



Power System and Market Studies at ISO New England

Current Capabilities

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BUSINESS ARCHITECTURE AND TECHNOLOGY



Overview of ISO-NE's Modeling Capabilities

- To aid stakeholders in the decision on what models and tools to employ in their future grid study, the ISO has compiled information on its key modeling capabilities for reliability, economic, and market assessments
- The ISO's existing studies can be categorized by four time horizons:
 - Long-term (3 - 10 years)
 - Mid-term (21 days - 3 years)
 - Short-term (1 day – 21 days)
 - Real-time (5 min – 24 hours)
- The ISO offers information on its processes and tools for reference and discussion, with emphasis on its long-term modeling



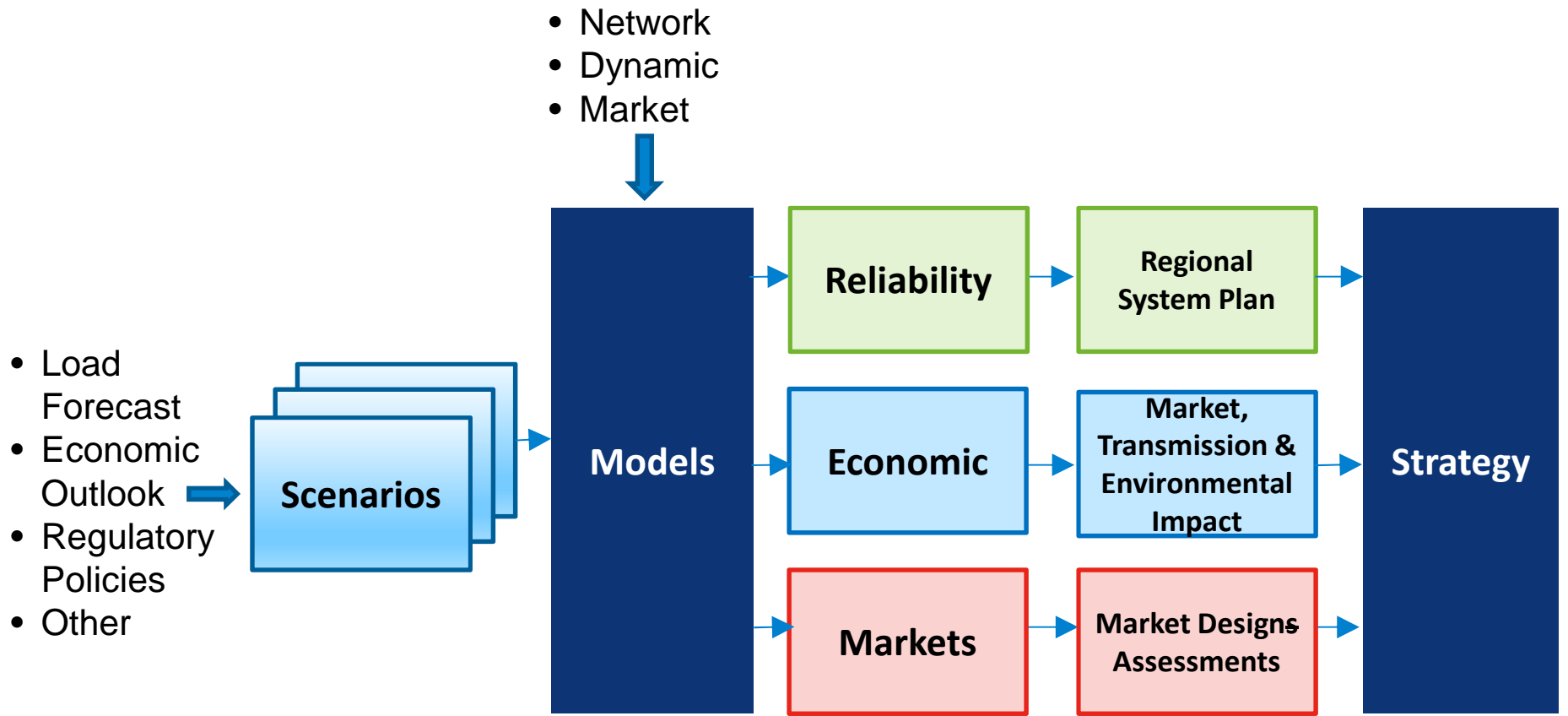
LONG-TERM STRATEGIC ANALYSES AND MODELING PROCESSES

Long-term Modeling Capabilities

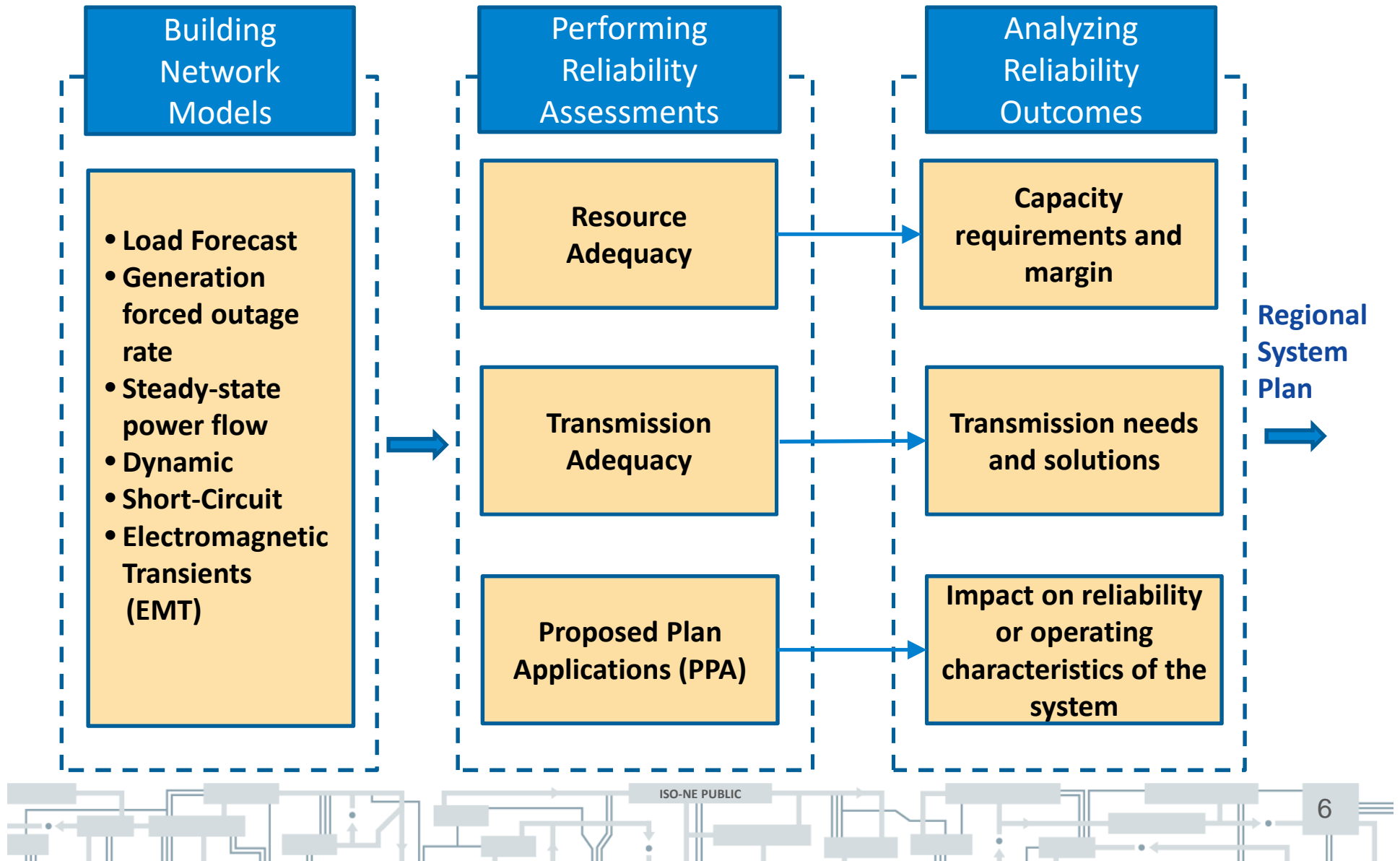
- ISO carries out a variety of studies focusing on assessing changes in the bulk transmission system, the generation resource mix, and market conditions in 3-10 years
 - Reliability studies, economic studies, and market simulations
- Modeling capabilities include:
 - Forecasting regional demand of electricity
 - Evaluating transmission system adequacy and resource interconnections
 - Evaluating long-term resource adequacy
 - Analyzing energy policies and their impact on planning, operations, and markets
 - Evaluating new market designs



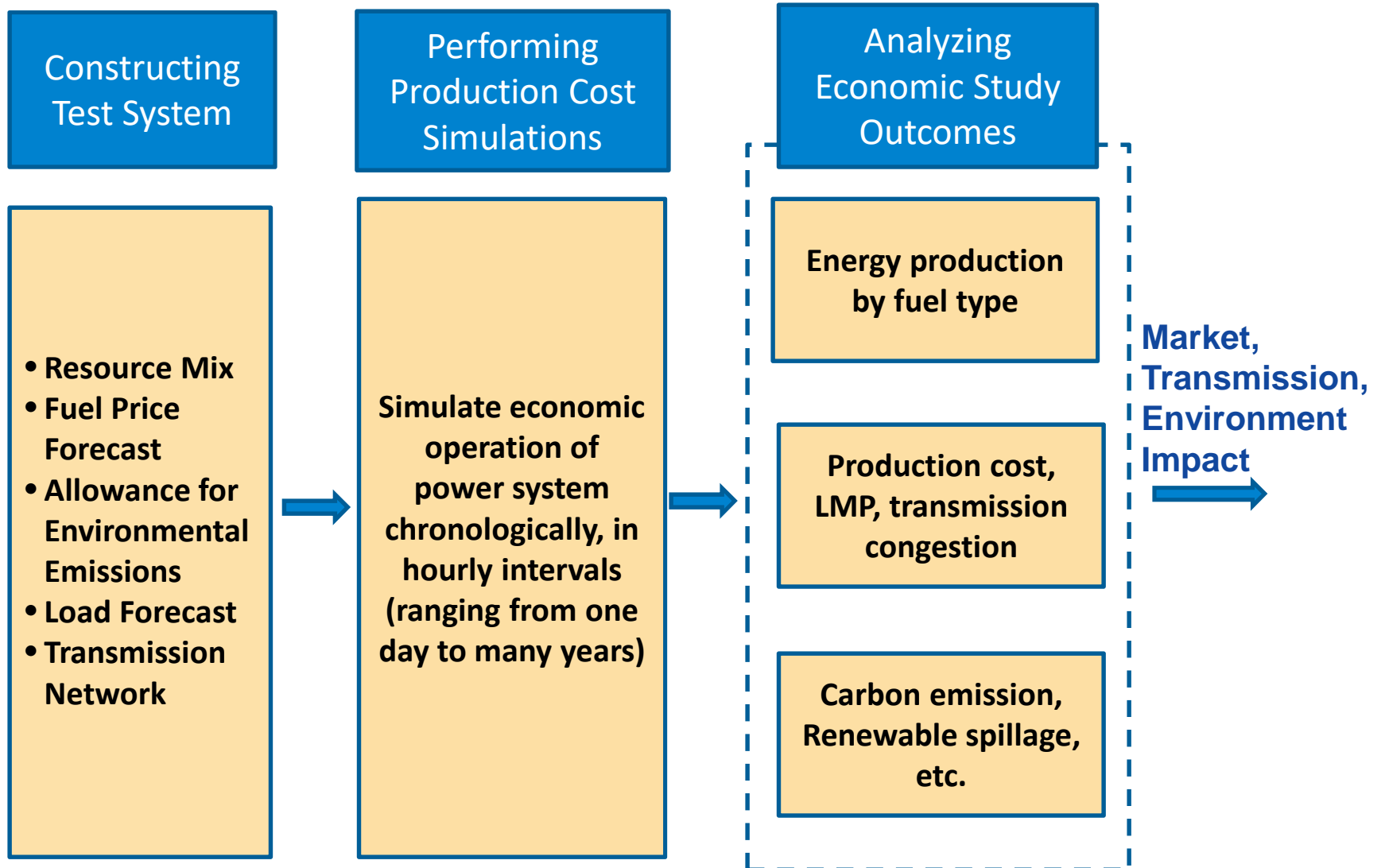
Long-Term Strategic Analysis Process



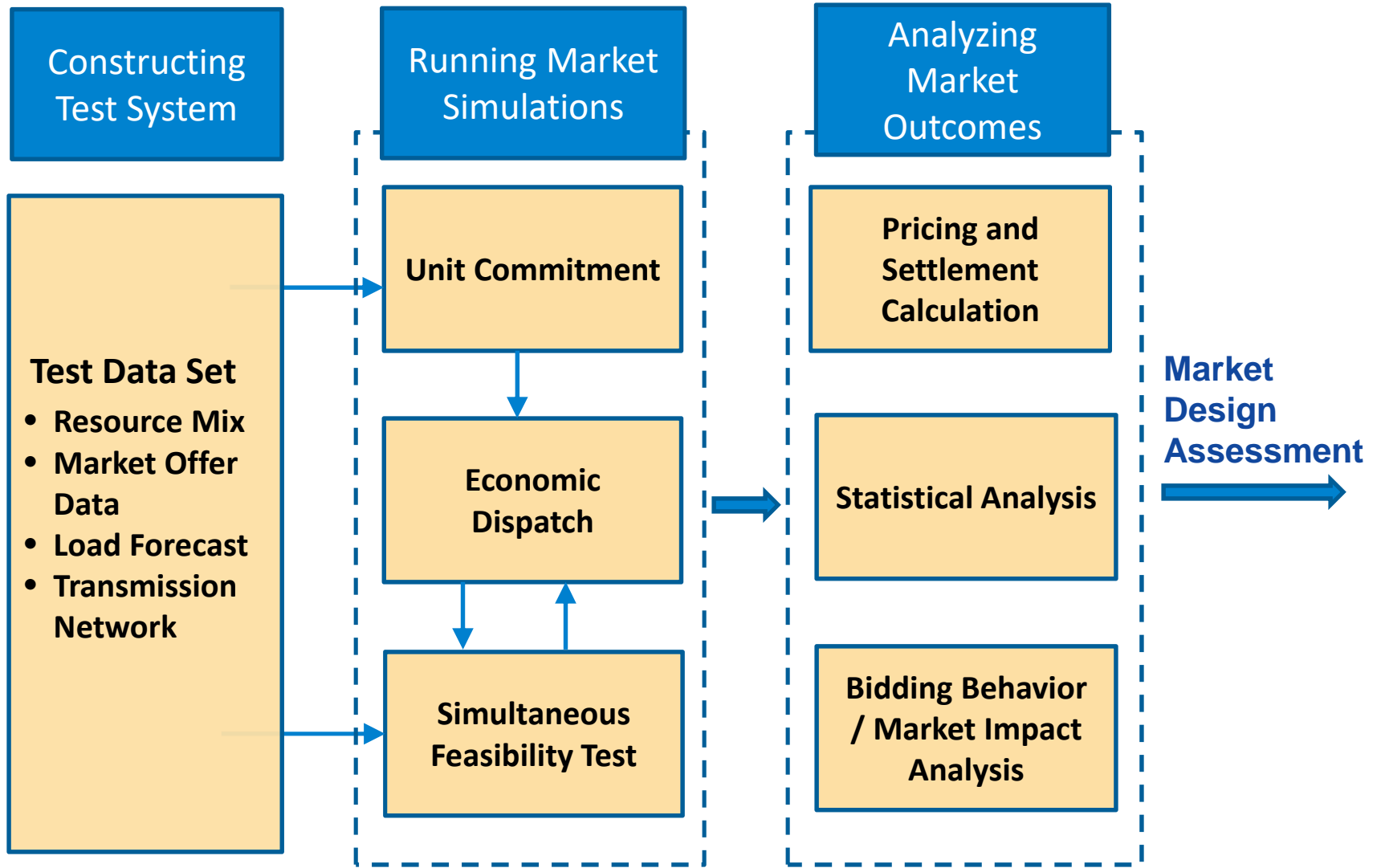
Key Processes for Reliability Studies



Key Processes for Economic Studies



Key Processes for Market Simulation



Forecasting Regional Electricity Demand

- Demand forecasting is a fundamental task in providing one of the key inputs to reliability studies, economic studies and market simulations
- ISO develops up to 10-year projections of electric energy usage and seasonal peak demand, based on
 - Economic outlook
 - Weather and load patterns
 - Pending or proposed legislation, regulation, and standards
- It also includes forecasting of
 - Energy Efficiency (EE)
 - Behind the Meter (BTM) PV
 - Electrification



Evaluating Transmission System Adequacy and Resource Interconnections

- An essential capability for evaluating system reliability
 - Identify transmission overloads, voltage violations and system dynamic behavior under different system conditions
- Widely used in planning studies:
 - Regional planning needs assessment and solution development
 - Annual NERC TPL Standards compliance assessment
 - Annual assessment of transmission transfer capability
 - Proposed Plan Application (I.3.9) study
 - New generators
 - Changes to existing generators
 - Transmission upgrades
 - Elective transmission upgrades



Evaluating Long-term Resource Adequacy

- Estimate representative net Installed Capacity Requirements (ICR) beyond Capacity Commitment Period (up to 10 yrs), based on
 - Latest Capacity, Energy, Loads, and Transmission (CELT) load forecast
 - Latest Forward Capacity Auction (FCA) resource assumptions
- System-wide Operable Capacity Analysis (up to 10 yrs) to estimate operable capacity margin
 - 50/50 and 90/10 peak load, plus operating reserve requirements
 - Representative net ICR, plus assumed unavailable capacity
 - Load or capacity relief actions of Operating Procedure 4 (OP-4)



Long-Term Reliability Studies

Studies	Purposes of the Study	Type of analysis (models)
Long-term load forecasting	<ul style="list-style-type: none"> • 10-year projections of electric energy usage and seasonal peak demand, based on economic outlook, weather and load patterns, etc. • Includes forecasting of EE, BTM PV and electrification 	<ul style="list-style-type: none"> • Descriptive statistics • Probabilistic and AI-based predictive forecast modeling, etc.
Regional planning needs assessment and solution development	<ul style="list-style-type: none"> • Evaluate transmission system adequacy over a 10-year planning horizon and identify reliability-based transmission needs • Development of transmission solutions to address identified needs using either the Solution Study process or the Competitive Solution process 	<ul style="list-style-type: none"> • Steady-state power flow • Transient stability • Short circuit



Long-Term Reliability Studies, cont.

Studies	Purposes of the Study	Type of analysis (models)
Proposed Plan Application (I.3.9) study	<ul style="list-style-type: none"> • Determine whether the proposed changes have any significant adverse effect on the stability, reliability or operating characteristics of the bulk power system • Include new generators, changes to existing generators, transmission upgrades, and elective transmission upgrades 	<ul style="list-style-type: none"> • Steady-state power flow • Transient stability • Short circuit • Electromagnetic transient
NERC TPL compliance study	<ul style="list-style-type: none"> • Annual compliance assessment of New England Bulk Electric System (BES) with NERC TPL planning criteria 	<ul style="list-style-type: none"> • Steady-state power flow • Transient stability • Short circuit • Geomagnetic disturbance (GMD)



Analyzing Energy Policies and Their Impact on Planning, Operations, and Market

- New England Wind Integration Study (NEWIS)
 - Determined the operational, planning and market impact of integrating substantial wind resources
 - ISO-NE, GE, EnerNex, AWS Truepower
- Economic Studies
 - Analyze impacts on energy market, transmission system, or environment, based on different scenarios of future resource mix and transmission expansion options
- System operational analysis and renewable energy integration study (SOARES)
 - Focused on system imbalance and operating reserves needs under different scenarios



Evaluating New Market Designs

- ISO evaluates new market designs through a variety of production cost simulation and market simulation tools
 - Impact analysis studies of new market design alternatives using market simulation tools developed in-house with Unit Commitment, Economic Dispatch, and Pricing capabilities
 - Analysis of various alternative pricing schemes for different market products using production and in-house developed market clearing software
 - Retrospective market studies using Day-Ahead study system



Limitations of in-use Economic and Market Simulation Tools

- Current production (GE) or in-house developed market simulation tool lack long-term simulation capability
- Production cost simulation tools don't capture real-time operational impact; require significant efforts of benchmarking upon change of market structure
- Electric Power Enterprise Control System (EPECS) simulation tool
 - Performance
 - Input/output data, simulation process control and speed
 - Modeling capability
 - Storage modeling, transmission constraints, etc.
 - Modeling accuracy
 - Reflection of ISO-NE market clearing, LMP, settlement, etc.



Long-Term Economic Studies and Market Simulations

Studies	Purposes of the Study	Type of analysis (models)
Economic Study	<ul style="list-style-type: none"> Analyze impacts on energy market, or transmission system, or environment, based on different scenarios of future resource mix and transmission expansion options 	<ul style="list-style-type: none"> Production cost simulation
Wind Integration Study	<ul style="list-style-type: none"> Determine the operational, planning and market impact of integrating substantial wind resources in NE 	<ul style="list-style-type: none"> Mesoscale wind Statistical analysis Production cost simulation
System operational analysis and renewable energy integration study	<ul style="list-style-type: none"> Investigate the effect of varying generation mix on system imbalance and operating reserves 	<ul style="list-style-type: none"> Market Simulation

Long-Term Economic Studies and Market Simulations, cont.

Studies	Purposes of the Study	Type of analysis (models)
Fast-start pricing assessment	<ul style="list-style-type: none"> Assess the market impact of fast-start pricing on both DAM and real-time market; The study implemented fast-start pricing prototype in the real-time market, and performed settlement calculations. 	<ul style="list-style-type: none"> LMP calculation
ESI market mitigation rule design	<ul style="list-style-type: none"> Design the market mitigation rules for ESI based on simulating different offering strategies for energy options and assessing the corresponding impact on the market 	<ul style="list-style-type: none"> GAMS-based market simulator

Modeling Challenges for Long-Term Studies

- Increasing number of inverter-based resources
 - Accuracy of dynamic models, esp. off-shore wind
 - Weak grid interconnection (control interaction resonance, protection, etc.)
 - Impact of reduced system inertia
- Strong and rapid growth of distributed energy resources
 - Tripping of DERs for a transmission fault adds to source loss
 - Accurate dynamic models and parameters
 - Mix of legacy and smart inverters
 - Under frequency and under voltage load shedding



Modeling Challenges for Long-Term Studies, cont.

- Transmission and distribution coordination
 - Unbalanced transmission faults
 - 1-ph and 3-ph inverters in distribution system
 - May need T&D co-simulation
- Multi-timescale market simulation
 - Simulation of the market operation process
 - Coupling of different markets
 - Consistent data set
 - Consideration of uncertain parameters
 - Computational performance



New Requirements for Network Models

- Bus-branch model
 - Eastern Interconnection representation
 - All transmission planning studies and operations planning technical studies
 - DERs are explicitly modeled at the specific substation, either as negative loads (1-5 MW) or generators (>5MW)
- Node-breaker model
 - EMS representation (NE, NY, and NB)
 - DA and RT network analysis and market clearing, outage coordination, FTR
 - Gradually expand the EMS model with sub-transmission network, potentially to model future DER integration



SHORTER-TERM ANALYSES AND MODELING PROCESSES

Mid-term Modeling Capabilities

- ISO operates mid-term markets and conducts planning studies to address both transmission and resource adequacy in a 3-year time frame
- Modeling capabilities include:
 - Assessing resource adequacy and reliability impacts of FCM resources
 - Evaluating reliability and economic impacts of transmission and generation outages
 - Establishing transmission operating limits and guides

*See Appendix for additional detail**



Short-term Modeling Capabilities

- ISO prepares for the real-time system and market operation through a variety of planning processes up to 21 days before the operating day
- Modeling capabilities include:
 - Short-term load forecasting
 - Evaluating short-term transmission and generation outages
 - Establishing current operating plan (COP)

*See Appendix for additional detail**



Real-time Modeling Capabilities

- ISO maintains system balance using various power system monitoring and controls, as well as decision-making tools during real-time system operation
- Modeling capabilities include
 - Assessing real-time security
 - Economically dispatching systems while maintaining system security

*See Appendix for additional detail**



LINKING ANALYSIS WITH TOOLS

List of Analysis Types and Tools

Analysis Types	Tools
Long- term load forecasting	ISO developed tools based on statistics, ANN, etc.
Short-term load forecasting	Simday, ANN, MetrixND
Market Clearing	<ul style="list-style-type: none">• FCA MCE• FTR (FTRO/SFT)• DAM (RSC/SPD/SFT)• RTM (SPD/SFT)• LMPC (LMP Calculator)
Market simulation	<ul style="list-style-type: none">• Day-ahead Study System (DASS)• EPECS Simulator (Dartmouth)• GAMS-based market simulator

List of Analysis Types and Tools, cont.

Analysis Types	Tools
Steady-state power flow analysis	<ul style="list-style-type: none">• PSS/E, TARA, PowerWorld, PSAT/VSAT• EMS PWRFLOW, RTCA, ILC, etc.
Voltage and transient stability	PSS/E, VSAT/TSAT
Small signal analysis	SSAT
Short circuit	ASPEN
On-line cascading failure analysis	POM, TSAT
Electromagnetic transient (EMT)	PSCAD
Production cost simulation	GridView, PROBE
Resource adequacy assessment	GE MARS
AGC simulation	KERMIT

CONCLUSION

Current and Future Modeling Needs

- Discussion covers the ISO's current capabilities for modeling and tools addressing various time horizons
- If the Future Grid studies would benefit from these capabilities, the ISO offers them to assist in that effort
- If there is a gap between the ISO's modeling processes and tools and those deemed necessary for the Future Grid studies, the ISO will work with stakeholders on the best way to address such gaps

Questions



APPENDIX

MID-TERM MODELING AND STUDIES

Assessing Resource Adequacy and Reliability

Impacts of FCM Resources

- Determining Tie Benefits and ICR
- Determining FCA and ARA parameters
- Interconnection analysis during FCM new resource qualification
- Reliability reviews of
 - permanent or retirement delist bids
 - dynamic de-list bids between FCA rounds
 - monthly CSO bi-laterals and reconfiguration auction



Evaluating Reliability and Economic Impacts of Transmission and Generation Outages

- Evaluating the reliability impact of long-term (21 days – 2 years) transmission and generation outage request
- Evaluating the economic impact of long-term (>90 days) transmission outage request



Establishing Transmission Operating Limits and Guides

- Transmission operations technical studies to identify thermal, voltage and stability limits
 - Transmission Operating Guides (TOGs)
- System restoration studies to develop and validate restoration plan
- Operational studies to determine Load Power Factor (LPF) limits, voltage schedules and limits for generators and key transmission substations, etc.



Mid-term Reliability Studies

Studies	Purposes of the Study	Type of analysis (models)
Resource Adequacy	<ul style="list-style-type: none"> • Determine Tie Benefits • Determine FCA and ARA parameters 	<ul style="list-style-type: none"> • Sequential Monte-Carlo simulation
Interconnection analysis during FCM new resource qualification	<ul style="list-style-type: none"> • Ensure that the new generating resource does not cause overloads that cannot be fixed in time for the CCP • Assess capacity deliverability within the load zone 	<ul style="list-style-type: none"> • Steady-state power flow
FCA dynamic de-list bids reliability review	<ul style="list-style-type: none"> • Reliability study to determine acceptance or rejection of dynamic delist bids between rounds of the FCA 	<ul style="list-style-type: none"> • Steady-state power flow
Monthly FCM reliability analysis	<ul style="list-style-type: none"> • Reliability reviews of bi-lateral and Reconfiguration Auction in support of the Monthly FCM process 	<ul style="list-style-type: none"> • Steady-state power flow

Mid-term Reliability Studies, cont.

Studies	Purposes of the Study	Type of analysis (models)
Long-term transmission and generation outage reliability analysis	<ul style="list-style-type: none"> Evaluates the reliability impact of long-term outage request (> 21 days) per OP-19. 	<ul style="list-style-type: none"> Steady-state power flow Transient stability
Transmission operations technical studies	<ul style="list-style-type: none"> Identify thermal, voltage and stability limits Transmission Operating Guides (TOGs) 	<ul style="list-style-type: none"> Steady-state power flow Transient stability Short circuit Electromagnetic transient



Mid-term Reliability Studies, cont.

Studies	Purposes of the Study	Type of analysis (models)
System restoration study	<ul style="list-style-type: none"> • Develop and verify restoration plans after a partial or total shutdown of the New England BES 	<ul style="list-style-type: none"> • Steady-state power flow • Dynamic stability • Electromagnetic transient
System voltage and reactive study	<ul style="list-style-type: none"> • Establish load power factor limits for study areas as defined in OP-17 • Develop voltage schedules and limits for generators and key transmission substations 	<ul style="list-style-type: none"> • Steady-state power flow • Dynamic stability



Mid-term Economic Studies and Market

Studies	Purposes of the Study	Type of analysis (models)
Forward Capacity Auction	<ul style="list-style-type: none"> • Determine capacity market clearing; • Annual/monthly/CASPR 	<ul style="list-style-type: none"> • Market clearing
Long-term transmission outage economic analysis	<ul style="list-style-type: none"> • Evaluate economic impact of long-term transmission outages (> 90 days) • Reposition transmission outages that exceed an incremental production cost of at least \$200,000 per week 	<ul style="list-style-type: none"> • Production cost simulation
FTR Auction	<ul style="list-style-type: none"> • Determine FTRs awards and market clearing prices; Annual/ Monthly and BOPP 	<ul style="list-style-type: none"> • FTR Market clearing

SHORT-TERM MODELING AND STUDIES

Short-term Load Forecasting

- Forecast hourly system-wide demand for today and the next two days
- Forecast capacity deficiency seven days in advance, based on forecasted weather, generating capacity, and peak demand



Evaluating Short-Term Transmission and Generation Outage

- Evaluate the reliability impact of short-term transmission and generation outage request (< 21 days)
- Estimate economic impact of short-term transmission outages (1 to 5 days in advance)
- 21-day energy security assessment forecast per OP-21



Establishing Current Operating Plan (COP)

- Calculate day-ahead 2nd contingency interface limits, which are enforced in Day-Ahead Market
- Day-Ahead Market clearing and analysis
- Reserve Adequacy Analysis (RAA) to assess system reliability for the operating day



Short-term Reliability Studies

Studies	Purposes of the Study	Type of analysis (models)
Short-term transmission and generation outage reliability analysis	<ul style="list-style-type: none"> Evaluates the reliability impact of short-term transmission and generation outage request (< 21 days) per OP-19. 	<ul style="list-style-type: none"> Steady-state power flow Transient stability
Day-Ahead 2nd contingency interface limits	<ul style="list-style-type: none"> Calculate limits and load shed values for 2nd contingency interfaces. Calculate proxy limits which are enforced in the DAM 	<ul style="list-style-type: none"> Steady-state power flow (TTC Calculator)



Short-term Reliability Studies, cont.

Studies	Purposes of the Study	Type of analysis (models)
21-day energy security assessment forecast	<ul style="list-style-type: none"> Forecast 21-day energy security based on current system conditions, forecasted weather, load, generators' reports of stored-fuel inventories and emissions limitations, and status of fuel delivery systems. 	<ul style="list-style-type: none"> Production cost simulation
Short term load forecasting	<ul style="list-style-type: none"> Forecast hourly system wide demand for today and the next two days Forecast capacity deficiency seven days in advance 	<ul style="list-style-type: none"> ANN Similar day METRIX

Short-term Economic Studies and Market

Studies	Purposes of the Study	Type of analysis (models)
Short-term outage economic analysis	<ul style="list-style-type: none"> Evaluate economic impact of short-term transmission outages (1 to 5 days in advance) 	<ul style="list-style-type: none"> Production cost simulation
Price Analysis	<ul style="list-style-type: none"> Satisfy FERC's data inquiry Compute the constraint sensitivities used in LMP calculation 	<ul style="list-style-type: none"> DA Study System
Day-ahead Market clearing	<ul style="list-style-type: none"> Clear DAM 	<ul style="list-style-type: none"> SCUC SCED CA
Reserve Adequacy Analysis	<ul style="list-style-type: none"> Assess system reliability for the operating day 	<ul style="list-style-type: none"> SCUC



REAL-TIME MODELING AND STUDIES

Assessing Real-time Security

- Evaluating system conditions using real-time data to assess existing (pre-Contingency) and potential (post-Contingency) operating conditions
 - State Estimation, real-time contingency analysis, interface limits, etc.
- On-line voltage stability assessment
- On-line transient stability assessment
- On-line cascading analysis
- Resilience – look ahead power grid risk monitoring for extreme events (prototype)



Economically Dispatching Systems While Maintaining System Security

- Intra-day SCRA study to assess system security and needs for intraday unit commitment
- Real time unit commitment and economic dispatch
- Automatic generation control
- Compute real-time LMP and fast-start lost opportunity cost
- Analyzing real-time pricing



Real Time Reliability

Studies	Purposes of the Study	Type of analysis (models)
Real time analysis and assessment	<ul style="list-style-type: none"> Evaluate system conditions using real-time data to assess existing (pre-Contingency) and potential (post-Contingency) operating conditions 	<ul style="list-style-type: none"> State Estimation RTCA ILC
On-line voltage stability assessment	<ul style="list-style-type: none"> Compute interface limits based on voltage violation and voltage instability 	<ul style="list-style-type: none"> Steady state power flow P-V analysis
On-line transient stability assessment	<ul style="list-style-type: none"> Compute interface limits based on angle stability, transient voltage dip, and oscillation damping 	<ul style="list-style-type: none"> Transient stability



Real Time Reliability, cont.

Studies	Purposes of the Study	Type of analysis (models)
On-line Cascading Analysis	<ul style="list-style-type: none"> Evaluate system exposure to instability, cascading failure, and uncontrolled separation for more severe than (n-1) conditions 	<ul style="list-style-type: none"> Steady-state power flow Transient stability
Resilience – look ahead power grid risk monitoring for extreme events (Prototype)	<ul style="list-style-type: none"> Estimate equipment outage probabilities taking into account real-time weather forecast, network equipment loading conditions, network equipment fragility characteristics, and available historical data 	<ul style="list-style-type: none"> Weather model Statistics Facility fragility models



Real-Time Market

Studies	Purposes of the Study	Type of analysis (models)
Intra-day SCRA	<ul style="list-style-type: none"> • Assess system security and needs for intraday unit commitment 	<ul style="list-style-type: none"> • SCED
Real-time unit commitment and dispatch	<ul style="list-style-type: none"> • Determine the commitment of fast-start units; runs every 15 minutes • Dispatch resources to satisfy system demand • Determine the dispatch points for variable resources (DNE) 	<ul style="list-style-type: none"> • SCUC • SCED
CTS process	<ul style="list-style-type: none"> • Determine schedules for transactions with NYISO; every 15 min 	<ul style="list-style-type: none"> • SCED



Real-Time Market, cont.

Studies	Purposes of the Study	Type of analysis (models)
RT pricing	<ul style="list-style-type: none">• Compute real-time LMP and fast-start lost opportunity cost	<ul style="list-style-type: none">• LMP calculation
LMPC Monitoring and Analysis	<ul style="list-style-type: none">• Analyze real-time prices	<ul style="list-style-type: none">• Dispatch and LMP analysis

