Training on Integrated Resource Planning for South Carolina Office of Regulatory Staff

Overview of the major components of an IRP and its development process

Load Forecasting and Capacity Expansion Modeling (More Details)

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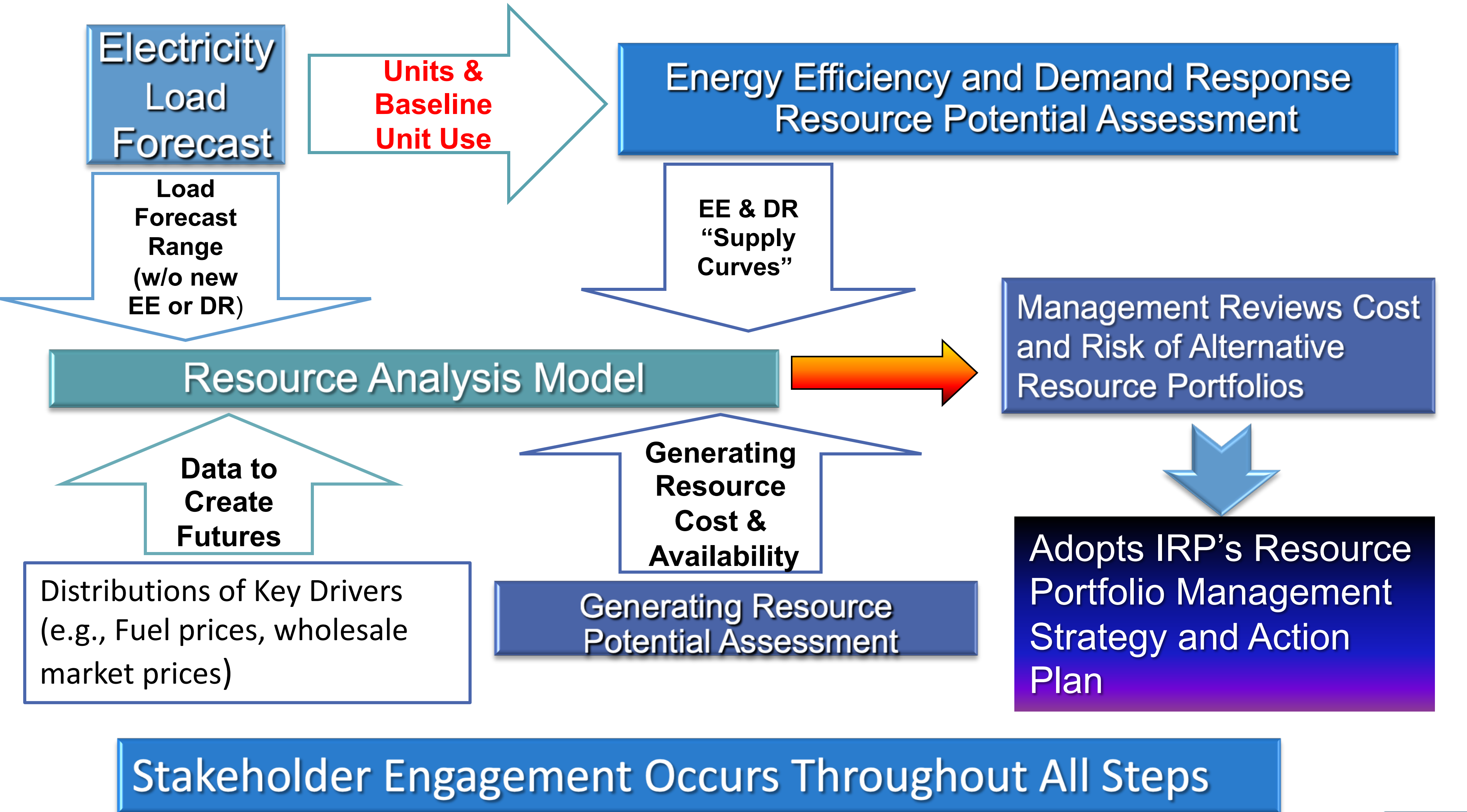
Models Used in IRP Development

- Load Forecasting Models
  - Simple linear extrapolation
  - Times series models
  - Econometric models
  - End use models
  - Hybrid approaches
- Capacity Expansion Models & Modeling
  - Deterministic
  - Stochastic
- Resource Adequacy Models & Modeling*
  - Deterministic
  - Stochastic

*May be separate model or integrated function in Capacity Expansion Model

IRP Development
Analytical Process Flow Between Models



Econometric Load Forecasting Models

- Most appropriate for short to medium term forecasts
- Advantages
  - Based on economic theory of how various factors are expected to affect demand
  - Moderate data requirements
  - Produce measures of fit to historical data
  - May be appropriate components of more sophisticated modeling approaches
- Disadvantages
  - Unsuited for analysis of most energy policy questions (e.g. impacts of future codes and standards, electrification, utility programs, carbon programs)
  - May not reflect structural changes in the economy (e.g. introduction of EVs, bit coin mining, electrication policies)
  - Inability to ensure consistency with energy efficiency potential analysis
  - Substantial expertise required for reliable model results

End Use Load Forecasting Models

- Energy demand is derived from production of energy services
  - D = A(Units) * B(Efficiency) * C(Utilization)
- Most appropriate for long term forecasts and policy analysis especially for residential and commercial sectors
- Advantages
  - Explicit about how energy is used and stocks of energy using equipment
  - Can evaluate the effect of equipment stock turnover.
  - Can evaluate energy policies intended to change efficiency of equipment or fuel choice
  - Permits checking consistency between load forecast and conservation potential analysis
- Disadvantages
  - Heavily data intensive (requires customer survey data)
  - Expensive to build and operate
  - Not reflective of human behavior responses, i.e. overoptimization

Hybrid Load Forecasting Models

- Combine end-use structure with econometric estimates
- Appropriate for long-term forecasts and policy analysis
- Advantages
  - Captures both equipment stocks and consumer behavior
  - Enables analysis of energy policies
- Disadvantages
  - Data requirements and expense
  - Can become difficult to explain results clearly

Load Forecasts Role in IRP

- The **I** in **IRP** stands for integrated; that is integration of the demand and supply sides of planning.
  - Specifically, that increased efficiency of energy use should be compared to the cost of electricity generation or gas supply to minimize the cost of energy services.
- In an integrated system, information flows both ways between the load forecasting systems and the capacity expansion and risk analysis modeling systems.

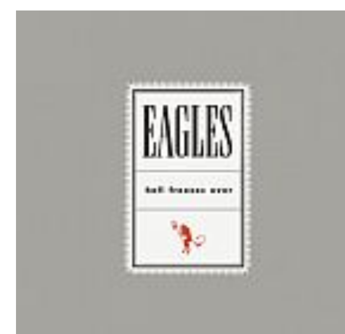
Connecting Load Forecast and Efficiency Potential

- The analysis of energy efficiency potential identifies technology improvements and their costs
- This information is provided to load forecasting staff to inform the development the efficiency trade-off curves used in the load forecasting model
- This ensures that efficiency choices and their costs used in the energy efficiency supply curves used in the capacity expansion model are consistent with those used in the load forecast
  - Example 1 – Load forecast model provides forecast of the number of new and replacement buildings and equipment based on forecast growth and stock turnover models. These “units” are used to develop aggregate energy efficiency potential
  - Example 2 – Load forecast includes efficiency levels mandated by known codes and standards and these efficiency levels serve as the baseline efficiency for estimating remaining potential (to avoid *double counting* of remaining energy efficiency potential)

Load Forecasting Realities

- There is no one best model
  - Methodology, level of detail, data requirements, and required expertise depend on the purpose of the forecast
- Nearly all forecasting techniques rely on history to some degree
- No forecast will be absolutely correct
- The future is unknown and no model can change that fact
- So . . .

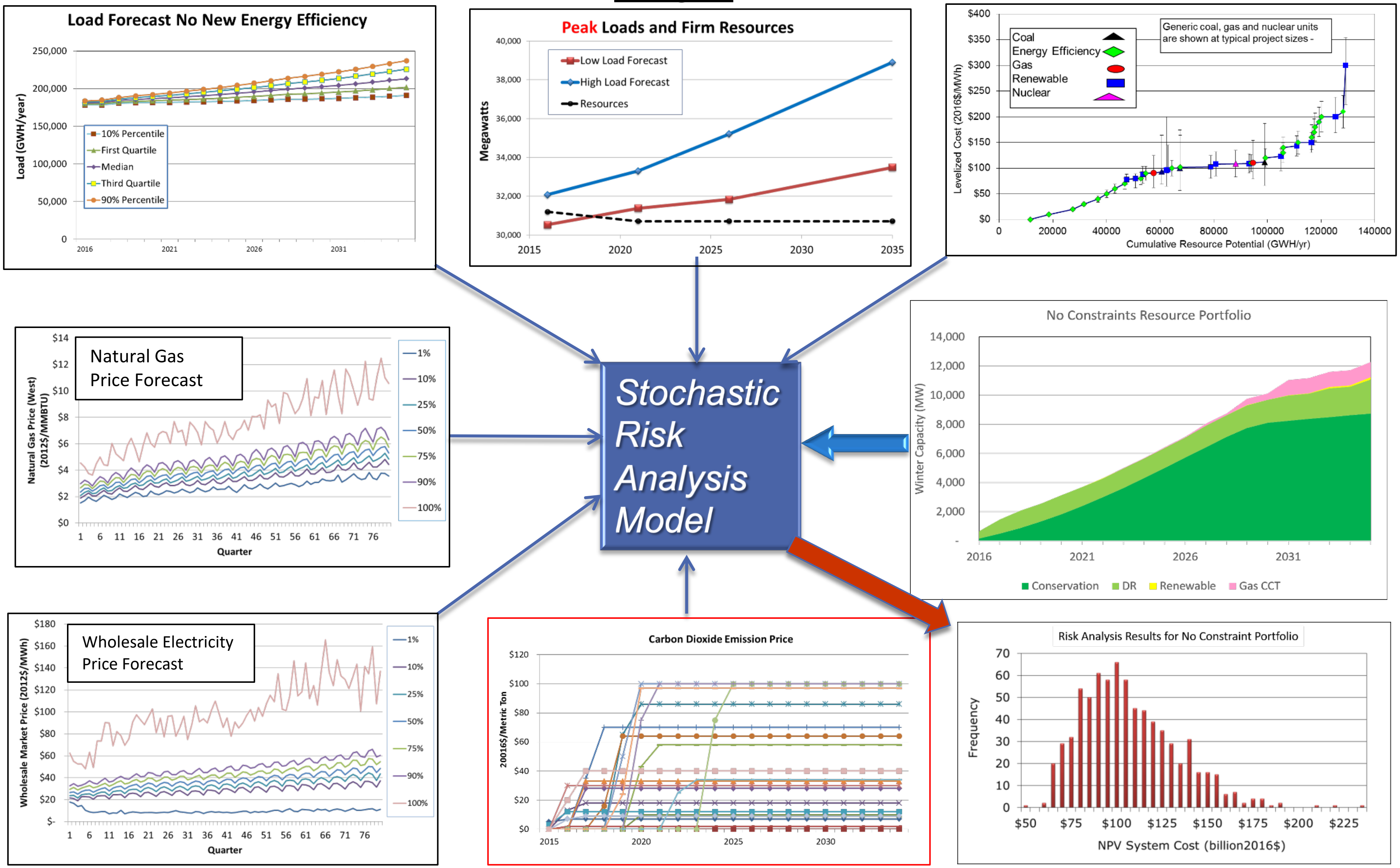
Get over it
Get over it
All this whinin' and cryin'
and pitchin' a fit
Get over it, get over it



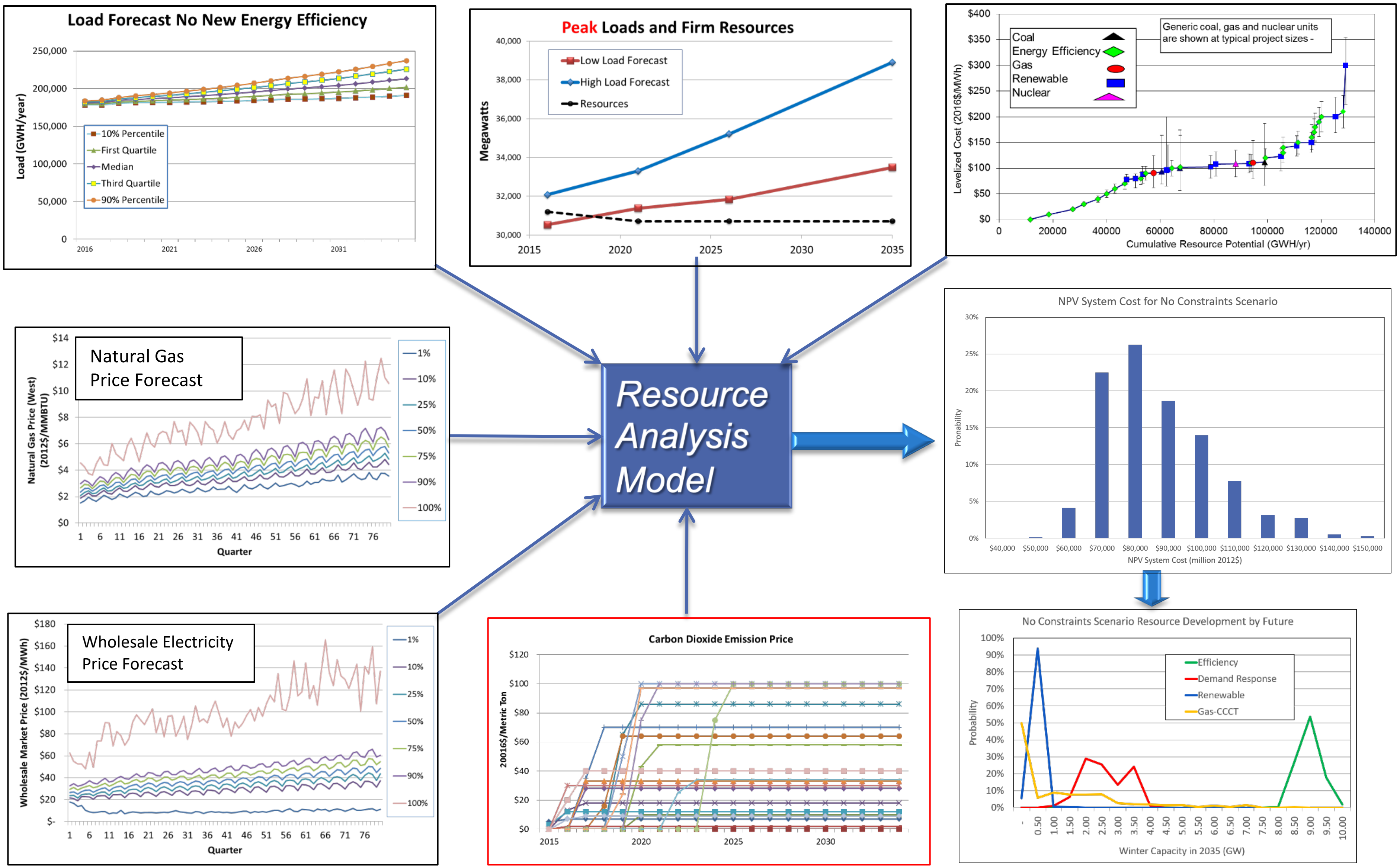
Capacity Expansion Models – Very High Level Overview

- Evolved from Production Costing/Market Equilibrium models
- Designed to "optimize" the type, amount, and timing of new resource development using assumptions about future load growth, fuel prices, resource characteristics and availability, policies and regulations
  - These models simulate generation and transmission capacity investment, given assumptions about future electricity demand, fuel prices, technology cost and performance, and policy and regulation
  - Examples - AURORAxmp®, PLEXOS®, EnCompass, the Northwest Power and Conservation Council's Regional Portfolio Model, and NREL's Resource Planning Model
- Key differences between models
  - Time resolution (e.g., sub-hourly, hourly, daily, weekly)
  - Unit commitment (e.g., chronological or based on load duration curve)
  - Transmission and power flow (pipe flow or DC)
  - Treatment of uncertainty

Stochastic Risk Analysis of Resource Strategies Optimized for a *Single* Future



Stochastic Risk Analysis for Resource Strategies Optimized *Across A Range* of Future Conditions



Role of Capacity Expansion/Resource Analysis Models

What They Do Do

- Test alternative resource mixes and development timing (aka, *Resource Strategies*) against a range of future conditions (e.g., load growth, natural gas prices, emissions costs/limits, etc.)
- Identify the "least cost" *Resource Strategy* and may account for "risk"

What They Don't Do

- Determine what is an *acceptable* level of "cost"
- Determine what is an *acceptable* level of "risk"
- Decide which Resource Strategy is "Preferred"

Resource Adequacy Models

- Designed to conduct "probabilistic" assessments of system's ability to meet load under broad range of potential future conditions accounting for variations in:
  - Loads (hourly)
  - Resources (e.g. thermal plant forced outages, the mean expected time to repair those units, variable wind plant generation, and available imports)
  - Weather (usually historical, but some now using climate change forecasts)
  - Market access (i.e., probability of transmission forced outages)
- Models are intended to measure the likelihood of possible shortfalls, when *all* relevant uncertainties are included in the adequacy metric calculation
- Simulate chronological system operation (usually hourly, but sometimes at smaller time-steps) to reflect
  - Resource ramping requirements/constraints
  - Minimum operation levels
  - Ancillary service needs (e.g., balancing reserves)
  - Stochastic forced outages
  - Variable energy resources (e.g., wind, solar)

What Is Resource Adequacy

- *Resource adequacy* is not the same as *Power system adequacy*. Resource adequacy only refers to having an ample supply of generating resources and efficiency measures to "keep the lights on" a relatively high percentage of time.
  - **Resource Adequacy Example** - Sufficient resources (generating, energy efficiency and demand response) are available to limit the likelihood of future years of curtailments to no more than *five* percent. The power supply must have sufficient capability to protect against both cold snaps in winter and heat waves in summer
- *Power system adequacy* includes both resources and the bulk transmission and distribution systems, which typically cause most customer interruptions.
  - **Power System Adequacy Example** – System meets the above Resource Adequacy standard *and* can withstand sudden disturbances, such as electric short circuits or unanticipated loss of system elements by having *security* reserves that can be brought on line quickly in the event of a system disruption and through controls on the transmission system.
  - The North American Electric Reliability Corporation (NERC) and regional electric reliability organizations establish *security* reserve requirements. The reserves required for security are an additional resource requirement necessary for a reliable power system.

Resource Adequacy Metrics Relationship to IRP Capacity Expansion Models and Modeling

- Capacity expansion models (CEMs) constrain resource portfolio optimizations to maintain "pre-determined" levels of resource adequacy (i.e., it's an input)
- One or more of five industry standard "adequacy" metrics derived from Resource Adequacy Models can be used to constrain CEM's optimization processes
- These five metrics measure one or some combination of three characteristics of a "curtailment" (i.e., the inability of the system to meet load)
  - Frequency
  - Duration
  - Magnitude

Resource Adequacy Metrics

- **Loss of load probability (LOLP),** which measures the likelihood of a load curtailment event occurring in any given simulation regardless of the frequency, duration and magnitude of the curtailment(s).
- **Expected unserved energy (EUE)**, which measures outage magnitude in MWh and is the *sum of all unserved energy/load curtailments across all hours and simulations divided by the number of simulations.*
- **Loss of load hours (LOLH)**, which measures outage duration and is *the sum of the hours with load curtailments divided by the number of simulations*.
- **Loss of load expectation (LOLE)**, which measures the *average number of days per year with loss of load* due to system load exceeding available generating capacity.
- **Loss of load events (LOLEV)**, which measures the *average number of loss of load events per year*, of any duration or magnitude, due to system load exceeding available generating capacity

Resource Adequacy Models Are Also Used to Assess Resource Characteristics Such as Capacity Contribution and Resource Flexibility

- A resources actual capacity contribution when integrated into an existing power system is *less* than its "nameplate" capacity
  - The exception is in systems that have significant hydro with storage capabilities (but not "run-of-river" or pumped hydro-storage)
- Resource Adequacy Models are used to derive the "Effective Load Carrying Capacity" (ELCC) of resources by modeling systems with and without varying levels of each resource to determine their actuall capacity contributions

Summary - Models Used in IRP Development

- **Load Forecasting Models**
  - Simple linear extrapolation
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  - Econometric models — Most Prevalent & Problematic
  - End use models
  - Hybrid approaches — (End use models and Hybrid approaches) Most Relevant & Useful
- **Capacity Expansion Models & Modeling**
  - Deterministic — Most Prevalent & Problematic
  - Stochastic — Most Relevant & Useful
- **Resource Adequacy Models & Modeling**
  - Deterministic — Most Problematic
  - Stochastic — Most Prevalent, Relevant & Useful

Any Questions?

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- Peak Demand Impacts from Electricity Efficiency Programs (forthcoming)
- Energy Efficiency in Electricity Resource Planning (forthcoming)

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- LBNL – Resources on Integrated Resource Planning (https://emp.lbl.gov/projects/utility-resource-planning)

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