# Climate change and infrastructure

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# Agenda

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- Climate change
- How weather impacts infrastructure
- Focus on energy infrastructure
- Infrastructure economic impacts

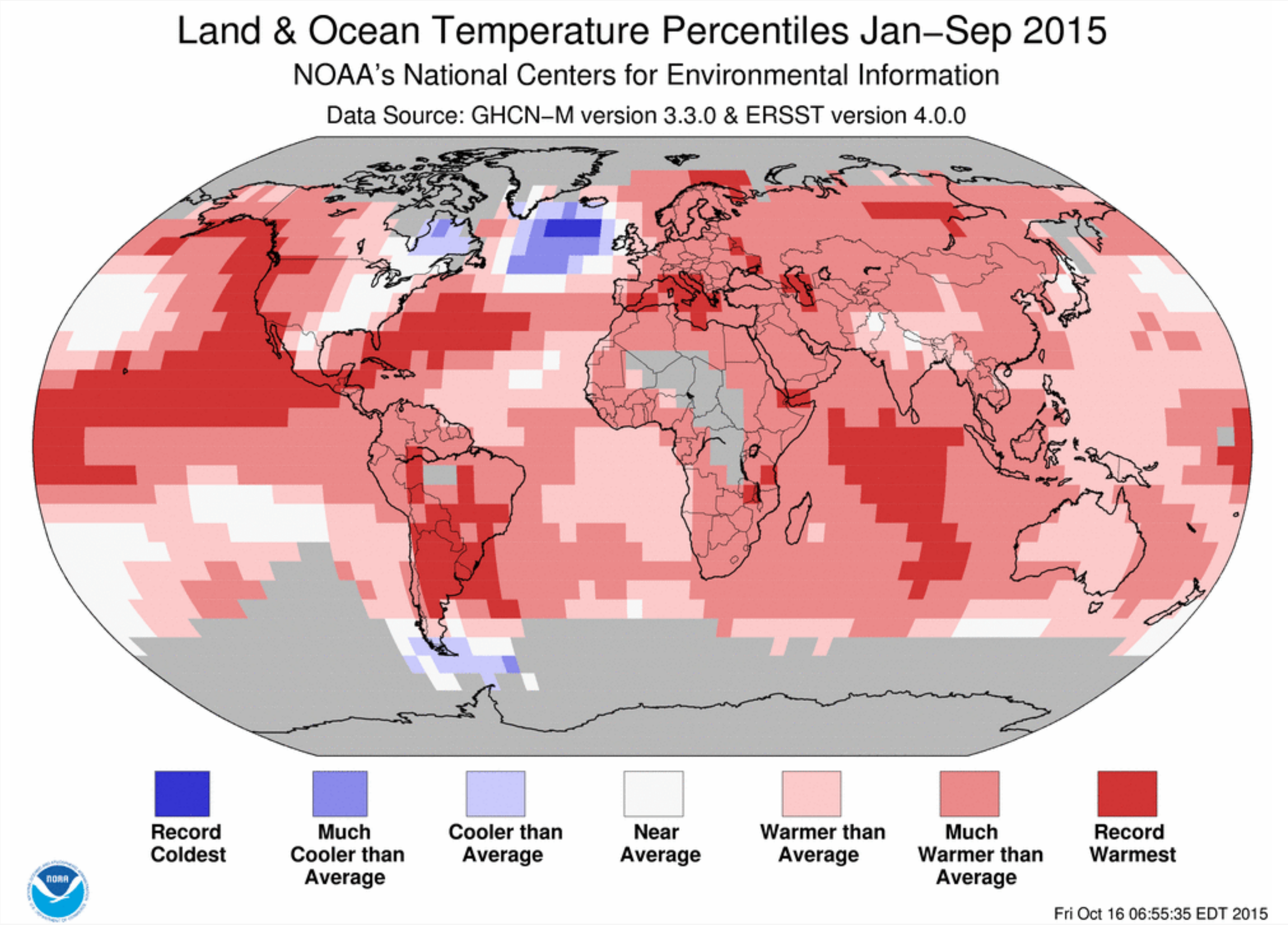
# Polling question 1

Do you believe climate change is occurring?

A. Yes
B. No
C. Don't know

# Climate change

## Emerging issues in natural catastrophe risk




The average temperature of all Jan-Sept periods over the past 136 years.

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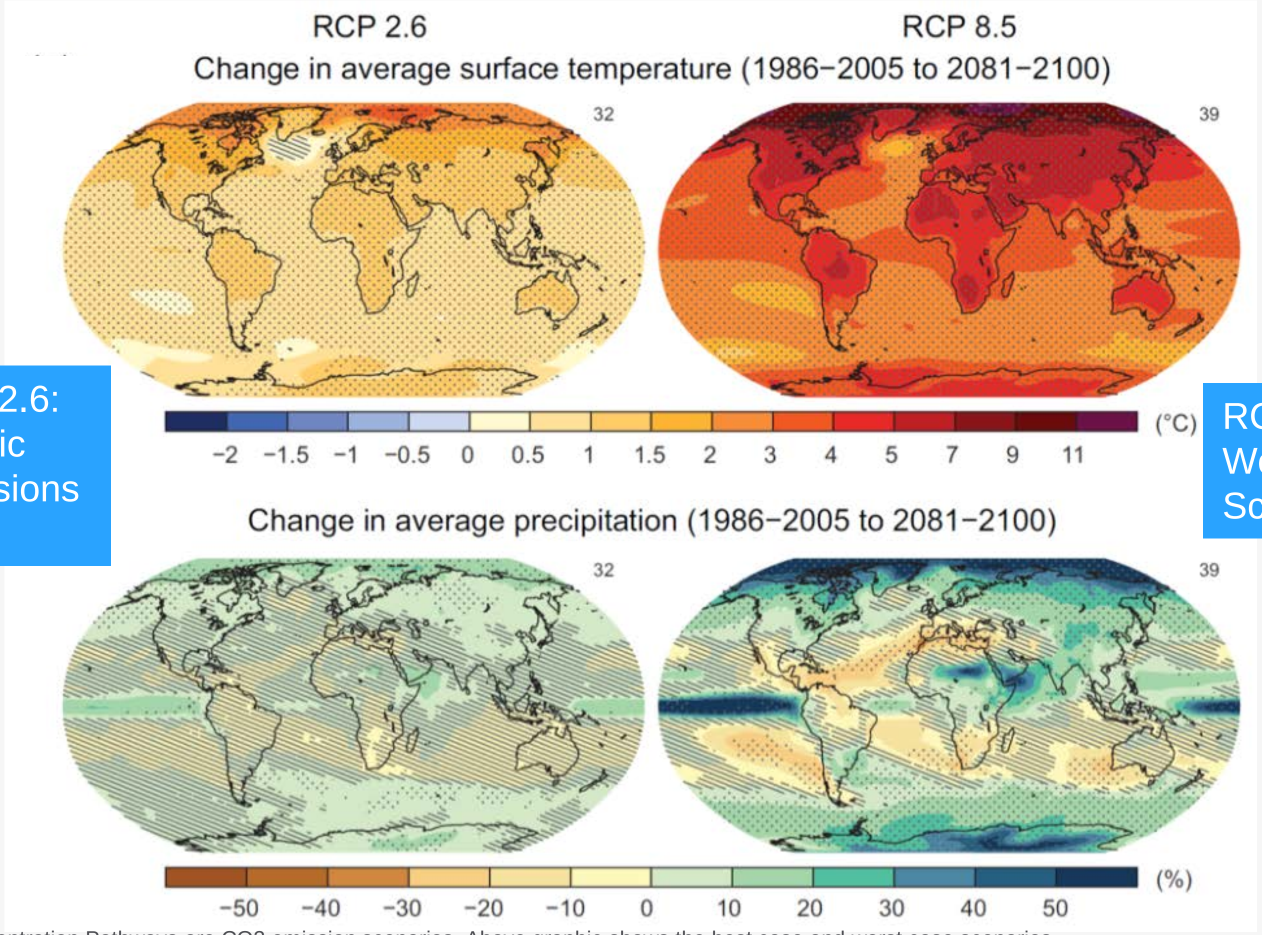
## Forecasted changes in temperature & precipitation, late 21st century vs. late 20th century




RCP 2.6: Drastic Emissions Cut

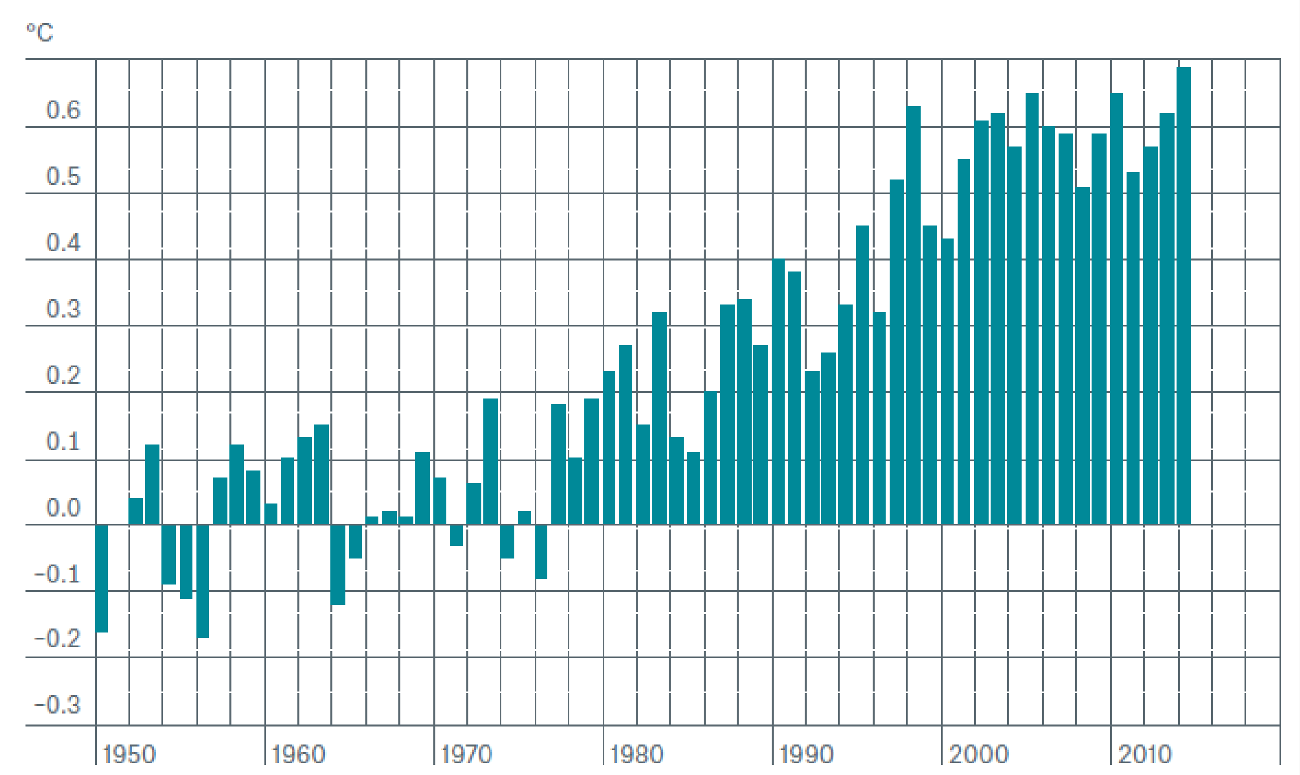
RCP 8.5: Worst-Case Scenario

RCP - Representative Concentration Pathways are CO2 emission scenarios. Above graphic shows the best case and worst case scenarios.

Source:NASA

# Climate change

## Anomalies of the global annual mean temperatures from the 1901–2000 average




The 14 warmest years in the observation period 1880 to 2014 have all been since 1998. The time series commences in 1880; the period shown here is 1950 to 2014

2014 was the warmest year since 1880.

Source: Munich Re, based on NCDC/NOAA

# Climate change

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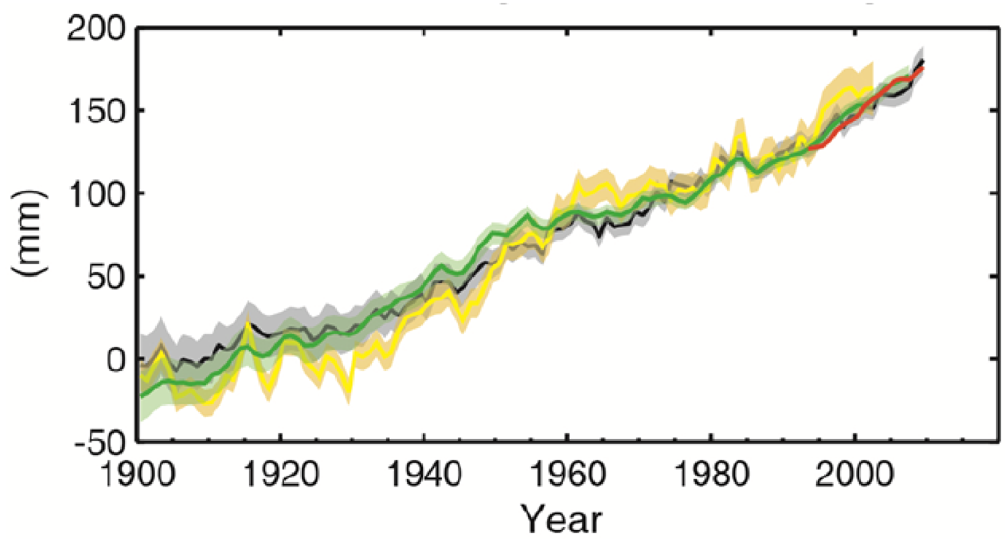
## Global mean sea level change relative to the 1900–1905 mean

Global average sea level change




All time-series (colored lines indicating different data sets) show annual values, and where assessed, uncertainties are indicated by colored shading.

The rate of sea level rise since the mid-19th century has been larger than the mean rate during the previous two millennia. Over the period 1901–2010, global mean sea level rose by 0.19 m.

Since the early 1970s, glacier mass loss and ocean thermal expansion from warming together explain about 75% of the observed global mean sea level rise.

Source: Intergovernmental Panel on Climate Change (IPCC) AR5, WG1 (2013)

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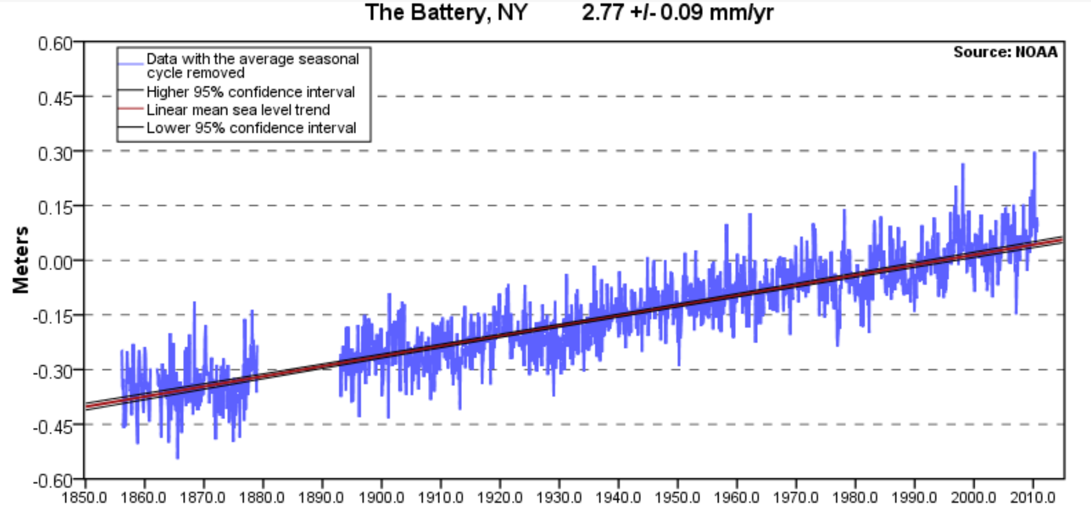
## Impacts on physical environment - example

| | Observed Changes (since 1950) | Projected Changes (up to 2100) with Respect to Late 20th Century | Probability |
|---|---|---|---|
| Extreme Sea Level and Coastal Impacts | Increase in extreme coastal water worldwide related to increases in mean sea level in the late 20th century | Mean sea level rise will contribute to upward trends in extreme coastal high water levels | High conf. - Very likely |
| | | Locations currently experiencing coastal erosion and inundation will continue to do so | High confidence |




**Likelihood assessment for high confidence**:

- About as likely as not 50-66%
- Likely 66-90%
- Very likely 90-99%
- Virtually certain 99-100%

Source: Intergovernmental Panel on Climate Change (IPCC) Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) 2012

# Climate change

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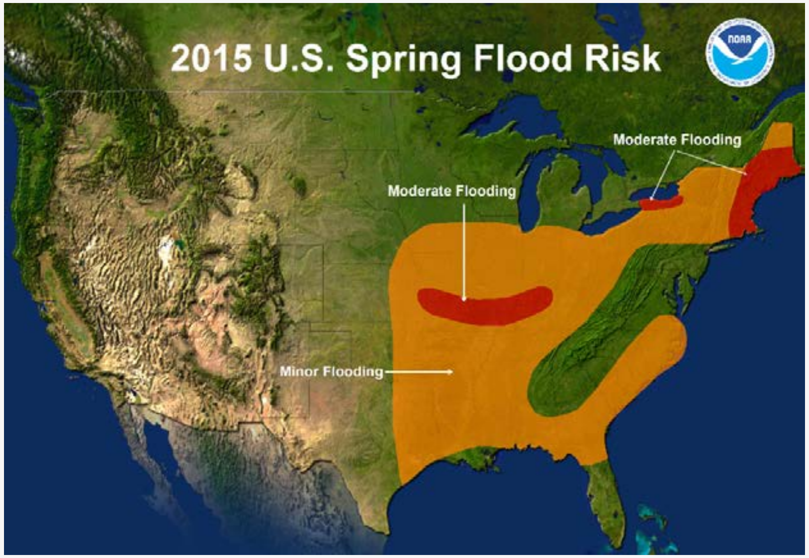
## Impacts on physical environment - example

| | Observed Changes (since 1950) | Projected Changes (up to 2100) with Respect to Late 20th Century | Probability |
|---|---|---|---|
| Floods | Trend toward earlier occurrence of spring peak river flows in snowmelt- and glacier-fed rivers | Earlier spring break | High conf. - Very likely |
| | | Contribution to rain-generated local flooding in some regions | Medium confidence |

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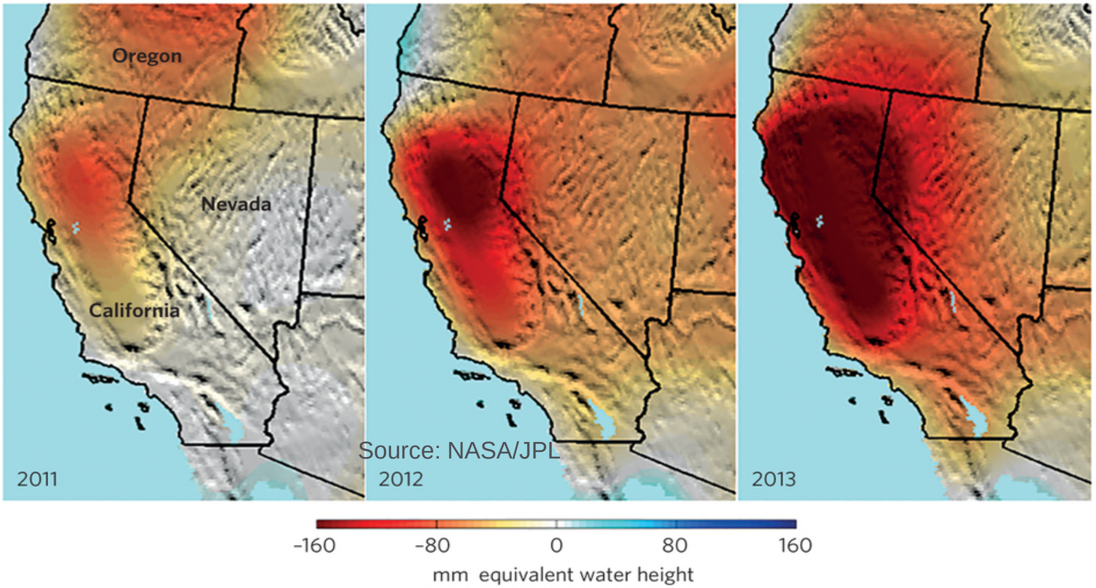
# Climate change

## Impacts on physical environment - example

| | Observed Changes (since 1950) | Projected Changes (up to 2100) with Respect to Late 20th Century | Probability |
|---|---|---|---|
| Droughts | Some regions have experienced more intense and longer droughts (opposite trends also exist) | Increase in duration/intensity of droughts in some regions | Medium confidence |

Map below shows ground water anomalies in California. Areas in dark red have 16cm less groundwater than "normal."

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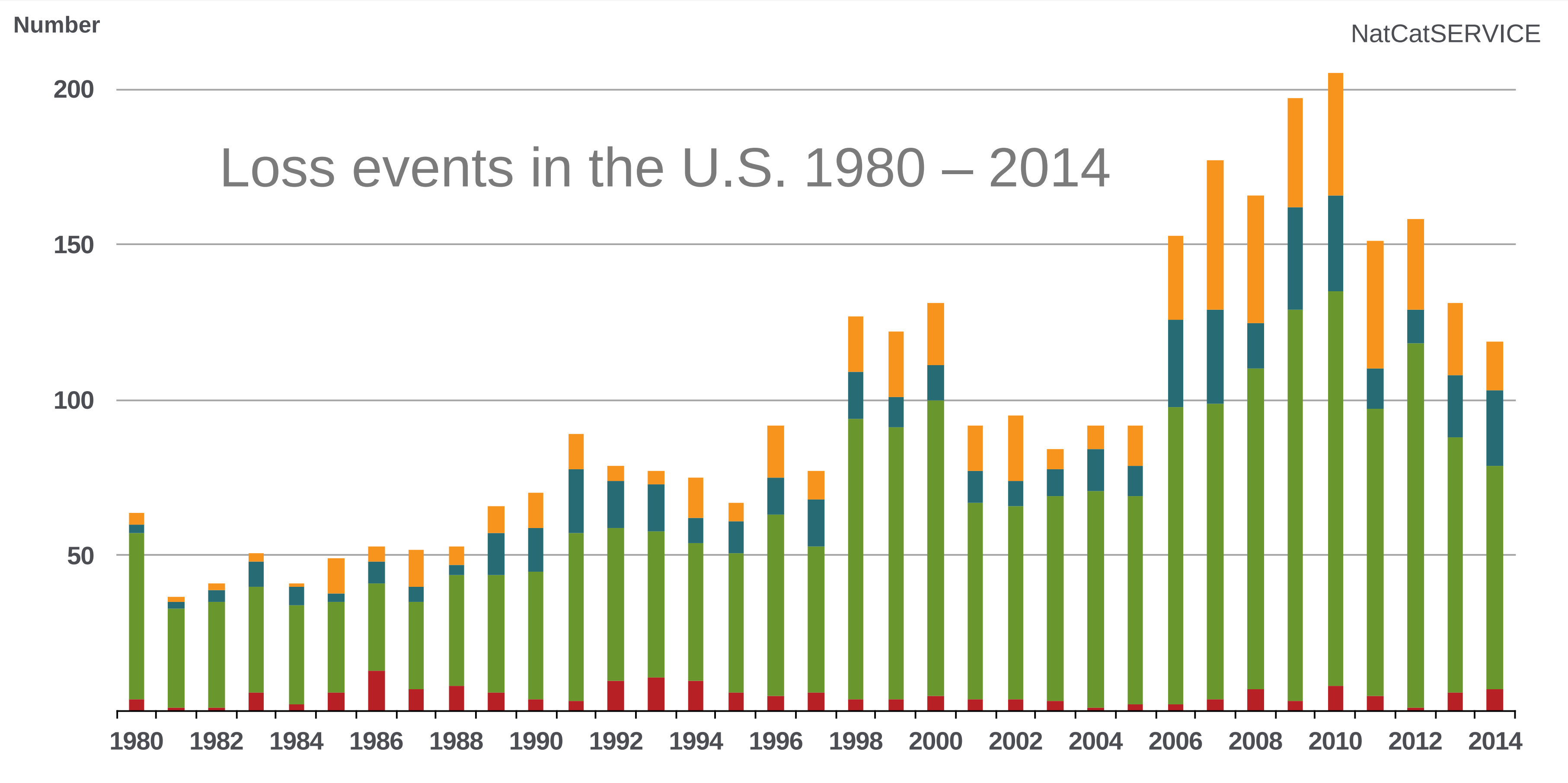
# Impact of climate change




**Geophysical events** (Earthquake, tsunami, volcanic activity)

**Meteorological events** (Tropical storm, extra tropical storm, convective storm, local storm)

**Hydrological events** (Flood, mass movement)

**Climatological events** (Extreme temperature, drought, forest fire)

# Recent impact of climate change

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## Recent extreme precipitation events in the U.S.

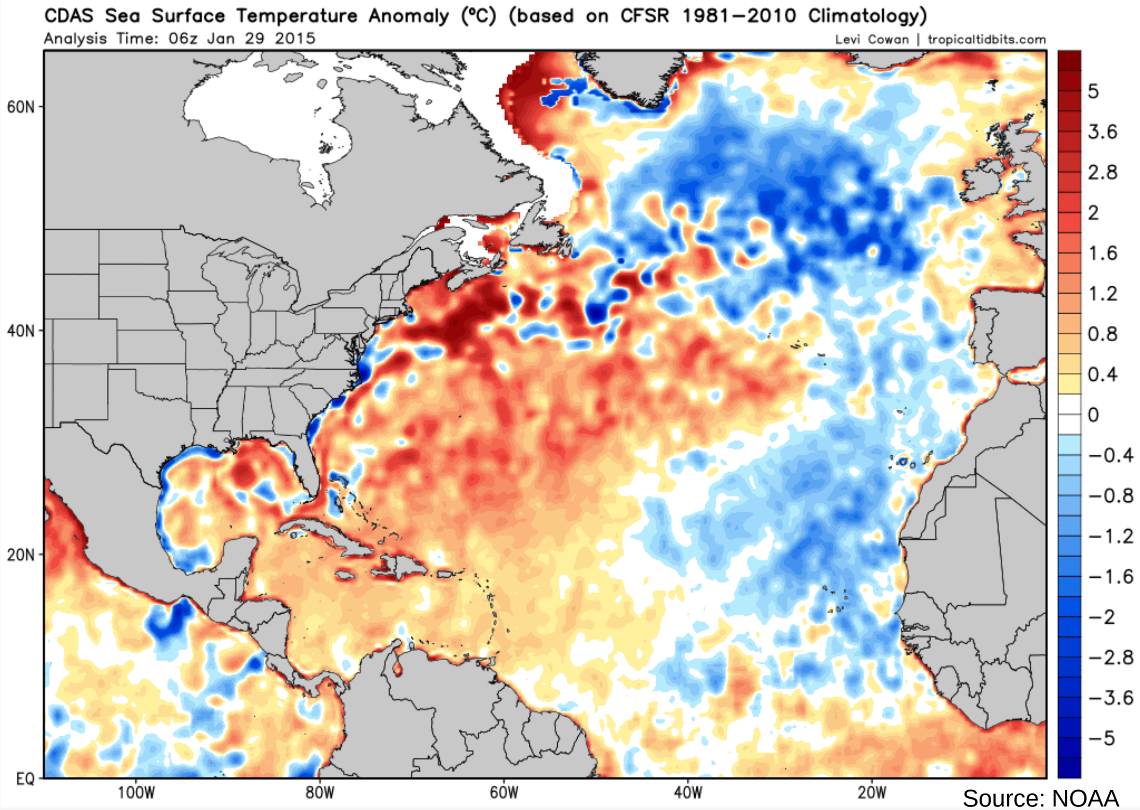
**South Carolina: Up to 24” of rain over October 2 – 5, 2015 (Hurricane Joaquin impact)**

Texas: Over 12 inches near Wimberley on May 24-25, 2015

Massachusetts: Over 6’ of snow over 2 weeks, February 2015

Islip, New York: 13” of rain in a single day on August 13, 2014.

Buffalo, New York: Over 6 feet of snow over the course of 4 days, November 2014.




Source: NOAA

# Recent impact of climate change

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## Hurricane Patricia – Outlier among eastern pacific storms

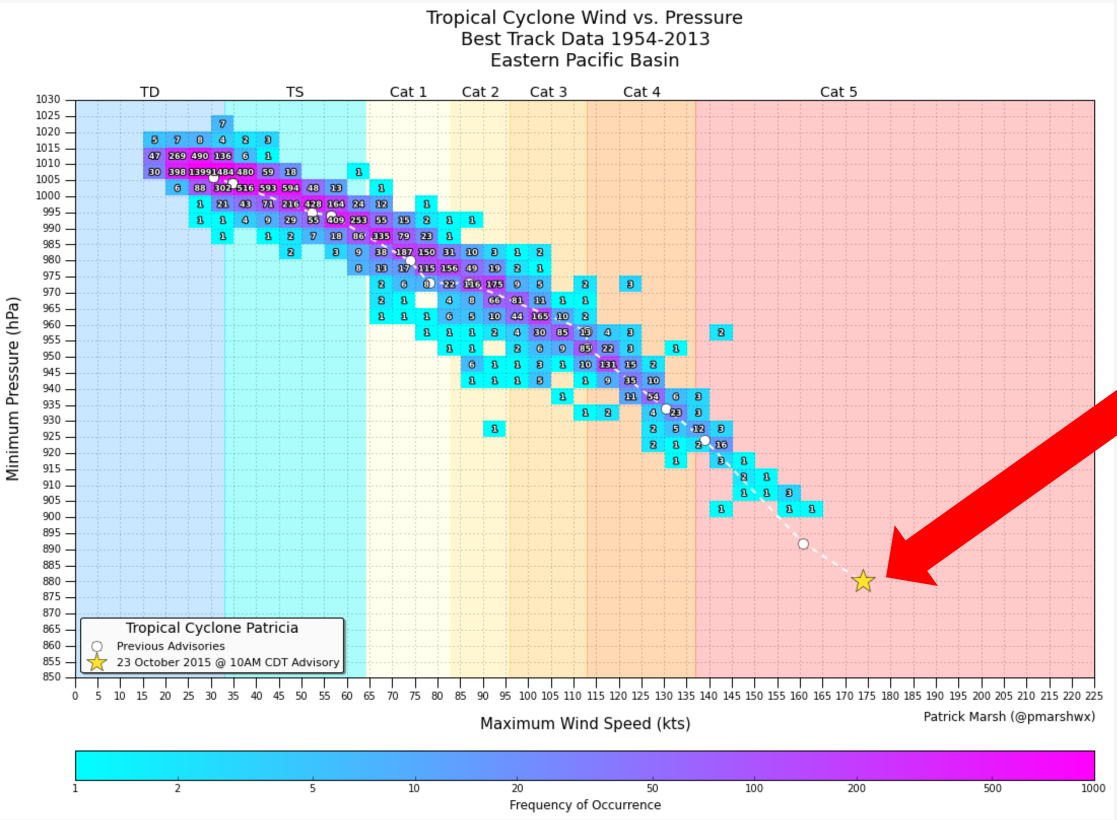


Chart plots all storms in the eastern Pacific from 1954-2013 on a pressure / wind basis. (storm counts by box shown numerically)

Yellow star in lower right represents Patricia clearly showing how extreme Patricia was, even in comparison to other category 5 storms

While the strong El Nino and associated warmer oceans contributed, many other factors also had to come together to allow for this **extreme outlier**!

# Recent impact of climate change

## Hurricane Patricia – Strongest hurricane, modest impact

### Hurricane Patricia western hemisphere records

Highest measured sustained winds – 200 mph

Lowest measured sea level pressure – 879mb (25.96”)

Most rapid intensification – 100mb drop in 24 hours

### Modest impact for a record breaking hurricane

Small inner core (8 mile wide eye) → small area experiencing strongest winds

Rapid weakening ongoing at landfall – pressure rose ~35 mb from peak to landfall 8 hours later – small core of Patricia meant it was more susceptible to rapid weakening

Landfall location on a sparsely populated portion of the coast

# How weather impacts infrastructure


Source: globalchange.gov

Source: ok.gov

In 15 years, will floods be a part of everyday life on the east coast?

# How weather impacts infrastructure

**Flooding/Heavy precipitation** - Reducing shipping access; inundating transportation system; physical damage to power generation, transmission and distribution facilities; runoff exceeding the capacity of storm drains and levees

**Rising sea levels -** Intruding saltwater may intrude coastal water infrastructure; increasing risk of erosion; storm surge damage; increasing risks to coastal infrastructure and offshore energy infrastructure

**Extreme heat** - Jet stuck in softened asphalt; heat-kinked track derailing a subway train; buckling of roads; power outages

**Drought** - Shrinking clay-rich soils buckle roads; hinder operation of nuclear and fossil fuel power plants; increased evaporation reducing water flows; longer wildfire season

**Hurricanes** - Damages offshore energy infrastructure; stress or damage electricity transmission and distribution infrastructure

Source: US Global Change Resource Program; images courtesy of globalchange.gov

# Focus on energy infrastructure




# Focus on energy infrastructure

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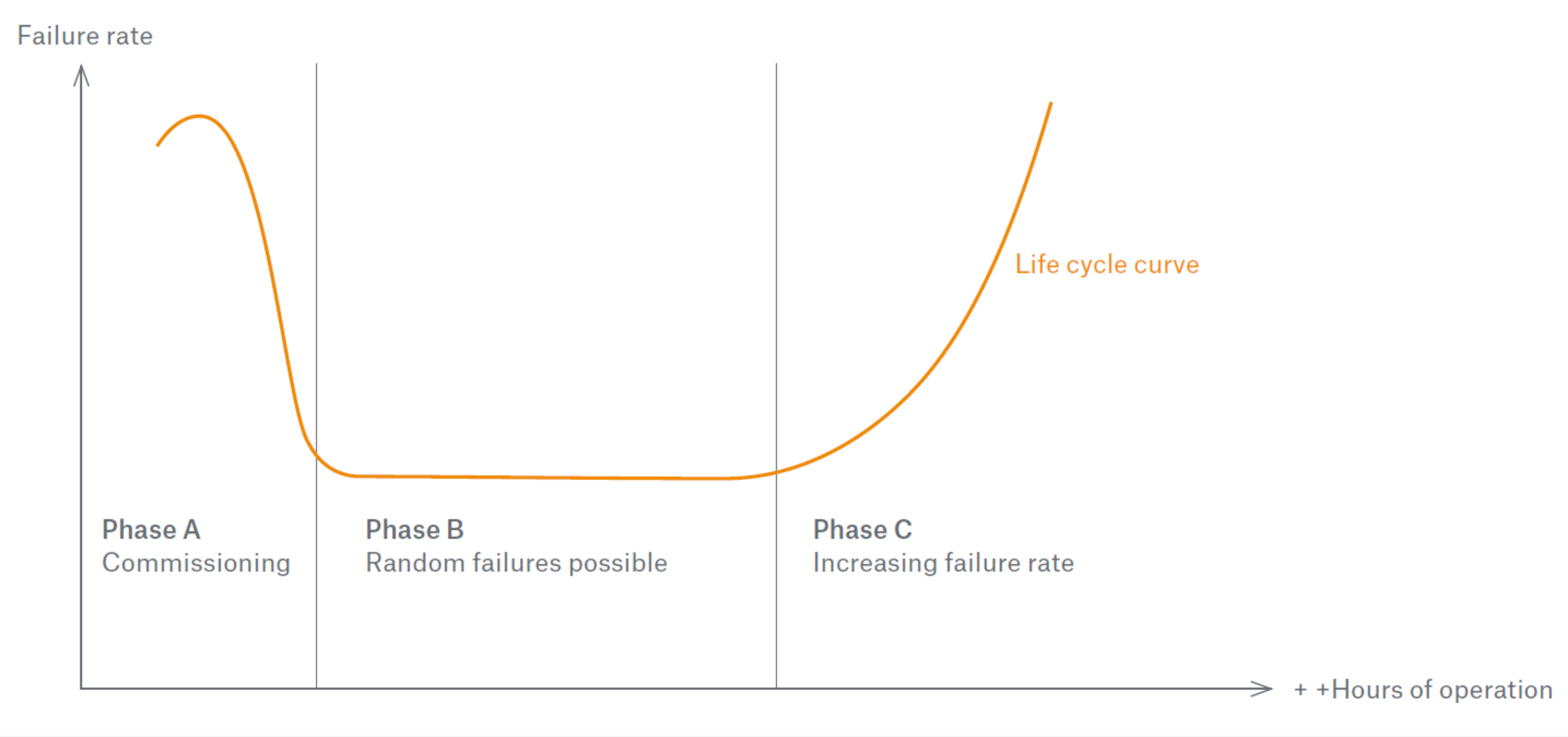
## Bathtub curve/life cycle curve for a power plant




Source: Munich Re Schadenspiegel 1/2011

# Focus on energy infrastructure

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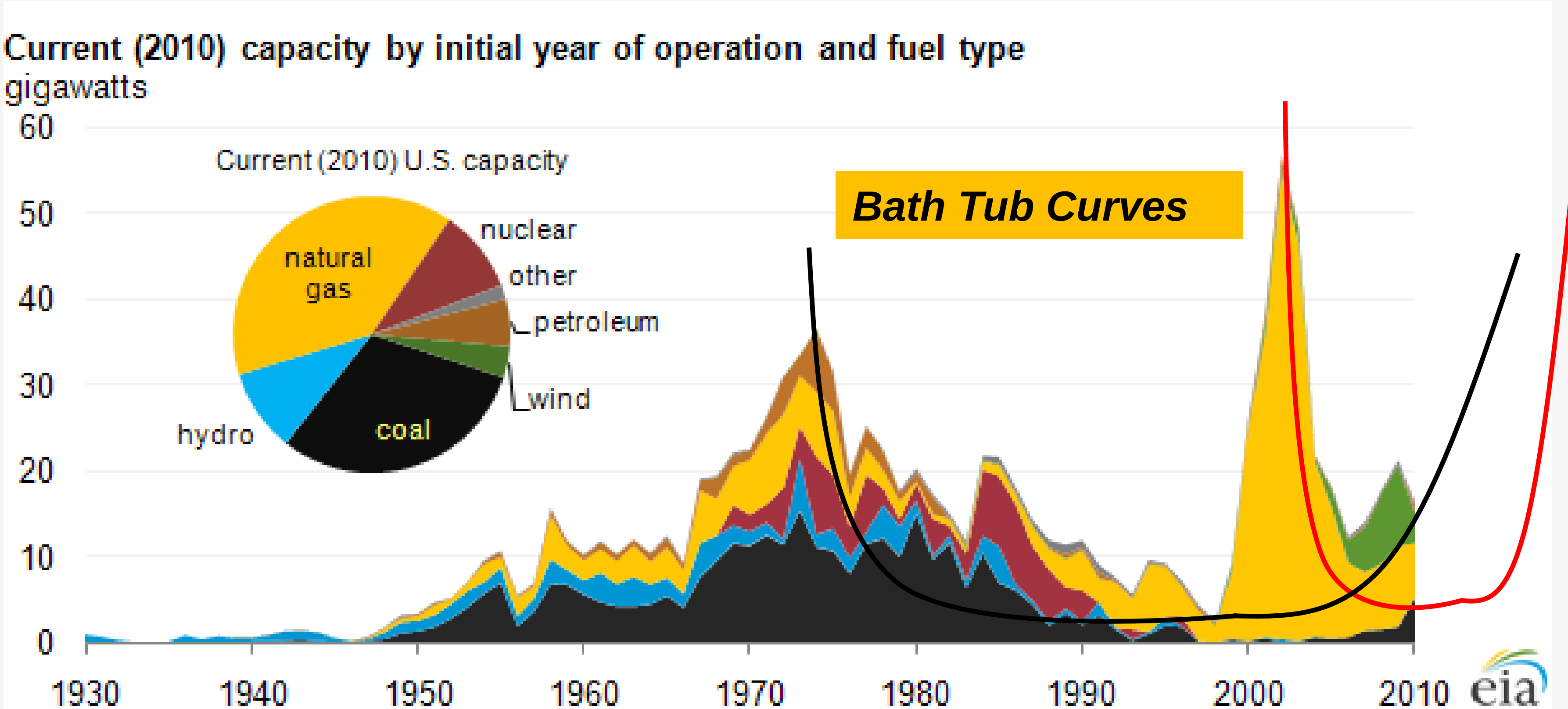
## Aging infrastructure in the US - coal, hydro, nuclear power plants




Source: EIA – Energy Information Administration

## What's the life expectancy of various types of power generation technologies?

# Focus on energy infrastructure

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## Aging power infrastructure issues

| Key plant equipment | Aging equipment issues |
|---|---|
| Boilers | Fuel isolation, boiler explosion water chemistry excursions, scaling, corrosion pitting, improper lay up, |
| Control systems | Obsolescence, sequential trip protective device testing / OST DC ELOP testing |
| GSU transformers | High total combustible gasses, insulation deterioration Furans Bushings |
| Turbines and generators | Aging blades & rotors, fatigue, stress corrosion cracking, loose wedges, and end windings, corona damage |
| **Grid** | Distribution transformers, storm hardening designs |

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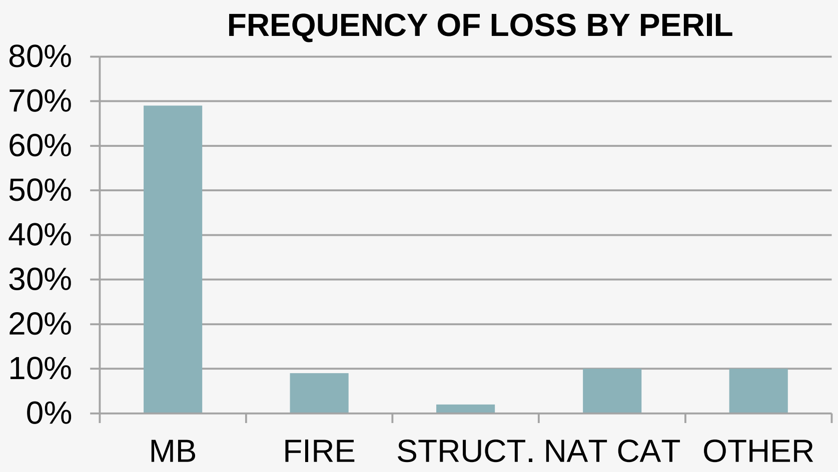
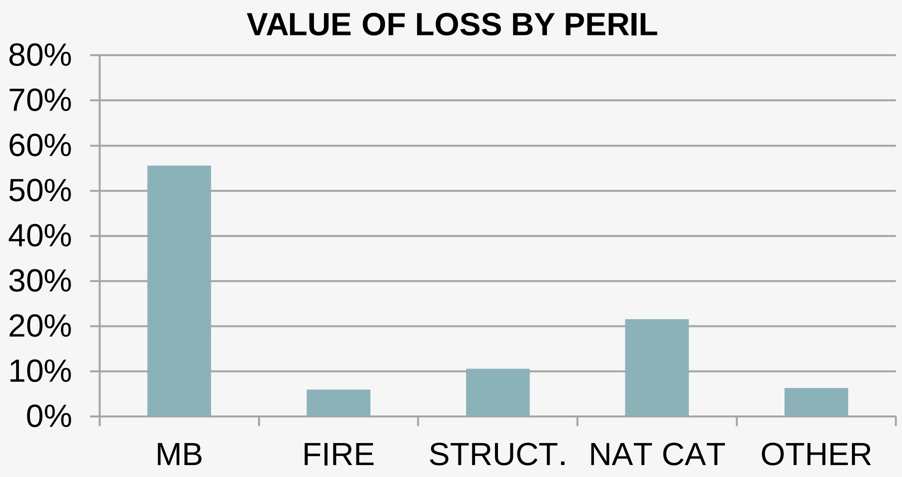
North American power generation fleet




Loss distribution by peril for US Power & Utility (2000 – 2014, Munich Re Loss Database)

**Emerging Trend**

As the renewable energy assets increase (wind, solar) the susceptibility to Nat Cat exposures increases significantly.

# Focus on energy infrastructure

## Superstorm Sandy

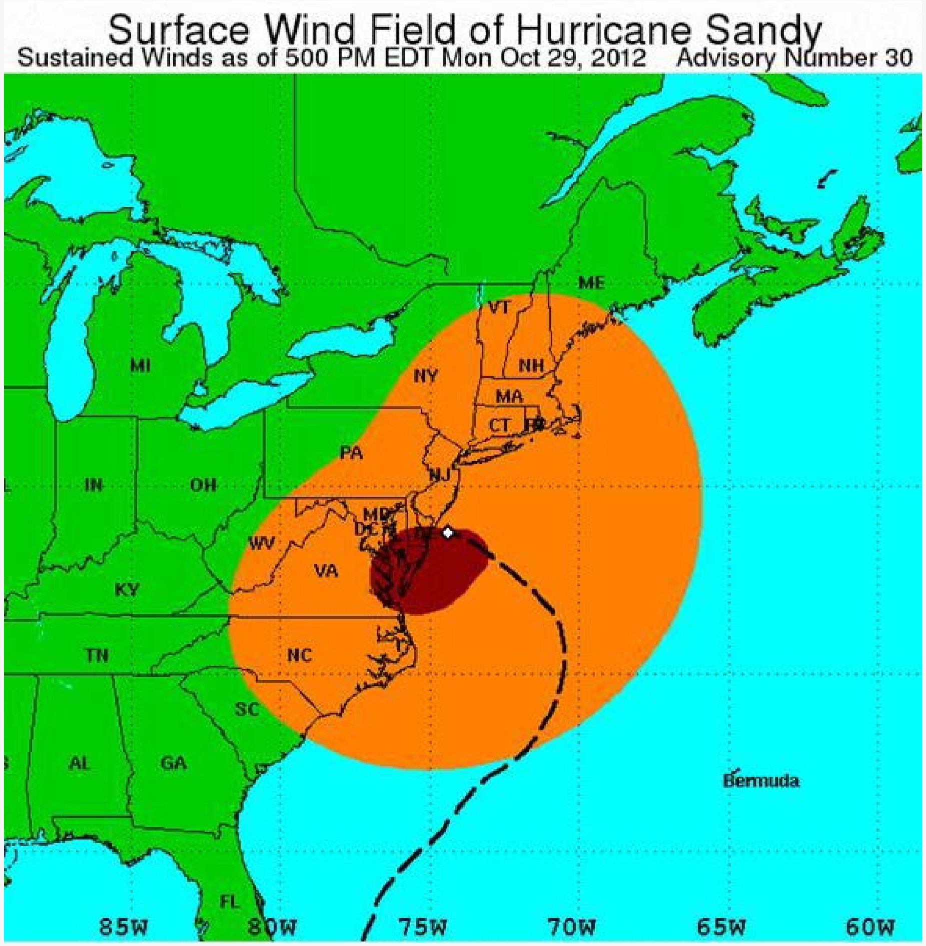
Approximately 8.5 M customers in the eastern U.S. lost power

An unprecedented 14-foot storm tide breached shorelines & flood-protection measures

Catastrophic flooding & corrosive salt water destroyed electrical equipment, downed trees & ravaged the transmission system

The actual storm surge of 14.06 feet exceeded official forecasts, surpassing a historical record set in 1821 by nearly three feet

The storm caused an estimated $18.75 billion in insured property losses at the time ($19.3 billion in 2014 dollars), making it the third costliest natural disaster in US history



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## What is storm hardening?

Modernization of infrastructure or retrofit existing infrastructure to be able to withstand extreme weather events such as wind, flooding or flying debris by re-evaluating site conditions due to new established codes and guidelines.

**Flood/Storm Surge Protection**

- Building/strengthening berms, levees and floodwalls
- Elevating substations/control rooms/pump stations
- Relocating/constructing new lines and facilities

**Wind Protection**

- Securing cooling towers
- Improving tank integrity
- Burying power lines underground
- Building/strengthening/retrofitting

# Focus on energy infrastructure

## Types of storm hardening flood control countermeasures


**Active**: control the infiltration of flood waters via barriers & sealants

**Passive**: raise critical equipment above the flood zone

**Operational:** preemptive storm preparation tasks to protect equipment

# Focus on energy infrastructure

## Storm hardening

Some utilities and their regulators are revisiting the economics of putting more power lines underground.

New York is studying measures to protect its waterfront from future storm surges such as building a seawall around the city.

# Focus on energy infrastructure

## Storm hardening

One of the most familiar is the 50-year, $50 billion Gulf Coast restoration initiative in the aftermath of Hurricane Katrina. This initiative will increase the height and resilience of levees and flood walls in New Orleans to combat rising sea levels and storm surge.

Following Hurricane Sandy, PSE&G is proposing efforts to make New Jersey's power grid more resilient -- such as building flood walls around or elevating substations and switching stations, which flooded after Sandy.

# Infrastructure economic impacts
# Polling question 2

Do you believe investing in our infrastructure will help our economy?

A. Yes
B. No
C. Don't know

# Infrastructure economic impacts

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## Infrastructure investment opportunities

### Energy infrastructure

**$107 billion** – national electricity infrastructure gap by 2020

**$126 billion for businesses/$71 billion for households** – blackouts' and brownouts' cumulative costs without more investment by 2020

**7% ($30 billion)** – amount of electricity the nation's antiquated power grid wastes

Investing an additional $11 billion per year through 2020 could result in…

- $496 billion in GDP
- $10 billion in US exports
- $656 billion in personal income
- 529,000 jobs

Source: infrastructureweek.org, infrastructurereportcard.org

# Infrastructure economic impacts

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## Investing in infrastructure

**$1.66 trillion** – current need to improve the nation's infrastructure

**$2.75 trillion** – 2020's need for infrastructure improvements

**$1.2 trillion for businesses/$611 billion for households** – costs due to aging and unreliable infrastructure

**$3.1 trillion** – cost to the nation's economy by 2020 without investing in infrastructure

Investing an additional $157 billion per year through 2020 could prevent……

- $3.1t loss in GDP
- $1.1t loss in total trade
- $3,100 per year reduction in personal disposable income per household
- $2.4t reduction in consumer spending
- 3.5m job losses

Source: American Society of Civil Engineers

# Infrastructure economic impacts

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Source: ncptt.nps.gov

Spending a dollar on disaster-risk mitigation and preparedness saves an average of $4 in future losses, according to a study for FEMA

Enforcing stronger building codes would have decreased wind damage from Hurricane Katrina by 80%, saving $8 billion

Implementing Mississippi River & Tributaries flood protection program prevented more than $478 billion in flood damages

Source: National Institute of Building Sciences - Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities; Dialogue on National Resilience

# Infrastructure economic impacts

Source: noaa.gov

Spending $3.6 billion in flood reduction projects, the Army Corp of Engineers' in the Great Lakes and Ohio River has prevented over $18 billion in damages.

Utilizing current building codes would have reduced property losses from Hurricane Charley (2004) by 42%

Building to Florida's 2004 building codes would have reduced Hurricane Andrew (1992) insurance losses by 50% for homes and 40% for commercial properties

Source: National Institute of Building Sciences - Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities; Dialogue on National Resilience

# Infrastructure economic impacts

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## The factors driving the trends of the past will also influence those of the future

1. Continuing population growth in most countries
2. Growing energy and water consumption, especially in the newly industrialized and developing countries
3. Increasing mobility and urbanization
4. Increasingly frequent exposure of densely populated areas to major natural catastrophes
5. Public spending cutbacks in the wake of economic and financial crises, preventing timely renewal of the infrastructure
6. Rising cost of maintenance for antiquated and hence increasingly unprofitable technologies

Source: Munich Re Schadenspiegel 1/2011

# NOT IF, BUT HOW

# Thank you



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