

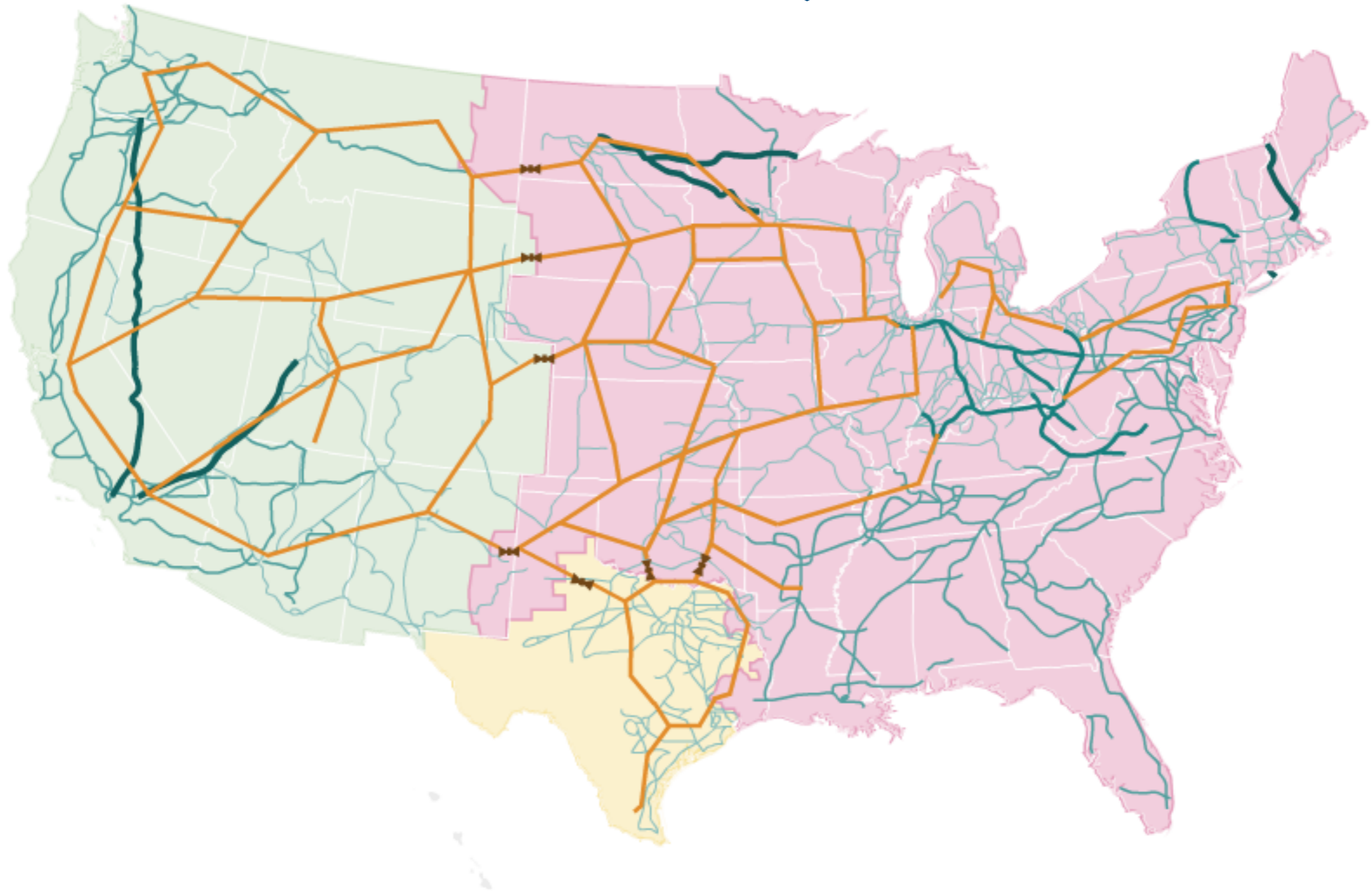
# Understanding how our electricity system works

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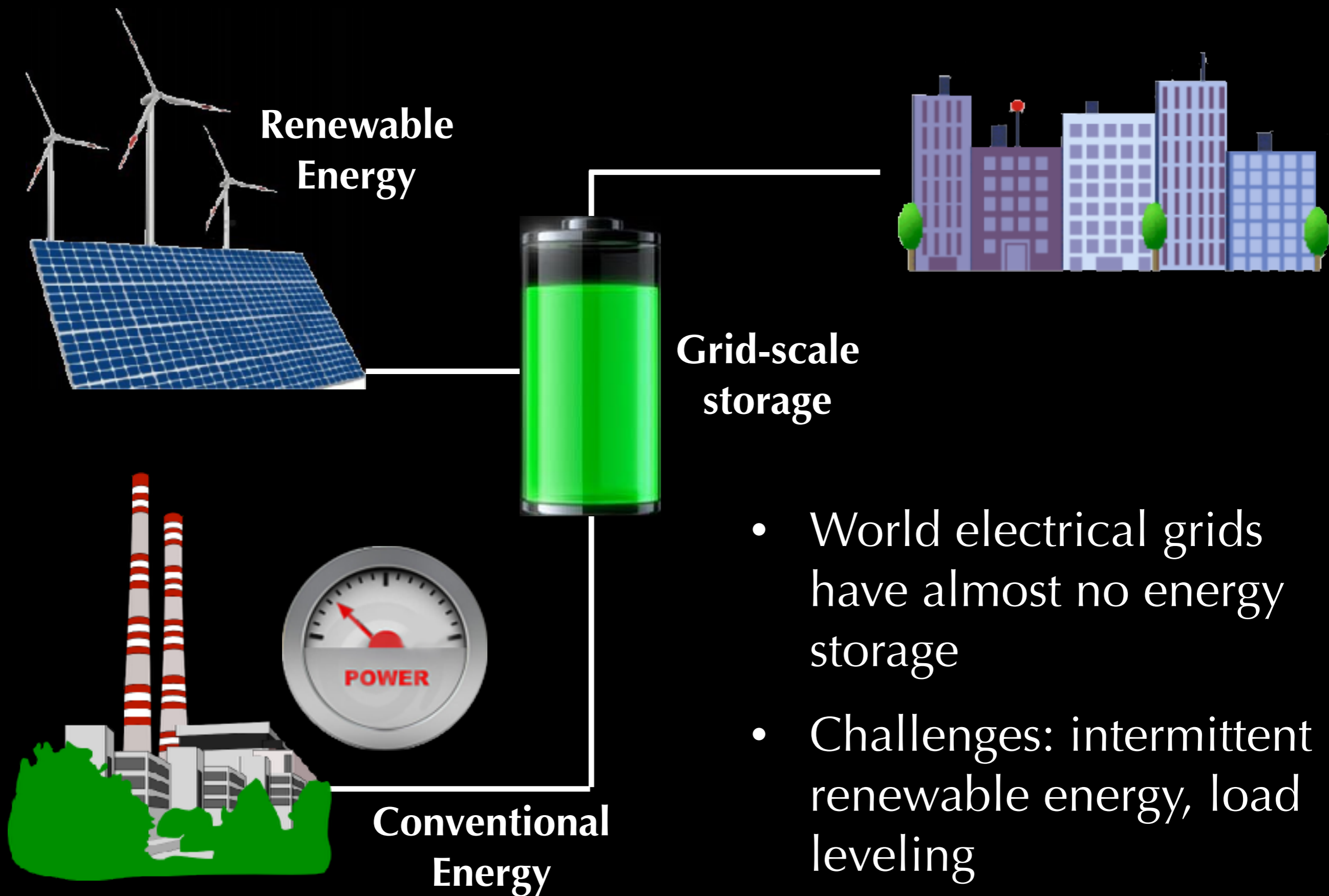
# MixingLab

[www.me.rochester.edu/projects/dhkelley-lab](http://www.me.rochester.edu/projects/dhkelley-lab)



- Ultrasound in liquid metal for next-generation casting
- Reactive mixing: Fundamentals & application to phytoplankton
- Biofluid mixing for brain waste disposal and inner ear homeostasis
- Liquid metal batteries for grid-scale storage ←

# Needed: Grid-scale storage



- World electrical grids have almost no energy storage
- Challenges: intermittent renewable energy, load leveling

## European utilities

# How to lose half a trillion euros

Europe's electricity providers face an existential threat

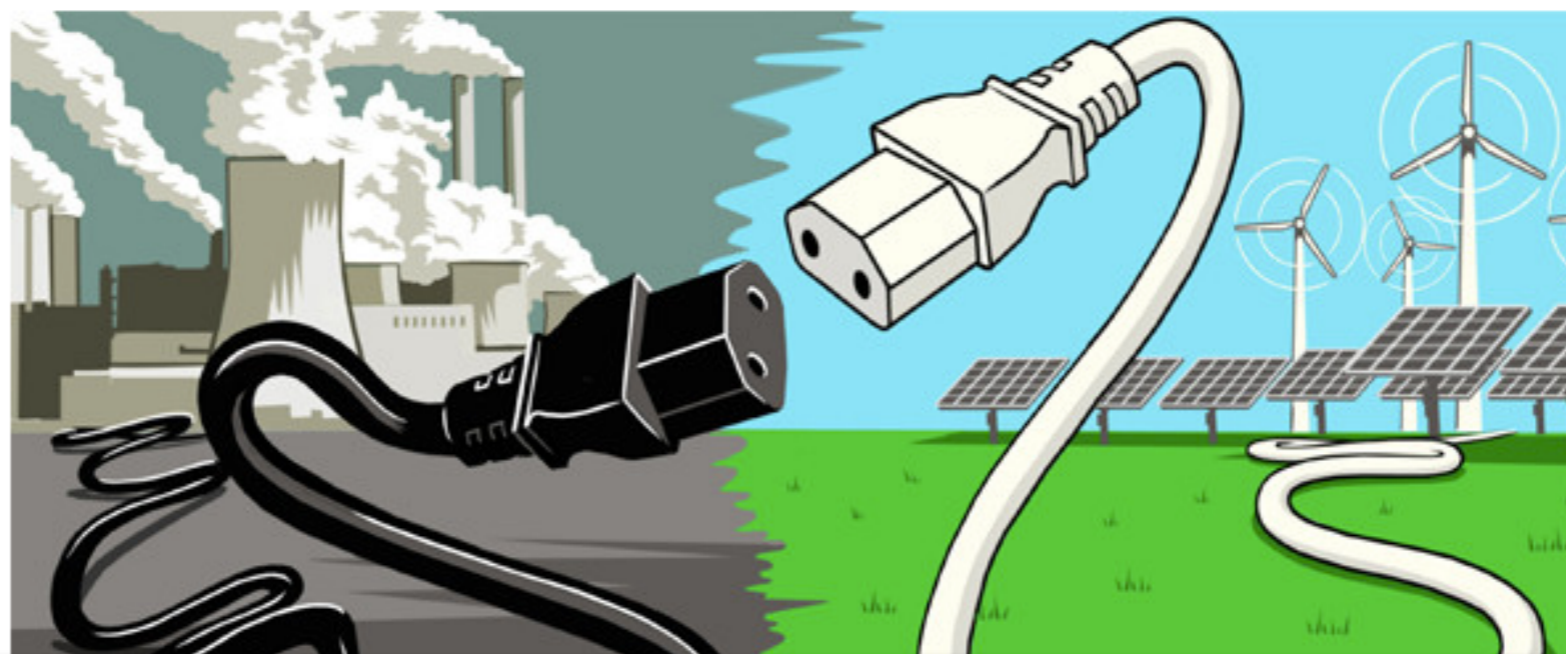
Oct 12th 2013 | From the print edition



7.4k



801



ON JUNE 16th something very peculiar happened in Germany's electricity market. The wholesale price of electricity fell to minus €100 per megawatt hour (MWh). That is,

ON JUNE 16th something very peculiar happened in Germany's electricity market. The wholesale price of electricity fell to minus €100 per megawatt hour (MWh). That is, generating companies were having to pay the managers of the grid to take their electricity. It was a bright, breezy Sunday. Demand was low. Between 2pm and 3pm, solar and wind generators produced 28.9 gigawatts (GW) of power, more than half the total. The grid at that time could not cope with more than 45GW without becoming unstable. At the peak, total generation was over 51GW; so prices went negative to encourage cutbacks and protect the grid from overloading.

# US electrical grids

## About This Map »

Click on the links below to switch layers on and off.

### EXISTING LINES




-  345-499 kV ?
-  500-699 kV ?
-  700-799 kV ?
-  1,000 kV (DC) ?

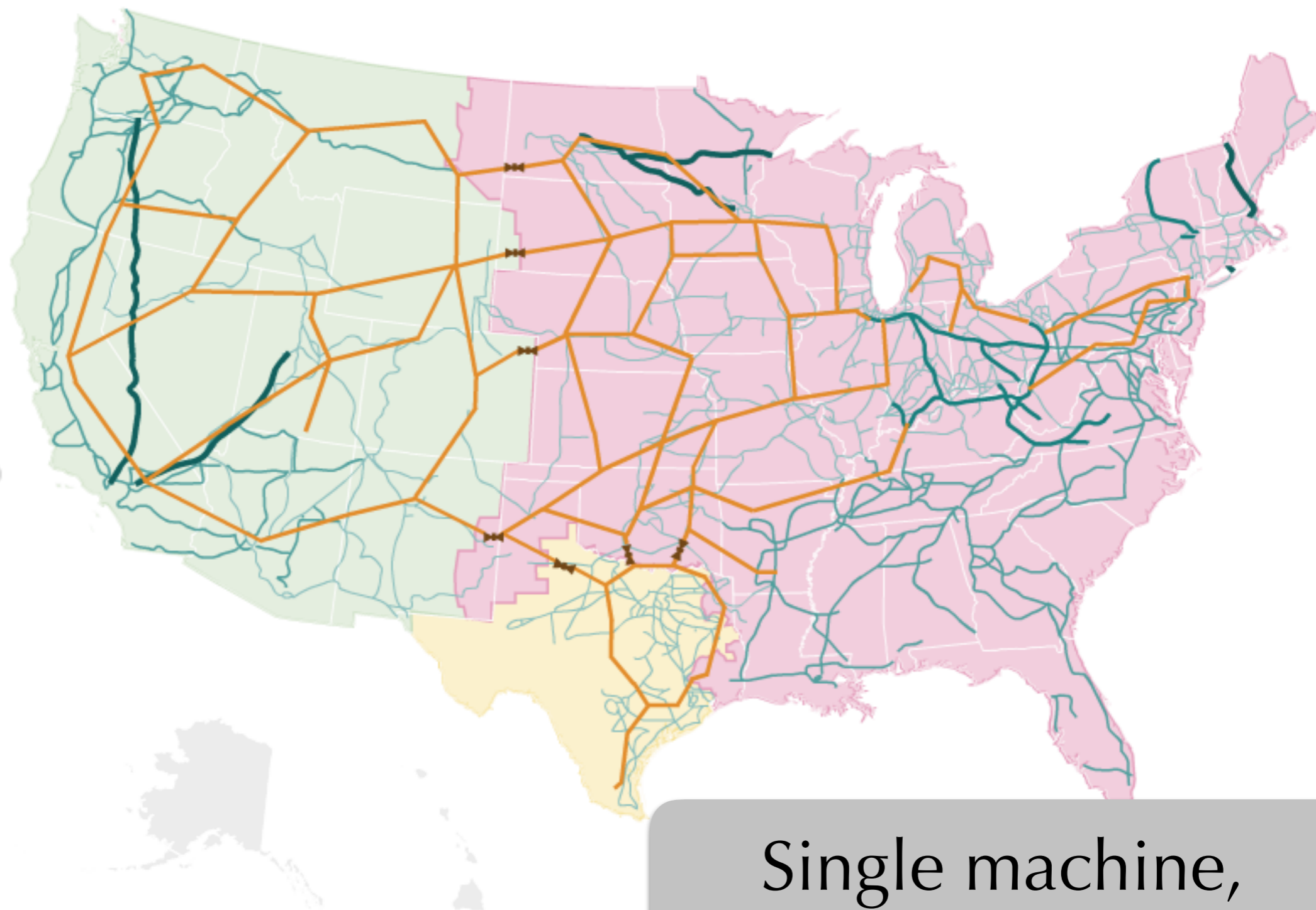
### PROPOSED LINES

-  New 765 kV ?
-  AC-DC-AC Links ?

### INTERCONNECTIONS

Major sectors of the U.S. electrical grid

-  Eastern
-  Western
-  Texas (ERCOT)



Single machine,  
almost zero storage.

# Existing generation

## About This Map »

Roll over the dots for detailed information about each power plant. Use the dropdown below to filter power plants by type.

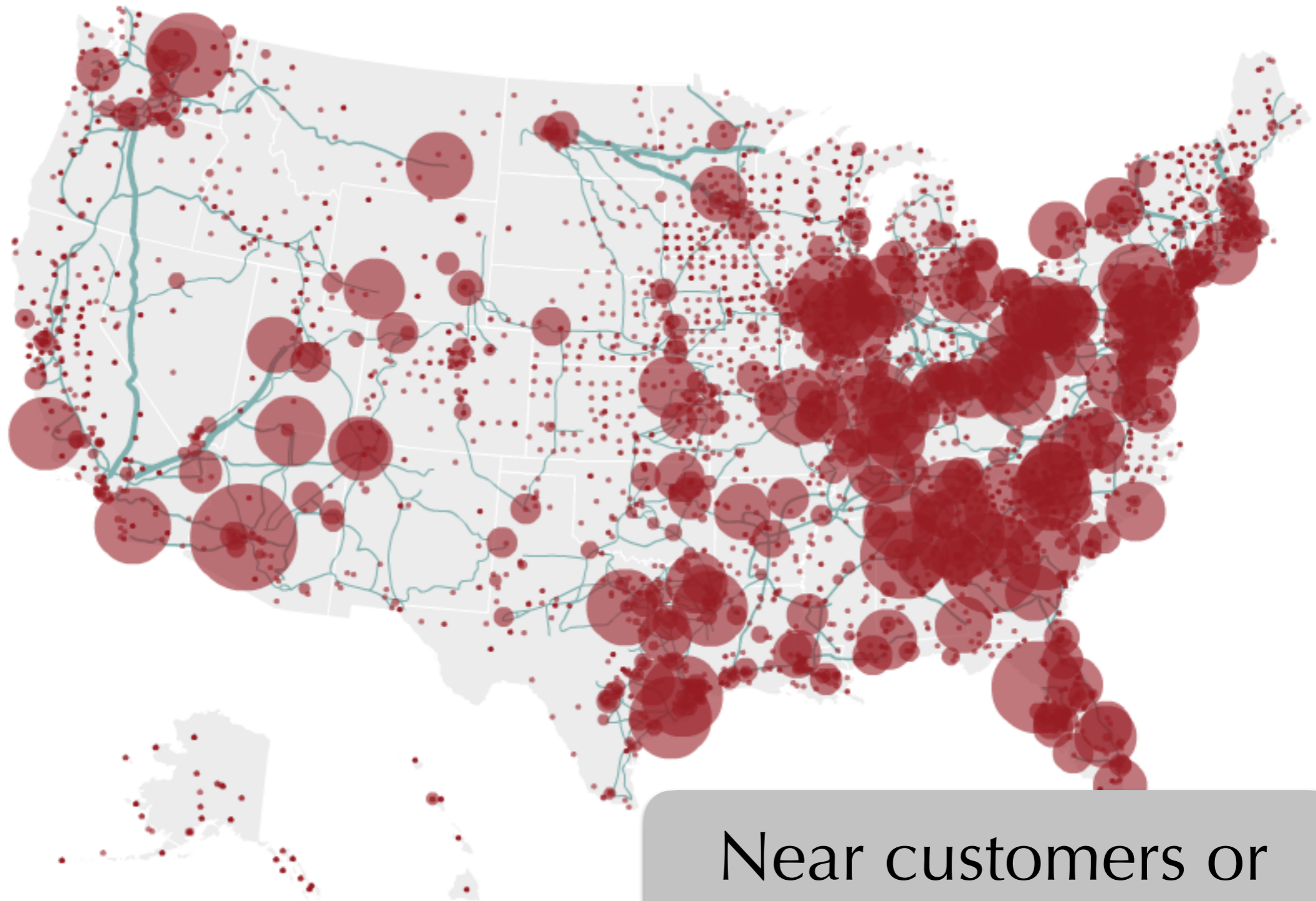
## POWER PLANTS

All plants ▼

Dots are sized with respect to each plant's annual net generation of power.

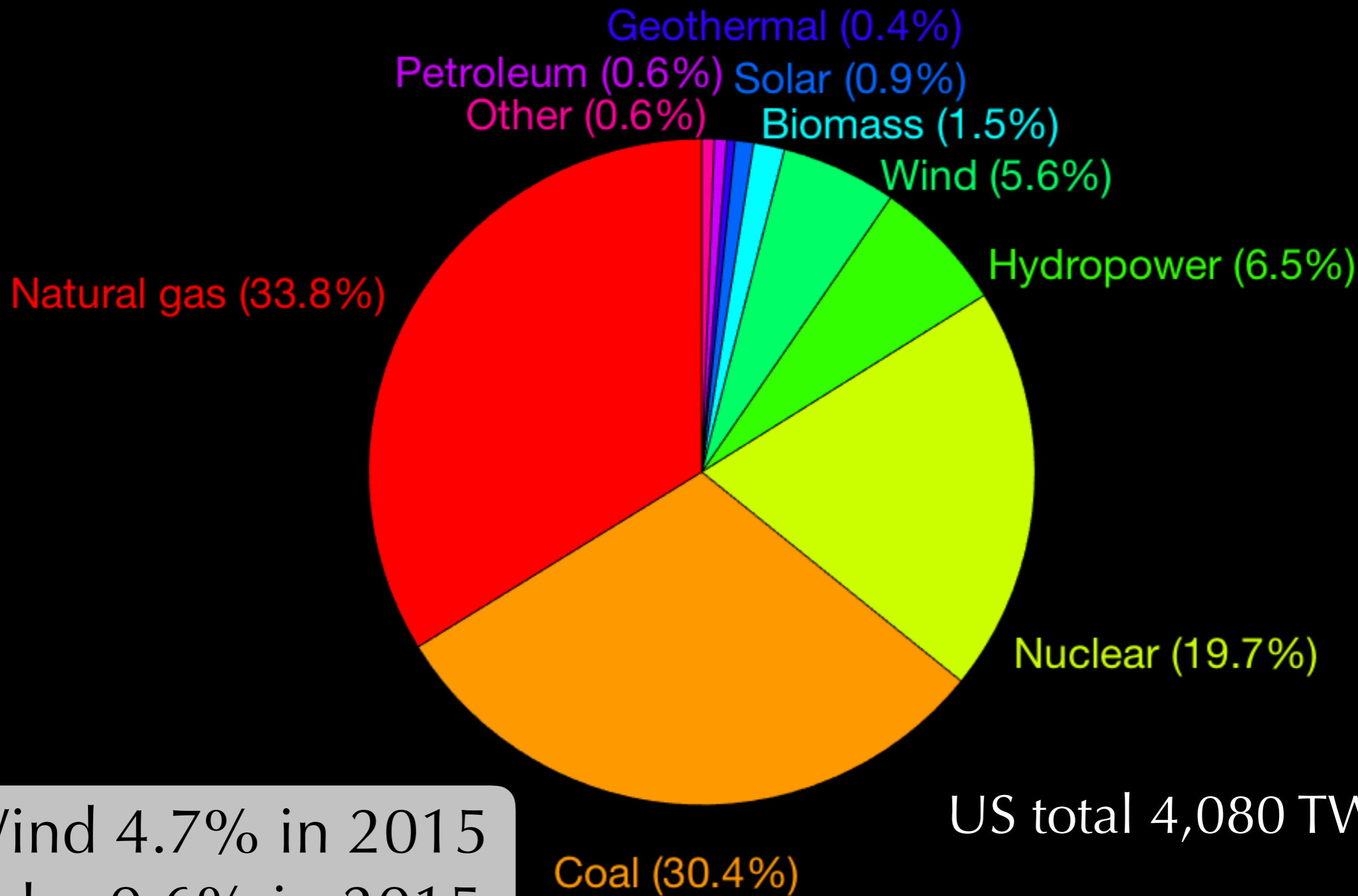
## EXISTING LINES

Existing electric power grid



Near customers or near power sources.

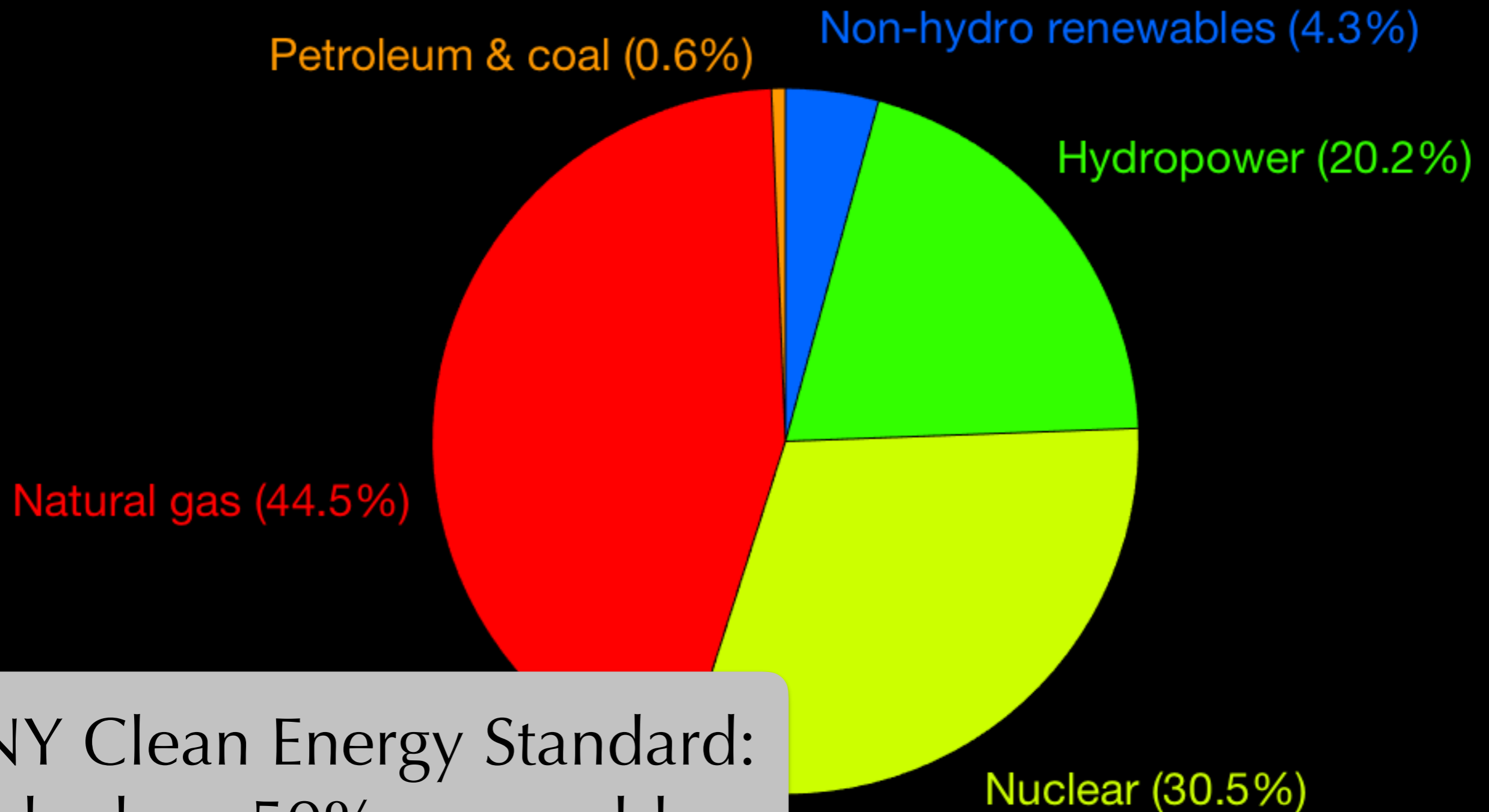
# US electricity generation, 2016



Wind 4.7% in 2015  
Solar 0.6% in 2015

US total 4,080 TWh

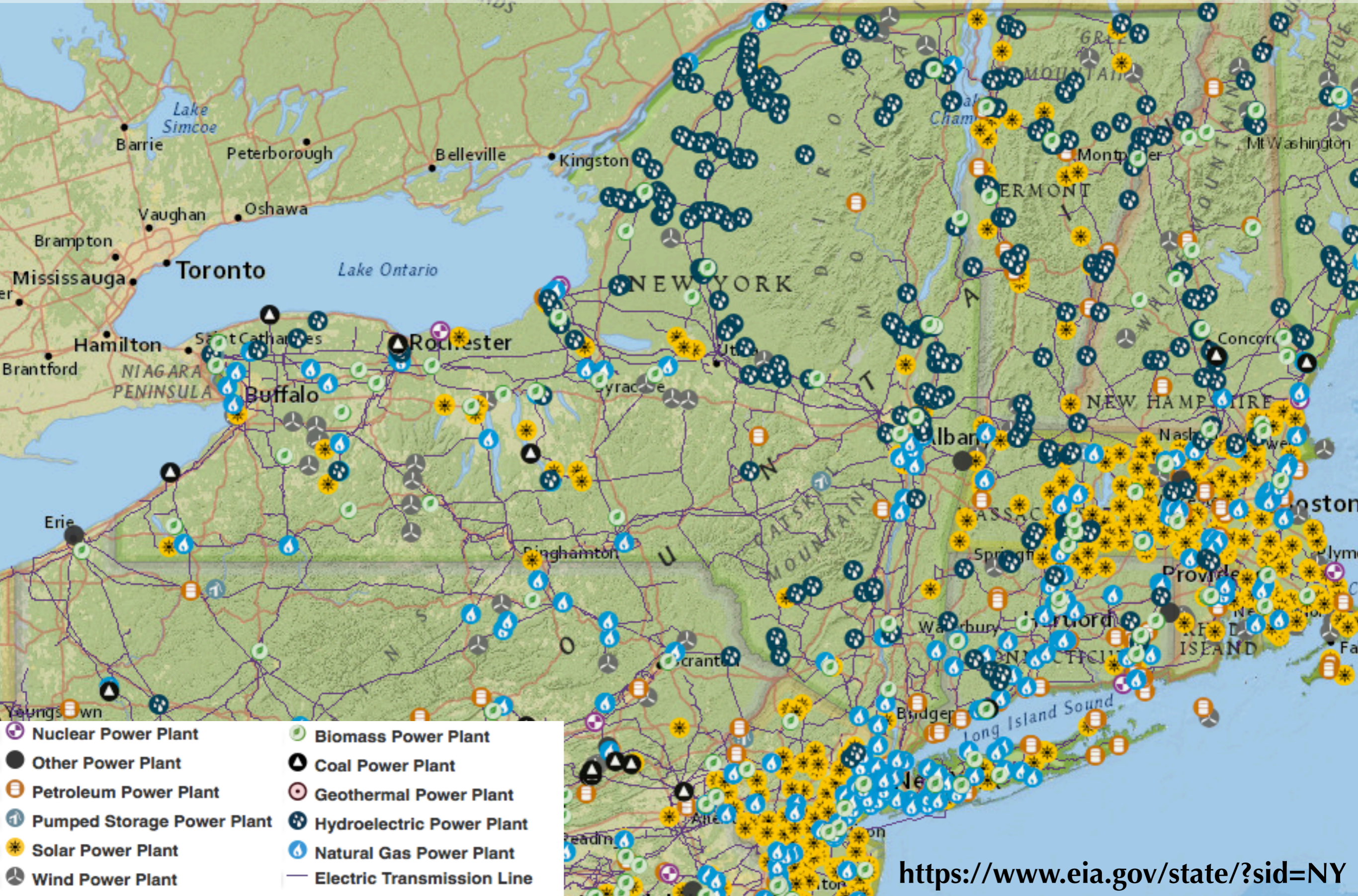
# NY State electricity generation, 2017



NY Clean Energy Standard:  
by law, 50% renewable  
electricity by 2030.

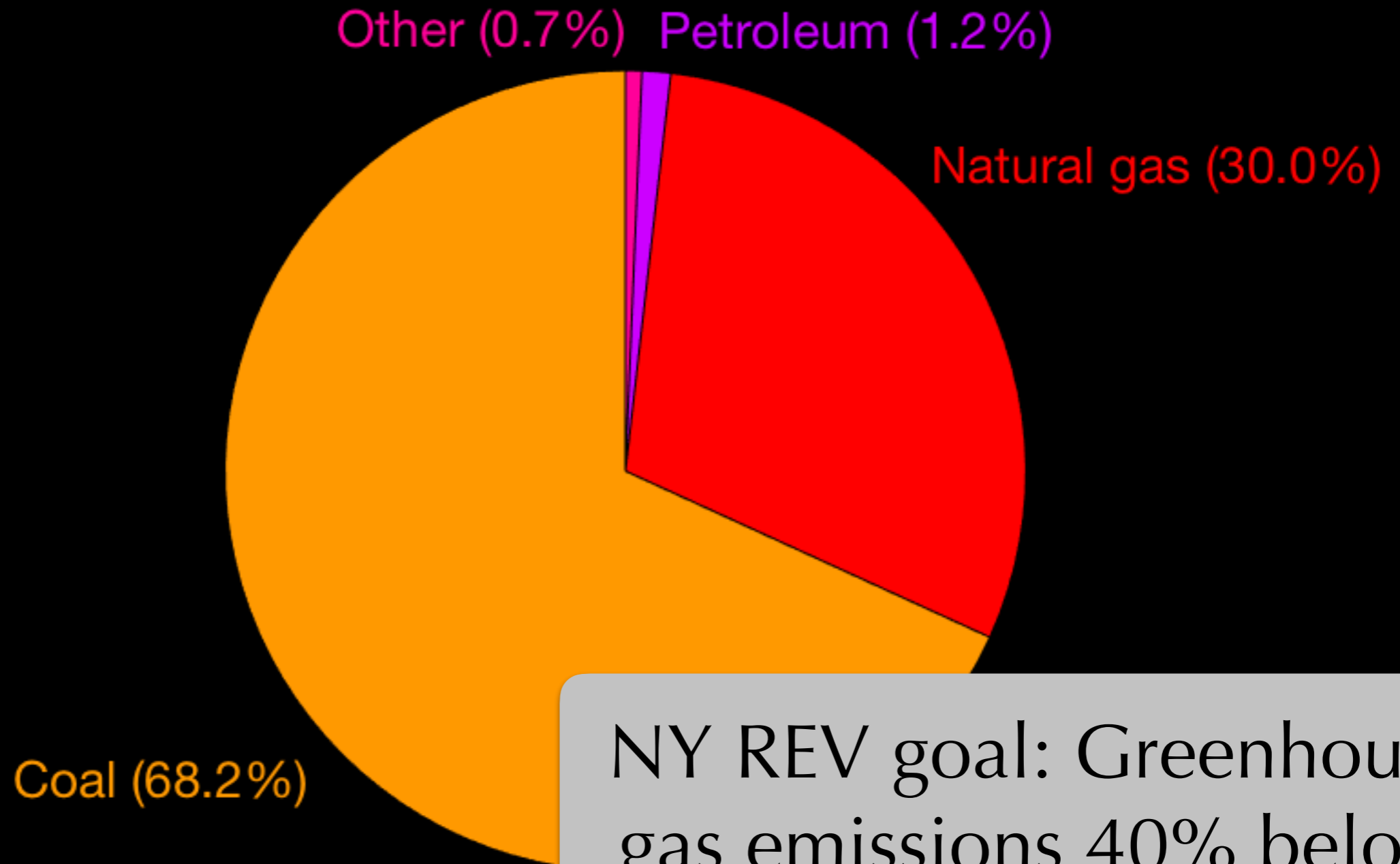


# NY State electricity generation, 2017



# US CO<sub>2</sub> emissions from electricity, 2016


US total: 1821 Mton for electricity, 35% of 5171 Mton total



NY REV goal: Greenhouse gas emissions 40% below 1990 levels by 2030

# Solutions

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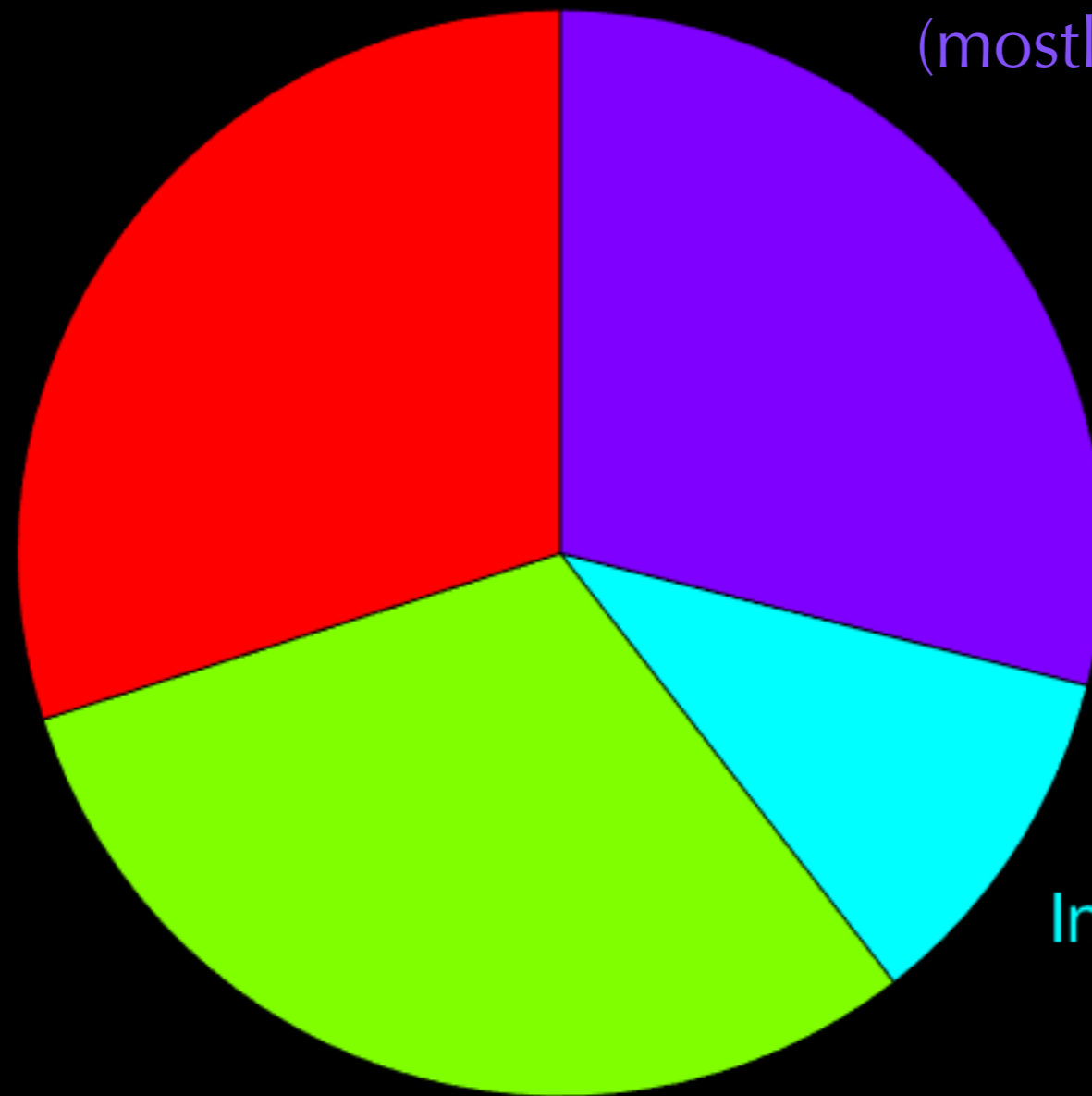
- 
- Increased efficiency.
  - Grid-scale storage and connectivity.
  - Regulatory structure that makes renewables and storage profitable.

# NY State energy consumption, 2015

Residential (29.9%)

Transportation (28.9%)

(mostly not electricity)

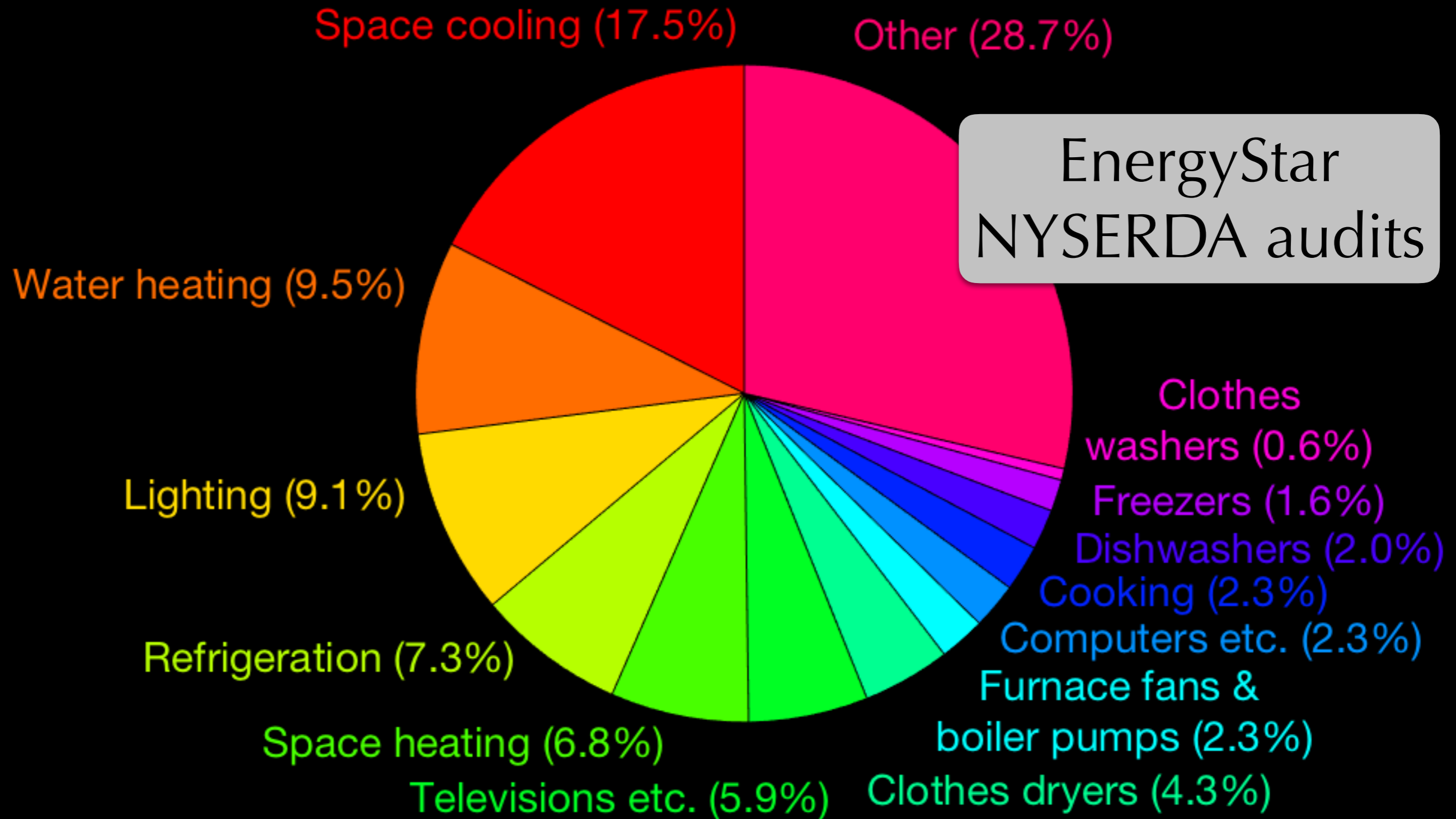


Industrial (10.6%)

Commercial (30.6%)

# US home electricity use, 2016

US average: 901 kWh/month. NYS average: 601 kWh/month.



# Example: HARBEC, Ontario, NY

NY REV goal: Building energy consumption 23% below 2012 levels by 2030



2015



2013

Bob Bechtold,  
President



# Solutions

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- Regulatory structure that makes renewables and storage profitable.



# Potential solar capacity

## About This Map »

Click on the links below to switch layers on and off.

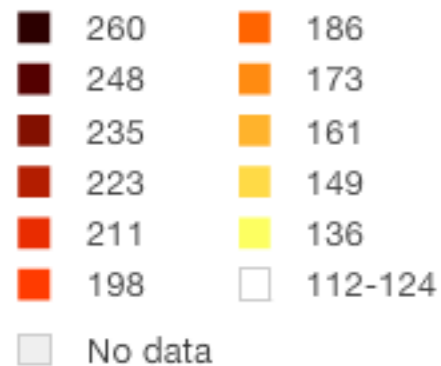
### PROPOSED LINES

✦ Solar power transmission lines

### EXISTING CAPACITY

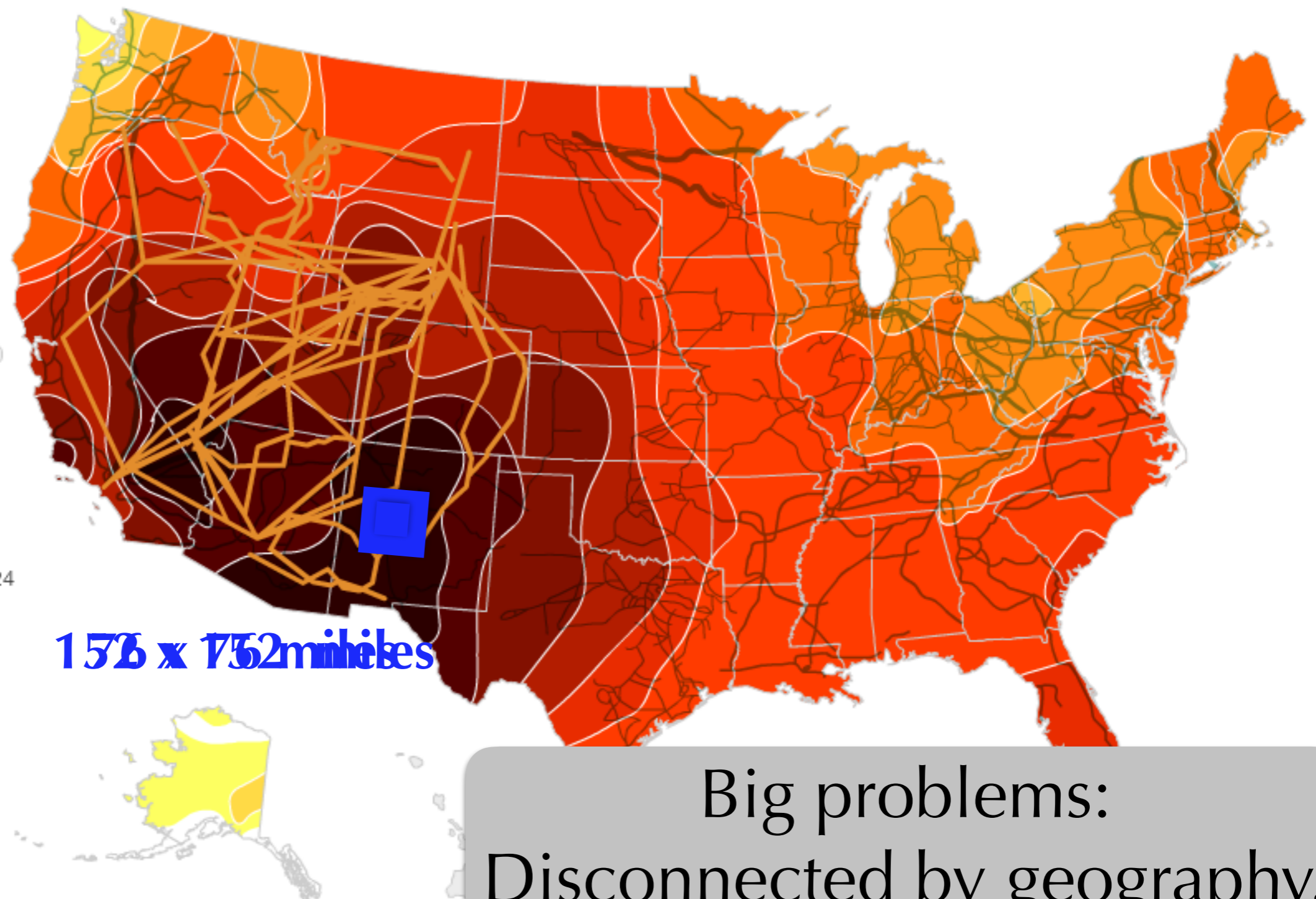
Solar power capacity ?

In kWh / sq. ft. per year



### EXISTING LINES

✦ Existing electric power grid



156 x 152 miles

Big problems:  
Disconnected by geography.  
Disconnected by time.



# Potential wind capacity

## About This Map »

Click on the links below to switch layers on and off.

### EXISTING LINES

Existing electric power grid

### PROPOSED LINES

Wind power transmission lines in 2030

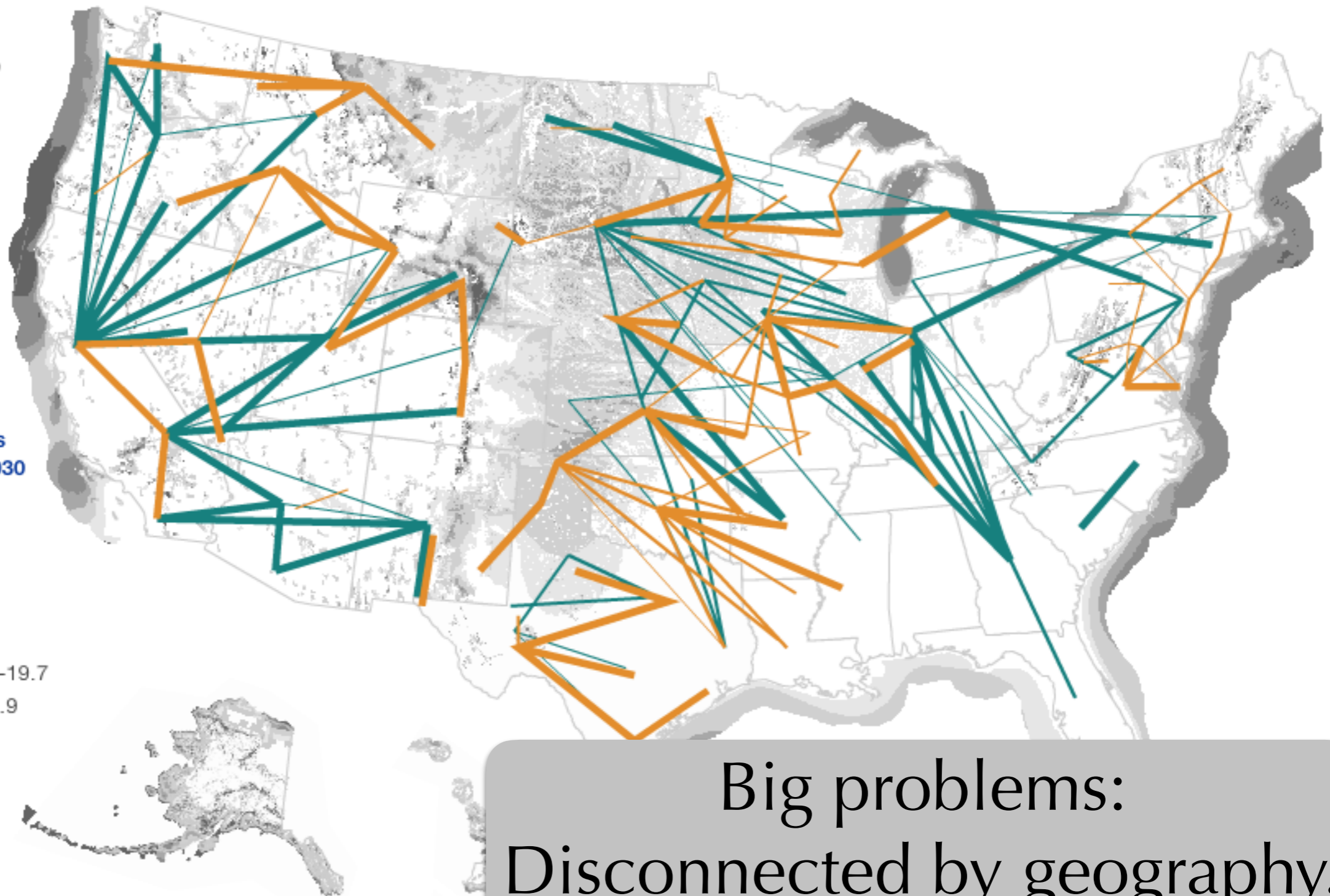
New wind power transmission lines projected after 2030

### EXISTING CAPACITY

#### Wind speed

At 50m (164 ft), in mph

- Superb: 19.7-24.8
- Outstanding: 17.9-19.7
- Excellent: 16.8-17.9
- Good: 15.7-16.8
- Fair: 14.3-15.7

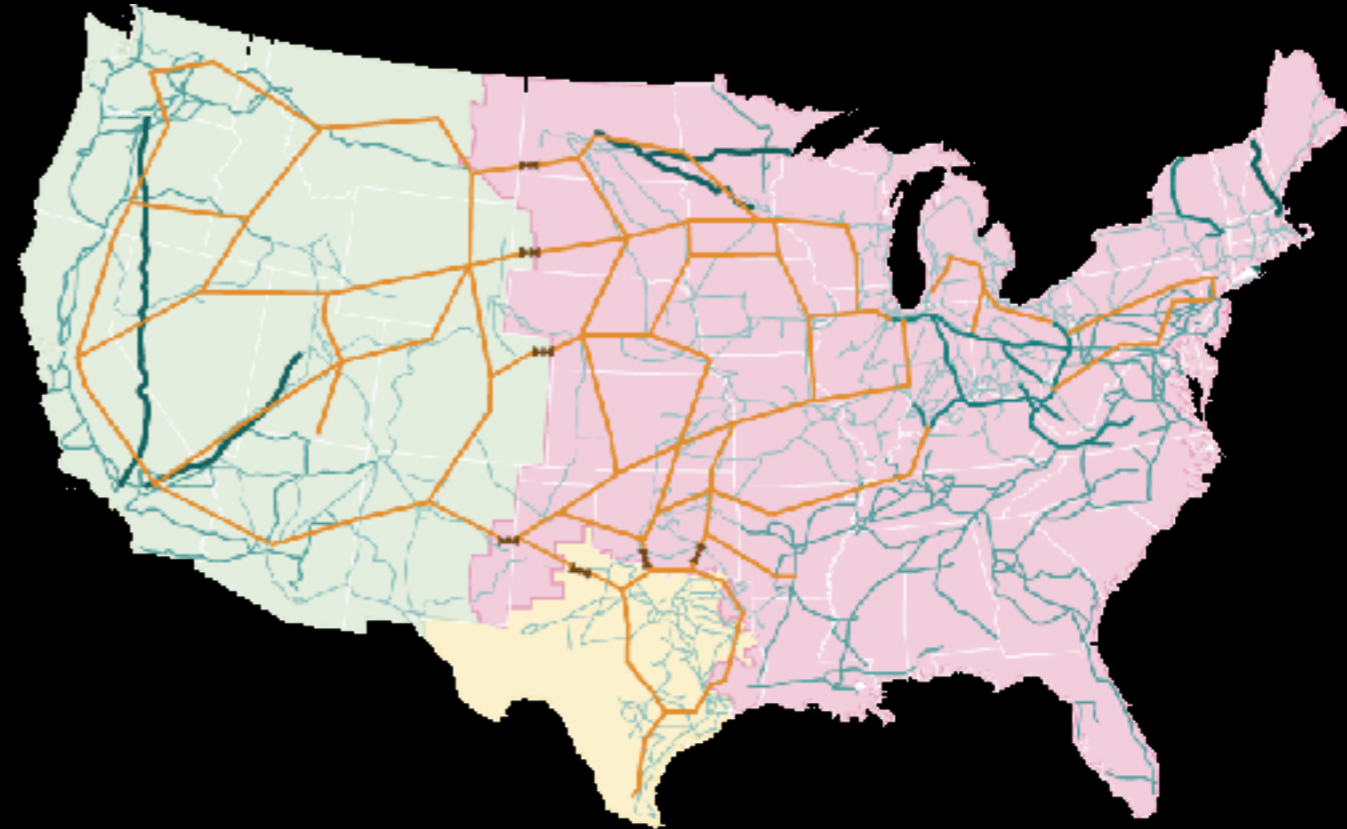
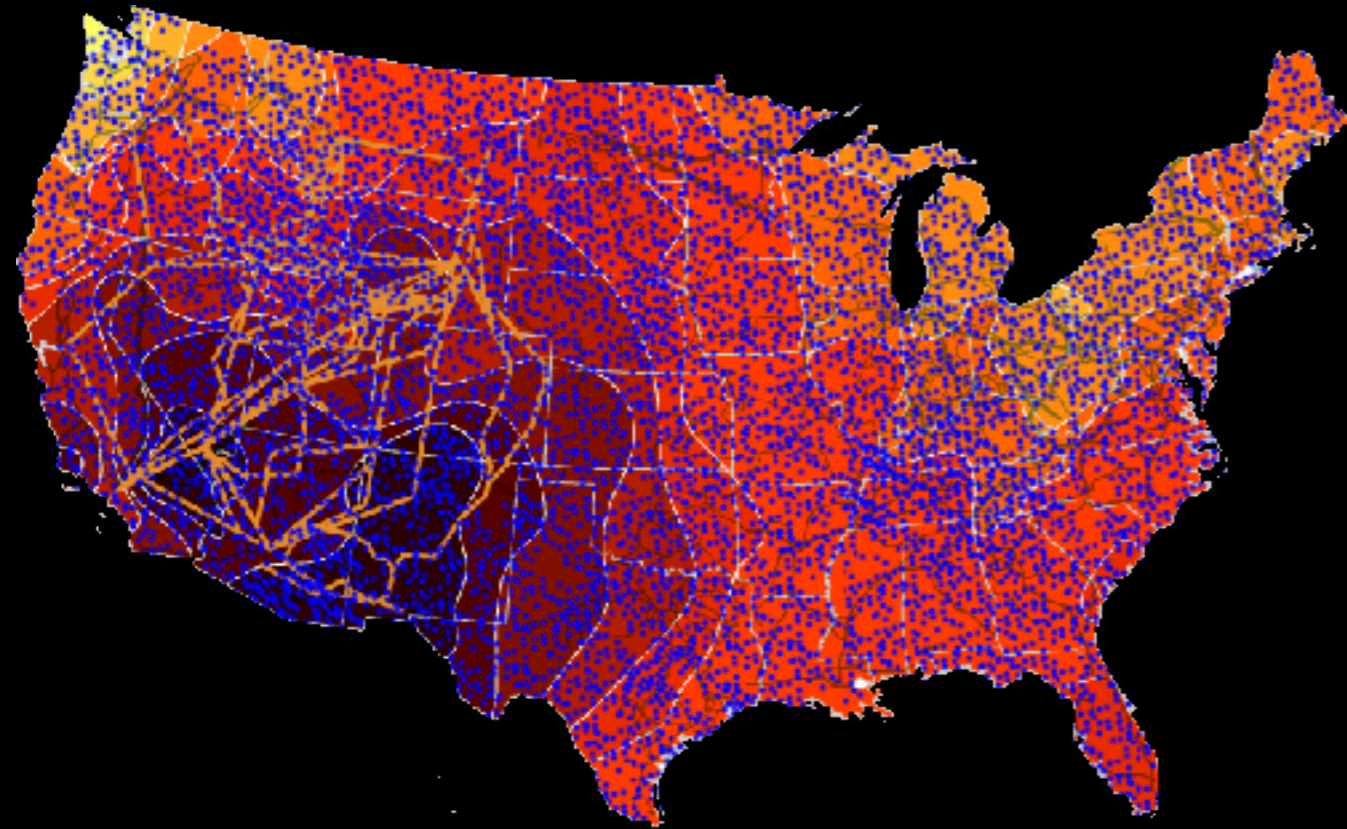


Big problems:  
Disconnected by geography.  
Disconnected by time.

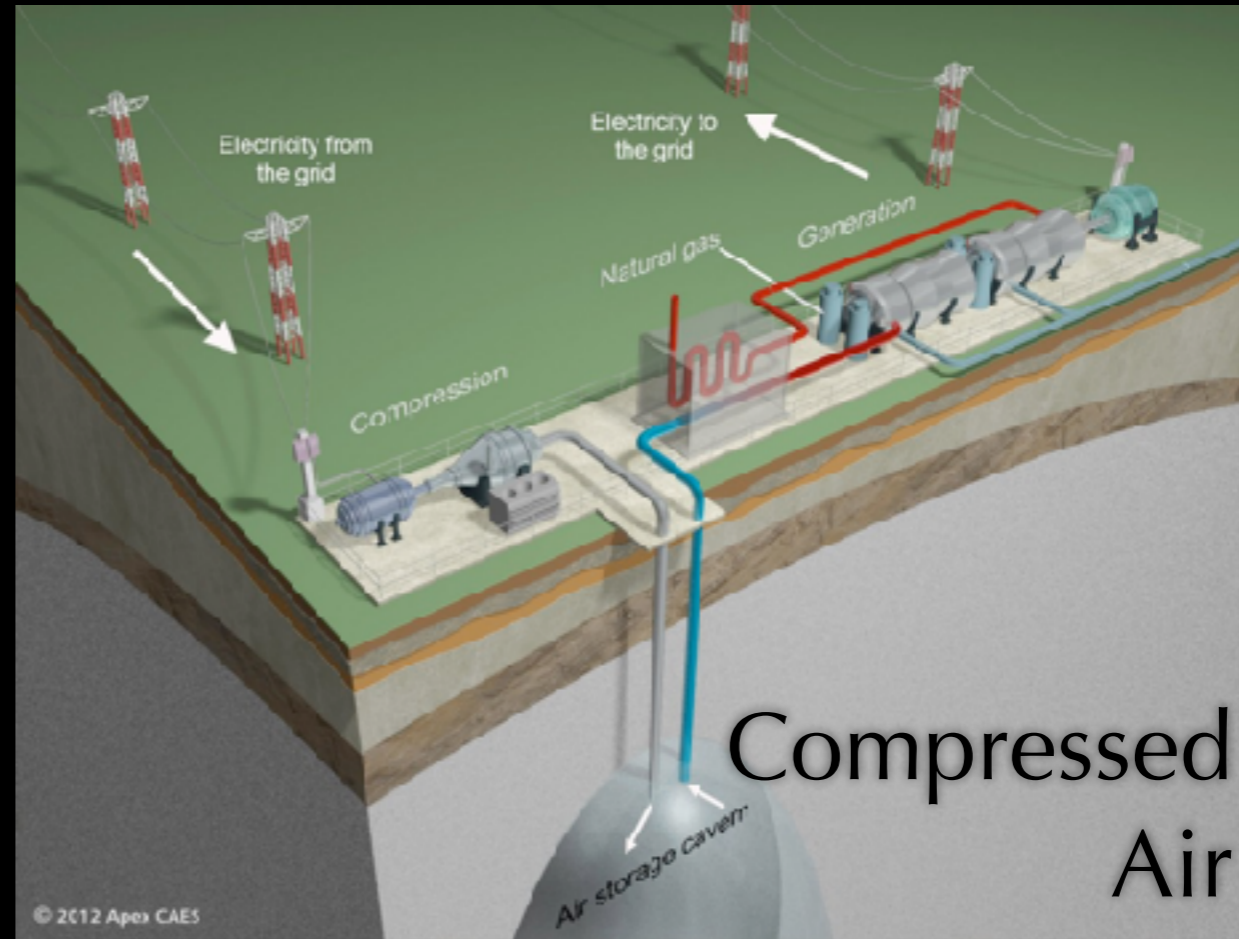
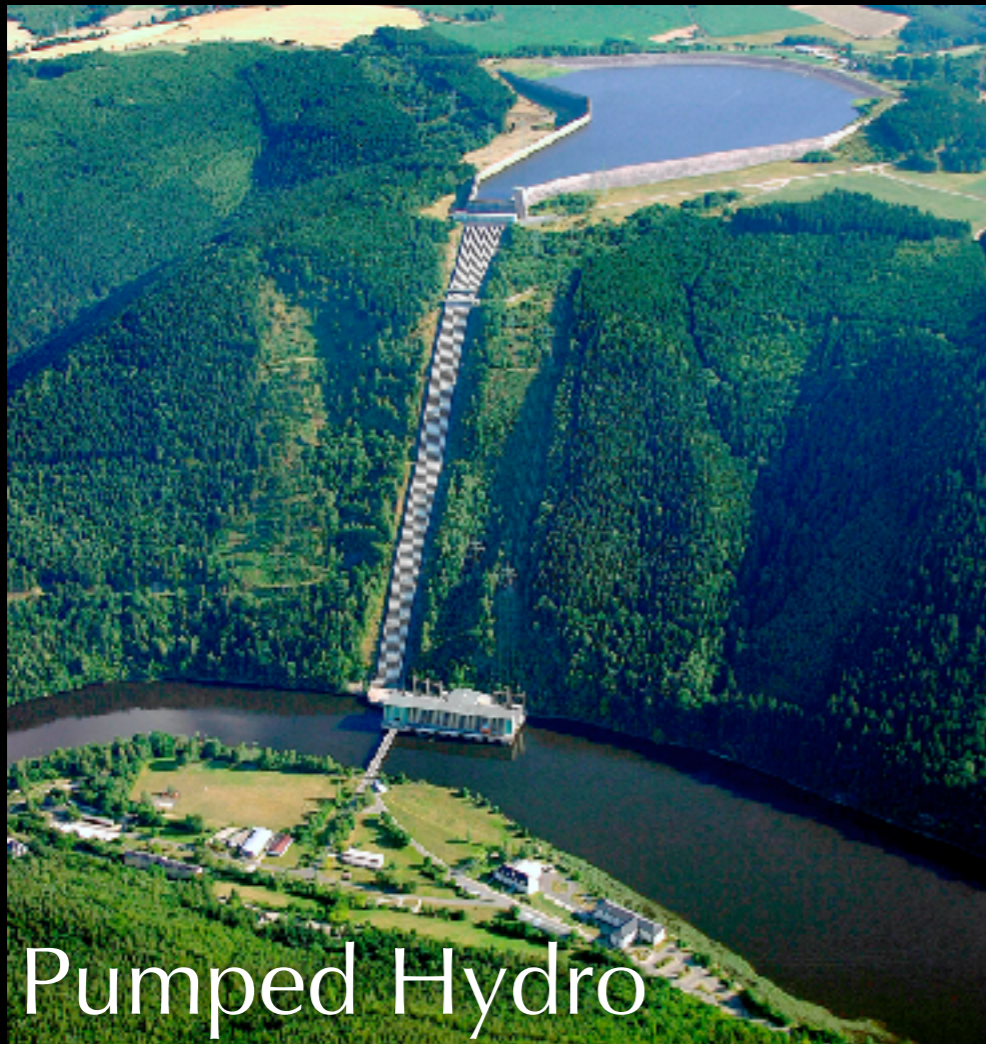
# Geographic connectivity

Distributed generation

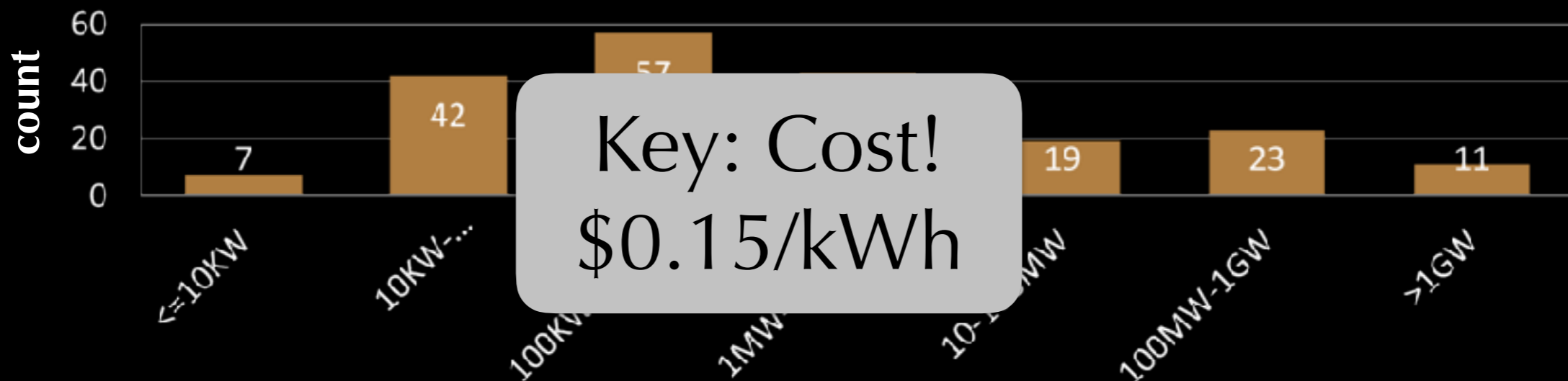
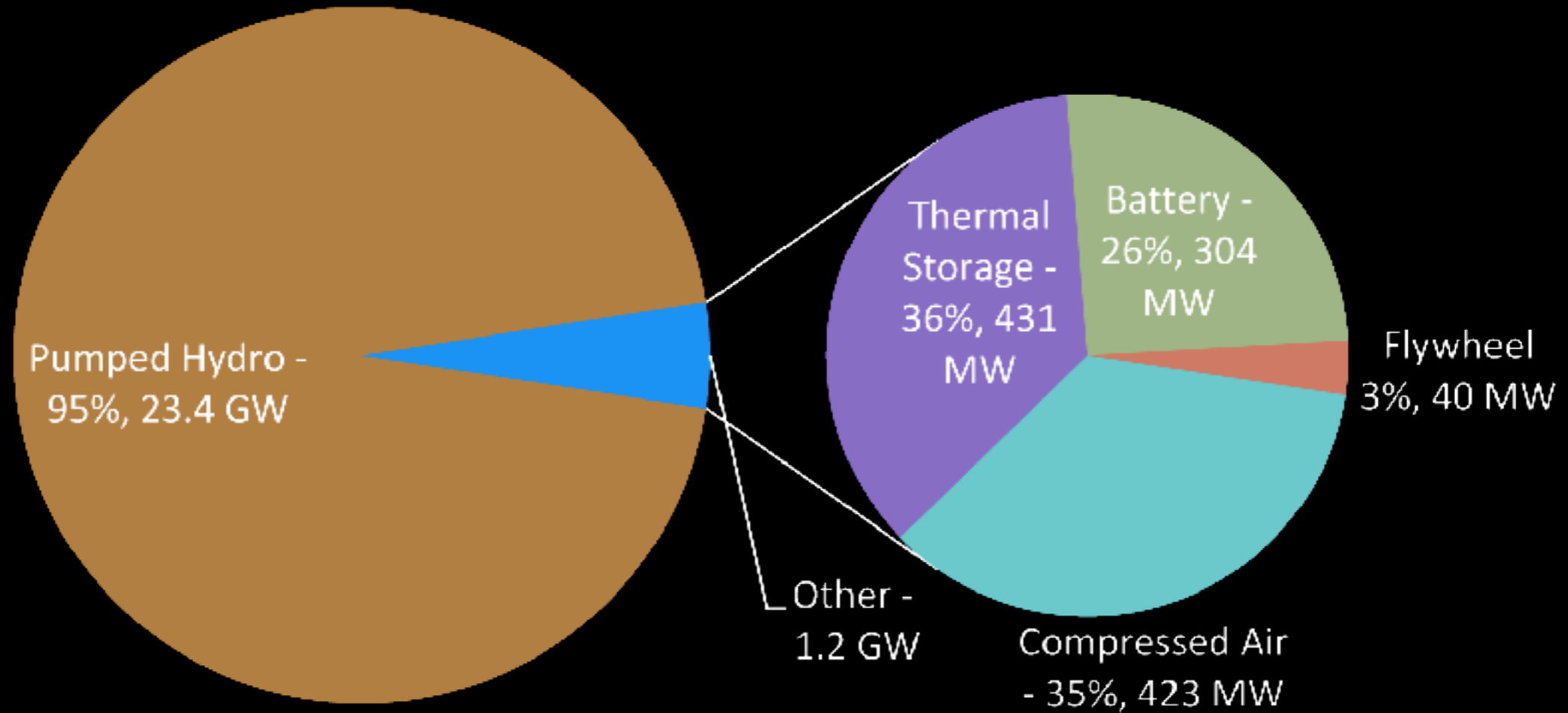
Increased transmission



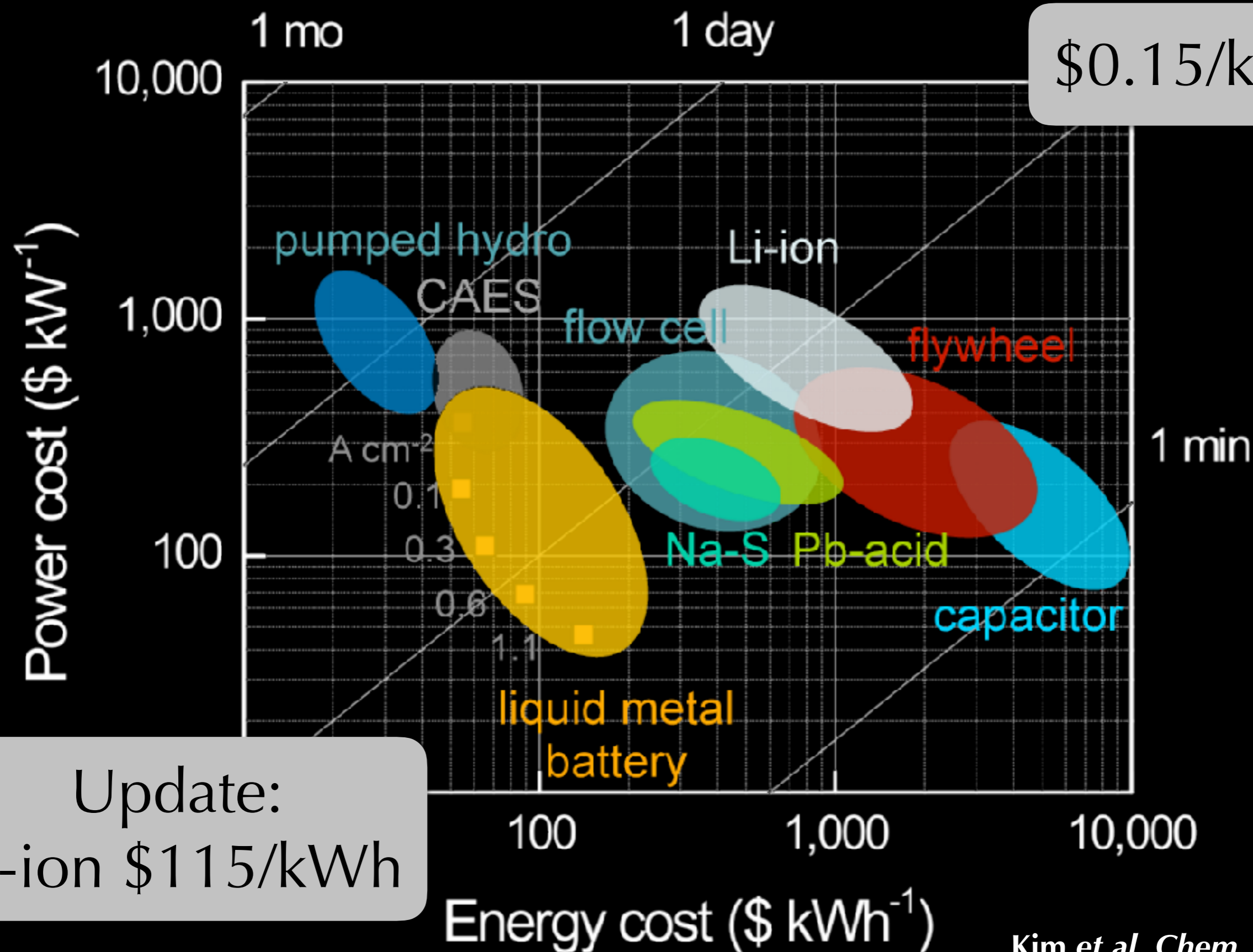
# Time connectivity: Storage



# Grid-scale storage deployed in US



# Grid-scale storage cost





- Manufacturers, academic institutions, utilities, startups, engineers, investors, government.
- **VISION:** Sustainable energy use requires transformative energy storage solutions. NY-BEST will lead the development and deployment of these solutions by linking energy markets with our world-class industries and research institutions.
- **MISSION:** To catalyze and grow the energy storage industry and establish New York State as a global leader.

# Solutions

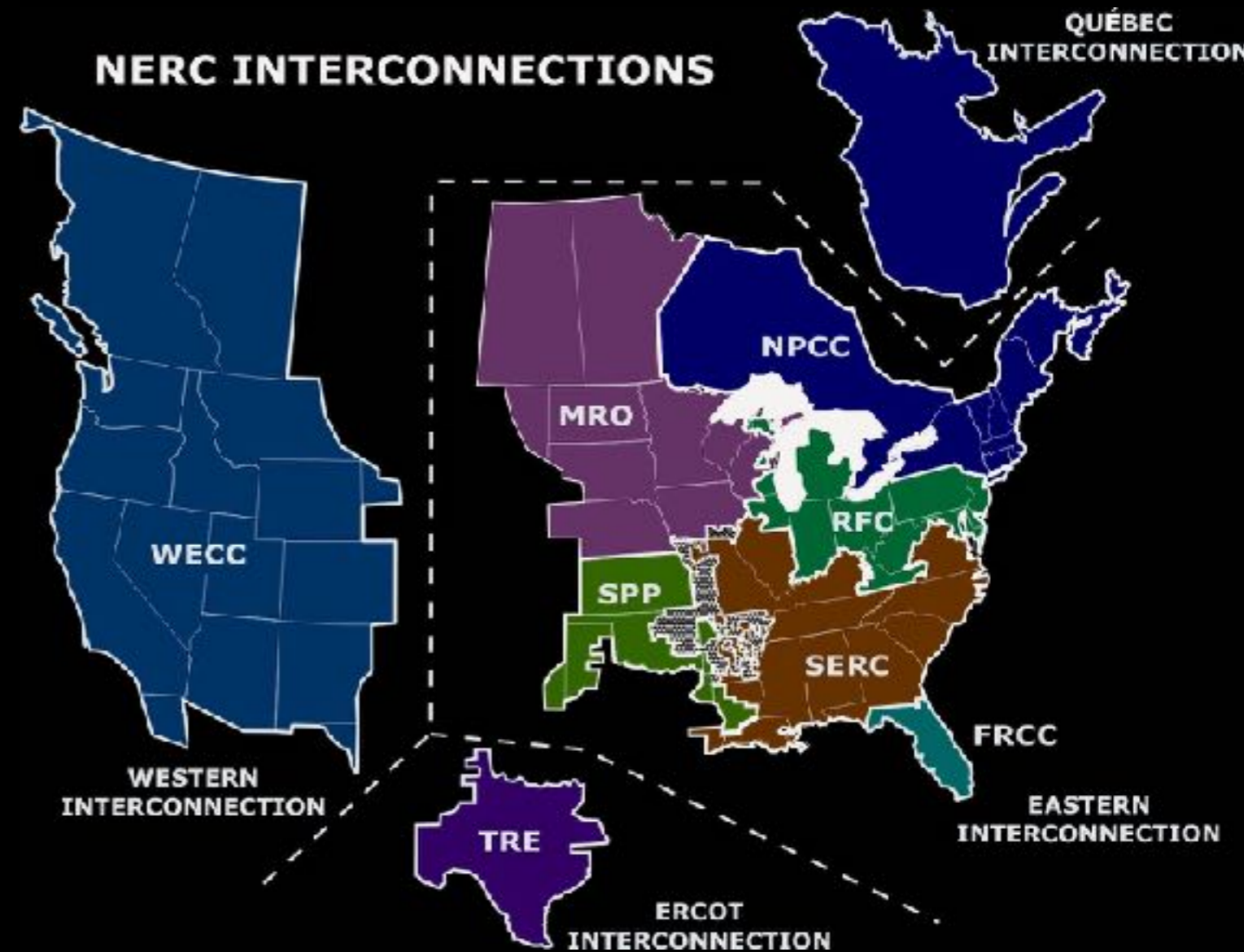
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- Increased efficiency.
- Grid-scale storage and connectivity.
- Regulatory structure that makes renewables and storage profitable.



# Regulatory Complexity

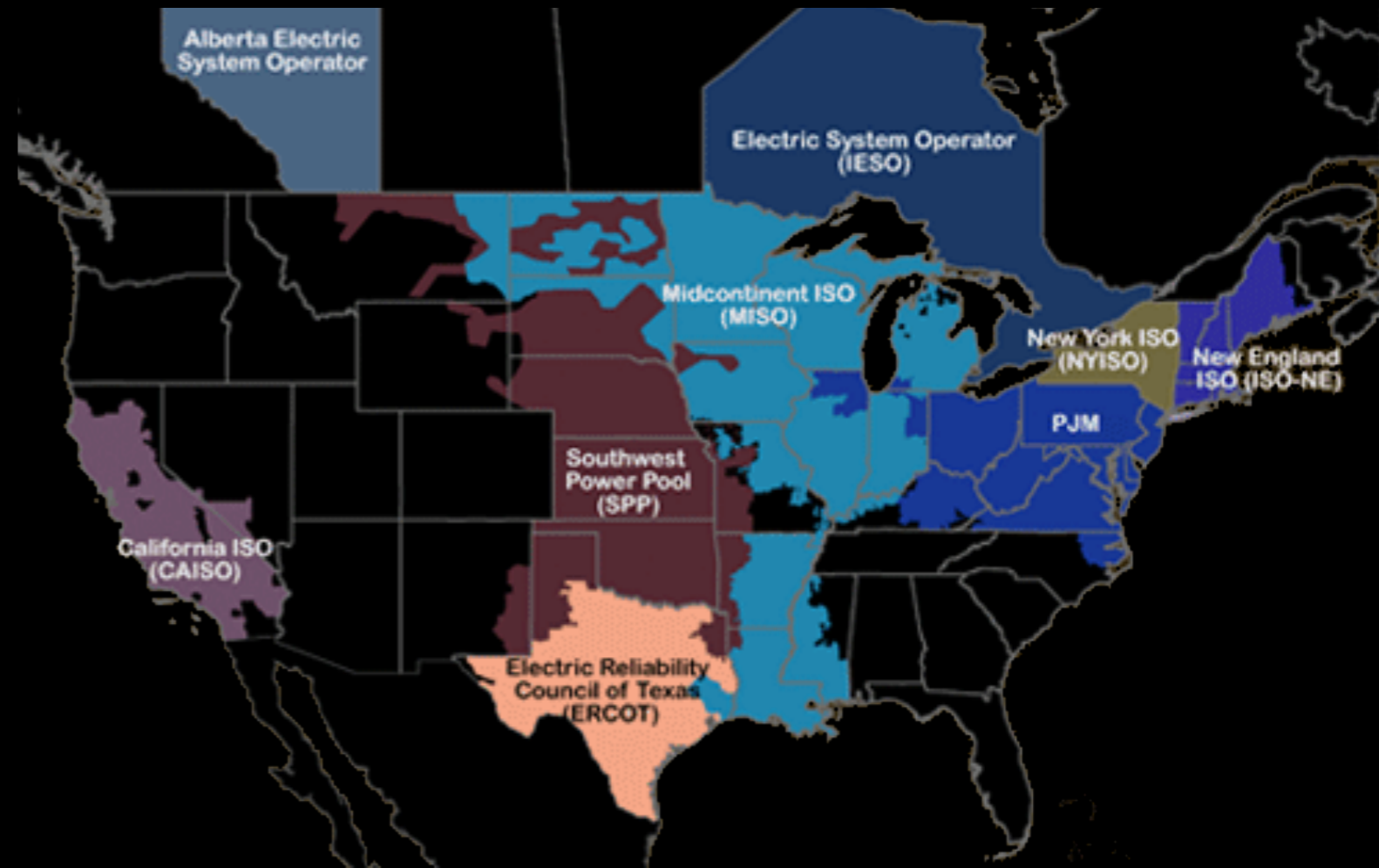
- North American Electric Reliability Corporation (NERC)
- Mission: assure reliability. 8 regions.





# Regulatory Complexity

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- Regional Transmission Organizations (RTOs) & Independent System Operators (ISOs)
  - Mission: provide producers access to transmission



# Regulatory Complexity

- North American Electric Reliability Corporation (NERC)
  - Mission: assure reliability. 8 regions.
- Regional Transmission Organizations (RTOs) & Independent System Operators (ISOs)
  - Mission: provide producers access to transmission
- Rural co-ops, investor-owned entities, publicly-owned utilities, federally-owned utilities
- Generators
- Wholesale brokers
- More.

# REV: Reforming the Energy Vision

- NY State initiative
- Pricing motives for utilities to innovate
- Permitting and approval
- Efficiency: BuildSmart NY, Energy Efficiency Measures in Affordable Housing, Combined Heat and Power
- Renewables and storage: NY Green Bank, REV Campus Challenge, K-Solar, NY-BEST



- NYS Energy Research & Development Authority
- Funded directly from utility bills (not State Assembly)
- Mission: Advance innovative energy solutions in ways that improve New York's economy and environment.
- Program portfolios: efficiency, business development, workforce development, environment, planning & policy
- \$22M for storage in 2016

# Summary & Outlook

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- Electrical grid: giant machine with almost zero storage.
- Disconnected by geography.  
Disconnected by time.
- Solutions:
  - Increased efficiency.
  - Grid-scale storage and connectivity
  - Regulatory structure that makes renewables and storage profitable.



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