Sandia National Laboratories

SAND2019-2648C

A SUNNY RESILIENT ENERGY FUTURE

PRESENTED BY

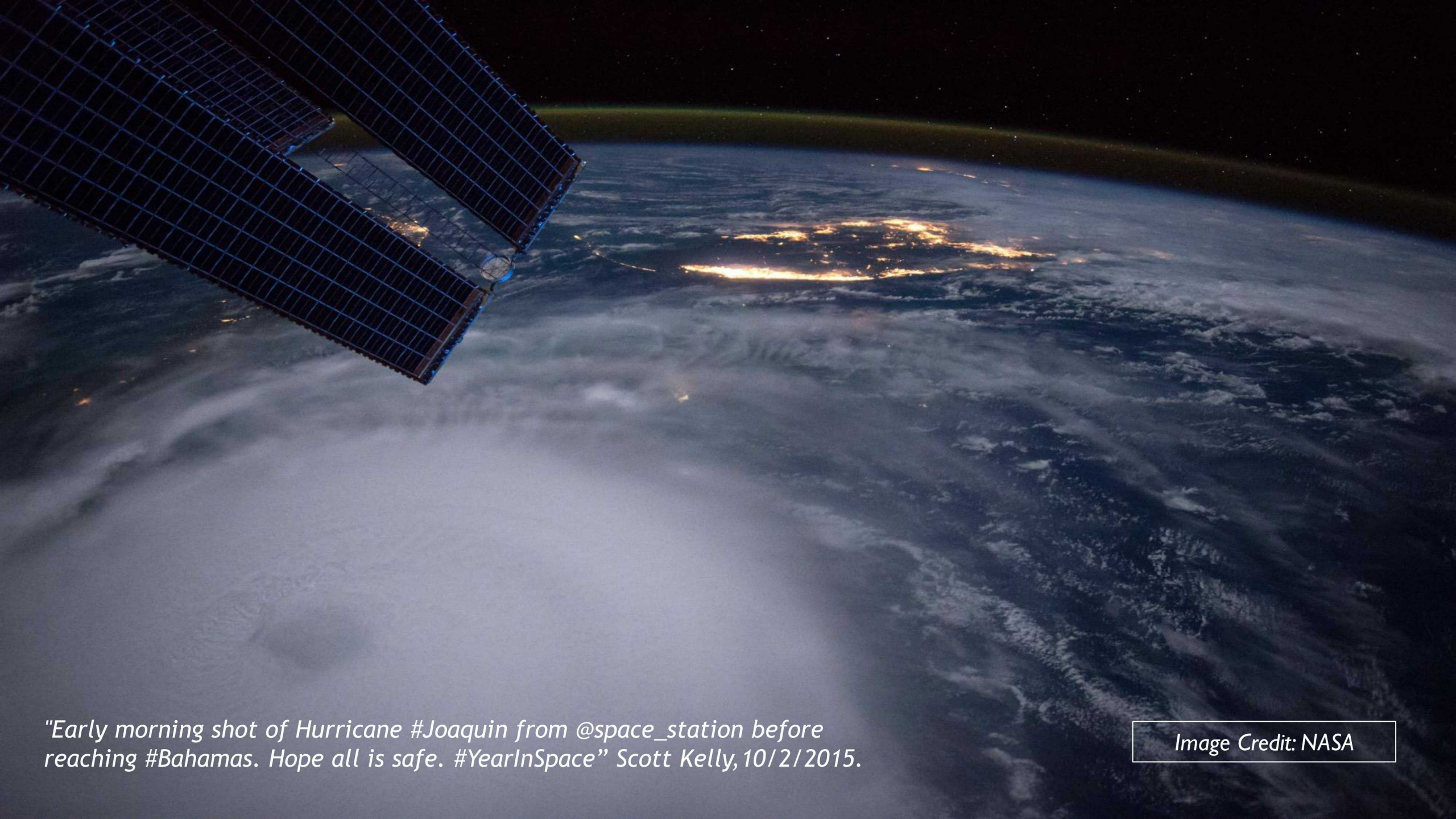
Abraham Ellis

aellis@sandia.gov

SAND2018-11263

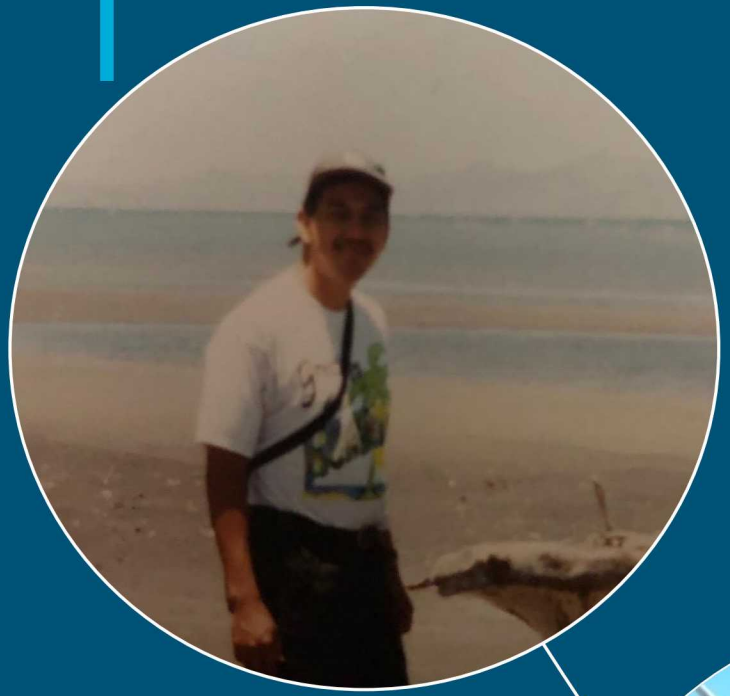
U.S. DEPARTMENT OF ENERGY NNSA

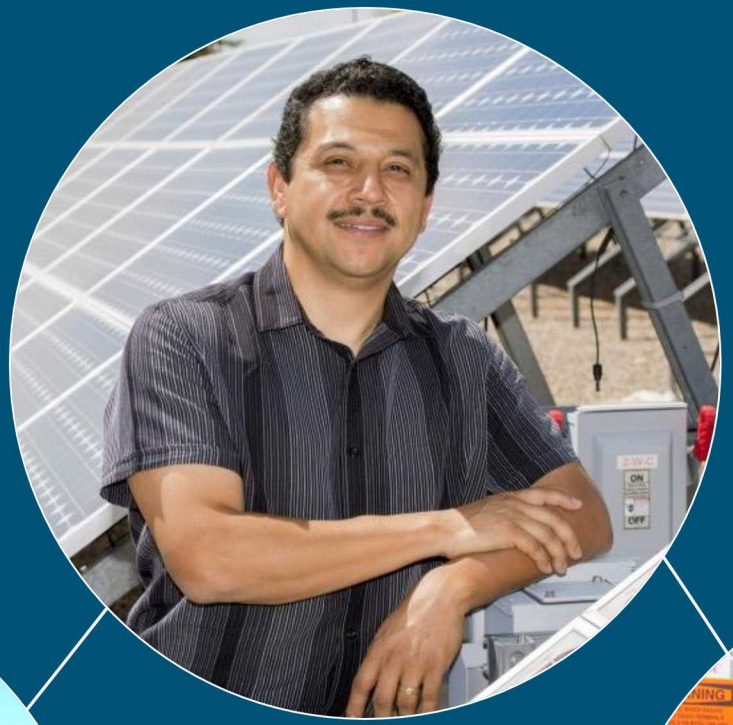
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.



"Early morning shot of Hurricane #Joaquin from @space_station before reaching #Bahamas. Hope all is safe. #YearInSpace" Scott Kelly, 10/2/2015.

Image Credit: NASA






ON
OFF
EAST ARRAY
0-600 VDC
WARNING
ROW 6
DISC.#1
240 VOLTS
SINGLE PHASE


ENERGIA SOLAR DE CALIFORNIA
ELECTRIFICACION DE CERCOS
ILUMINACION Y
SISTEMA DE BOMBEO

PV deployment has come a long way…

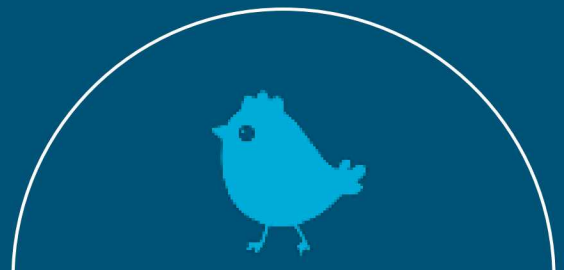
…but none of these systems work during a grid outage!

PV Eras

We are here, and solar is ready to play major role.

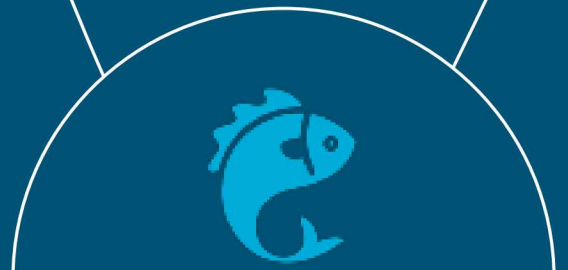
Flexible demand and storage enable a solar powered future

Birkenstock Era



Chicken Little Era

Essential Reliability Era



Mudskipper Era

Super Inverter Era

Grand Bargain Era

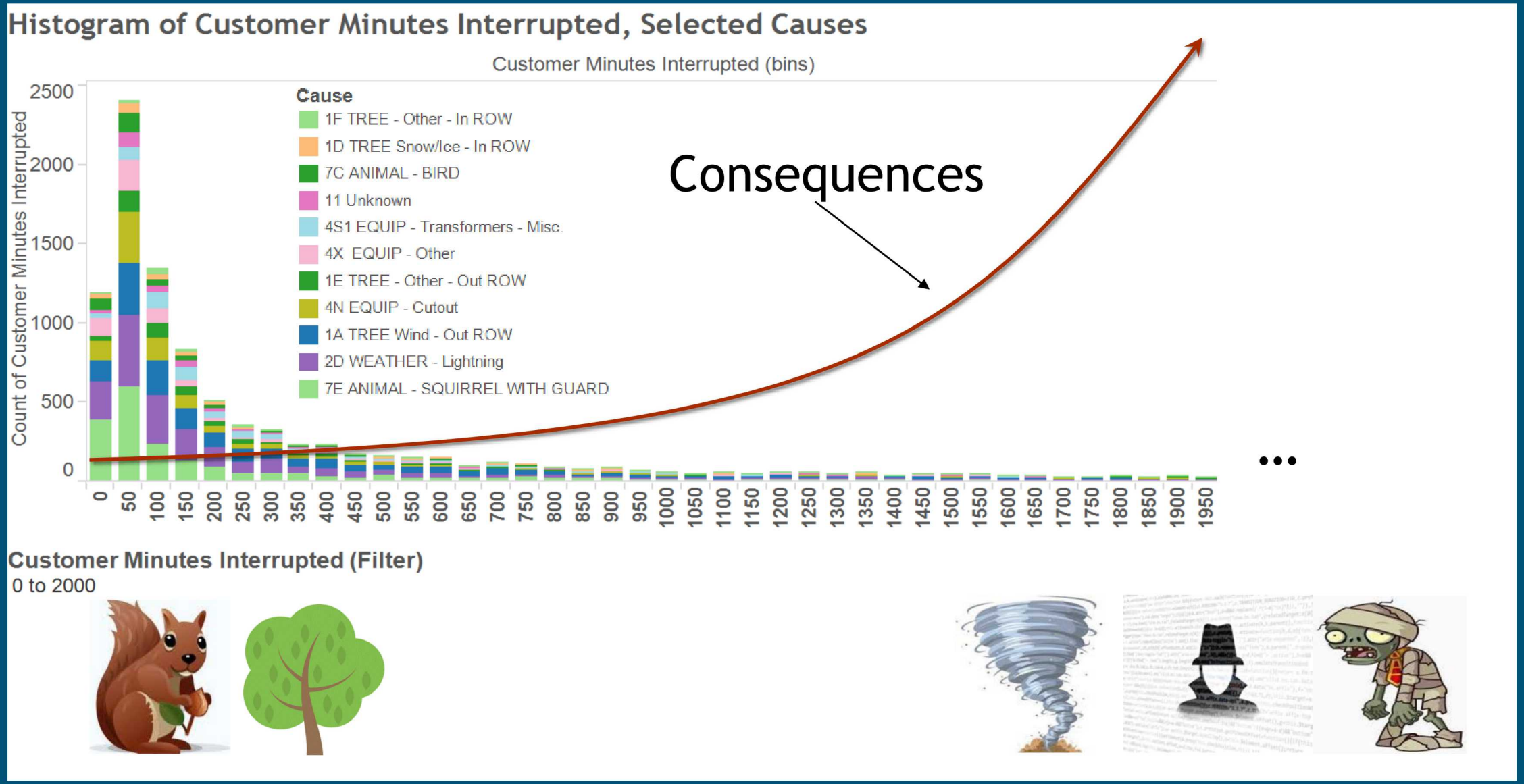
RELIABILITY

99.97%

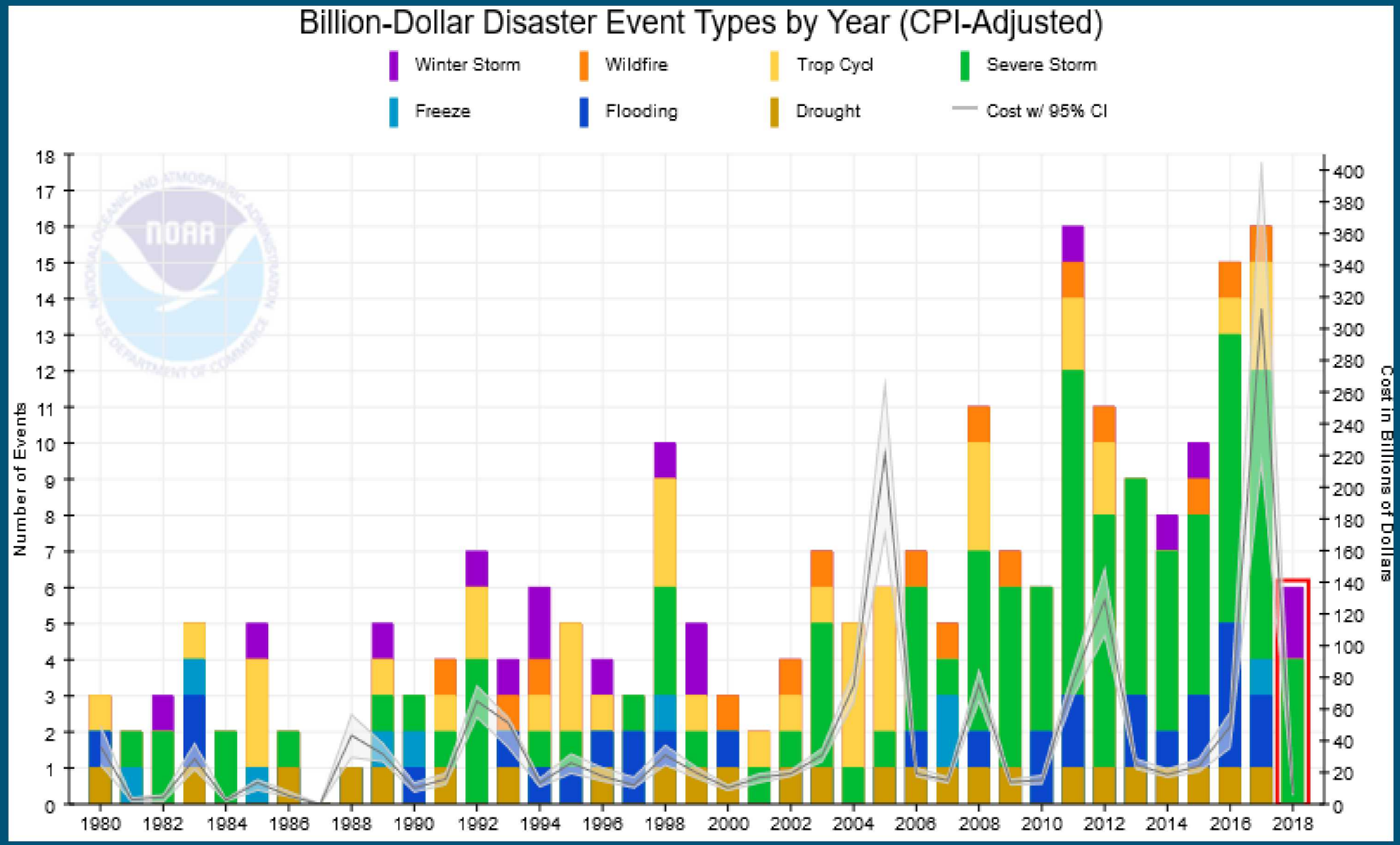
What would it cost add another "9" of reliability?


HESS

Reliability focuses on average system performance, skips large-scale events, and does not consider consequences…



Large-scale events becoming more frequent…



Large-scale events becoming more frequent…

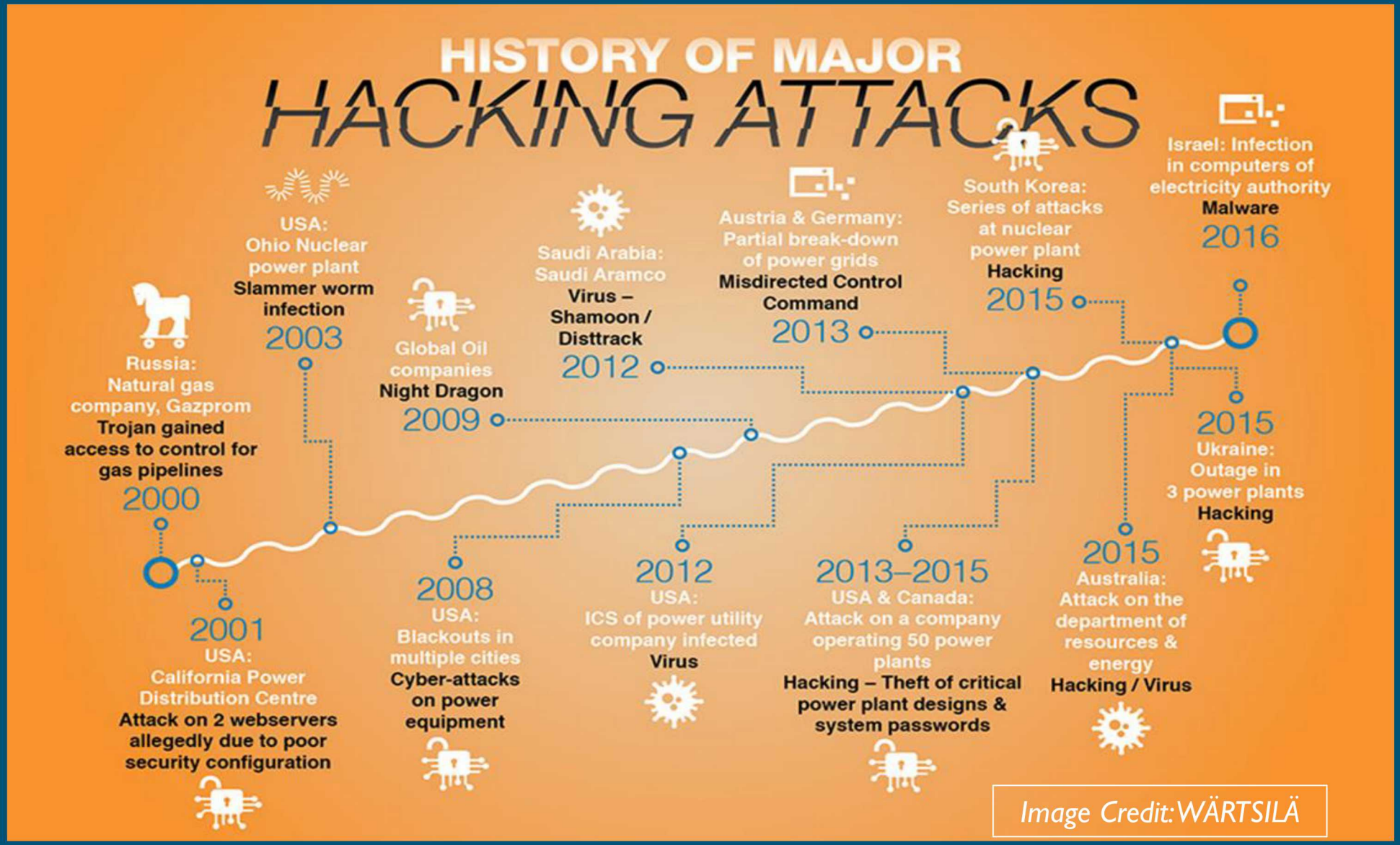
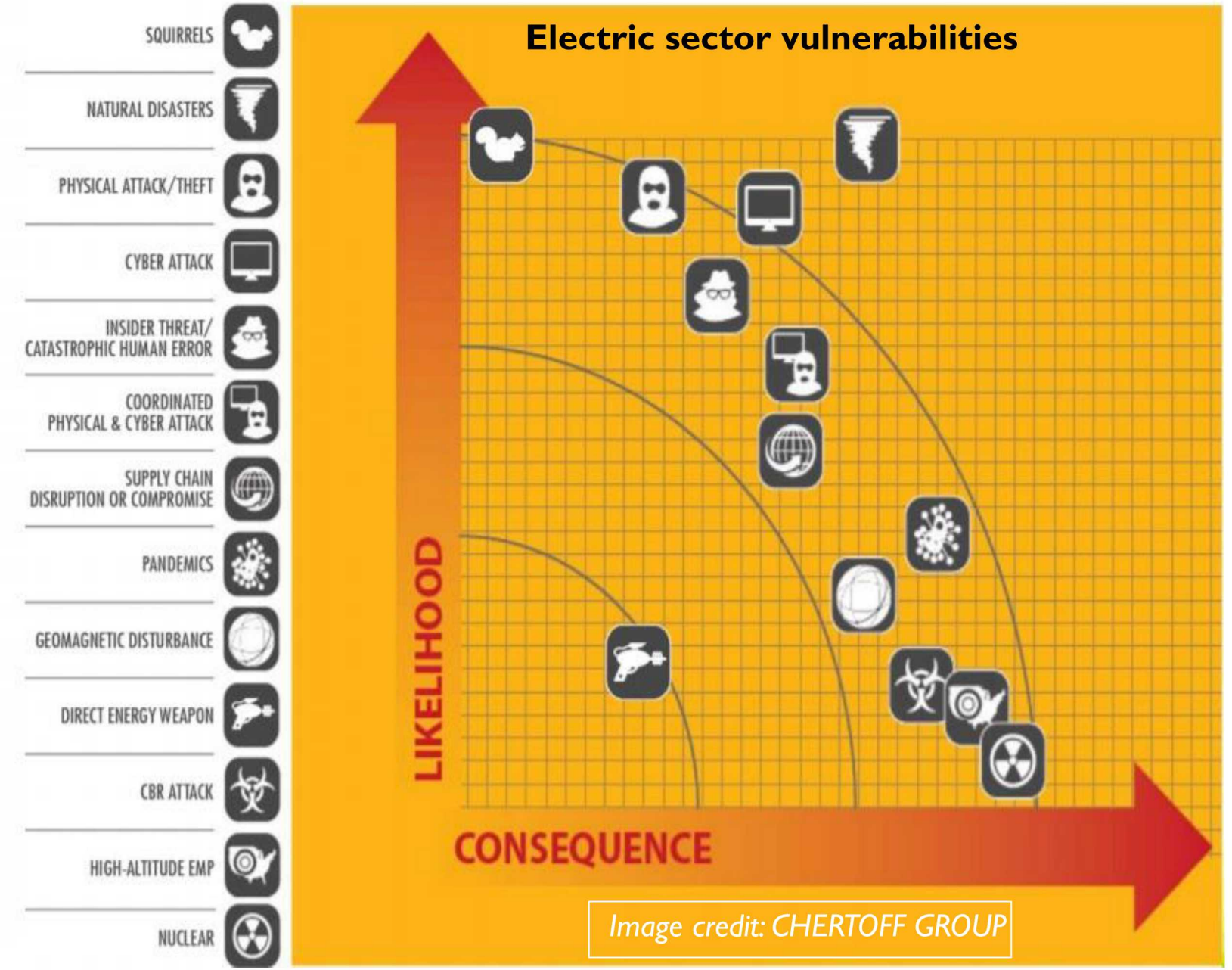


Image Credit: WÄRTSILÄ

"You don't really know better until you do better."

Existing grid planning framework does not effectively deal with high-consequence events, even if those that are likely!

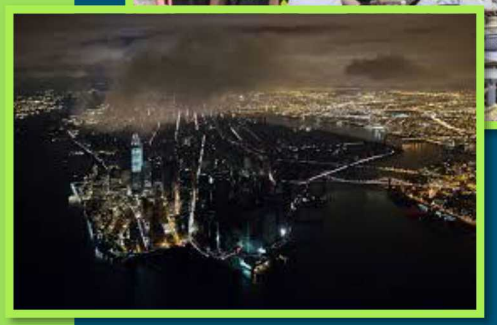


Resilience can be considered an extension of Reliability…

Resilience

Includes Reliability concepts, but also ***low probability, high consequence*** events.

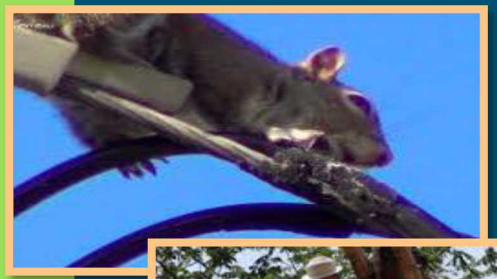
Not widely adopted for grid infrastructure investment. Need new ***methods, metrics and tools***



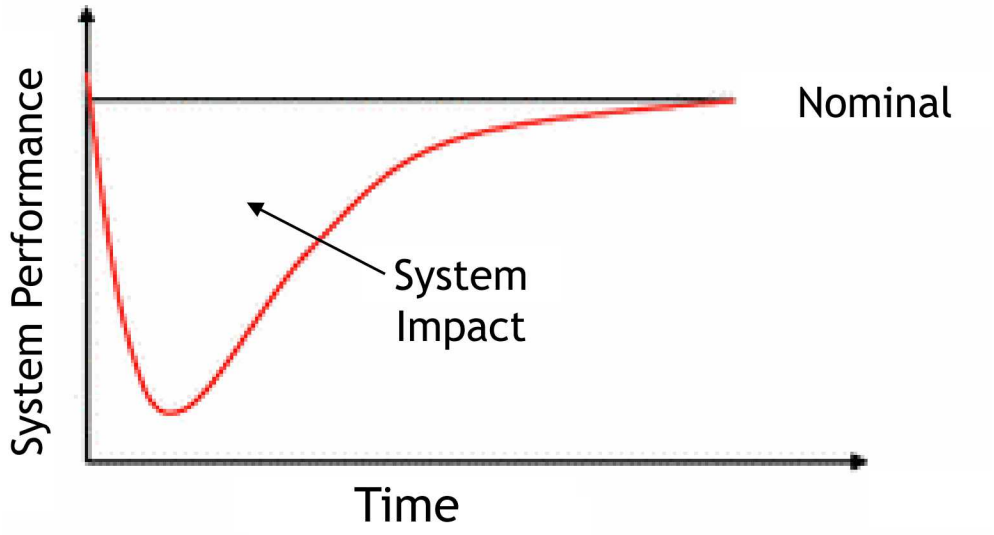
Reliability

Focuses on system performance with respect to **commonly expected events** (component failure, etc.)

Widely adopted for infrastructure investment decision-making.



Defining Resilience



Ability to **Prepare for, Withstand and Recover from** disruptions caused by major **Accidents, Attacks, or Natural Disasters.**

Pop Quiz

What problem are we trying to solve?

☒ Improve resilience of the whole grid

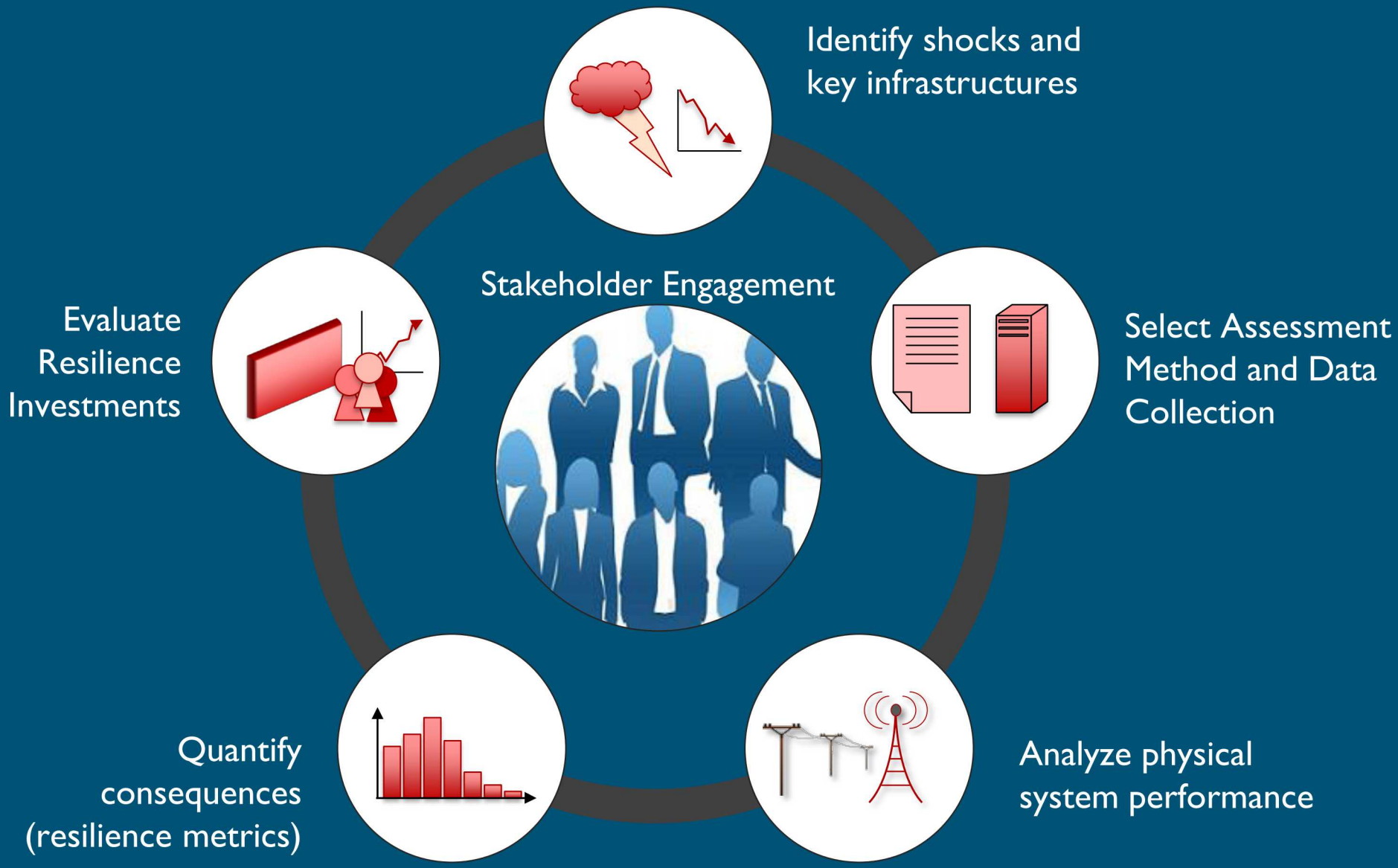
☑ Improve resilience of infrastructure that supports critical services at selected locations

A consequence-based view of Resilience

Measure	Examples of Resilience Metrics
Economics	Gross Municipal Product / Net Economic Losses
	Change in Capital Wealth
	Business Interruption Costs
People and Community	Number of People Without Basic Services
	Lives at Risk
	Societal Burden to Acquire Services

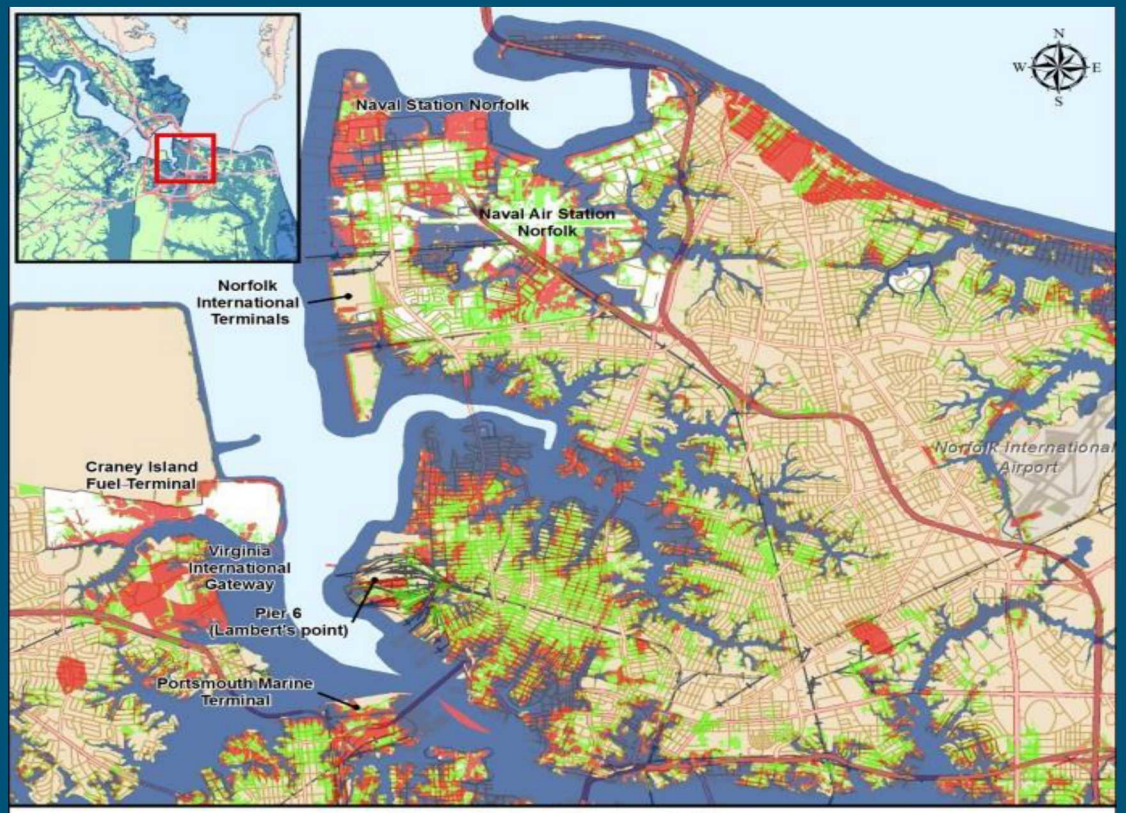
Image Credit: REUTERS / S. Stapleton

A Resilience Planning Framework



Resilience Analysis using Economic and Community Metrics

Norfolk, VA

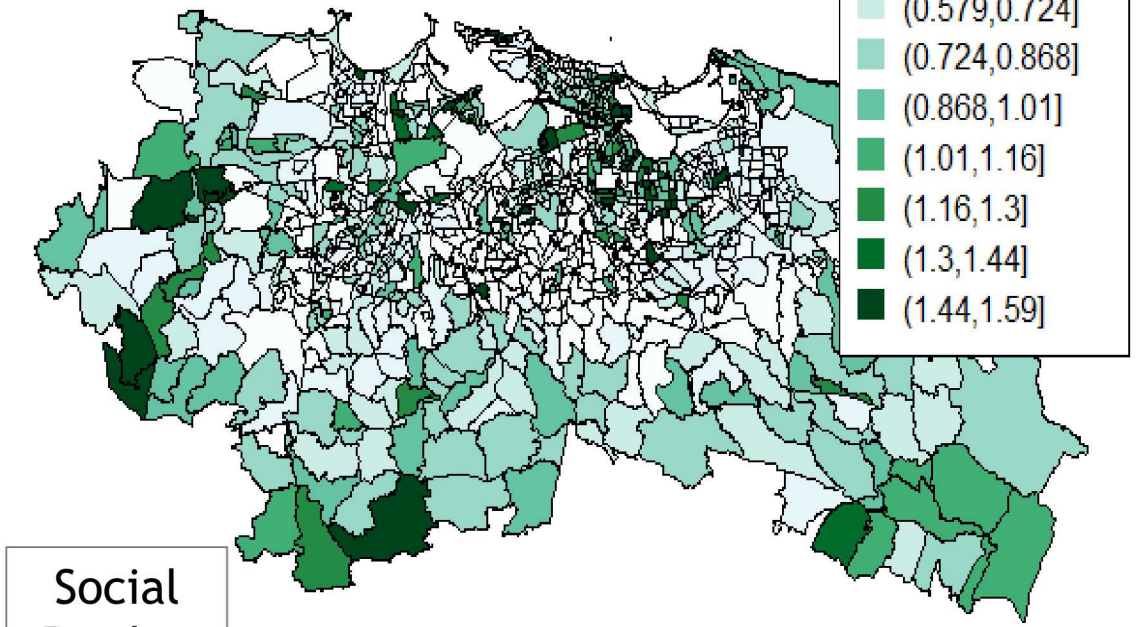


	100yr+0ft	100yr+1.5ft	100yr+3.0ft
Annual Direct Losses	$135 M	$182 M	$231 M
Annual Indirect Losses	$219 M	$296 M	$375 M
Total	$354 M	$478 M	$606 M

San Juan, PR

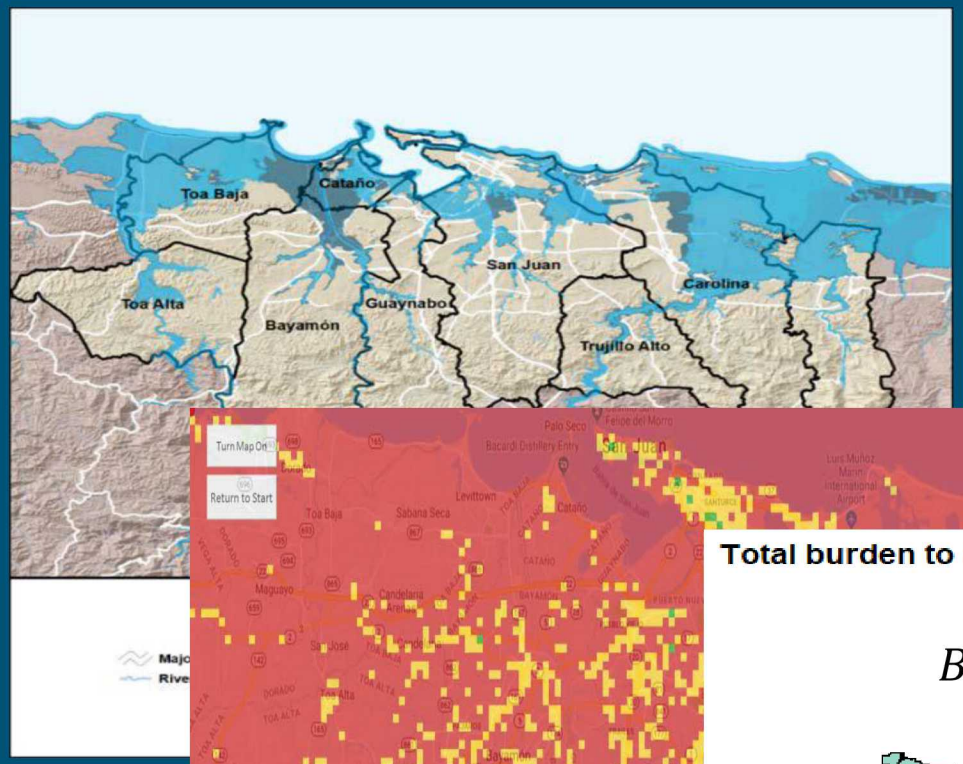
Total burden to acquire food for a random 34-microgrid portfolio

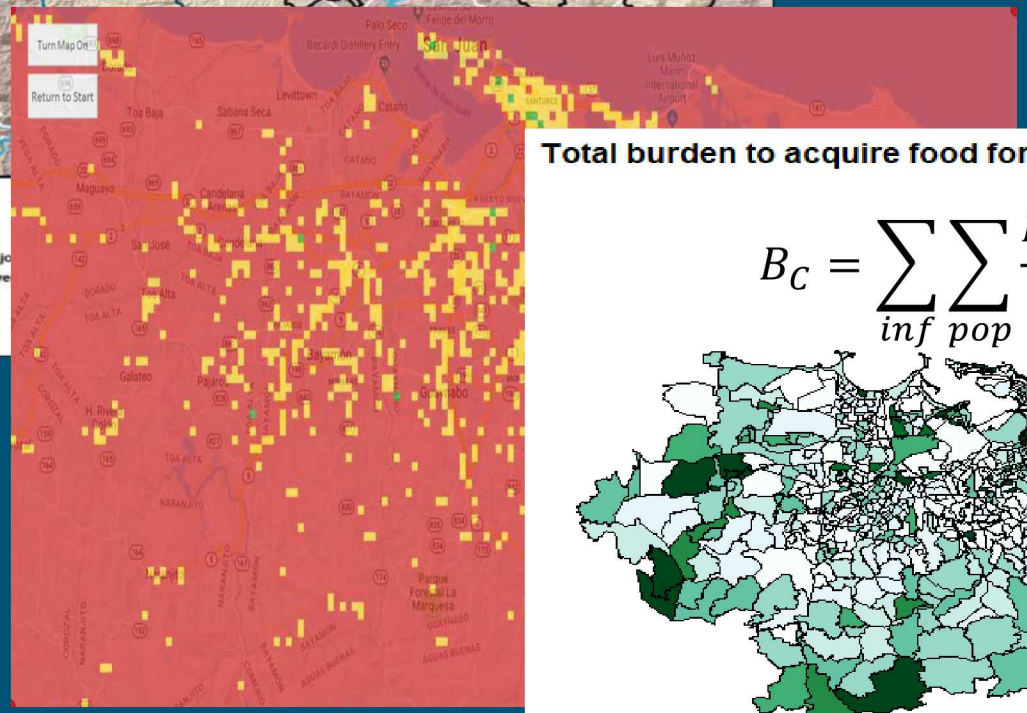
$$B_C = \sum_{inf} \sum_{pop} \frac{E_{inf,pop}}{A_{pop}}$$



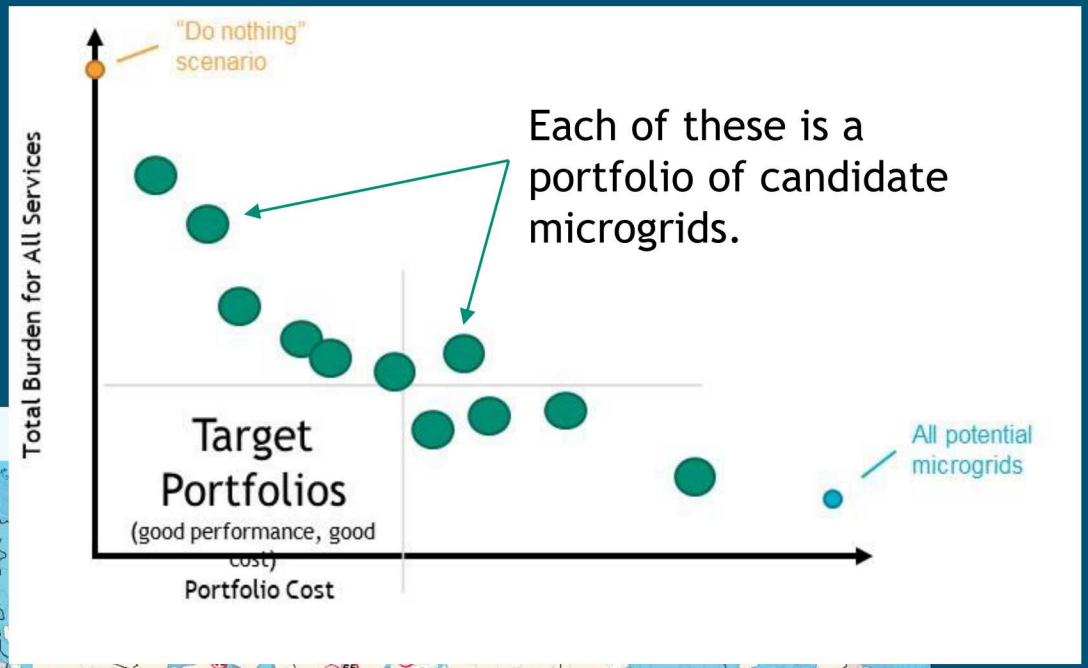
Social Burden

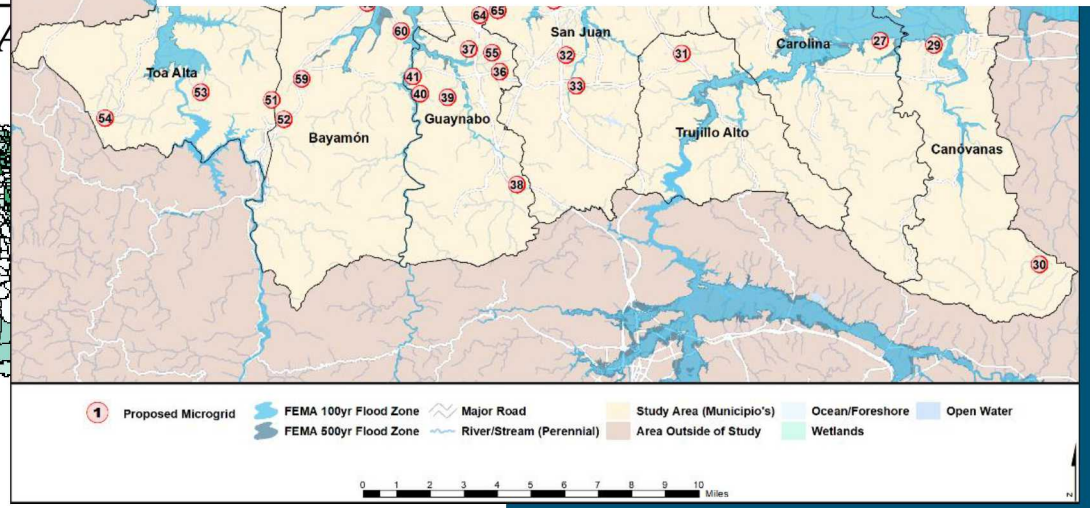
Resilience Planning Process in Action – San Juan, PR

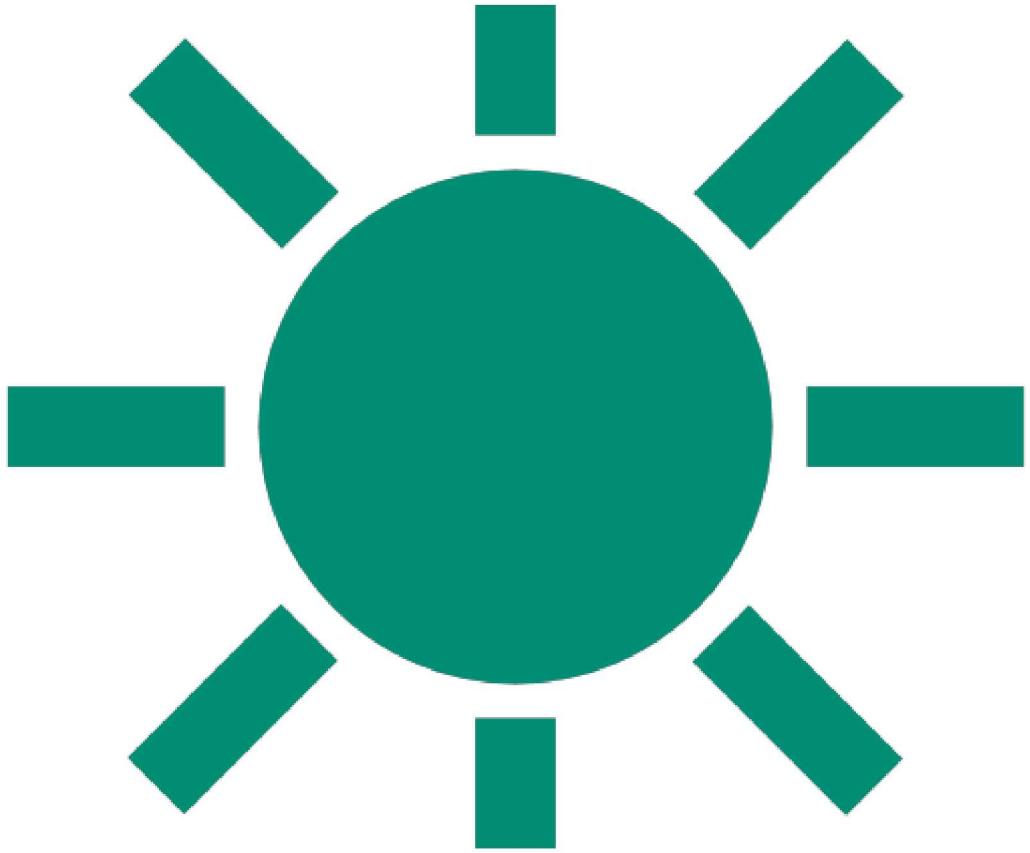




Social Burden



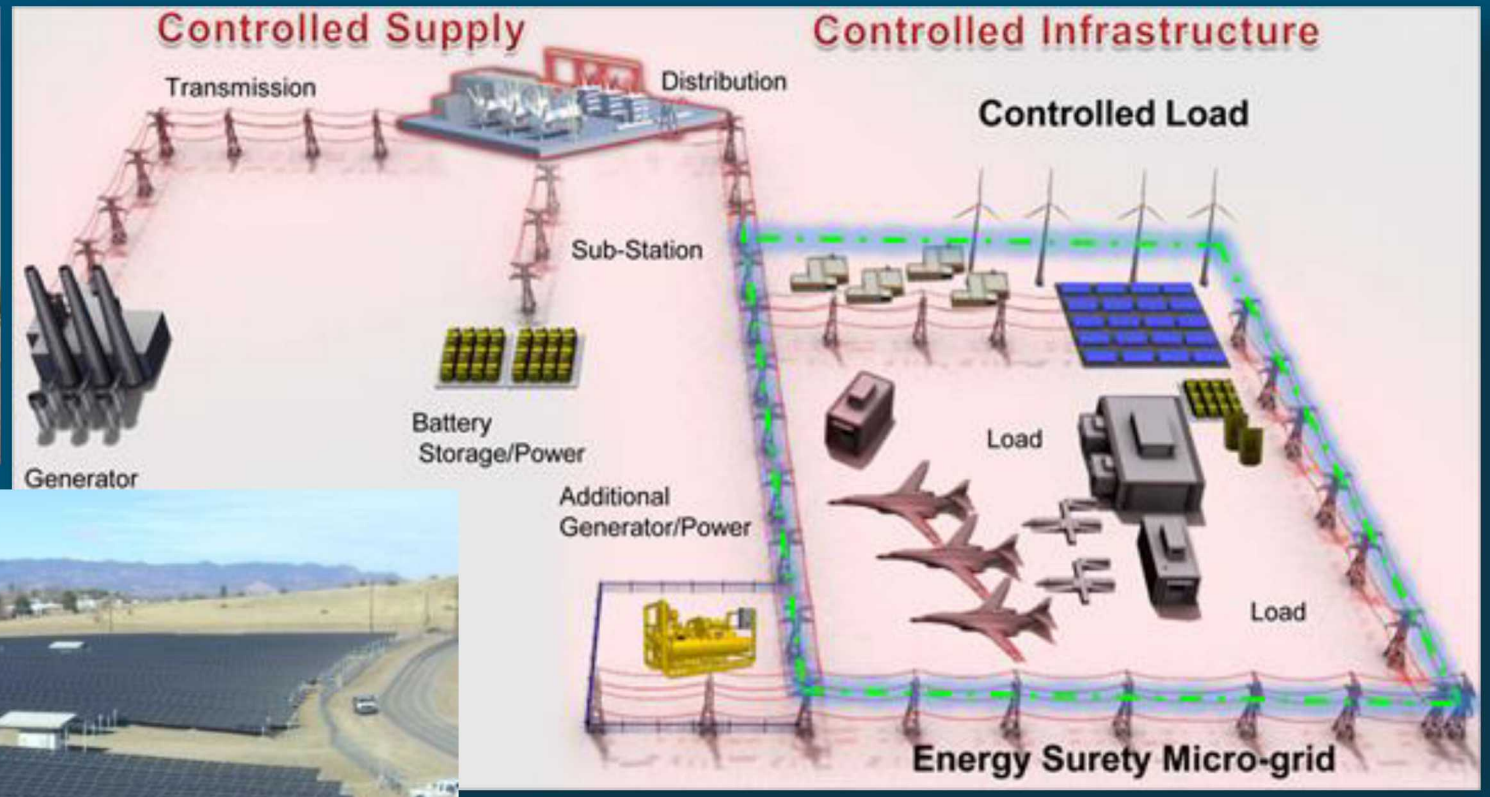




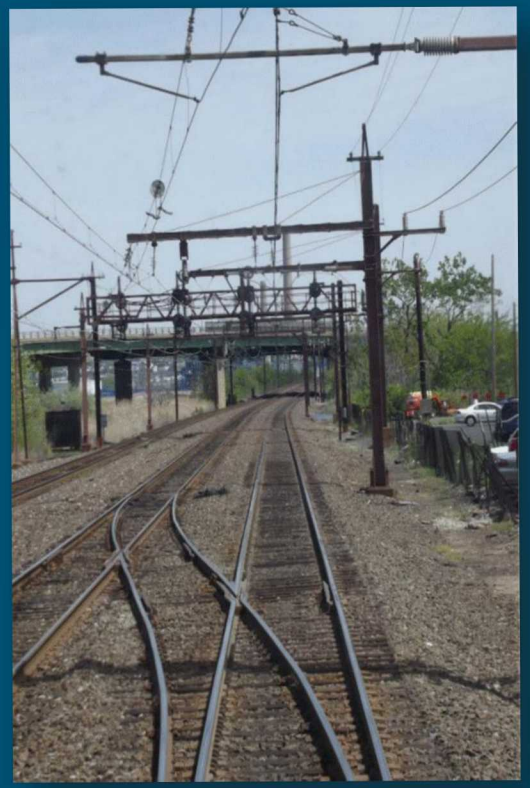
Energy Resilience – A Case for PV *

- Rugged, dependable
- Modular, scalable, portable
- Fuel avaialble onsite, everywhere
- **And** generates value all the time!

* As part of a grid-tied microgrid with storage and/or other fuel, depending on the application.



Hybrid microgrid supporting US Army's Ft Carson in Colorado Springs, CO



Large hybrid microgrid supporting rail and ferry transportation in Newark, NJ (under development)

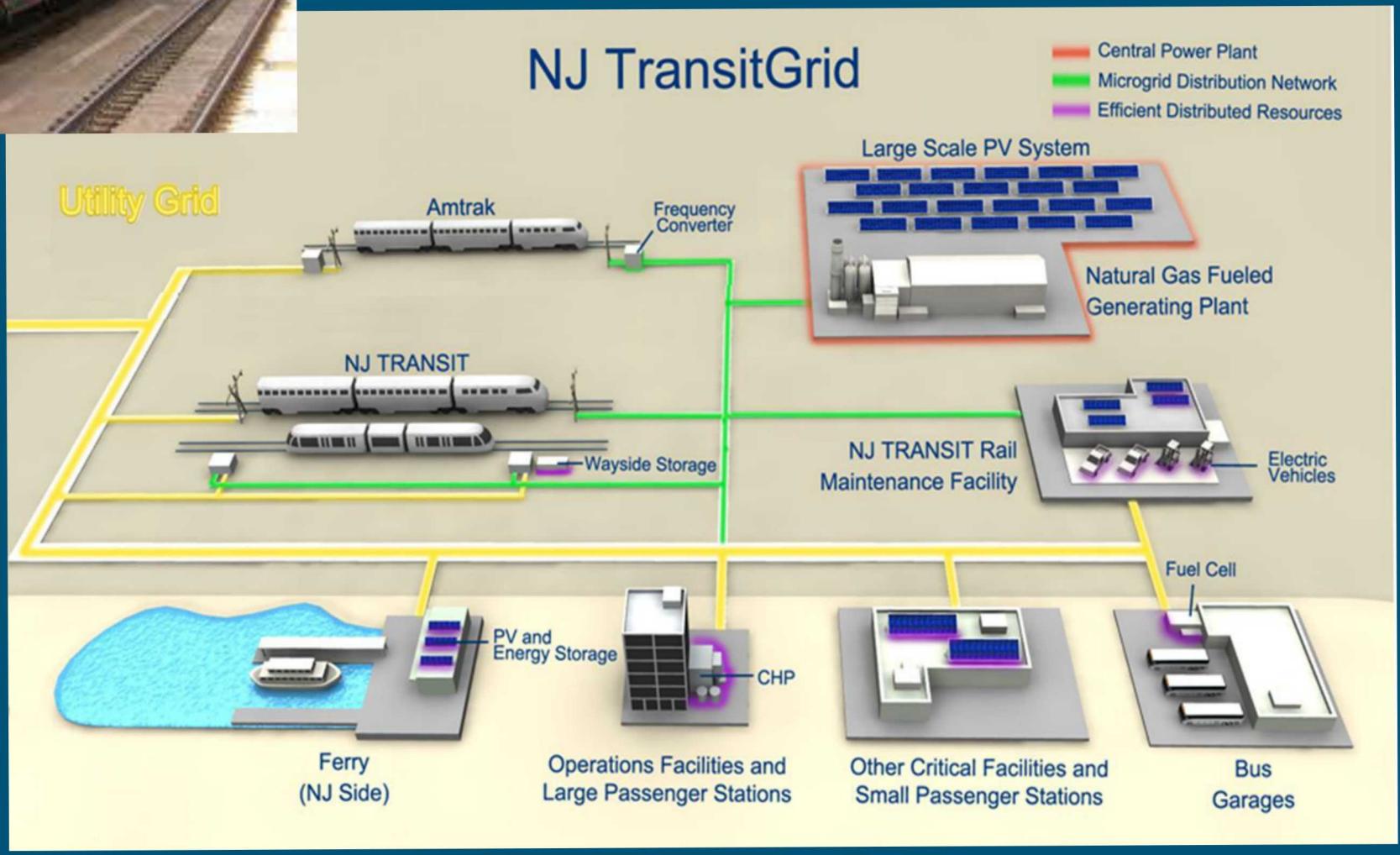


Image Credit: Green Mountain Power

PV + Storage Microgrid supporting community resilience in Rutland, VT

Image Credit: Eos Energy Storage

PV + Storage Microgrid for a water treatment facility in Cardwell, NJ

Necessary Institutional and Technical Considerations

Resilience-based planning methods

Advanced power electronics: Grid-tied grid-forming inverters

New regulatory & business models

Advanced grid architectures: Dynamic, Networked microgrids

Proactive codes and standards

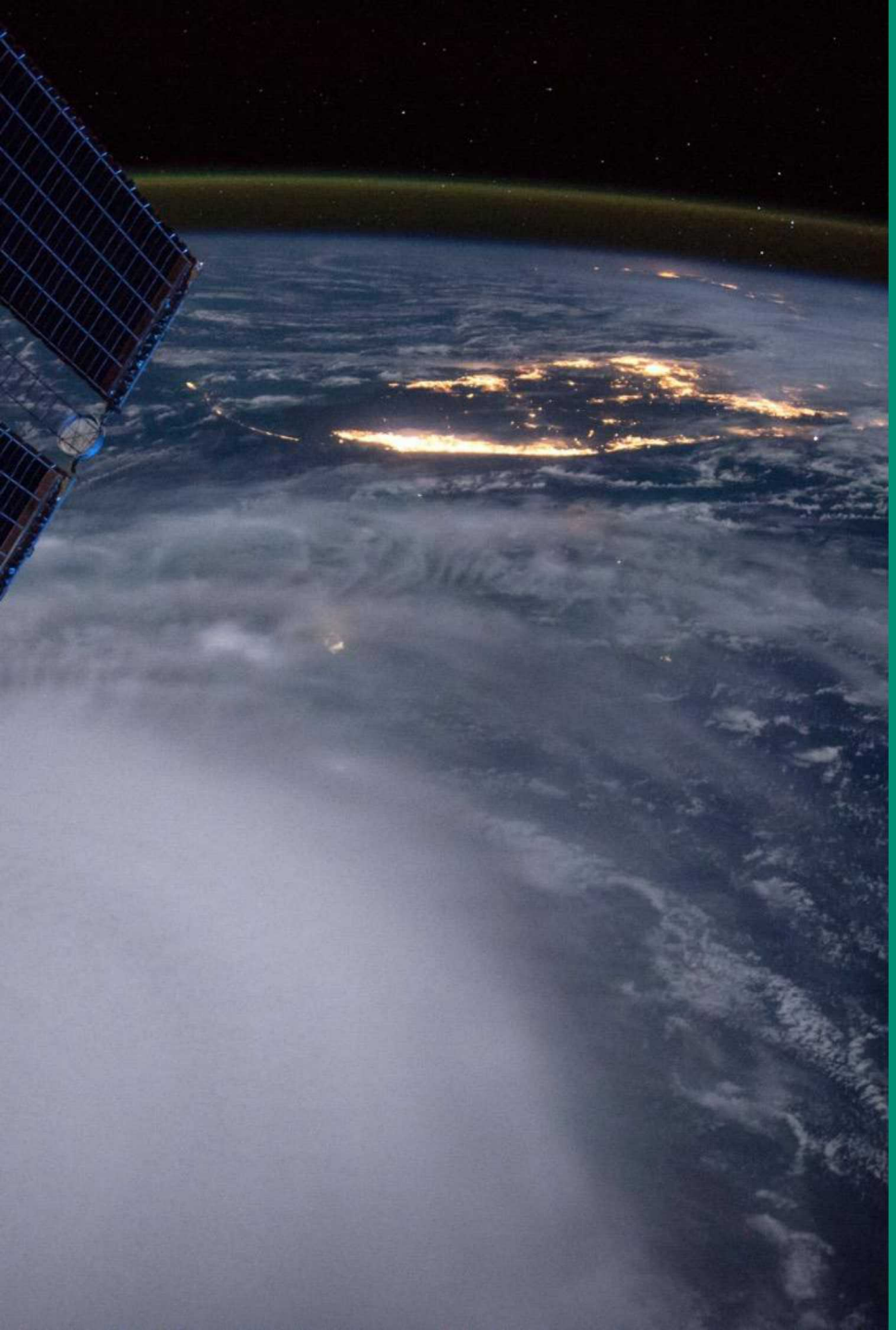
Resilience by Design: Built-in Physical and Cyber Security

What problem will we solve with a large fleet of PV-based resilient microgrids?

- ☑ Improve resilience of the whole grid
- ☑ Improve resilience of infrastructure that supports critical services at selected locations

Pop Quiz, Reframed

Bonus: access to a vastly larger market for solar!



Closing Argument

- ❑ Planning for resilience is an imperative
- ❑ Need practical methods, models, tools
- ❑ Solar can and must play a key role
- ❑ Time to think really big:

Solar can indeed enable a sunny and resilient energy future!