Assessing climate change hazards to electric power infrastructure

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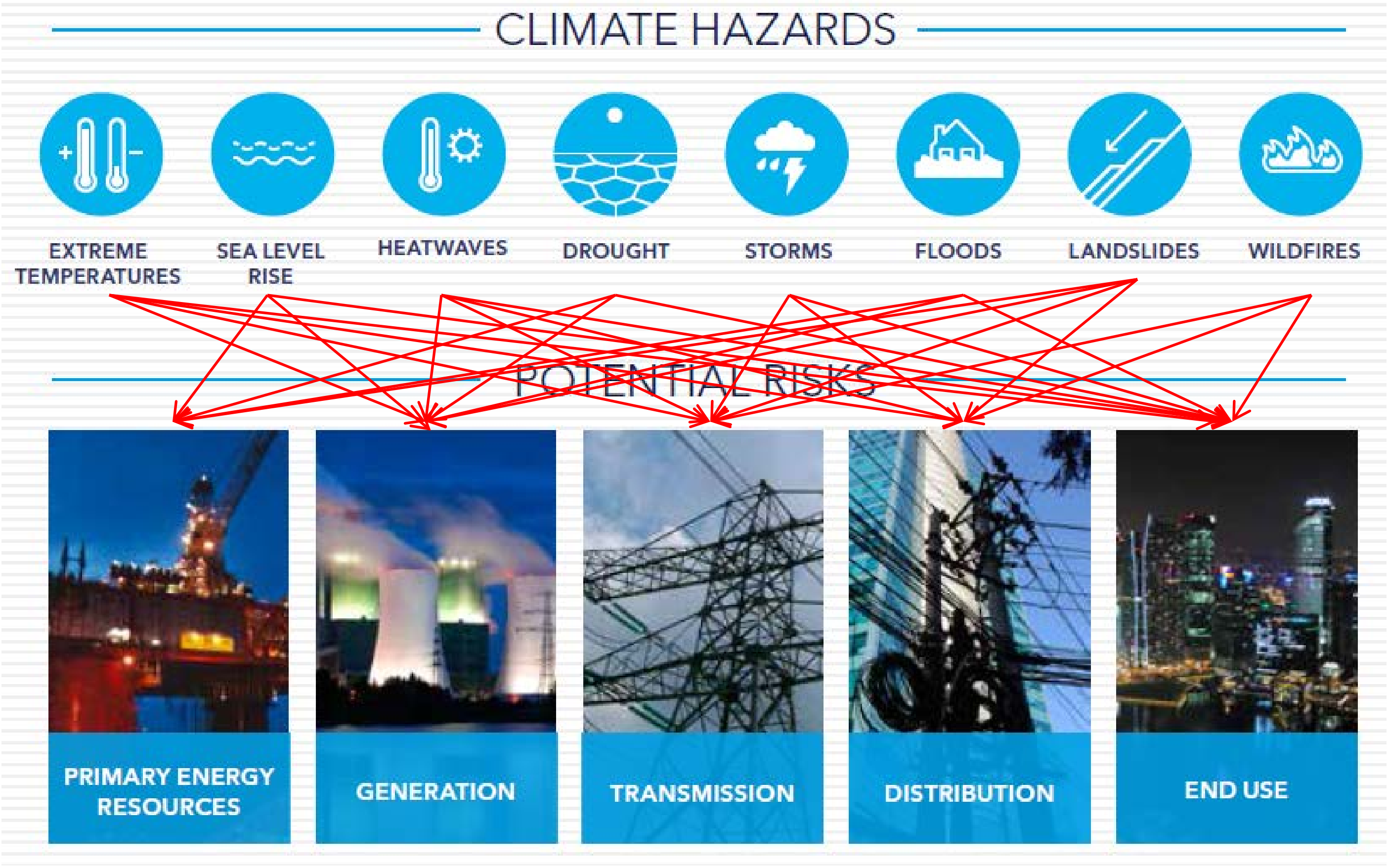

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Responses to 2013 CDP Information Request

“Please describe your risks that are driven by change in physical climate parameters.”

Company	Change in Mean Temperature	Change in Temperature Extremes	Change in Precipitation Extremes and Droughts	Change in Precipitation Pattern	Change in Mean Precipitation	Snow and Ice	Sea Level Rise	Tropical Cyclones (Hurricanes and Typhoons)	Induced Changes in Natural Resources	Uncertainty of Physical Risks
Pepco Holdings, Inc. (PHI)	X	X	X			X	X		X	X
Con Edison		X		X	X		X	X	X	X
Entergy		X	X				X	X	X	X
American Electric Power	X	X	X	X	X	X				X
PG&E		X		X			X		X	
Exelon	X	X	X					X	X	X
Sempra Energy			X				X		X	X

Quantifying climate change risk

$$Risk = Probability\ of\ an\ event\ occurring\ \times\ consequences\ of\ event$$

$$Climate\ Change\ Risk$$

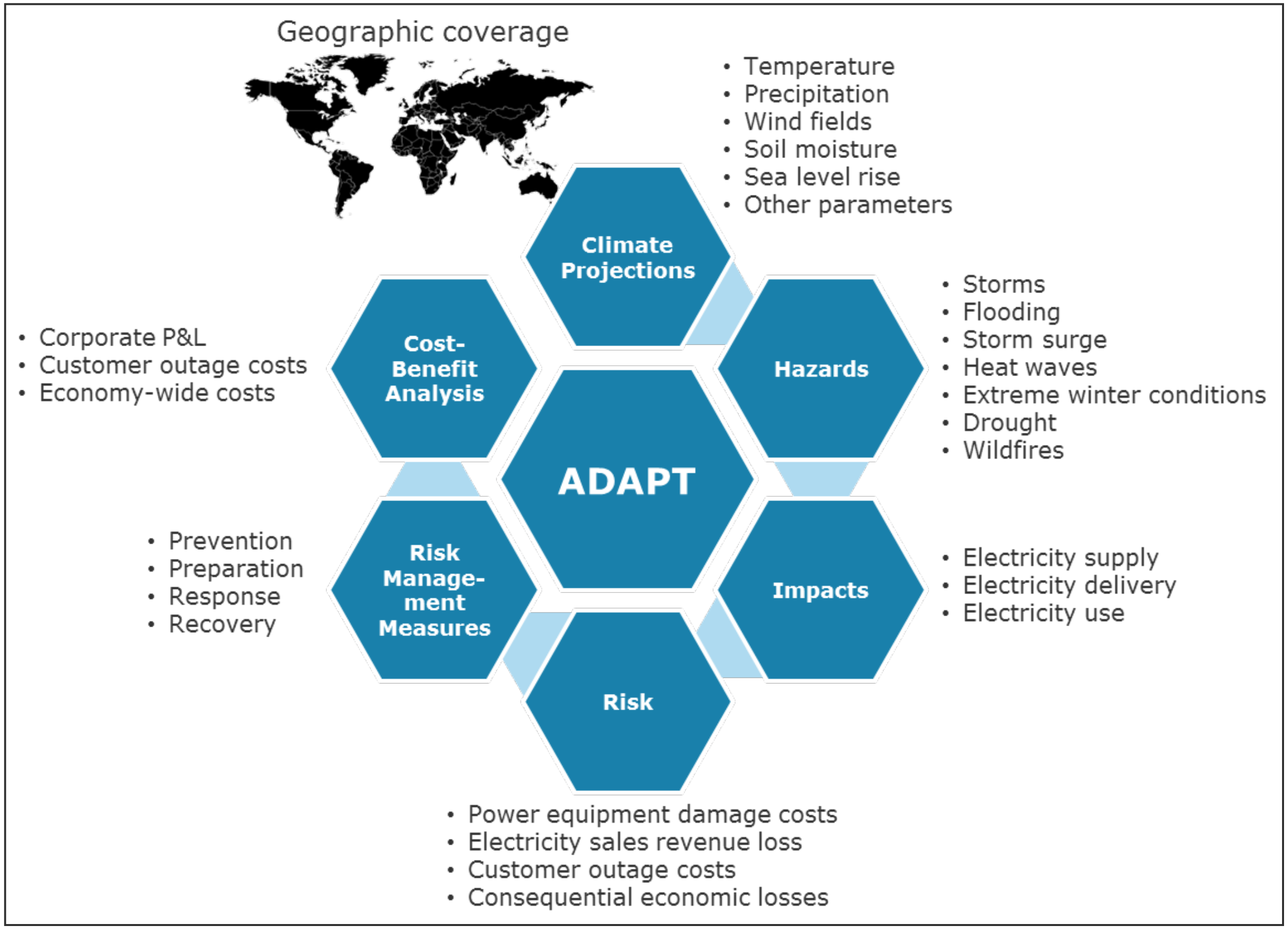
$$= \sum \left\{ \begin{array}{c} Pr(climate\ change \mid GHG\ emission\ scenarios) \\ \times \\ Pr\left(infrastructure\ or\ operational\ hazards\ occur \mid climate\ change\right) \\ \times \\ Pr(impacts \mid hazards) \\ \times \\ Consequences\ (\$) \end{array} \right\}$$

Managing risks from climate change is clouded by uncertainty

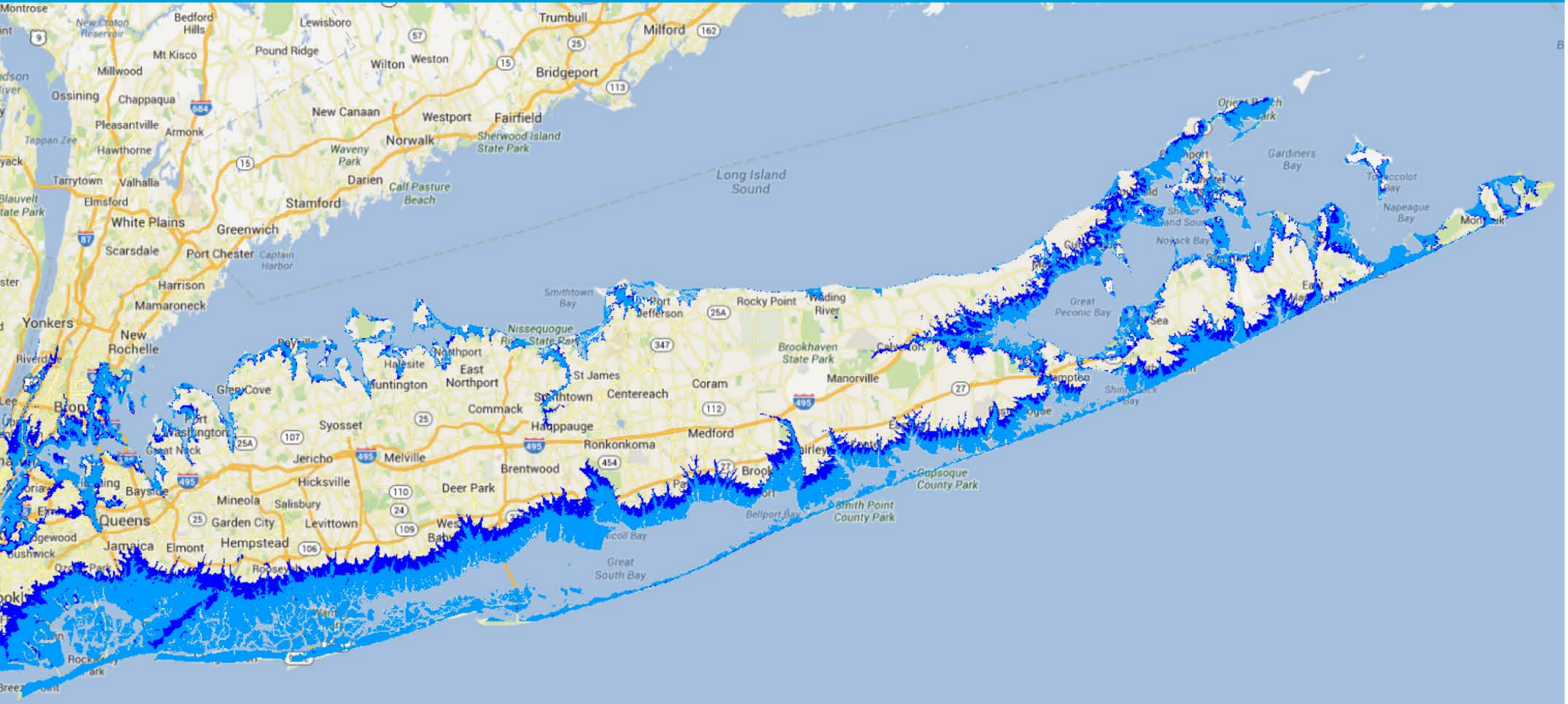
- Power companies and regulatory decision makers must determine
  - How much to spend in order to create a power system that is resilient to risks resulting from climate change
  - How best to allocate financial resources among alternative measures
- Questions that must be considered include:
  - What hazards may occur, where, and how often?
  - How could the electric grid be impacted?
  - What are the consequences of those impacts?
  - What can we do to prevent damage to the grid?
  - How can we minimize the effects of grid failure?
  - What are the investments with the greatest return?
  - How will climate change affect the efficacy of investments?

DNV GL's ADAPT risk management framework

ADAPT is a probabilistic risk analysis framework for assessing hazards and vulnerabilities, and identifying cost-effective risk management measures, explicitly accounting for uncertainties



Long Island Case Study



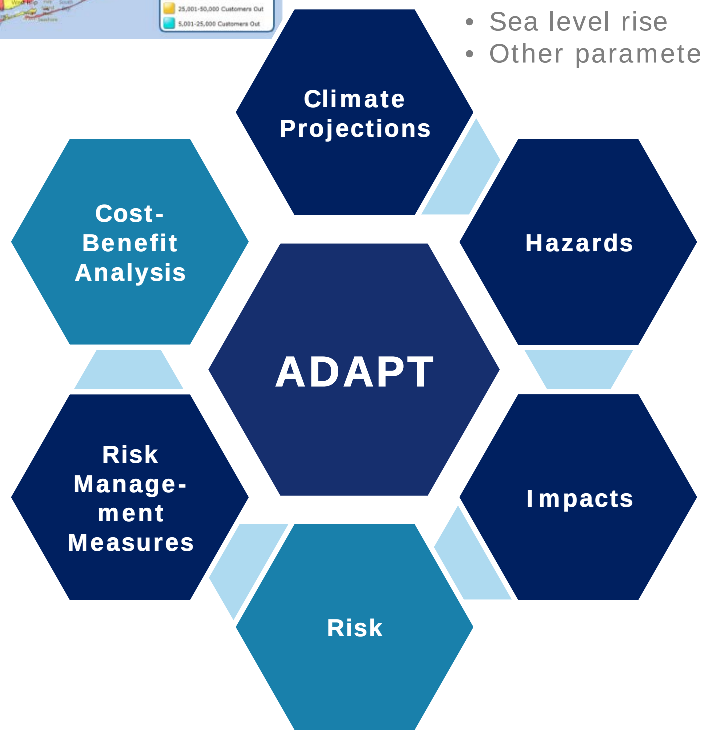
Long Island case study scope

Case Study Goal:

Demonstrate application of the ADAPT framework to T&D system impacts of extreme weather under a future Superstorm Sandy

Geographic coverage

- **Temperature**
- **Precipitation**
- **Wind fields**
- **Soil moisture**
- Sea level rise
- Other parameters



- **Storms**
- **Flooding**
- **Storm surge**
- Heat waves
- Extreme winter conditions
- Drought
- Wildfires

- Electricity supply
- **Electricity delivery**
- Electricity use

- Power equipment damage costs
- Electricity sales revenue loss
- Customer outage costs
- Consequential economic losses

- **Prevention**
- Preparation
- Response
- Recovery

- Corporate P&L
- Customer outage costs
- Economy-wide costs

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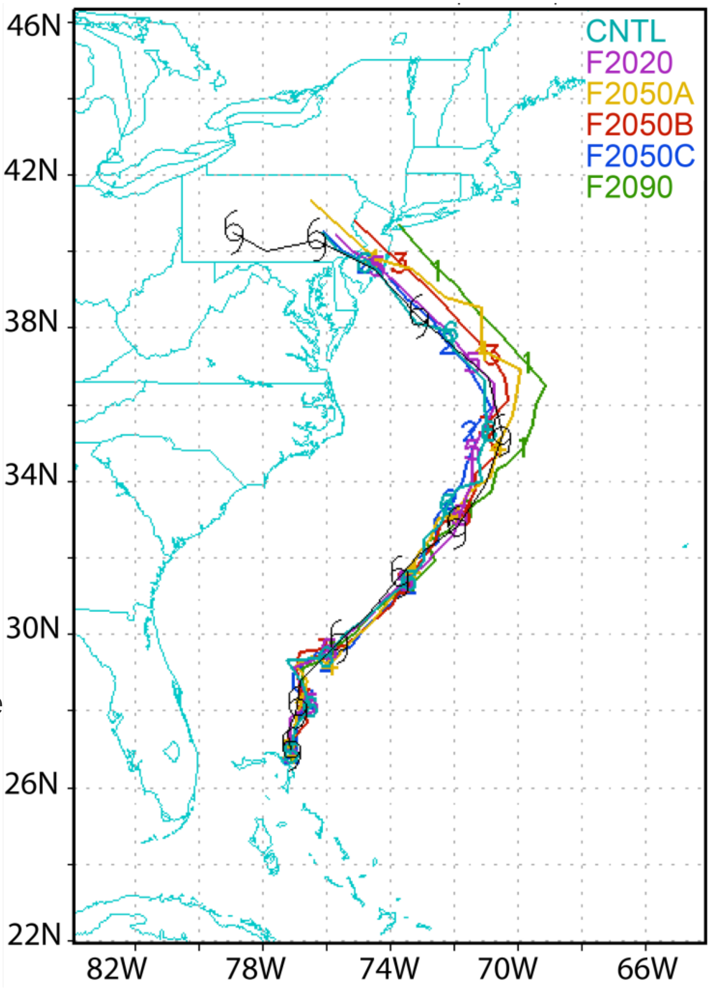
Superstorm Sandy, as it occurred and in the future

- National Center for Atmospheric Research (NCAR) collaborated with DNV GL to evaluate what Superstorm Sandy might look like in a warmer world

Numerical experiments		Initial and Boundary Conditions		
		Air temperature	**Deep soil temperature**	**Sea surface temperature**
F2020: a climate warming scenario for 2020		+ 1°C	+ 1°C	+ 0.3°C
F2050: three 2050 climate warming scenarios	A	+ 2°C	+ 2°C	+ 0.6°C
	B	+ 2°C	+ 2°C	+ 0.9°C
	C	+ 2°C	+ 2°C	+ 1.2°C
F2090: a climate warming scenario for 2090		+ 4°C	+ 4°C	+ 1.8°C

Hazard analysis

- Increasing temperatures force the future Sandy scenarios to move northward
  - Therefore the timing and location of landfall shifts
- When approaching the coast, storms produce heavier precipitation than the control simulation
  - Higher temperature increases generated significantly greater precipitation, especially in western Long Island
  - The 2090 scenario produced doubled precipitation throughout Long Island
- Before landfall, wind speeds over the ocean are substantially higher (up to ~40 m/s higher than the control simulation)
  - This and “direct hit” have important implications for storm surge



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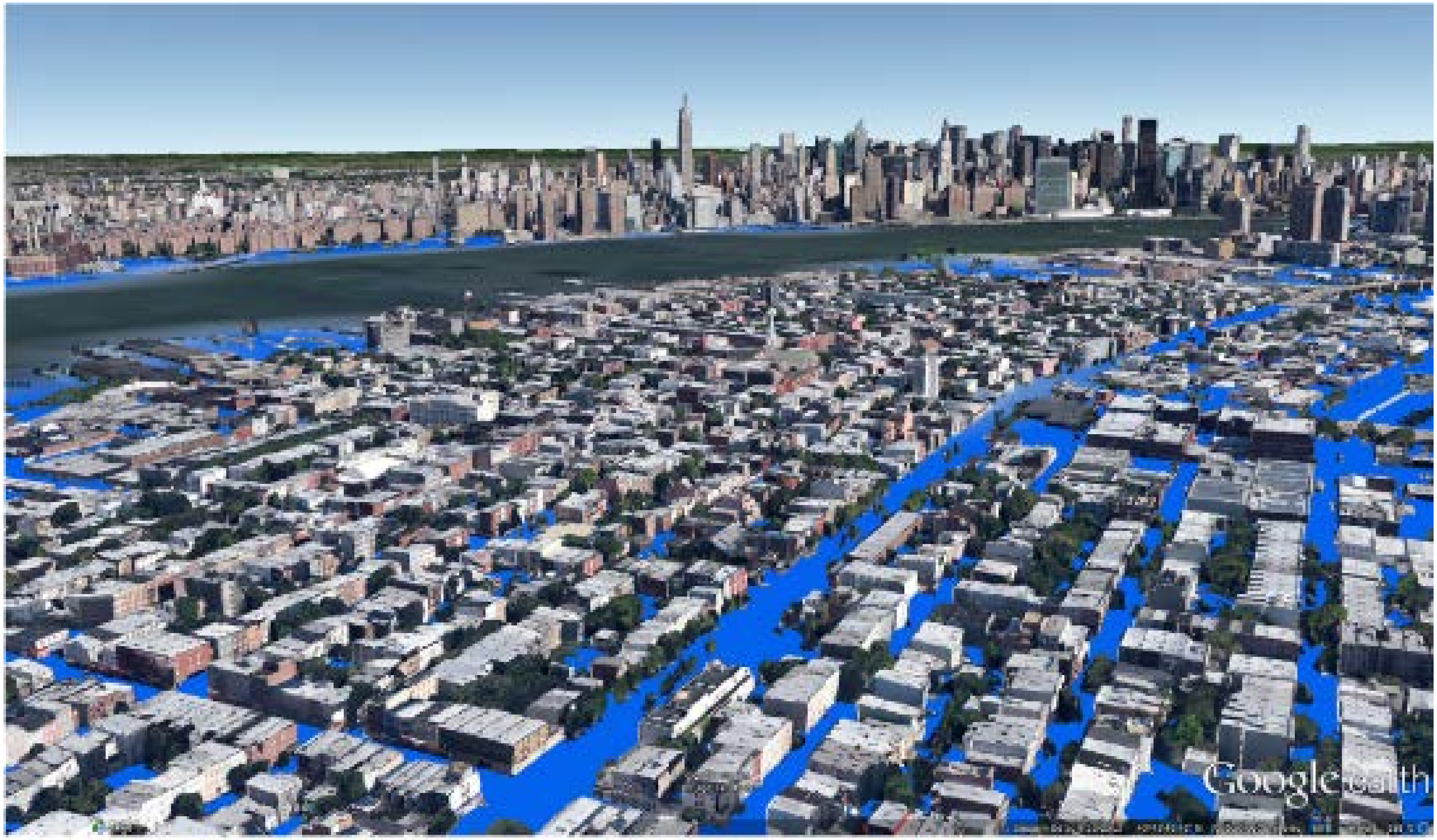
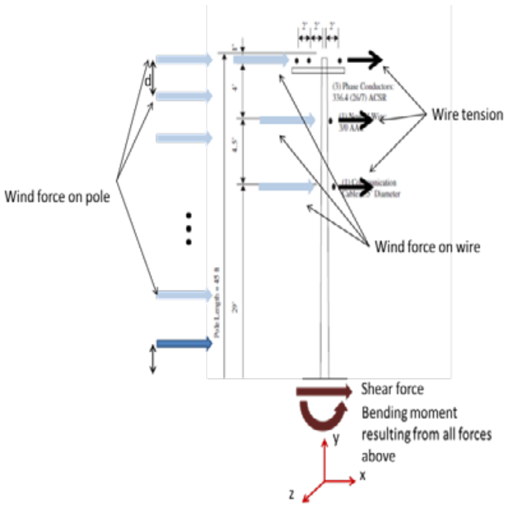
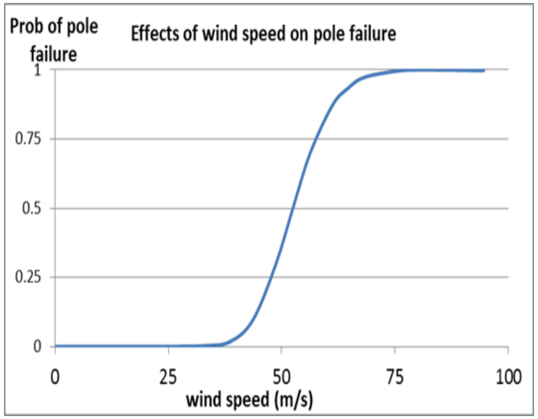
Flood extent

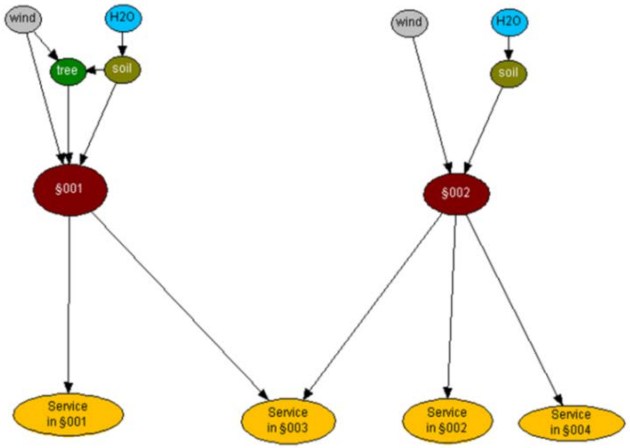


Impact analysis

- Probabilistic models for power system apparatus failure were developed that use wind, soil moisture, and flood level as inputs



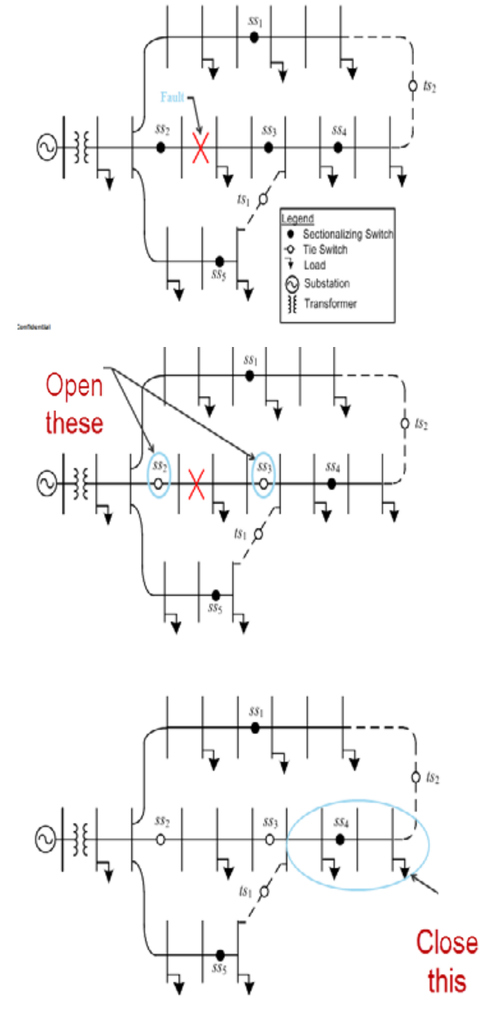




- Bayesian networks (graphical models for reasoning under uncertainty) were used to evaluate cause and effect relationships

Distribution risk analysis

- The resilience of the power grid, measured as the amount of electrical load served immediately after an adverse weather event, can be improved substantially
  - In our case study, investments in additional sensors, grid communications, and automation to facilitate rescheduling of flows increased load served from 70% to 98%



In conclusion…

- The most advanced climate science can be used to create scenarios of future hazards of climate change for electricity infrastructure
- Ensuring resilience of the grid will require not just hardening utility structures but also enabling electric facilities to continue operating despite damage and promoting a rapid return to normal operations after the event has passed
- If we can make the electrical grid smarter and more flexible, the impact of even the worst storm can be reduced
- ADAPT provides a proven framework for assessing natural or man-made disaster risks to electric power systems

Thank you!

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