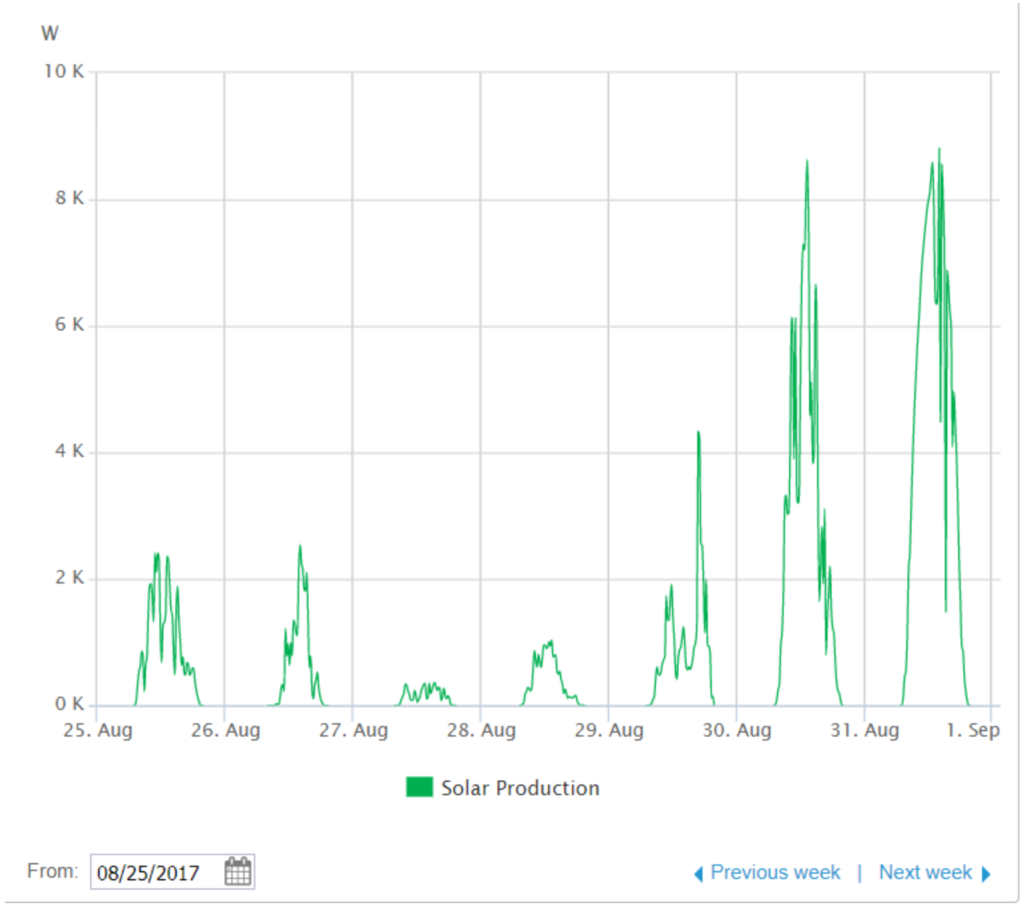
Certainties in the planning process: PV Production

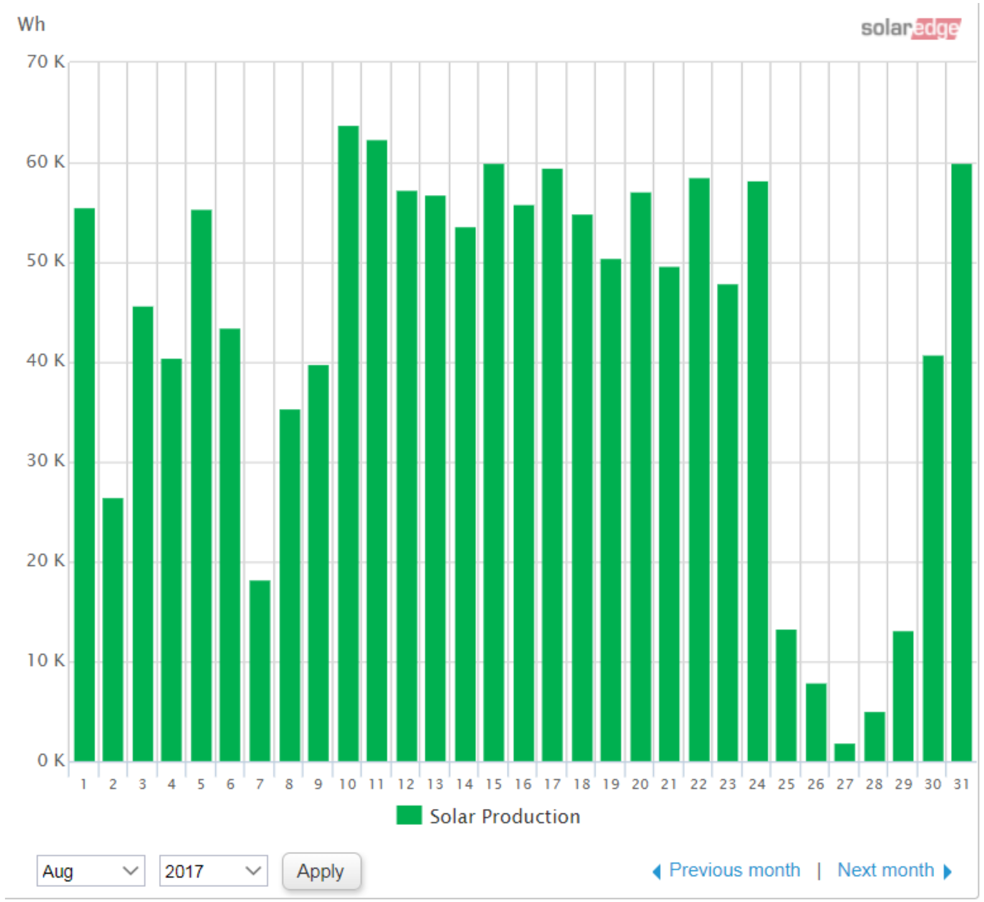
Generation capacity drops around 14% in summer due to high temperatures



Certainties in the planning process: PV Production

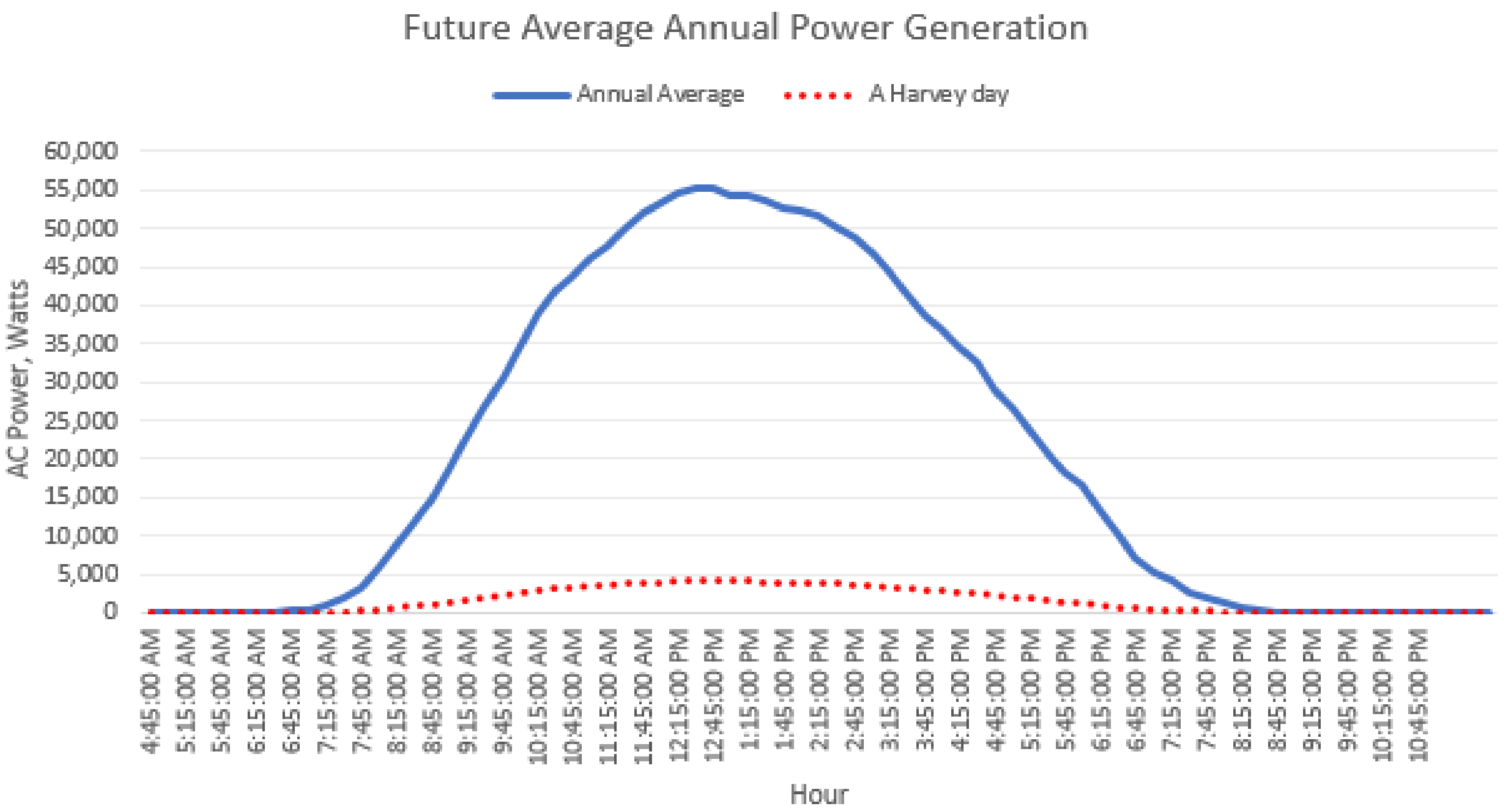
Generation capacity decrease during hurricane Harvey: 92.3% (average)



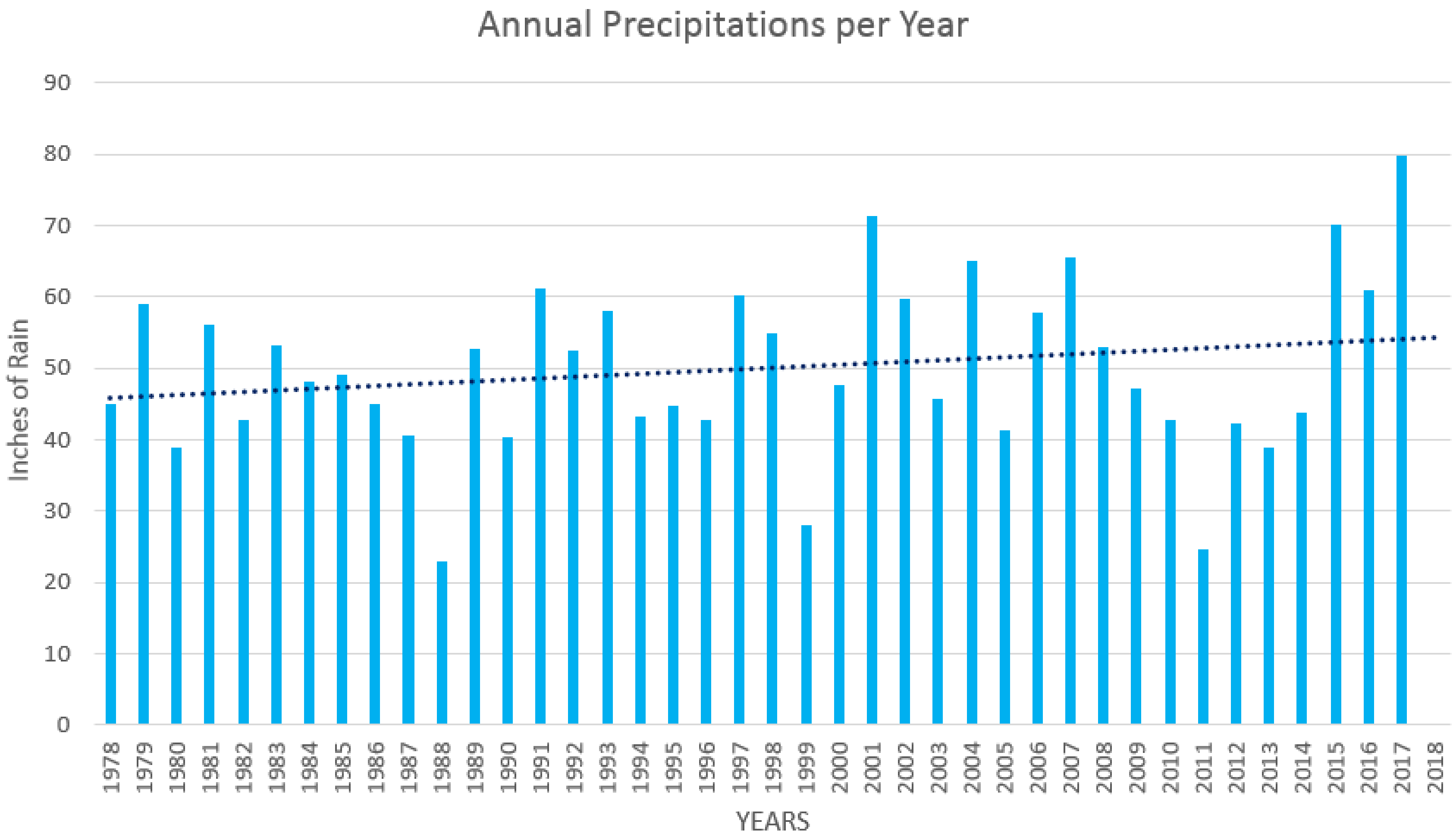


Certainties in the planning process: PV Production

- The new 85 kW solar plant with similar performance as during Harvey (very limited sunlight) will produced +/- 78 kWh per day.



Uncertainty Sources: Rain



SOURCE: NOAA National Centers for Environmental Information (NCEI)

Certainties in the Planning Process: Floods

2004	NOV 22-23	Flooding between I45 northebound feeder and FM 1960. Clay road covered with a foot and a half of water. Water covered road at I10 feeder [illegible] Hwy 6. Buffalo Bayou at Piney Point 1.35' above flood stage. (18)(9)
2005	MAY 29	Flooding in Aldine. (9)
2005	JUL 14	Flooding along I10 East, Downtown Houston and U of H area. 3.31" in 1 hour at Buffalo Bayou and Shephard. [illegible] out of its banks. (17) (8)
2005	DEC 14	Strong thunderstorms streamed across west and north Houston causing 4 to 6 inches of rainfall [illegible]
2006	JUN 19	Upper Level low remains over Houston causing flooding. 11" of rain fell south and [illegible]
2006	OCT 16	Tropical low and upper level disturbance combined with a warm front which [illegible] Monday. Several bayous were close to bankfull or over the banks [illegible] (18) (8)
2006	OCT 26-27	Storms ahead of an advancing cold front trained [illegible]
2007	JUN	Several days of rain. (8)
2009	APR 28	2100 homes flooded. Freeways [illegible]
2012	JUL 12-13	71 homes in Harris [illegible]
2013	MAY 10	Many [illegible]
2015	MAY 27-28	[illegible] flooded.
2016	APRIL 17-18	[illegible] Cypress Creek and in Meyerland area. [illegible] flooded. 10,000 homes flooded.
2016	MAY 14	[illegible] rescue from cars./td>
2016	JUN 2	[illegible] that occurred in and around La Porte, Pasadena, and Webster. [illegible] Highway 225 from Deer Park to La Porte.
2016	JUN 4	[illegible] subdivision.
2017	JAN 18	[illegible] which caused wide spread flooding. 100 homes and businesses flooded. 75 water rescues.
2017	AUG 26-28	[illegible] hurricane near Rockport, Texas during the evening of August 25th. The storm then weakened to a tropical [illegible] tracking over SE Texas then back over the Gulf of Mexico making a second landfall along the Louisiana [illegible] hours of August 30th. Over that 5 day period over Southeast Texas TS Harvey produced catastrophic flooding [illegible] 30 to 60 inches of rain, 23 tornadoes, tropical storm force winds and a moderate storm surge near Matagorda Bay. In some [illegible] bands rain fell at a rate of over 5 inches per hour. Roads and highways in and around Houston were flooded and therefore closed [illegible] long time periods. Catastrophic flooding occurred on nearly every one of the 22 watersheds in Harris County. 10 out of the 19 bayous in the county reached record crests and flooding.
2018	JUL 4	Slow moving low caused 5 to 8 inches of rain over Houston and Harris County causing many vehicle rescues and some flood waters in homes.

The Houston Area Floods Almost Every year

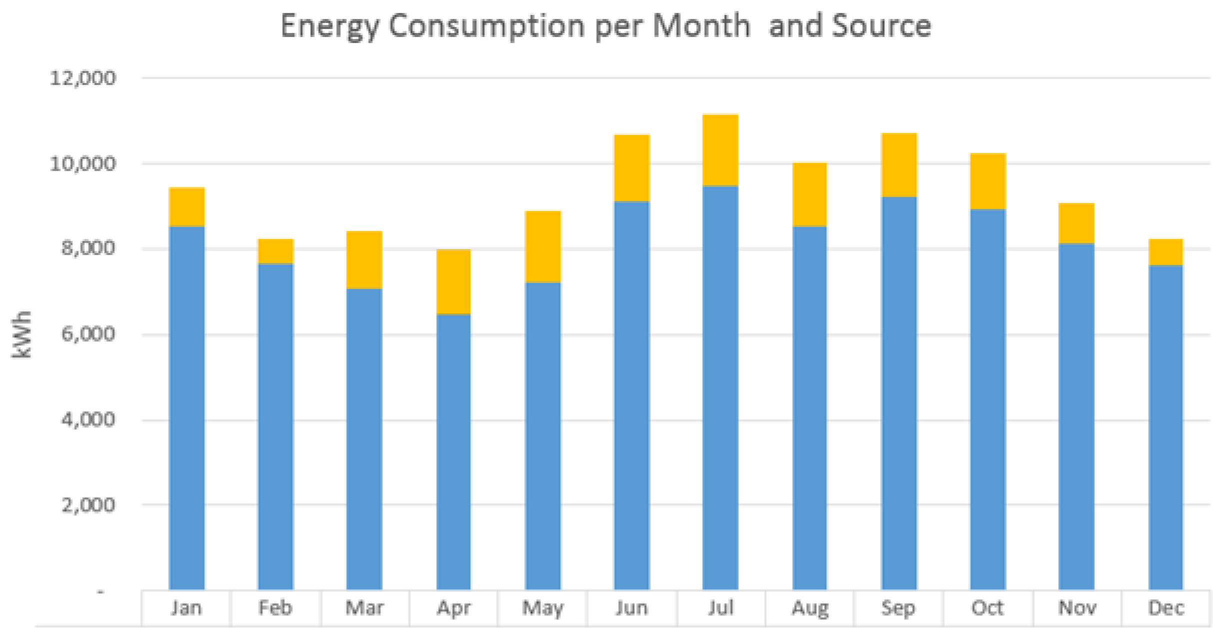
SOURCE: http://www.wxresearch.com/almanac/houflood.html

HARC Energy Planning for Microgrids

Energy Supply Analysis

Entergy (Local utility) + PV Solar

- Low voltage power supply (120/208V)
- Net metering. No capacity charges.
- Peak power demand 42 kW.
- Average power demand 12.93 kW.
- 113,297 kWh in the last 12 months
- 13.25% of HARC's energy consumption comes from PV solar

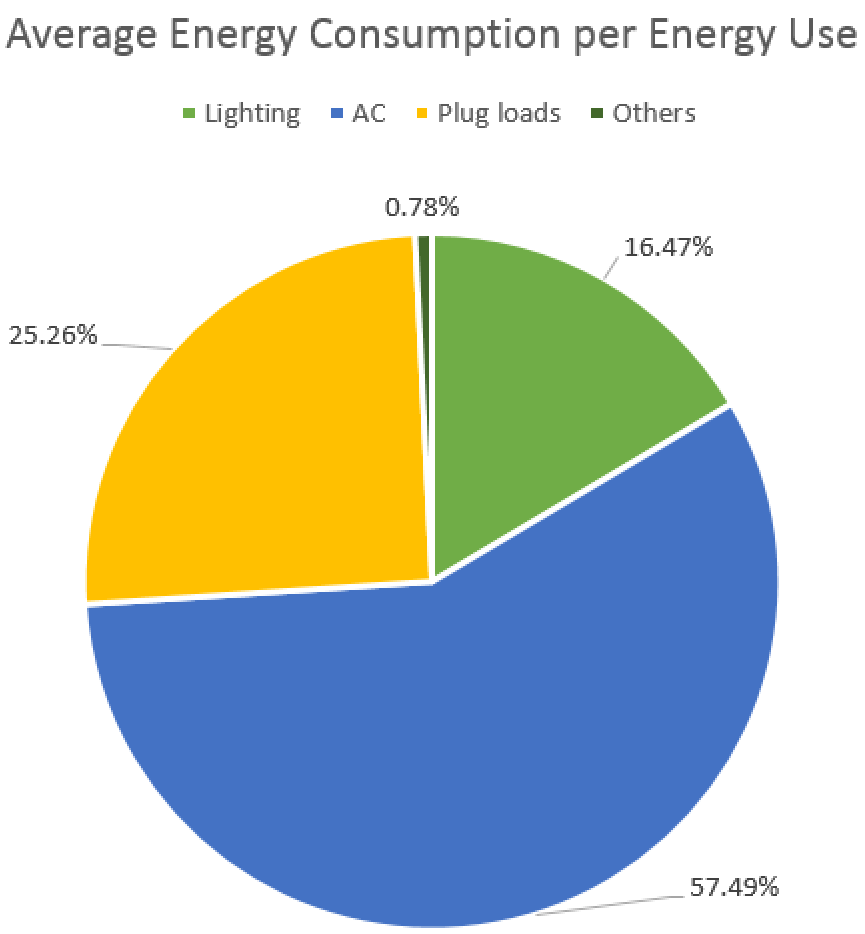


Energy Efficiency

Building's Energy Consumption

- 113,297 kWh in the last 12 months
- 6.1 kWh (20.8 KBtu) per sq. ft. annually
- 310.4 kWh per day

Savings goal is 5% of annual energy consumption per year for the next 2 years under building's usage conditions.



HARC Emergency Operating Mode

- **Power blackout or severe weather event: staff required to stay at home and work remotely.**
  - **Mode 1, Server backup**: Emergency lighting, server and server AC, 108 kWh per day (4.5 kW average, 6 kW peak).
  - **Mode 2, Building stand-by**: Energy demand 181 kWh per day (7.54 kW average, 11 kW peak).
  - **Mode 3, Full building operations**: Energy demand 312 kWh per day (13 kW average, 35 kW peak).

- HARC buys power at $0.103 and sells excess power back to the grid at $0.02 per kWh → additional savings of $0.0753 per kWh from solar stored and provided by battery.

Opportunity in PV solar + battery microgrid for energy savings during regular operations while increasing resilience.

HARC’s Microgrid Scenarios

HARC microgrid design

- Power supply as of November 2019: Existing 85 kW Solar + Power grid
- Energy and design goals in order of importance:
  - ✓ Resilience
  - ✓ Costs savings
  - ✓ Minimum environmental impact

- Main candidate technologies:
  - **SOLUTION 1**: Minimum investment: 50 kW propane gas generator
  - **SOLUTION 2**: Maximum efficiency: Battery storage+ PV island

HARC microgrid design

- Power supply as of November 2019: Existing 85 kW Solar + Power grid
- To increase HARC building's resilience HARC requires
  1. Energy efficiency improvements
  2. Changes in the interconnection scheme with the utility.
  3. Define the right microgrid and strategy to operate it

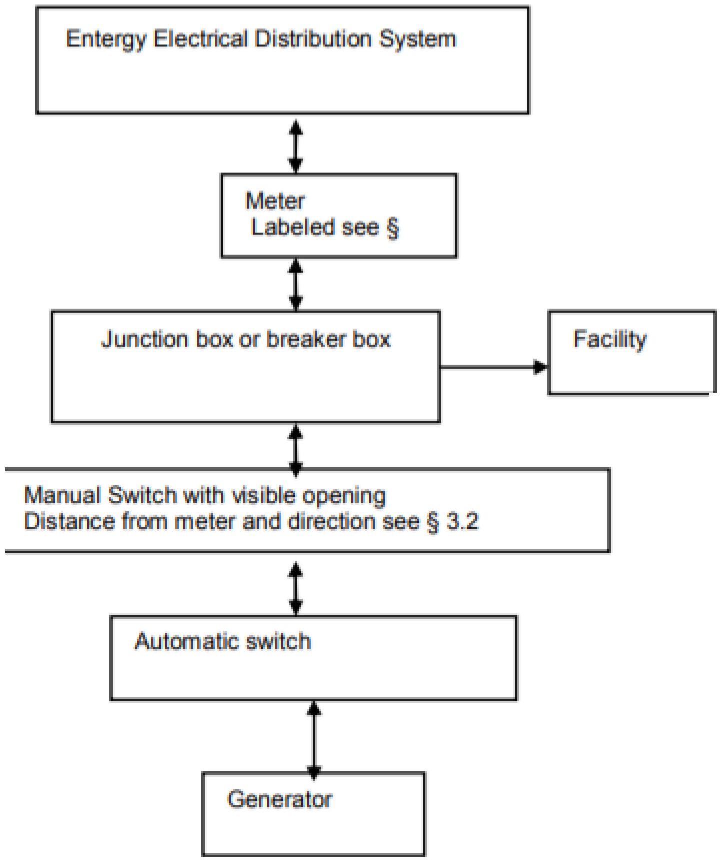
ENERGY STAR

U.S. GREEN BUILDING COUNCIL LEED PLATINUM USGBC

Existing Interconnection Scheme

- Existing Layout

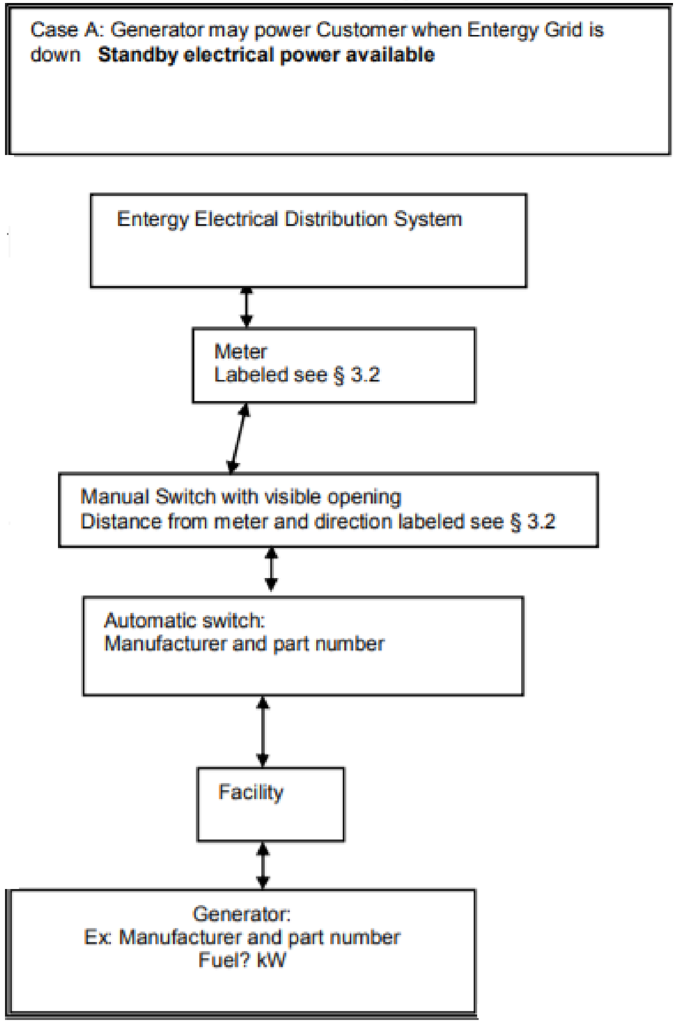
Case B: Generator is off when Entergy Grid is down
No standby electrical power



Solution 1: Propane Generator

SOLUTION 1: Minimum investment

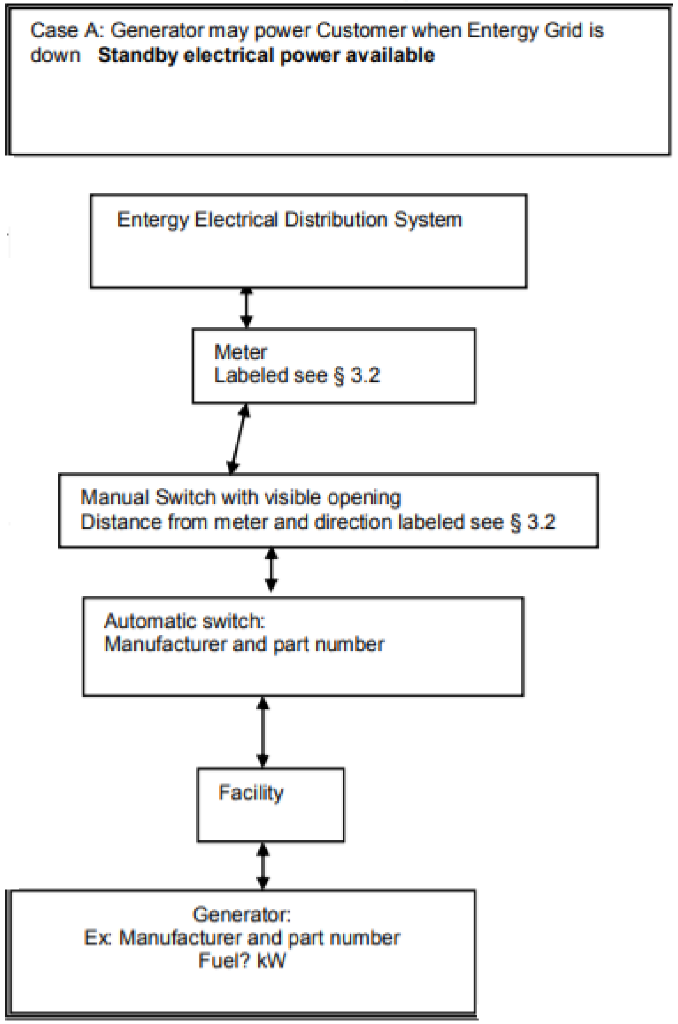
- Standby propane genset 50 kW, 120/208, 3-Phase
- 500 gallons propane tank and automatic transfer switch.
- Only for emergency uses when the grid is down
- PV solar down when grid is down in emergency mode
- Estimated budget $24,000
- Around 4 days autonomy for full building operations.
- Up to 10 days autonomy for building in emergency mode.



Solution 2: PV + Batteries + Grid

SOLUTION 2: PV + Batteries + Grid for full building operations

- 85 kW DC PV plant
- 50 kW peak power supply in island mode
- Battery to be sized for different autonomy levels
- Basic energy management system required.
- Estimated budget $2,000 per KW (peak) + battery cost



Solution 2: PV + Batteries + Grid

- As stated before, the new 85 kW solar plant with similar performance as during Harvey (very limited sunlight) will produced +/- 78 kWh per day.
- In order to not discontinue operations during a Harvey-type day, the battery must provide the energy not generated by solar during the day.
- **A 200 kWh battery could provide a six days autonomy for mode 1 and two days autonomy for mode 2.**

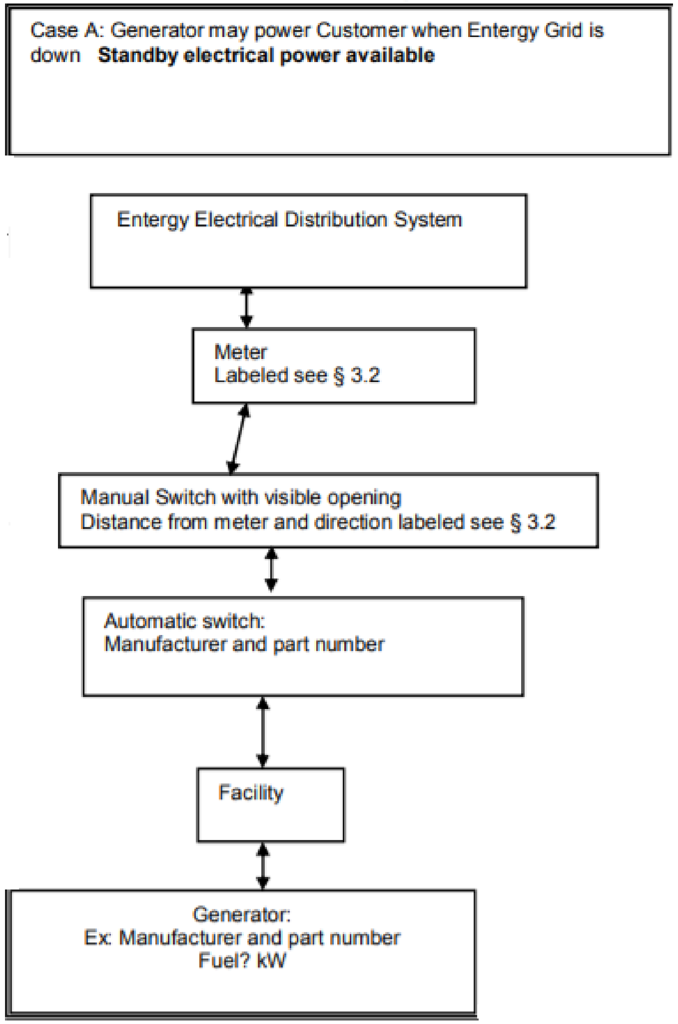
		WORSE CASE (HARVEY) SCENARIO				
	Daily Energy Demand (kWh)	PV-generated day time (kWh)	From battery Night hours 1 day (kWh)	From battery Night hours 5 days (kWh)	From battery night hours 6 days (kWh)	From battery night hours 7 days (kWh)
MODE 1	108	78	30	150	180	210
MODE 2	181	78	103	515	618	721
MODE 3	312	78	234	1,170	1,404	1,638

(red)	Not covered by a 200 kWh battery
(light green)	Covered by a 200 kWh battery

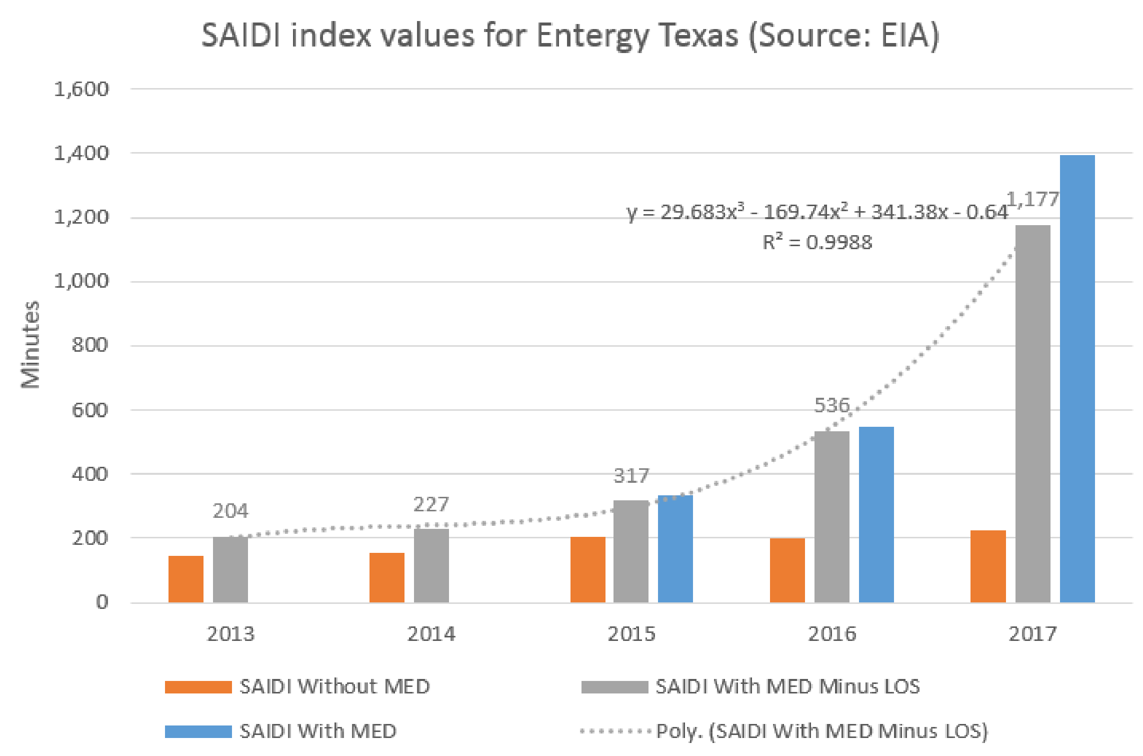
Solution 2: PV + Batteries + Grid

SOLUTION 2: PV + Batteries + Grid for full building operations

- 85 kW DC PV plant
- 50 kW peak power supply in island mode
- Battery to be sized for different autonomy levels
- Energy management system required
- **Estimated budget: $180,000**
  - ✓ **50 kW x $2,000/kW= $100,000**
  - ✓ **Battery cost 200 kWh x $400/kWh= $80,000**



Cost of the Lack of Resilience and Economic Constraints



- Potential blackout duration is increasing in the area.
- Average power outage 2013-2017: 8.20 hours per year
- $11,278 in economic losses estimated per average power outage for HARC
- Propane genset: budget limitation $10,000 if positive NPV after 12 years is possible.
- Profitability threshold PV + battery MG: 8 years

Economic Analysis of Microgrid Solutions- 1

SCENARIO 1:

- ✓ Zero power outages in next 12 years
- ✓ Electricity price escalation 3% per year
- ✓ Interest rate 5%

Incentives required for profitability limits:

- Genset + grid: $14,000
- PV + battery + grid: $145,500

	SOLUTION1	SOLUTION 2					
	50 kW Genset	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh
TOTAL Investment	$ (24,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)
Incentives	$ 14,000	$ -	$ 40,000	$ 80,000	$ 120,000	$ 145,419	$ 160,000
Avoided costs	-	-	-	-	-	-	-
Own capital	$ (10,000)	$ (180,000)	$ (140,000)	$ (100,000)	$ (60,000)	$ (34,581)	$ (20,000)
Year 1	0	4,323	4,323	4,323	4,323	4,323	4,323
Year 2	0	4,452	4,452	4,452	4,452	4,452	4,452
Year 3	0	4,586	4,586	4,586	4,586	4,586	4,586
Year 4	0	4,723	4,723	4,723	4,723	4,723	4,723
Year 5	0	4,865	4,865	4,865	4,865	4,865	4,865
Year 6	0	5,011	5,011	5,011	5,011	5,011	5,011
Year 7	0	5,161	5,161	5,161	5,161	5,161	5,161
Year 8	0	5,316	5,316	5,316	5,316	5,316	5,316
Year 9	0	5,476	5,476	5,476	5,476	5,476	5,476
Year 10	0	5,640	5,640	5,640	5,640	5,640	5,640
Year 11	0	5,809	5,809	5,809	5,809	5,809	5,809
Year 12		5,984	5,984	5,984	5,984	5,984	5,984
NPV ($)	0	(129,008)	(90,913)	(52,818)	(14,722)	9,486	23,373
Payback (Years)	-	41.64	32.39	23.13	13.88	8.00	4.63
IRR (%)	-	-13.1%	-10.4%	-6.5%	0.3%	9.5%	21.7%

Economic Sizing of Microgrid - 2

SCENARIO 2:

- ✓ 1 power outage (8 hours) in the next 12 years (year 2)
- ✓ Electricity price escalation 3% per year
- ✓ Interest rate 5%

Incentives required for profitability limits:

- Genset + grid: $3,369
- PV + battery + grid: $134,800

	SOLUTION1	SOLUTION 2					
	50 kW Genset	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh
TOTAL Investment	$ (24,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)
Incentive	$ 3,369	$ -	$ 40,000	$ 80,000	$ 120,000	$ 134,787	$ 160,000
Avoided costs	$ 10,631	$ 10,631	$ 10,631	$ 10,631	$ 10,631	$ 10,631	$ 10,631
Own capital	$ (10,000)	$ (169,369)	$ (129,369)	$ (89,369)	$ (49,369)	$ (34,581)	$ (9,369)
Year 1		4,323	4,323	4,323	4,323	4,323	4,323
Year 2	-	4,452	4,452	4,452	4,452	4,452	4,452
Year 3	-	4,586	4,586	4,586	4,586	4,586	4,586
Year 4	-	4,723	4,723	4,723	4,723	4,723	4,723
Year 5	-	4,865	4,865	4,865	4,865	4,865	4,865
Year 6	-	5,011	5,011	5,011	5,011	5,011	5,011
Year 7	-	5,161	5,161	5,161	5,161	5,161	5,161
Year 8	-	5,316	5,316	5,316	5,316	5,316	5,316
Year 9	-	5,476	5,476	5,476	5,476	5,476	5,476
Year 10	-	5,640	5,640	5,640	5,640	5,640	5,640
Year 11	-	5,809	5,809	5,809	5,809	5,809	5,809
Year 12	-	5,984	5,984	5,984	5,984	5,984	5,984
NPV ($)	-	(118,883)	(80,788)	(42,693)	(4,598)	9,486	33,498
Payback (Years)	-	39.18	29.93	20.67	11.42	8.00	2.17
IRR (%)	-	-12.5%	-9.6%	-5.1%	3.3%	9.5%	48.6%

Economic Sizing of Microgrid - 3

SCENARIO 3:

- ✓ 2 power outages (16 hours) in the next 12 years (years 2 and 8)
- ✓ Electricity price escalation 3% per year
- ✓ Interest rate 5%

Incentives required for profitability limits:

- Genset + grid: $0
- PV + battery + grid: $126,000

	SOLUTION1	SOLUTION 2					
	50 kW Genset	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh
TOTAL Investment	$ (24,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)
Incentives	$ -	$ -	$ 40,000	$ 80,000	$ 120,000	$ 125,884	$ 160,000
Avoided costs	$ 19,535	$ 19,535	$ 19,535	$ 19,535	$ 19,535	$ 19,535	$ 19,535
Own capital	$ (10,000)	$ (160,465)	$ (120,465)	$ (80,465)	$ (40,465)	$ (34,581)	$ (465)
Year 1		4,323	4,323	4,323	4,323	4,323	4,323
Year 2	-	4,452	4,452	4,452	4,452	4,452	4,452
Year 3	-	4,586	4,586	4,586	4,586	4,586	4,586
Year 4	-	4,723	4,723	4,723	4,723	4,723	4,723
Year 5	-	4,865	4,865	4,865	4,865	4,865	4,865
Year 6	-	5,011	5,011	5,011	5,011	5,011	5,011
Year 7	-	5,161	5,161	5,161	5,161	5,161	5,161
Year 8	-	5,316	5,316	5,316	5,316	5,316	5,316
Year 9	-	5,476	5,476	5,476	5,476	5,476	5,476
Year 10	-	5,640	5,640	5,640	5,640	5,640	5,640
Year 11	-	5,809	5,809	5,809	5,809	5,809	5,809
Year 12	-	5,984	5,984	5,984	5,984	5,984	5,984
NPV ($)	9,524	(110,404)	(72,308)	(34,213)	3,882	9,486	41,977
Payback (Years)	-	37.12	27.87	18.61	9.36	8.00	0.11
IRR (%)	-	-11.9%	-8.7%	-3.8%	6.6%	9.5%	932.0%

Economic Sizing of Microgrid - 4

SCENARIO 4:

- ✓ 3 power outages (24 hours) in the next 12 years (years 2, 6 and 8)
- ✓ Electricity price escalation 3% per year
- ✓ Interest rate 5%

Incentives required for profitability limits:

- Genset + grid: $0
- PV + battery + grid: $117,500

	SOLUTION1	SOLUTION 2					
	50 kW Genset	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh	200 kWh
TOTAL Investment	$ (24,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)	$ (180,000)
Incentives	$ -	$ -	$ 40,000	$ 80,000	$ 117,492	$ 120,000	$ 160,000
Avoided costs	$ 27,927	$ 27,927	$ 27,927	$ 27,927	$ 27,927	$ 27,927	$ 27,927
Own capital		$ (152,073)	$ (112,073)	$ (72,073)	$ (34,581)	$ (32,073)	$ 7,927
Year 1		4,323	4,323	4,323	4,323	4,323	4,323
Year 2	-	4,452	4,452	4,452	4,452	4,452	4,452
Year 3	-	4,586	4,586	4,586	4,586	4,586	4,586
Year 4	-	4,723	4,723	4,723	4,723	4,723	4,723
Year 5	-	4,865	4,865	4,865	4,865	4,865	4,865
Year 6	-	5,011	5,011	5,011	5,011	5,011	5,011
Year 7	-	5,161	5,161	5,161	5,161	5,161	5,161
Year 8	-	5,316	5,316	5,316	5,316	5,316	5,316
Year 9	-	5,476	5,476	5,476	5,476	5,476	5,476
Year 10	-	5,640	5,640	5,640	5,640	5,640	5,640
Year 11	-	5,809	5,809	5,809	5,809	5,809	5,809
Year 12	-	5,984	5,984	5,984	5,984	5,984	5,984
NPV ($)	3,927	(102,411)	(64,316)	(26,220)	9,486	11,875	49,970
Payback (Years)	-	35.18	25.93	16.67	8.00	7.42	0.00
IRR (%)	-	-11.3%	-7.9%	-2.3%	9.5%	11.0%	0.00

Conclusions & Next Steps

Conclusions

- The propane genset microgrid would be profitable if HARC suffers at least 16 working hours of power outages in the next 12 years.
- The PV + batteries microgrid project would be profitable if:
  - ✓ HARC suffers a 106 working hours power blackout (13.25 working days), **an scenario that already happen in the area during hurricane Ike in August 2008.**
  - ✓ OR HARC receives a $145,500 incentive.
  - ✓ AND Several scenarios in between, such as a 24-working hours power outage and a $117,500 incentive.

Next Steps

- Other business models and power storage technologies might be considered as well.
  - ✓ Work with a third party on an energy savings performance contract with some specific conditions for power supply during emergency operating conditions.
  - ✓ Exploring with the manufacturer the alternatives to transform our grid-tied inverters to off-grid inverters and install batteries or other power storage technology.
- Develop our own solution and energy management system in collaboration with partners.

Thank You!

Carlos Gamarra, PE, CEM
cgamarra@harcresearch.org

HARC (härk), *n.*
an independent research
hub helping people thrive
and nature flourish.