# Joint Integrated Resource Plan (IRP) Stakeholder Presentation

February 3, 2016

# Agenda

Welcome

1. IURC Director's Report Development Process
2. Public Advisory Process Overview
3. IRP Building Blocks & Development
4. Load Forecasting
5. Resources
6. Scenarios and Sensitivities

Lunch Break

7. Regional Transmission Organizations
8. Resource Modeling

Day in Review/Feedback

Closing Remarks

# WELCOME (MARK MAASSEL, IEA - FACILITATOR)

# Welcome and Objective

- The process of Integrated Resource Planning is accomplished using data, forecasts and strategic assumptions, conducting analyses to formulate a preferred resource plan for each utility and defining a short-term implementation plan
- Key components of this complex process will be addressed at a high level in this presentation
- At the end of this session you should understand the key components of the process and how they all fit together
- Each company may apply principles with variation but the process is consistent

# 1 IURC DIRECTOR'S REPORT DEVELOPMENT PROCESS (IURC)

# IURC's Director's Report Development Process

- Dr. Bob Pauley

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# IRP PUBLIC ADVISORY PROCESS OVERVIEW (OUCC)

# IRP Public Advisory/Participation Process (OUCC)

- Barbara Smith
  - Overview of the IRP Stakeholder Process
  - Where We Are Now
  - The Road Ahead

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# IRP BUILDING BLOCKS & DEVELOPMENT (IPL)

# IRP Building Blocks & Development Outline

- Purpose of Integrated Resource Planning (IRP)
- Development process
- Building blocks
- Results

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# IRP Building Blocks & Development

- Purpose of IRP:
  - “IRPs describe how the utility plans to deliver safe, reliable, and efficient electricity at just and reasonable rates”.
- Process to screen options, model variables, produce possible resource plans for multiple scenarios
- Complex effort to balance multiple stakeholder interests
- Includes qualitative and quantitative information

*Source: IURC

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# IRP Building Blocks

## Load Forecast
- Economic drivers
- EE standard impacts

## Resources
- Supply side-generation
- Demand side – EE, DR, DG

## Costs
- Fuel – NG, coal, other
- Market prices – energy & capacity
- Risks – e.g. environmental costs

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# IRP Building Blocks

Load Forecast

Resources

Costs

Scenarios

&

Sensitivities

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# Process & Results

- Develop scenarios or future views of the world to shape inputs and frameworks for analysis
- Include sensitivity analysis of specific variables
- Results in multiple resource plan options
- Model outputs include parameters of each plan such as:
  - Present Value Revenue Requirements (PVRR)
  - Fuel consumption
  - Environmental impacts

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# QUESTIONS

# 4 LOAD FORECASTING (VECTREN)

# Load Forecasting

- Load forecasting is a fundamental building block of the IRP process
  - Use historical data and known/projected future drivers to predict future energy and demand requirements
  - Indiana requires a 20 year forecast period for the IRP
- The utility is required to serve its peak load + a reserve margin
  - Peak demand is the maximum power consumption in a given year for the utility's service area, typically measured in Mega Watts (MW)
  - Energy is the product of power and time, Kilowatt Hour (kWh)
  - Reserve Margin is required capacity by the Regional Transmission Operator (RTO) to ensure reliability

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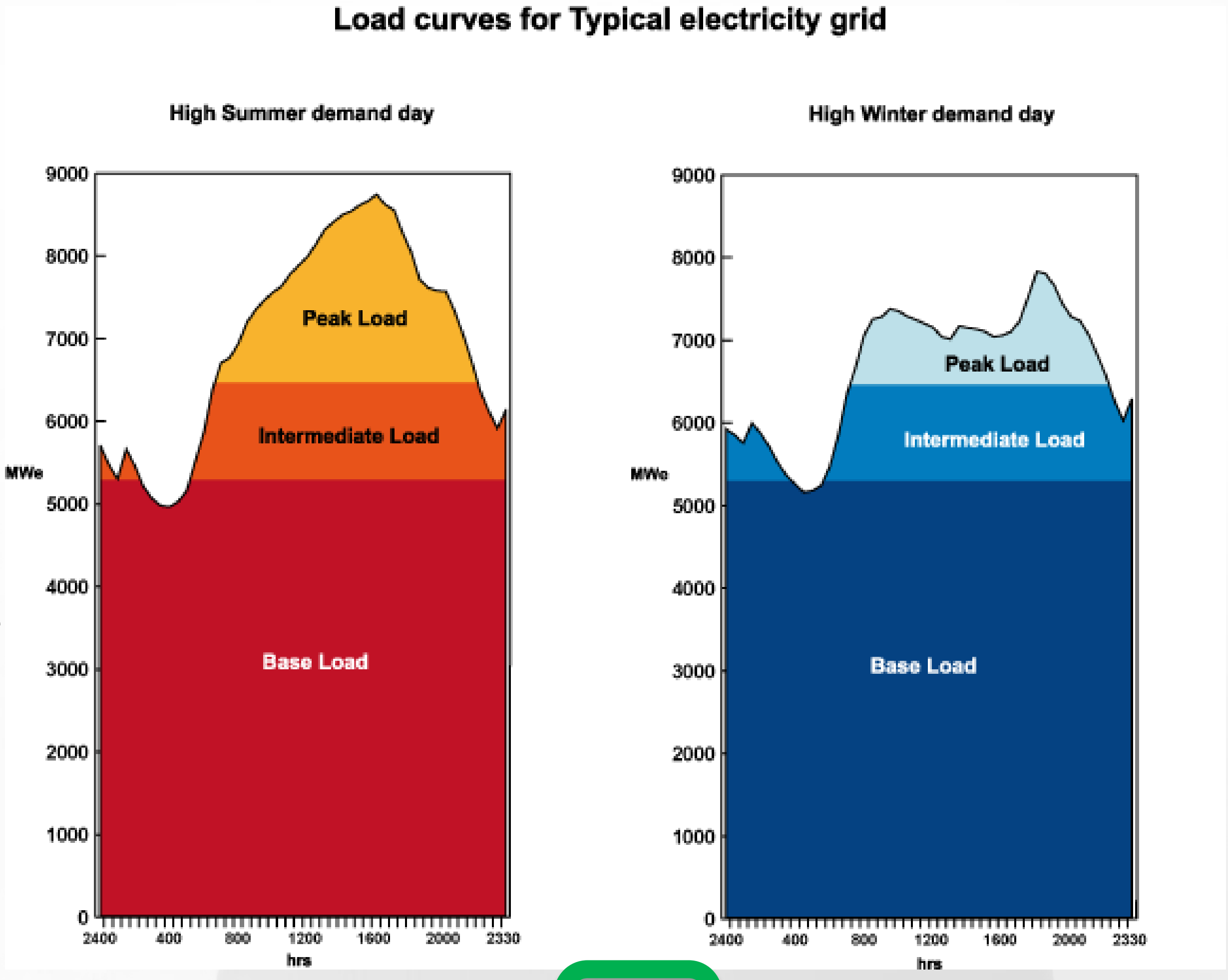
# Load Forecasting

- Base Load
  - Minimum level of demand on an electrical supply system over 24 hours
  - Power sources: those plants which can generate consistent and dependable power
- Intermediate Load
  - Medium level of demand
  - Power sources: plants which can operate between extremes and generally have output increased in the morning and decreased in the evening
- Peak Load
  - Highest level of demand within a 24 hour period
  - Power sources: plants which can be switched “on” when the additional power is needed without much delay

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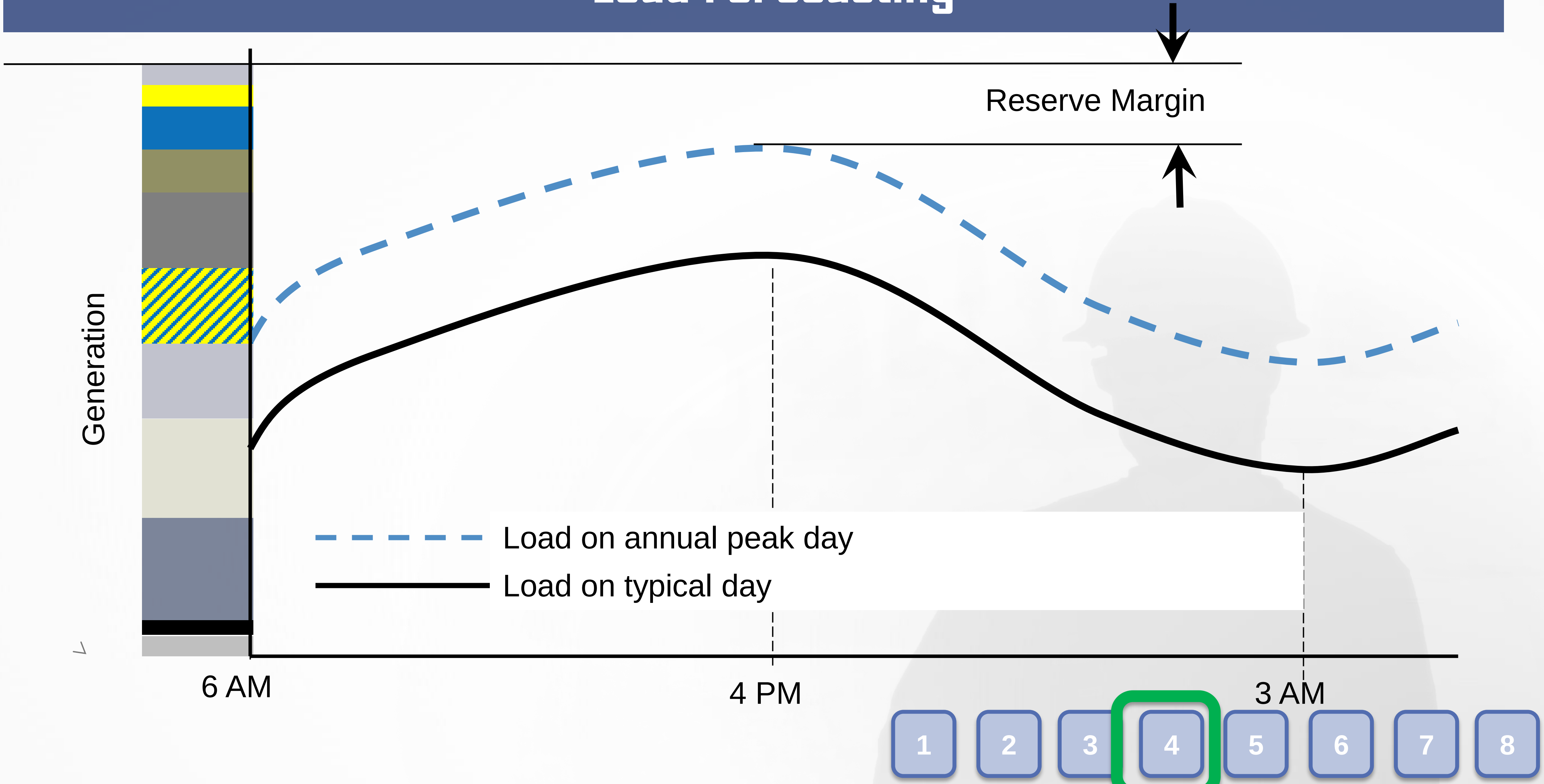
# Load Forecasting



# Load Forecasting

- Utilities typically forecast energy by customer class
  - Residential, Commercial, Industrial
  - Street Lighting, Government Use, Wholesale
- System energy derived by aggregating across the sales forecast and adjusting for line losses
- Peak demand forecast is typically based on the historical demand/energy relationship
  - Load factors
  - Regression models that relate peak demand to total energy or end-use energy trends, and weather

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# Load Forecasting - Drivers

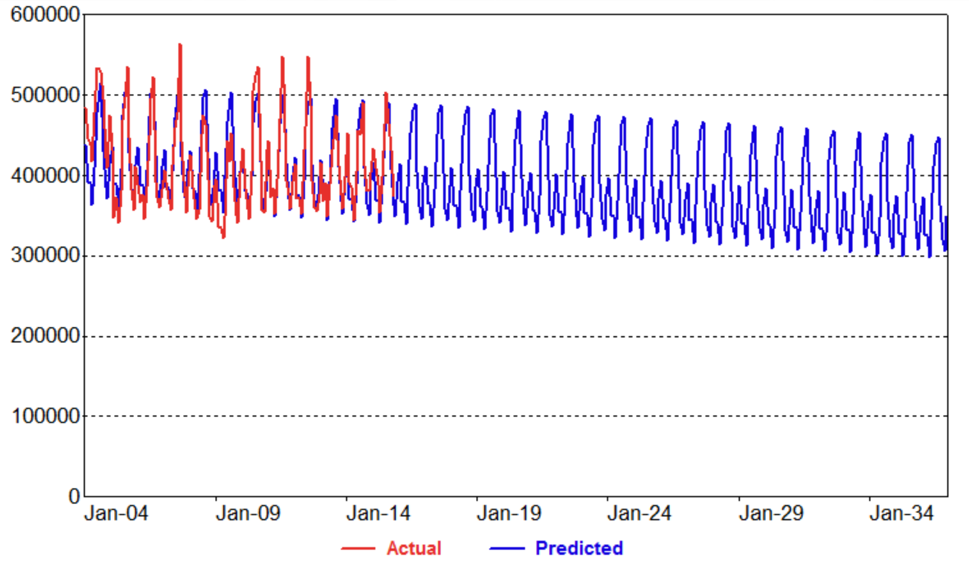
- Weather
- Economy
- Demographics
- Appliance saturation and size
- Appliance efficiency trends driven by
  - Consumer demand
  - Utility sponsored demand side management (DSM) programs
  - Government codes and standards
- Consumer behavior and technology changes
- Thermal shell of homes or businesses
- Price of electricity
- Customer owned generation

# Load Forecasting – Typical Methods

- Simple Pattern or Trend Model
  - Extrapolate past usage trends into the future
- Econometric Model
  - Relate historical energy sales to weather, demographics, economic activity, efficiency trends with statistical models and project this relationship forward based on these factors
- End Use Forecasting
  - Engineering based model that projects end-use sales based on appliance ownership, efficiency, utilization and changes in codes and standards using known information about appliance shares, usage, and changes in codes and standards
- Statistically Adjusted End Use (SAE) Model
  - Blend of econometric modeling and end use forecasting
- Survey Customers
  - Speak to customers about their future plans

# Patterns and Trend Models

- The forecast is extrapolated from past energy trends and monthly/seasonal patterns
  - Exponential Smoothing
  - ARIMA Models
  - Simple trend-based linear regression models




- Trend models are simple to estimate and can be useful in projecting near-term trends. Trend models implicitly assume that future energy usage will look like the past

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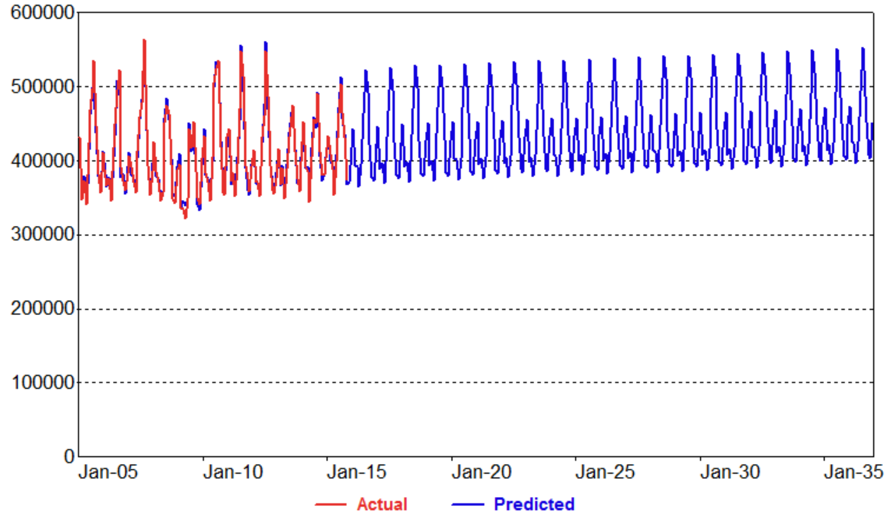
# Econometric Model

- Captures the factors that impact electricity use
  - Weather, population, economic activity, more efficient appliances
    - Linear and non-linear regression models: estimate the relationship between monthly electric sales (the dependent variable) and the variables that cause electricity to change (the independent variables)




| Variable | Coefficient | StdErr | T-Stat |
|---|---|---|---|
| Days | 9042.6 | 946.6 | 9.6 |
| HDD | 83.3 | 4.6 | 18.0 |
| CDD | 417.4 | 9.4 | 44.6 |
| GDP | 3176.8 | 1911.1 | 1.7 |

The estimated coefficients tell us how much monthly energy changes given a change in the number of days in the month, heating degree days (HDD) , cooling degree days (CDD), and the economy (GDP)

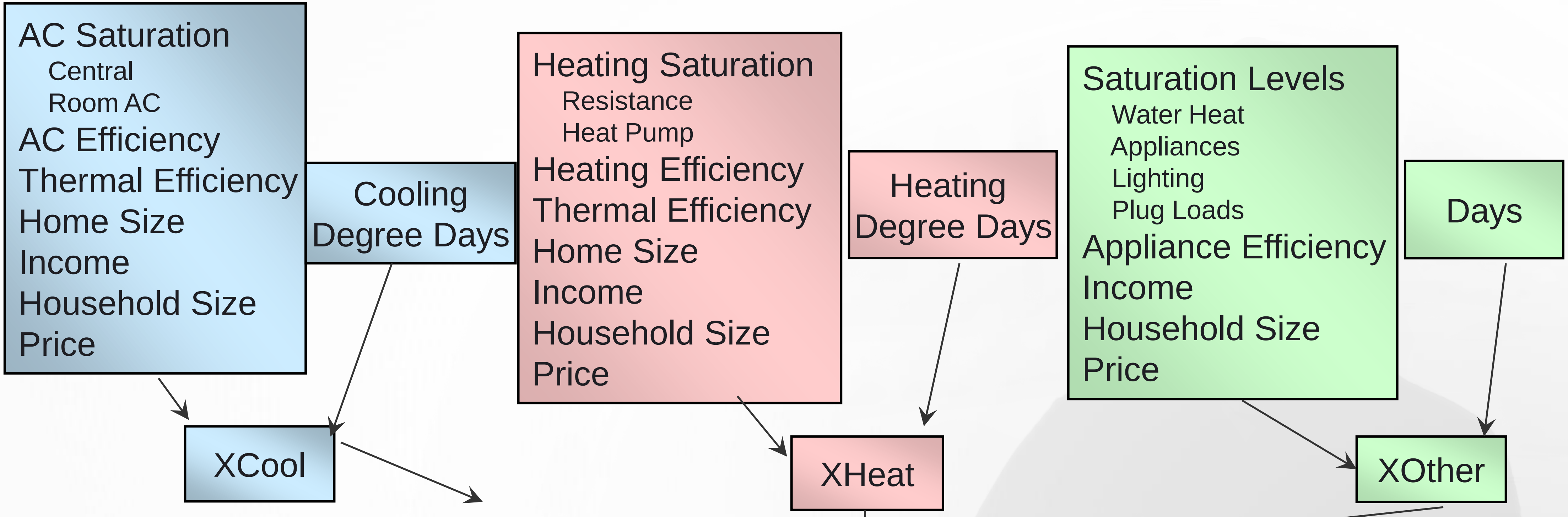
- This regression model assumes that the relationship between sales and model variables are the same in the future as it has been in the past

# End Use Forecasting

- End-use models: An engineering-based approach were we develop annual kWh forecasts for defined end-uses
  - *Electric Power Research Institute (EPRI) End-Use models: REEPS* and *COMMEND*
- Collect and maintain detailed end-use database
  - Number of units, appliance age distribution, technology options, technology costs, starting average and marginal unit energy consumption (UEC), housing square footage, thermal shell integrity
- Embed assumption as to how these characteristics will change over time with households, income, energy price, appliance costs, and standards
- Generate and sum resulting end-use energy requirements

# Statistically Adjusted End Use (SAE) Model

- Blend of econometric and end use modeling
  - Incorporates end-use ownership and efficiency trends as well as weather, price, and economic data




$$AvgUse_m = a + b_c \times XCool_m + b_h \times XHeat_m + b_o \times XOther_m + e_m$$

**Estimate monthly model with historical billed sales data**

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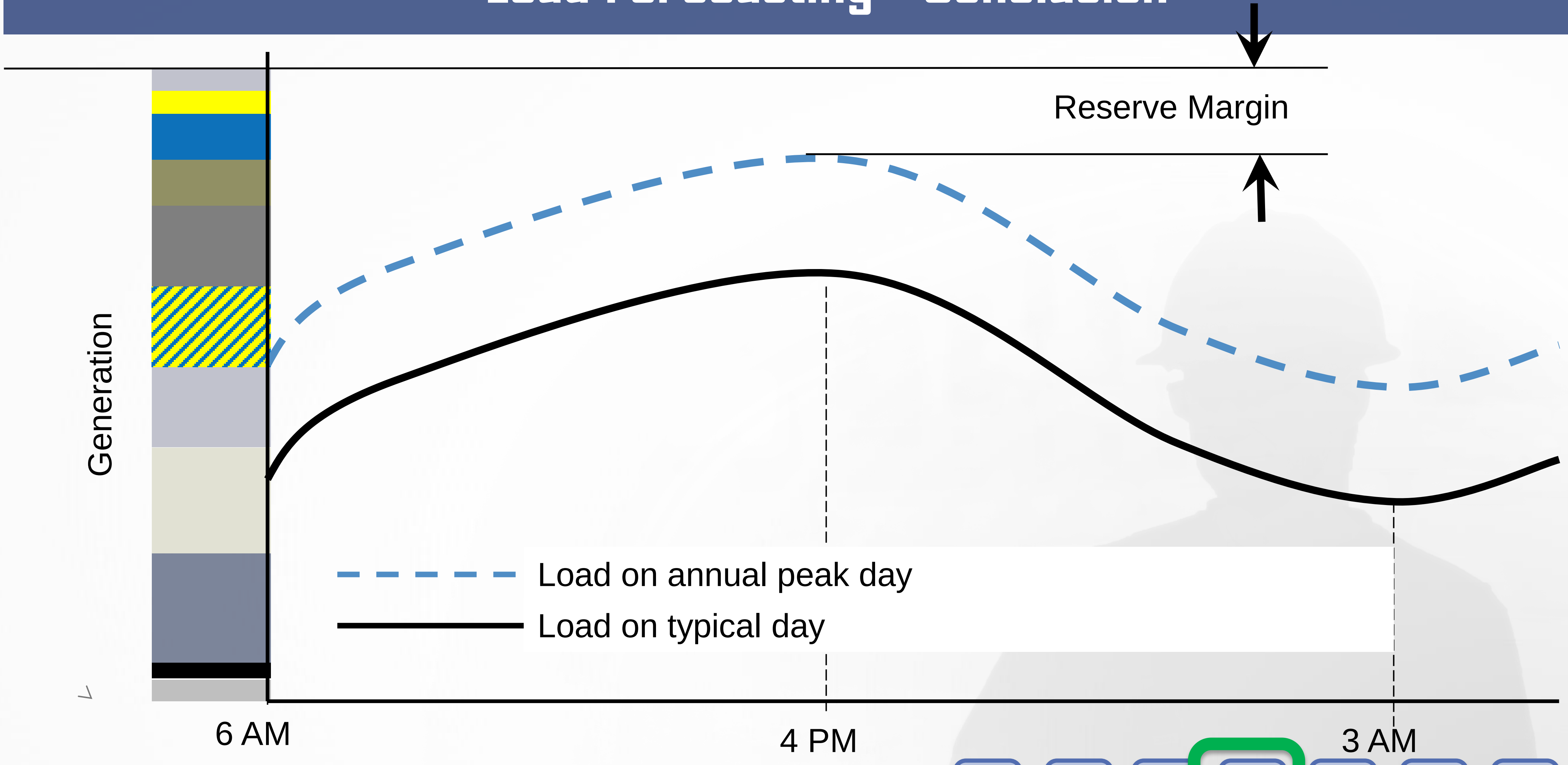
# Load Forecasting - Conclusion

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# QUESTIONS

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# RESOURCES (DUKE)

# Resources Overview

- Load Shapes

- Resources categories:
  - Dispatchable supply side
  - Variable supply side
  - Demand side
  - Distributed generation

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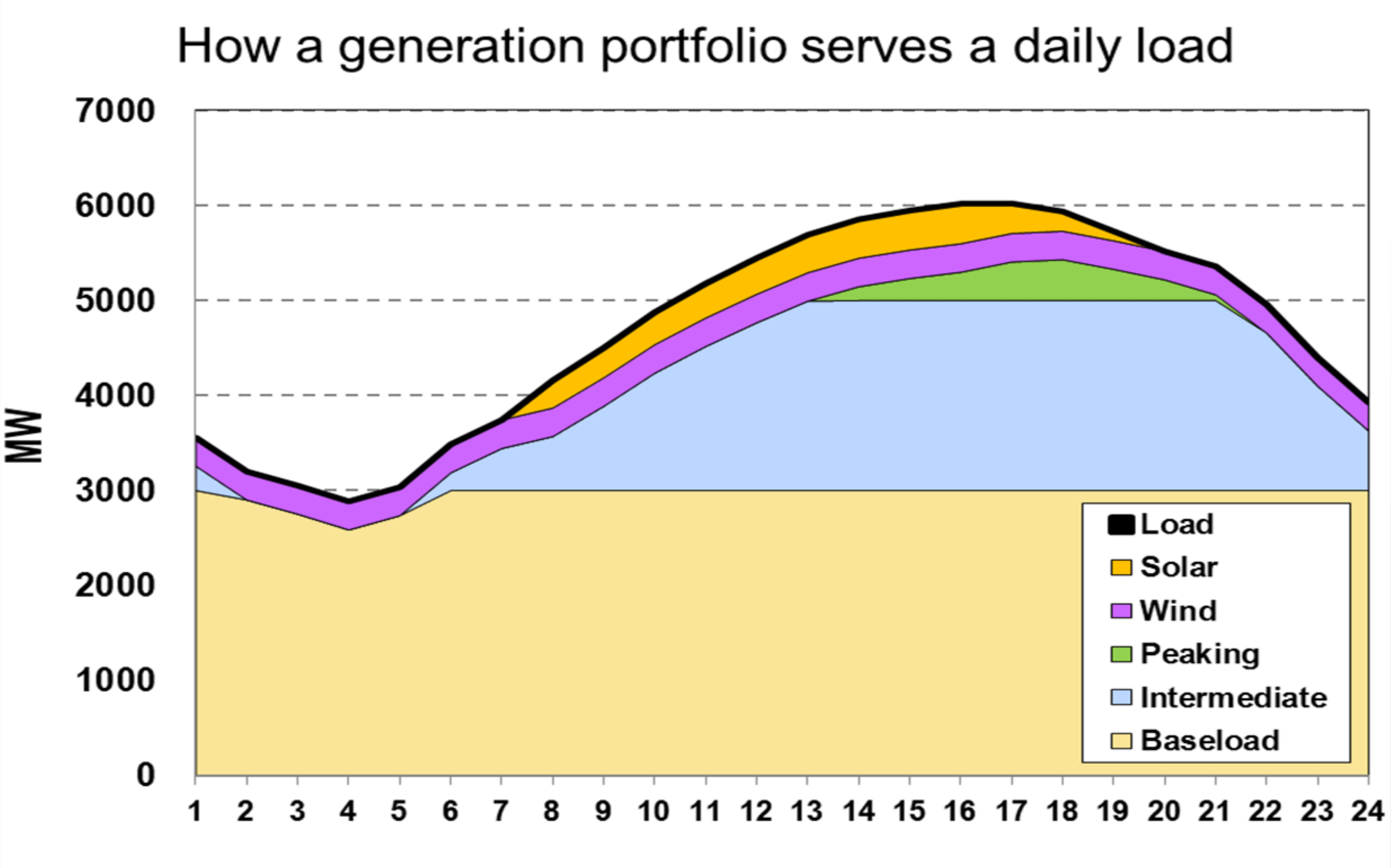
# Resources – Summer & Winter Load Shapes

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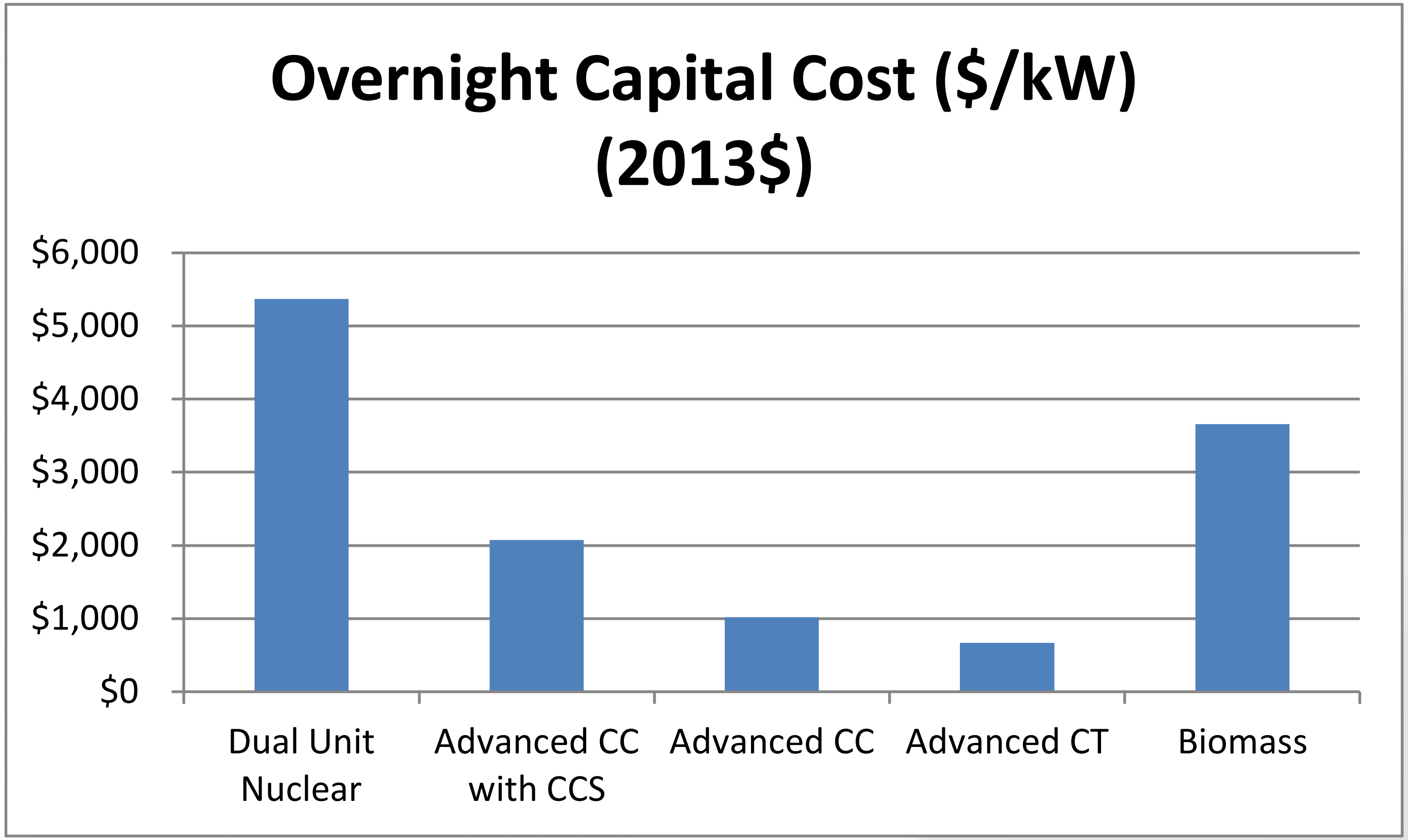
# Resources Categories

- Dispatchable supply side
  - Nuclear, coal, combined cycle (CC)/ combustion turbine (CT)
  - Biomass, reservoir hydro, batteries, combined heat & power (CHP)
- Variable supply side
  - Solar & wind
  - Run of river hydro
- Demand side
  - Energy Efficiency
  - Demand Response
- Distributed Generation

# Resources – Dispatchable Supply Side




CCS: Carbon Capture and Sequestration or Carbon Capture and Storage
CC: Combined Cycle
CT: Combustion Turbine

Source: U.S. Energy Information Administration | Assumptions to the Annual Energy Outlook 2015

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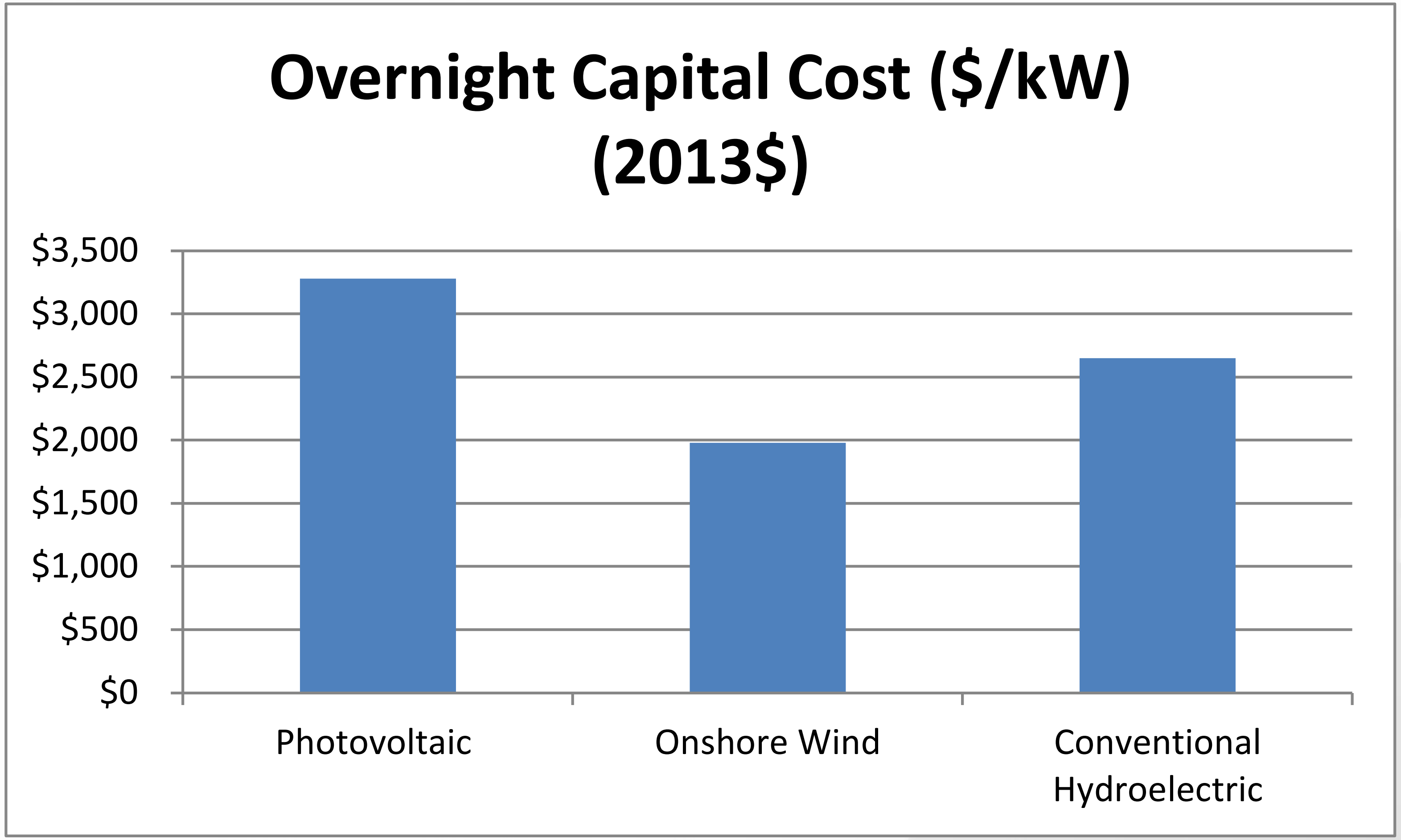
# Resources – Variable Supply Side




Source: U.S. Energy Information Administration | Assumptions to the Annual Energy Outlook 2015

# Resources – Demand Side (Energy Efficiency)

- Resource Description
  - EE is not a single resource but rather a collection of hundreds of different measures such as lighting, appliances or motors
  - Typically,
    - EE is incorporated into the load forecast implicitly
    - EE levels are frequently described in terms of
      - Technical potential
      - Economic potential
      - Achievable potential
  - There are various methods to model DSM/EE
    - Indiana Utilities will address this within their IRP Stakeholder Meetings

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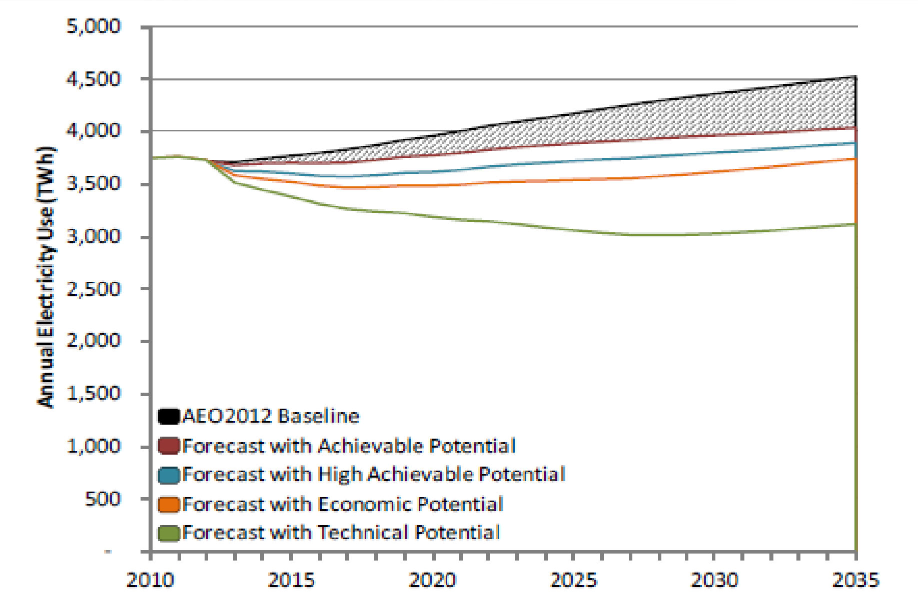
# Resources – Demand Side (Energy Efficiency)

- Resource Description
  - EE can be incented by the utility, but frequently requires an action by the customer
    - Participation is less than what purely economic behavior would suggest



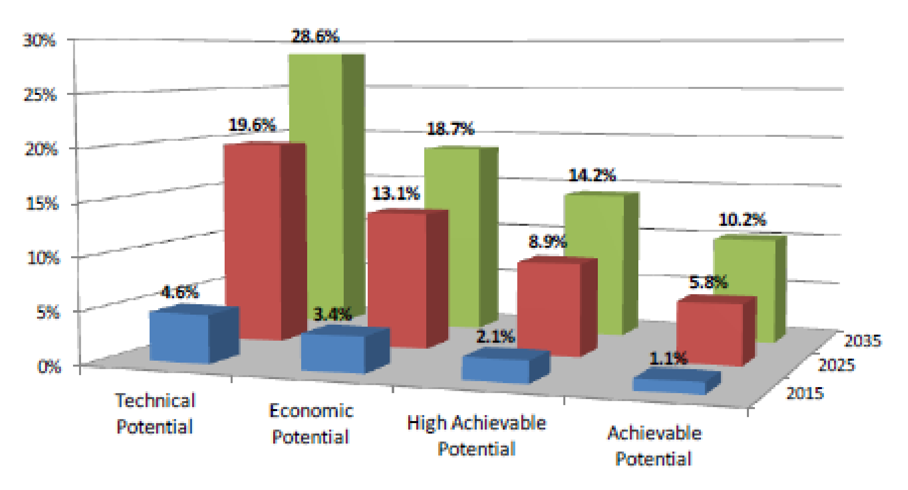




*Figure 12*
*U.S. Summer Coincident Peak Demand Reduction*

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# Resources – Demand Side (Demand Response)

- Resource Description
  - Demand Response (DR) is a resource used to reduce peak load by one of these options:
    - Customers agreeing to load curtailment in exchange for an option, e.g. Air Conditioning Load Management (ACLM) or industrial curtailment
    - Calling upon customer-owned generation
    - Utility modifies system operating parameters, e.g. Conservation Voltage Reduction or Volt/VAR Optimization


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# Resources – Demand Side (Demand Response)

## Benefits

- Capacity value in RTO market
- Opportunity for customers to lower bill in exchange for agreeing to load curtailment
- Useful in peak shaving or shifting
- May include EE benefits too

## Challenges

- Unique Evaluation Measurement & Verification (EM&V) requirements
- Higher use of DR may can drive customers away from program
- Incremental DR capacity gets increasing expensive
  - Higher payments are needed to incent new participants and that higher rate also gets paid to all participants and drives up the cost of incremental DR

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# Resources – Distributed Generation

Resource Description: Distributed Generation are resources connected on distribution circuits. Examples include solar, wind, combined heat and power (CHP), and energy storage.

## Benefits

- Avoided line losses/T&D expenses
- Less "chunky" resource additions
- Potential customer specific reliability improvements
- Customer choices
- Reduced emissions

## Challenges

- System operations
  - Dispatch-ability
  - Intermittency
- Interconnection issues
- Loss of economies of scale

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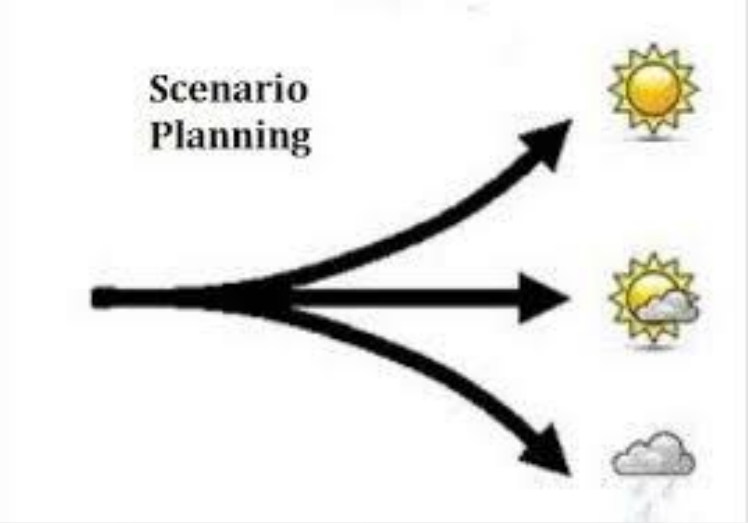
# QUESTIONS

# 6 SCENARIOS AND SENSITIVITIES (IPL)

# Scenarios & Sensitivities

- IRPs include a multitude of options amidst a range of uncertainties given a 20+ year future view
- Consider risks and uncertainties through scenario planning
  - Examples:
    - Economic drivers
    - Environmental regulations
    - Technology advancements

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# Definitions

- Risk – the variance from expected outcome due to a change in one or more assumptions.
- Uncertainty – the potential range of possibilities that a particular variable or assumption may vary
- *Base Case Scenario – "The base case [scenario] should describe the utility's best judgment (with input from stakeholders) as to what the world might look like in 20 years if the status quo would continue without any unduly speculative and significant changes to resources or laws/policies affecting customer use and resources."
- Driver – a specific variable that if changed results in a significantly different outcome
- Resource Plan – a utility plan for meeting forecasted annual peak and energy demand, plus some established reserve margin, through a combination of supply side and demand side resources over a specified future period
- *Scenario – "A scenario is a simulation of a future world technical, regulatory and load environment."
- Sensitivity– A sensitivity measures how a resource plan performs across a range of possibilities for a specific driver or variable

*2015 IURC Director's Report

# Scenario Planning vs. Sensitivity Analysis

- Scenario Planning
  - Example potential future world outcomes
    - Strong Economy
    - Weak Economy
    - Public Policy focus on energy independence
    - Public policy focus on environmental impact
    - Technology enabling extensive Distributed Generation

- Sensitivity Analysis
  - Example assumptions tested
    - Load Forecast
    - Commodity Prices : Locational Marginal Pricing (LMPs), Natural Gas (NG), Coal
    - $CO_2$ Costs
    - Capacity Prices

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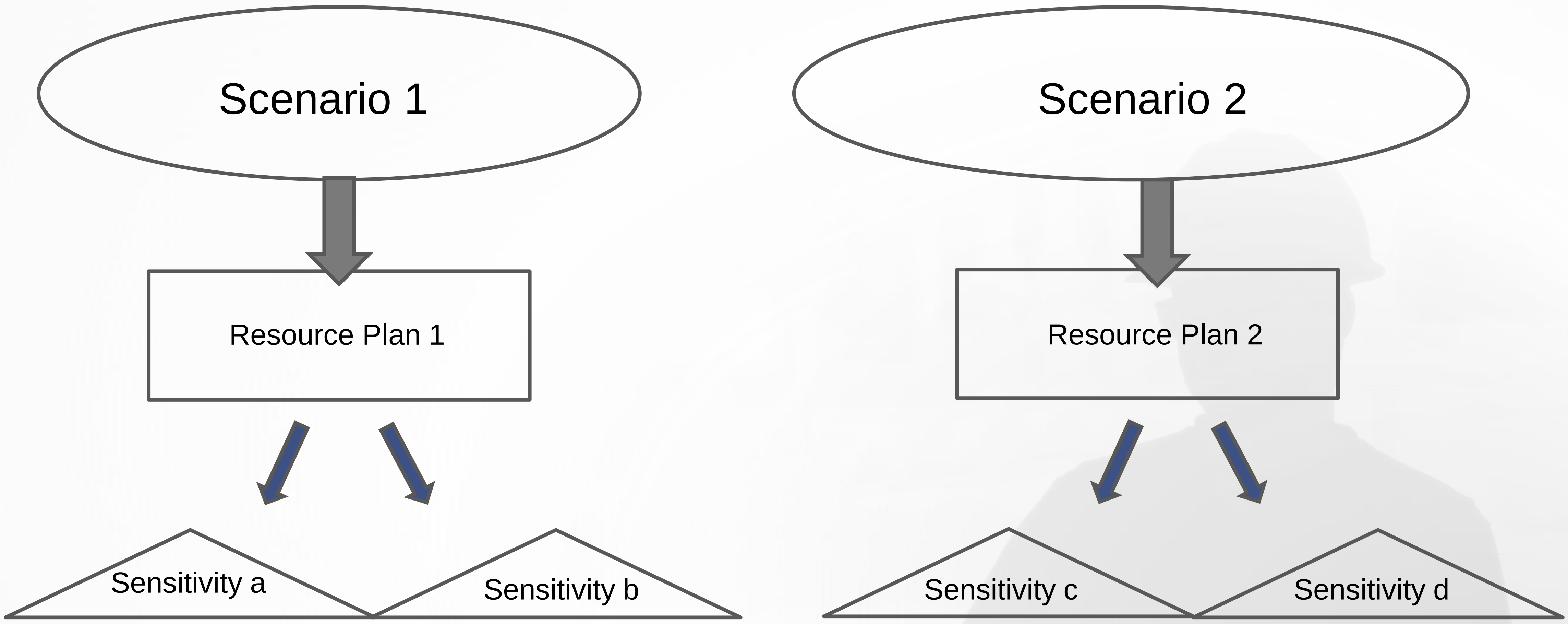
# Scenarios and Sensitivities



# Scenario Planning

- Characteristics
  - Starts with understanding major factors / drivers (external) that move potential future world outcomes in different directions.
    - Intuitive
    - Inclusive
  - Then develop different plausible potential future world outcomes
  - Each scenario incorporates multiple uncertainties over multiple time periods
  - Lays foundation for modeling and developing Resource Plans

# Sensitivity Analysis

- Characteristics
  - Identifies key assumptions
    - Assumptions to which our plan results are most and least sensitive
  - Identifies Resource Plans that are most robust to the most key assumptions
  - Identifies Resource Plans that are most sensitive to the most key assumptions (i.e. least robust)
  - Helps prioritize risks and uncertainties

# Probabilistic Analysis

- Characteristics
  - Varying intensity
  - Various methods - Monte Carlo simulation, probabilistic decision tree, other
  - May be in IRP and/or specific project/certificate of need analysis
- Quantitative
  - Assign specific percentage probability based on statistics or even educated estimates
    - Commodity prices lend themselves to quantitative analysis because you have histories, forwards markets, and fundamental forecasts
- Qualitative
  - Assign range of probability (low vs. high vs. intermediate) based on educated estimates
    - Future policy decisions lend themselves to qualitative analysis because of the lack of data and objective analysis.

# QUESTIONS

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# REGIONAL TRANSMISSION OPERATORS (NIPSCO)

# Agenda

- Overview of RTOs
  - What they are
  - Who participates
  - What they do
  - How they benefit Indiana's customers
- RTOs and the IRP
  - Relevancy to Indiana's IRP process
- RTOs and Utilities – Information Exchanged
- Questions

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# OVERVIEW OF REGIONAL TRANSMISSION ORGANIZATIONS

# Overview of RTOs – What is an RTO?

- Regional Transmission Organizations (RTOs) or Independent System Operators (ISOs) are independent, non-profit organizations that optimize the operation and planning of the transmission systems of their region
  - Reliably operate their portion of the Bulk Electric System
  - Provide regional and interregional reliability planning for the system
  - Administer capacity, energy, financial transmission rights, and ancillary services markets
- RTOs are required to comply with Federal Energy Regulatory Commission (FERC) Orders and North American Electric Reliability Corporation (NERC) Standards

# Overview of RTOs – How many RTOs are there?

- There are 7 RTOs across the US
- Indiana participates in two:
  - PJM
    - Indiana Michigan Power
  - MISO
    - Duke Indiana
    - Indianapolis Power & Light
    - NIPSCO
    - Vectren

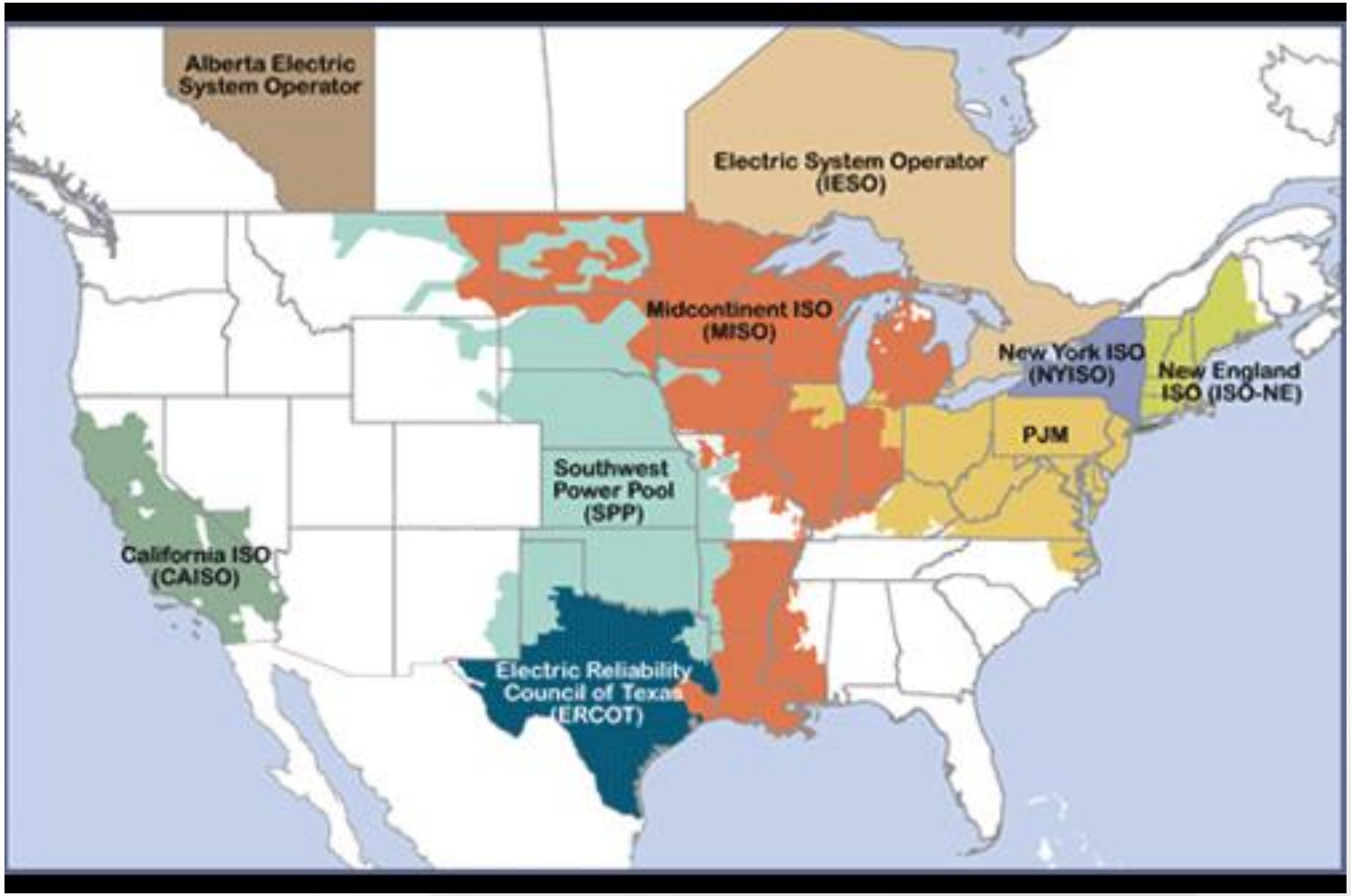


*Image source: www.ferc.gov/industries/electric/indus-act/rto.asp*

# Overview of RTOs – Why are there RTOs?

- FERC envisioned RTOs as a way for existing US power pools to satisfy the requirement of providing non-discriminatory access to transmission for competitive generation
- Subsequently, FERC encouraged the voluntary formation of RTOs to administer the transmission grid on a regional basis throughout North America (including Canada)
- State participation in RTOs has slowly expanded since the mid-1990's and holdouts remain

# Overview of RTOs – Who makes up an RTO?

- Participants - operationally and/or through stakeholder process
  - Transmission owners
  - Load serving entities
  - Transmission developers
  - Generators and independent power producers
  - Power marketers
  - End use customers
  - State regulators and consumer groups
  - Environmental organizations
  - Municipalities, Co-Ops and other transmission-dependent entities
  - Coordinating members

# Overview of RTOs – What does an RTO do?

- Reliably operates a portion of the Bulk Electric System
  - As transmission service provider, RTOs facilitate the scheduling of electric transmission
  - As transmission operator* and reliability coordinator, RTOs ensure the real time reliability of their region’s transmission system
  - As balancing authority*, RTOs balance load and generation and maintain frequency for their region

** Can be a shared function with local utility*

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# Overview of RTOs – What does an RTO do? (cont.)

- Provides reliability planning for the electric system
  - Transmission studies including impact of new generator interconnections
  - Generation assessments (not generation reliability planning)
  - Coordination for outage planning
  - Coordinated regional and interregional transmission planning
    - Performs open and transparent long-term system planning
    - Identifies reliability adequacy on a larger regional basis and ensures that the transmission plans of each member company are compatible with one another
    - Interregional planning studies evaluate transmission issues/solutions for the areas where RTOs adjoin one another (seams)

# Overview of RTOs – What does an RTO do? (cont.)

- Administers the energy and ancillary services markets on a daily basis
  - Dispatches the system by matching generation resources to load to provide the needed electrical energy
    - Security constrained, economic dispatch
      - Lowest cost available resources are dispatched before higher cost resources unless reliability is jeopardized
    - Utilities can buy and sell electricity on behalf of their customers depending on how competitive and available their resources are both in the “day ahead” and real time
    - Price of electricity changes constantly during the day and is influenced by multiple factors including:
      - Weather, electrical load, system constraints, available generation, available fuel, environmental considerations, etc.

# Overview of RTOs – What does an RTO do? (cont.)

## Administers the annual capacity market/auction

- Capacity markets (or MISO's auction) provide a competitive structure for generation owners to sell their available capacity to load serving entities like Indiana utilities
  - Utilities can also purchase or sell capacity through bilateral agreements outside of the capacity construct.
- Utilities serving load are obligated to procure enough resources to satisfy their Planning Reserve Margin which is based on their contribution to the RTO's system peak
  - A utility can satisfy this obligation by showing it has enough Unforced Capacity resources available
  - Utilities have the option to self schedule or provide a fixed resource adequacy plan or participate in the auction/market to obtain the necessary capacity
  - Depending on its resource position, a utility can buy additional capacity in the market or sell any excess
- Once a generation resource is "cleared" in the capacity market, it must be offered into the daily energy market unless it is in outage
  - Resources are also obligated to perform when dispatched

# Overview of RTOs – What does an RTO do? (cont.)

- MISO's Single Year Capacity Construct (Duke, IPL, NIPSCO, Vectren)
  - Auction for the next Planning Year running June 1 – May 31
  - Capacity obligation established to meet summer peak and carried for entire year
  - Footprint is separated into individual local resource zones which limits over-importing/exporting
  - MISO is planning to move to a two-season approach with Winter and Summer auction periods

- PJM's Three Year Forward Capacity Market (I&M)
  - Auction for the Planning Years running June 1 – May 31
  - Three-year forward market with multiple auctions
    - Base Residual auction, then yearly secondary auctions provide a longer-term price signal
  - Generation pay-for-performance recently implemented
    - Higher performing resources receive a higher capacity payment than underperformers

While capacity markets show the value of capacity in the future, these markets/auctions are relatively near term when compared to the 20-year timeline for Indiana's IRP process

# Some benefits of the RTO/ISO approach

## Optimized Transmission System

- Real Time Operations
- System Planning
- Overall Enhanced Reliability

## Economies of Scale

- Centralized operating activities v. locally duplicated activities

## Available Capacity Reserves

- Available at competitive prices

## Potential Long Term Price Signal

- Bringing more certainty to capacity price in distant years

## Evolving Markets

- Capacity, Energy & Ancillary Services
- Can match products to address customer needs or solve operational / reliability issues

# RTOs AND THE IRP

# RTOs and the IRP – How do they interact?

- The Indiana Utility Regulatory Commission (IURC) is the regulator of Indiana's resource adequacy
  - The IURC regulates the resource requirement for each utility
    - Through the IRP, utilities demonstrate that they have enough resources to meet the forecasted system peak in future years plus an additional reserve margin
  - Many of the concepts between the IRP and the way MISO and PJM conduct their capacity auction/market are similar, but differences exist
    - Some examples:
      - A utility's system peak may not peak at the same time as the RTO's system peak
      - Unforced capacity in the IRP may not equal the utility's Unforced Capacity (UCAP) in the RTO
  - In the IRP, utilities include RTO energy and capacity cost forecasts in order to model market dispatch and select the preferred resource plan in multiple scenarios

# RTOs and the IRP – How do they interact? (cont.)

- RTOs perform an analysis role for the region's resource adequacy
  - RTOs also evaluate the ability of smaller areas in the region to meet their Planning Reserve Margin requirements
  - These areas do not break cleanly on state boundaries and are even more complicated for states like Indiana that are separated between two RTOs
  - While obligated by FERC to perform this verification function, the authority and obligation to ensure Indiana's resource adequacy lies with Indiana

# RTOs AND UTILITIES – INFORMATION EXCHANGED

# RTOs and Utilities – What Information is exchanged?

- Information exchanged includes
  - Load and Resource forecasts
  - Maintenance outage plans
  - Plans for generation retrofits, retirements and additions
  - Environmental compliance plans
  - Demand side resources
  - Generation fuel assumptions
  - Transmission investments and upgrades
  - Historical performance of generation resources (NERC-GADS)
  - Historical performance of demand response resources (NERC-DADS)
  - Scenario planning and risk assessment
  - Emergency recovery planning

# QUESTIONS

# 7 RESOURCE MODELING (I&M/AEP)

# Resource Modeling

## Agenda

- Objective: Provide a basic overview of resource modeling and how it is used in developing an IRP
  - List software criteria necessary for resource modeling
  - Identify and describe resource modeling inputs
  - Provide examples of model output
  - Describe risk modeling options and provide examples
  - Development of a preferred plan

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# Resource Modeling

- Role of Resource Modeling in Developing an IRP
  - Utilities must select among a variety of resource options (supply and demand-side) to meet their customers’ energy needs
  - Each resource option has a different cost and energy profile
  - The optimal suite of resources will vary based on the modeling input assumptions (scenarios/sensitivities)
  - Goal of resource modeling is to identify the suite of resources that meets customer requirements at the lowest reasonable cost
  - Model outputs are used to inform utility decision makers in developing a preferred portfolio of resources

# Resource Modeling

- Production Costing Function
  - Production Costing accounts for the costs of converting fuel and other variable and fixed costs in order to produce electrical energy to meet customers' load
- Resource Planning Function
  - Long-Term resource optimization is the development of a system resource expansion plan that balances "least-cost" objectives with planning flexibility, asset mix considerations, adaptability to risk, and conforms with applicable NERC and RTO criteria

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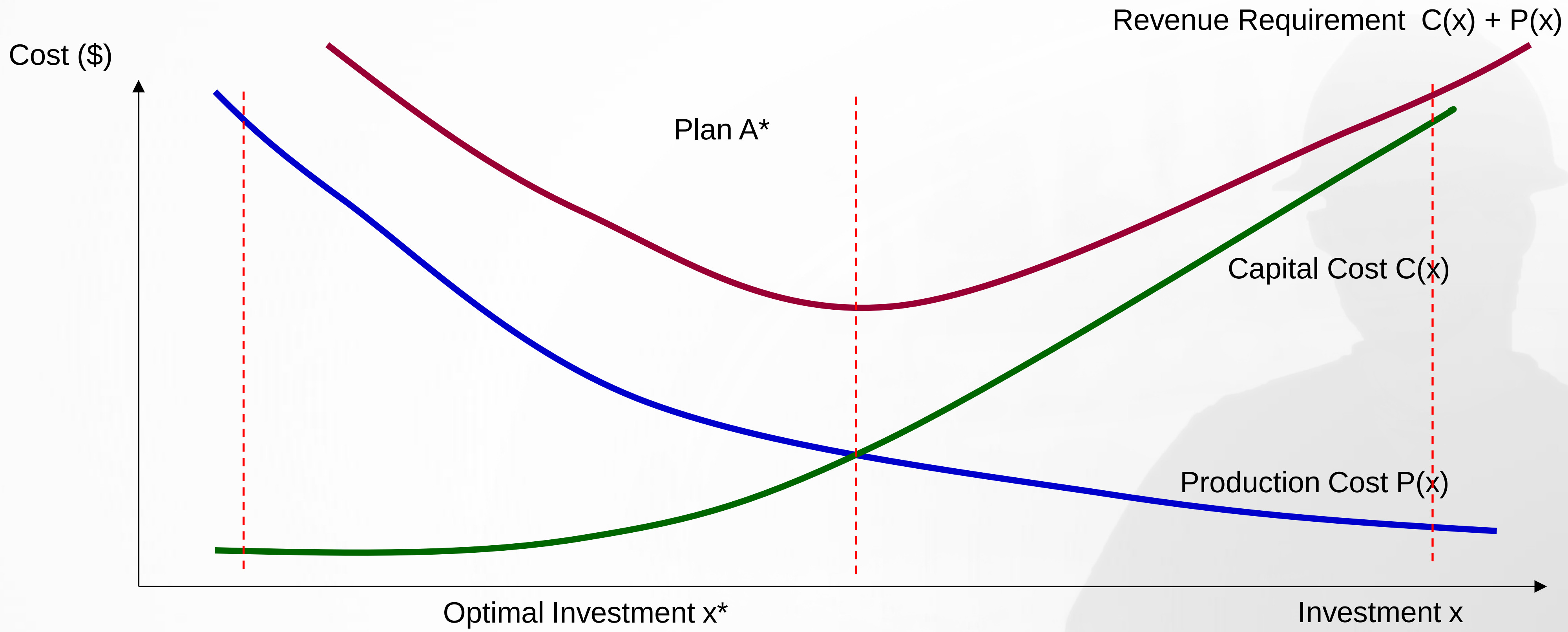
# Resource Modeling

- The “Objective Function” is to minimize net present value of forward-looking costs (i.e. capital and production costs)

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# Resource Modeling

- Software tools used in resource modeling functions (Production Costing and Resource Planning)

PLEXOS®
Integrated Energy Model

Energy Exemplar
Est. 1999

System Optimizer

Strategist

PROMOD IV

Power and productivity for a better world™ ABB

PCI GenTrader ®

PCI
ENERGY IN FOCUS.

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# Resource Modeling

- Criteria for selecting Resource Planning Software
  - Market-based commitment & dispatch
  - Easily model emission-limited dispatch
  - User-friendly input/output interface
  - Responsive user support

# Resource Modeling

- **Inputs used in the modeling**
  - Existing System
  - Resource Options
  - Scenario Drivers
  - Financial Rate Inputs

# Resource Modeling

Inputs : **Existing System** → Resource Options → Scenario Drivers → Financial Inputs

- **Existing system operating characteristics**
  - Heat rates
  - Load points (MW)
  - Start cost
  - Start cost times (hours)
  - Rating (firm, max, min)
  - Min up Min down times
  - Ramp rates (MW/min)
  - Variable O&M ($/MWh)
  - Fixed O&M ($/kW/year)
  - Capital expenditures
  - On-going capital
  - Maintenance schedule (dates)
  - Forced outage rates (%)
  - Outage ratings (MW)
  - Mean, min, max repair times (hours)
  - Transmission interconnection

1 2 3 4 5 6 7 8

# Resource Modeling

Inputs : Existing System → **Resource Options** → Scenario Drivers → Financial Inputs

- **Resource Options**
  - Thermal
    - Base load, Intermediate, and Peaking
  - Energy efficiency
    - Commercial and Residential
  - Wind
  - Solar
    - Utility and customer owned
  - Grid optimization

- Build costs ($/kW)
- Construction profiles
- Economic life
- Technical life
- Min and max units built (by horizon or year)
- Operating characteristics
- Generation profiles (wind/solar)

1 2 3 4 5 6 7 8

# Resource Modeling

Inputs : Existing System → Resource Options → **Scenario Drivers** → Financial Inputs

- **Scenario drivers**
  - Load forecast (base)
    - Load sensitivities (high, low)
  - Commodity prices (base)
    - Coal, Gas, Market energy price
    - Price sensitivities (high, low)
  - Environmental Regulation
    - Water, $CO_2$, Coal Combustion Residuals

1 2 3 4 5 6 7 8

# Resource Modeling

Inputs : Existing System → Resource Options → Scenario Drivers → **Financial Inputs**

## Financial Rate Inputs

| | |
|---|---|
| 1 | Composite Tax Rate (%) |
| 2 | Customer Discount Rate (%) |
| 3 | Debt Service Reserve Percent (%) |
| 4 | Federal Income Tax Rate (%) |
| 5 | Inflation Rate (%) |
| 6 | Real Discount Rate (%) |
| 7 | Reserve and Contingency Reserve (%) |
| 8 | Utility Discount Rate (%) |
| 9 | Weighted Cost of Capital (%) |

Discounting

Discount Rate (%): 10

End Effects Method

None · Perpetuity

Depreciation Method

None · Straight-line · Declining

Tax Rate (%): 10

Inflation Rate (%): 2

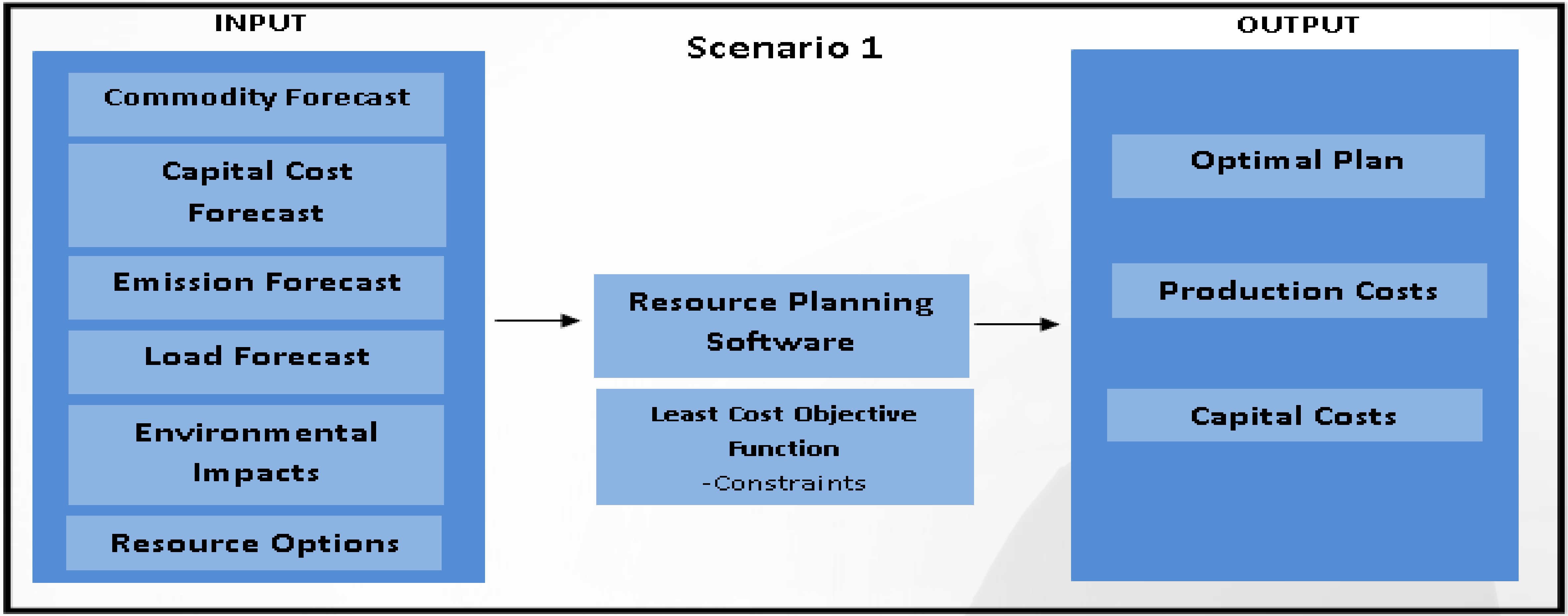
1 2 3 4 5 6 7 8

# Resource Modeling

- Long term resource models utilize the objective function described earlier while abiding by the following possible constraints:
  - Minimum and maximum reserve margins
  - Resource addition and retirement candidates (*i.e.*, maximum units built)
  - Age and lifetime of generators
  - Operation constraints such as ramp rates, minimum up/down times, capacity, heat rates, etc.
  - Fuel burn minimum and maximums
  - Emission limits on effluents such as $SO_2$ and $NO_x$

1 2 3 4 5 6 7 8

# Resource Modeling

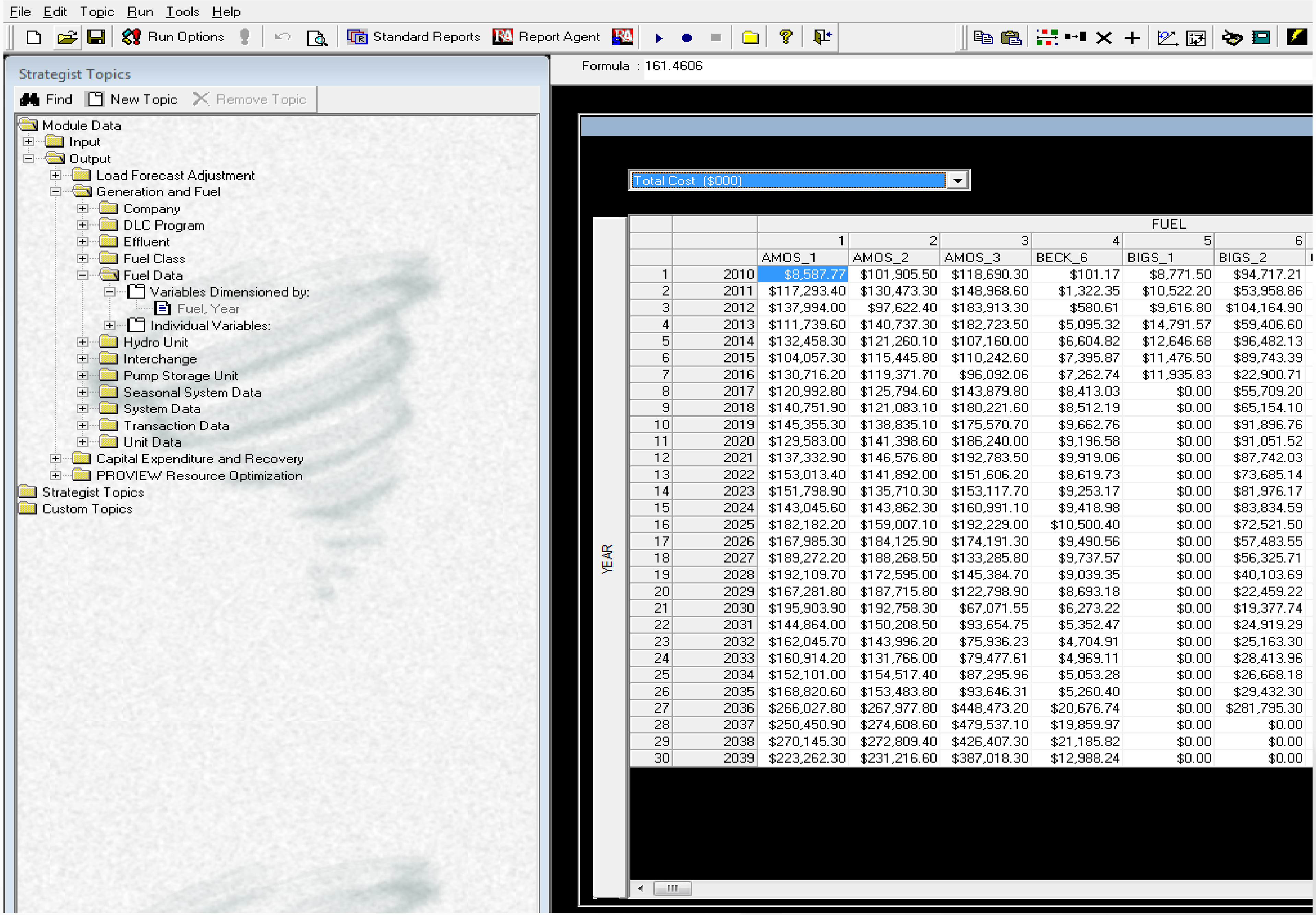


# Resource Modeling

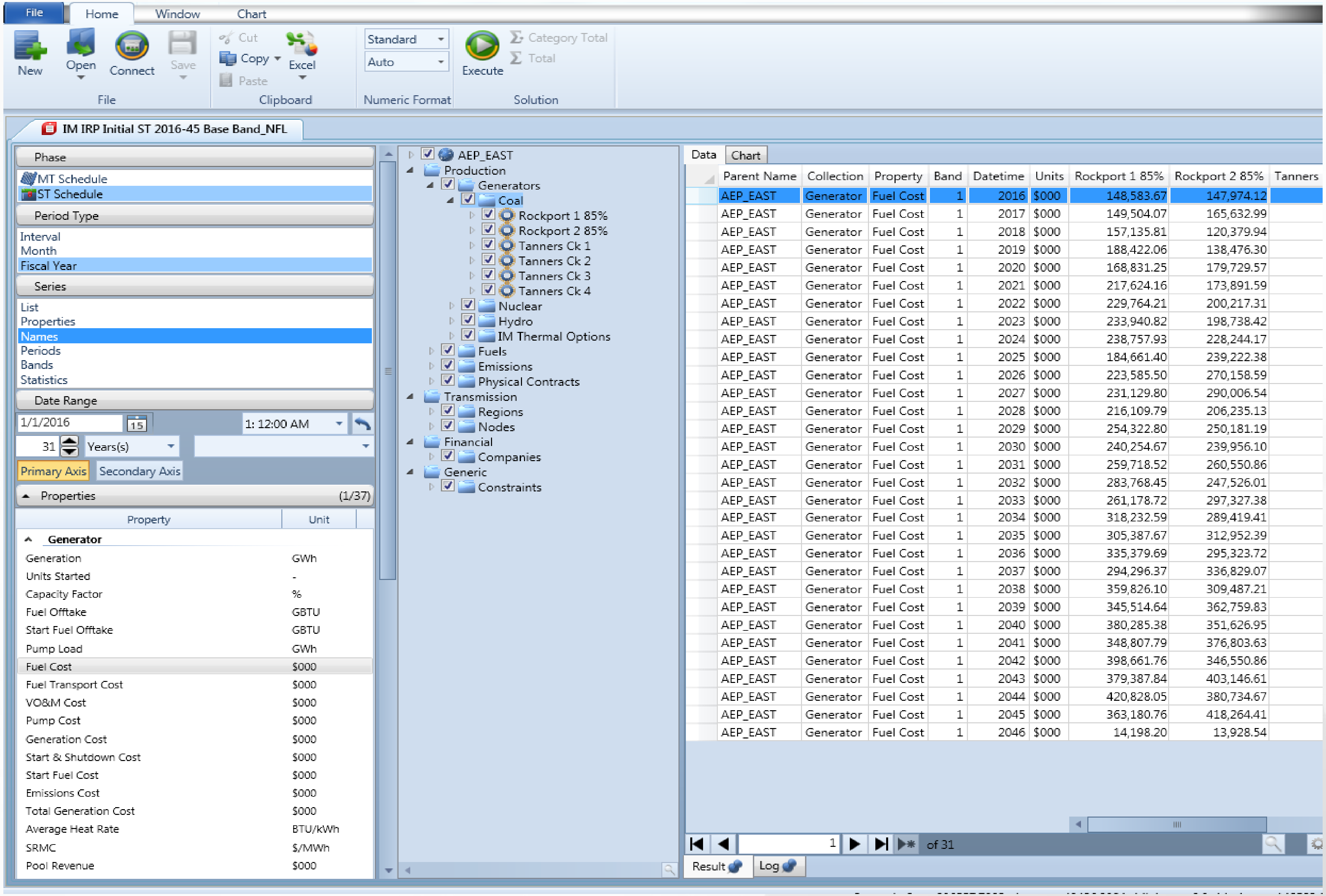
- Long term resource models provide multiple plans for each scenario analyzed
  - Cost of plan is represented by the cumulative present worth of revenue requirements (CPW) or present value of revenue requirements (PVRR)
  - Models produce an optimal plans fuel cost, Variable O&M and Fixed O&M cost, start fuel cost, emissions cost, total generation cost, revenues from energy sales to market, recovery of capital investments on generation additions

1 2 3 4 5 6 7 8

# Outputs




| | | FUEL | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| | | AMOS_1 | AMOS_2 | AMOS_3 | BECK_6 | BIGS_1 | BIGS_2 |
| 1 | 2010 | $8,587.77 | $101,905.50 | $118,690.30 | $101.17 | $8,771.50 | $94,717.21 |
| 2 | 2011 | $117,293.40 | $130,473.30 | $148,968.60 | $1,322.35 | $10,522.20 | $53,958.86 |
| 3 | 2012 | $137,994.00 | $97,622.40 | $183,913.30 | $580.61 | $9,616.80 | $104,164.90 |
| 4 | 2013 | $111,739.60 | $140,737.30 | $182,723.50 | $5,095.32 | $14,791.57 | $59,406.60 |
| 5 | 2014 | $132,458.30 | $121,260.10 | $107,160.00 | $6,604.82 | $12,646.68 | $96,482.13 |
| 6 | 2015 | $104,057.30 | $115,445.80 | $110,242.60 | $7,395.87 | $11,476.50 | $89,743.39 |
| 7 | 2016 | $130,716.20 | $119,371.70 | $96,092.06 | $7,262.74 | $11,935.83 | $22,900.71 |
| 8 | 2017 | $120,992.80 | $125,794.60 | $143,879.80 | $8,413.03 | $0.00 | $55,709.20 |
| 9 | 2018 | $140,751.90 | $121,083.10 | $180,221.60 | $8,512.19 | $0.00 | $65,154.10 |
| 10 | 2019 | $145,355.30 | $138,835.10 | $175,570.70 | $9,662.76 | $0.00 | $91,896.76 |
| 11 | 2020 | $129,583.00 | $141,398.60 | $186,240.00 | $9,196.58 | $0.00 | $91,051.52 |
| 12 | 2021 | $137,332.90 | $146,576.80 | $192,783.50 | $9,919.06 | $0.00 | $87,742.03 |
| 13 | 2022 | $153,013.40 | $141,892.00 | $151,606.20 | $8,619.73 | $0.00 | $73,685.14 |
| 14 | 2023 | $151,798.90 | $135,710.30 | $153,117.70 | $9,253.17 | $0.00 | $81,976.17 |
| 15 | 2024 | $143,045.60 | $143,862.30 | $160,991.10 | $9,418.98 | $0.00 | $83,834.59 |
| 16 | 2025 | $182,182.20 | $159,007.10 | $192,229.00 | $10,500.40 | $0.00 | $72,521.50 |
| 17 | 2026 | $167,985.30 | $184,125.90 | $174,191.30 | $9,490.56 | $0.00 | $57,483.55 |
| 18 | 2027 | $189,272.20 | $188,268.50 | $133,285.80 | $9,737.57 | $0.00 | $56,325.71 |
| 19 | 2028 | $192,109.70 | $172,595.00 | $145,384.70 | $9,039.35 | $0.00 | $40,103.69 |
| 20 | 2029 | $167,281.80 | $187,715.80 | $122,798.90 | $8,693.18 | $0.00 | $22,459.22 |
| 21 | 2030 | $195,903.90 | $192,758.30 | $67,071.55 | $6,273.22 | $0.00 | $19,377.74 |
| 22 | 2031 | $144,864.00 | $150,208.50 | $93,654.75 | $5,352.47 | $0.00 | $24,919.29 |
| 23 | 2032 | $162,045.70 | $143,996.20 | $75,936.23 | $4,704.91 | $0.00 | $25,163.30 |
| 24 | 2033 | $160,914.20 | $131,766.00 | $79,477.61 | $4,969.11 | $0.00 | $28,413.96 |
| 25 | 2034 | $152,101.00 | $154,517.40 | $87,295.96 | $5,053.28 | $0.00 | $26,668.18 |
| 26 | 2035 | $168,820.60 | $153,483.80 | $93,646.31 | $5,260.40 | $0.00 | $29,432.30 |
| 27 | 2036 | $266,027.80 | $267,977.80 | $448,473.20 | $20,676.74 | $0.00 | $281,795.30 |
| 28 | 2037 | $250,450.90 | $274,608.60 | $479,537.10 | $19,859.97 | $0.00 | $0.00 |
| 29 | 2038 | $270,145.30 | $272,809.40 | $426,407.30 | $21,185.82 | $0.00 | $0.00 |
| 30 | 2039 | $223,262.30 | $231,216.60 | $387,018.30 | $12,988.24 | $0.00 | $0.00 |




| Parent Name | Collection | Property | Band | Datetime | Units | Rockport 1 85% | Rockport 2 85% | Tanners |
|---|---|---|---|---|---|---|---|---|
| AEP_EAST | Generator | Fuel Cost | 1 | 2016 | $000 | 148,583.67 | 147,974.12 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2017 | $000 | 149,504.07 | 165,632.99 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2018 | $000 | 157,135.81 | 120,379.94 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2019 | $000 | 188,422.06 | 138,476.30 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2020 | $000 | 168,831.25 | 179,729.57 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2021 | $000 | 217,624.16 | 173,891.59 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2022 | $000 | 229,764.21 | 200,217.31 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2023 | $000 | 233,940.82 | 198,738.42 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2024 | $000 | 238,757.93 | 228,244.17 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2025 | $000 | 184,661.40 | 239,222.38 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2026 | $000 | 223,585.50 | 270,158.59 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2027 | $000 | 231,129.80 | 290,006.54 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2028 | $000 | 216,109.79 | 206,235.13 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2029 | $000 | 254,322.80 | 250,181.19 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2030 | $000 | 240,254.67 | 239,956.10 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2031 | $000 | 259,718.52 | 260,550.86 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2032 | $000 | 283,768.45 | 247,526.01 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2033 | $000 | 261,178.72 | 297,327.38 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2034 | $000 | 318,232.59 | 289,419.41 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2035 | $000 | 305,387.67 | 312,952.39 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2036 | $000 | 335,379.69 | 295,323.72 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2037 | $000 | 294,296.37 | 336,829.07 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2038 | $000 | 359,826.10 | 309,487.21 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2039 | $000 | 345,514.64 | 362,759.83 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2040 | $000 | 380,285.38 | 351,626.95 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2041 | $000 | 348,807.79 | 376,803.63 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2042 | $000 | 398,661.76 | 346,550.86 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2043 | $000 | 379,387.84 | 403,146.61 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2044 | $000 | 420,828.05 | 380,734.67 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2045 | $000 | 363,180.76 | 418,264.41 | |
| AEP_EAST | Generator | Fuel Cost | 1 | 2046 | $000 | 14,198.20 | 13,928.54 | |

# Resource Modeling

- Sample output for one resource plan

| | Plan A | | | | | | |
|---|---|---|---|---|---|---|---|
| Year | Fuel Cost ($000) | VOM Cost ($000) | Emission Cost ($000) | FOM Cost ($000) | Annualized Build Cost ($000) | Pool Revenue ($000) | Revenue Requirement ($000) |
| 2016 | 104,492 | 7,652 | 12,500 | 5,854 | 107,357 | 161,562 | 76,293 |
| 2017 | 111,806 | 8,188 | 13,375 | 6,264 | 107,357 | 172,871 | 74,119 |
| 2018 | 119,633 | 8,761 | 14,311 | 6,702 | 107,357 | 184,972 | 71,792 |
| 2019 | 128,007 | 9,374 | 15,313 | 7,171 | 107,357 | 197,920 | 69,302 |
| 2020 | 136,968 | 10,030 | 16,385 | 7,673 | 107,357 | 211,775 | 66,638 |
| 2021 | 146,555 | 10,732 | 17,532 | 8,211 | 107,357 | 226,599 | 63,788 |
| 2022 | 156,814 | 11,484 | 18,759 | 8,785 | 107,357 | 242,461 | 60,738 |
| 2023 | 167,791 | 12,287 | 20,072 | 9,400 | 107,357 | 259,433 | 57,475 |
| 2024 | 179,537 | 13,148 | 21,477 | 10,058 | 107,357 | 277,594 | 53,983 |
| 2025 | 359,073 | 26,295 | 42,955 | 20,117 | 322,071 | 555,187 | 215,324 |
| 2026 | 384,209 | 28,136 | 45,961 | 21,525 | 322,071 | 594,050 | 207,851 |
| 2027 | 411,103 | 30,105 | 49,179 | 23,031 | 322,071 | 635,634 | 199,856 |
| 2028 | 439,880 | 32,213 | 52,621 | 24,644 | 322,071 | 680,128 | 191,301 |
| 2029 | 470,672 | 34,468 | 56,305 | 26,369 | 322,071 | 727,737 | 182,147 |
| 2030 | 503,619 | 36,880 | 60,246 | 28,214 | 322,071 | 778,679 | 172,352 |

1 2 3 4 5 6 7 8

# Resource Modeling

- Sample output for multiple resource plans

| INDIANA MICHIGAN POWER COMPANY<br>I&M Capacity Resource Optimization<br>PRELIMINARY - Summary Comparison Plan A, Plan B, Plan C Under High Band Commodity Pricing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ***CPW $000 (2016$)*** | Load Cost | Fuel Costs | Emission Costs | Fixed O&M+ Var O&M+ On-going Capital | New Build Capital+ New Build Program Costs | Contract (Revenue)/Cost | *Less:* Market Revenue | ICAP Value | Revenue Requirements |
| ***Plan A*** | | | | | | | | | |
| Utility Cost Present Worth 2016-2045 | 18,527,589 | 8,691,690 | 2,853,690 | 3,689,931 | 5,465,294 | (219,164) | 28,155,696 | 185,130 | 10,668,203 |
| NPV of End Effects beyond 2045 | | | | | | | | | 1,402,022 |
| Total Utility Cost, Cumulative Present Worth | | | | | | | | | 12,070,226 |
| ***Plan B*** | | | | | | | | | |
| Utility Cost Present Worth 2016-2045 | 18,527,589 | 8,817,296 | 1,875,660 | 2,662,676 | 6,354,900 | (219,164) | 27,229,749 | 262,091 | 10,527,117 |
| NPV of End Effects beyond 2045 | | | | | | | | | 1,571,701 |
| Total Utility Cost, Cumulative Present Worth | | | | | | | | | 12,098,818 |
| ***Plan C*** | | | | | | | | | |
| Utility Cost Present Worth 2016-2045 | 18,527,589 | 5,922,547 | 734,031 | 2,045,270 | 5,903,289 | (219,164) | 22,033,360 | 139,263 | 10,740,938 |
| NPV of End Effects beyond 2045 | | | | | | | | | 1,872,035 |
| Total Utility Cost, Cumulative Present Worth | | | | | | | | | 12,612,972 |

# Resource Modeling

- Risk Modeling Options

- Deterministic
  - Subject specified plan through a variety of commodity price assumptions and load sensitivities.
  - Present value of revenue requirements (PVRR) created for a band of scenarios and sensitivities.

- Probabilistic
  - Identify variables
    - Energy Price, Fuel Price, Emission Price
  - Randomly selected iterations
  - PVRR for each iteration to determine Revenue Requirement at Risk (RRaR)
    - Higher RRaR the "riskier" the plan is.

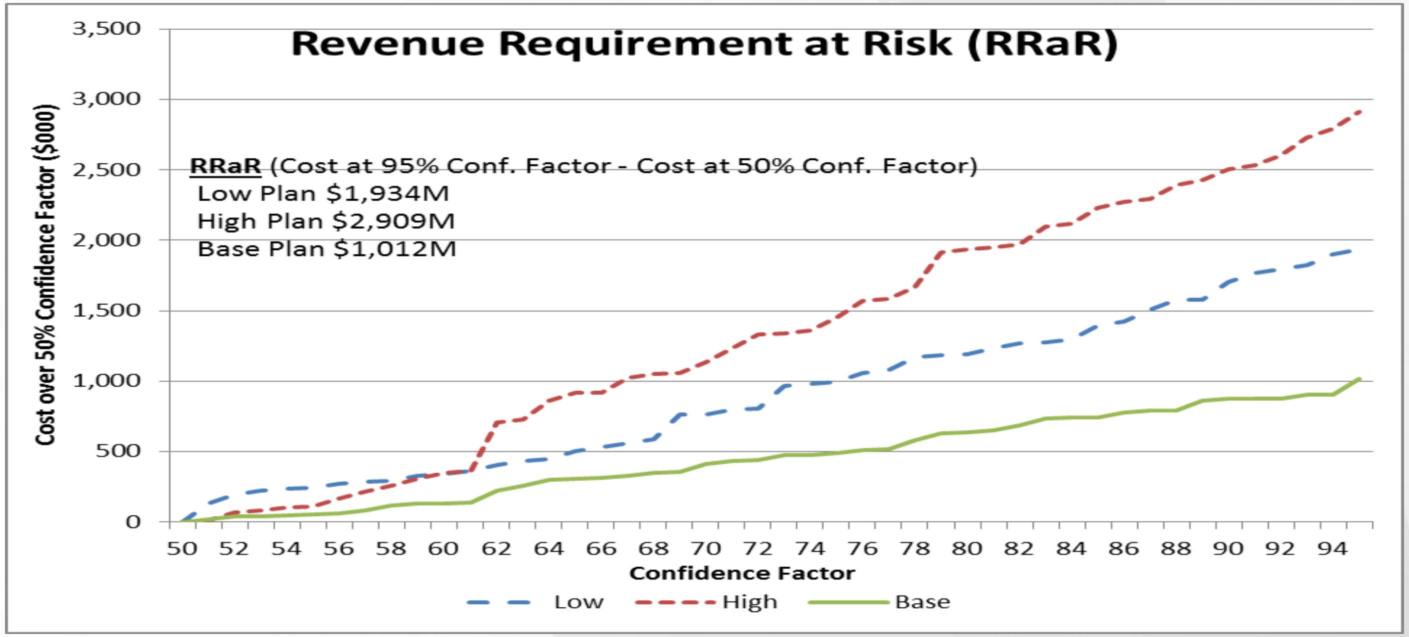
1 2 3 4 5 6 7 8

# Resource Modeling

- Risk Modeling Output
  - Deterministic

| | Revenue Requirements $ | | |
|---|---|---|---|
| | Low Plan | Base Plan | High Plan |
| Low Commodity | 6,000,000 | 7,456,123 | 8,456,123 |
| Base Commodity | 7,894,123 | 7,000,000 | 9,456,123 |
| High Commodity | 9,456,321 | 8,456,123 | 8,000,000 |

  - Probabilistic



# Resource Modeling

- Using Resource Model Results to Determine Preferred Plan
  - Look for similar elements in optimal plans under a variety of input scenarios
    - Quantify impact of modifying resource selection
    - Measure risk characteristics of Preferred Plan to Optimal Plans that are developed under a variety of pricing scenarios
  - Consider variations to existing fleet when constructing portfolios
    - Quantify impact of modifying existing resource assumptions
    - Useful in determining retirement candidates
    - Helpful in determining incremental cost related to policy decisions – for example, increasing renewable energy component of capacity mix to hedge against future $CO_2$ restrictions

# QUESTIONS

# Day in Review/Feedback

- Invite participants to complete brief feedback form
- Any suggestions for improvements

# Utilities IRP Contact

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# CLOSING REMARKS