Bulk Power System Virtual Learning Modules:
Integrated Electricity Planning Trainings

This three-part trainings series will dive into key concepts of integrated planning, a holistic planning approach to develop affordable, reliable, and robust investment plans by integrating traditionally siloed processes.

***Open to NARUC, NASEO, NASUCA, NGA, NCSL, and NACAA Members**

Spring 2025 Sessions (all hosted virtually from 2:00 to 4:30 p.m. ET):

- **February 13: Integrated Electricity Planning for Different Types of Entities**
- **February 20: System Expansion Modeling: Considering Transmission and Distribution in Capacity Expansion Modeling**
- **March 6: Tools, Data and Processes for Integrated Planning**

Register Now

NARUC
National Association of Regulatory Utility Commissioners

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

About NARUC

- Founded in 1889, the National Association of Regulatory Utility Commissioners (NARUC) is a non-profit organization dedicated to representing the state public service commissions who regulate the utilities that provide essential services such as energy, telecommunications, power, water, and transportation.

- NARUC's members include all 50 states, the District of Columbia, Puerto Rico, and the Virgin Islands.

- Our mission is to serve the public interest by improving the quality and effectiveness of public utility regulation.

About CPI

- The NARUC Center for Partnerships & Innovation (CPI) builds relationships, develops resources, and delivers training to assist state commissions contending with complex current and emerging issues.

- CPI is funded by cooperative agreements with the U.S. Department of Energy (DOE) and the U.S. Department of Commerce's National Institute of Standards and Technology (NIST).

- NARUC CPI conducts work across five key energy areas and many topics within each: generation; transmission; distribution; customers; and critical infrastructure preparedness, response, and resilience.

- For more information, visit: https://www.naruc.org/cpi/

Bulk Power System Virtual Learning Modules

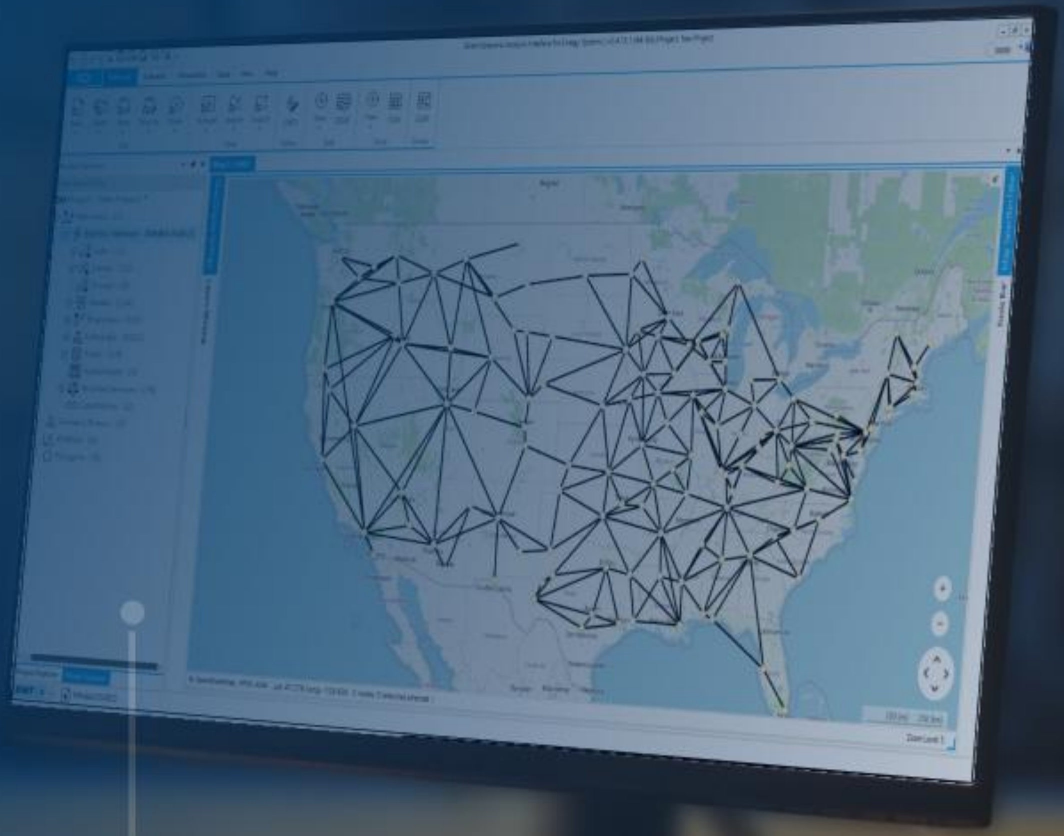
- Online series of bulk power system learning modules including topics like resource adequacy, system balancing, load forecasting, interconnection, and many more.
- These resources have been developed by NARUC, with support from the National Association of State Energy Officials (NASEO), the National Association of State Utility Consumer Advocates (NASUCA), and the U.S. Department of Energy. Other partners include Energy Systems Integration Group, Pacific Northwest National Lab, National Renewable Energy Lab, and Lawrence Berkeley National Lab.
- Learning modules website: https://www.naruc.org/core-sectors/electricity-energy/bulk-power-system/bulk-power-system-learning-modules/

encoord
Plan the Energy Future

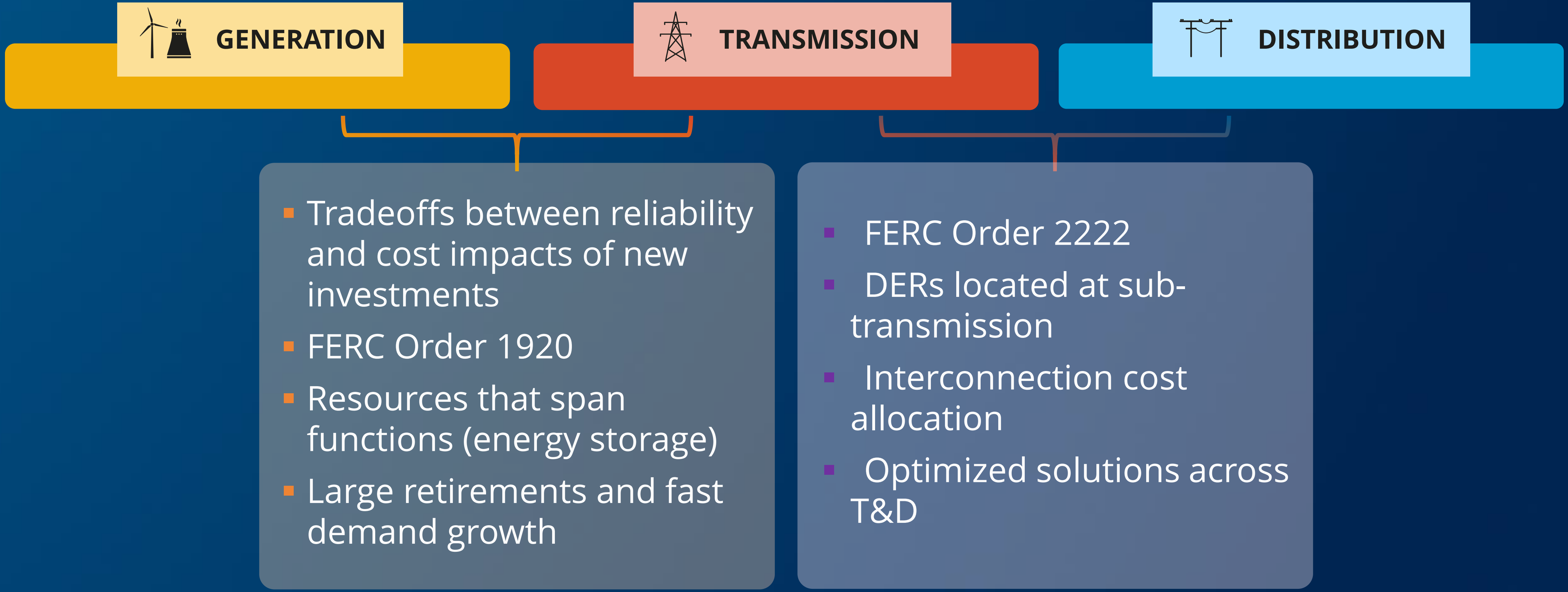
Linking Data, Tools, and Processes for Integrated Planning

ESIG Integrated Planning Guidebook

March 6, 2025



Change Drivers Impacting Integrated Planning Needs



GENERATION

TRANSMISSION

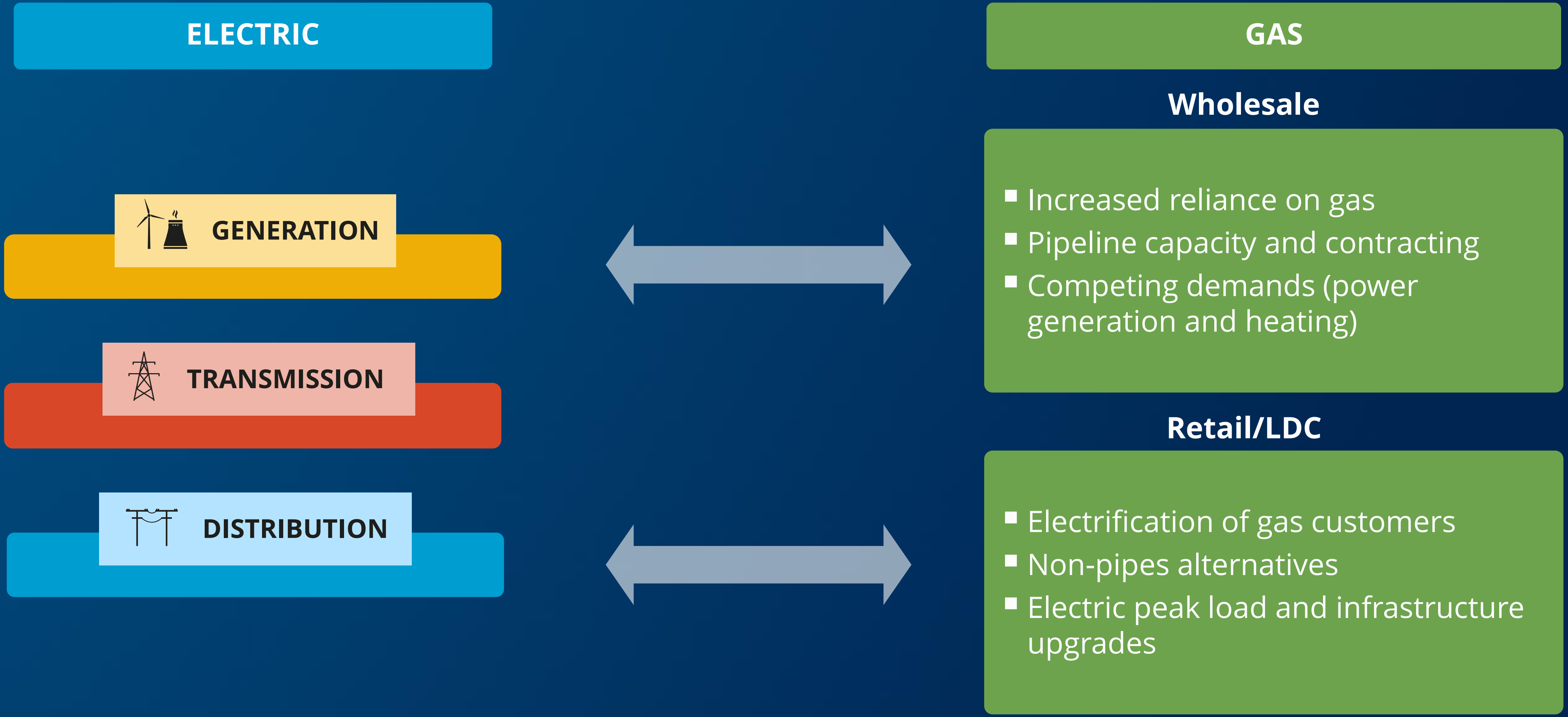
DISTRIBUTION

- Tradeoffs between reliability and cost impacts of new investments
- FERC Order 1920
- Resources that span functions (energy storage)
- Large retirements and fast demand growth

- FERC Order 2222
- DERs located at sub-transmission
- Interconnection cost allocation
- Optimized solutions across T&D

* Content adapted from ScottMadden

Electric & Gas Integrated Planning Needs



ELECTRIC

GENERATION

TRANSMISSION

DISTRIBUTION

GAS

Wholesale

- Increased reliance on gas
- Pipeline capacity and contracting
- Competing demands (power generation and heating)

Retail/LDC

- Electrification of gas customers
- Non-pipes alternatives
- Electric peak load and infrastructure upgrades

* Content adapted from ScottMadden

Integrated Planning Challenges

People

Process

Data

Tools

Integrated Planning Guidebook

A practical entry point to integrated power system planning for generation, transmission, distribution, and customer planners. It provides guidance on how to integrate planning processes across G, T, D, and C using a practical "walk/jog/run" framework.

Informed by an industry-wide taskforce of planning experts from utilities, system operators, national labs, software vendors, and consulting shops. Expected publication in Summer 2025.

Definition of Integrated Planning:

A holistic energy system planning approach that links traditionally siloed planning processes to develop affordable, reliable, and robust investment plans. Integrated planning may be coordinated across electric generation, transmission, distribution, and customer loads and distributed energy resources, and may also consider interactions between the electric system and other energy systems.

*Draft – please do not cite!

Overview of Planning Functions & Modeling Domains

Scope **Horizon** **Scale** **Action**

GENERATION

- Capacity Expansion Modeling
- Probabilistic Resource Adequacy Assessment
- Production Cost Modeling

TRANSMISSION

- Balanced AC Power Flow Simulations
- Short-Circuit/Fault Modeling
- Phasor Domain Transient Simulations
- Electromagnetic Transient Simulations

DISTRIBUTION

- Unbalanced AC Power Flow Simulations
- Short-Circuit/Fault Modeling

CUSTOMER

- Load Forecasting Modeling
- Rate Design and Tariff Models
- Demand Response and Demand-Side Management Planning Models
- Cost-Effectiveness Tests
- Customer Behavior and Adoption Models

*Draft – please do not cite!

The Integrated Planning Framework

Walk: communication and understanding

Jog: aligning data inputs

Run: integrated modeling and execution

*Draft – please do not cite!

Walk example: Generation & Transmission

<u>What Transmission planners need to understand about Generation planning:</u>

- Modeling abstraction: location, capacity, and expected dispatch of existing generation and storage assets are planned with models that absolve some practical constraints.
- Future uncertainty: potential interconnection location of planned generation projects comes with uncertainty.

<u>What Generation planners need to understand about Transmission planning:</u>

- Physical reality: transmission constraints can impact the operation of generation and storage assets in substantial, and at times counterintuitive ways.
- Computational limitations: detailed analysis is effort-intensive, which means brute-force reliability assessments can be prohibitive.

*Draft – please do not cite!

Jog example: Generation & Transmission

Aligning System Assets

Time-series Approach for Transmission Studies

Effective Feedback Mechanisms

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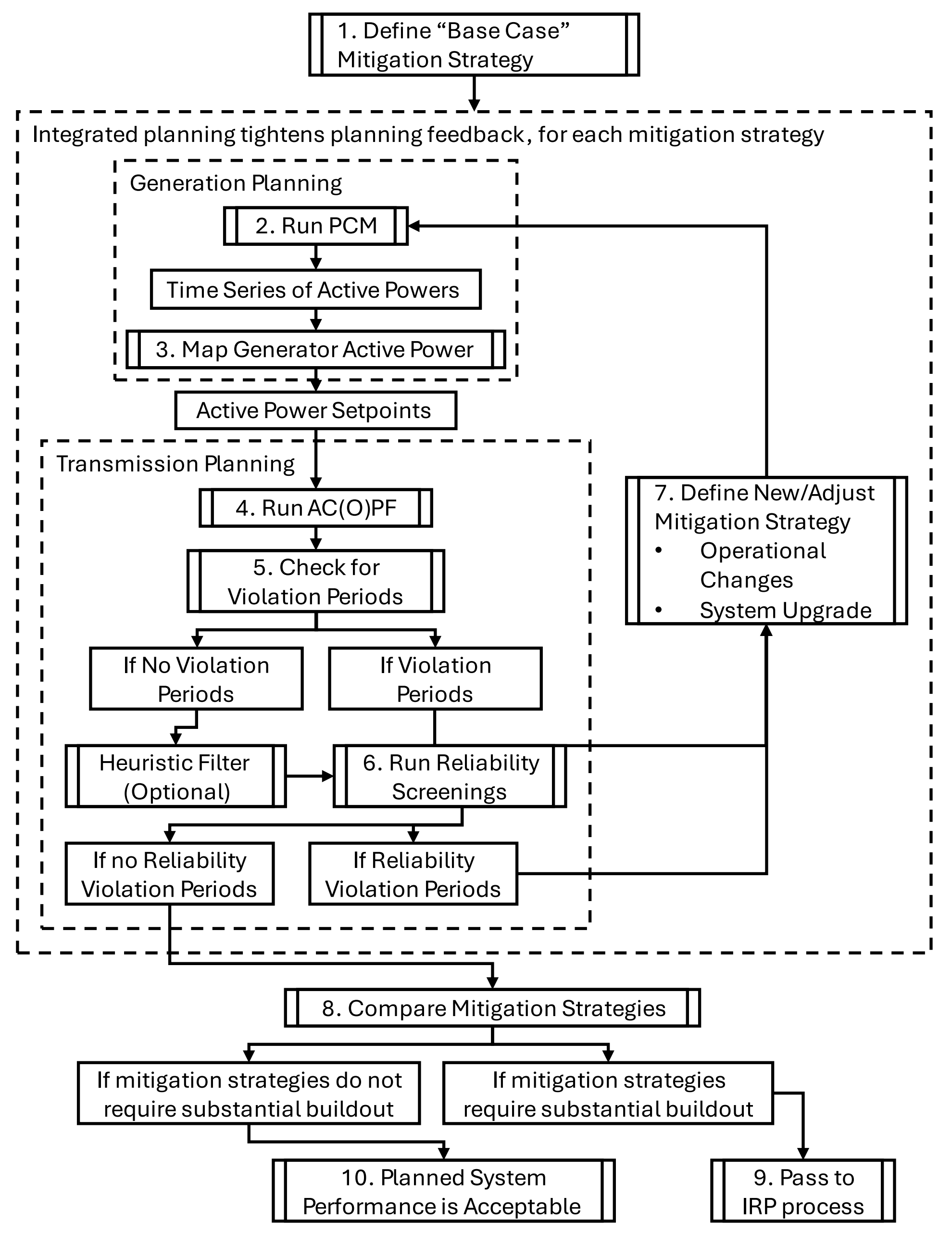
Run example:

Generation & Transmission


1. Define "Base Case" Mitigation Strategy

Integrated planning tightens planning feedback, for each mitigation strategy

Generation Planning

2. Run PCM

Time Series of Active Powers

3. Map Generator Active Power

Active Power Setpoints

Transmission Planning

4. Run AC(O)PF

5. Check for Violation Periods

If No Violation Periods

If Violation Periods

Heuristic Filter (Optional)

6. Run Reliability Screenings

If no Reliability Violation Periods

If Reliability Violation Periods

7. Define New/Adjust Mitigation Strategy
- Operational Changes
- System Upgrade

8. Compare Mitigation Strategies

If mitigation strategies do not require substantial buildout

If mitigation strategies require substantial buildout

10. Planned System Performance is Acceptable

9. Pass to IRP process

*Draft – please do not cite!

Walk, jog, run levels of integration applied to:

- Generation & Transmission
- Transmission & Distribution
- Customer & Distribution
- Generation & Distribution
- Customer & Generation

*Draft – please do not cite!

Technology that advances Integrated Planning

- Common data structures
- Application Programming Interfaces (APIs)
- Advanced modeling tools:
  - Time-series analysis
  - Detailed storage representation
  - Granular DER representation
- Planning tools that cover multiple modeling domains

*Draft – please do not cite!

The Value of Integrated Planning

- Lower costs
- Increased system resilience
- Streamlined processes
- Data integrity
- Synergistic outcomes
- Balancing competing objectives

*Draft – please do not cite!

Where to begin: pilot/demonstration projects

- Solves a real challenge the utility is facing.
- Is of sufficient scope to solve an important problem but not so large that it requires an entire planning team to perform the work.
- Can be performed concurrently with existing planning activities.
- Has a leader willing to champion the effort, who can overcome organizational and process challenges.
- Will provide lessons to the organization about process and change management needed to further advance integrated planning.
- Is driven by a regulatory mandate.

*Draft – please do not cite!

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encoord.com

info@encoord.com

Learn More

SRP’s Integrated System Plan Overview

ESIG Training with NARUC/NASEO/NASUCA

March 6, 2025

What is SRP?

- One of the nation’s largest public power utilities
- Provide sustainable, affordable, reliable water and power to more than **2 Million** people

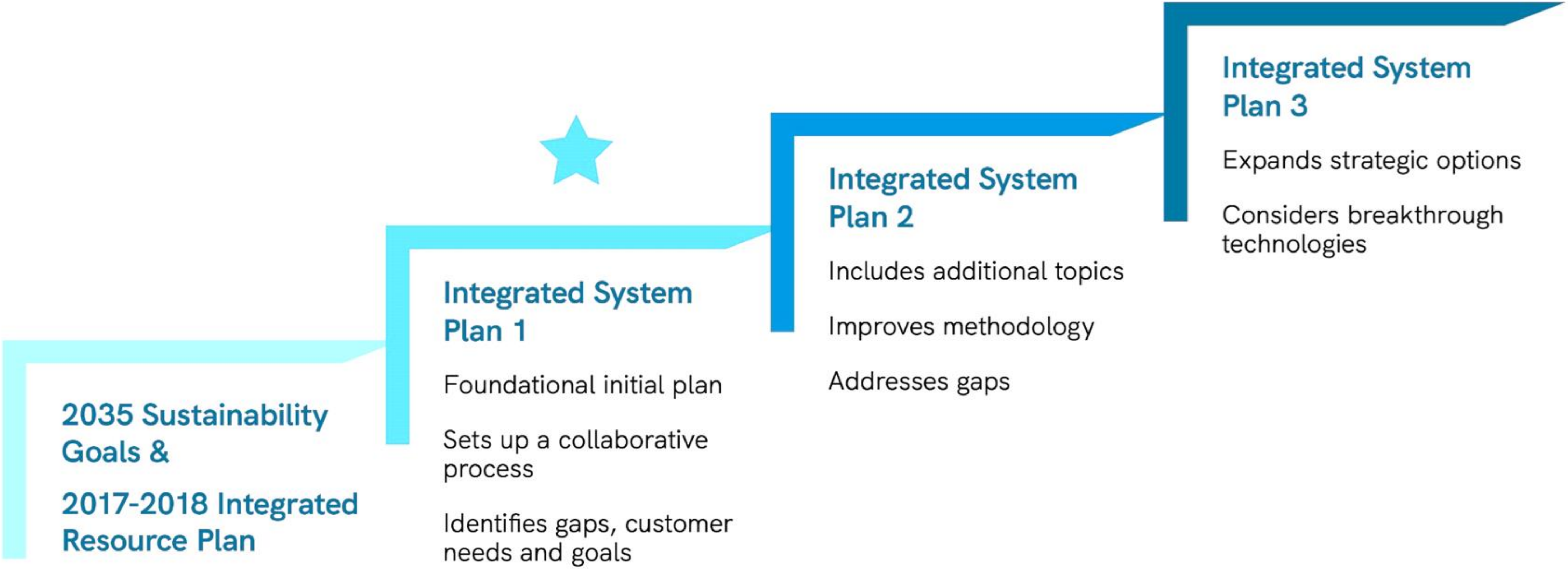
Mission

SRP serves our customers and communities by providing reliable, affordable and sustainable water and energy.

Overview of SRP’s ISP

- How we got started
- Scenarios and sensitivities
- Analysis and outcomes

Progression of the ISP



2035 Sustainability Goals &

2017-2018 Integrated Resource Plan

Integrated System Plan 1

Foundational initial plan

Sets up a collaborative process

Identifies gaps, customer needs and goals

Integrated System Plan 2

Includes additional topics

Improves methodology

Addresses gaps

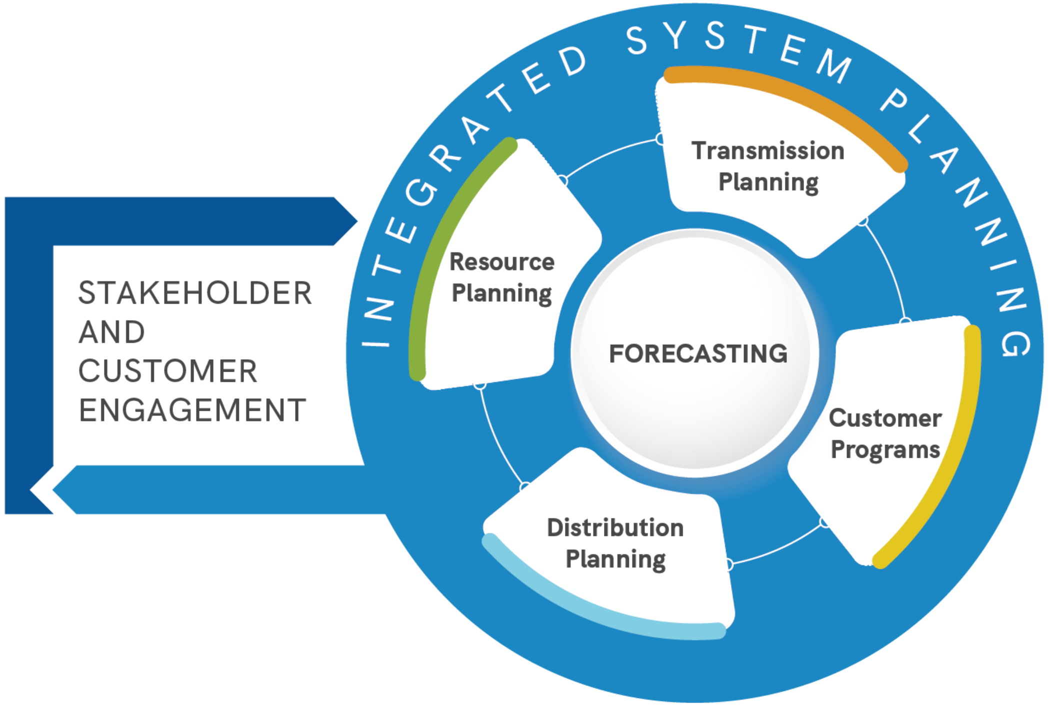
Integrated System Plan 3

Expands strategic options

Considers breakthrough technologies

Integrated System Plan

- Viable pathways for achieving SRP’s goals
- Costs, risks and tradeoffs of different strategic approaches
- Identifies system solutions that are viable across different future scenarios
- Informed by, and visible to stakeholders and customers



Resourcing and Alignment

Key Contributing Departments

- **Integrated System Planning & Support**
- **Forecasting & Load Research**
- **Resource Planning & Development**
- **Transmission Planning, Strategy & Develop**
- **Distribution Planning & Strategy**
- **Customer Programs**
- **Financial Planning & Analysis**
- **Pricing**
- **Strategic Research & Insights**

Coordination, Leadership Guidance, Analysis & Support

Consultants:

Energy+Environmental Economics

KEARNS & WEST

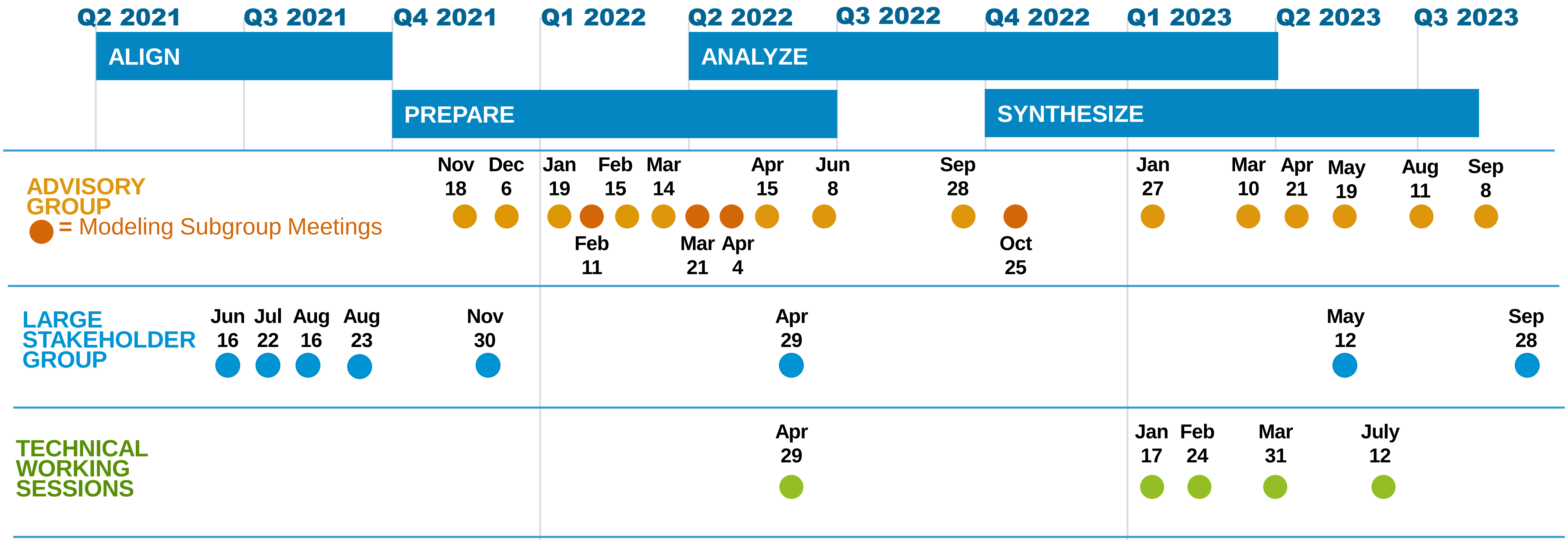
Leadership Guidance & Analysis Teams

Customer Research Team

Consultant:

bellomy

ISP Timeline



RESIDENTIAL CUSTOMER RESEARCH

Virtual Focus Groups

4

90-minute focus groups

Confirmation Survey

400

respondents

Choice Exercise Survey

1,011

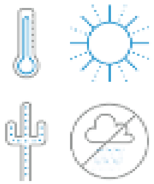
respondents

Scenarios and Sensitivities

Planning for Uncertainty

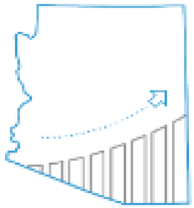
What if climate change makes the **desert** a **less favorable** place to live?

DESERT CONTRACTION



What happens if SRP experiences **strong load growth**, and **renewable costs** continue to **decline**?

CURRENT TRENDS

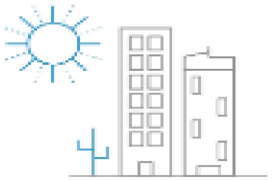


What if the U.S. passes increasingly **aggressive climate policy**?
What if renewables are cheaper and emerging tech available sooner?

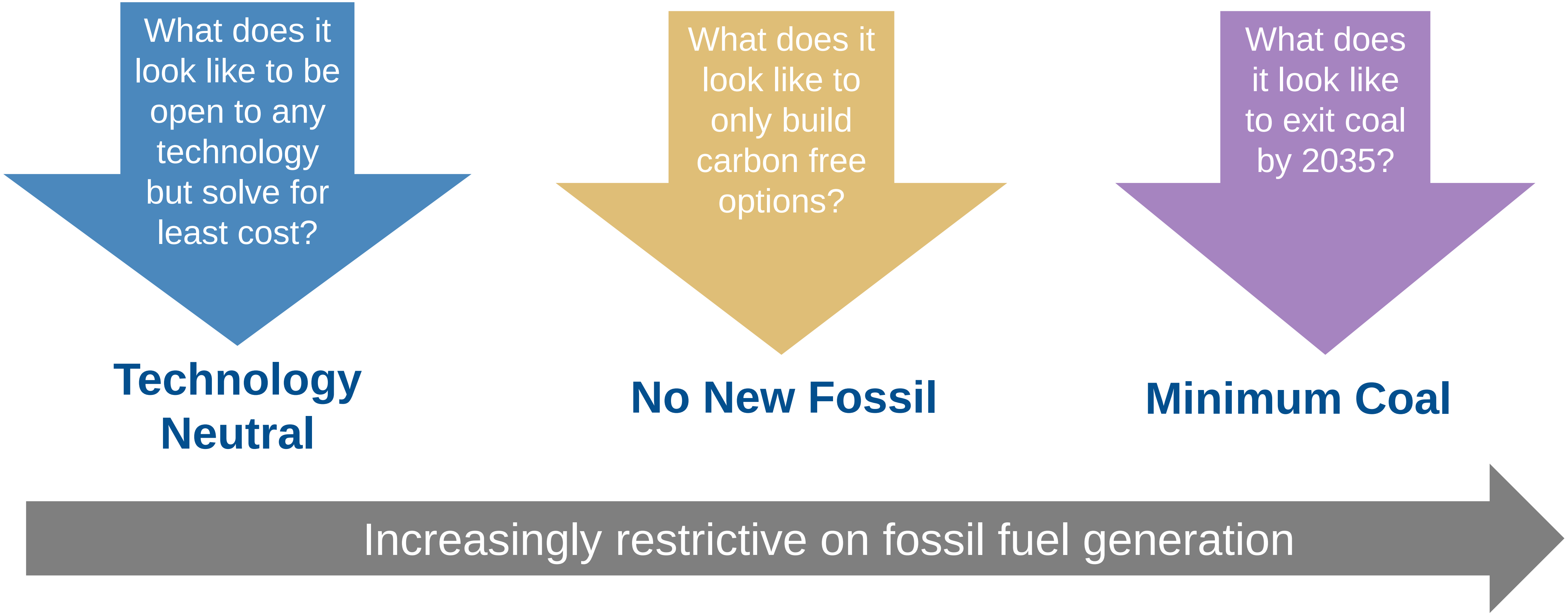
STRONG CLIMATE POLICY

What if Arizona becomes an employment and data hub resulting in **explosive load growth?**

DESERT BOOM



The Strategic Approaches in the ISP Study Plan



What does it look like to be open to any technology but solve for least cost?

Technology Neutral

What does it look like to only build carbon free options?

No New Fossil

What does it look like to exit coal by 2035?

Minimum Coal

Increasingly restrictive on fossil fuel generation

Scenario Analysis

Strategic Approaches

Scenarios	Technology Neutral	No New Fossil	Min. Coal
Desert Contraction	●	●	●
Current Trends	●	●	●
Strong Climate Policy	●	●	●
Desert Boom	●	●	●

12 Scenario-Based System Plans

+

30 Sensitivity Cases

Sensitivities

Sensitivies

High Demand Response

High Energy Efficiency

High Distributed Generation Adoption

Increased Load Management

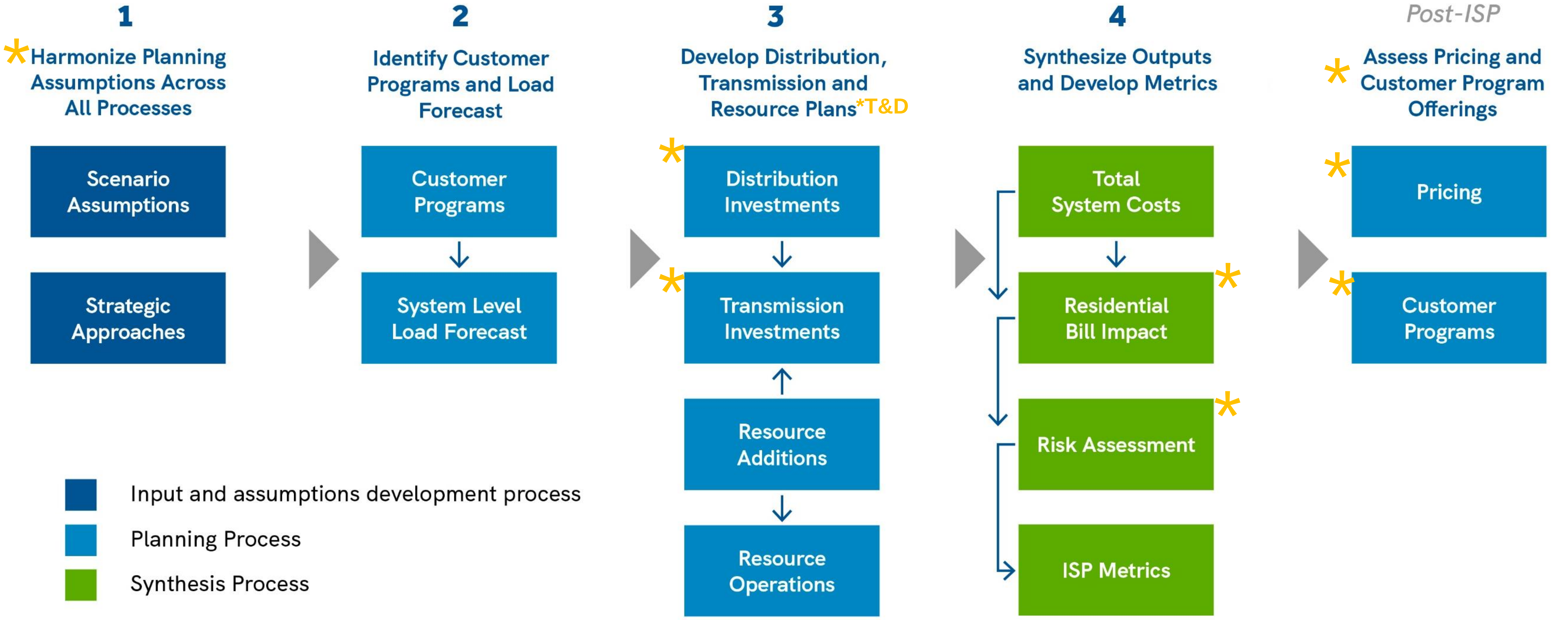
High, Low & Volatile Gas Prices

High & Low Technology Costs

Regional Diversity

Analysis and Outcomes

Modeling / Analytical Framework



1

*Harmonize Planning Assumptions Across All Processes

Scenario Assumptions

Strategic Approaches

2

Identify Customer Programs and Load Forecast

Customer Programs

System Level Load Forecast

3

Develop Distribution, Transmission and Resource Plans*T&D

*Distribution Investments

*Transmission Investments

Resource Additions

Resource Operations

4

Synthesize Outputs and Develop Metrics

Total System Costs

Residential Bill Impact*

Risk Assessment*

ISP Metrics

Post-ISP

*Assess Pricing and Customer Program Offerings

*Pricing

*Customer Programs

■ Input and assumptions development process

🟦 Planning Process

🟩 Synthesis Process

*** New for the ISP**

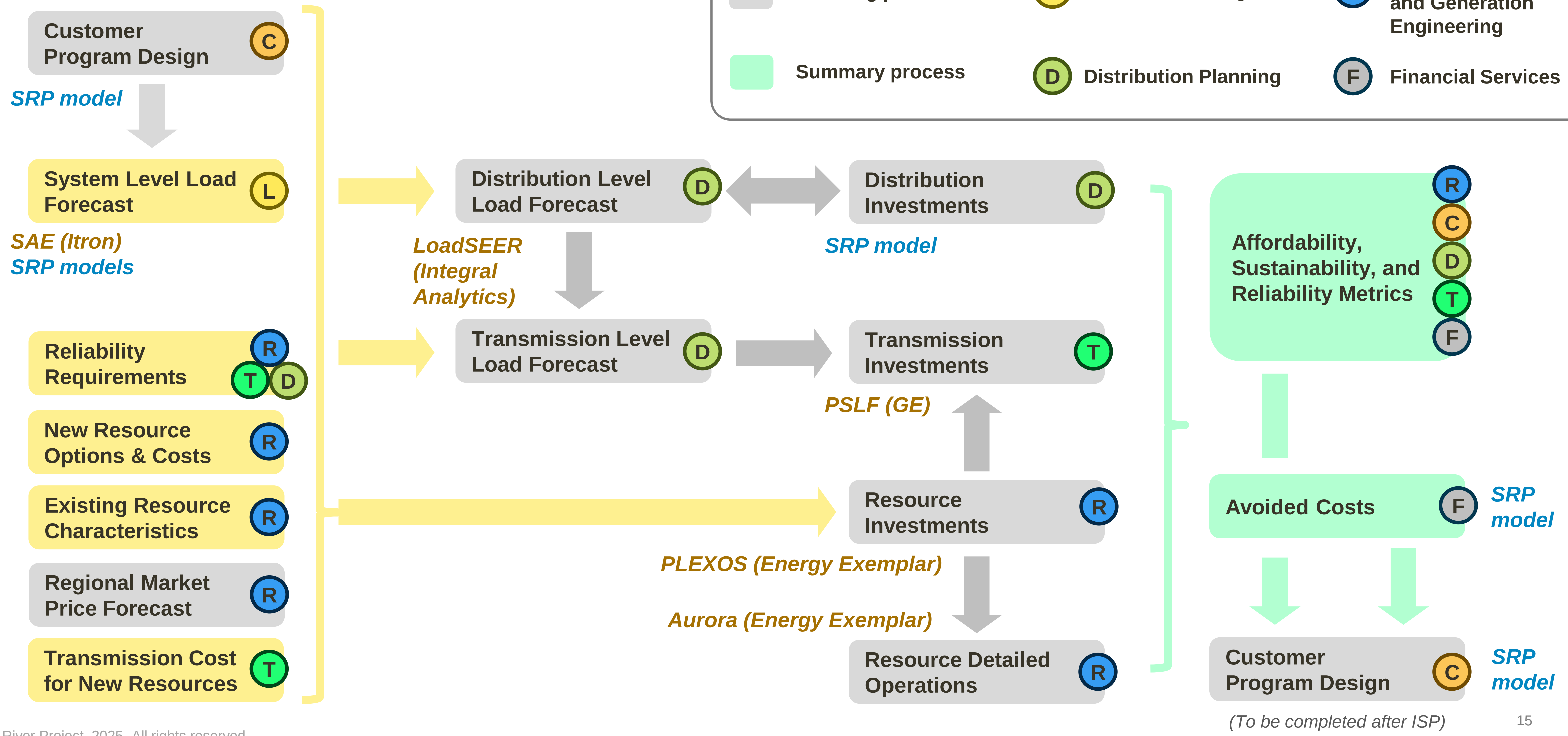
ISP Analytical Framework

SRP and third-party models

🟨 Input and assumptions development process
⬜ Planning process
🟩 Summary process

Ⓒ Customer Programs
Ⓛ Load Forecasting
Ⓓ Distribution Planning

Ⓣ Transmission Planning
Ⓡ Resource Planning, Resource Acquisition, and Generation Engineering
Ⓕ Financial Services



Customer Program Design Ⓒ

SRP model

System Level Load Forecast Ⓛ

SAE (Itron)
SRP models

Reliability Requirements Ⓡ Ⓣ Ⓓ

New Resource Options & Costs Ⓡ

Existing Resource Characteristics Ⓡ

Regional Market Price Forecast Ⓡ

Transmission Cost for New Resources Ⓣ

Distribution Level Load Forecast Ⓓ

LoadSEER (Integral Analytics)

Transmission Level Load Forecast Ⓓ

Distribution Investments Ⓓ

SRP model

Transmission Investments Ⓣ

PSLF (GE)

Resource Investments Ⓡ

PLEXOS (Energy Exemplar)

Aurora (Energy Exemplar)

Resource Detailed Operations Ⓡ

Affordability, Sustainability, and Reliability Metrics Ⓡ Ⓒ Ⓓ Ⓣ Ⓕ

Avoided Costs Ⓕ

SRP model

Customer Program Design Ⓒ

SRP model

(To be completed after ISP)

ISP Outputs

System Strategies – Long-term strategies for planning and operating the power system to achieve SRP’s 2035 goals.

***Balanced System Plan –** Illustrative path for SRP’s system that is consistent with the ISP System Strategies.

Actions – Set of near-term actions that the SRP team will complete following the publication of the ISP.

* **New for the ISP**

Integrated System Plan: System Strategies

Energy Investments

Invest in renewable resources and storage to manage fuel consumption, and drive carbon and water reductions.

Capacity Investments

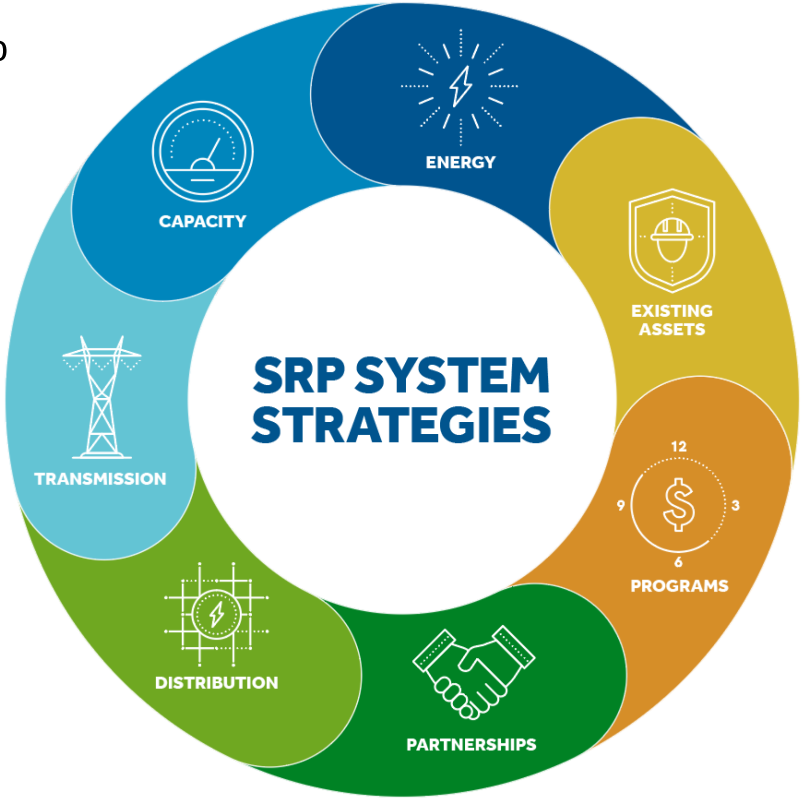
Invest in firm generation, including natural gas, to support reliability and manage affordability, while also supporting advancement of emerging firm technologies.

Proactive Transmission

Proactively plan to expand transmission infrastructure to enable generator interconnections and load growth.

Distribution Innovation

Ensure distribution grid readiness to maintain reliability and enable customer innovations to drive carbon reductions.



Strategic Investment & Reinforcement of Existing Assets

Reinforce and maximize value of existing infrastructure with strategic investments to manage affordability, and ensure future performance, grid security and resilience.

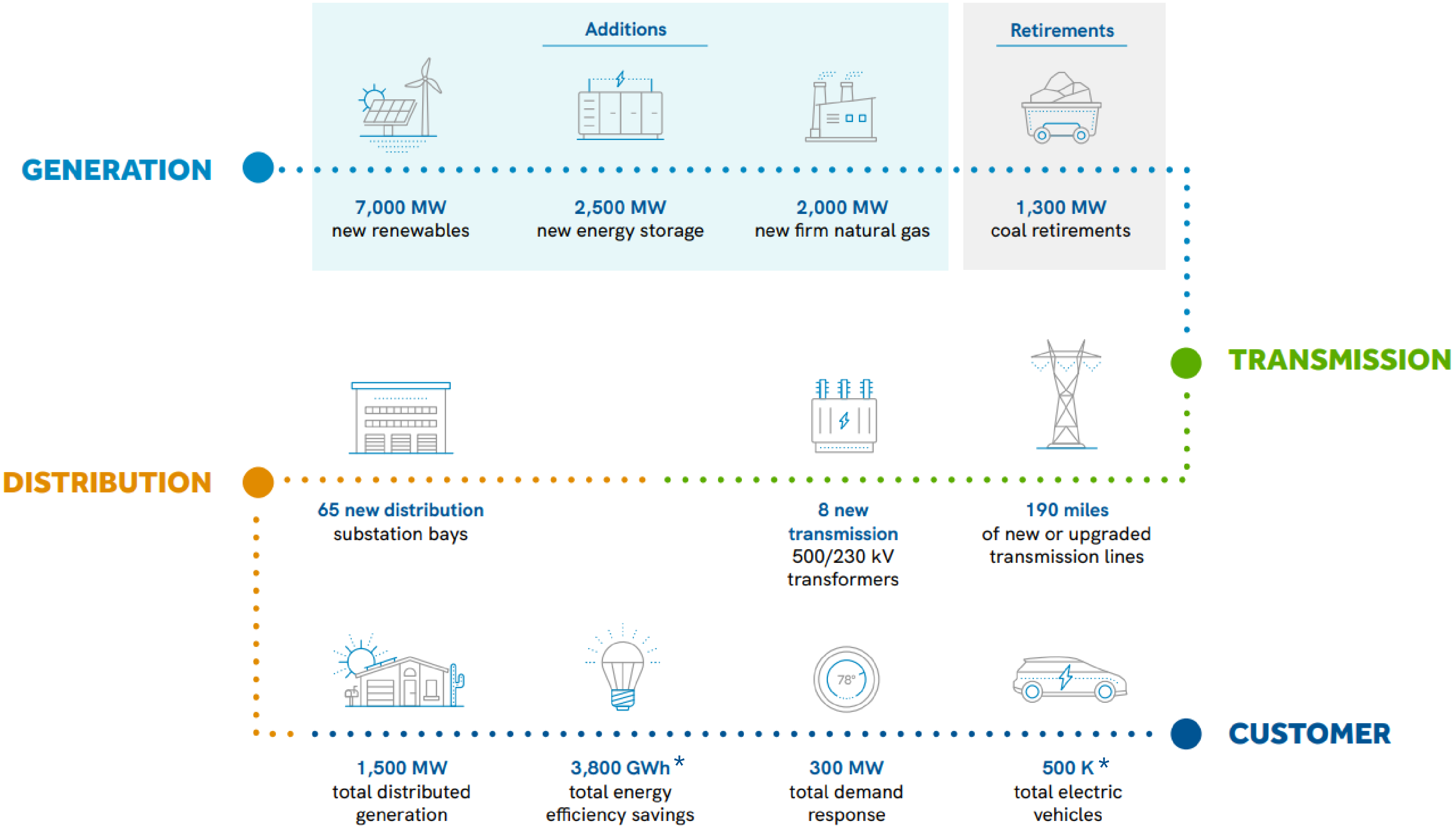
Evolution of Customer Programs & Pricing

Evolve pricing and customer programs to improve economy-wide carbon reductions and pace infrastructure development, while recognizing customers' diverse needs.

Partnerships & Suppliers

Explore partnerships, supply chain and development solutions that manage cost and availability to meet the pace of transformation.

Balanced System Plan (2035)



GENERATION

Additions

7,000 MW
new renewables

2,500 MW
new energy storage

2,000 MW
new firm natural gas

Retirements

1,300 MW
coal retirements

TRANSMISSION

190 miles
of new or upgraded transmission lines

8 new transmission
500/230 kV transformers

DISTRIBUTION

65 new distribution
substation bays

CUSTOMER

1,500 MW
total distributed generation

3,800 GWh *
total energy efficiency savings

300 MW
total demand response

500 K *
total electric vehicles

*Targets for 2035 have been adjusted with new goals

ISP Actions

Customer Grid Focused Actions

1. Residential Time-of-Use Pilot
2. Time-of-Use Evolution
3. Customer Program Refresh
4. EV Managed Charging Roadmap
5. Electrification
6. Distribution Enablement Roadmap

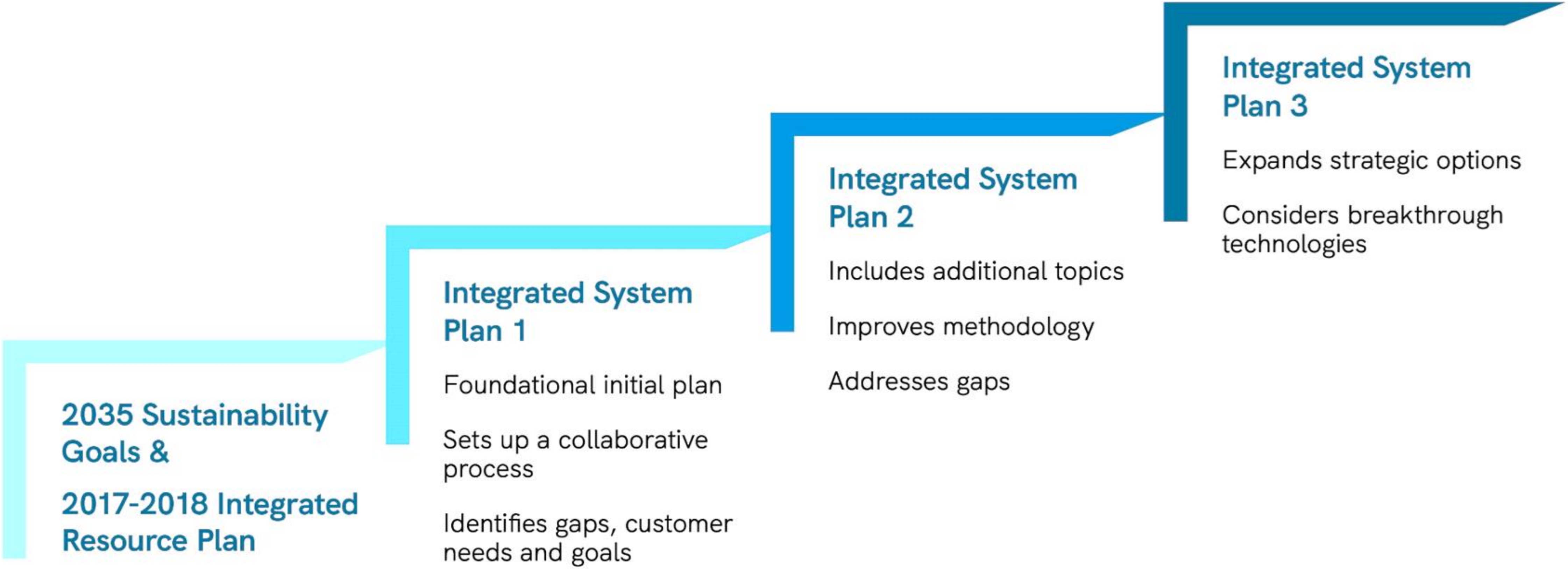
Bulk Grid Focused Actions

7. Resource Request for Proposals/Information
8. Coal Transition Plan
9. Proactive Siting
10. Regional Transmission

ISP Results: System Investments Needed at a Rapid Pace

- SRP will need to **double** if not **triple** resource capacity in the **next decade** to serve customers while achieving reliability and sustainability goals. This is an unprecedented pace.
- New renewables **combined with** firm generation capacity are part of a least-cost portfolio, even under a wide range of gas price and technology cost sensitivities.
- Without **new firm generation capacity**, the system cannot satisfy reliability requirements under a high load growth scenario.
- **Hundreds of miles** of new or upgraded transmission lines and nearly double the number of 500/230 kV transformers could be needed relative to today. Location matters.
- SRP will need to **evolve programs and price plans** to shift consumer behavior and to further educate customers on when to consume and when to conserve energy.

Progression of the ISP



2035 Sustainability Goals &

2017-2018 Integrated Resource Plan

Integrated System Plan 1

Foundational initial plan

Sets up a collaborative process

Identifies gaps, customer needs and goals

Integrated System Plan 2

Includes additional topics

Improves methodology

Addresses gaps

Integrated System Plan 3

Expands strategic options

Considers breakthrough technologies

thank you!

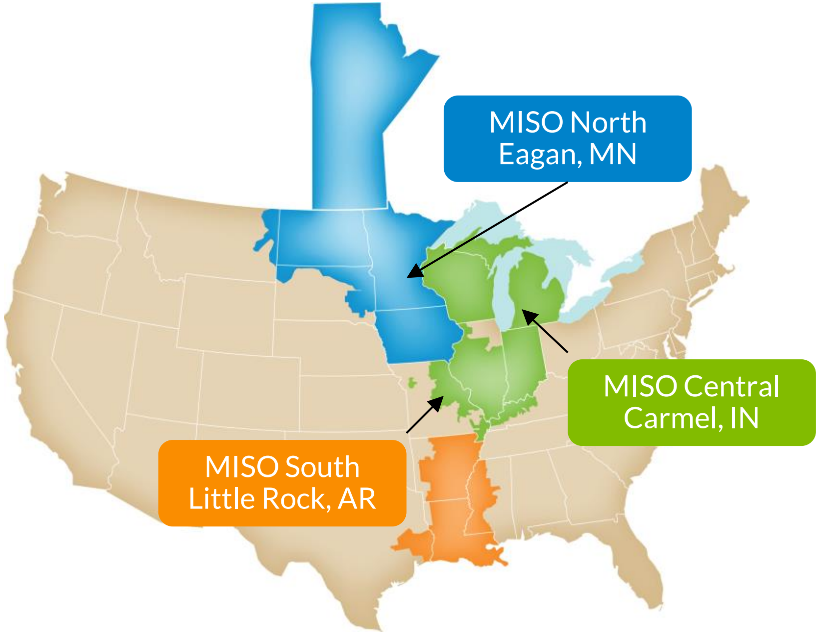
Tools, Data and Processes for Integrated Planning

Armando Figueroa Acevedo (MISO)

NARUC

March 6, 2025

MISO is an independent, not-for-profit, member-based organization responsible for keeping the power flowing across the region reliably and cost-effectively.



MISO's reliability footprint and regional control center locations

MISO KEY FACTS

Area Served	15 U.S. States and Manitoba, Canada
Population Served	45 Million
Transmission Line	77,000 Miles
Generating Units	> 1,447
Record Demand	127.1 GW 7/20/2011
Wind Peak	25.6 GW 1/12/2024
Solar Peak	10.4 GW 2/17/2025
Members	59 Transmission Owners
	143 Non-transmission Owners
Market Participants	> 500
Market Transactions	> $40 billion
Carbon Reduction	Approximately 32% since 2014

MISO's primary responsibilities: manage the flow of electricity, facilitate the energy market and plan the grid of the future set the foundation for its core business operation

System Planning

Transmission Planning

- Cost Allocation & Competitive Transmission
- Expansion Planning
- Economic & Policy Planning

Resource Planning

- Resource Utilization
- Resource Adequacy

Markets & Operations

Market Operations

- Market Administration
- Operations Engineering
- Operations Risk Management
- Settlements
- Operations Planning

System Operations

- Reliability Coordination
- Operations Management & Support

Markets & Digital Strategy

Market & Grid Strategy

- Market Design & Development
- Market Evaluation
- Demand Response

Market & Grid Research

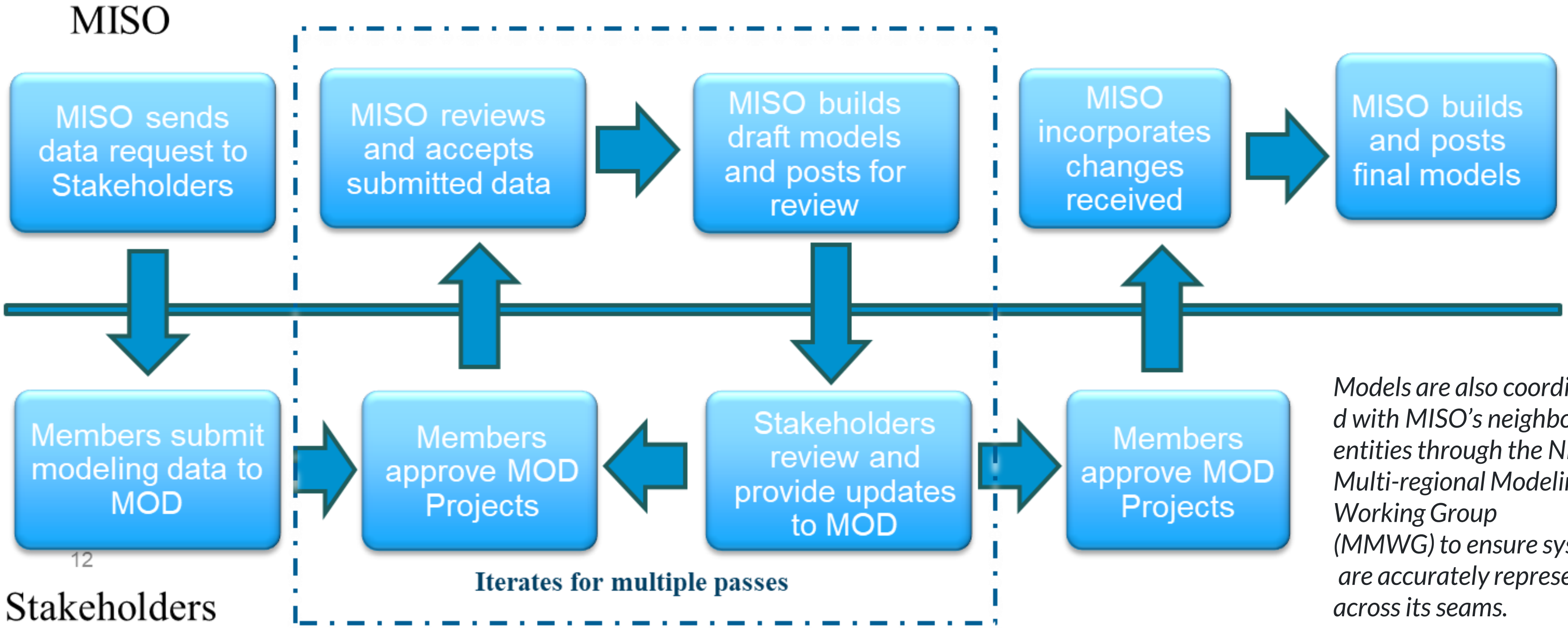
- Research & Development
- Strategic Initiatives & Assessments
- Strategic Ventures

Legal FERC & NERC regulatory and compliance efforts, Tariff management, Federal administration and congressional issues

Human Resources, Finance, Digital Technology, Security, Data, Customer Experience, External Affairs

☐ Focus of this presentation

MISO develops annual models using stakeholder data for a variety of near-term and long-term planning studies; models represent a 10-year planning horizon. The modeling process runs from September to the following August.



MISO

MISO sends data request to Stakeholders

MISO reviews and accepts submitted data

MISO builds draft models and posts for review

MISO incorporates changes received

MISO builds and posts final models

Members submit modeling data to MOD

Members approve MOD Projects

Stakeholders review and provide updates to MOD

Members approve MOD Projects

12

Stakeholders

Iterates for multiple passes

Models are also coordinated with MISO's neighboring entities through the NERC Multi-regional Modeling Working Group (MMWG) to ensure systems are accurately represented across its seams.

MOD: model on demand

MISO models and tools used in Transmission Planning processes

Model	Modeling Tool
Power Flow	
• Current year, 1-year, 2-year, 5-year and 10-year out representations • Peak models for each season • Shoulder models • Light load models • Minimum load model • High and average renewable scenarios	• Siemens PTI Model on Demand (MOD) database • Siemens PSS/E for Power flow and Dynamics
Dynamics	
• 1-year, 2-year, 5-year and 10-year out representation • Summer and Winter Peak • Summer Shoulder and Spring Light Load • High and Average renewable scenarios	• Siemens PTI Model on Demand (MOD) database • Siemens PSS/E for Power flow and Dynamics • Powertech DSATools for Dynamics

MISO models and tools used in Resource Planning processes

Model	Modeling Tool
Resource Adequacy	
• Current year, 1-year, 6-year, 10-year and 20-year out representations • Generating availability Data System (GADS) data • Wide range of hourly load and renewables shapes • Generation forced and planned outages hourly profiles • Cold-weather outages hourly profiles • Load forecast uncertainty	• SERVM (Astrapé) for base business • PLEXOS (Energy Exemplar) for forward looking assessments
Resource Forecasting	
• 1-20 year out representations • Based on members plans, state goals, state/federal policies, reliability, and economics • Based on average system conditions (e.g., 2018 weather year)	• PLEXOS (Energy Exemplar)

Examples of MISO studies and assessments related to System Planning

2024 Regional Resource Assessment

A RELIABILITY IMPERATIVE REPORT

JANUARY 2025

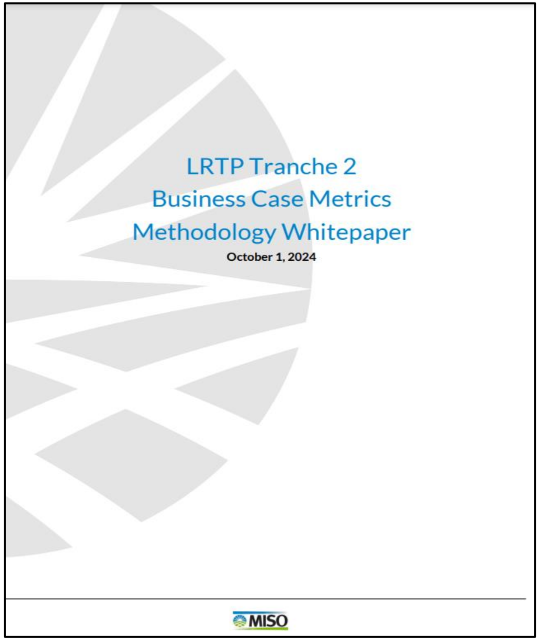
HIGHLIGHTS

- Members and states may need to add capacity at 17GW/year — over three times the recent average of 4.7GW/year — for 20 years to reliably meet future demand and policy goals. Achieving this pace will require overcoming supply chain, permitting, labor and interconnection queue delays.
- Under MISO's new Direct Loss of Load (DLOL) accreditation methodology, thermal resources will continue to provide the bulk of the region's accredited capacity even while RRA modeling indicates that lower-accredited wind and solar will account for 62% of installed capacity and 87% of the region's energy by 2043.
- Greater reliance on solar power is shifting the region's net load ramp from morning to evening, which is increasing the region's 1-hour ramp need by 2-3 times by the early 2030s.

misoenergy.org

https://cdn.misoenergy.org/2024%20RRA%20Report_Final676241.pdf

Resource Planning



LRTP Tranche 2
Business Case Metrics
Methodology Whitepaper
October 1, 2024

https://cdn.misoenergy.org/LRTP%20Tranche%202%20Business%20Case%20Metrics%20Methodology%20Whitepaper633738.pdf

Transmission Planning

MISO's
Renewable Integration
Impact Assessment
(RIIA)

SUMMARY REPORT – FEBRUARY 2021

misoenergy.org

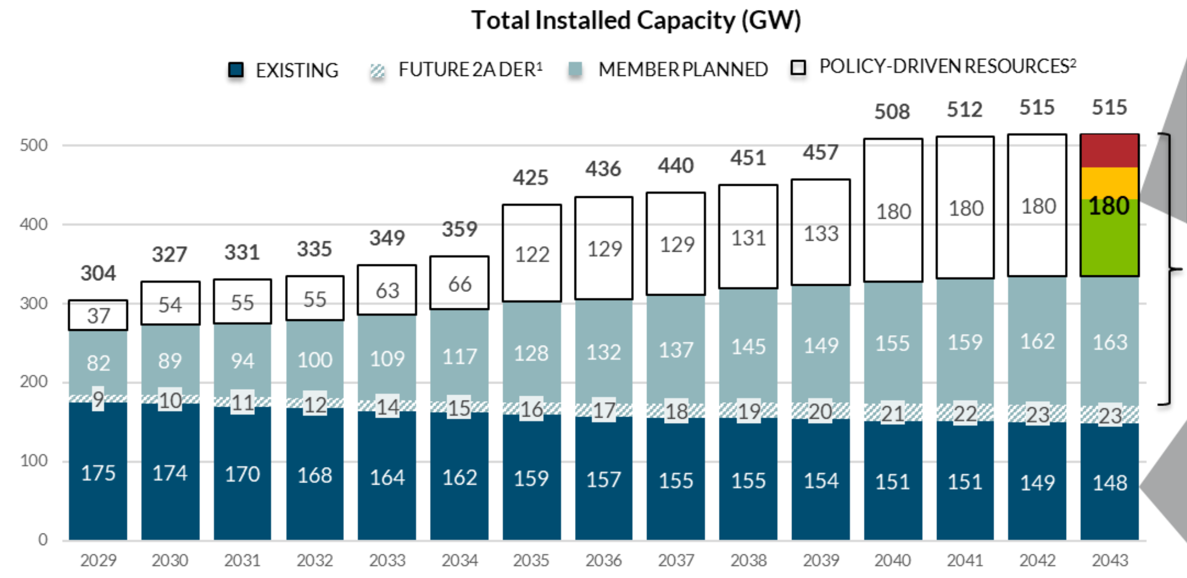
https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf

Resource & Transmission Planning

Regional Resource Assessment (RRA)

MISO's Regional Resource Assessment (RRA) provides a collective view of the evolution of members' resource plans and aims to provide insights and implications that help members, states and MISO prepare for the energy transition

Total Installed Capacity (GW)



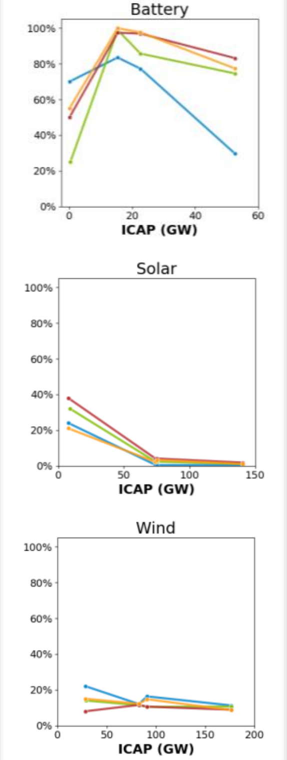
180 GW RRA simulation-built **battery**, **solar** and **wind** selected to meet member & state policy objectives.

343 GW

Between 2029 – 2043

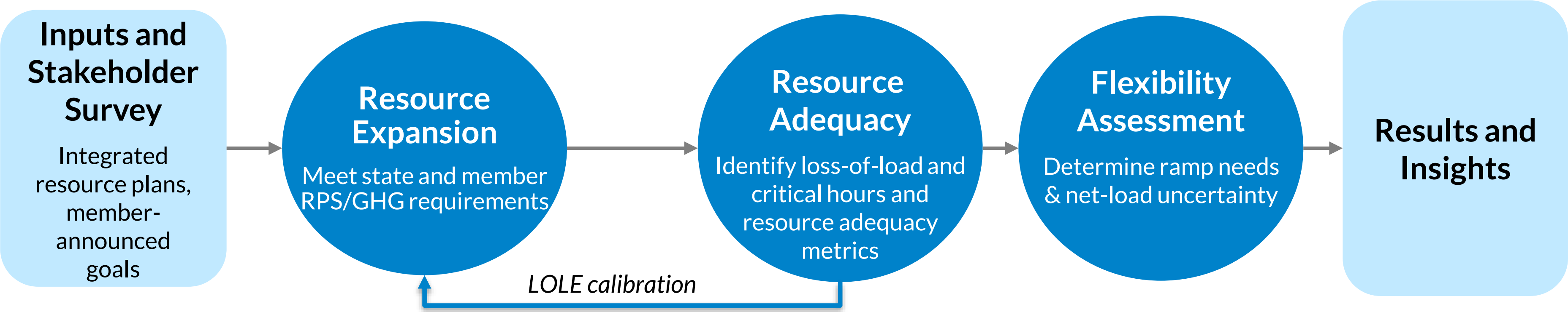
- 27 GW thermal retirements
- 11 GW thermal additions

Accreditation forecast



☑ Resource Planning ☐ Transmission Planning ☑ Probabilistic ☐ Co-optimization G&T

How were tools, data and processes integrated in RRA?



Inputs and Stakeholder Survey

Integrated resource plans, member-announced goals

Resource Expansion

Meet state and member RPS/GHG requirements

Resource Adequacy

Identify loss-of-load and critical hours and resource adequacy metrics

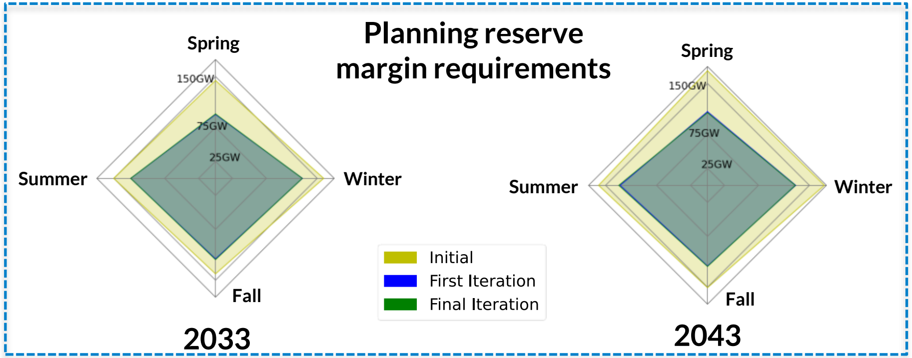
Flexibility Assessment

Determine ramp needs & net-load uncertainty

Results and Insights

LOLE calibration

Tool: PLEXOS (Energy Exemplar)



Planning reserve margin requirements

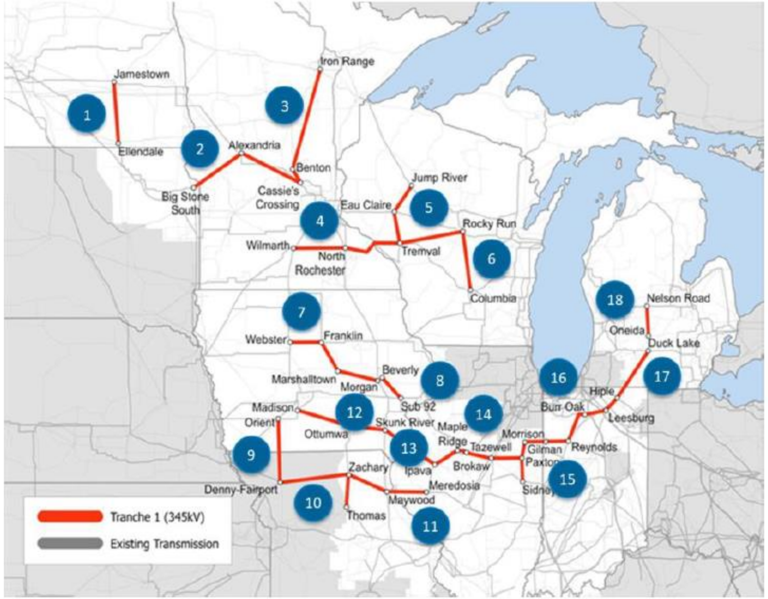
- Integrated resource expansion and resource adequacy allows for the simultaneous evaluation of investment decisions, policies and RA
- Differences in PRMR between iterations highlight the importance of including LOLE assessments in expansion planning models
- No differences between the first and final iterations demonstrate convergence in both processes

☑ Resource Planning ☐ Transmission Planning ☑ Probabilistic ☐ Co-optimization G&T

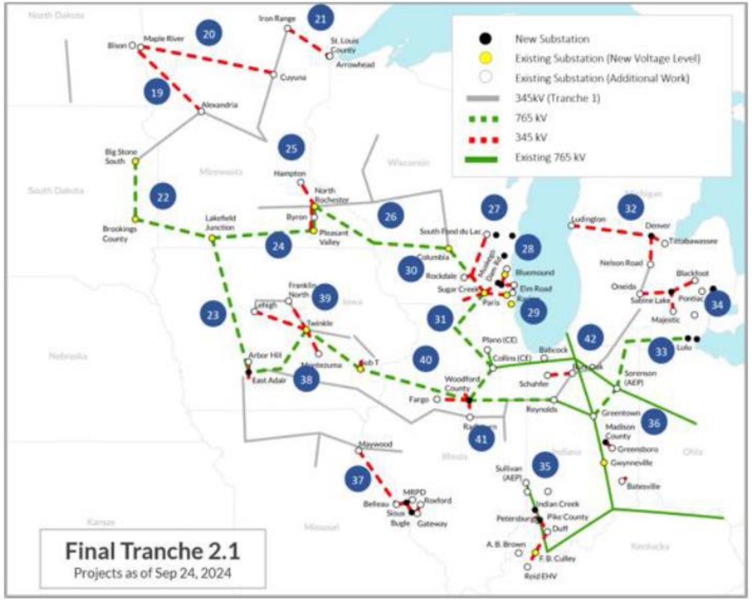
Long-range transmission planning (LRTP)

MISO's Long-range transmission planning ensures the values of a reliable and efficient grid are achieved under a range of Futures and establishes a "transmission roadmap" for this long-term horizon that will be the foundation to drive future investment decisions.

Tranche 1 Portfolio

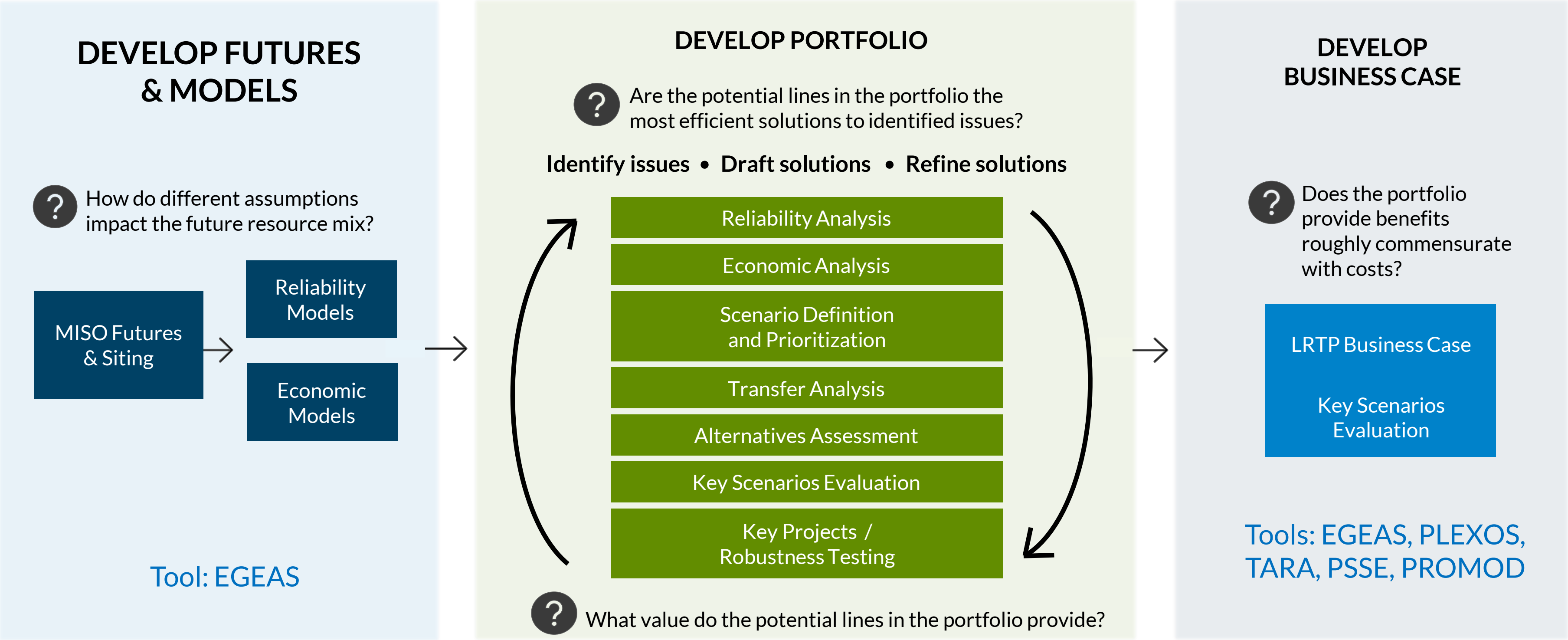


Tranche 2.1 Portfolio



☑ Resource Planning ☑ Transmission Planning ☑ Probabilistic ☐ Co-optimization G&T

How were tools, data and processes integrated in LRTP?



DEVELOP FUTURES & MODELS

? How do different assumptions impact the future resource mix?

MISO Futures & Siting → Reliability Models / Economic Models →

Tool: EGEAS

DEVELOP PORTFOLIO

? Are the potential lines in the portfolio the most efficient solutions to identified issues?

Identify issues • Draft solutions • Refine solutions

- Reliability Analysis
- Economic Analysis
- Scenario Definition and Prioritization
- Transfer Analysis
- Alternatives Assessment
- Key Scenarios Evaluation
- Key Projects / Robustness Testing

? What value do the potential lines in the portfolio provide?

→

DEVELOP BUSINESS CASE

? Does the portfolio provide benefits roughly commensurate with costs?

LRTP Business Case

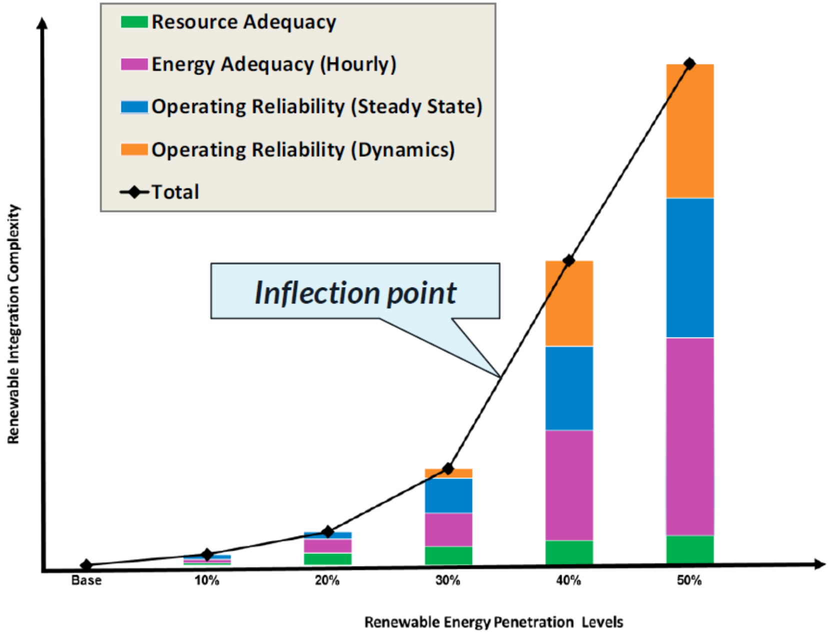
Key Scenarios Evaluation

Tools: EGEAS, PLEXOS, TARA, PSSE, PROMOD

☑ Resource Planning ☑ Transmission Planning ☑ Probabilistic ☐ Co-optimization G&T

Renewable Integration Impact Assessment (RIIA)

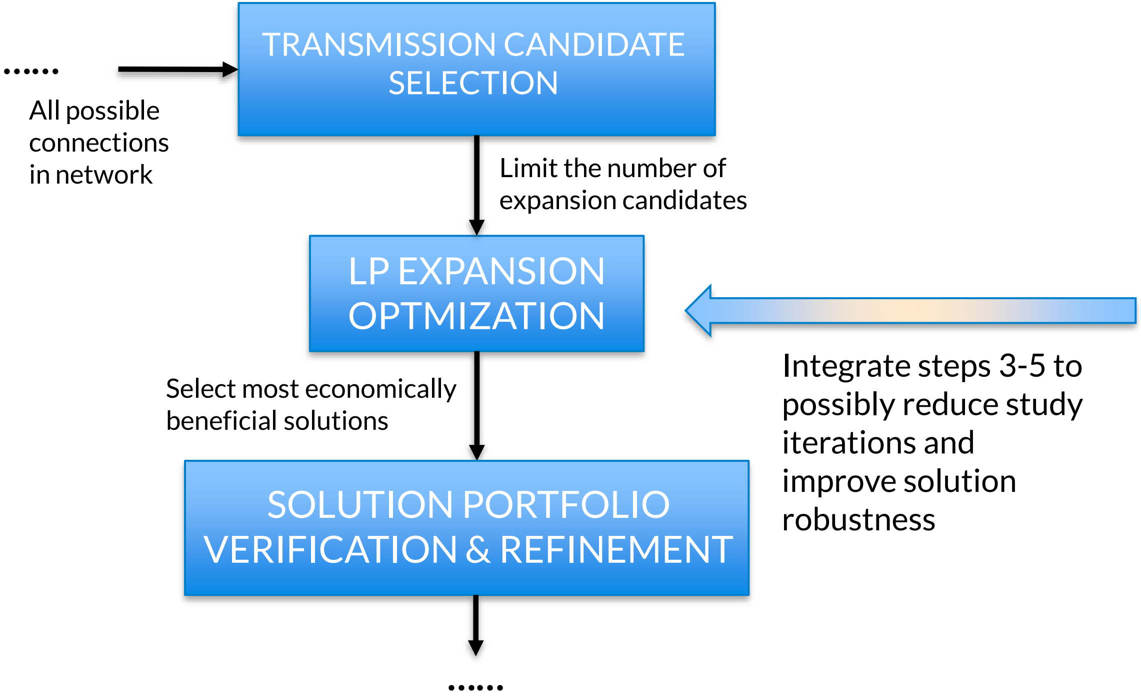
MISO's Renewable Integration Impact Assessment (RIIA) indicates integration complexity increasing sharply beyond 30% renewable penetration



1. Risk of losing load compresses into a small number of hours and shifts into the evening
2. Existing infrastructure becomes inadequate for fully accessing the diverse resources across the MISO footprint
3. Regional energy transfer increases in magnitude and becomes more variable leading to a need for increased extra- high-voltage line thermal capabilities
4. Power delivery from low short circuit areas may need transmission technologies equipped with dynamic support capabilities
5. Frequency response is stable up to 60% instantaneous renewable penetration, but may require additional planned headroom beyond
6. Grid-technology-needs evolve as renewable penetration increases, leading to an increased need for integrated planning
7. Diversity of technologies and geography improves the ability of renewables to serve load

☑ Resource Planning ☑ Transmission Planning ☑ Probabilistic ☑ Co-optimization G&T

RIIA implemented co-optimization techniques to explore interdependencies between resource and transmission planning processes



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All possible connections in network

TRANSMISSION CANDIDATE SELECTION

Limit the number of expansion candidates

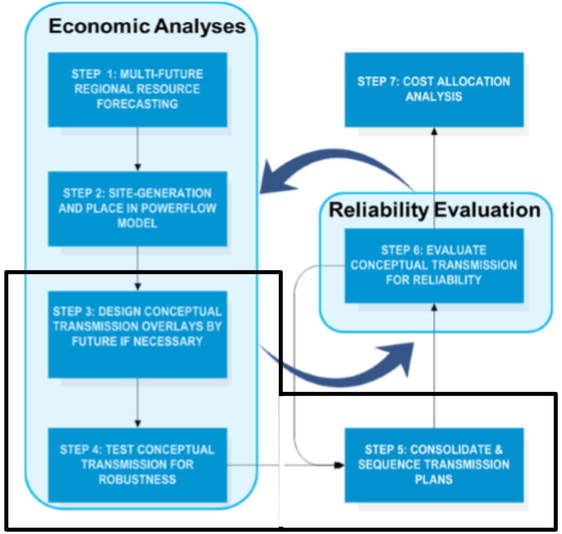
LP EXPANSION OPTMIZATION

Select most economically beneficial solutions

SOLUTION PORTFOLIO VERIFICATION & REFINEMENT

……

Integrate steps 3-5 to possibly reduce study iterations and improve solution robustness



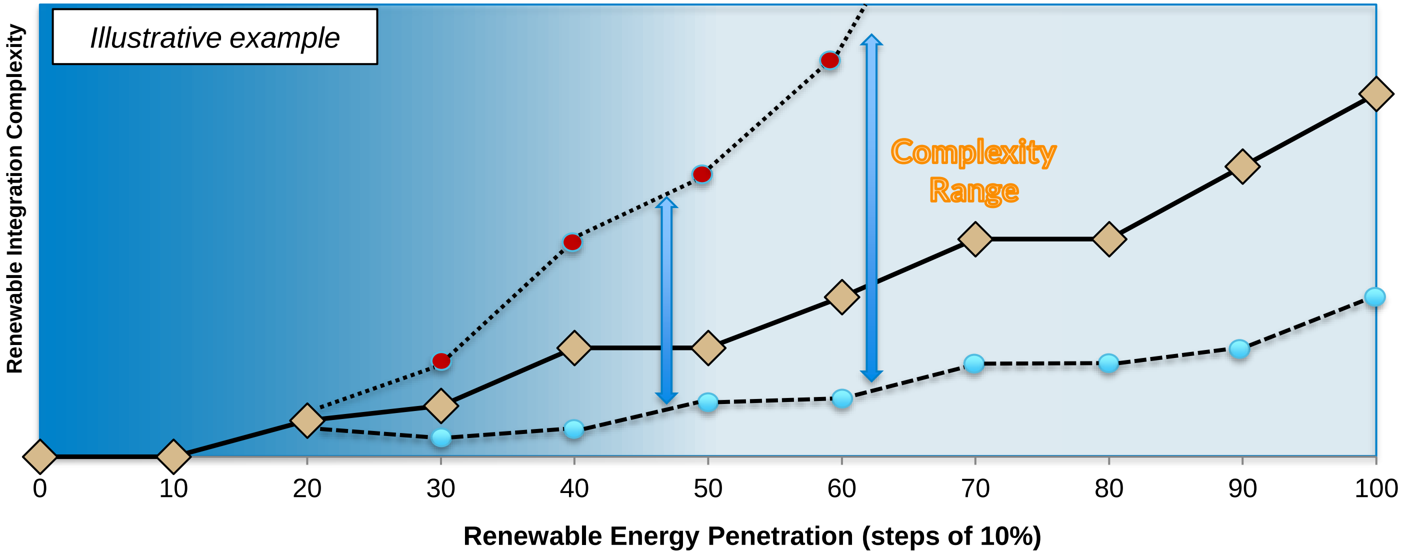
Traditional MISO 7-step Value-based Planning Process

Tool: PLEXOS (Energy Exemplar)

☑ Resource Planning ☑ Transmission Planning ☑ Probabilistic ☑ Co-optimization G&T

The integration of resource adequacy, steady state, and dynamics modeling features within the co-optimized expansion model provided useful insights about the complexity range

Co-optimize among various system planning perspective to find holistic solution; explore and approach the lower bound of renewable integration complexity, with consideration of …



Resource mix
Siting location & MW
Overbuild

Storage
Operation decision
Transmission expansion

Thermal & Voltage
Losses
Contingency

☑ Resource Planning ☑ Transmission Planning ☑ Probabilistic ☑ Co-optimization G&T

Questions?

Power System Optimizer

POLARIS
SYSTEMS OPTIMIZATION

Integrated Planning of Transmission and Generation

Optimizing Tools, Data and Processes

MAIN MESSAGE

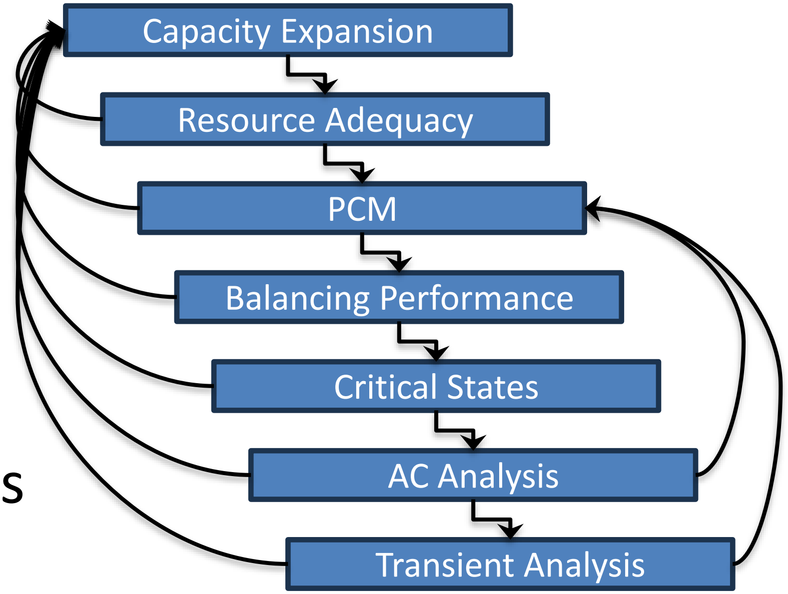
Tools exist or can quickly be developed to support integrated planning;

… however, business processes are outdated and based on incorrect assumptions about what is possible.

As a result, current planning efforts

1. **Provide an inaccurate guide to future conditions**
2. **Are too hard to execute**

Integrated Planning



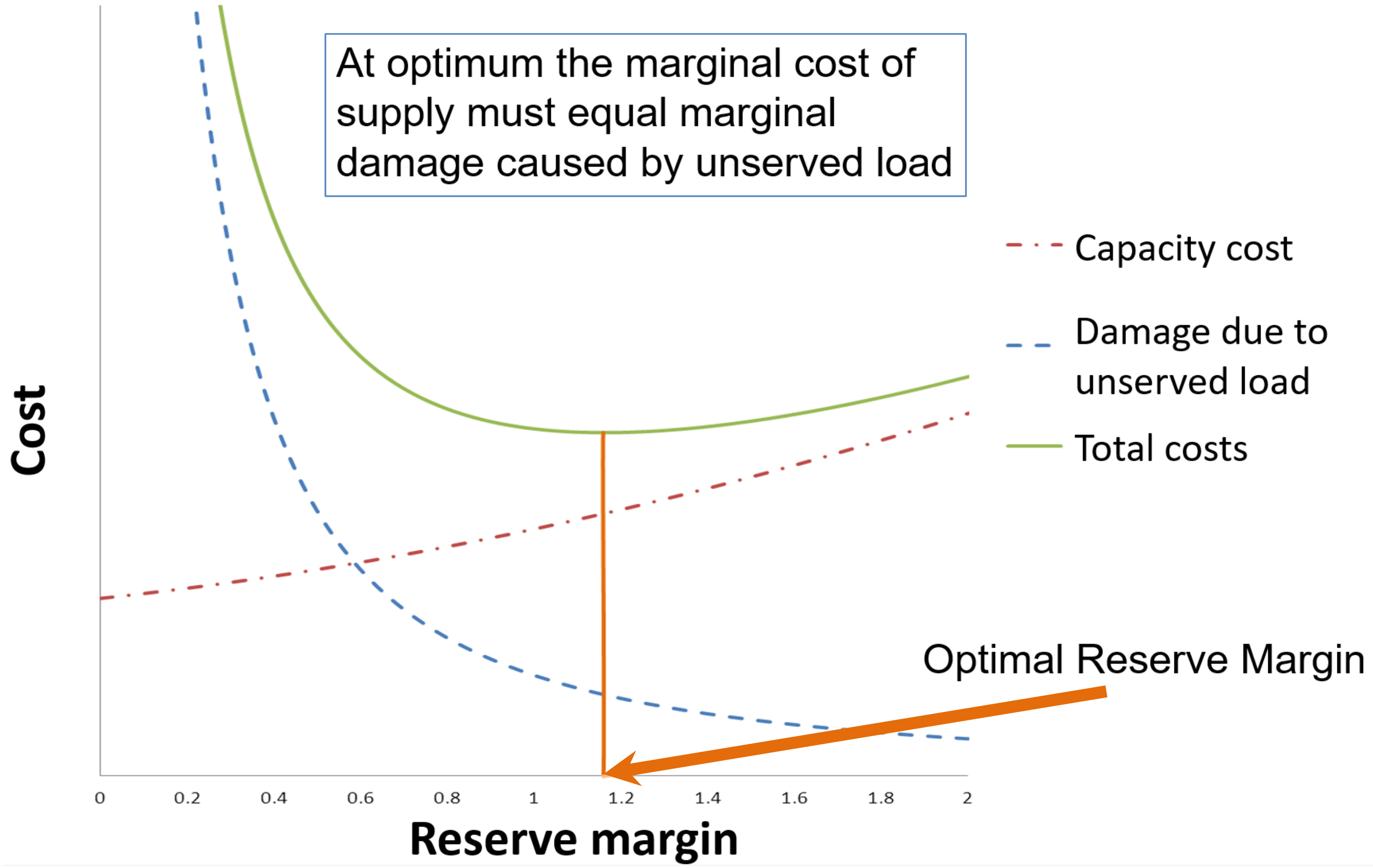
Drivers:

- Cheap solar and wind generation
- Cheap batteries (but not cheap enough)
- Public policy

Challenges:

- Loss of ancillary services if synchronous generators replaced by IBRs without comparable services
- Lack of load participation
- Missing/inefficient incentives for reliability services
- Inaccurate and difficult study processes
- Identification and allocation of costs and benefits
- Uncertainty (policy, climate, public)

Determining the Optimal Level of Installed Capacity

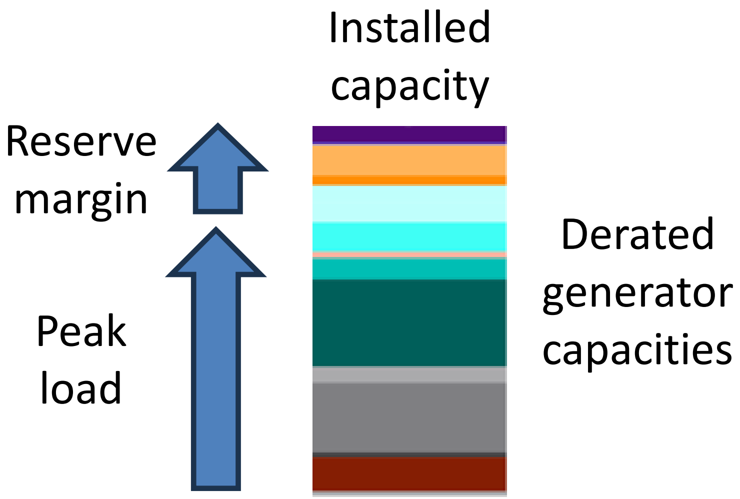


At optimum the marginal cost of supply must equal marginal damage caused by unserved load

Optimal Reserve Margin

Traditional Approach

- Reserve margin based on heuristic metrics, not economics
- Stack rated generation capacity to meet Reserve Margin
- Limited accounting of system flexibility and needs
- Ignore transmission, resource details, adjacent systems, …



Incorrect Assumptions

Assumptions about capacity expansion (CX) and resource adequacy (RA):

- **Need capacity reserve margins and resource capacity factors (or ELCC)**
    - Arbitrary and administratively determined needs and capabilities
    - Inaccurate beyond the near-term (e.g., next year)
    - Only known after capacity expansion decisions have been made
- **Can’t handle detailed system models**
    - Transmission modeled using zonal models
    - Lack of operational detail: Costs, constraints, ancillary services
- **Can’t model long-duration storage without modeling full chronology**
    - Can’t co-optimize LDS with other system resource

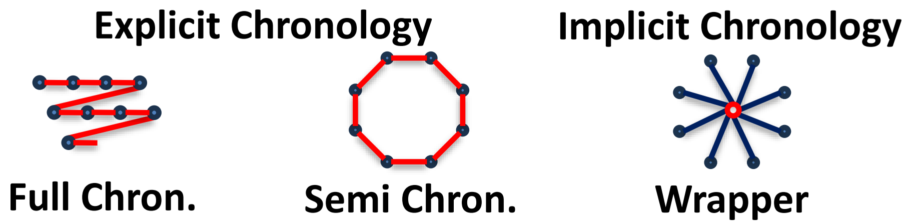
Overcoming Limitations

Capacity Expansion (CX) planning is the foundation of most integrated planning studies: What, where and when to build new or retire old.

- Generation, transmission, distribution, adjacent energy systems

A fundamental challenge of CX is the long horizon of time considered, typically decades into the future.

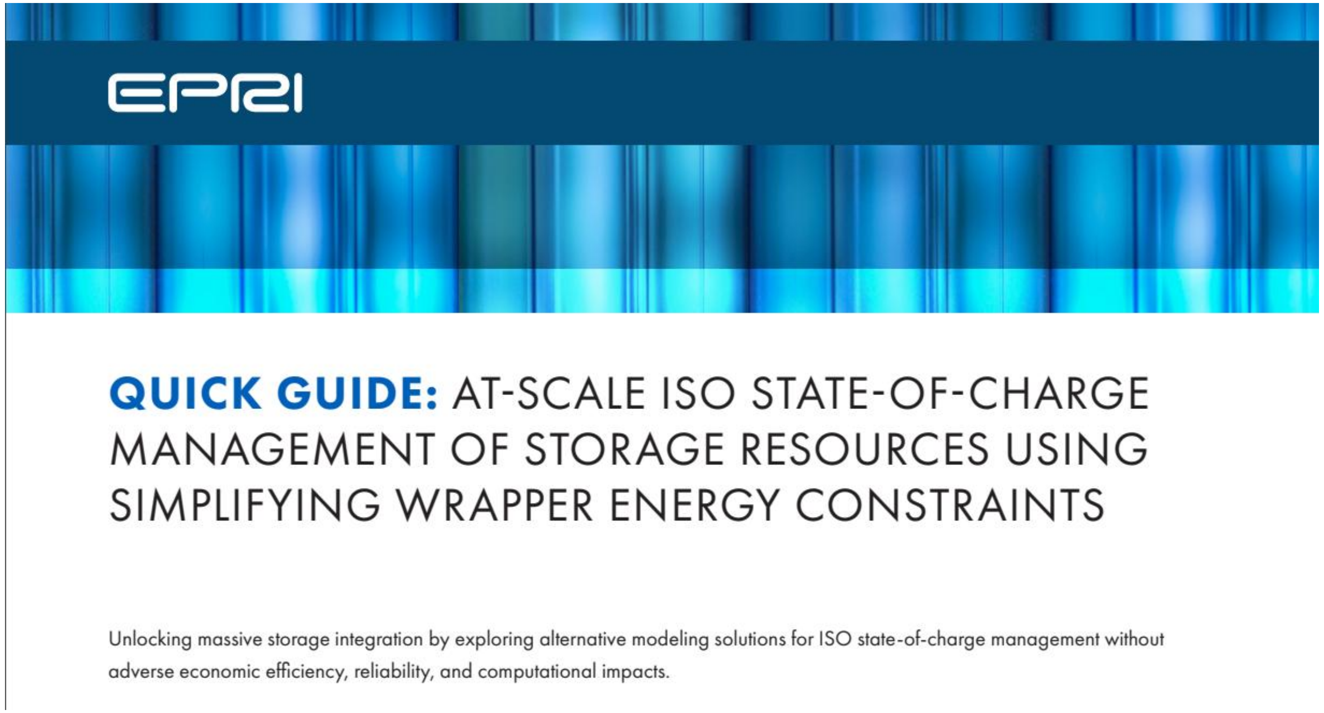
- Impractical to solve with hourly granularity
- Variability modeled using a range of scenarios (representative day/week)
- How we model chronology is the critical decision



Explicit Chronology **Implicit Chronology**

Full Chron. **Semi Chron.** **Wrapper**

Example: New Approaches



EPRI

QUICK GUIDE: AT-SCALE ISO STATE-OF-CHARGE MANAGEMENT OF STORAGE RESOURCES USING SIMPLIFYING WRAPPER ENERGY CONSTRAINTS

Unlocking massive storage integration by exploring alternative modeling solutions for ISO state-of-charge management without adverse economic efficiency, reliability, and computational impacts.

- **Goal**: Enable at scale state of charge management by ISO markets
- **Outcome**: Demonstrated computational benefits of simplified state-of-charge management

W. Aslam, N. Singhal, E. Ela, and R. Philbrick, At-Scale ISO State-of-Charge Management of Storage Resources Using Simplifying Wrapper Energy Constraints. EPRI, Palo Alto, CA: 2023. 3002026964. [Online]. Available: https://www.epri.com/research/products/000000003002026964

Concept: Alternative formulation of chronology

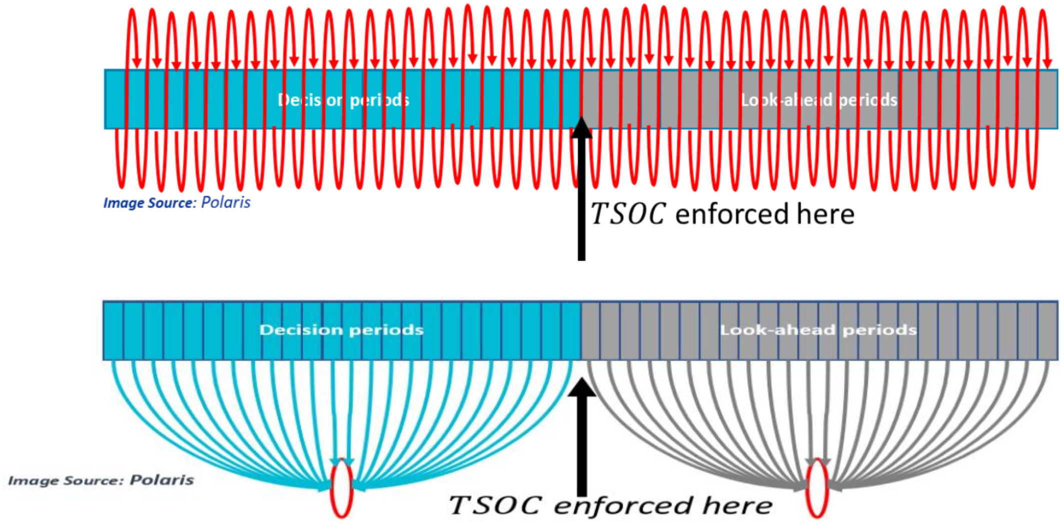


Image Source: *Polaris*

Image Source: Polaris

Zonal vs Nodal Modeling

Common assumption: Capacity Expansion (CX) cannot include power flow

- Too many power flow states based on usual models of chronology

Impact of zonal models

- Need to define zones, but congestion impacts are dynamic
- Need to define zonal interchanges, but this underutilizes transmission
- Need to map zonal results to power flow
- Need to manage multiple inconsistent data sets
- Need staff to understand and manage diverse and inconsistent tools

Solution: Reduced-state representation and efficient DC power-flow models

- Avoids limitations of zonal models
- Enables new applications: Optimal Transmission Expansion

Case study: high electrification long-term decarbonization pathway scenario for the Northeast

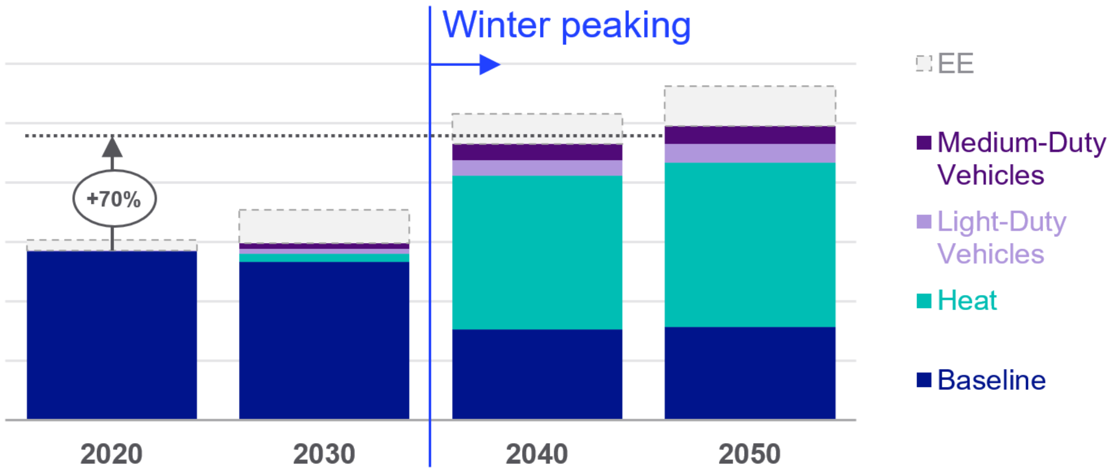
We demonstrate our approach to co-optimizing Tx and generation on a long-term decarbonization scenario

Key scenario inputs

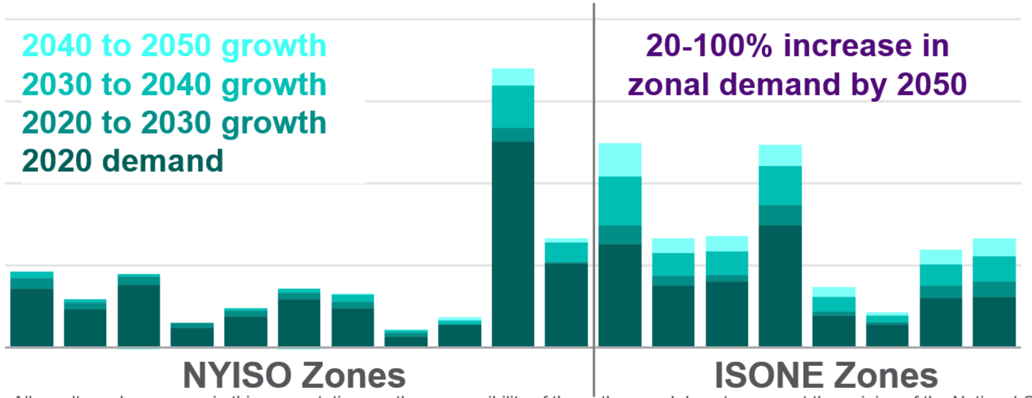
- **100% electrification** of light-duty vehicles and building heat by 2050 substantially increases electricity demand and switches system to winter peaking by 2030s
- Policy requirement for electric supply to be **100% clean in NYISO by 2040 and in ISONE by 2050**
- **OSW targets met on schedule** for Northeast states
- Technology costs for renewables and storage decline substantially out to 2050

Simulation projects expansion of Northeast supply and Tx over the 2021-2050 time horizon at a zonal level, subject to policy, capacity, power balance, and operating constraints

Scenario Northeast electric peak by component & year (GW)



Scenario Northeast zonal energy demand growth by decade (TWh)



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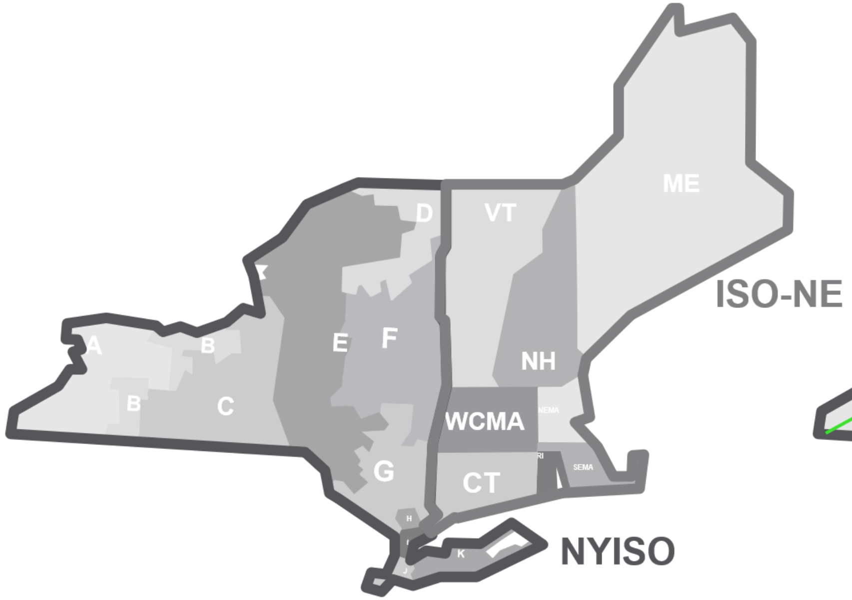
We analyze outcomes in the scenario under three representations of the transmission system

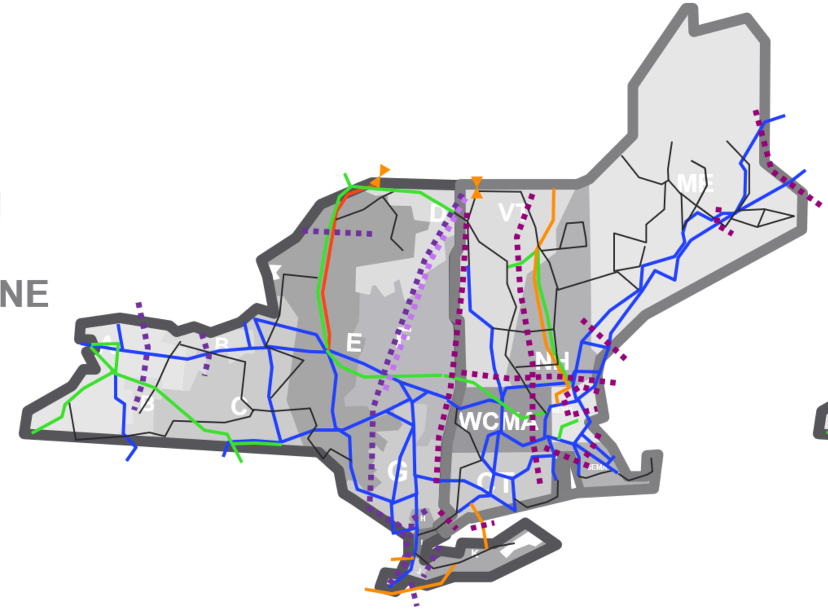
[a] Not Tx Constraints ("copper sheet")

What is the "ideal" supply mix under the scenario assumptions?



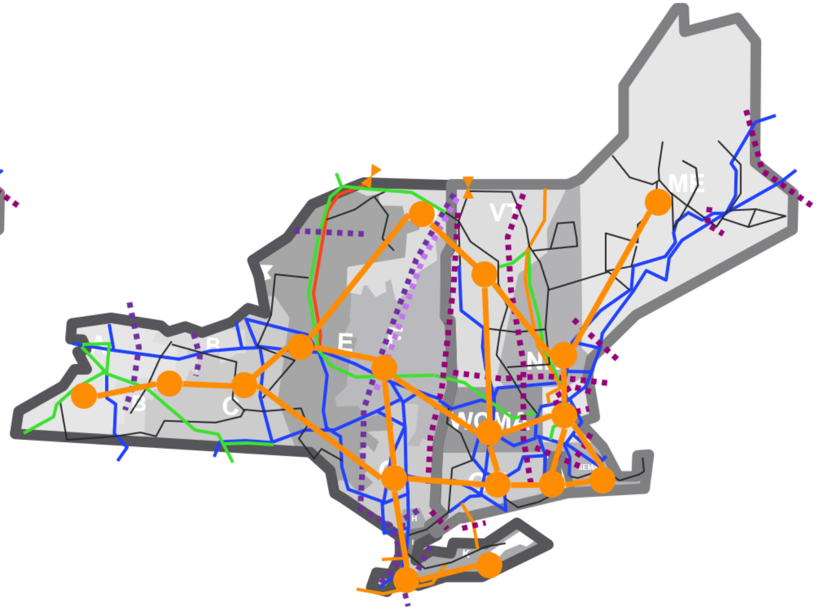
[b] Tx Constraints (but no Tx builds)

How is the "ideal" supply mix impacted by transmission bottlenecks?



[c] Tx Constraints & Tx builds

How does co-optimizing Tx builds with supply impact the mix?



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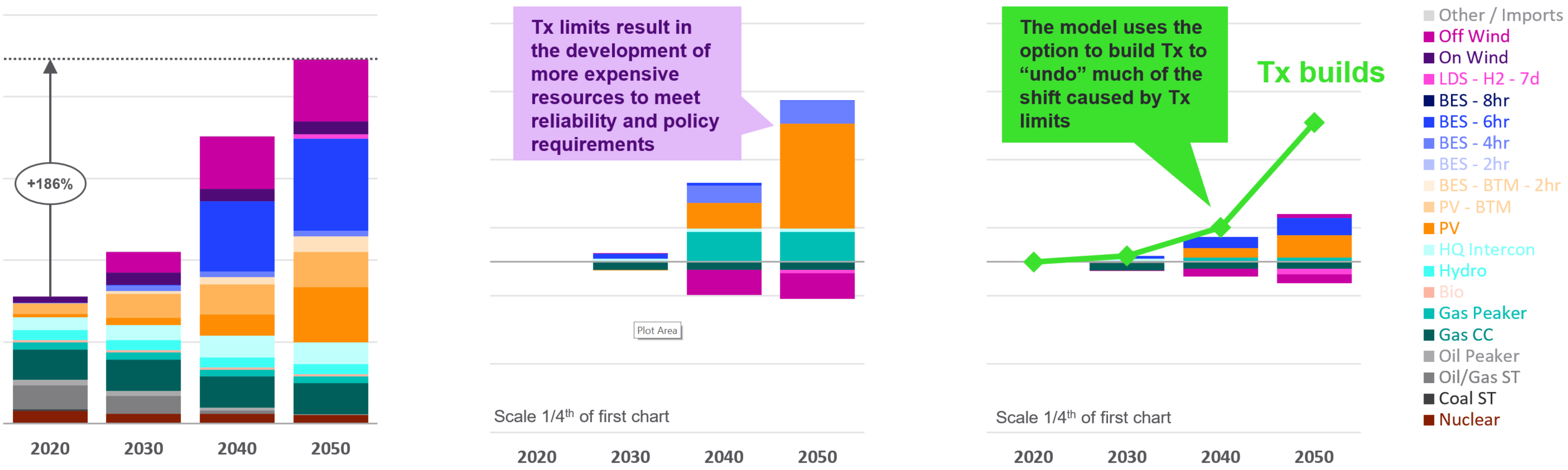
Case Study

The option to build transmission result in a supply mix similar to that in the “copper sheet” case

Northeast Cumulative Installed capacity by type & year (GW)



No Tx Constraints [a]

Tx Const. [b] – [a]

Tx limits result in the development of more expensive resources to meet reliability and policy requirements

Tx Const. & Builds [c] – [a]

The model uses the option to build Tx to “undo” much of the shift caused by Tx limits

- A near tripling of installed capacity needed to meet capacity, energy, & policy requirements out to 2050
- Imposing transmission constraints displaces offshore wind with onshore resources to meet localized needs
- As we might expect, allowing builds reduces the impact of transmission constraints, resulting in a more “optimal” mix

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The option to build transmission result in a supply mix similar to that in the "copper sheet" case

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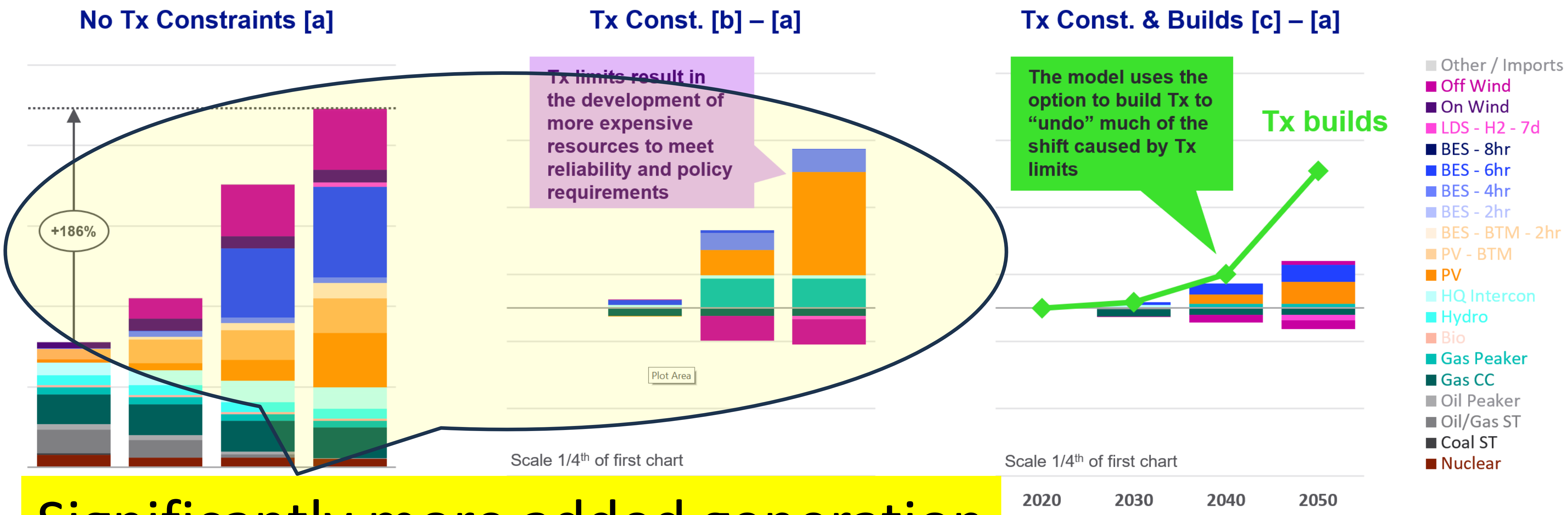

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Tx limits result in the development of more expensive resources to meet reliability and policy requirements

The model uses the option to build Tx to "undo" much of the shift caused by Tx limits

Significantly more added generation when transmission is considered

- A … we might expect, allowing builds
  ne… luces the impact of transmission
  po… nstraints, resulting in a more
  …timal" mix

Case Study

National Grid, FERC Software Workshop, 2021

The option to build transmission result in a supply mix similar to that in the "copper sheet" case

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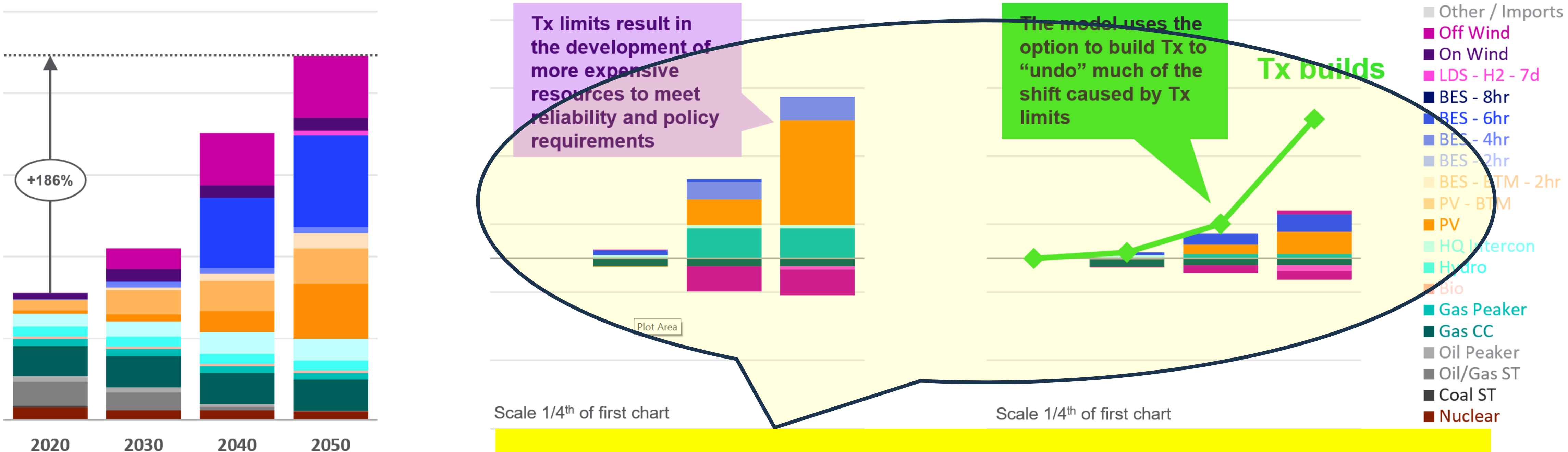

Tx limits result in the development of more expensive resources to meet reliability and policy requirements

The model uses the option to build Tx to "undo" much of the shift caused by Tx limits

- A near tripling of installed capacity needed to meet capacity, energy, & policy requirements out to 2050
- Imp
  dis
  res

Significantly less added generation with ability to build transmission

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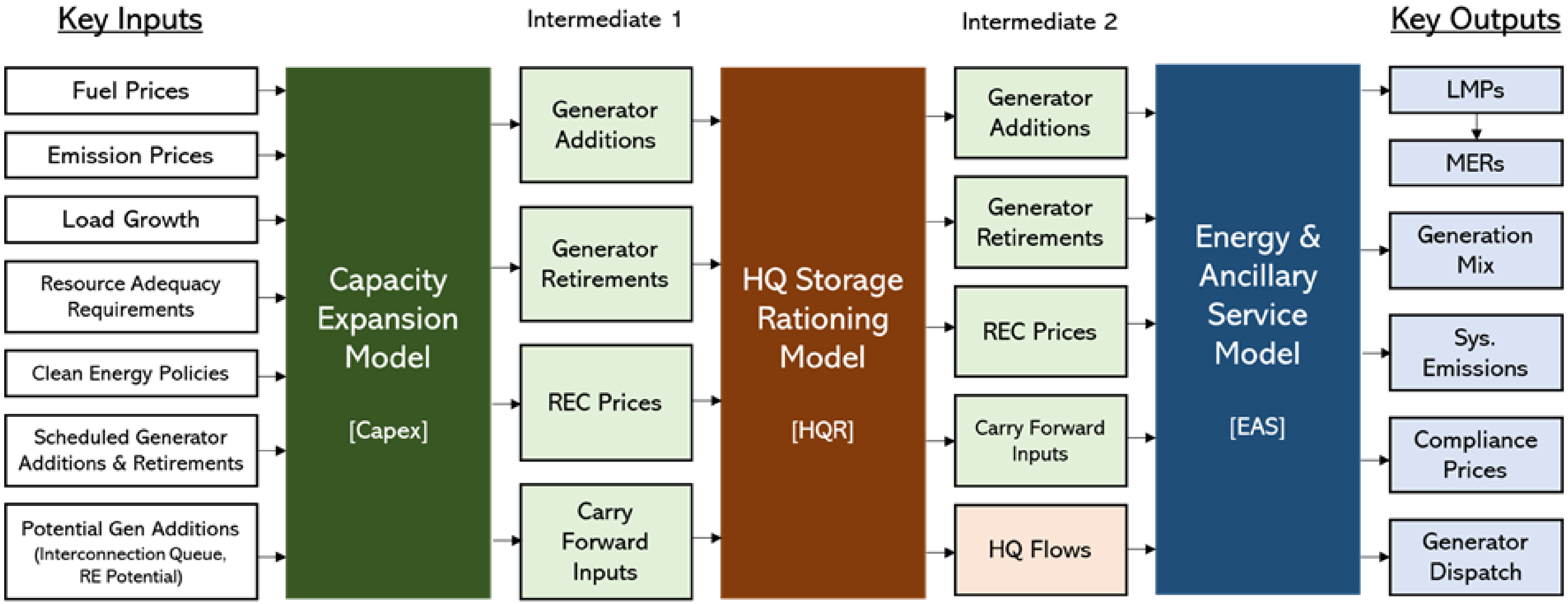
Example: Hydro Quebec LDES service to New England



Additional benefits of detailed CX models:

- Accurate impacts from a changing mix of flexible, variable and base-load generation
- Dynamically define capacity contributions without ELCC or other metrics
- Define reliable resource mix without the “safety net” of capacity reserve margins

Current Gaps

Though tools exist to allow process improvements, work still remains:

- Coordination between economic tools (CX, RA, PCM) and reliability tools (AC power flow, stability)
    - Quantify and optimized ancillary services (e.g., inertia, fault current)
- Simulation of adjacent energy systems
    - Gas network constraints and impacts on power systems
- Getting operations into planning
    - Few planners understand operations
    - Operational data, details and practices are often not available to planners
    - Operations frequently not properly reflected in planning models

Summary

Models are excessively simplified

- Presentation focused on simplifications using zonal models, but impacts also from simplifications applied to models of
  - Ancillary-services requirements
  - Resource flexibility and ability to provide ancillary services
  - Resource costs and efficient resource mix to achieve reliable operations
  - Long-duration storage (including fuels, emissions and policy requirements)
  - Adjacent energy systems (gas networks, heat, fuel conversion)

Modeling is too hard

- Simple approaches create challenges
  - Impacts on data, people, process

Perspective

Chronological Modeling

Goal of Chronological Modeling

Two goals:

- Capture variability across time
- Capture causality of decisions
  - Storage state of charge (dispatch in one hour affects storage available in next)
  - Demand-side management (bounce back effect of curtailment)

Terminology

- “Hours” of the year = “states” of the system (aka “scenarios”)
- Cliques identify collections of states
- For example, in PCM, we can group minutes and hours into longer periods. We refer to these as “states” vs “hours”.

Goal of Chronological Modeling

Need to reduce the number of states while preserving variability and causality

- Without reduction, problems are too large unless drastically simplified (e.g., price-taker models)
  - Many states/hours are similar and redundant
- Multiple choices in this reduction
  - Full chronology: no reduction
    - Full year/multiple years solved in single optimization
  - Semi chronology: representative day
    - Range of days selected to represent variability
  - Implicit chronology: cliques
    - Days/weeks/months/years represented by groups of states
    - Causality enforced using wrapper constraints

Capacity Expansion using “cliques”

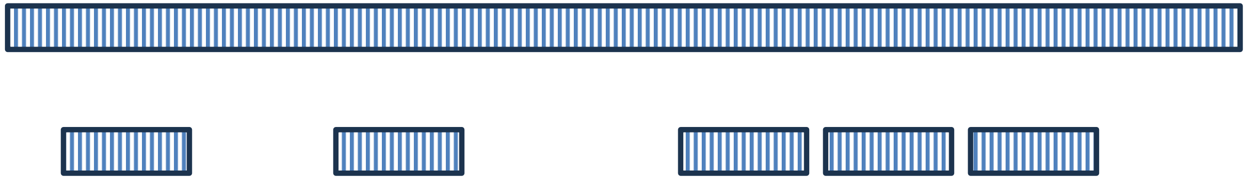
Capture variability with system states (aka scenarios)

Granular data (e.g., 8760)

Full chronology

Capacity Expansion using “cliques”

Capture variability with system states (aka scenarios)

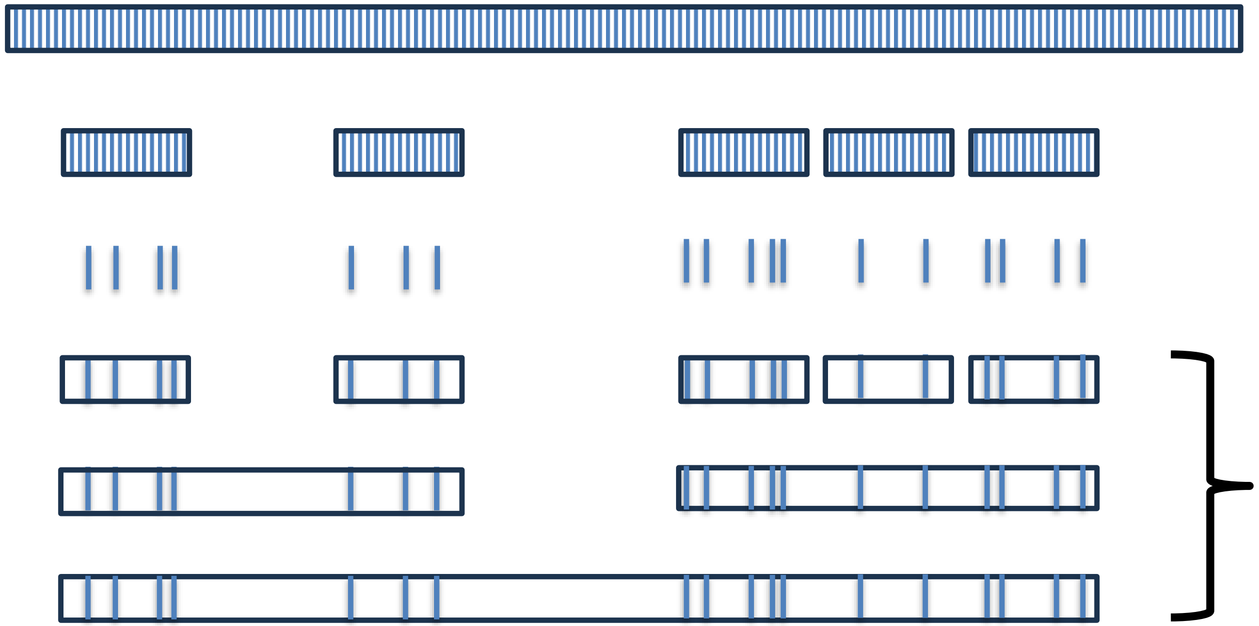


Granular data (e.g., 8760) — Full chronology

Representative days — Semi-chronology

Capacity Expansion using “cliques”

Capture variability with system states (aka scenarios)



Granular data (e.g., 8760) — Full chronology

Representative days — Semi-chronology

State reduction — Implicit chron.

Day cliques

Month cliques

Year cliques

Define
wrapper
constraints