Energy Markets & Planning
BERKELEY LAB

Transmission Basics

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ENERGY TECHNOLOGIES AREA | ENERGY ANALYSIS DIVISION | ENERGY MARKETS & PLANNING

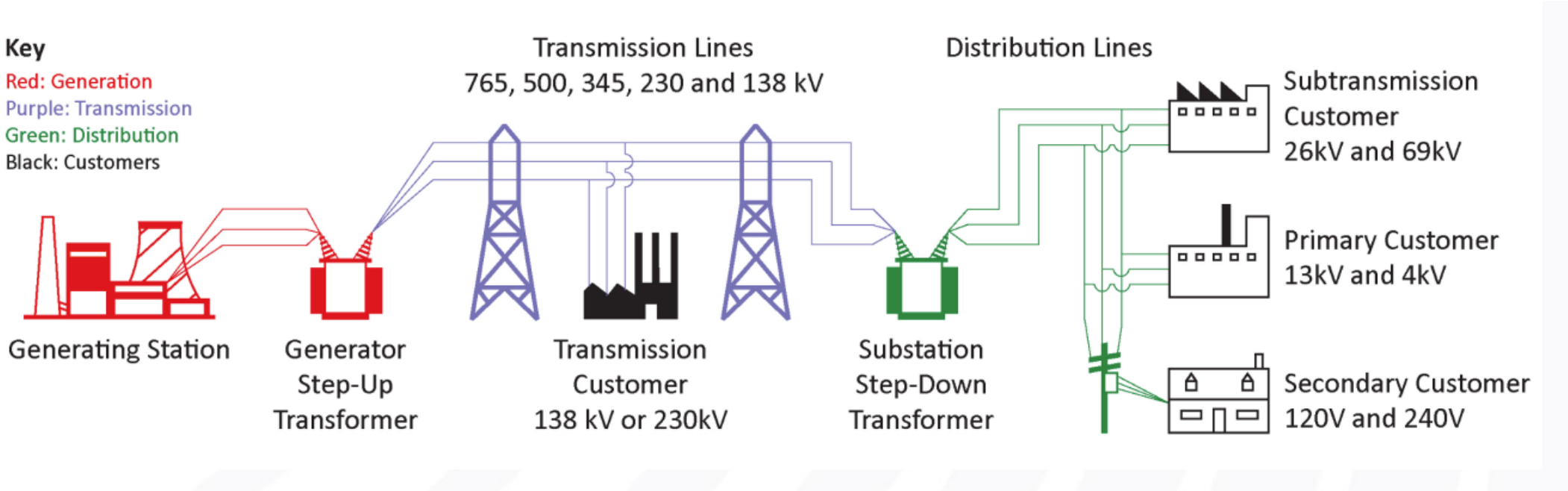
Agenda

1. Background
   - Transmission actors, functions, types, regulatory framework
2. Why build transmission?
   - Basics of transmission reliability, economics, and regulation
3. How is transmission built?
   - Overview of transmission development processes
4. Who pays for transmission?
   - Overview of cost allocation

Background

What Is the Transmission System?

The transmission system is usually delineated by voltage



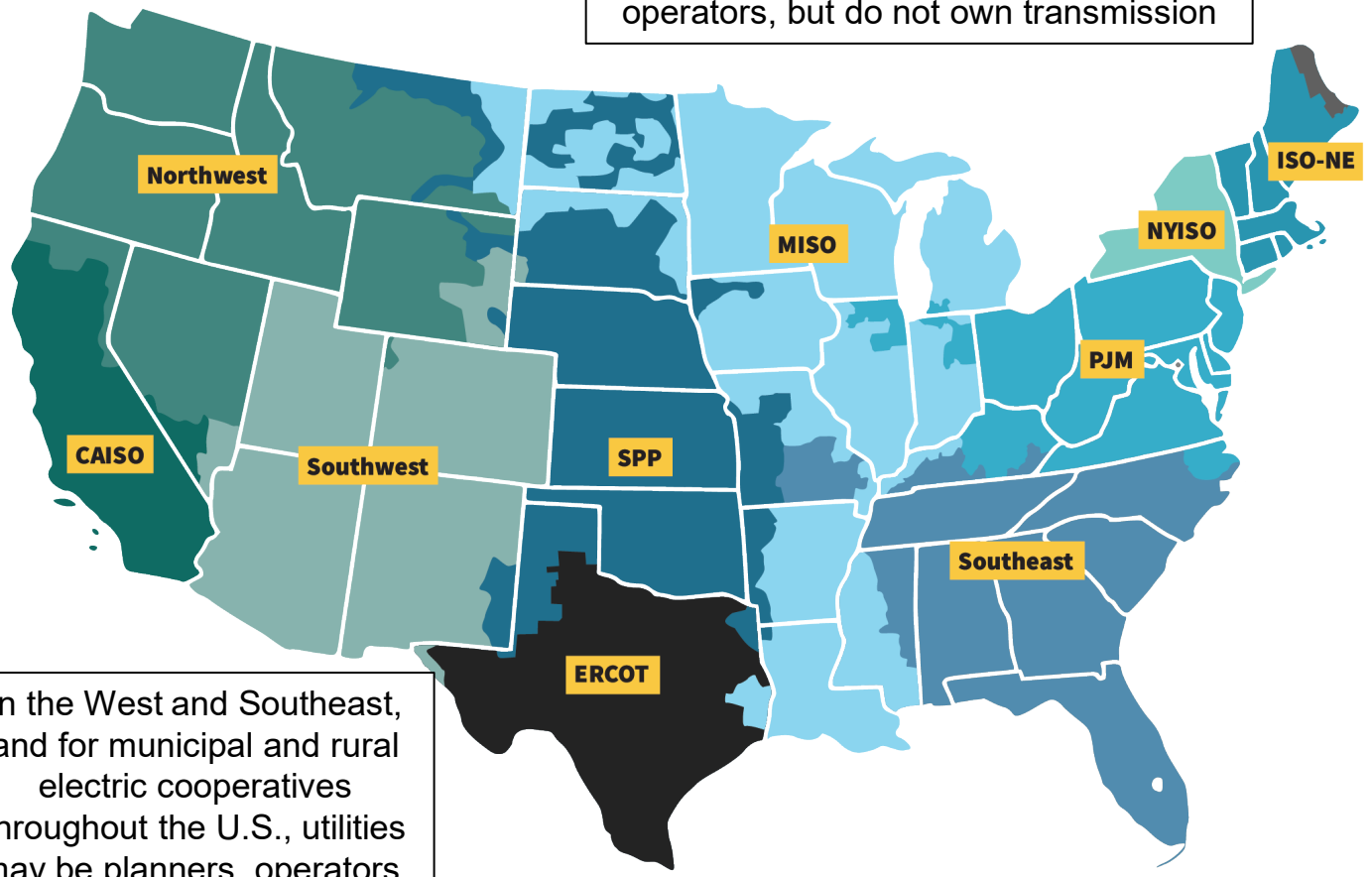
Notes: Other transmission and distribution voltages exist; FERC 7-factor test delineates “local” distribution

Source: NERC

Key Actors and Functions

- **Transmission planner** identifies transmission needs and solutions; may be different than owners and operators
- **Transmission owner** owns transmission infrastructure; may be different than planners and operators
- **Transmission operator** operates the transmission system; may be different than planners and owners
- In a regulatory context, the Federal Energy Regulatory Commission (FERC) defines **transmission provider** as "a public utility that owns, operates or controls facilities used for transmission of electric energy"

Independent system operators (ISOs) and regional transmission organizations (RTOs) are transmission planners and operators, but do not own transmission



In the West and Southeast, and for municipal and rural electric cooperatives throughout the U.S., utilities may be planners, operators, and owners

Source: FERC

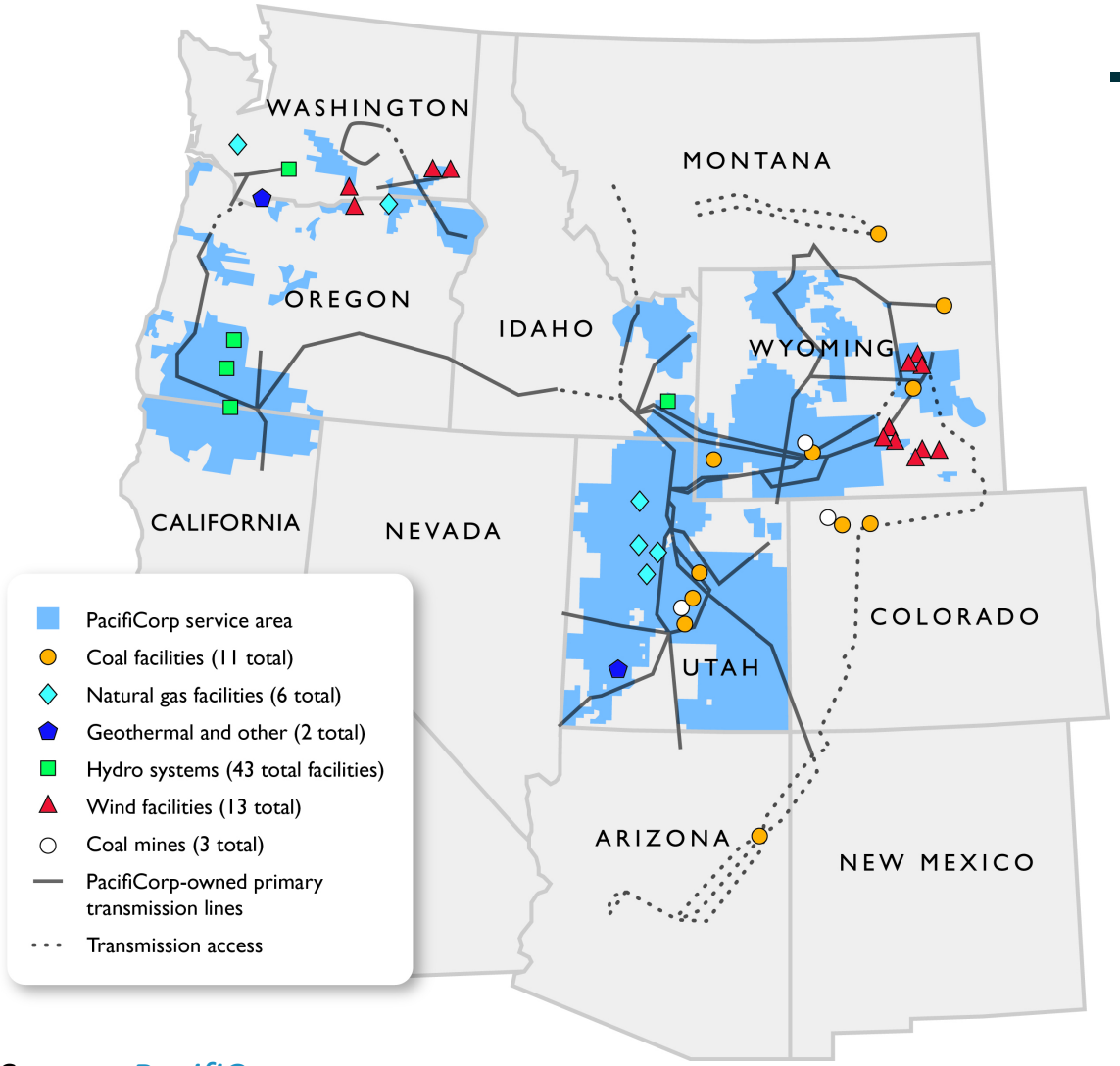
Transmission Types

Local transmission – lower voltage transmission located exclusively within a transmission owner's service territory

Regional transmission – transmission between transmission owners

Interregional transmission – transmission between transmission providers

PacifiCorp's transmission system



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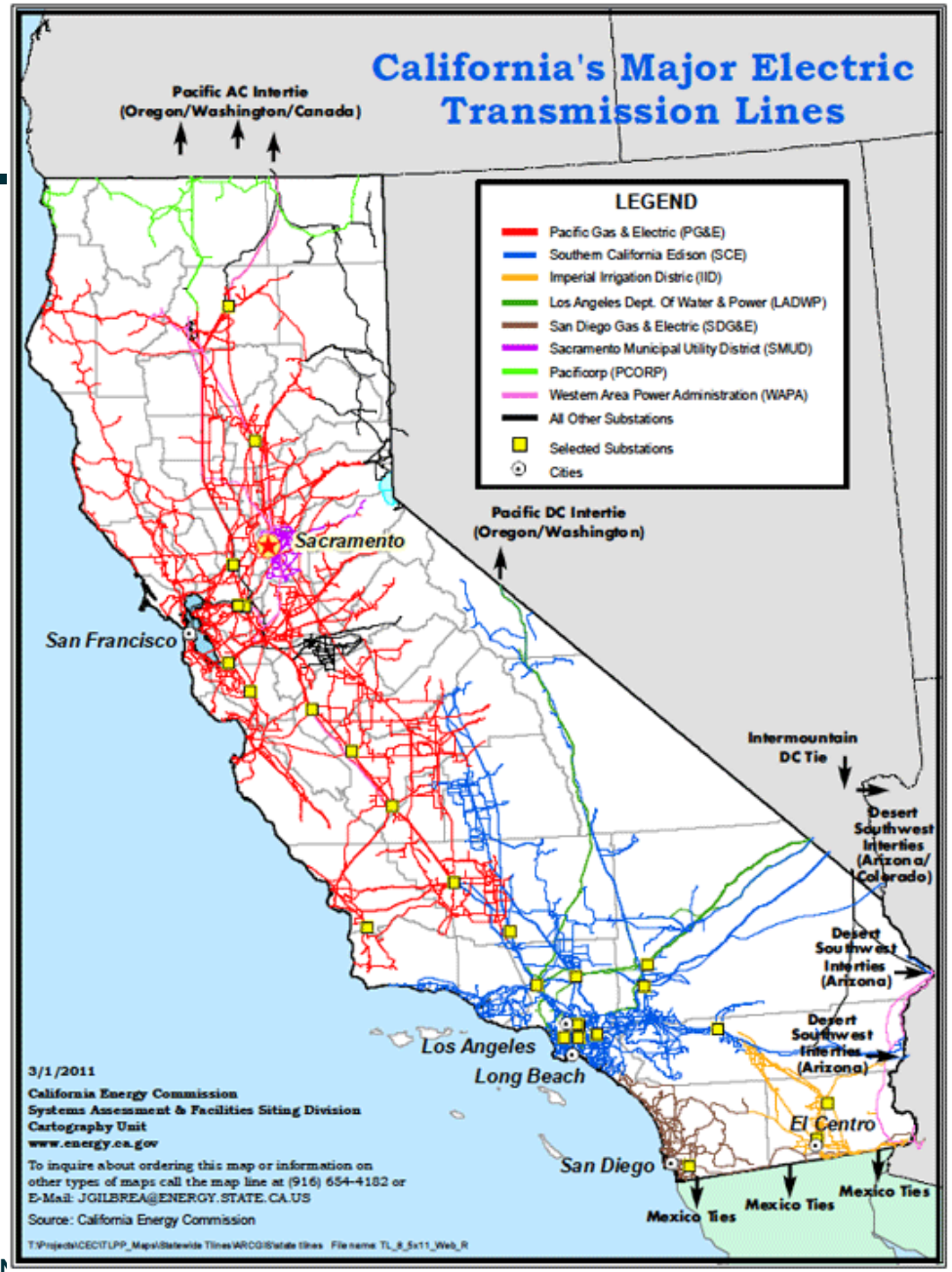

Source: [California Energy Commission]

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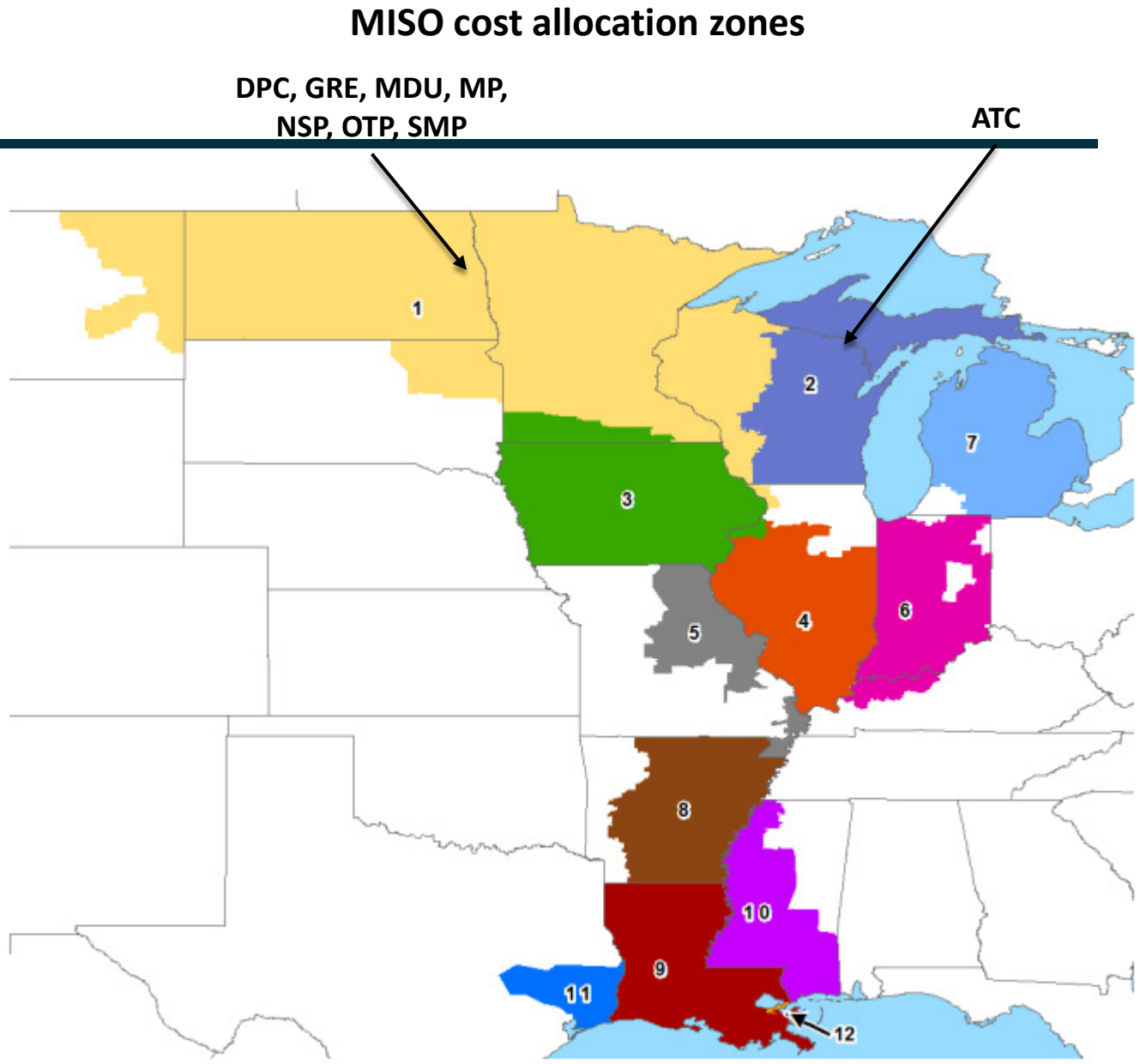

Source: California Energy Commission

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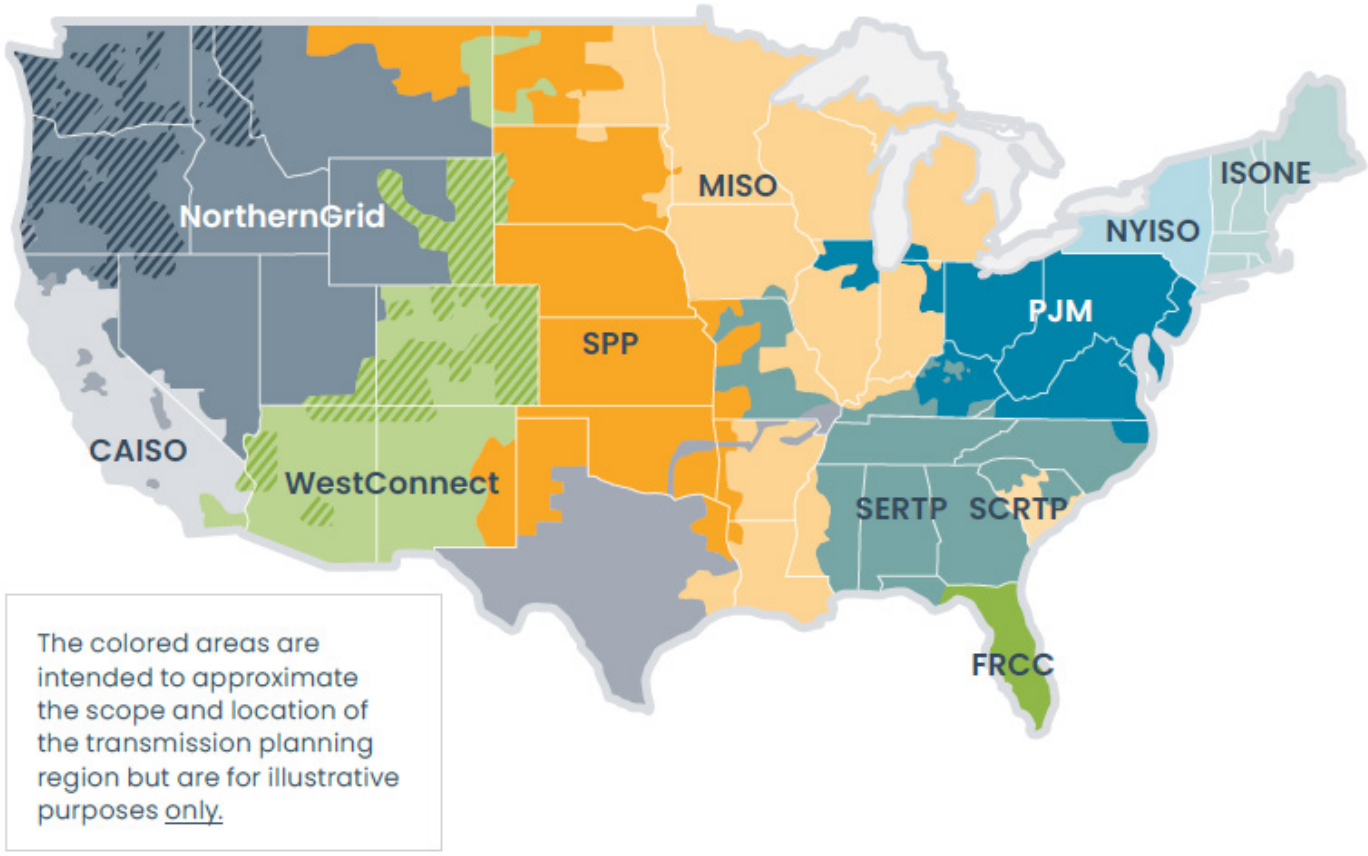
Order 1000 Transmission Planning Regions



Source: GridLab

Regulatory Framework

- **Open access** (Orders 888, 2003/2023) – requires transmission providers to provide non-discriminatory transmission access for all customers; sets transmission cost responsibilities for loads and generators
- **Open planning** (Order 890) – requires transmission providers to design and conduct an open transmission planning process
- **Regional planning** (Order 1000) – requires regional planning and cost allocation; limits the right of first refusal (ROFR)
- **Long-term planning** (Order 1920) – requires standardized long-term transmission planning

Why Build Transmission?

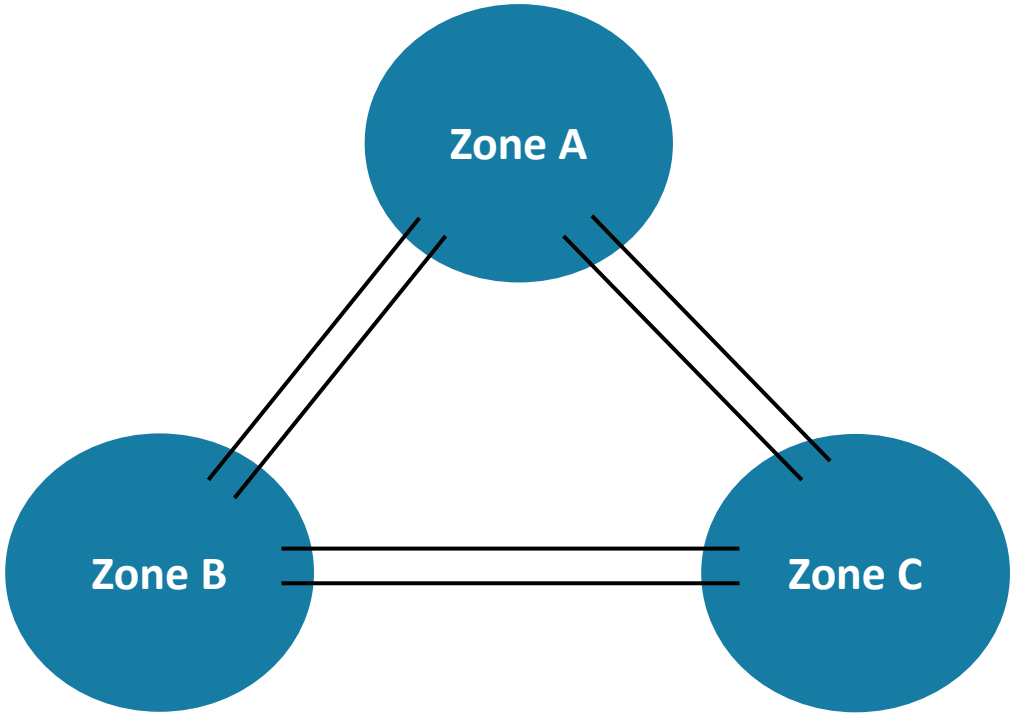
Why Build Transmission?

- Meet National American Electric Reliability Corporation (NERC) planning standards for reliability ("reliability transmission")
  - TPL-001 – Transmission System Planning Performance Requirements
- Improve economic efficiency ("economic transmission")
- Meet public policy goals ("public policy transmission")
- Other
  - Maintain reliable operations during extreme weather events
  - Improve competition
  - Facilitate reserve sharing

Reliability Transmission

- The need for reliability transmission is driven by three main limits
  - **Thermal** – rated capacity of transmission equipment
  - **Voltage** – system voltage limits
  - **Stability** – ability of the system to recover from a disturbance
- NERC requires that transmission planners evaluate whether transmission systems will be able to operating during normal and contingency conditions within these limits

Normal operating conditions
No generators or transmission equipment is out of service



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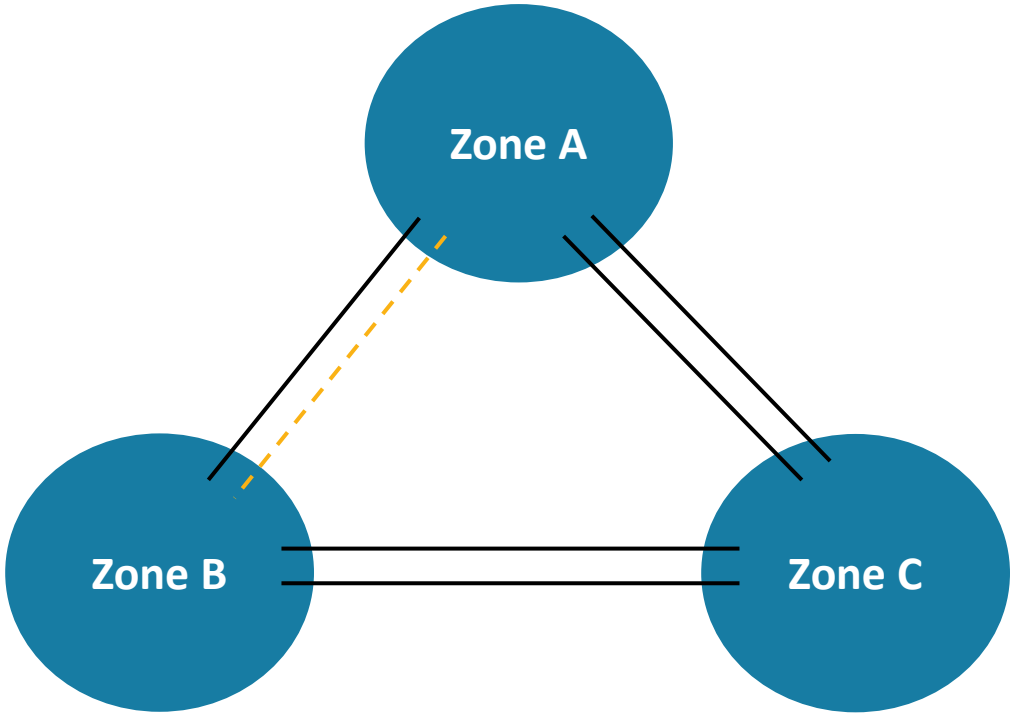
Contingency operating conditions

A transmission line is out of service



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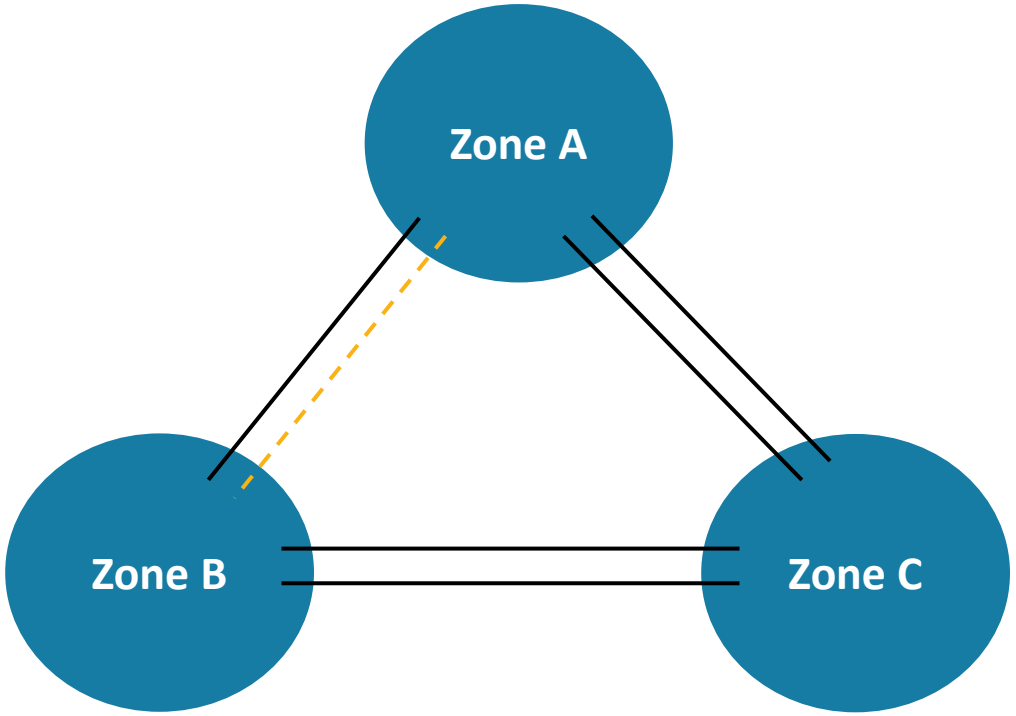
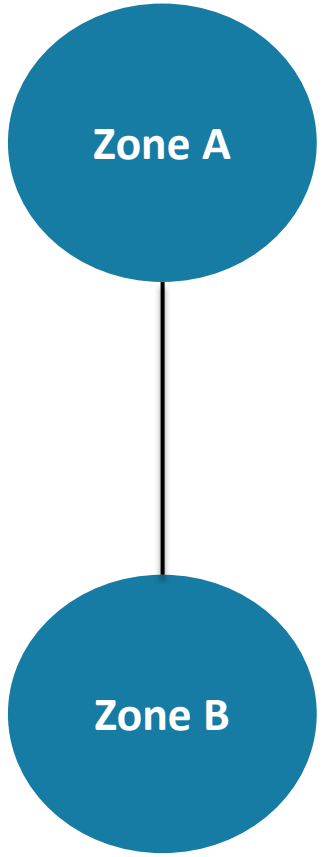
Whether the system can be reliably operated under contingency conditions depends on physics of the transmission system

Can generation still reliably meet demand under contingency conditions?



Economic Transmission

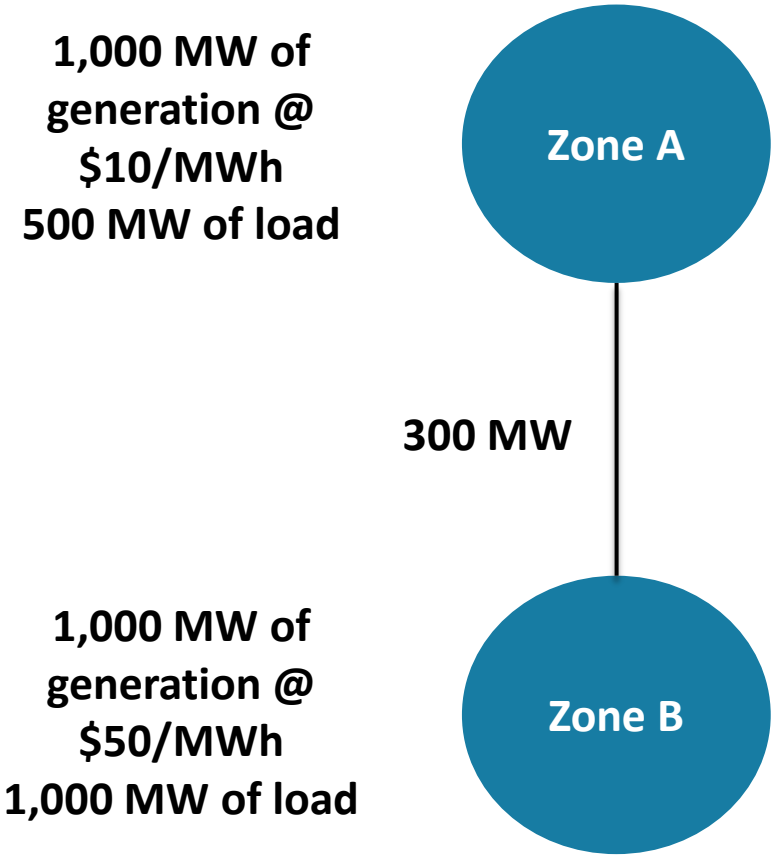
- The main driver of economic transmission is congestion mitigation
  - Additional drivers — e.g., resource adequacy (RA), reduced line losses) also could be involved
- Congestion occurs when lower cost power in one region cannot be delivered to another due to transmission constraints
- Congestion imposes costs and leads to regional price separation, but some amount of congestion will always be economic



Example with two zones connected by a transmission line

Economic Transmission

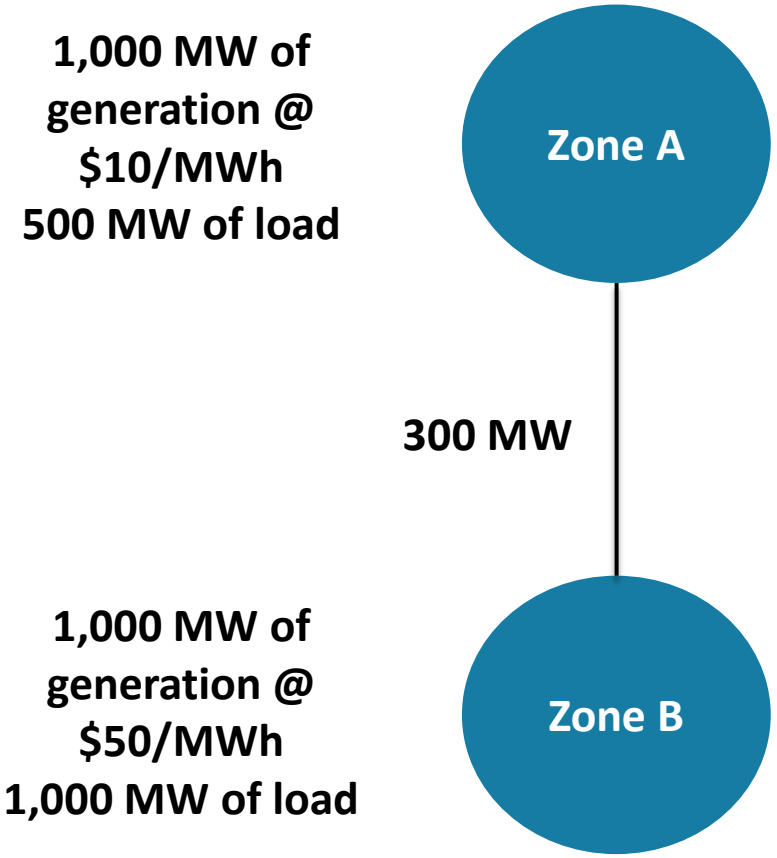
- Congestion cost is the difference between:
  - Least-cost dispatch without transmission constraints, and
  - Least-cost dispatch with transmission constraints
- If expected congestion costs are higher than the cost of new transmission, it may be cost-effective to build new transmission



Example with two zones connected by a transmission line

Economic Transmission

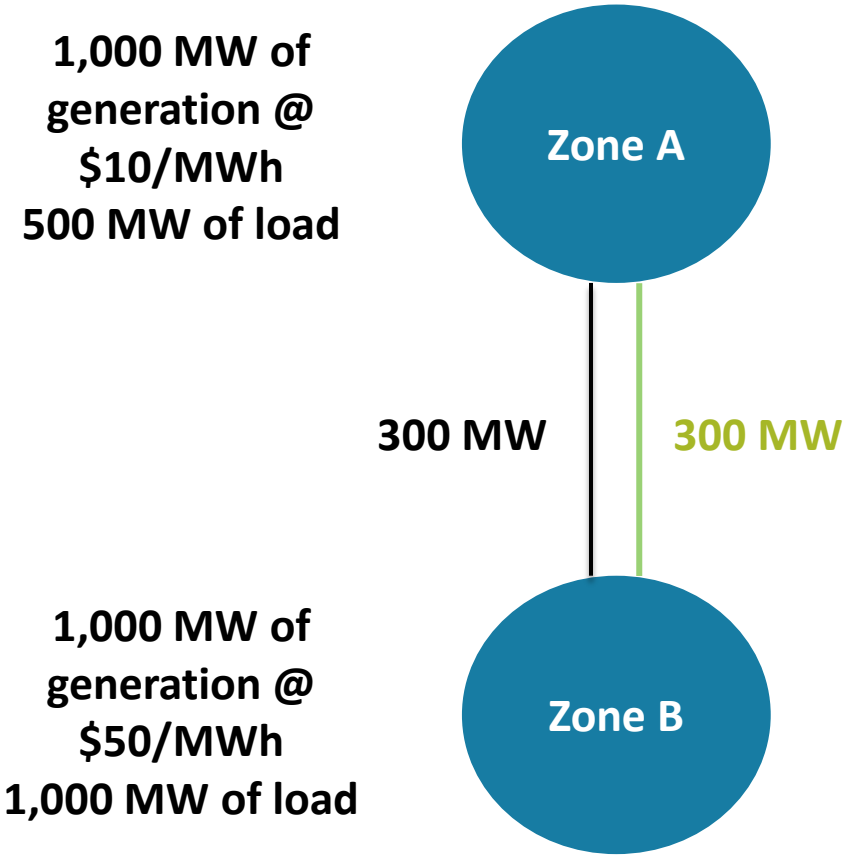
- This system has 1,500 MW of load
- Least-cost dispatch is $35,000/h [(1,000 MW × 10/MWh) + (500 MW × $50/MWh)]
- Transmission-constrained dispatch cost is $43,000/h [(800 MW × 10/MWh) + (700 MW × $50/MWh)]
- Congestion costs are $8,000/h ($35,000/h – $43,000/h)
- Congestion costs represent maximum congestion cost savings from new transmission



Example with two zones connected by a transmission line

Economic Transmission

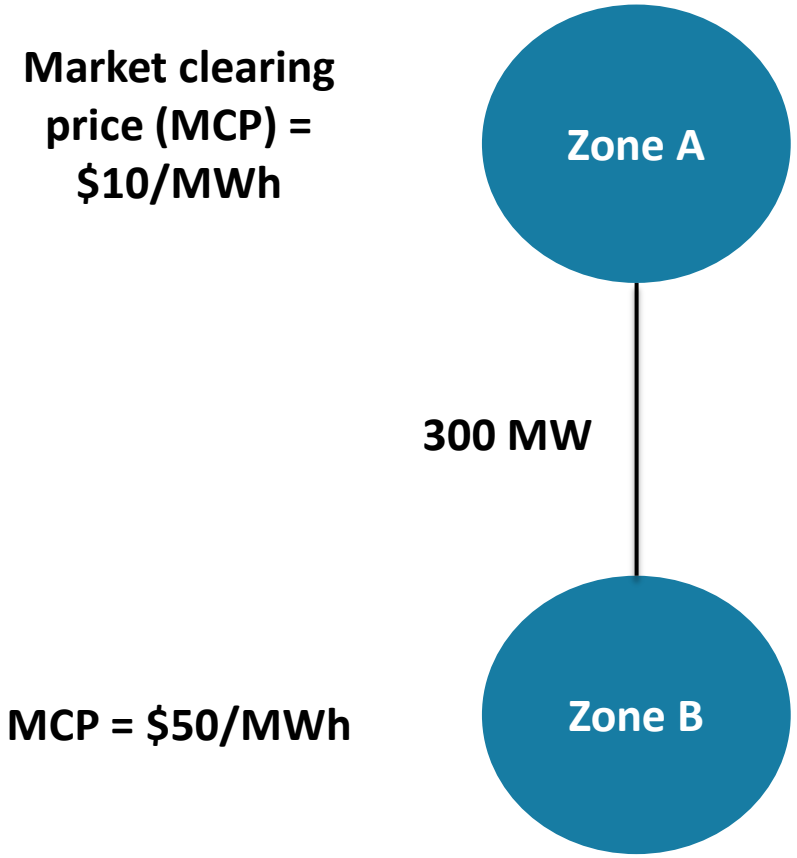
- To evaluate whether transmission is cost-effective, we need to compare cost savings from reduced congestion over time with the cost of new transmission
- For instance, we could add another 300 MW of transmission and compare the expected costs with and without the new line over its lifetime



Example with two zones connected by a transmission line

Economic Transmission

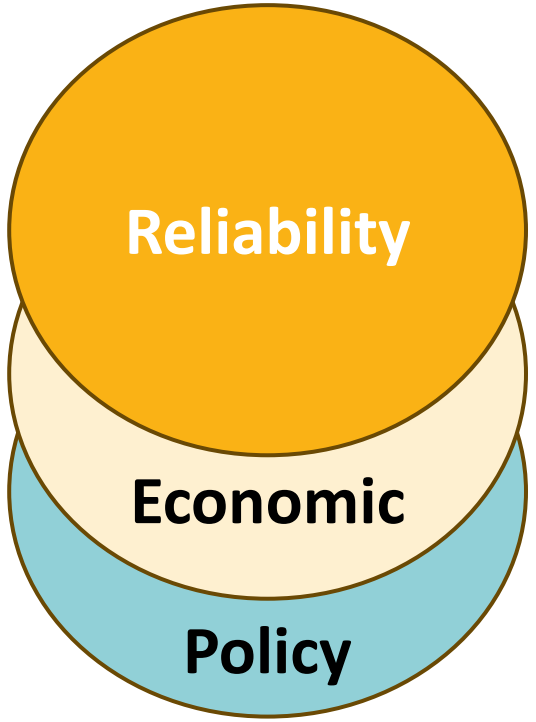
- Congestion cost provides a neutral benchmark for determining whether new transmission is cost-effective
- But often the benefits of reducing congestion for generators and loads depend on market prices and transmission cost allocation
- In our example, which generator or load benefits from reduced congestion?



Example with two zones connected by a transmission line

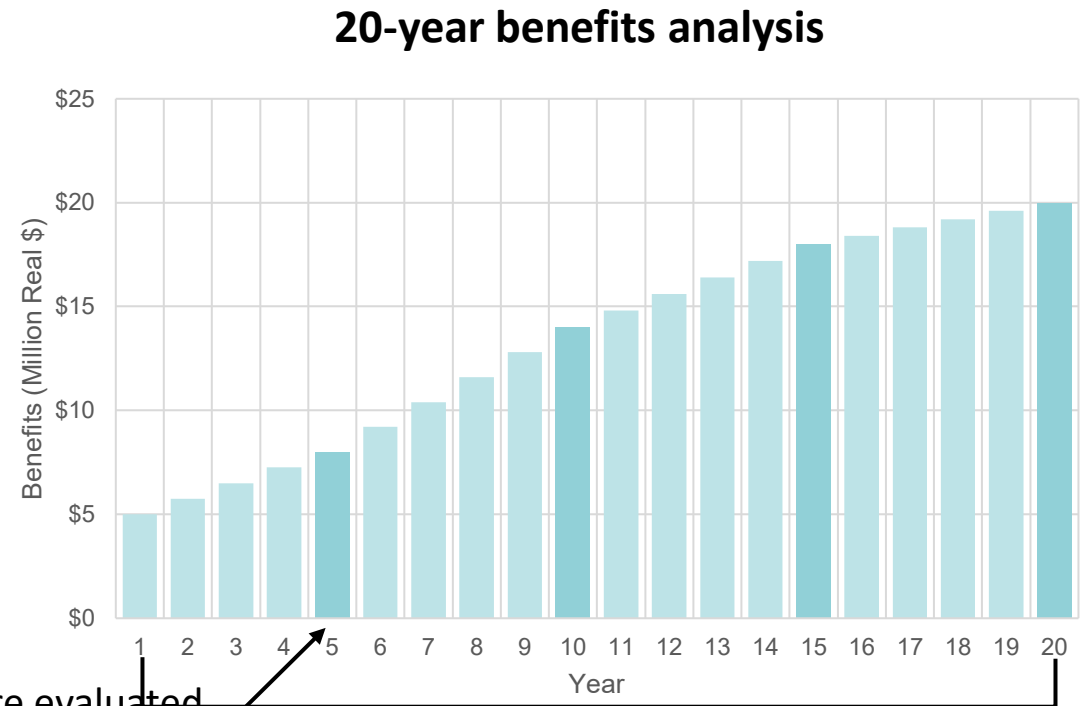
Public Policy Transmission

- Public policy transmission refers to transmission that is needed to meet public policy goals
- In many cases, public policy transmission is driven by reliability or economic needs, but there are cases in which it might not
  - For instance, resilience value not covered under reliability

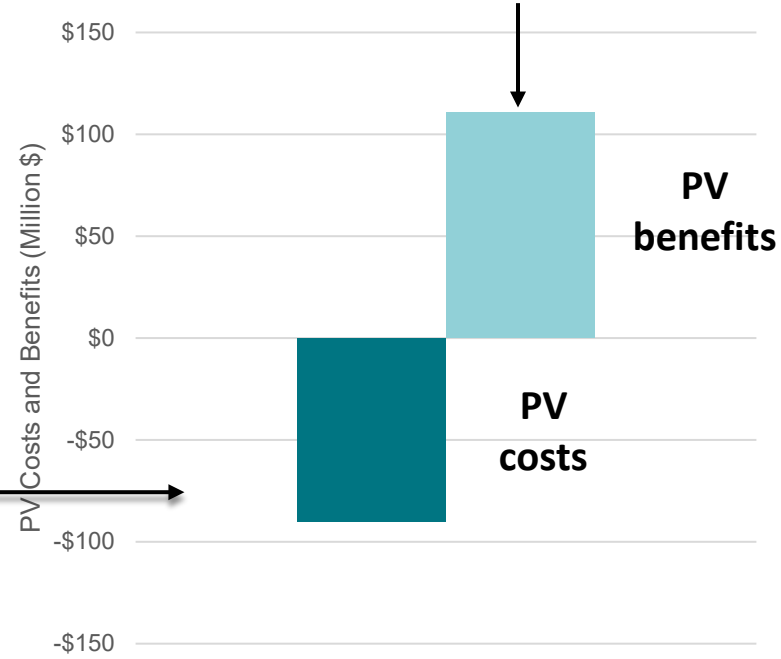


BCA for Transmission

- Some kinds of transmission require BCA to meet approval criteria
- BCA compares the present value (PV) of benefits versus costs for new transmission
- Benefits often change over time, as loads, generation, and fuel prices change
  - Often benefits are interpolated between modeled years
- Order 1920 requires BCA for long-term transmission planning



Benefits are evaluated in model years (dark green) and are interpolated in other years (light green)



Benefit-to-cost ratio = PV benefits / PV costs = $110 million / $90 = 1.23

Reliability versus Economic Transmission

- Where is the boundary between reliability and economic transmission? Why does it matter?
- It may be easier to accept that all transmission customers should pay for higher voltage reliability transmission, but in principle economic transmission should be paid for by the parties that benefit from lower congestion or other economic benefits (e.g., more deliverability)
- How does this work in practice, and ideally how would this work?

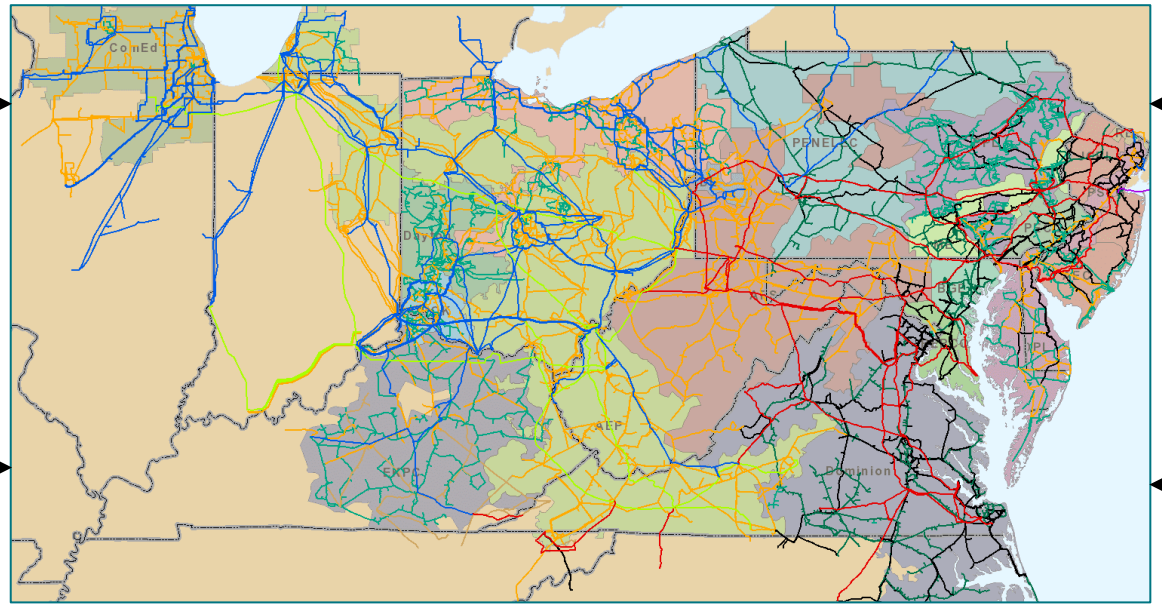
How Is Transmission Built?

How Is Transmission Built?

- Transmission may be built through multiple processes
- Our focus will be on regional planning, but it will be important to keep other avenues in mind

Transmission planning (local, regional, interregional)

Generator interconnection

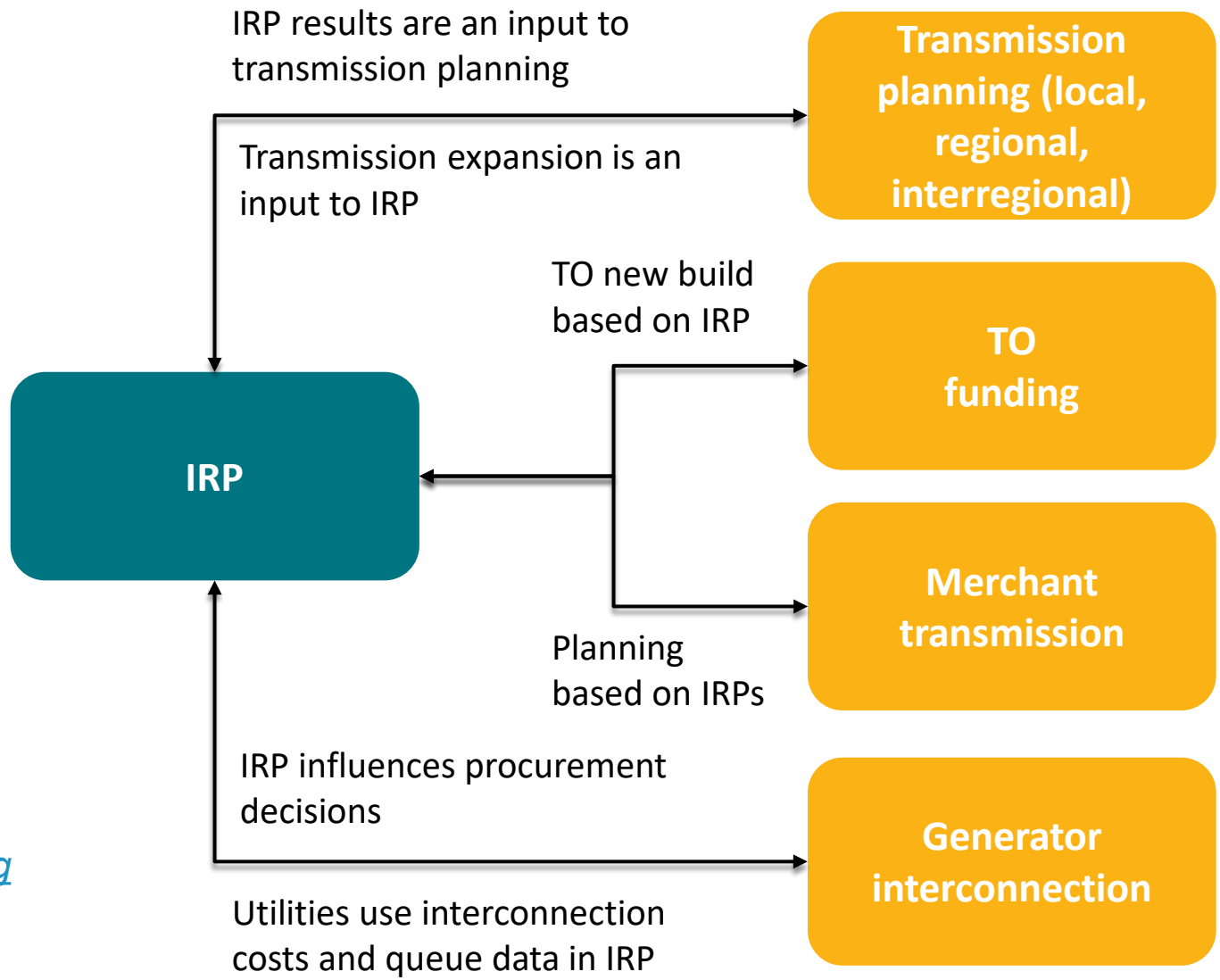


Transmission owner (TO) funding

Merchant transmission

Interactions with Resource Planning

- Utilities are the largest buyers of electricity
- Most regulated utilities, and some others, use integrated resource plans (IRPs) to plan for resource procurement
- How does IRP interact with transmission expansion?



See *Best Practices in Integrated Resource Planning*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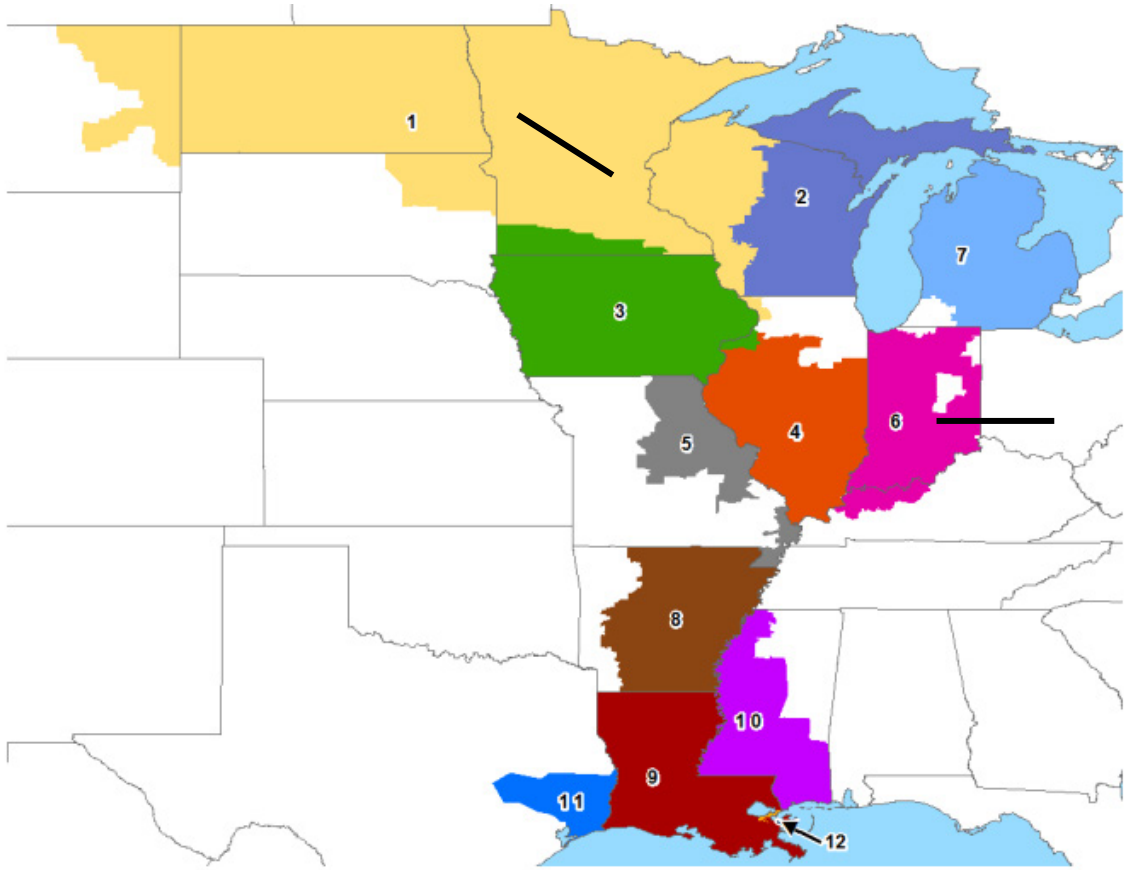
Who Pays for Transmission?

Who Pays for Transmission?

- Say we build high voltage transmission within Minnesota (MN), or between Indiana (IN) and Ohio (OH)
- *Who should pay?*
- Should generators pay for some of the costs? Under what conditions?
- Should all MISO transmission customers pay? Only MN, IN, and OH customers? Which transmission customers? Should PJM and SPP customers pay? On what basis? Under what conditions?

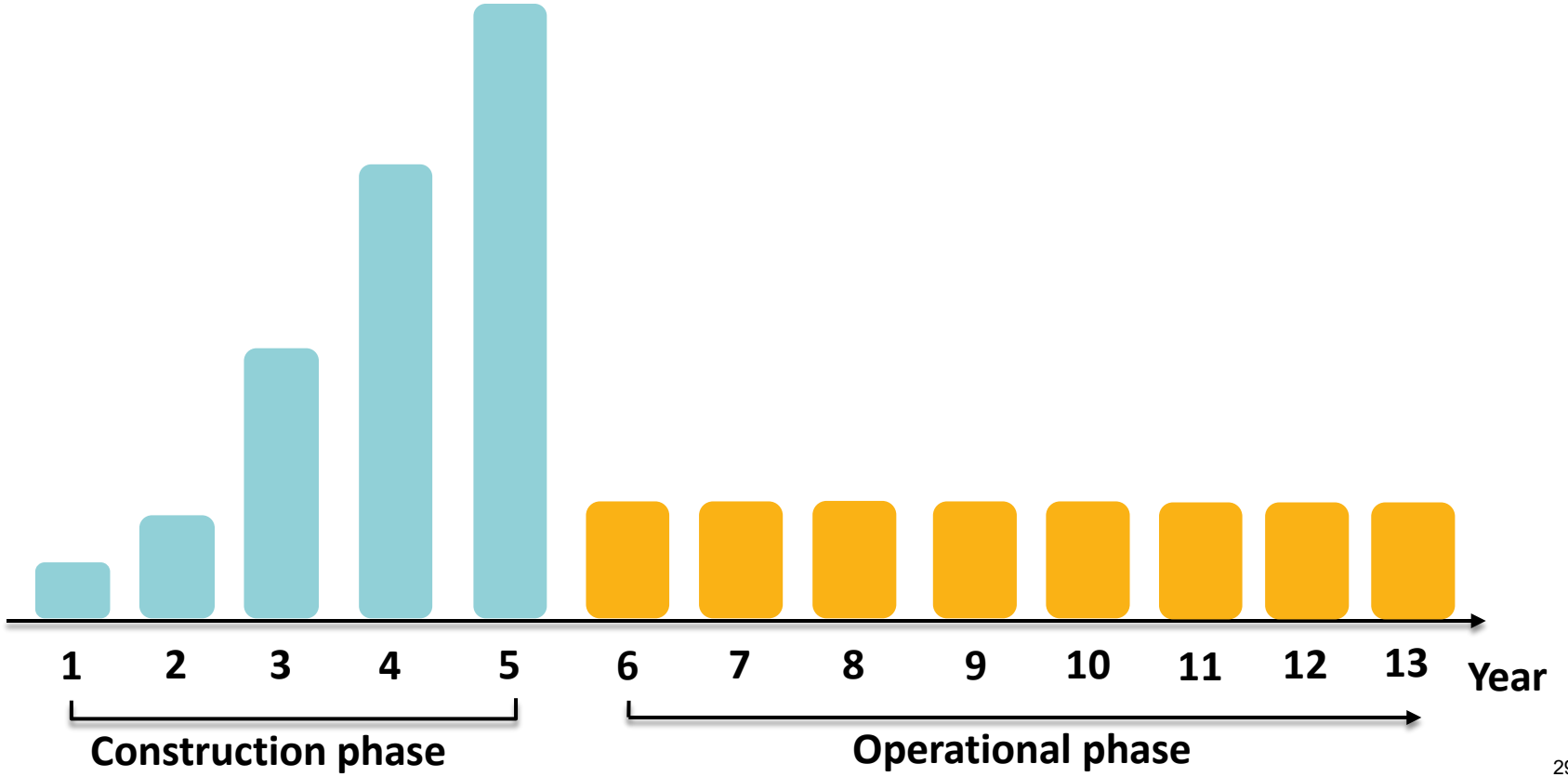


Transmission Costs

- Transmission costs to be allocated are the annual transmission revenue requirement (ATRR), which includes but is not limited to investment costs

Investment costs
Siting, permitting, equipment, construction

ATRR
Depreciation, return, O&M, taxes

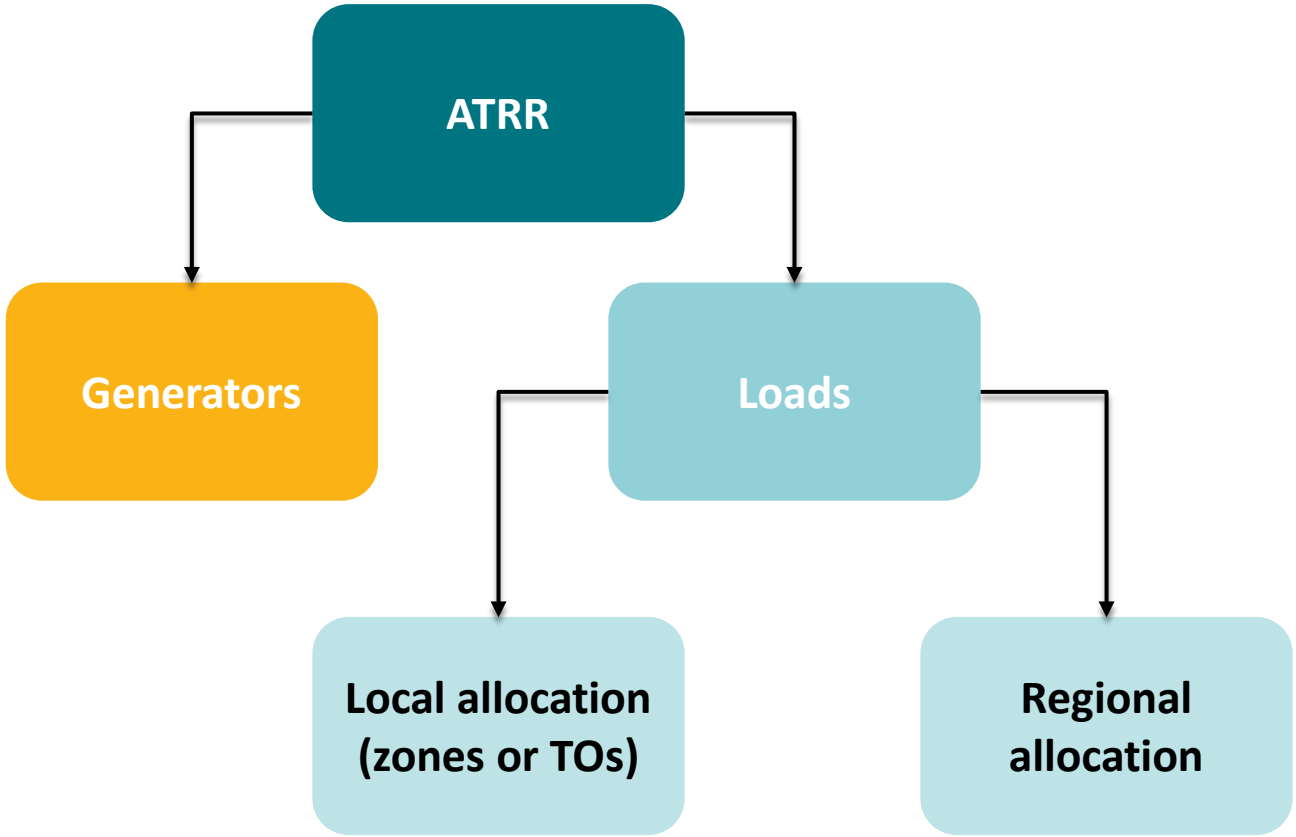


Key Considerations for Cost Allocation

- **3 main considerations**
  - **Location** (within or between transmission owners or transmission zones)
  - **Voltage** (lower, higher)
  - **Drivers** (reliability, economics, public policy)
- Costs for projects located solely within a transmission owner's territory are more likely to be allocated locally
- Higher voltage projects tend to be more important for regional reliability and have more complex and regional economic benefits
- Drivers provide a window into who benefits from transmission
- These considerations underlie the logic of cost allocation

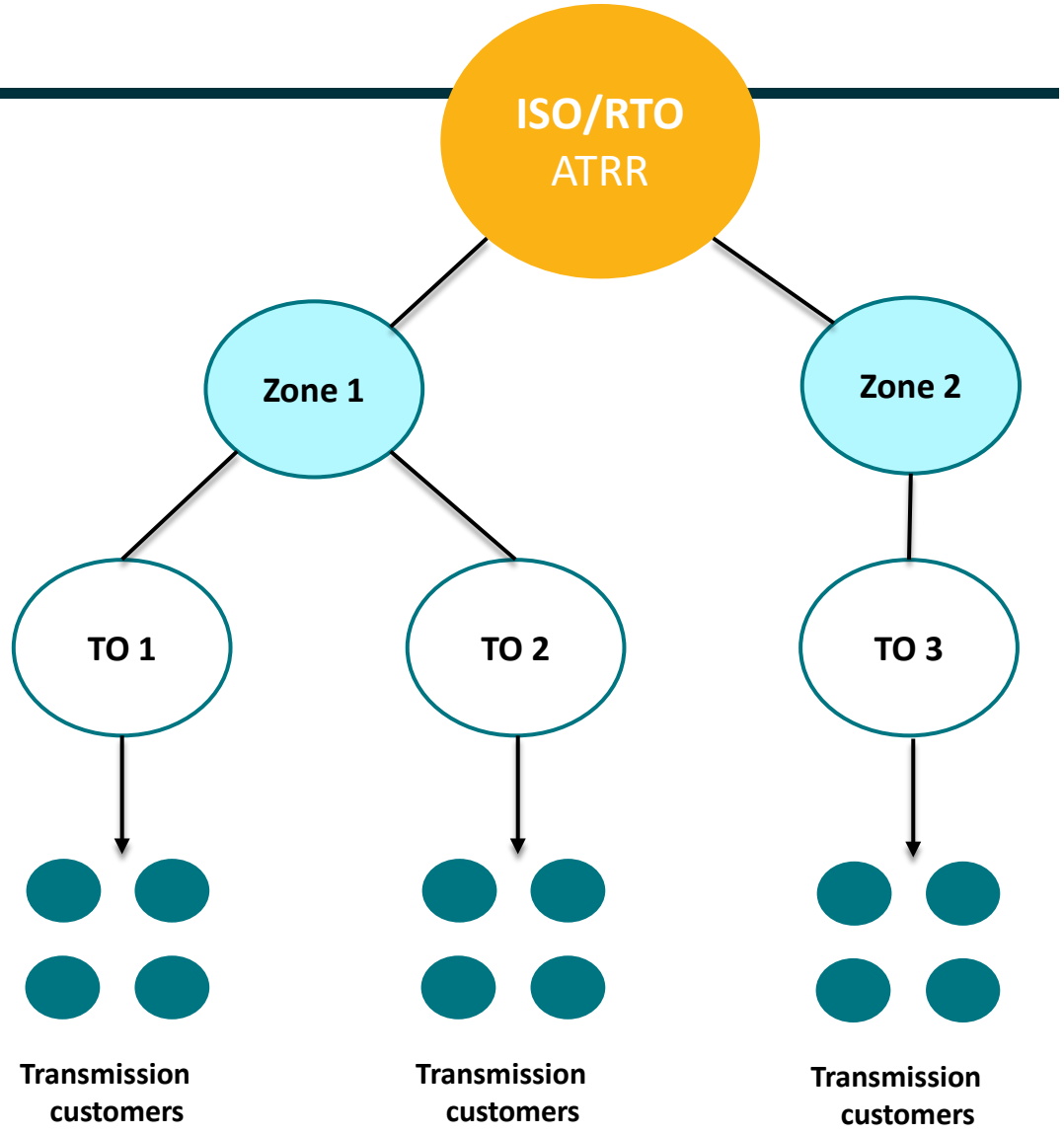
Basic Cost Allocation Framework

- At the highest level, there are two main decision points for transmission cost allocation
  - Generation v. loads
  - Local v. regional loads



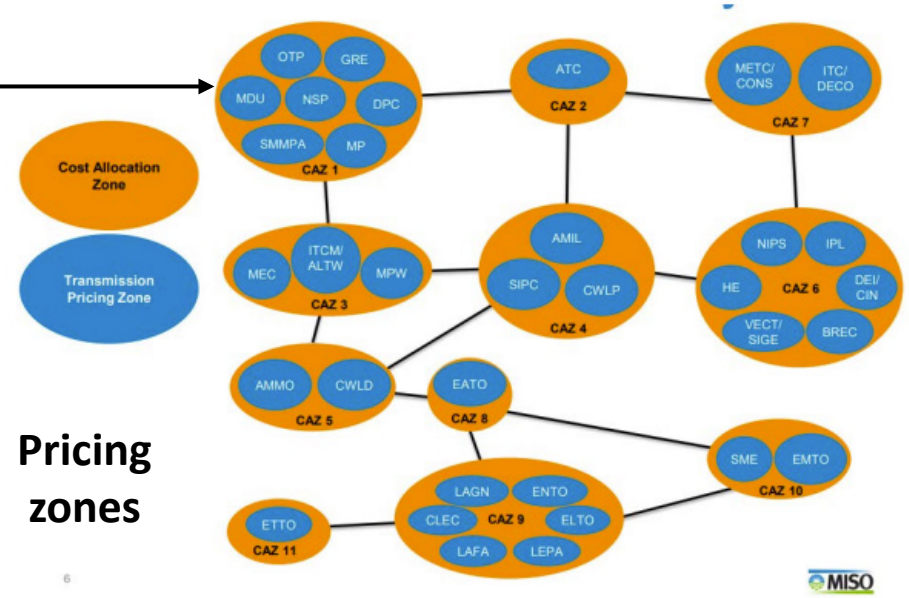
Cost Allocation "Levels"

- For loads, there are multiple levels of cost allocation, particularly in RTOs
- In ISOs/RTOs, transmission cost allocation involves two main levels of allocation:
  1) Allocation of an annual ATRR to a transmission zone and transmission owners
  2) Allocation to individual customers within that zone
- RTOs are responsible for (1)
  - May be several levels within (1)
- Transmission owners are responsible for (2), subject to FERC approval and oversight

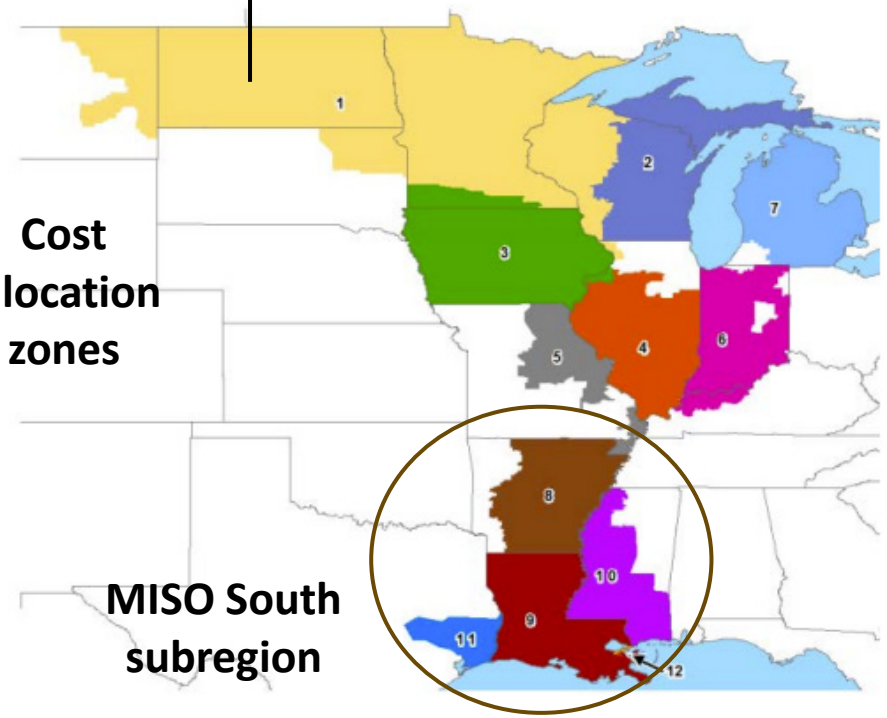


MISO Levels

- MISO illustrates the many different zones
- MISO has four levels
  - MISO footprint (all colored areas)
  - MISO subregion
  - Cost allocation zone
  - Pricing zone



Pricing zones



Cost allocation zones

MISO South subregion

Source: Organization of MISO States

Cost Allocation in Practice (Broadly)

- Historically, cost allocation was often segmented into reliability and economic drivers
  - Reliability transmission – cost either allocated locally or regionally for higher voltage lines
  - Economic transmission – cost allocated based on benefits (reduced congestion costs), or in some cases regionally for higher voltage lines
- Public policy transmission often integrated into reliability and economic transmission
  - MISO began to experiment with regionally-allocated multi-value transmission in the early 2010s

Cost Allocation in PJM

Driver	Category	Allocation method
Reliability	Regional	50% load ratio share (LRS) 50% directionally-weighted solution-based distribution factors (DFAX)
	Lower voltage	100% directionally-weighted solution-based DFAX
Market efficiency (economic)	Regional	50% LRS 50% zones with decreased net load payments
	Lower voltage	100% to zones with decreased net load payments
Public policy (State Agreement Approach)	All	100% to sponsoring state
Multi-driver	All	Proportional allocation based on benefit estimate

Notes: Regional refers to double circuit projects ≥ 345 kV; lower voltage refers to projects 200-345 kV

Cost Allocation in MISO

Driver	Category	Allocation method
Reliability	TO-planned (Other)	Local to transmission owner
	Local (Base Reliability Project)	Local to transmission owner
Market efficiency (economic)	Regional	100% based on adjusted production costs; only triggered if smeets criteria
Multi-driver	Regional (Multi-value)	LRS ($/MWh)

Note: Regional refers to the MISO footprint

Cost Allocation in CAISO

Driver	Category	Allocation method
All	All	100% LRS based on energy consumption ($/MWh)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