A Primer on Transmission:
Basics and More

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NARUC Electricity Committee
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Power System Overview and Transmission

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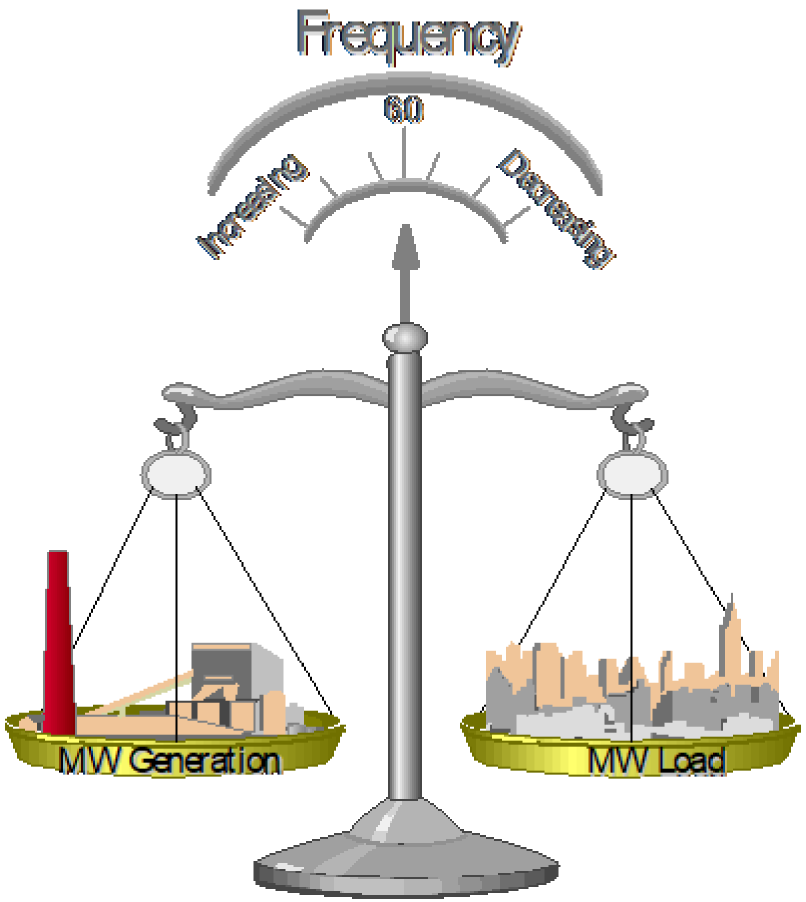
Power System Overview

Electricity works by moving electrical energy from the generator to the load according to the laws of physics (Ohm, Kirchoff, etc)

Power System Overview



Electricity has to be supplied to all loads

- When needed
- In exact amounts

With a few exceptions, the bulk power system was not designed to store electricity

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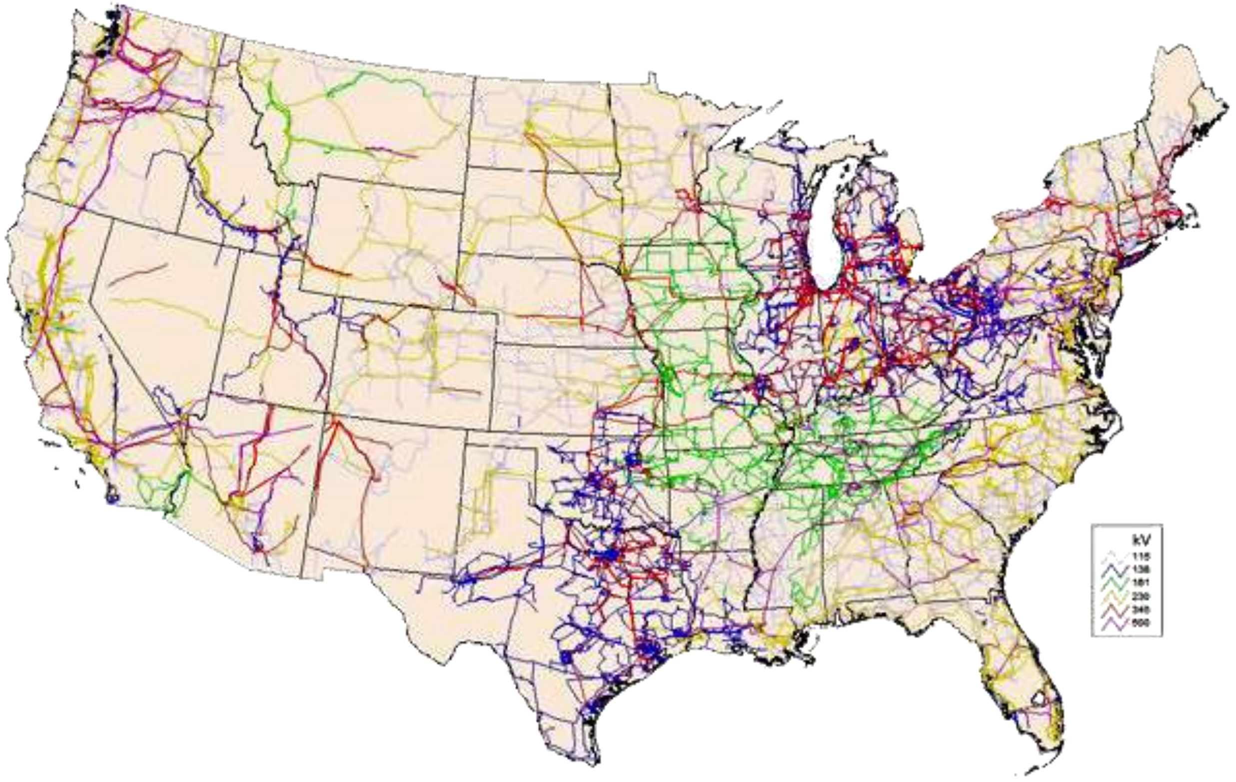
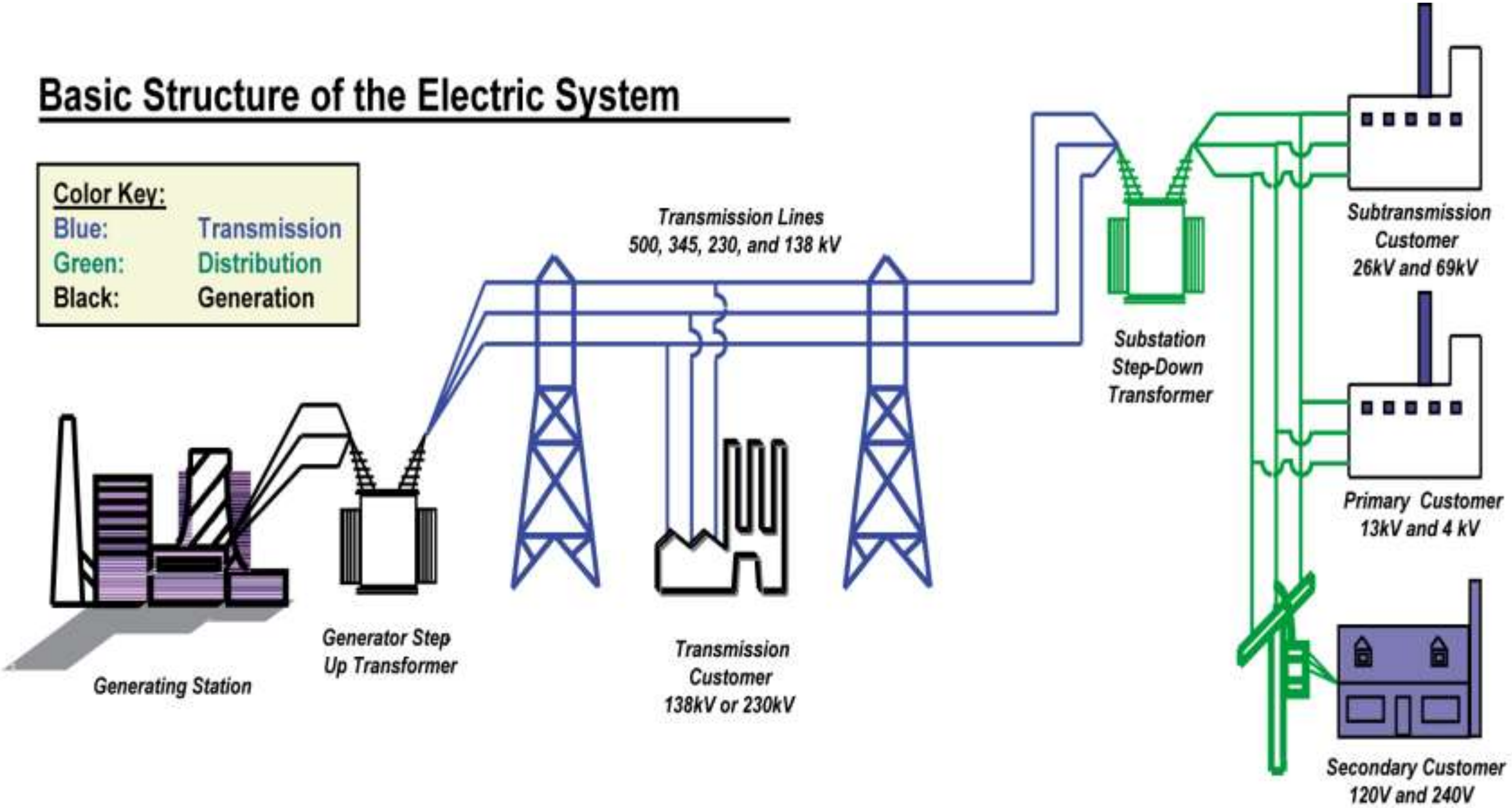
Power System Overview

- Transfer of electric power from point A to point B can be thousands of miles
- All generators and motors in an “Interconnection” have synchronized operation, e.g., 60Hz
- A problem in New York can be felt in in Louisiana



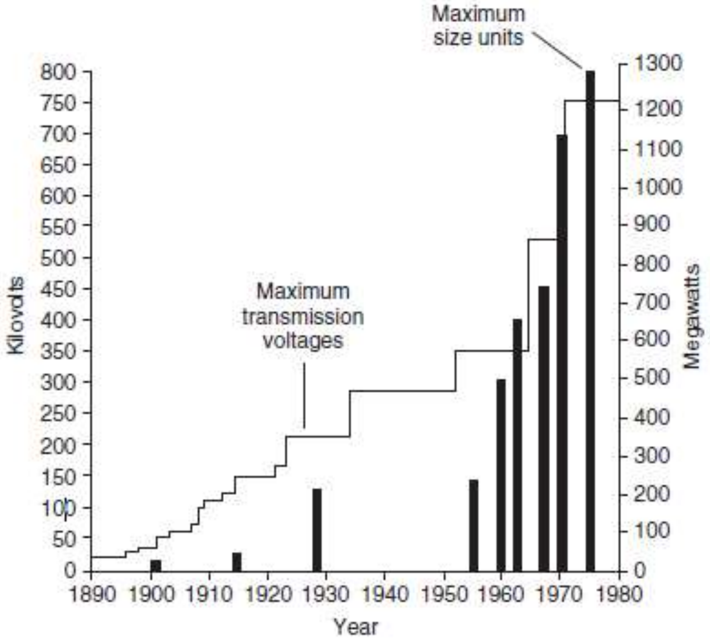
A Complex Man-Made Machine

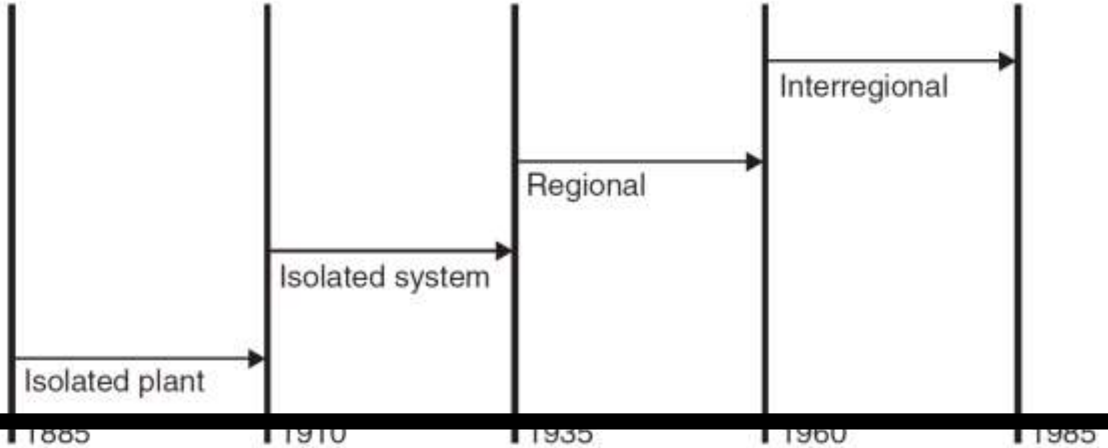
Power System Overview



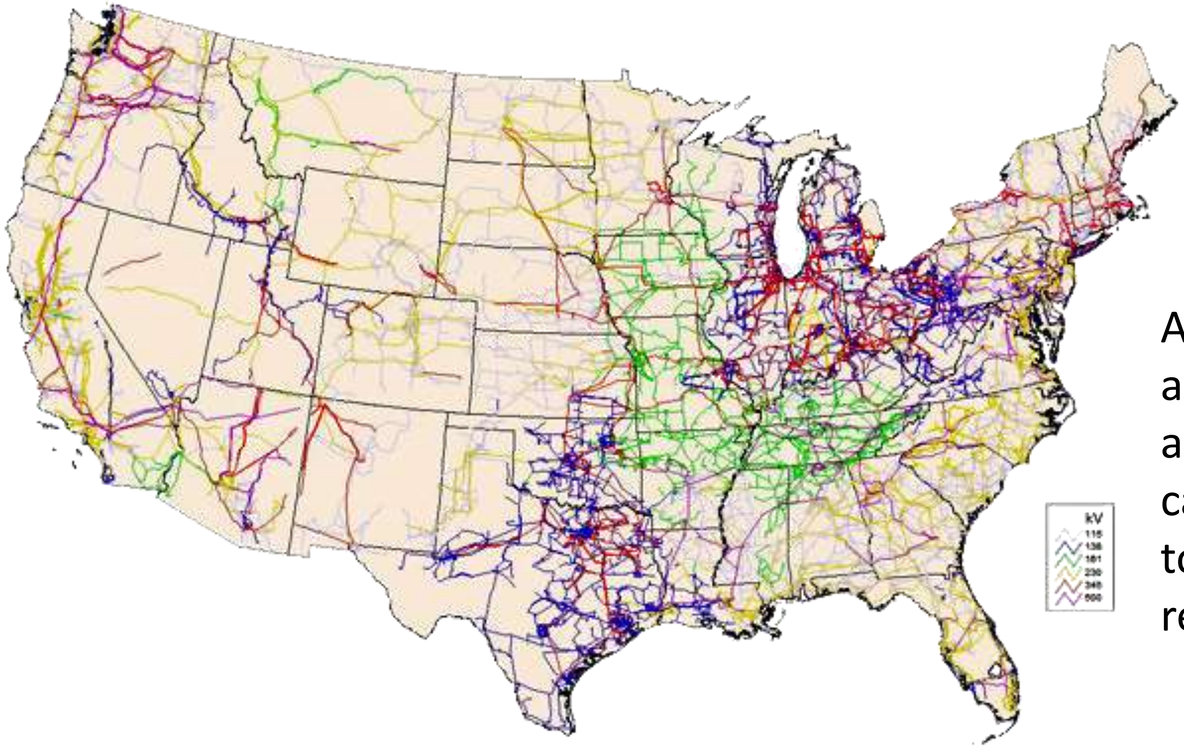
System Evolution and Growth

- During the 70 year period to 1970, power consumption doubled every 10 years (~7% per year)
- Growth dropped to almost 0 in 1970s due to energy crisis
- Today, it expected that growth will be 1% per year to 2030, absent potential impacts due to electrification which could be very significant





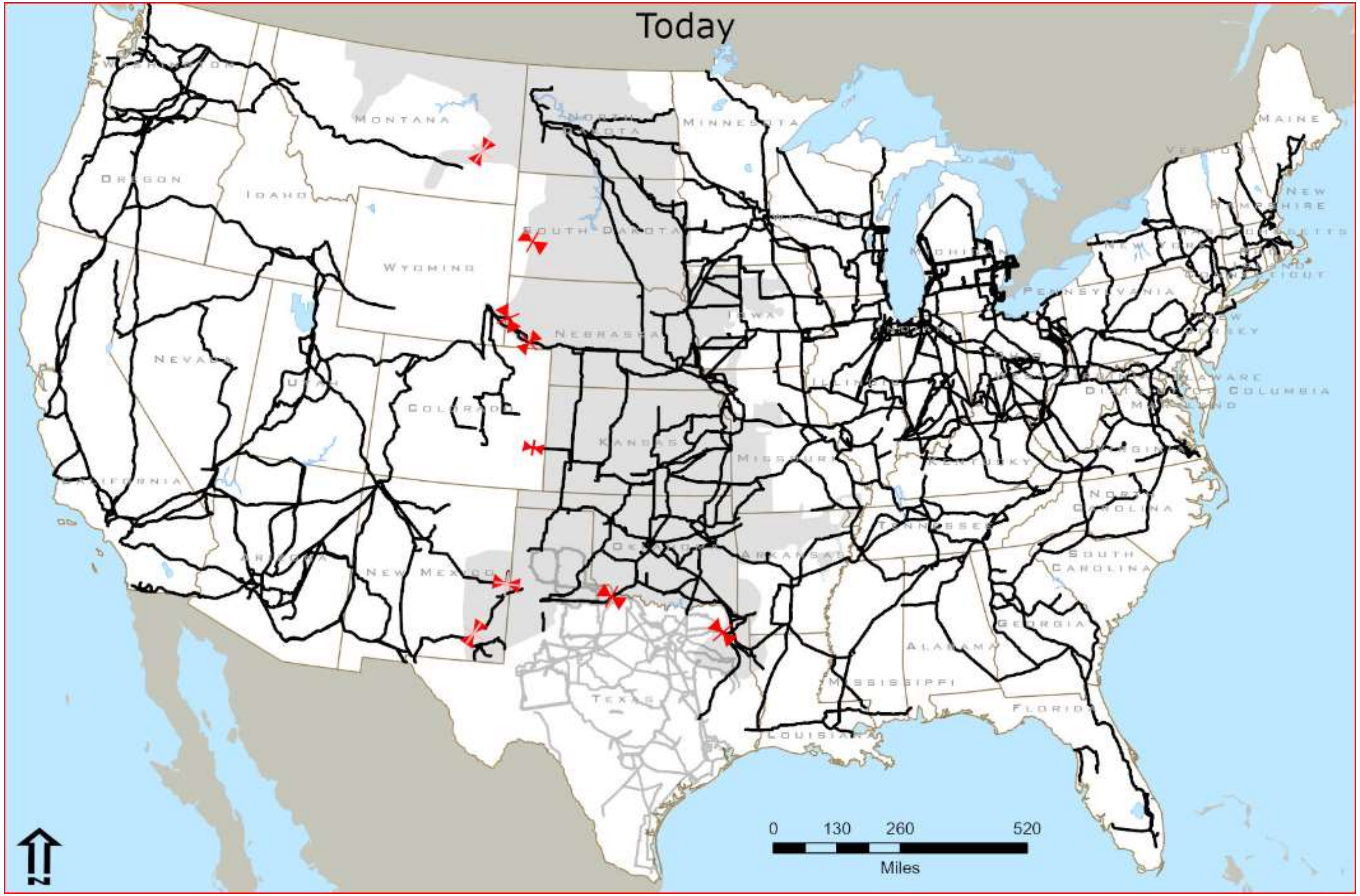
The Transmission System



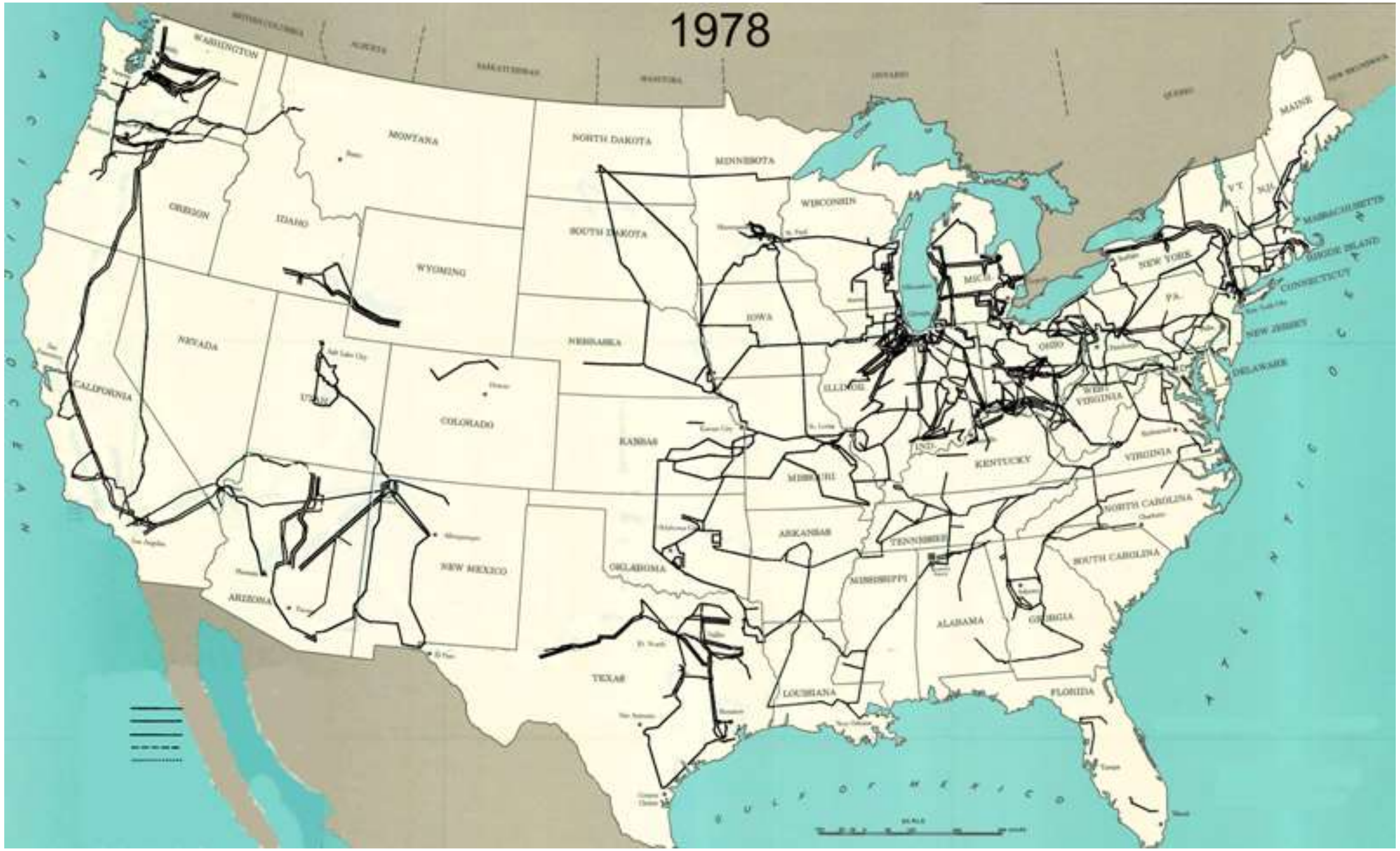
AC Transmission networks are normally meshed and, absent controls, operators cannot force electrical power to flow on a select path from resource to load.

AC Power Flows on the Path of Least Resistance

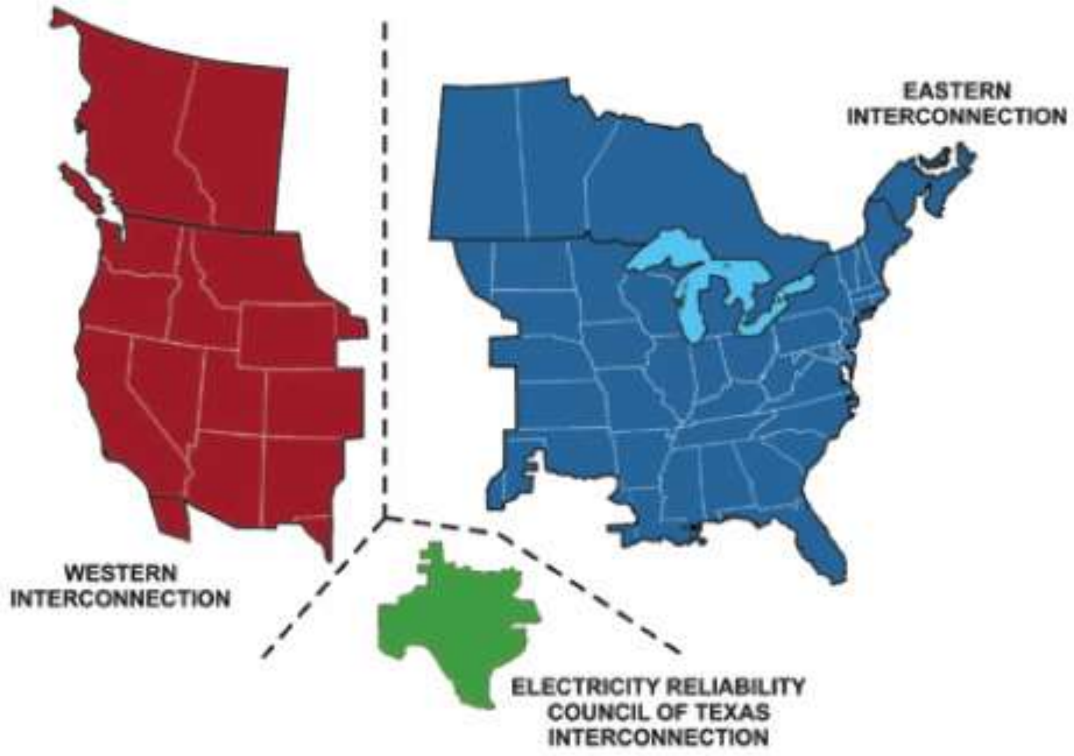
Current EHV (300kV+) Network



EHV (300kV+) Lines Approaching EOL



Major North American Interconnections



Most Canadian Provinces Have Strong Connections with US States on their Southern Borders

Efforts to Create or Expand Regional Transmission Expansion at FERC

1993: Regional Transmission Group Policy Statement

1994: Transmission Pricing Policy Statement

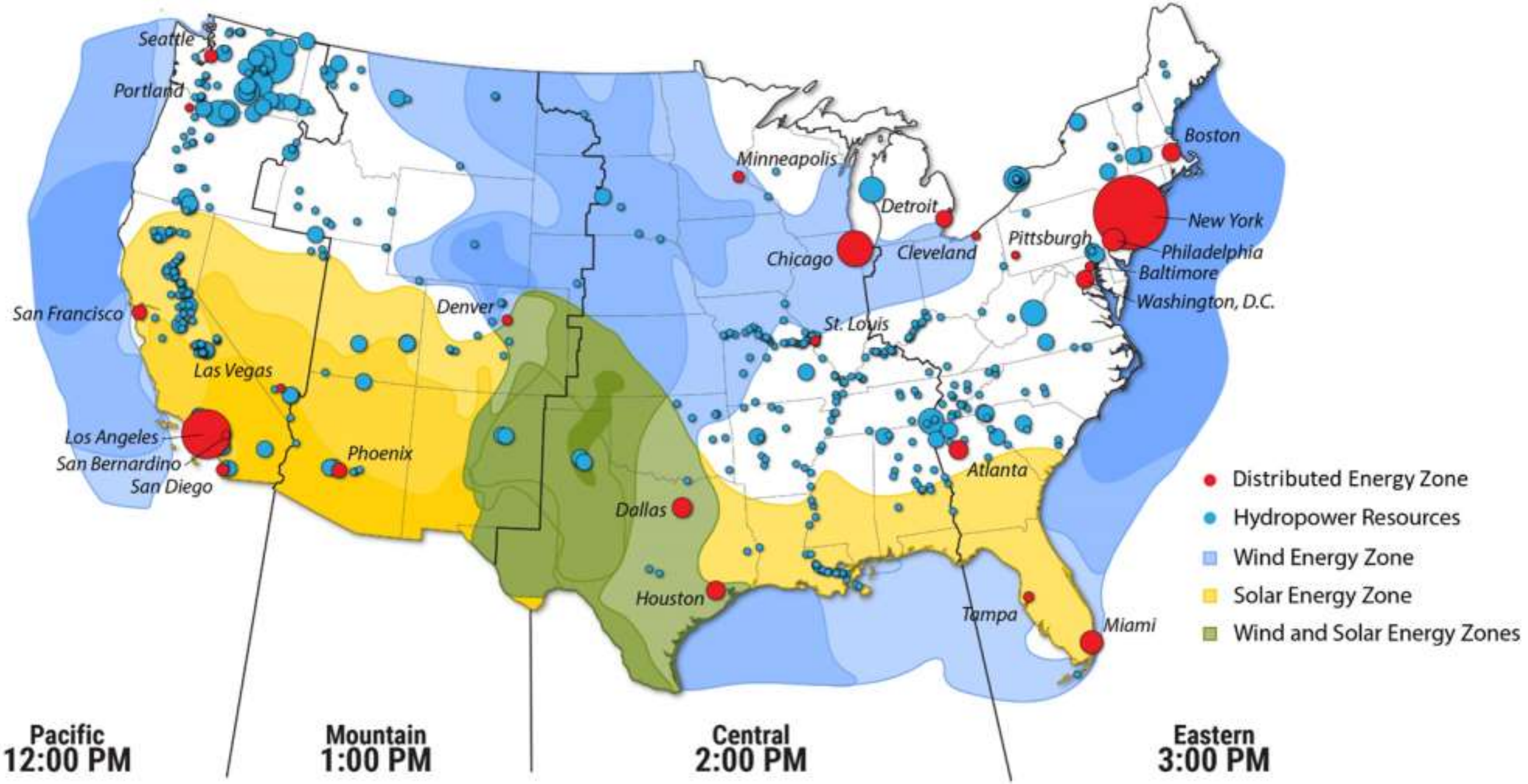
1996: Order 888—Independent System Operator Principles—conduct planning studies

1999: Order 2000—encourage Regional Transmission Organizations with regional planning function

2007: Order 890—minimum planning guidelines for all public utilities

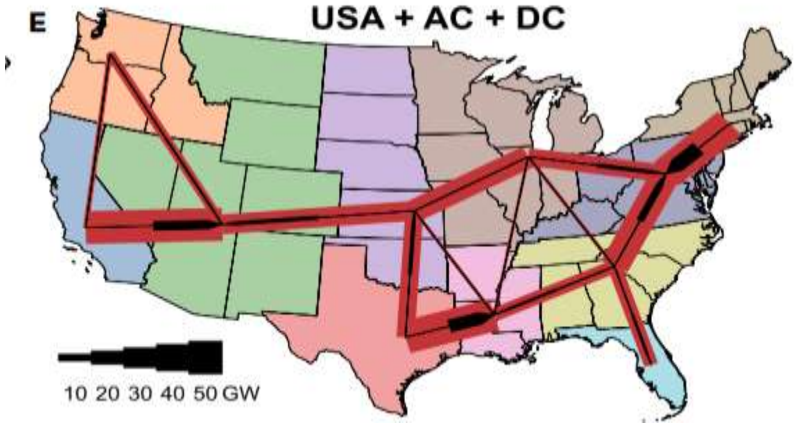
2011: Order 1000—regional plans, regional cost allocation, eliminate Right of First Refusal (ROFR)

Renewable Energy Zones

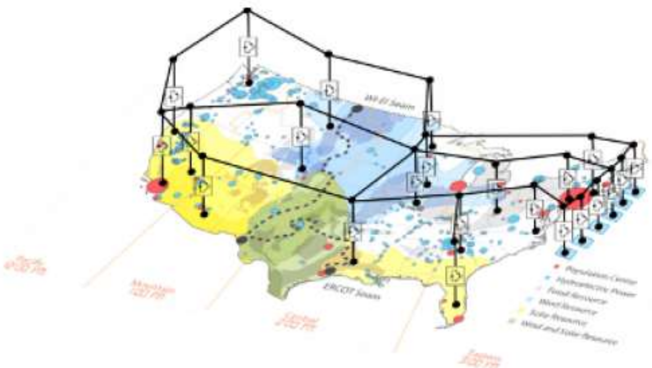


Ultimate Need: Enable 10s of GWs of power transfer

Back and forth across and between regions
2-3x increase in national transmission capacity



https://www.cell.com/joule/fulltext/S2542-4351(20)30557-2



https://cleanenergygrid.org/wp-content/uploads/2020/11/Macro-Grids-in-the-Mainstream-1.pdf

Modeled flows NREL Seam study

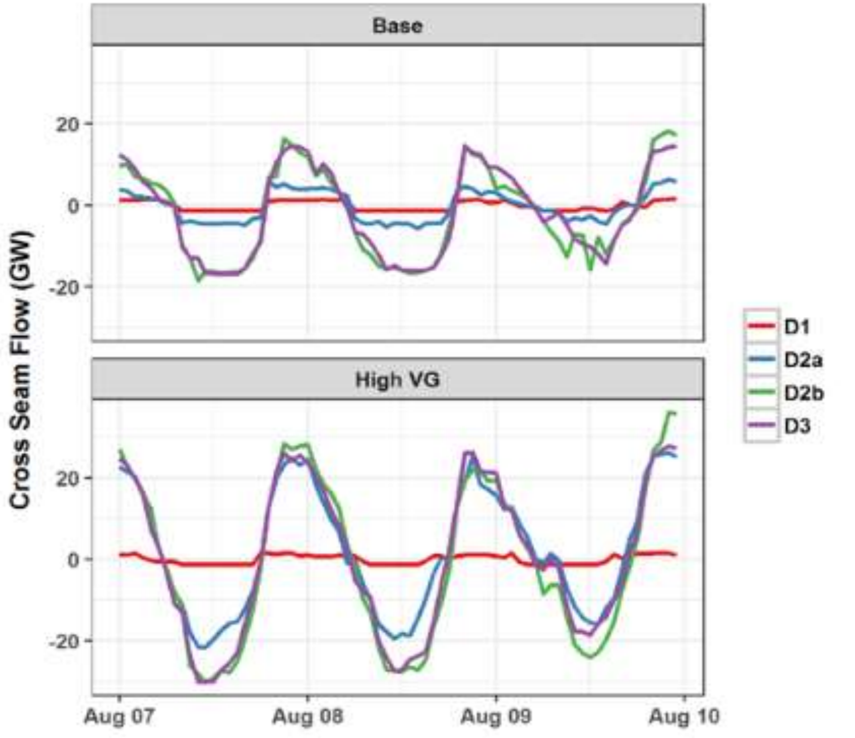
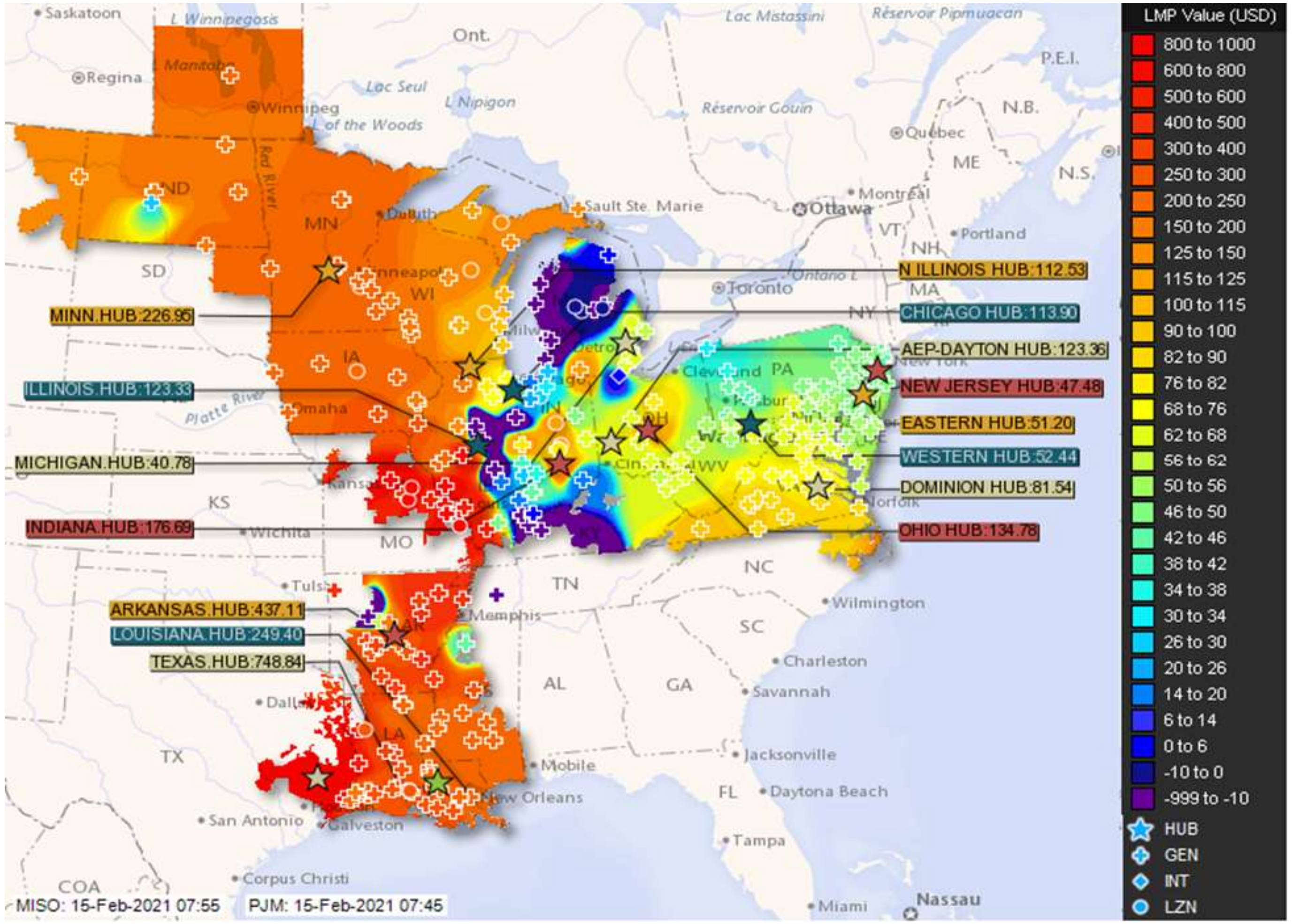


Fig. 3. Cross-seam transmission power flow (B2B and HVDC) during the coincident peak load period. A positive flow is a net export from the EI to the WI; a negative flow is a net import into the EI from the WI. Times are Eastern Standard Time.

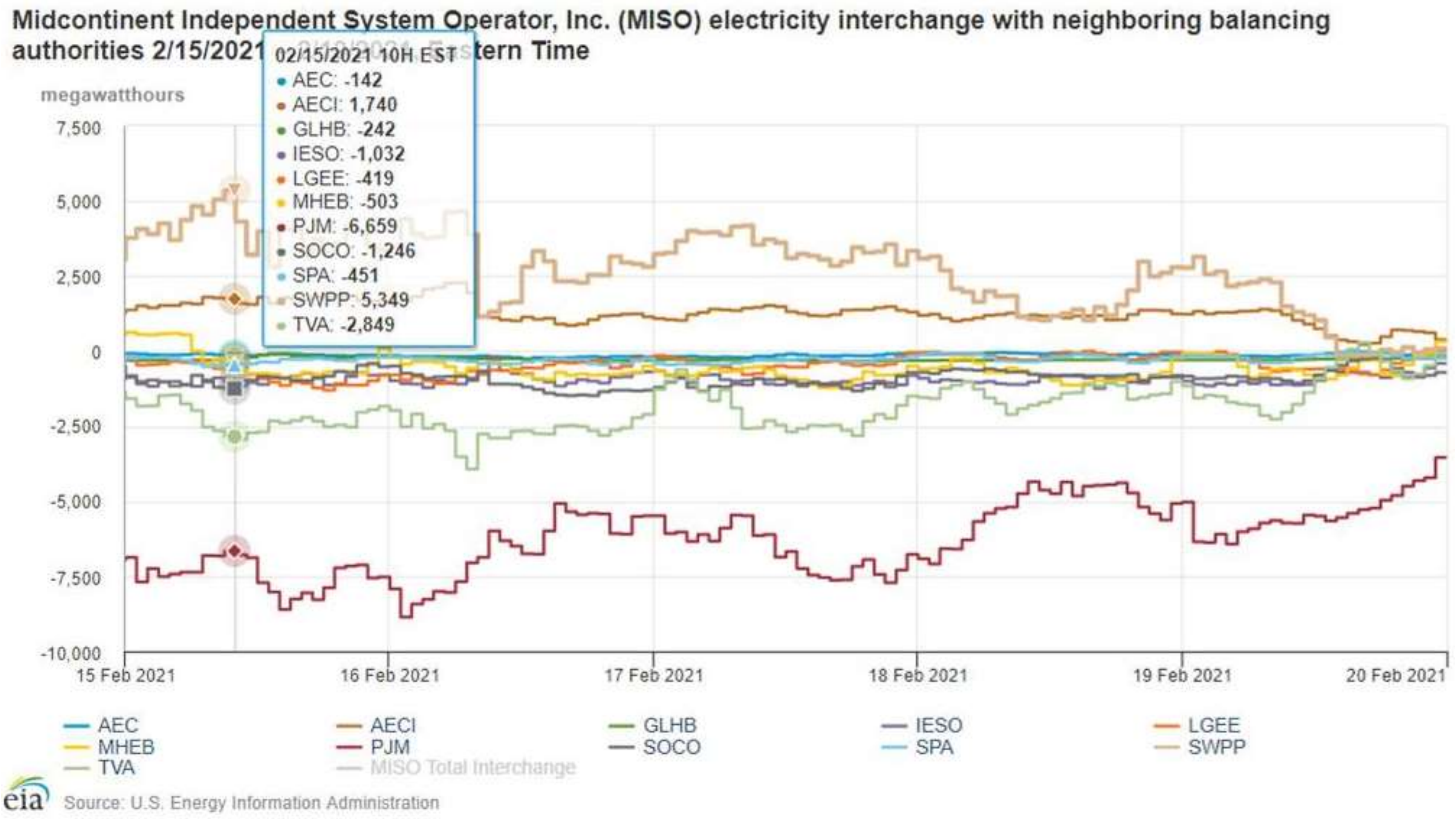
Interregional Transmission Kept the Lights On

in Winter Storm Uri Feb 2021

MISO imported 13 GW, ERCOT only 0.8 GW



Power flowed from PJM to MISO to SPP



Let's build the grid of the future, but first we must get the most out of the existing and approved grid

with Grid-Enhancing Technologies (GETs)
See www.watt-transmission.org

- GET some Dynamic Line Ratings, topology optimization, storage-as-transmission, advanced power flow controllers
- GETs are VERY low cost, $0.5m - $25m
- GETs are deployable in MONTHS
- GETs are scalable
- GETs are modular
- GETs are mobile and re-deployable

The Basics of Transmission Planning in a Rapidly Changing World

Steve Gaw, Advanced Power Alliance

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“The future depends on what you do in the present” (Mahatma Gandhi)

Why are we planning?

- Eisenhower: “I tell this story to illustrate the truth of the statement I heard long ago in the Army: **“Plans are worthless, but planning is everything.”**
- Churchill: “…**the best generals are those who arrive at the results of planning without being tied to plans.”**

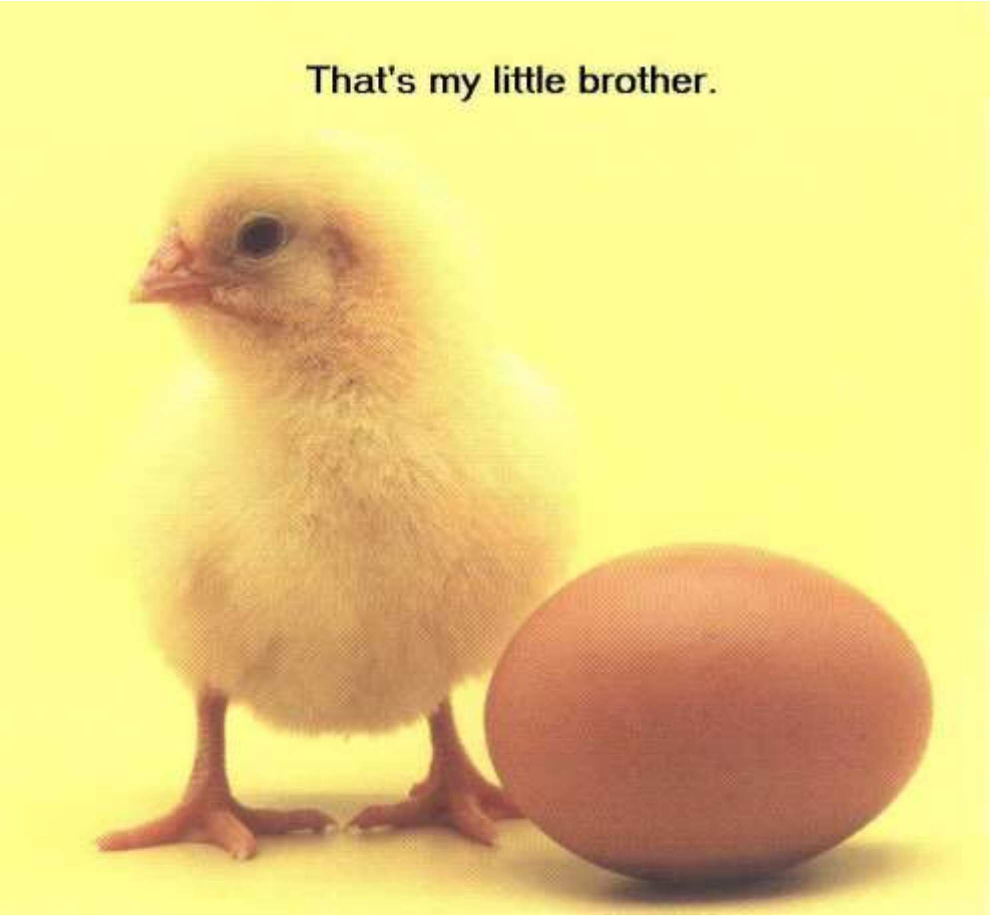
Need for Transmission Planning

- **Transmission:** takes a long time to construct
- **Waiting:** costs money and risks reliability
- **Generation:** additions and retirements are occurring at an increasing rate
- **Public Policy:** requirements have increased the need for transmission
- Planning produces a design that takes into account a multitude of needs rather than just one. The result should be a better and more cost-effective transmission system

Time

- It takes time to plan and construct a transmission upgrade
  - Planning
  - Authorization (RTO)
  - Siting
  - Right of Way
  - Actual Construction
  - Unknowns

Planning for now or tomorrow



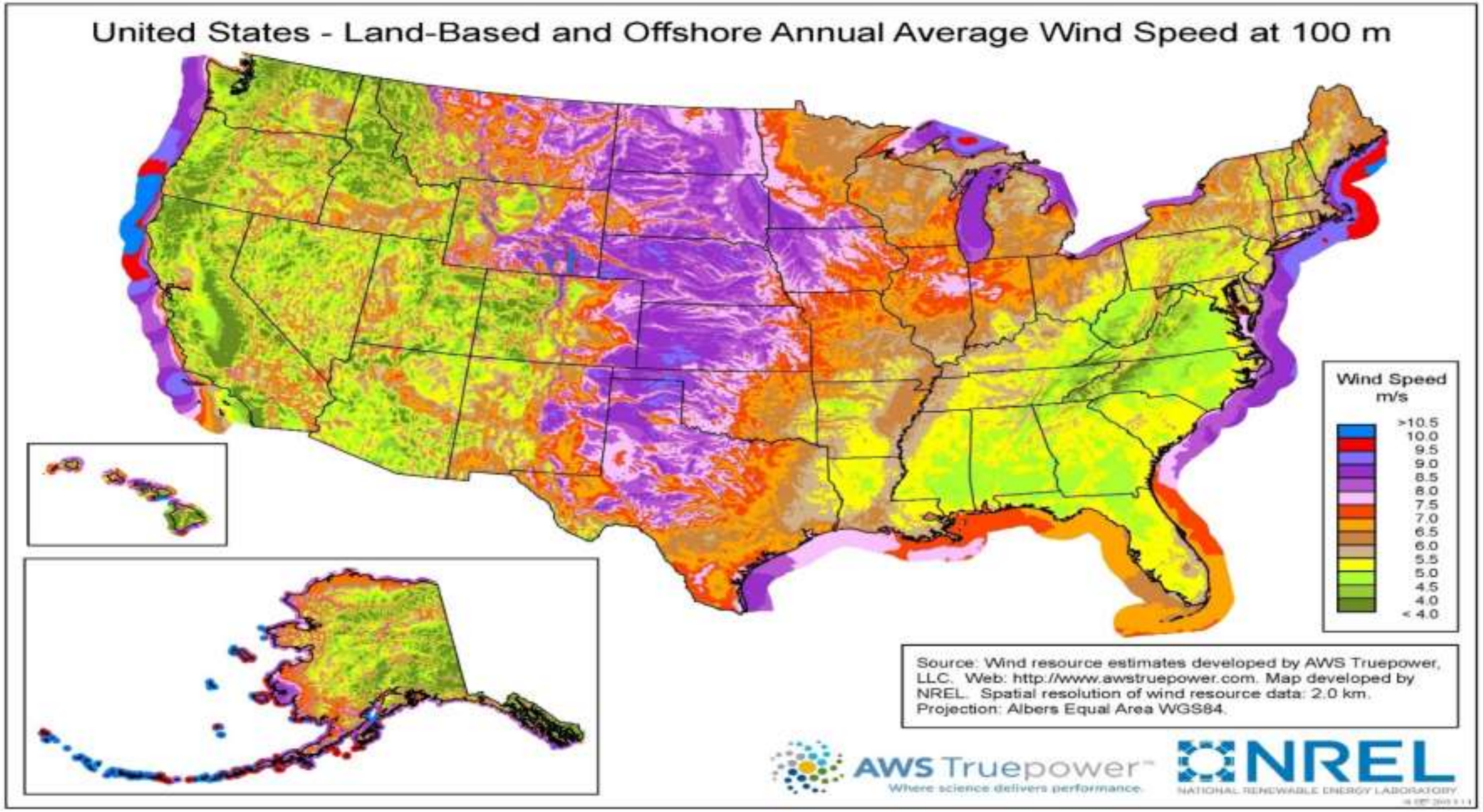
Planning

- *Gretzky: "I skate to where the puck is going to be, not where it has been."*
  - *Lead the receiver and the clay pigeon.*
- *Set of needs*
- *Flexibility*
- *Cost-effective plan*

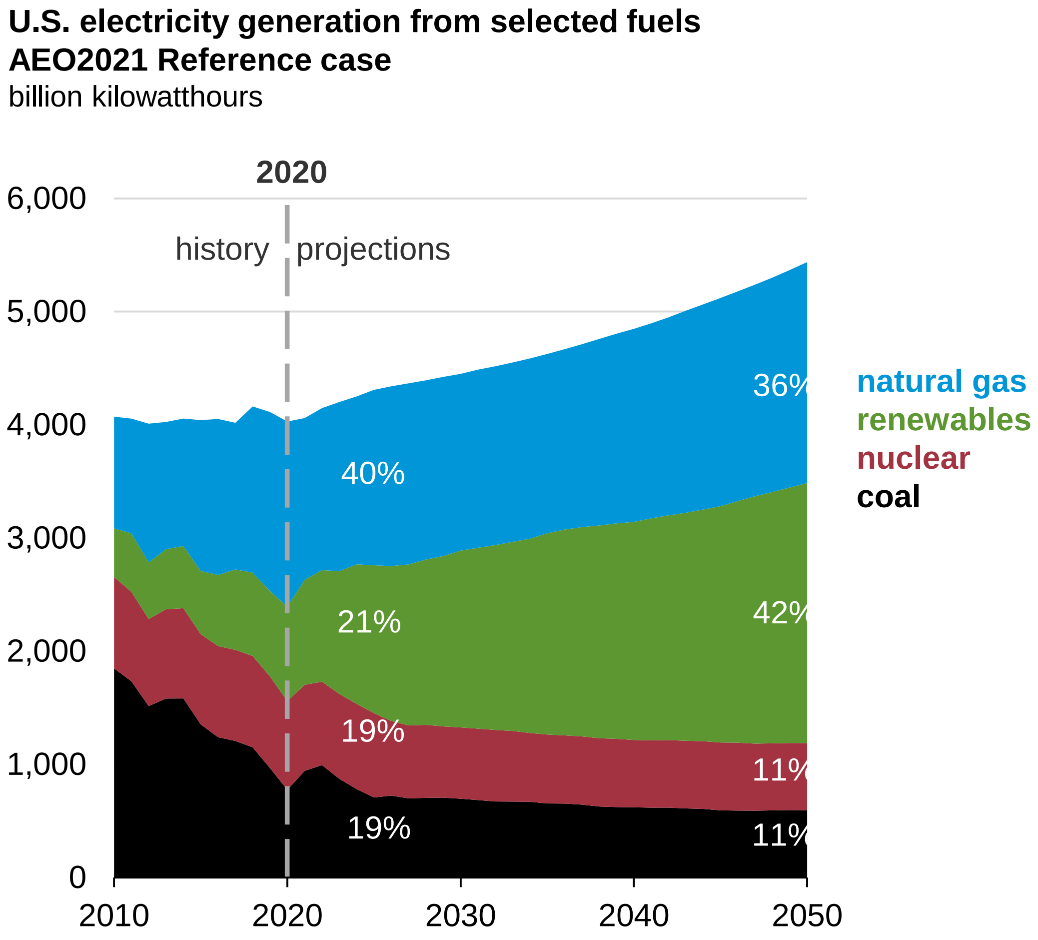
What is Transmission Planning?

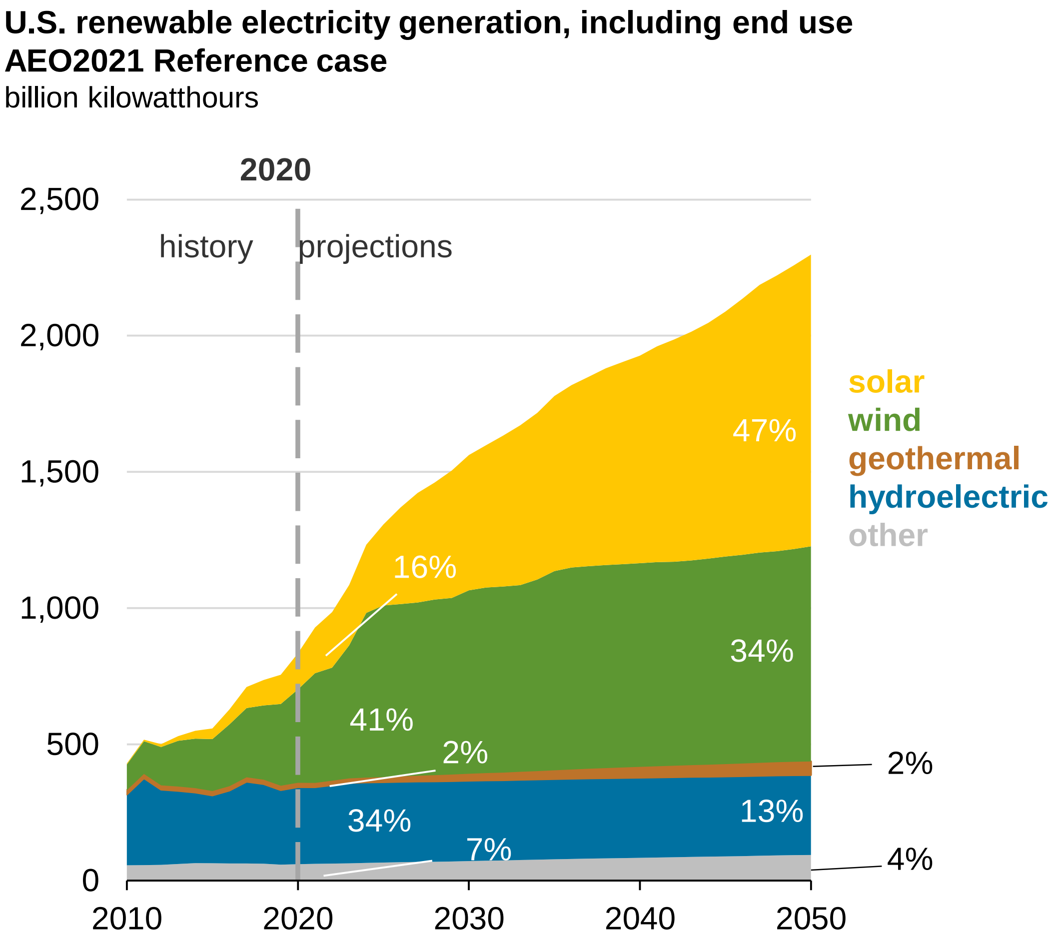
- Identifying the needs for transmission
  - What is a need?
  - When is it needed?
  - Where is it needed?
  - How certain is the need?
  - How do you evaluate the need?
  - How do you determine solutions?

Renewable Potential

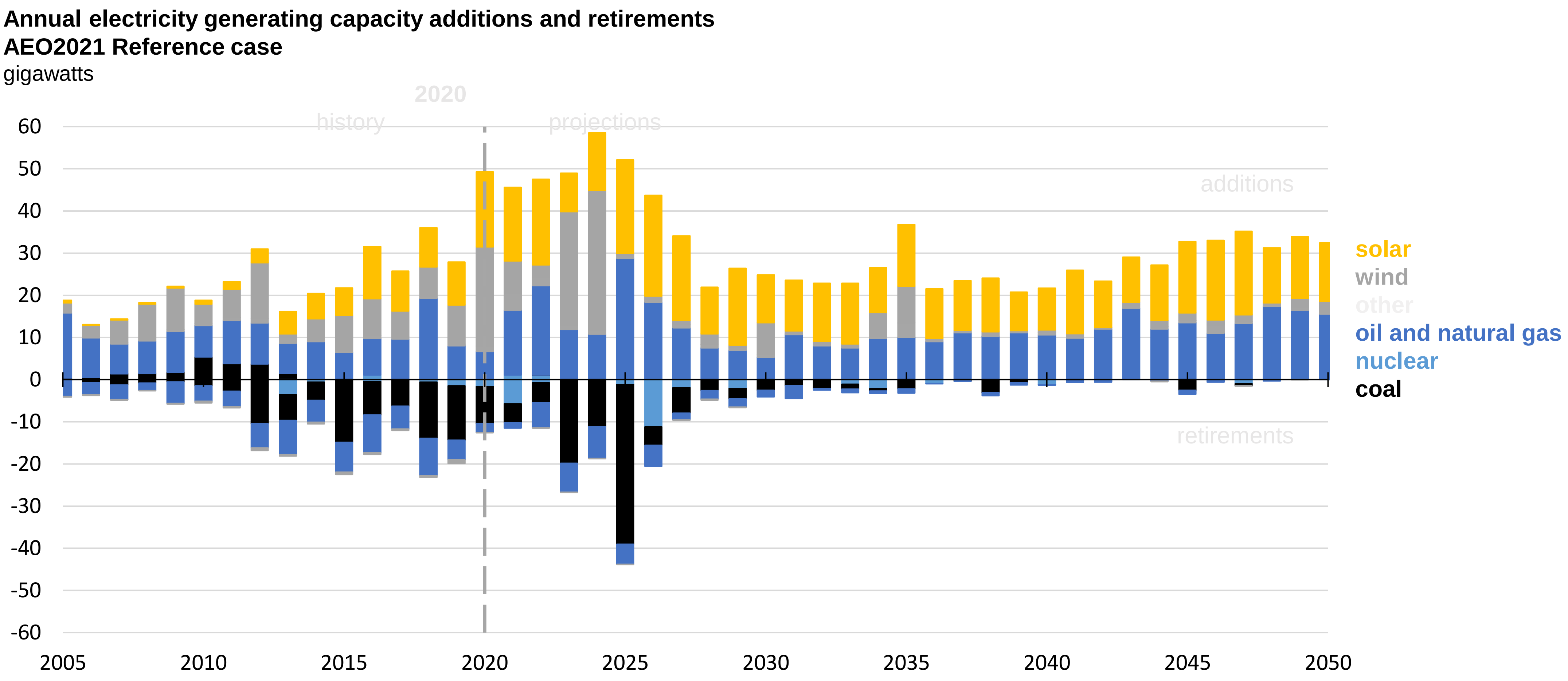


U.S. electricity generation and share from selected fuels and renewable sources



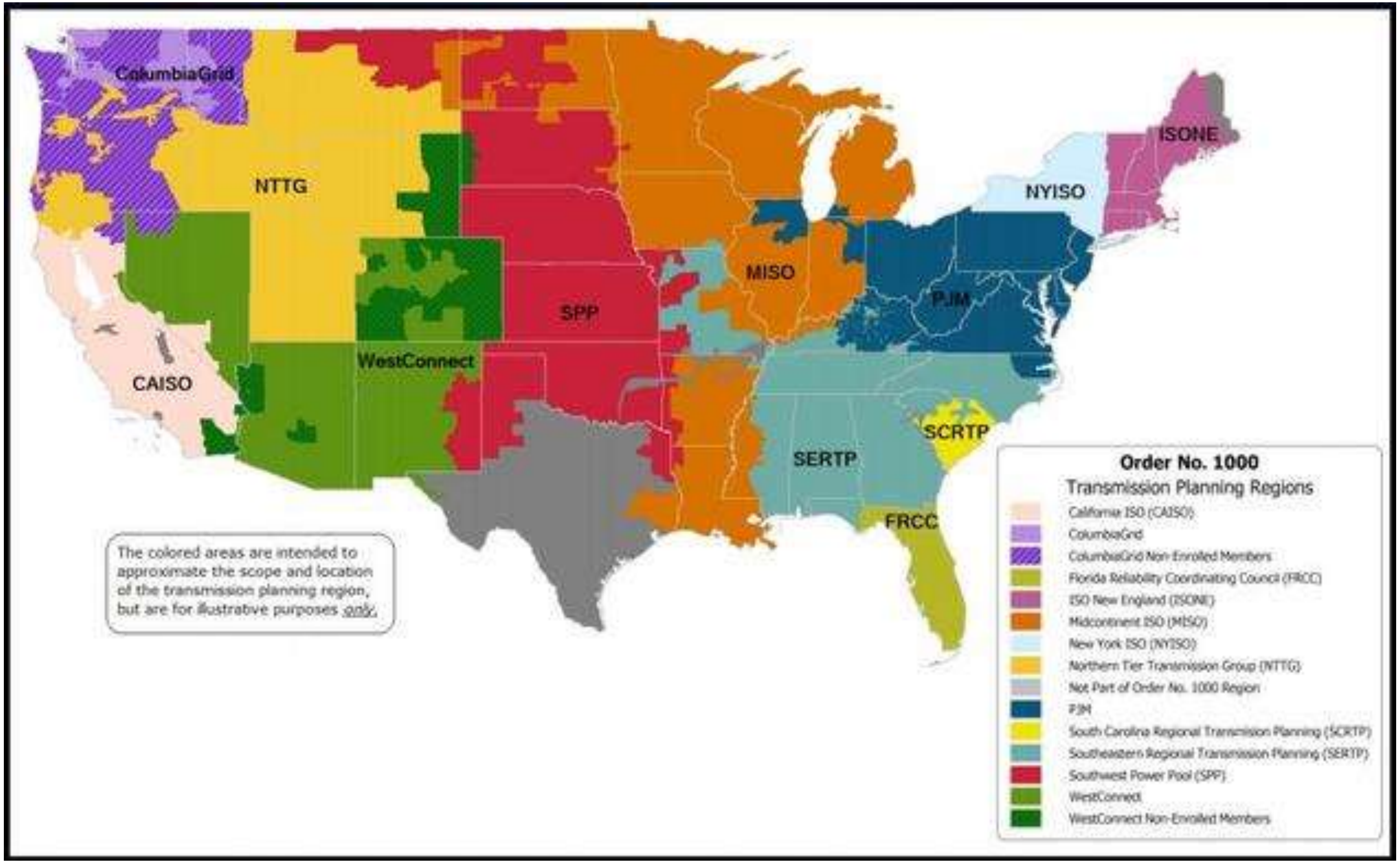


U.S. retiring and new generating capacity



Source: Form EIA-860M, *Monthly Update to the Annual Electric Generator Report*, July 2020

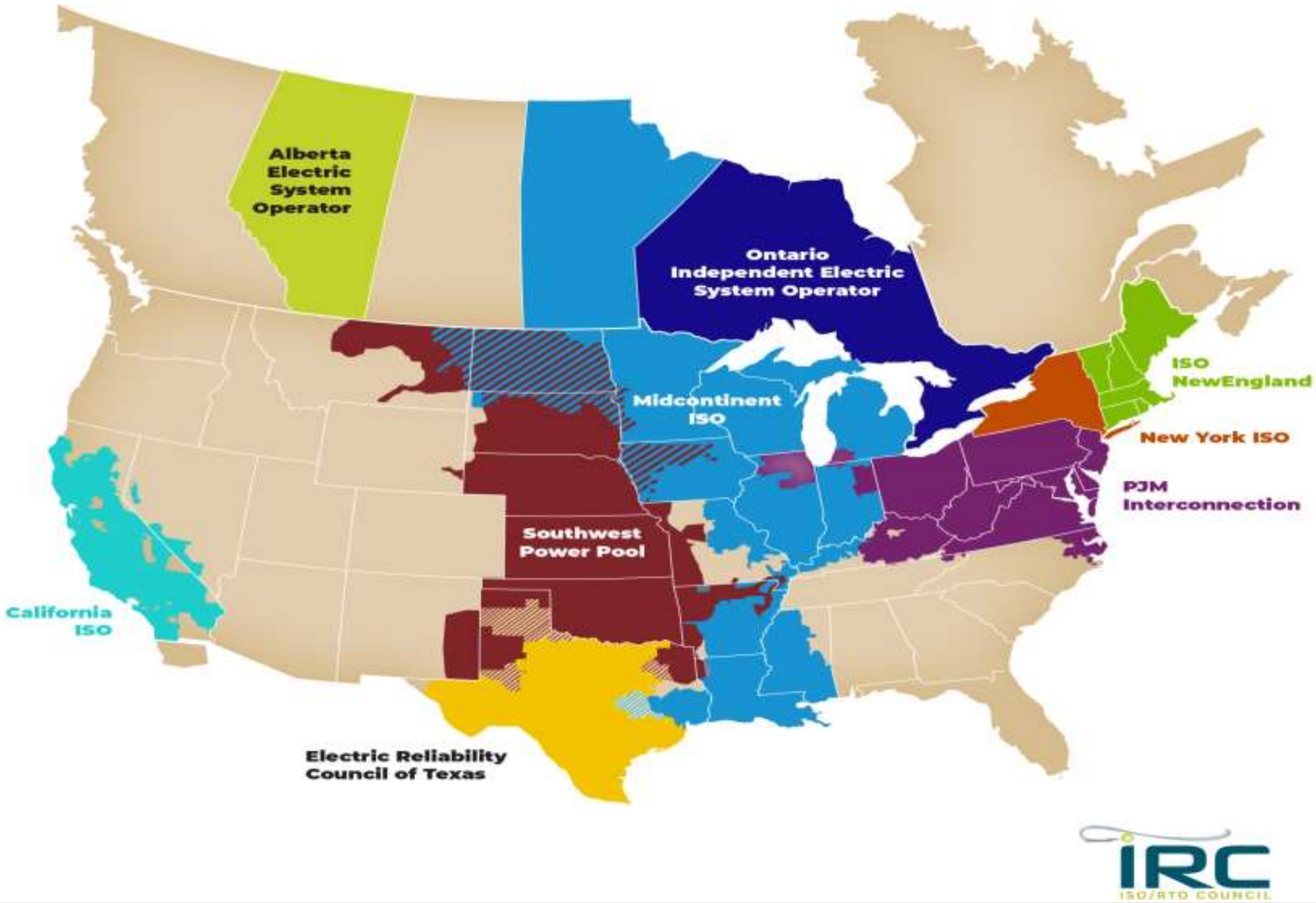
Planning Regions



Non-RTO Planning

- Non-RTO or non-market based region:
  - Delivery of generation to load
  - Reliability based
  - Present and Future Needs: IRPs are relevant
  - Local Planning based
  - Planning region assessment

RTO Map


Alberta Electric System Operator
Ontario Independent Electric System Operator
Midcontinent ISO
ISO NewEngland
New York ISO
PJM Interconnection
Southwest Power Pool
California ISO
Electric Reliability Council of Texas
IRC
ISO/RTO COUNCIL

RTO Planning

- RTOs: Market determines dispatched
- Transmission limitations are determined by a market dispatch
- Economics is critical to planning

RTOs Changed Transmission Planning

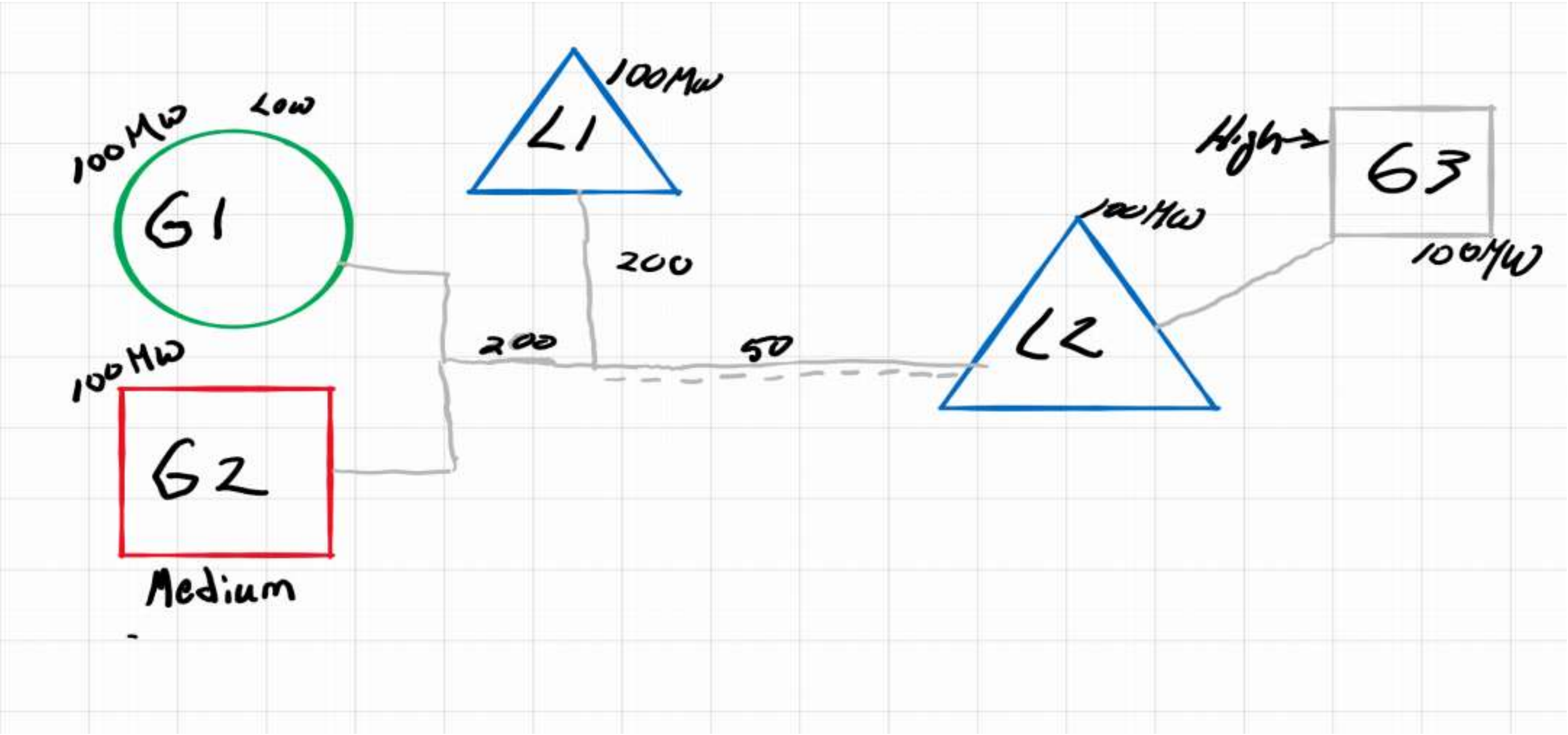
- Regionally focused
- Reliability
- Economic
- Public Policy

Economic

- Adjusted Production Cost Savings: Benefit of reducing congestion costs in order to make lower cost generation available to more of the region
- Measured against the cost of the investment

How much does it cost to get the cheaper price?

Accessing lower cost generation with transmission



Reliability Needs

- Reliability issues: addressed in the most economic fashion
- Evaluating reliability needs
  - Resource Adequacy and deliverability
  - Reliability of the system: when?

Public Policy Needs

- State Renewable Energy Standards or Goals
  - Transmission needs were identified to allow states having renewable energy policies to meet them in the most **cost-effective** way
  - Benefits of meeting the needs with transmission enhancements were assumed to be at least equal to the cost of the improvement
  - Assumptions were made on location of generation that placed some emphasis on the state with the public policy

Quantifying Benefits

- Reduction of Emission Rates and Values
- Savings Due to Lower Ancillary Service Needs and Production Costs
- Capacity Cost Savings Due to Reduced On-Peak Transmission Losses
- Avoided or Delayed Reliability Projects
- Mitigation of Transmission Outage Costs
- Benefit of Mandated Reliability Projects
- Marginal Energy Losses
- Increased Wheeling Through and Out Revenues
- Better energy and capacity ratings for renewable generation
- Benefit from cost-effectively meeting Public Policy Goals
- Reduced emissions

Components of Good Planning

- Forward Looking
  - Long-term and Short-term needs
  - Generation Additions to match Long-term Resource Adequacy Requirements based upon economics and State Policy Goals
- Multiple Plausible Futures
- Flexible and optimal design
  - Resulting plan should be flexible enough to meet more than one plausible future and optimize a variety of needs

Futures Assumptions

- Plausible Futures: help evaluate the need for transmission
- Supply and Demand
  - Variance and Type of Supply
    - Generation
      - Capital Costs
      - Fuel Assumptions
      - Type and location of generation
  - Variance and Type of Demand
    - Load
    - Demand side resources
    - Energy efficiency

SPP Staff Proposal Futures Template

Key Assumptions	DRIVERS						
	Year 2	2022 ITP F1- Reference Case			2022 ITP F2- Emerging Technology		
Year	**2**	**5**	**10**	**20**	**5**	**10**	**20**
Peak Demand Growth Rates	As submitted in load forecast	As submitted in load forecast			As submitted in load forecast		
Energy Demand Growth Rates	As submitted in load forecast	As submitted in load forecast			Increase due to electric vehicle growth		
Natural Gas Prices	Current industry forecast	Current industry forecast			Current industry forecast		
Coal Prices	Current industry forecast	Current industry forecast			Current industry forecast		
Emissions Prices	Current industry forecast	Current industry forecast			Current industry forecast		
Fossil Fuel Retirements	Current forecast	*Coal age-based 56+, Gas/Oil age-based 50+, subject to generator owner review*			*Coal age-based 52+, Gas/Oil age-based 48+, subject to GO review and ESWG approval*		
Environmental Regulations	Current regulations	Current regulations			Current regulations		
Demand Response	As submitted in load forecast	As submitted in load forecast			As submitted in load forecast		
Distributed Generation (Solar)	As submitted in load forecast	As submitted in load forecast			+300MW	+500MW	
Energy Efficiency	As submitted in load forecast	As submitted in load forecast			As submitted in load forecast		
Storage	None	20% of projected solar (1.4 GW/2.2 GW)			35% of projected solar (3.7 GW/5.2 GW)		
Total Renewable Capacity							
Solar (GW)	Existing + RARs	7	11		9	15	
Wind (GW)	Existing + RARs	33	36		38	42	

Planning for Solutions

Solutions for Reliability, Economics, and Public Policy Needs

- Transmission solutions designed to meet needs across the spectrum of futures and type of needs
- Transmission solutions may be primarily constructed for one need, but meet other uses
- Avoiding “jerry-rigged solutions”: The analysis should not contemplate one transmission line addition at a time, rather it should evaluate the design of different potential upgrades working together, optimized to provide the best long-term solution across multiple scenarios and needs

Need By Date

- Staging is an important part of planning
- When are the upgrades needed or show net benefit
- Years 2, 5, and 10 years
- Forty-year assets in transmission utilized to assess benefit

Optimization and Consolidation

- Transmission Planning Improvements
  - Integrated Regional Planning
  - Combination of Reliability, Economic, and Public Policy needs
  - Optimizes solutions across reliability, economic, and policy needs

- Additional optimization is needed across the GI, Transmission Service and related arenas where transmission is constructed

Examples of this concept today

- **SPP**
  - Design Phase: Economic portfolios are examined to see if they address Reliability needs that have that have been identified in the reliability assessment
  - SCRIPT

- **MISO**
  - Multi-Value Projects

Interregional Planning: Still a long way to go

- Order 1000
- PJM-MISO
  - TMEPs
- SPP-MISO
  - States OMS and SPP RSC Seams Liaison Committee
  - JTIQ

Planning and Cost Allocation

Thank you!

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