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What's the Problem? Can Markets Help?

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HEPG Session on "Grid Resilience:
A Problem in Search of a Solution, or a Solution in Search of a Problem?"
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Outline

I. Resilience: Engineer's definition

II. Traditional resource adequacy (independent outages)

III. Traditional RA (correlated outages)

IV. Multiple stressors

V. Large & long system-wide outages

I. Engineer's Definition of Reliability & Resilience (Billinton & Allan, *Reliability Analysis of Engineered Systems*)

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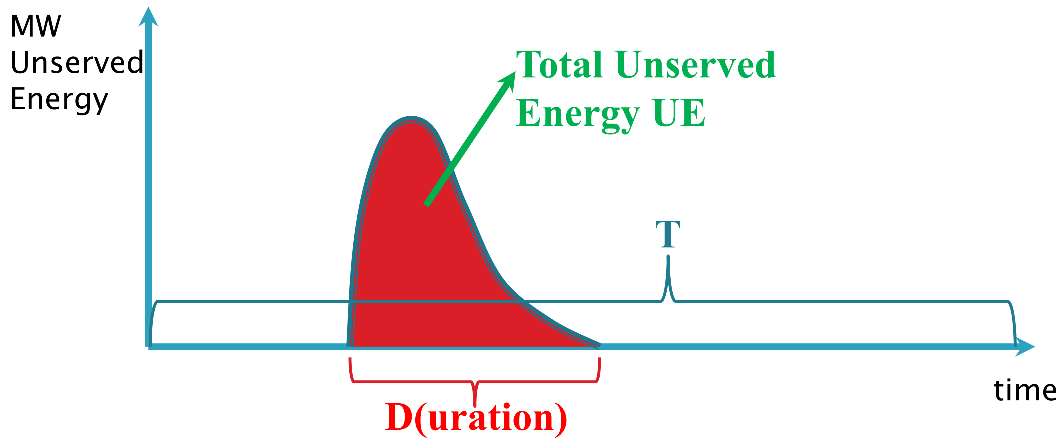

- Reliability = P(UE>0) = LOLP = 1−(D/T)
- Severity = UE/T
- Resilience = 1/D
  - Event-based: D in response to assumed stressor
  - Probabilistic: Prob-weighted Average D

Two Systems with Same Reliability, Differing Resilience

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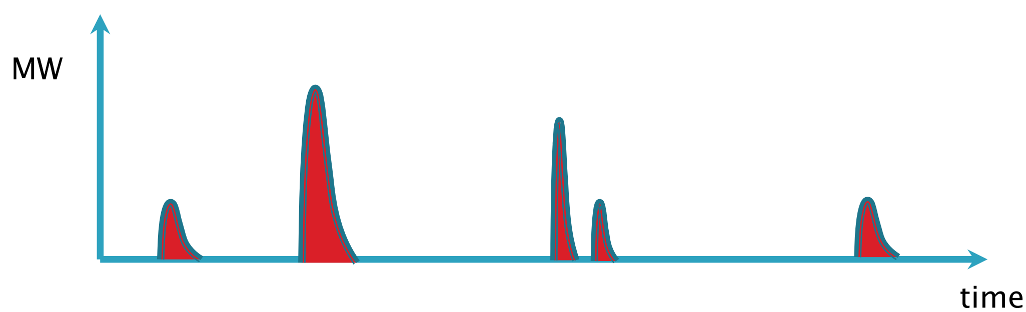
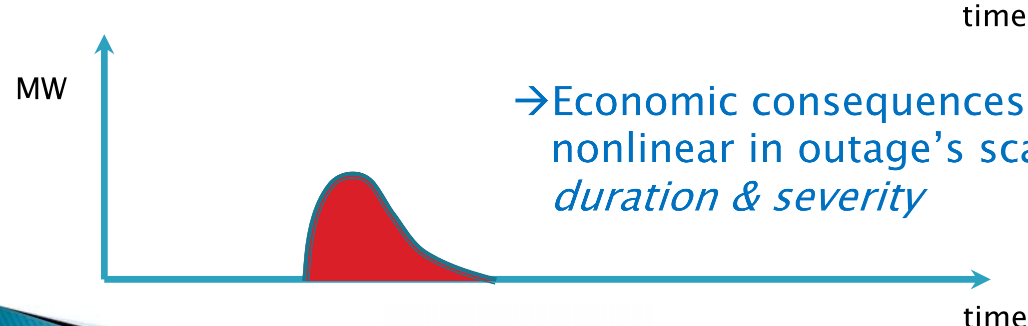
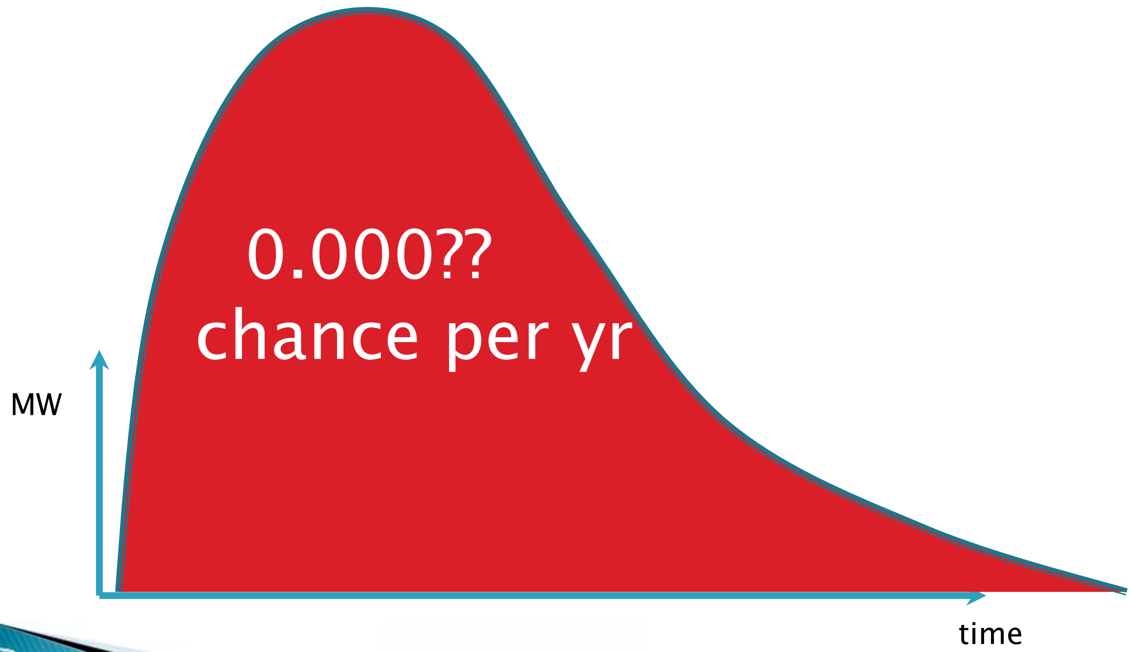




→Economic consequences are nonlinear in outage's scale: *duration & severity*

A third system with same reliability, but .....



FERC's Game of "Twenty (four) Questions"

- ***Ask Engineers:***
  - What's the system' reliability/resilience?
  - What are the causes of problems?
  - How would resilience change if measure X is taken?
- ***Ask Economists:***
  - What are the social costs of outages?
    - How does that depend on warning, customer type, duration, severity....?
      (Sanstad, *Regional Economic Modeling of Electricity Supply Disruptions*, LBNL, 2016)
  - What's the B/C of implementing X? Which X is most cost-effective?
  - *How* to implement X: Rely on markets, regulation, or central planning?
- ***When rely on markets?***
  - When solutions not obvious,
  - Actions by many parties needed,
  - Responsibility/property rights can be assigned & traded
  - When events are (relatively) frequent, not severe
- ***When rely on regulation/central planning?***
  - Solutions obvious, or
  - Actions by few or 1 party needed, or
  - Public good, or
  - Events rare, potentially catastrophic

II. Simplest Case: Classical Generator Adequacy under Independent Events

- Assume:
  - Generator outages are random ..
  - ..and (conditionally) independent of each other and of load
- Classic engineering methods:
  - LOLP, EUE by convolution methods (Billinton/Allan)
  - Expected load carrying capability (Garver, *IEEE TPAS*, 1966)
    - Increase in peak load that can be accommodated by adding resource, while maintaining reliability standard

Classic method's insights still useful!

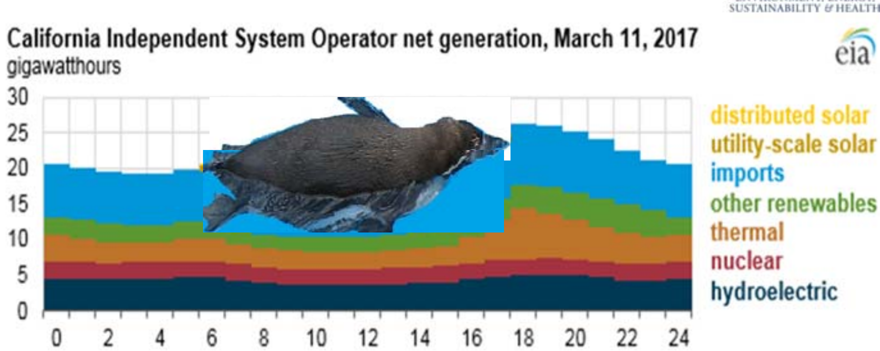
- Consider:
  - Gens with 10% EFOR
  - Normally load, 50% LF (relative to 1 hr peak)
  - 24 Hour/10 yr LOLP standard
- ***Larger units have lower ELCC***
  - Ten 100 MW units: ELCC = 802 MW
  - Five 200 MW units: ELCC = 676 MW
  - *Disregarded by ISO capacity counting methods (EFOR)*
- ***Interconnection lowers needed reserve margins***
  - Two systems, each with 2000 MW peak & 100 MW units
  - On own: need 14.5% reserve margin
  - Together: need 11.1% reserve margin

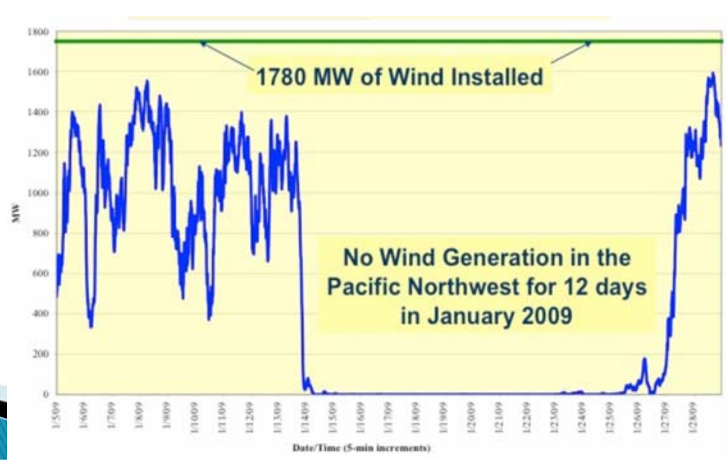
Markets play lead role

- Saint Fred (Schweppe): Spot markets with appropriate scarcity pricing alone can incent optimal investment and flexibility
- Capacity markets can work
  - Desirable if scarcity underpriced in spot markets, or long run contract markets absent
- Need good rules
  - Appropriate credits considering marginal contributions
  - Forfeiture of payments if unavailable when needed
    - Simulate impact of efficient spot market
  - Leakage, look-ahead, locational
- However, an awkward way to incent *flexible* investment
  - CAISO FRACMOO
  - But how do you compare the following?
    - Fully dispatchable turbines
    - Renewables that can turn down
    - 1 start/day resources
    - 4 calls/mo demand response
    - Fly wheels (15 minutes stored)
  - Belts and suspenders (CAISO MSC): Work on improving spot markets to reward output when system values it

III. Correlated Outages

- Renewables:
  - Duck curve
  - Long tail of distribution (BPA BA wind)



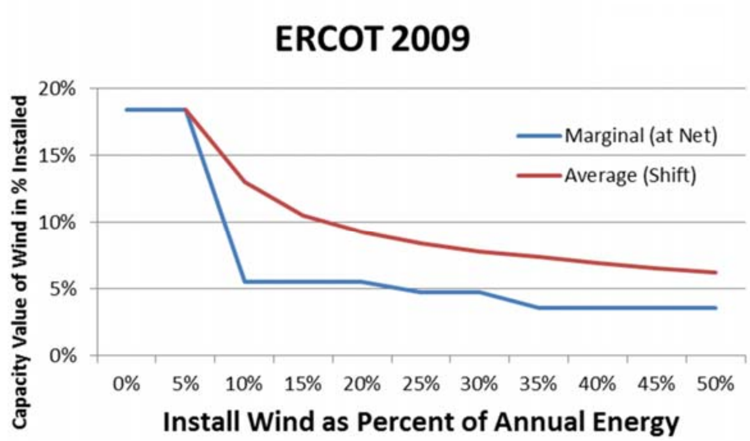


Correlated Outages

- Classic methods still insightful
  - 2000 MW peak (0.5 LF), 100 MW units (EFOR = 0.1)
  - LOLP 24 hr/10 yr
    - 0 correlation of outages → 14.5% reserve margin
    - 0.3 correlation → *need 89.2%*

Correlated Outages

- Capacity counting
  - Use marginal value
  - Should be locational
  - *No ISOs do this*

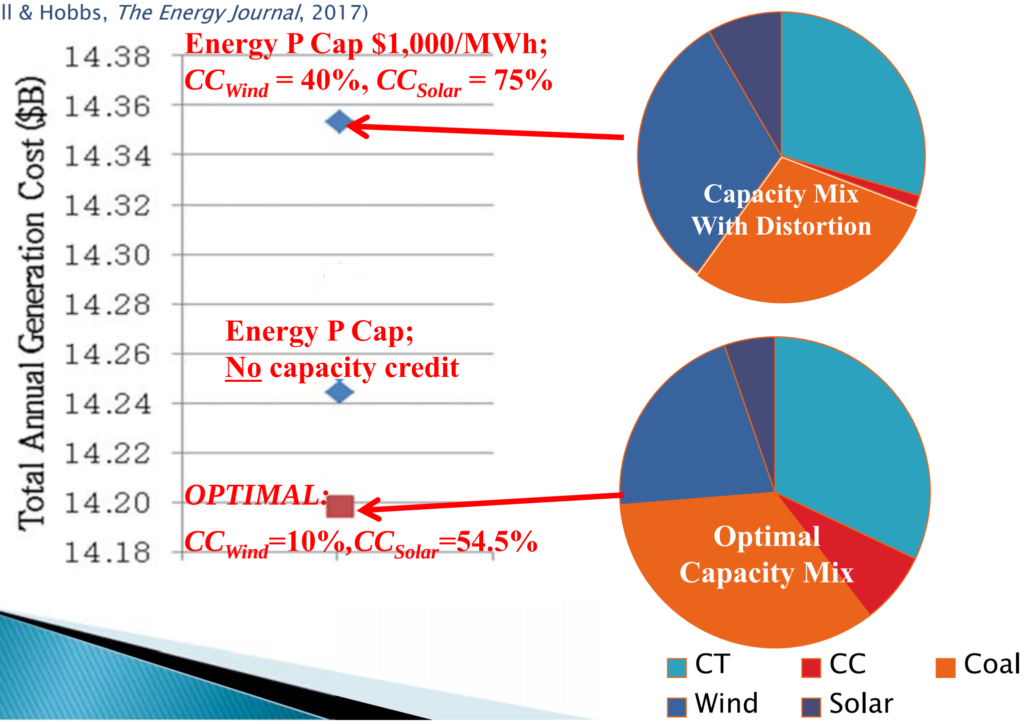


ERCOT 2009 wind conditions: Average versus Marginal Contribution
(Bothwell & Hobbs, 2017)

Market simulations of renewable capacity credits

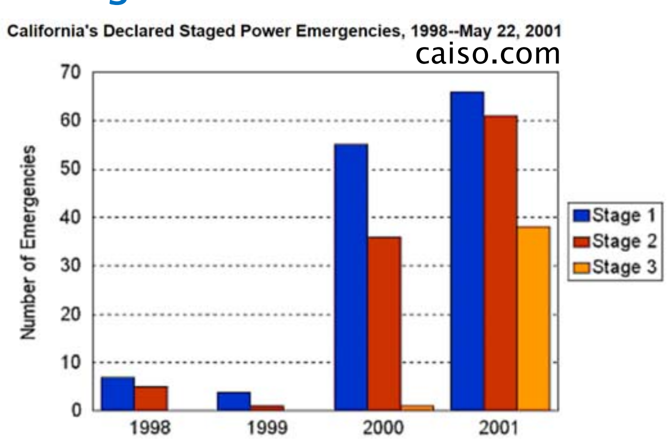
- What are welfare effects of giving the wrong credit?

(Bothwell & Hobbs, *The Energy Journal*, 2017)



IV. Correlated Multiple Stressors

- "*When sorrows come, they come not single spies. But in battalions*." King Claudius, *Hamlet* Act 4 Scene 5 (Thx to Cooke et al.)
- California 2000-01: Seven Plagues of Egypt
  - Fuel (compressor station outage)
  - Hydro shortage
  - NO_x allowance shortages
  - Kelp
- Compounded by market design failures



Operational Fuel-Security Analysis

For Discussion

JANUARY 17, 2018
ISO-NE PUBLIC

Resource Retirements

LNG Availability

Oil Tank Inventories

Imported Electricity

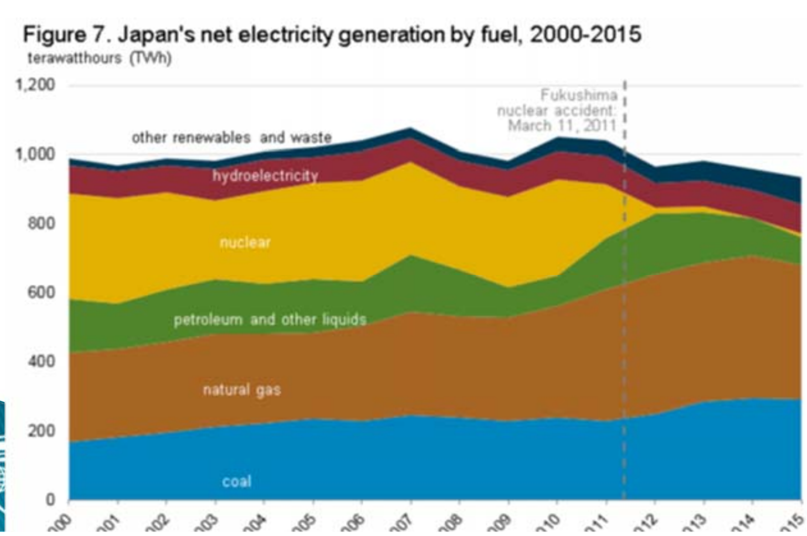
Renewable Resources

Energy shortfalls due to inadequate fuel would occur with almost every fuel-mix scenario in winter 2024/2025, requiring frequent use of **emergency actions** to keep power flowing and protect the grid. Emergency actions that would be visible to the public range from requests for energy conservation to load shedding (rolling blackouts affecting blocks of customers).

V. Extreme system-wide events

Source: CAISO

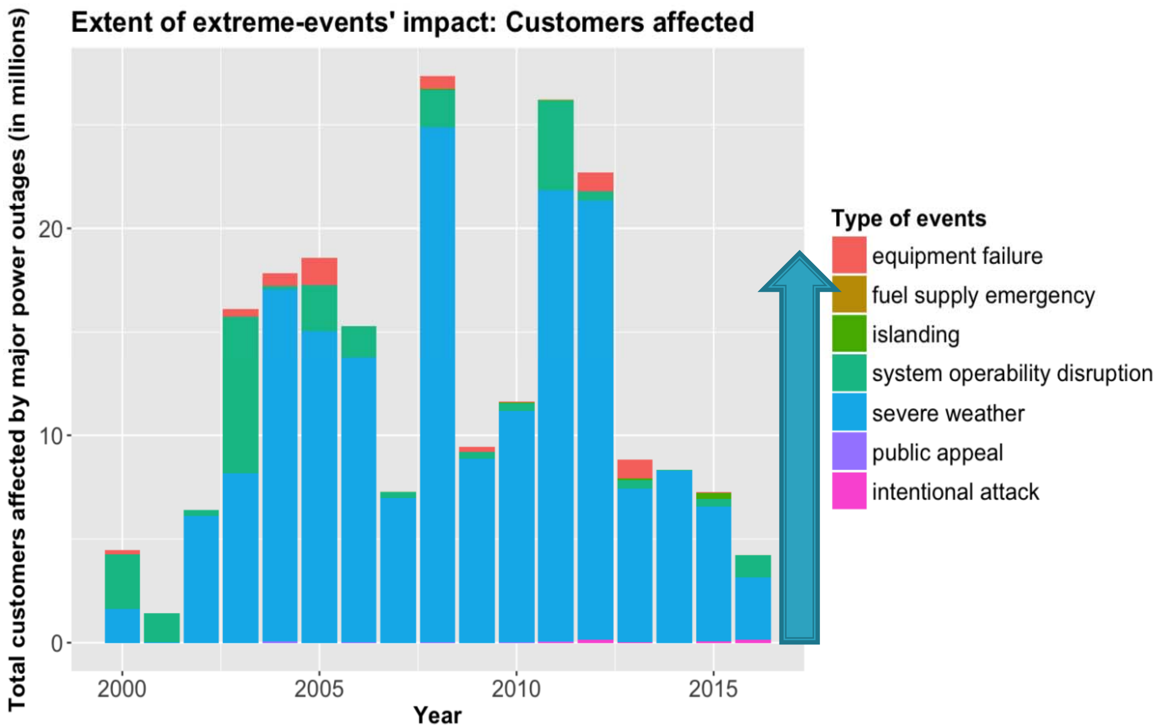
- Sometimes gen is to blame:
  - Feb. 1-4, 2011 ERCOT cold snap: 210 units on outage
  - High load → 4 GW curtailed



Fukushima: 17% of Japan's capacity lost

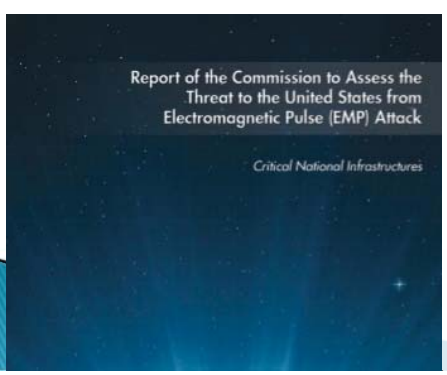
But T&D poses greatest risk of catastrophic region-wide outages

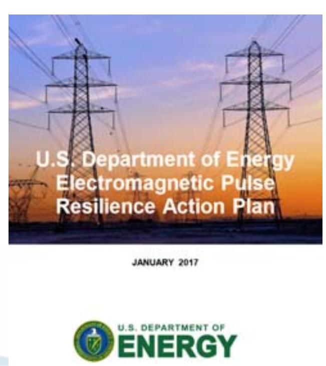
(Mukhopadhyaya, Nateghi, Hastak, in review, 2017)



Transmission: Long tails, profound uncertainty

- Cascading outages, system collapse
  - Managing frequency excursions in a renewable heavy system
- Electromagnetic disturbances
  - Solar flares
  - Twitchy fingers



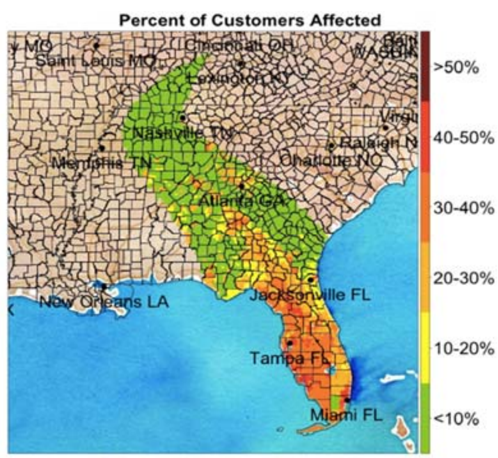


Natural disasters

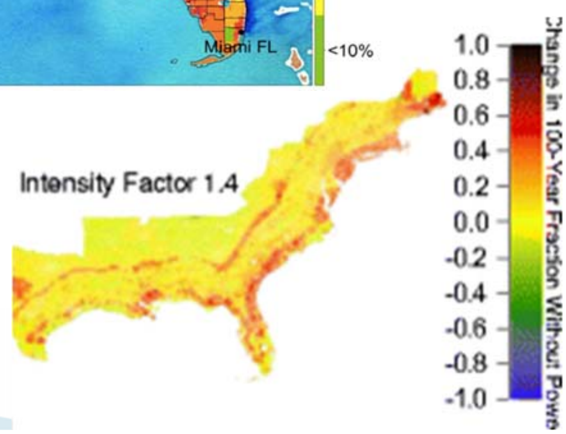
- Fire
- Earthquakes & transformer replacement
  (Enders et al. 2010 *Energy Systems*)

Engineers can estimate consequences of events, but not the probabilities (e.g., Guikema et al. 2017)

(Actually 12 million in FL!)



Change in power outage risk as a function of changes in mean storm intensity in the future (Staid et al., 2014)



Role of Markets for Managing Extreme Risks

- **For extreme events:**
  - Probability estimates are unreliable
  - Insurance is unlikely to be available or very expensive

    …three particular phenomena of climate related risks that will require a change in our thinking about risk management: global micro-correlations, fat tails, and tail dependence. (Their) consideration …will be particularly important for natural disaster insurance, as they call into question traditional methods of securitization and diversification (Kousky & Cooke, RFF-DP-09-03-REV.pdf, 2009)
- **Public good of network reliability → central planning, NERC rules, …**
- **(Quasi) market roles**
  - Bidding to provide equipment, services
  - Performance-based ratemaking for grid owners

Time to Discuss:

For the following situations:

- What's the problem?
- What X has the highest net benefits?
- Implement with what mix of standards, central planning, markets?

- Traditional resource adequacy (independent outages)
- Traditional RA (correlated outages)
- Multiple stressors
- Large & long system-wide outages