BERKELEY LAB

ELECTRICITY MARKETS & POLICY

IRP Contemporary Issues Technical Conference

Workshop 1: Energy Efficiency and Load Forecasting

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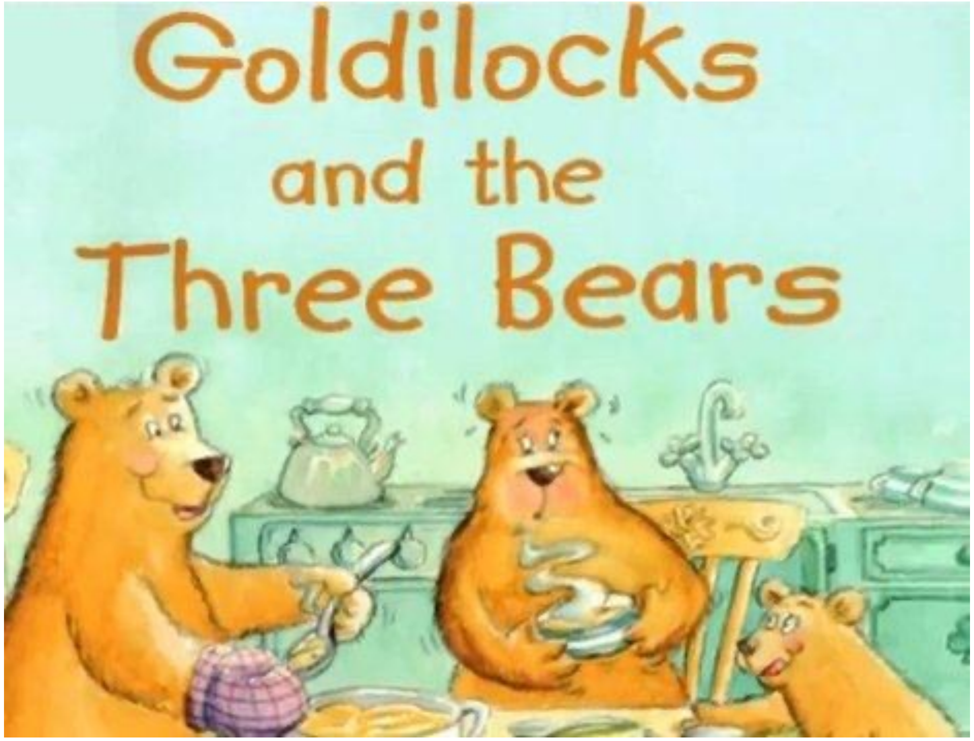
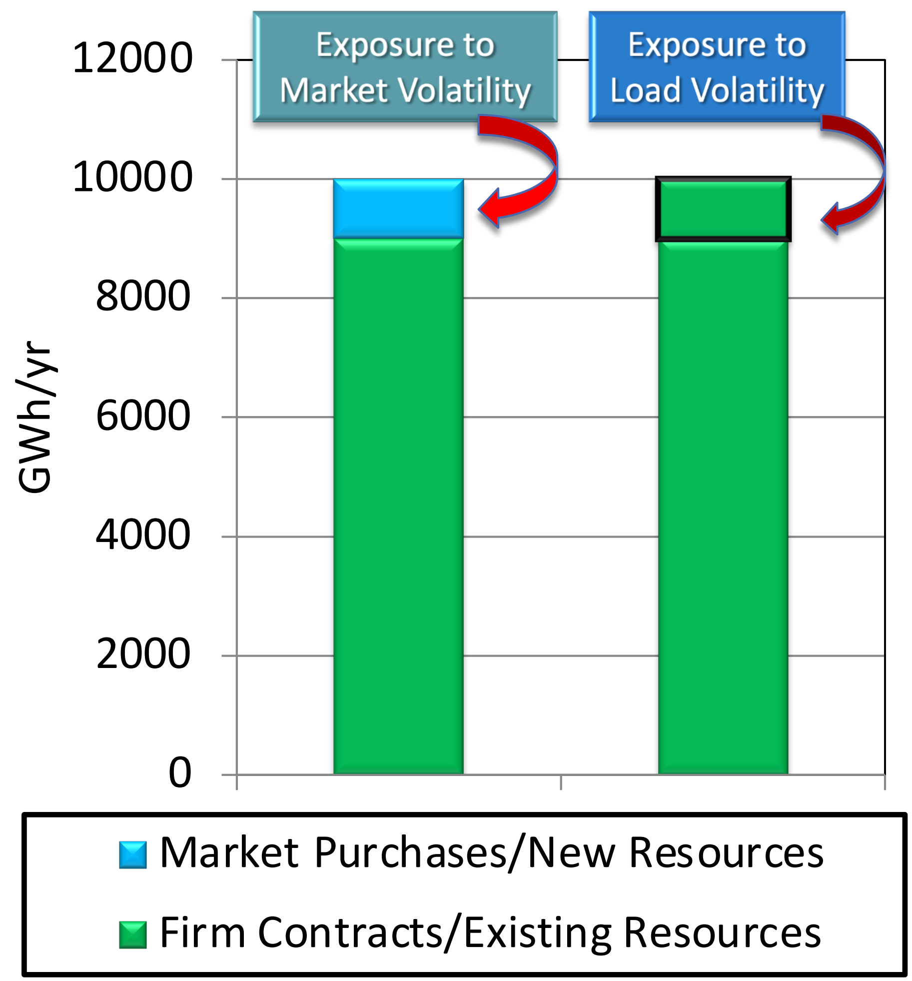
The Resource Planner's Problem

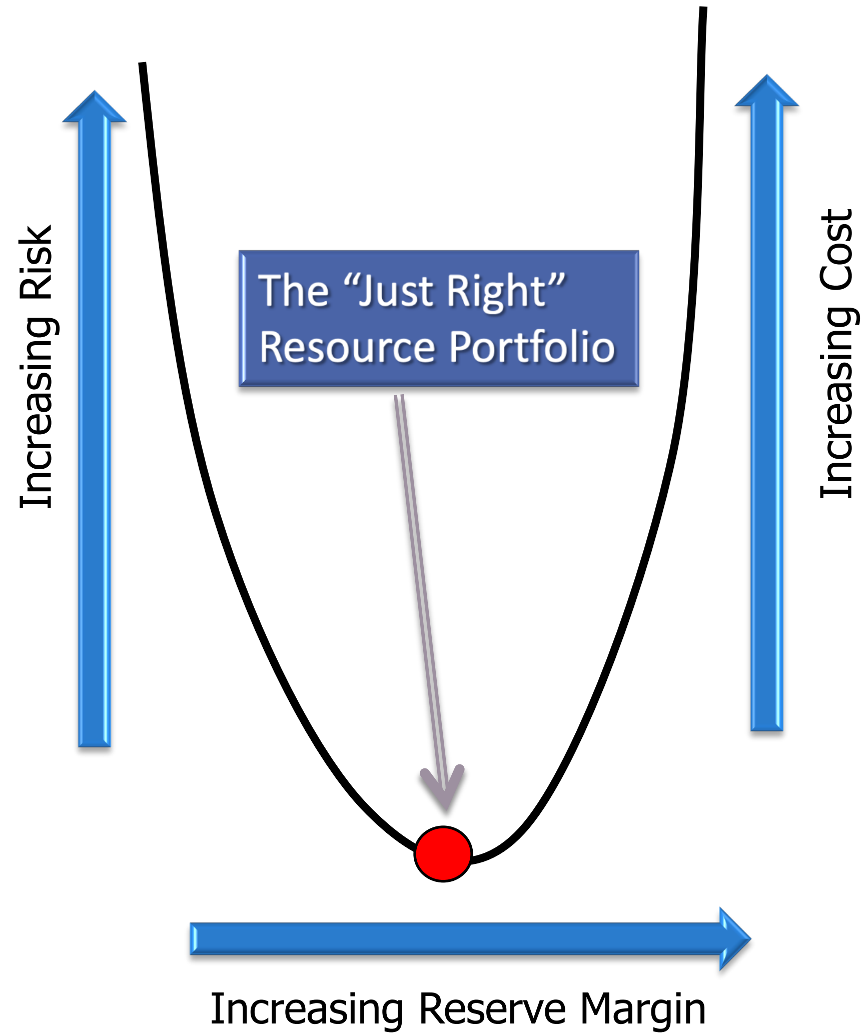


- Don't have too many resources
- Don't have too few resources
- Have "just the right amount" of resources*

**The "right amount" means not only the quantity developed, but the timing of their development and the mix (type) of resources required to provide energy, capacity, flexibility, and other ancillary services for system reliability, including risk management and resilience.*

Solving the "Goldilocks' Problem" Requires Analysis Comparing *Cost* and *Risk* of Alternative Resource Options





IRPs Attempt to Find the "Just Right" Resource *Timing*, *Type* and *Amount* by Answering Six Simple Questions

1. *When Will We Need Resources?*
2. *How Much Will We Need?*
3. *What Should We Build/Buy?*
4. *How Much Will It Cost?*
5. *What's the Risk?*
6. *Who Can We Blame If We Get It Wrong?*

Load forecasts are intended to answer questions #1 and #2.

Why Model efficiency and Other DERs as Resources?

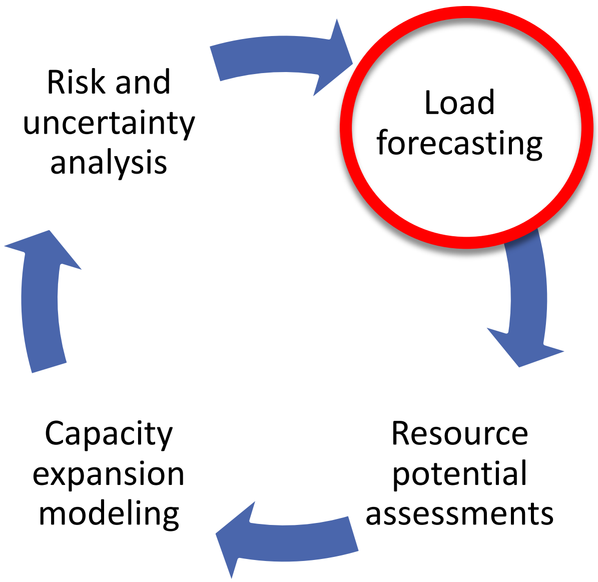
Cost

Risk

- Integrated Resource Planning (IRP) is intended to evaluate multiple resource portfolio options in an organized, holistic, and technology-neutral manner and normalize solution evaluation across generation, distribution, and transmission systems *and* demand-side resources.
  - This allows for ***consideration of relative cost and risk*** across the broadest array of potential solutions.

How to Model Efficiency or Other DERs as Resources

- Using energy efficiency (EE) or other DERs as a selectable resource requires a *different process* than using these resources as a decrement to the load forecast.
- Allowing a capacity expansion model to select EE or other DERs permits optimization between *all resources* (e.g., supply and demand side).
- Over three workshops, we will discuss changes that may need to be made to four components of planning: load forecasting, resource potential assessments, capacity expansion model and risk and uncertainty analysis.
- Today we focus on load forecasting.



Topics and Concepts in Today's Presentation

- Topics
  - Load forecast basics
  - Load forecast models
  - Load and resource risk
- Concepts

1. *Frozen Efficiency Forecast - When efficiency or other DERs are considered as selectable resources, the potential impact of efficiency or other DERs is not included in the load forecast.* Only efficiency impacts from known codes and standards and stock turnover are included in the load forecast.
2. *Load Forecast Consistency with Potential Assessments* – The load forecast and efficiency potential assessment should use consistent assumptions regarding baseline use and forecast "units" (e.g., number of appliances, buildings). While this calibration is a more straightforward process when end-use/econometric load forecasting models are used, it can also be done, although with much less certainty, when econometric load forecasting models are used.
3. *Range Forecast – Load uncertainty is a source of risk that should be reflected by the use of range load forecast, preferably without specifying a "reference" case.* Use of a range forecast permits resource planners to evaluate the relative risk of efficiency compared to other resources in mitigating the impacts of load uncertainty.

Load Forecast Basics

Tom Eckman

This work was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Building Technologies Office, under Contract No. DE-AC02-05CH11231

Load Forecasts Can Serve Many Purposes

- Long Term Planning - Forecasts of future energy and capacity needs for IRPs that model the effects of economic conditions, changing technologies and policies on load growth (and shape)

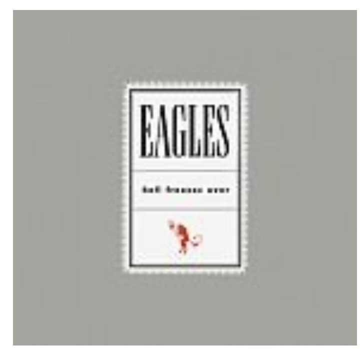
- Short-Term Planning - Forecasts for operational planning, revenues, fuel supply and market purchases

- Policy Analysis - Forecasts to predict the effects of specific policies intended to affect demand (e.g., code and standards, electrification, EVs)

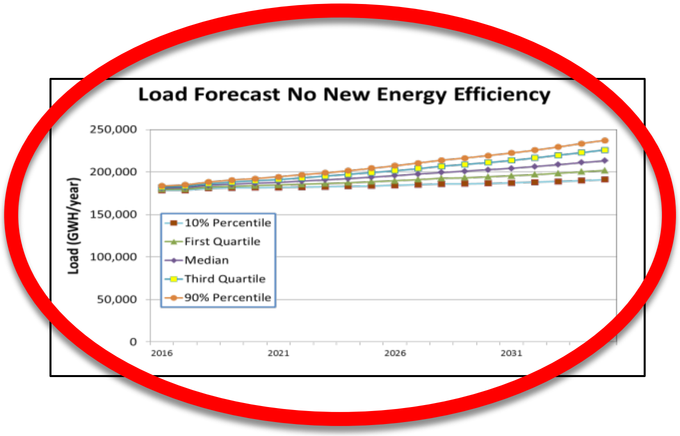
Load Forecasting Realities

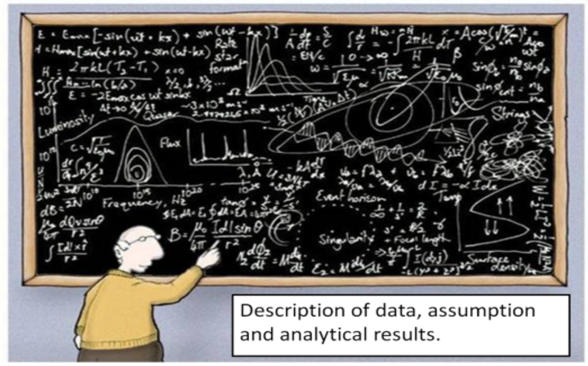
- There is no one best model
  - Methodology, level of detail, data requirements, and required expertise depend on the purpose of the forecast
- Nearly all forecasting techniques rely on history to some degree
- No forecast will be absolutely correct, accuracy can only be determined in hindsight
- The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

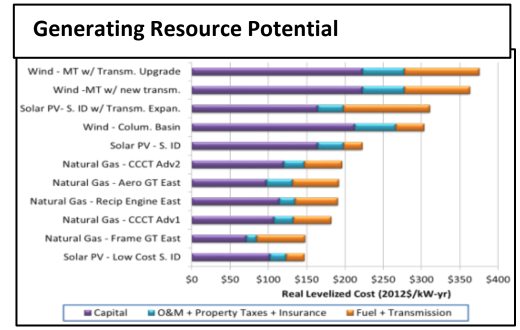
Get over it
Get over it
All this whinin' and cryin'
and pitchin' a fit
Get over it, get over it

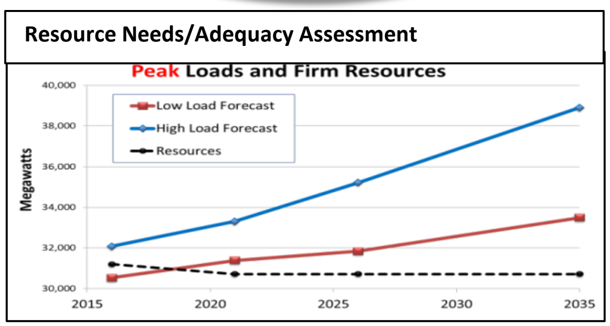


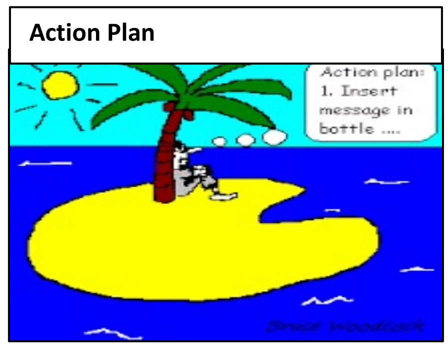
Load Forecasts Are A Key Components of IRPs

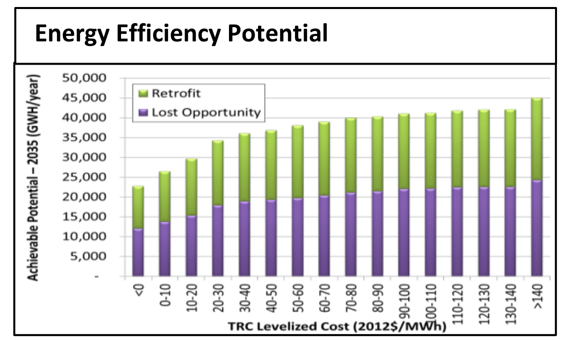


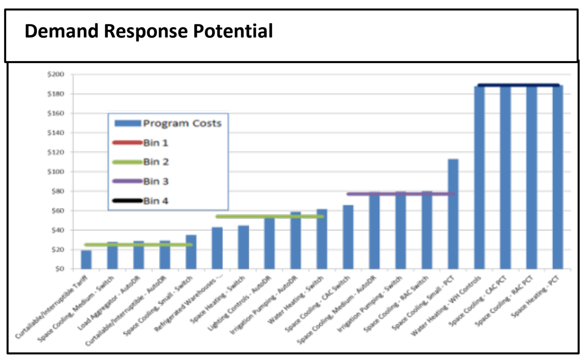


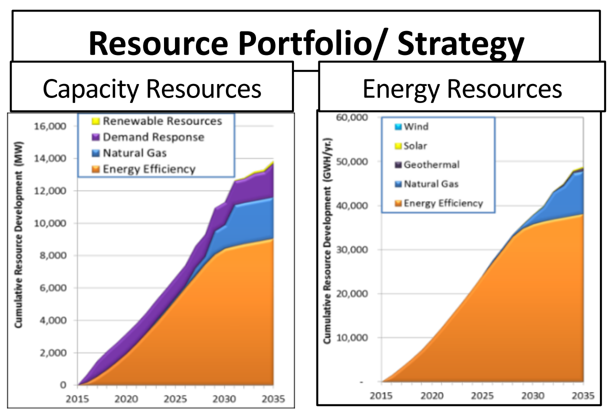






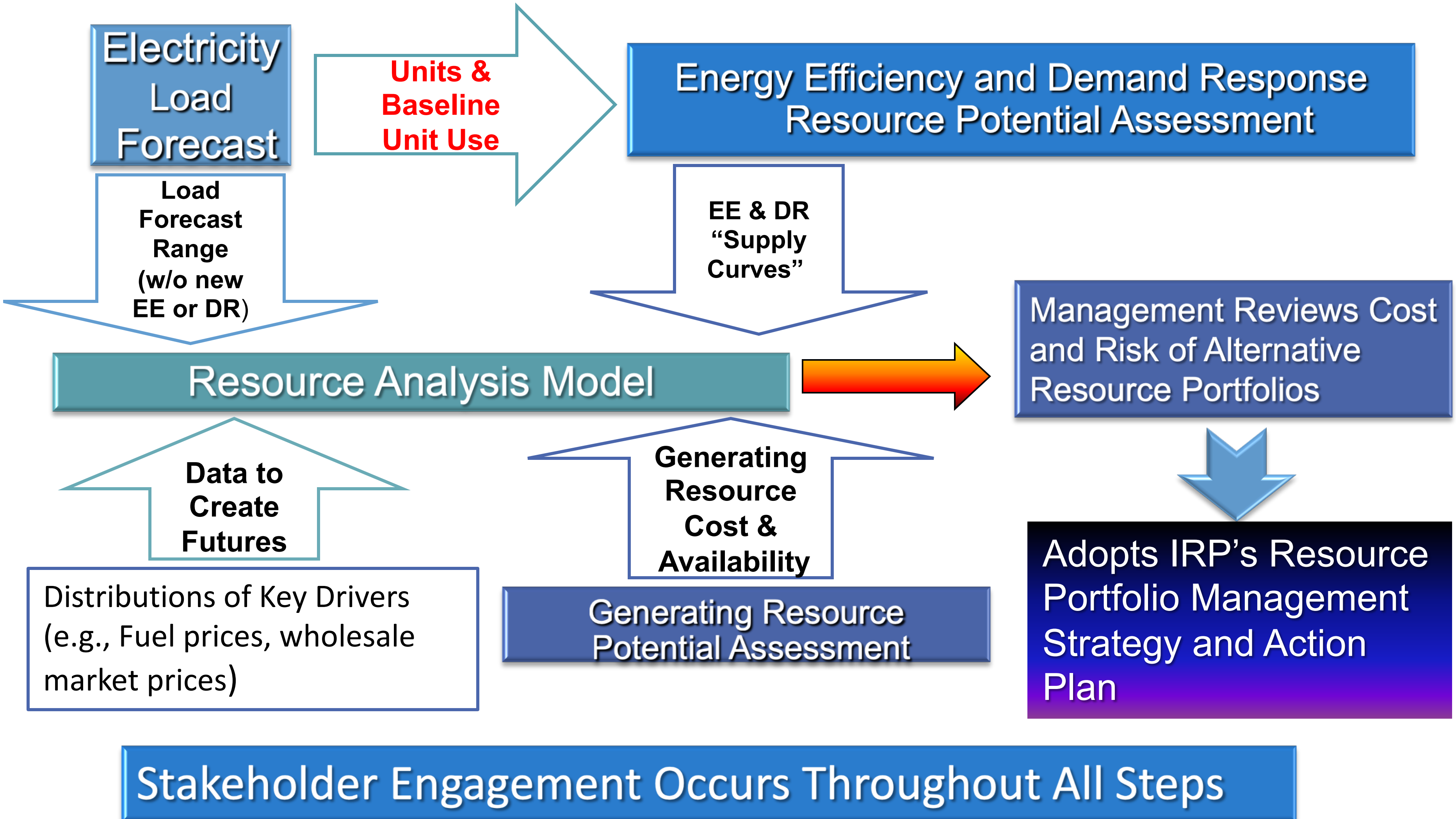






Risk Analysis

IRP Development
Analytical Process Flow Between Models



Concept # 1- Frozen Efficiency Forecast

- Frozen-efficiency forecast: The technical efficiency choices are kept at current levels in the forecast, but existing or expected efficiency standards are included
  - Used in the capacity expansion model to prevent *double counting* of efficiency savings, once from price response and once from policies and efficiency programs
  - Allows remaining energy efficiency potential to be considered as a selectable resource option in capacity expansion model (i.e., treats efficiency as a "supply side resource")

When EE is treated as a selectable resource most efficiency is not a included as load reduction in the load forecast.

- "Baseline use" assumed in the load forecast includes efficiency levels mandated by known codes and standards. This serves as the *baseline* efficiency for estimating remaining potential (to avoid *double counting* of remaining energy efficiency potential).
- Future efficiency impacts from the continuation of existing programs or new programs are not included as a load reduction.
- All other remaining efficiency potential, regardless of attribution, is available (i.e., considered as a resource option) for selection in the capacity expansion model.

Stock turnover for code compliance is included in load forecast
Above code purchases are part of efficiency supply curves

Code compliant 2010 refrigerator ~650 kWh/year

Load forecast reduction by ~250 kWh

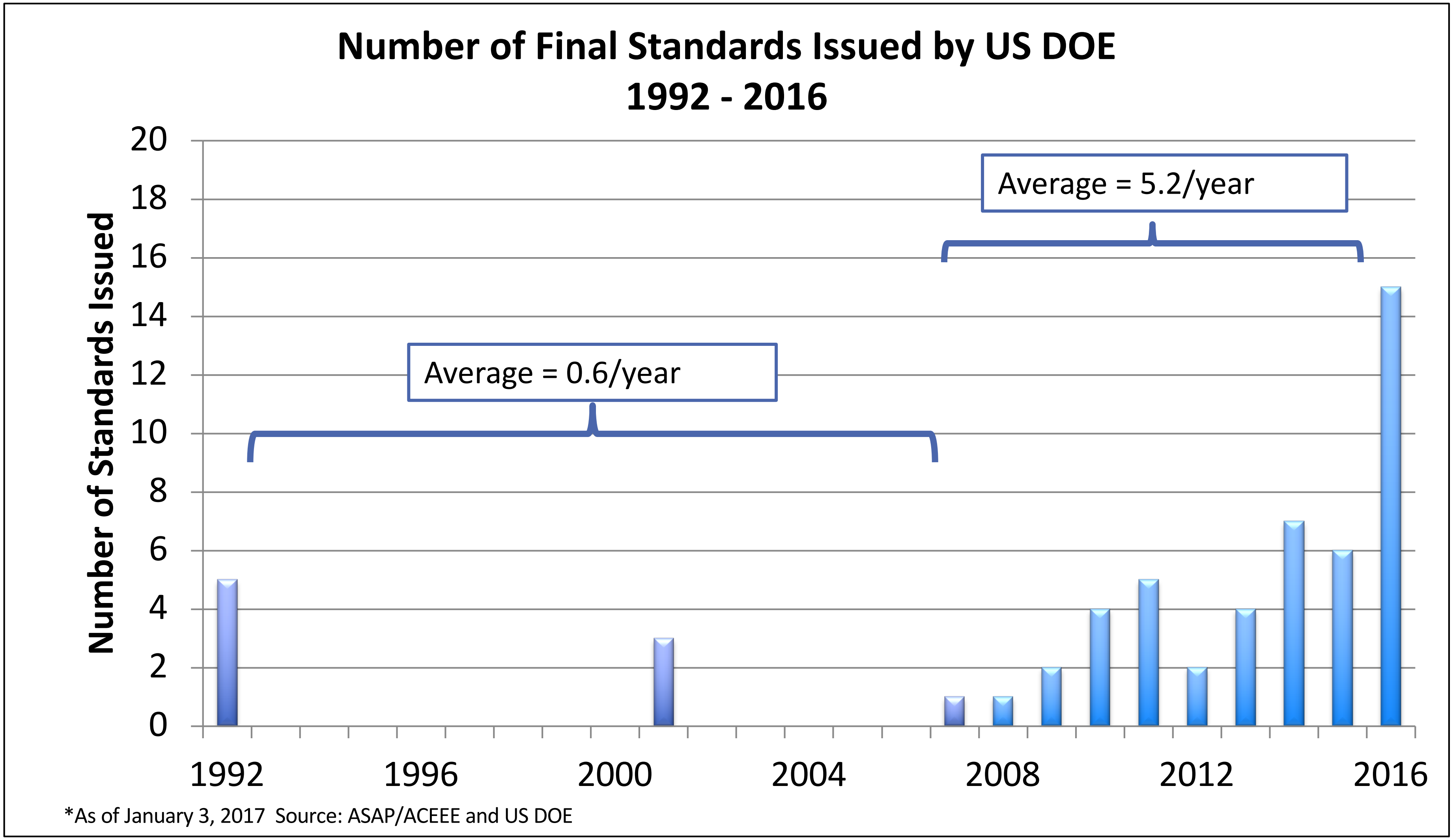
Code compliant 2021 refrigerator ~400 kWh/year

~50 kWh of efficiency in supply curve

Above code refrigerator 2021 ~350 kWh/year

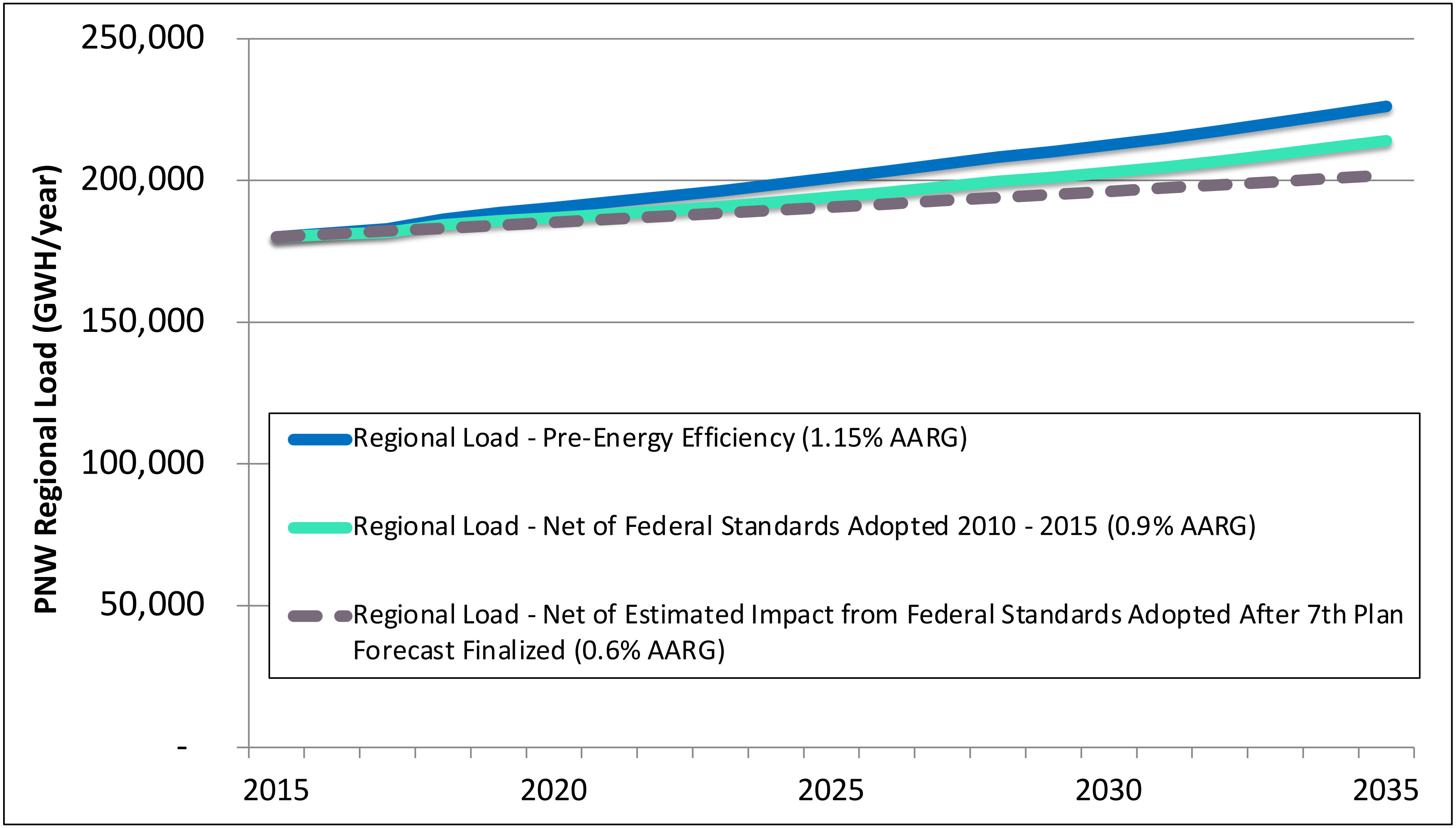
Sidebar Comment on Load Forecasting Methods:

Econometric load forecasting models generally fail to fully reflect the impact of recently adopted/updated codes and standards – this can lead to systematically over forecasting growth.



Accurately Accounting for Such Impacts Matters:

Potential Impact on Load Forecast of Known Codes and Federal Standards
Seventh Northwest Power and Conservation Plan



Concept # 2 – Load Forecast Consistency with Potential Assessments

- Load forecasts don't stand alone
  - In an integrated system, information flows between the load forecasting systems and the efficiency potential assessment.
- From efficiency potential assessment to load forecast model
  - The analysis of technical efficiency potential identifies technologies and costs. This data is used to develop the efficiency trade-off curves (more on this later) so that efficiency choices for resource development are consistent with the technologies considered in the load forecast.
- From (end-use) load forecast model to efficiency potential assessment
  - The load forecast model provides the number of new and replacement buildings and equipment based on forecast growth and stock turnover models, after accounting for fuel choices for each end use.

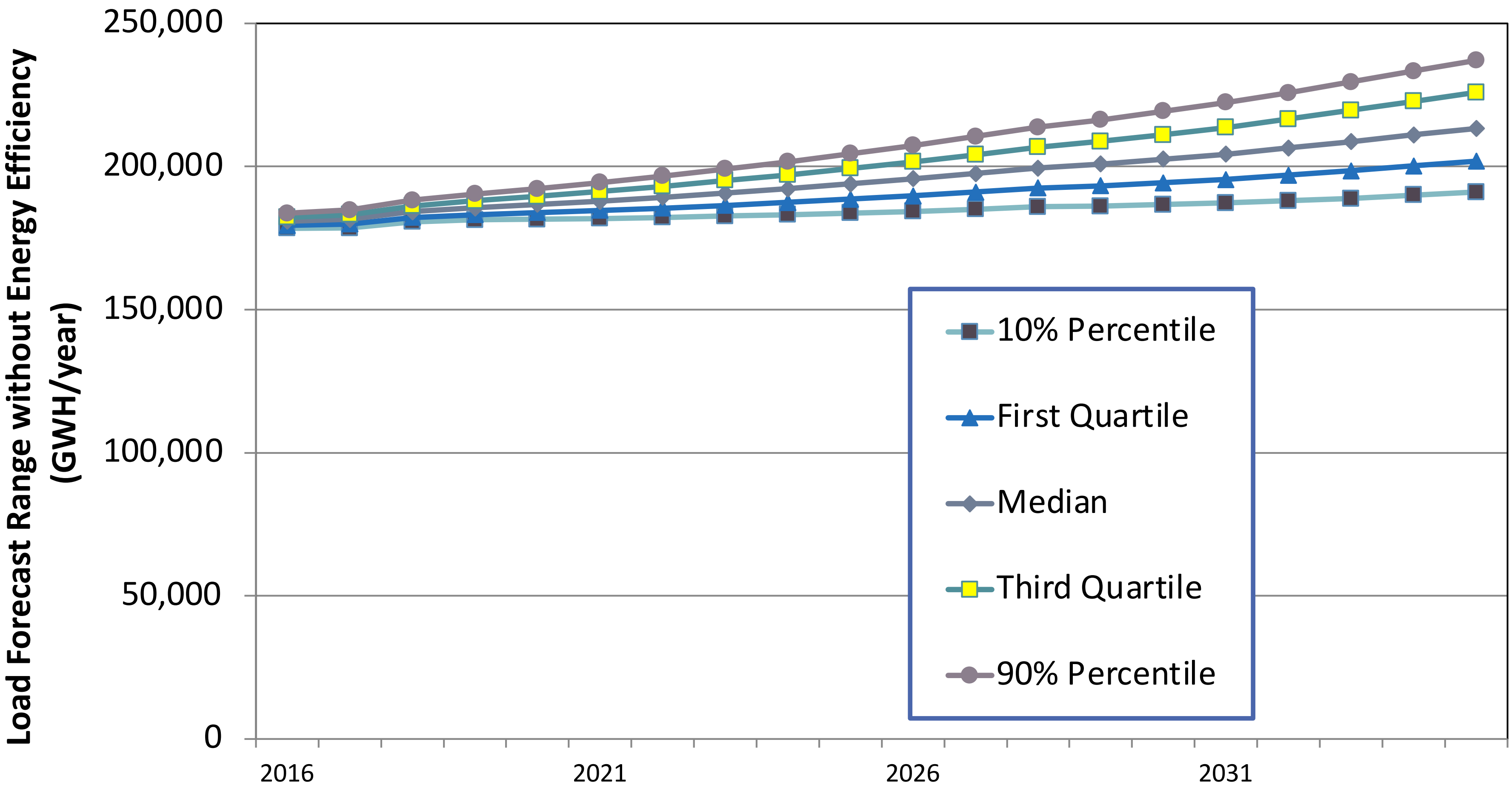
Connecting Load Forecast and Efficiency Potential

- 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).

Concept # 3 - Range Forecasts to Reflect Uncertainty

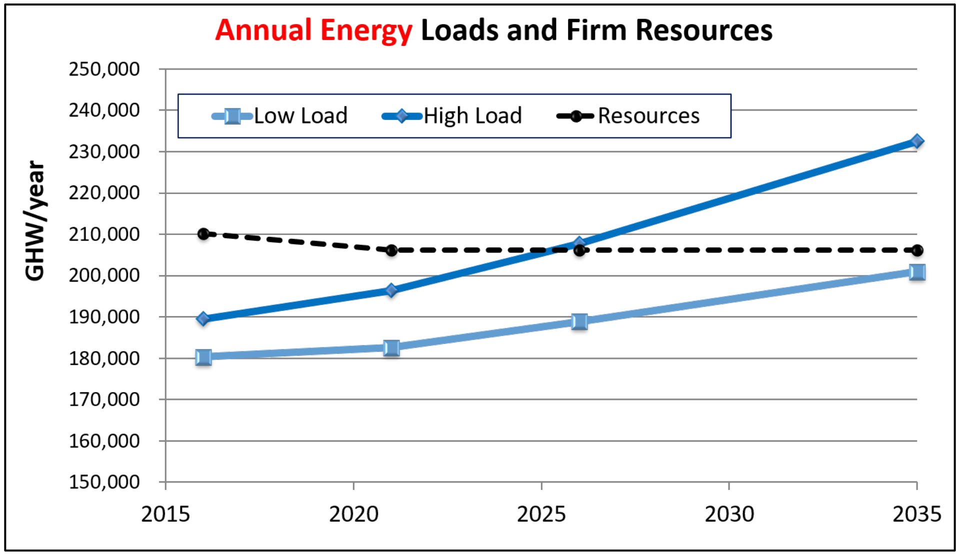
- All forecast models depend on a set of economic drivers (independent variables)
  - Some are relatively certain (e.g. population, employment, households)
  - Others may be highly uncertain in the long term, or have high volatility (e.g. fuel prices, weather, technology changes)
- A range of load forecasts can be developed by determining a range and probability distribution for each of the driving variables of the forecast.
- The resulting range of load forecasts provides insights into the possible risks of the forecast and what, if any, mitigation strategies might be available.

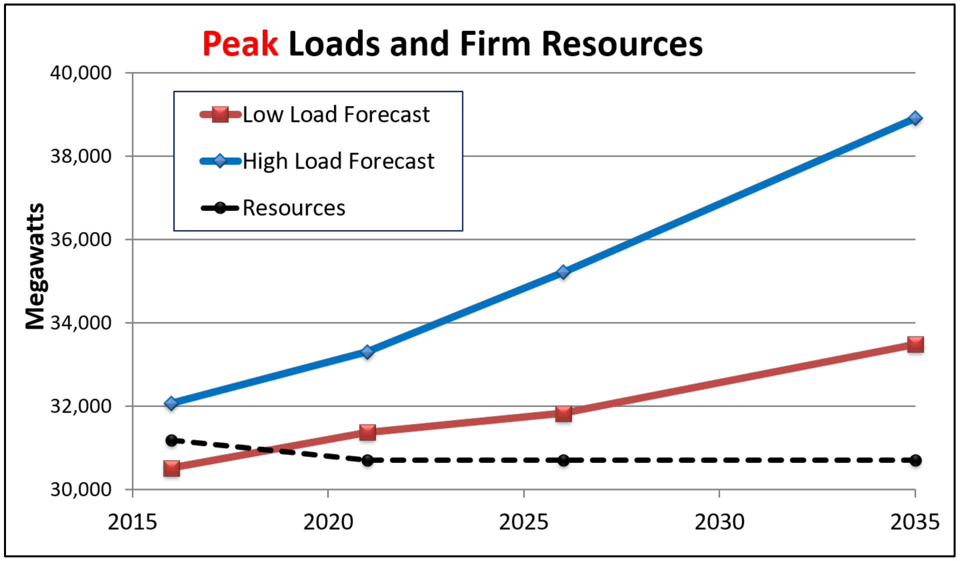
Range Load Forecast for Energy and Capacity – *Without* additional energy efficiency or demand response



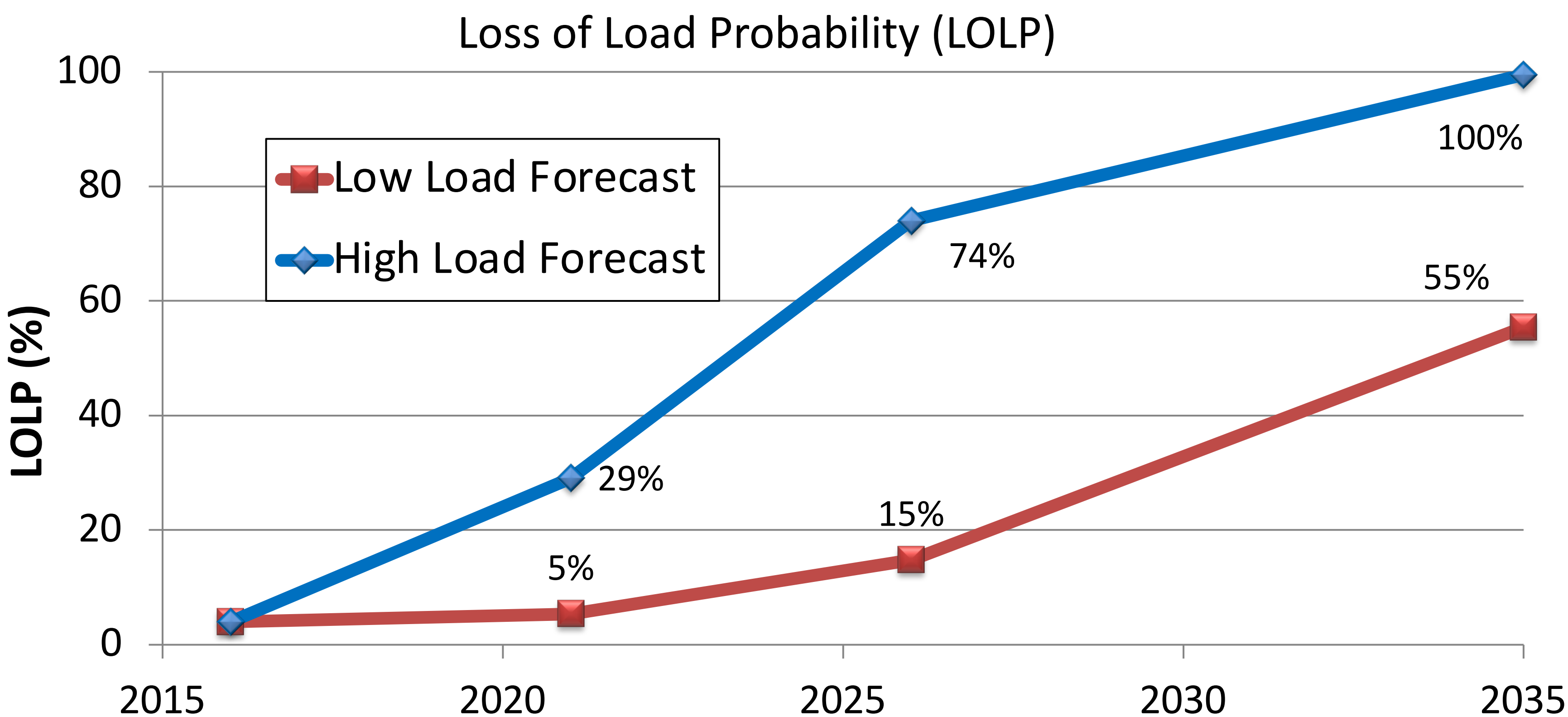
Note: To avoid implying more certainty than exists, it is generally advisable not to refer to a specific "reference case" load forecast

Historically "Point Forecast" Were Used in "Needs" Assessments of Energy and Capacity





Now Resource Adequacy Assessments Employ Probabilistic Resource Adequacy Analysis Evaluated Over A Range of Future Load Growth*



*Note: Resource Adequacy Assessments may be done independently of IRPs, but their results are used in an IRP, so data and assumptions used in both analyses should be internally consistent.

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Load Forecasting Models

Tom Eckman

Contributions from Terry Morlan

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Models Used in IRP Development

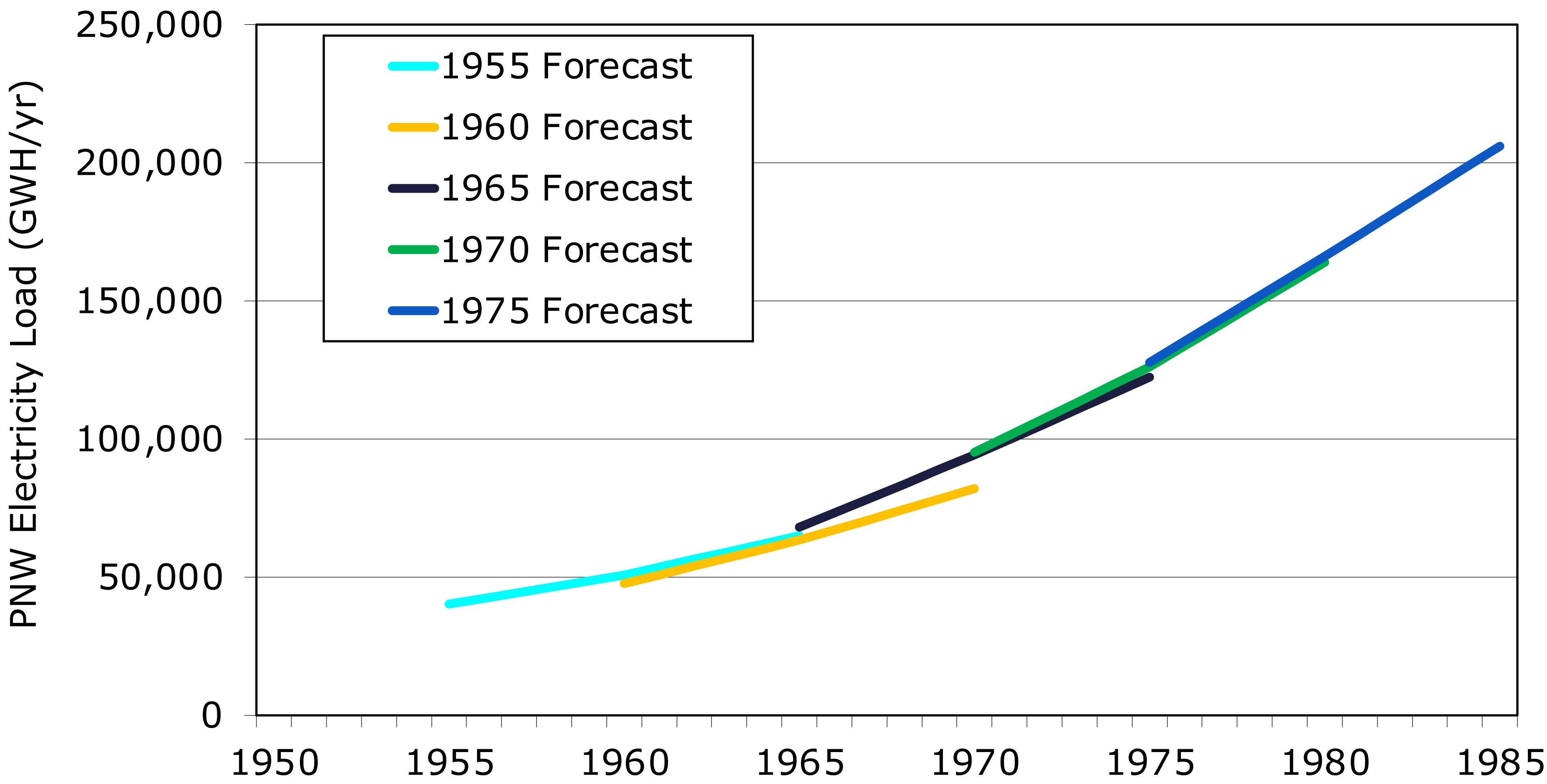
- Load Forecasting Models
  - Simple linear extrapolation
  - Times series models
  - Econometric models
  - End use models
  - Hybrid approaches
- Capacity Expansion Models & Modeling
  - Deterministic
  - Stochastic
- Resource Adequacy Models & Modeling*
  - Deterministic
  - Stochastic

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

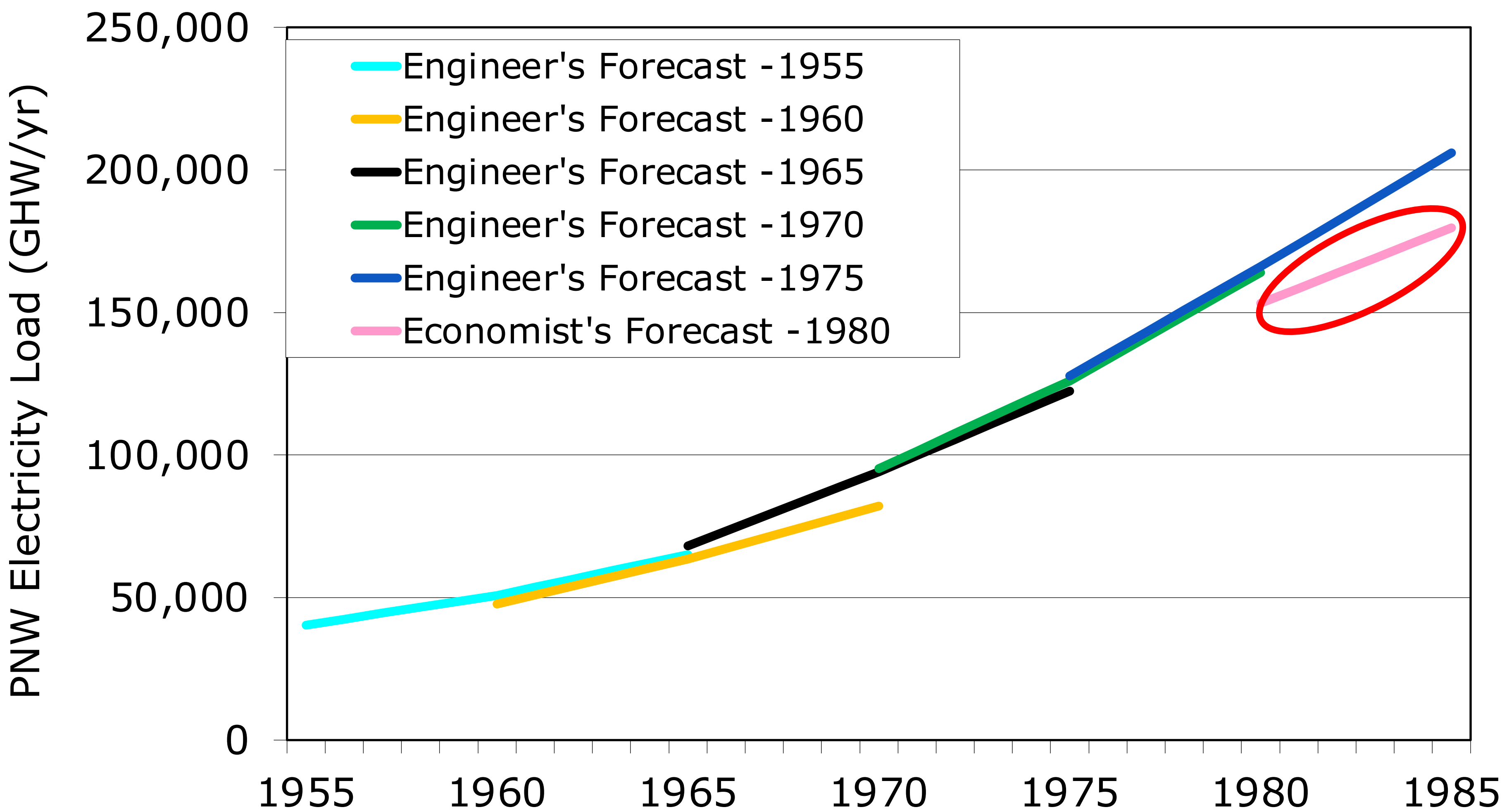
Simple Linear Extrapolation

- When most appropriate
  - Static situation for economy and energy demand
  - Short-term forecast (year or two)
- Advantages:
  - Easy to implement, requires only past demand data
- Disadvantages:
  - Often inappropriate for situation
- Source of some spectacular mistakes (PNW 1960s and 70s)

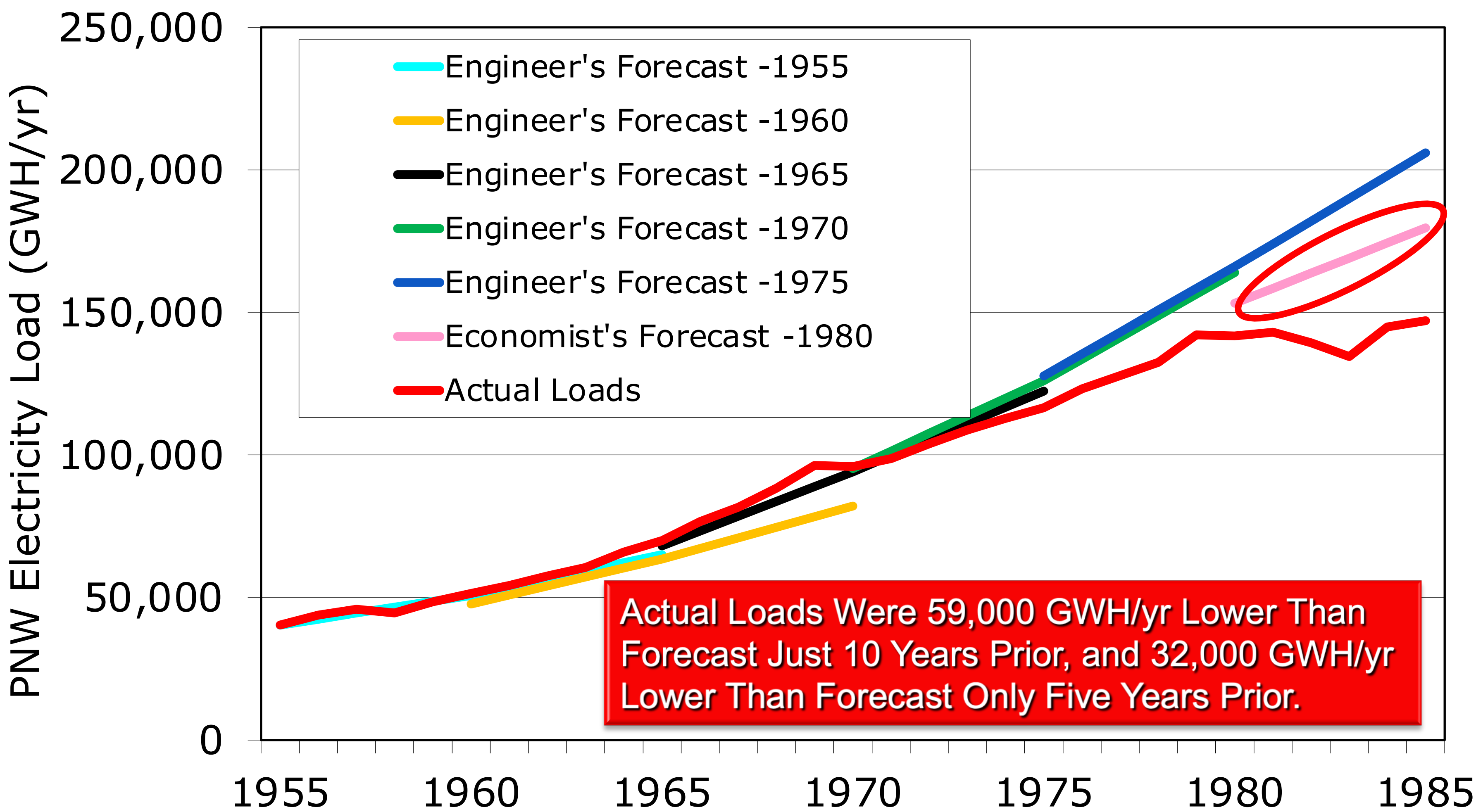
Engineers, Observing This Data, Forecast Continued "Trend Line" Growth



Economists Recognized "Price Response" and *Significantly* Lowered Forecast



Utility Economist's Forecasts Dramatically Underestimated Consumer "Price Effects"



Time Series Forecast Models

- Demand forecast depends only on past demands
- When most appropriate
  - Short-term forecasts (few years)
  - Stable demand trends and patterns, limited changes in technology or economic trends
- Advantages
  - Limited data requirements
  - Can address underlying patterns of demand, e.g. seasonal, monthly, annual
- Disadvantages
  - No recognition of factors that might cause future demand to depart from past temporal trends, such as major changes in technology (EVs) or codes and standards

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, electricification 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

Example: Demand from Water Heating in New Homes

Electric water heaters demand in new homes is calculated as:

A = Number of new single-family homes: 20,000/yr

B = Baseline Electricity Efficiency: 0.90 Energy Factor = 3600 kWh/yr

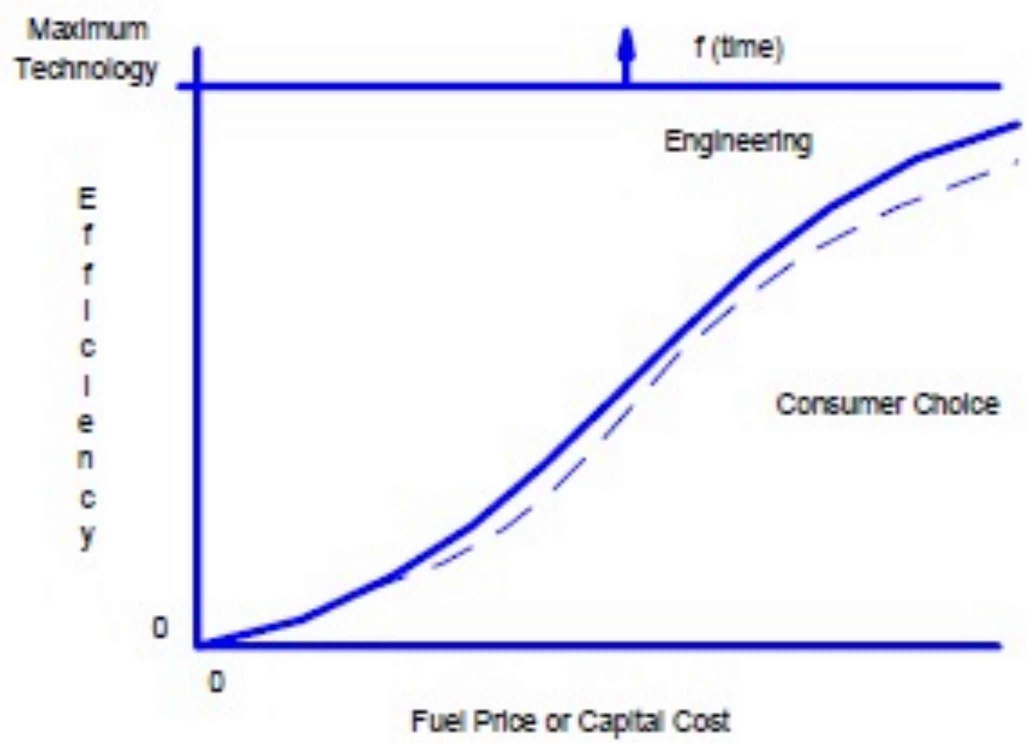
C = Market share of electric: 69%

- Electricity Demand for water heating added per year
- 20,000*3600*.69 ~ 49,680 MWH ~ 5.67 aMW
- Every year, number of appliances, their efficiency and energy requirements are tracked using stock turnover logic.

Similar approach is used for existing homes. Existing homes are tracked over-time and the energy use is reduced each year based on the physical life of the device (i.e., as existing units fail, they are replaced units meeting greater of federal minimum efficiency standards or the current market efficiency).

Technology Choice

EFFICIENCY/CAPITAL COST TRADE OFF



Hybrid Load Forecasting Models

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

Choice of Dimensions of Load Forecast Modeling

- Temporal
  - Annual, Monthly, Hourly, Quarterly
  - If planning for long term *energy* needs, annual may be enough
  - If planning for long term *capacity* needs, hourly is needed
  - If planning for ancillary services and other operational needs, sub-hourly may be needed
- Sectoral
  - Residential, commercial, industrial sectors are driven by different variables
  - For long-term forecasts and policy analysis, modeling specific building types and their end uses and industrial sectors may be required
  - Specific large industrial plants may need to be handled individually

Examples of Economic Sectors
Residential, Commercial, Transportation

Residential

- Single Family
- Multi Family
- Manufactured Homes

Commercial

- Large Office
- Medium Office
- Small Office
- Big Box-Retail
- Small Box-Retail
- High End-Retail
- Anchor-Retail
- K-12
- University
- Warehouse
- Supermarket
- Minimart
- Restaurant
- Lodging
- Hospital
- Elder care
- Assembly
- Other

Transportation

- Passenger
- Freight
- Air Passenger
- Air Freight
- Off Road

Choice of Dimensions of Load Forecast Modeling (2)

- Geographic
  - Load growth by sub-areas may be needed
    - If economic conditions or policies significantly differ
    - If there are transmission or distribution constraints between areas
- End use
  - Important for policy analysis relating to technology change, efficiency standards, fuel choice, building retrofit, etc
- Granularity
  - Increased granularity increases the cost and complexity of forecasting, but also increases the accuracy (up to a point) and the usefulness for policy analysis.
    - When you start making up data, you probably lose the benefits of more detail.
  - The most detailed end-use models require detailed customer surveys that are expensive.
  - Level of granularity is determined by the underlying purpose and use of the forecast

End Uses: Residential, Commercial, Industrial

Residential End Uses	Commercial End Uses	Industrial End Uses
• Space Heating (by tech) • Water Heating (by tech) • Cooking (by fuel) • Refrigeration(freezer) • Lighting • Air Conditioning (room, central) • Misc. • Home electronics, etc	• Space Heating • Water Heating • Other Substitutables • Refrigeration • Lighting • Air Conditioning • Other Non-Substitutables	• Process Heat • Motors • Other Substitutables • Miscellaneous • Off-Road

Choice of Dimensions of Load Forecast Modeling (3)

- Granularity
  - Increased granularity increases the cost and complexity of forecasting, but also increases the accuracy (up to a point) and the usefulness for policy analysis.
    - When you start making up data, you probably lose the benefits of more detail.
  - The most detailed end-use models require detailed customer surveys that are expensive.
  - Level of granularity is determined by the underlying purpose and use of the forecast

Notes on Choosing the Dimensions of Load Forecast Models

- It is possible to include different levels of detail within the same modeling system, e.g., end-use modeling of residential sector, hybrid modeling of the commercial sector and econometric modeling of the industrial sector
- In addition to its analytical scope and purpose, the dimensions of a load forecasting model are determined by the available data and budget

Summary - Models Used in IRP Development

- Load Forecasting Models
  - Simple linear extrapolation
  - Times series models
  - Econometric models
  - End use models
  - Hybrid approaches

Most Prevalent & Problematic

Most Relevant & Useful

- Capacity Expansion Models & Modeling
  - Deterministic
  - Stochastic
- Resource Adequacy Models & Modeling
  - Deterministic
  - Stochastic

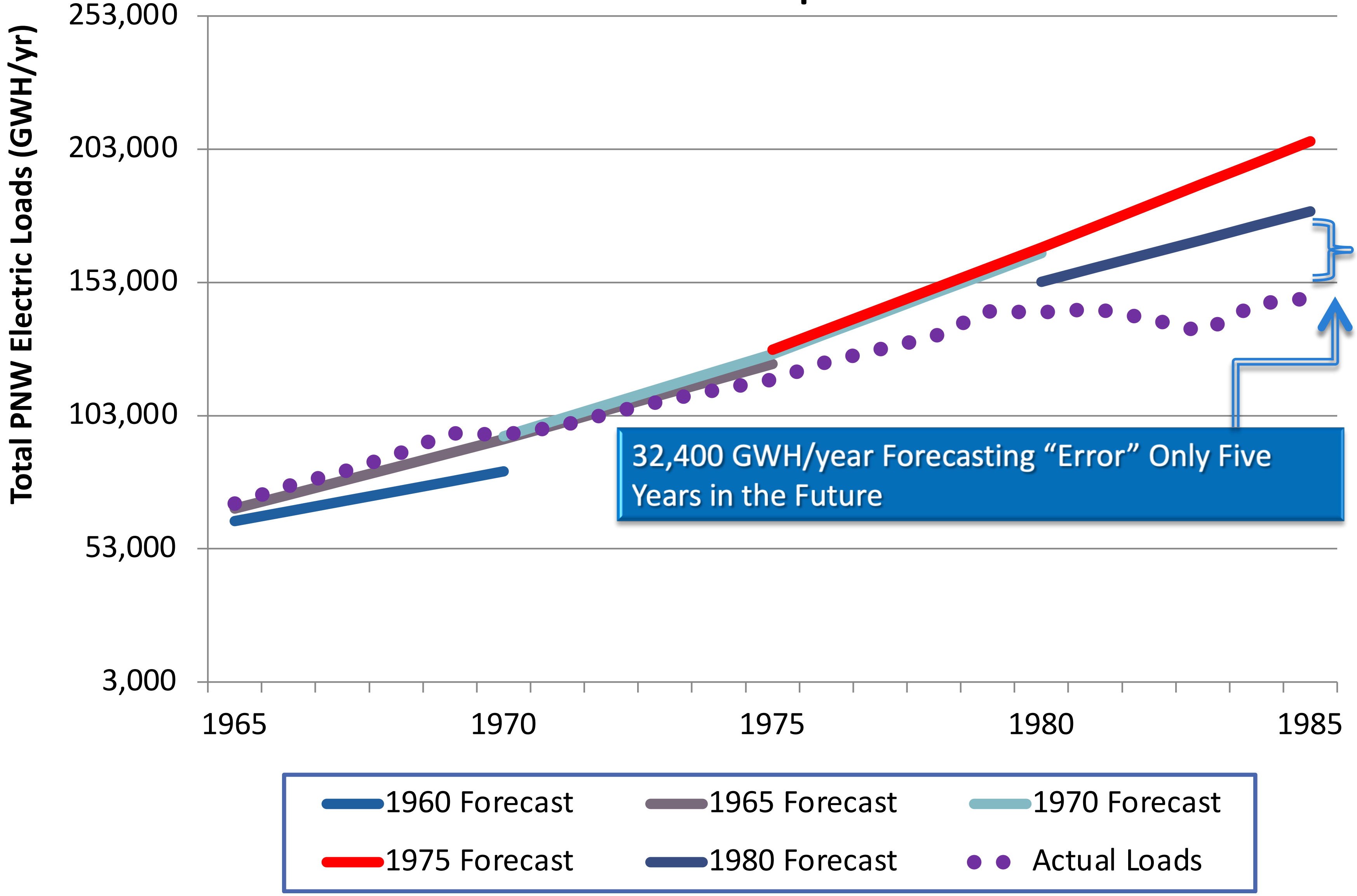
Load Uncertainty and Risk

This work was funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy's Building Technologies Office, under Contract No. DE-AC02-05CH11231

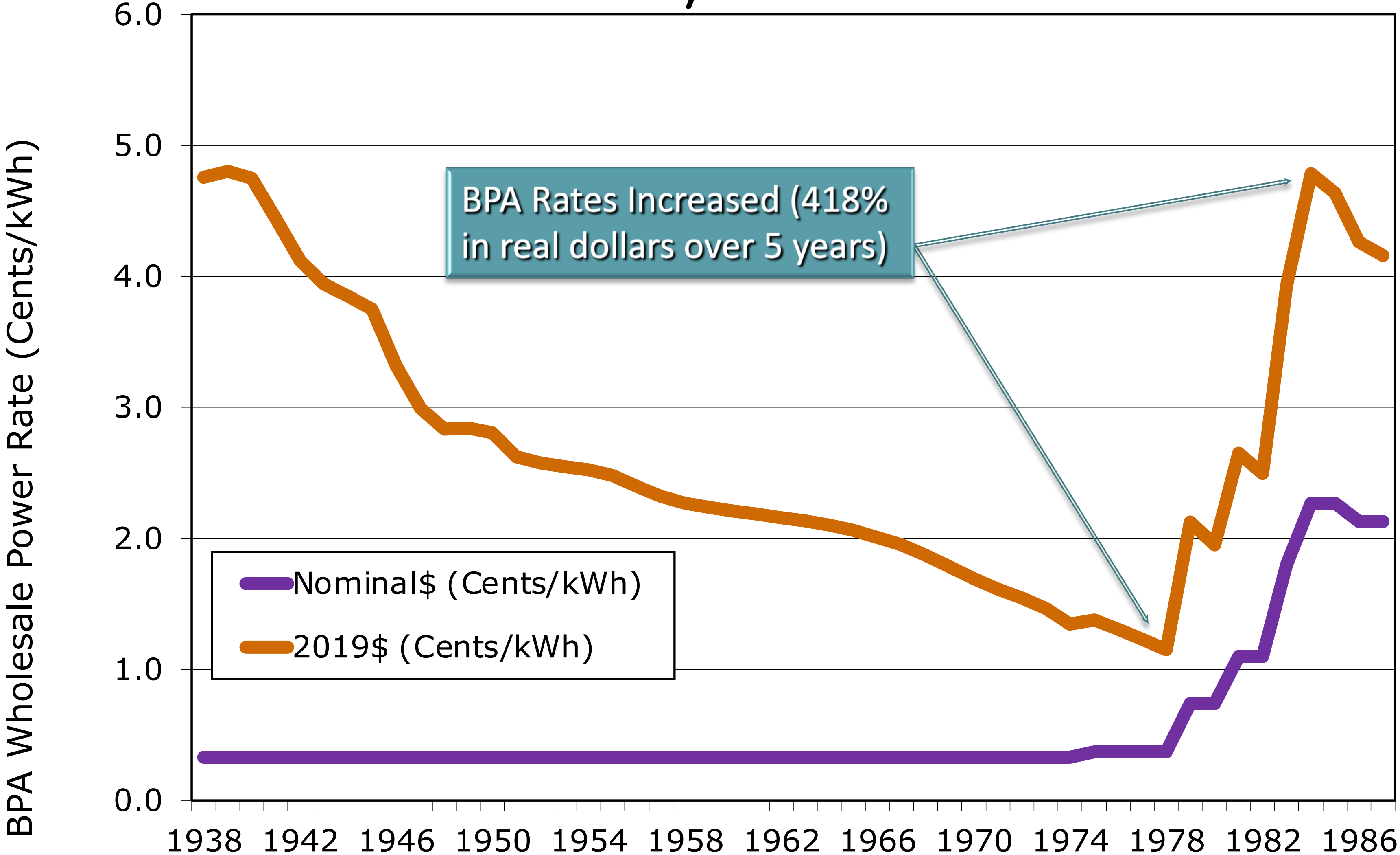
Major Sources of Uncertainty

- Load Uncertainty
  - Business cycles (e.g., post-2008 recession, COVID-19)
  - Technology "shifts" (e.g., electrification of transportation, distributed generation)
- Resource Uncertainty
  - Output (e.g., prolonged outages due to terrorist action, storms)
  - Cost
  - Construction lead times (e.g., pumped storage, transmission expansion)
  - Technology change (e.g., declining cost of renewables, batteries)
- Wholesale Electricity Market Price Uncertainty
- Regulatory Uncertainty (e.g., required reductions in GHG emissions)

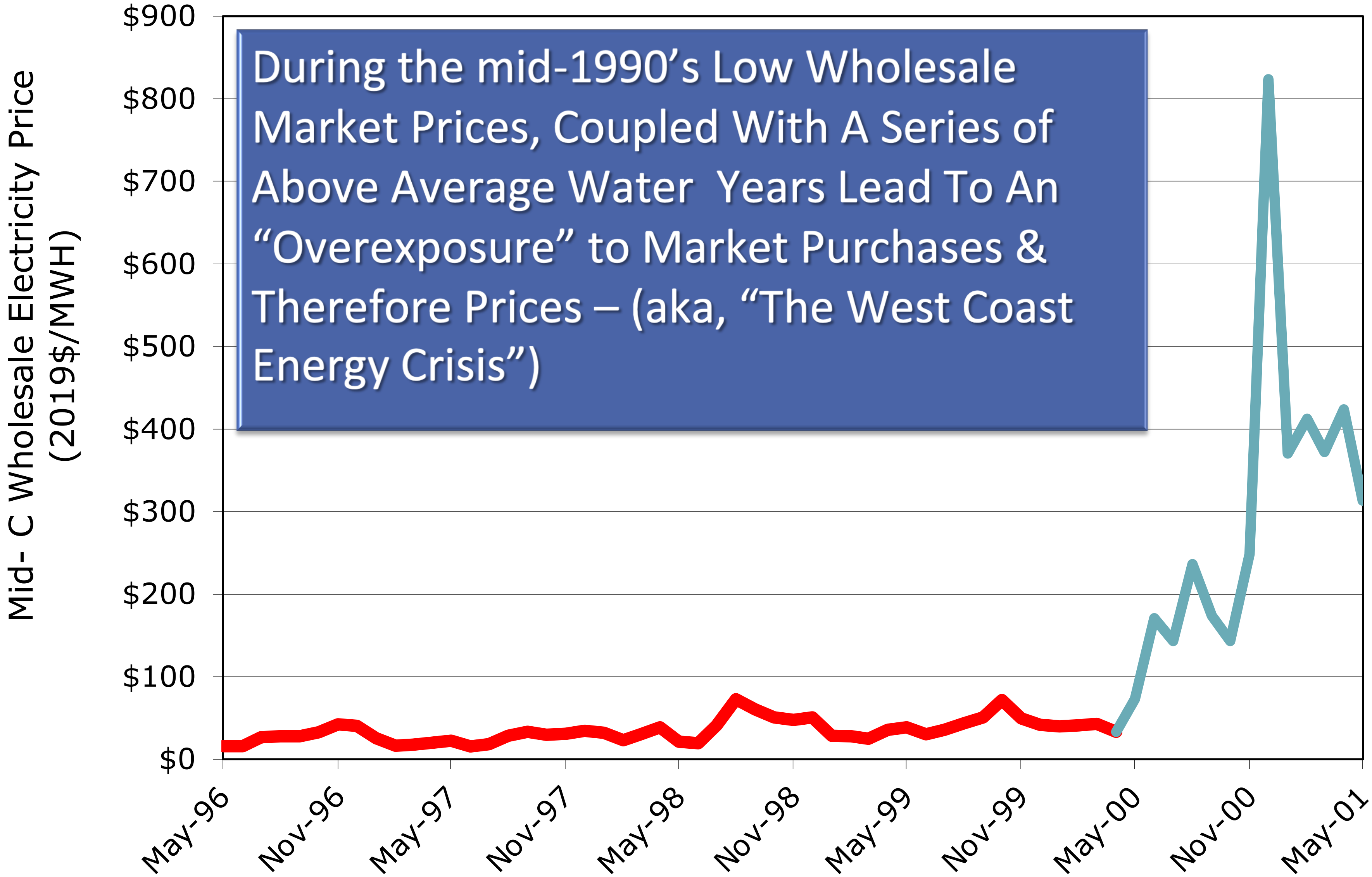
Perfect Foresight Can Lead to Overbuilding: PNW Example



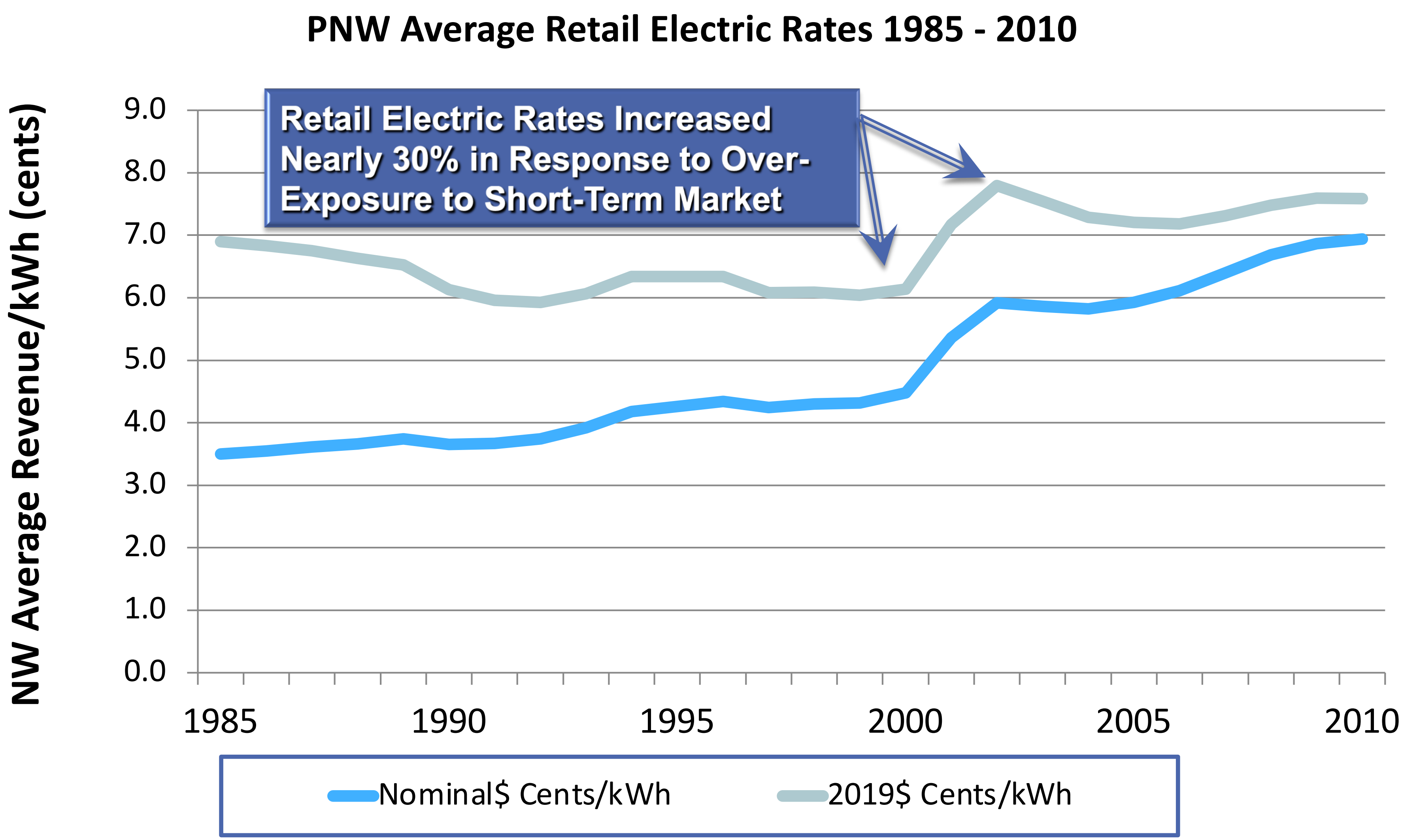
Real World Example of the Cost of "Too Many Resources"



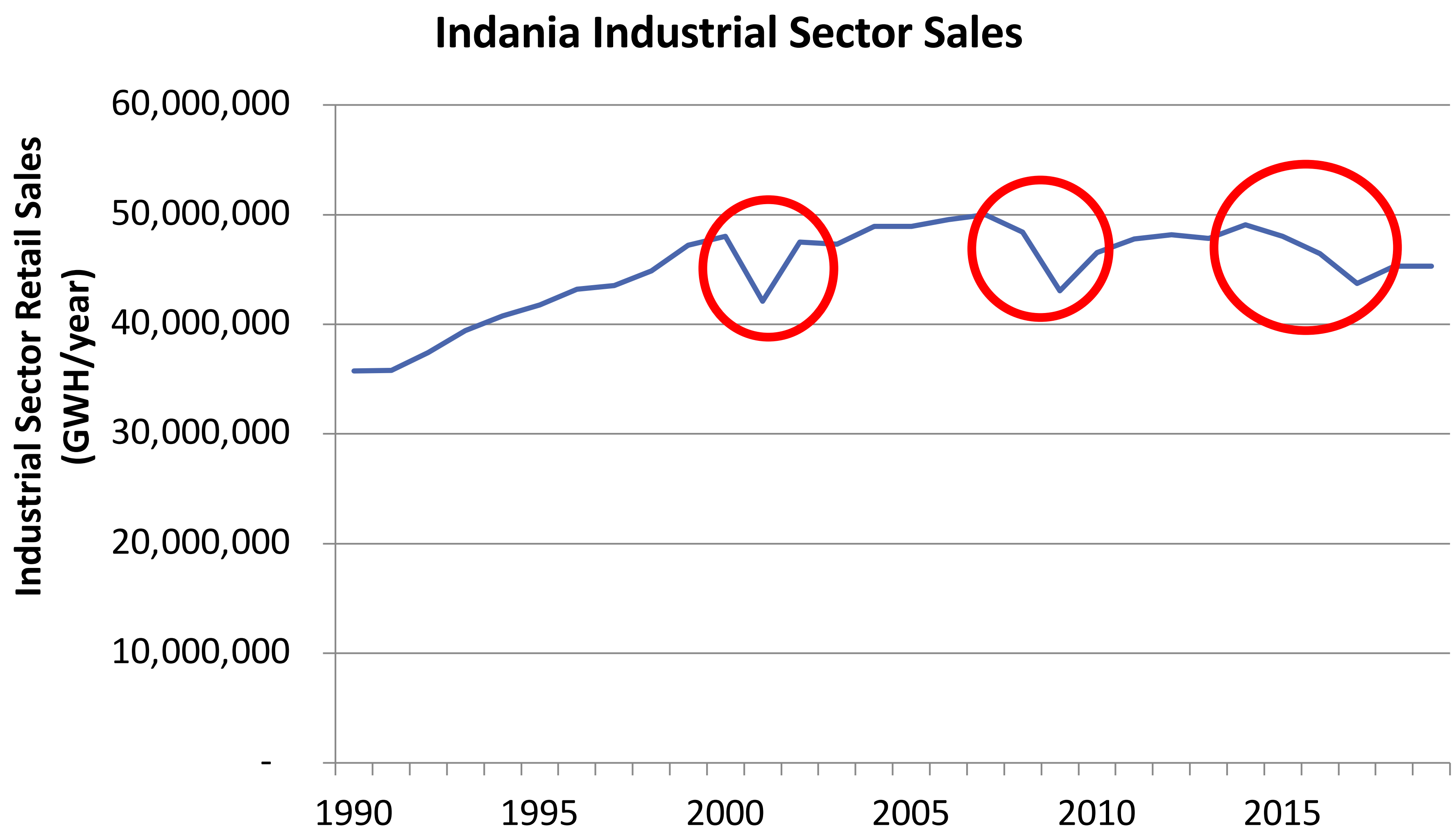
Perfect Foresight can also lead to underbuilding: PNW Example



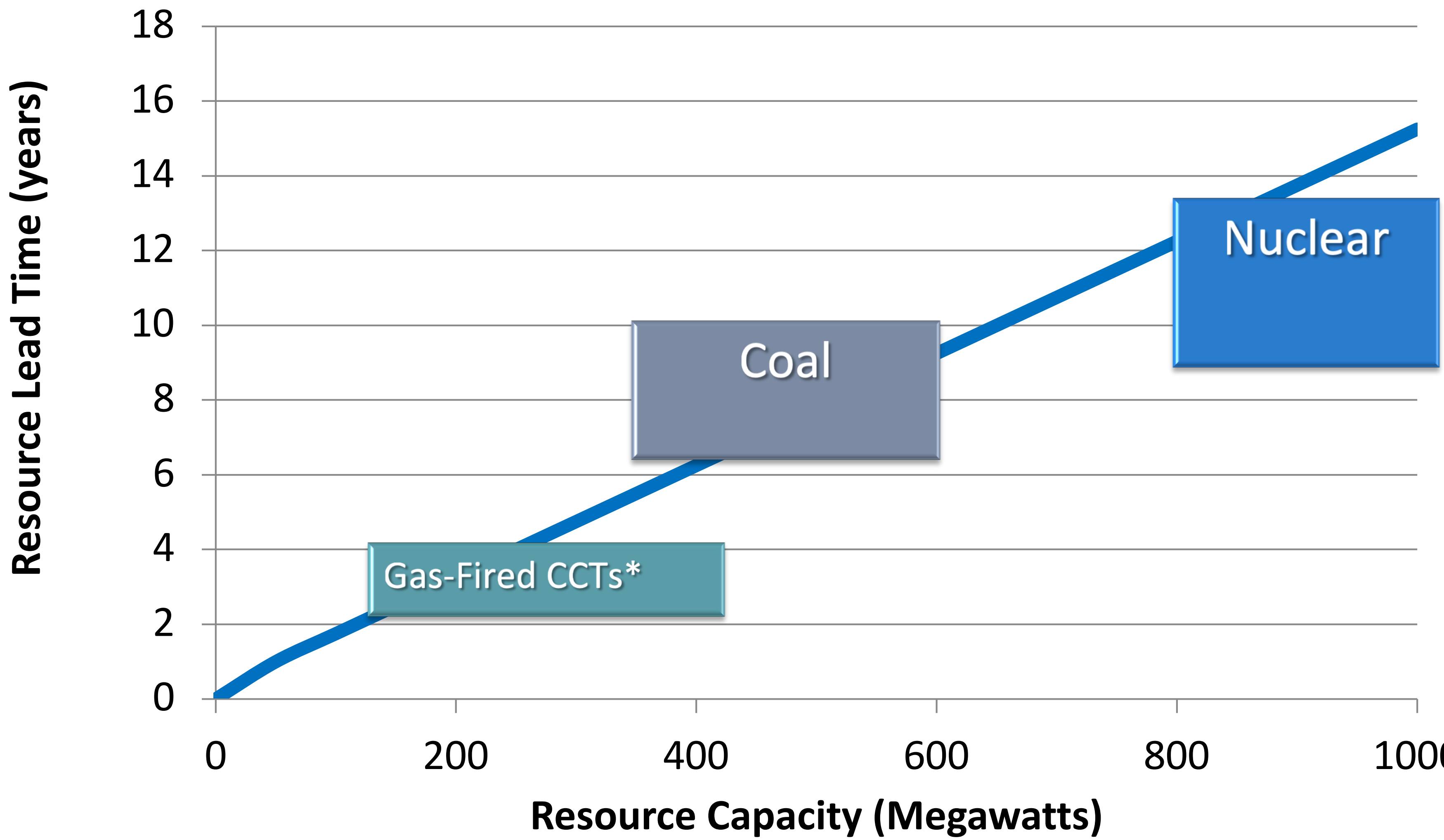
Real World Example of the Cost of "Too Few Resources:" PNW Example



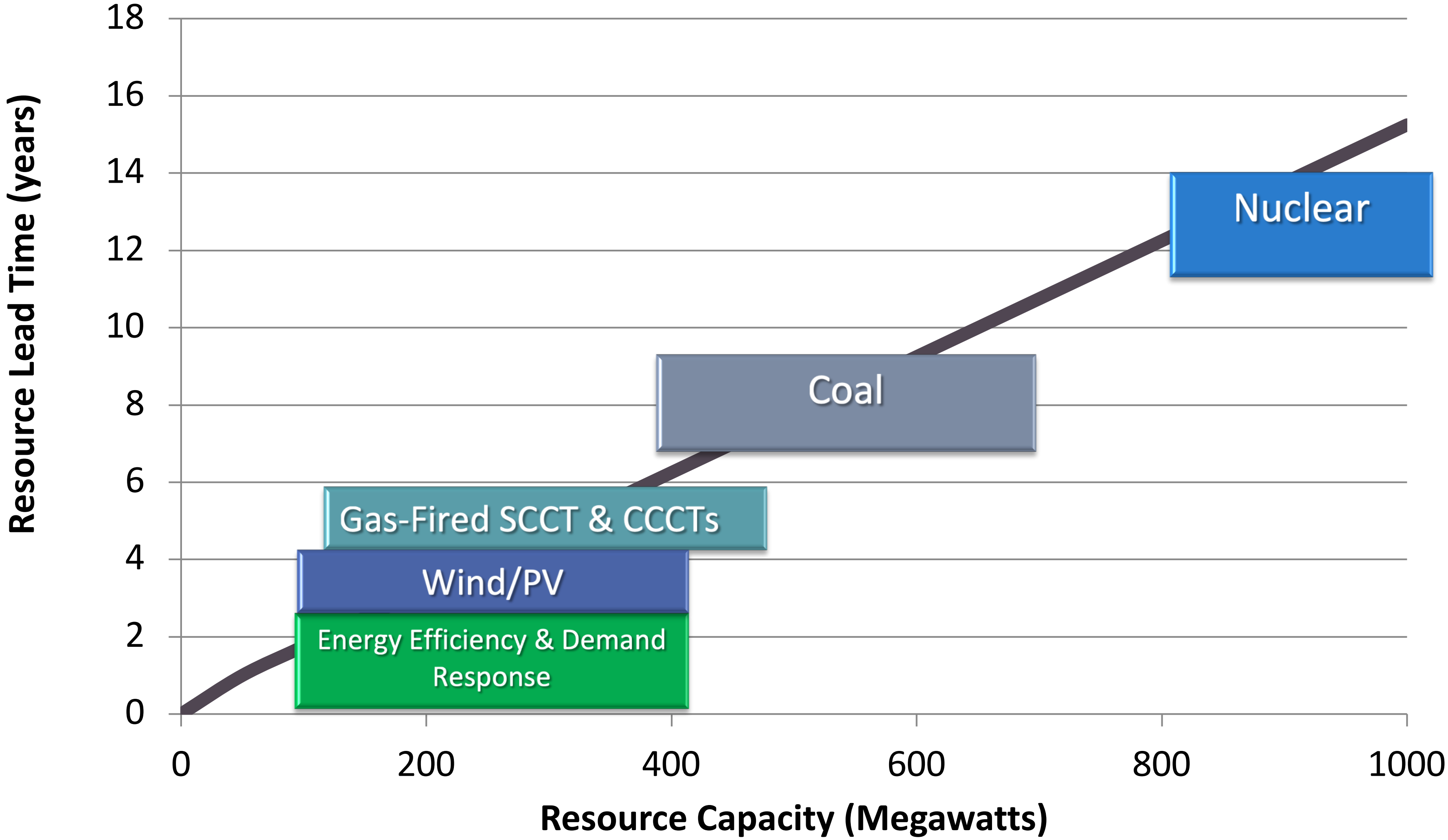
Load Uncertainty Is Often Driven by Large Industrial Loads



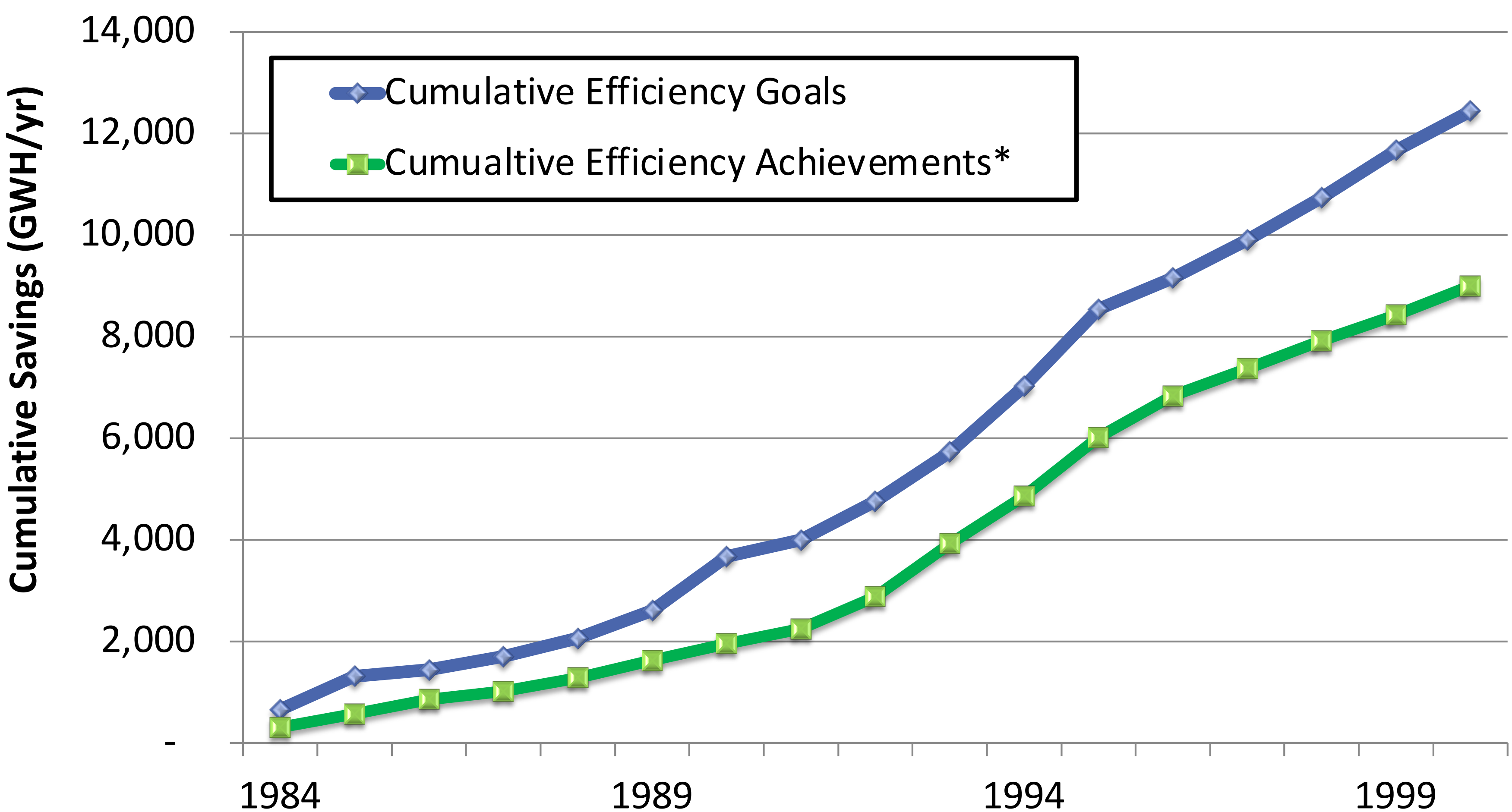
Load Uncertainty Is Particularly A Problem For Resources With Long Lead Times and Large Sizes



Energy Efficiency, Demand Response and Shortened Lead Times and Smaller Sizes For Some Generating Resources Has Reduced Exposure to Load Uncertainty

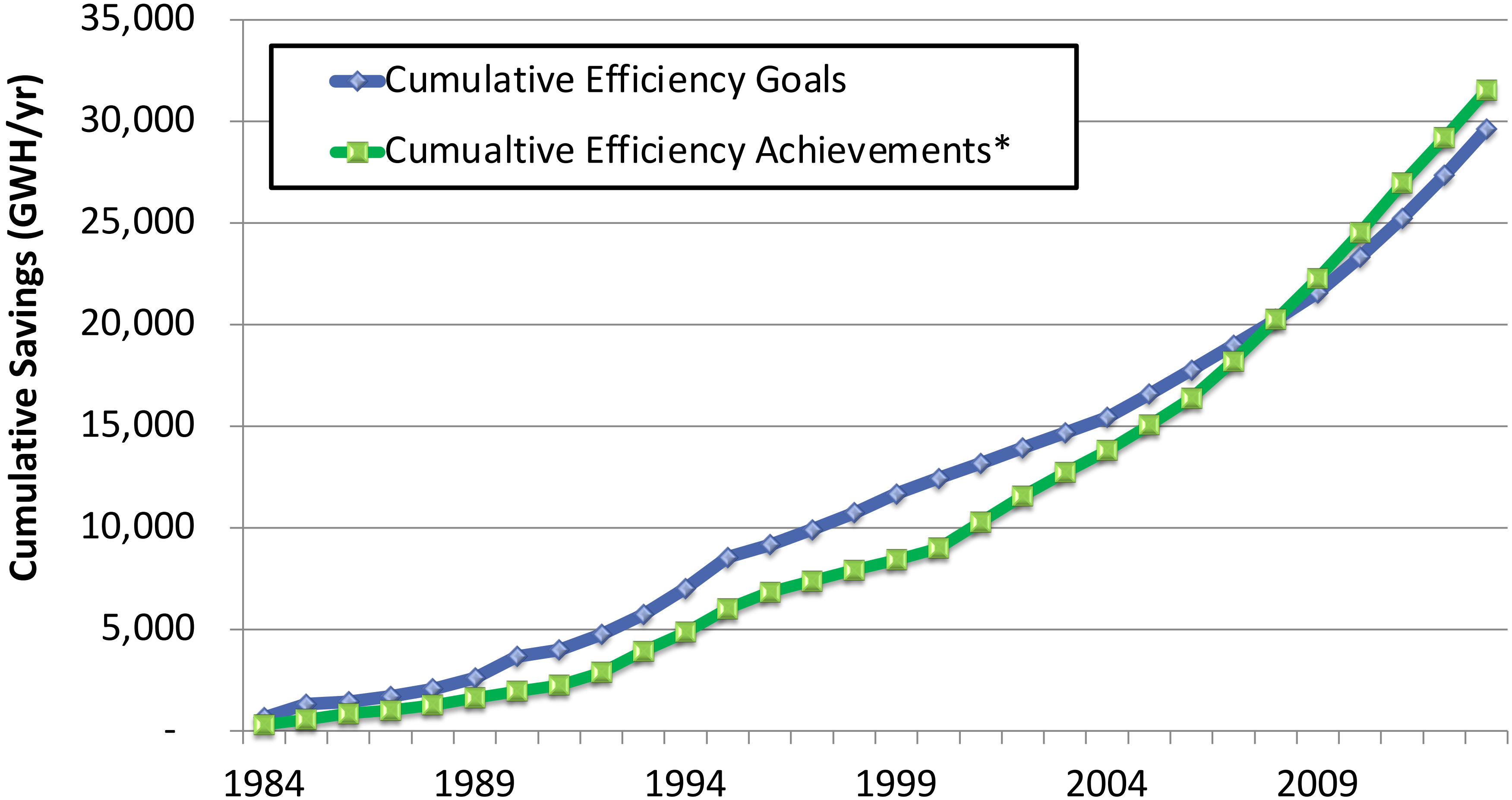


Energy Efficiency Resource Uncertainty Stems from Delays in Deployment (i.e. construction) Schedule



*Achievements reflect utility funded savings only. Savings from codes and standards are included as baseline adjustments in each IRP's baseline load forecast

Since the West Coast Energy Crisis Energy Efficiency Resource Development Delays in Deployment Have Been Less Uncertain



*Achievements reflect utility funded savings only. Savings from codes and standards are included as baseline adjustments in each IRP's baseline load forecast

The future is uncertain

- Regardless of the brilliance of the modeling (and modelers), the historical fit, and the economic theory behind it, the future is still largely unknown.
- Errors with significant economic consequences can (and have) resulted in reliance on a point forecast for planning
- So what can we do about it?


EMBRACE
UNCERTAINTY

Dealing with Uncertainty in Load Forecasts

- Understand the strengths and weaknesses of forecasting model
  - What impacts does it capture?
  - What impacts does it miss?
  - How difficult is it to ensure calibration with the efficiency potential assessment?
- Conduct sensitivity tests on the primary drivers of load growth for the forecast model to identify risk
- Develop range load forecast and integrate them into capacity expansion modeling

Conduct Sensitivity Analysis

- Identify the sensitivity of forecast results to changes in individual driving factors (e.g. number of households, price of electricity, temperature)
  - This reveals the importance of specific assumptions driving the analysis
- Sensitivities should be inspected for reasonability (i.e., does the *direction* and *magnitude* of the impact of a change in a driving factor seem reasonable)
- Sensitivity analysis can inform the development of range of forecasts
  - The more sensitive the forecast is to an assumption, and the larger its impact of the forecast, the greater its role in the creation of the forecast range

Use Range Load Forecasts in Resource Planning

- Range Load forecasts can be used
  - In "deterministic" capacity expansion models to create an optimized resource plan for <u>*each*</u> forecast in the range.
  - In *Monte Carlo* simulation (stochastic) capacity expansion models, with "perfect foresight" to select an optimize resource plan(s) across an array of future conditions
  - In Monte Carlo simulations without "perfect foresight" (i.e., the model makes resource development errors and incurs their costs) to identify resource plans with the lowest cost at varying levels of risk

Questions?

Resources

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- End-Use Load Profiles for the U.S. Building Stock
- Electricity Markets and Policy energy efficiency research
- Time and locational sensitive value of efficiency
  - Time-varying value of electric energy efficiency (2017)
  - Time-varying value of energy efficiency in Michigan (2018)
  - No Time to Lose: Recent research on the time-sensitive value of efficiency (webinar)
  - Locational Value of Distributed Energy Resources (forthcoming)
- Peak Demand Impacts from Electricity Efficiency Programs (forthcoming)
- Energy Efficiency in Electricity Resource Planning (forthcoming)

Resources

- Mims Frick, Natalie, Eckman, T., Leventis, G., and Sanstad, A. Methods to Incorporate Energy Efficiency in Electricity System Planning and Markets. January 2021. Berkeley, CA: Lawrence Berkeley National Laboratory. Available at: https://eta-publications.lbl.gov/sites/default/files/lbnl_ee_resource_planning_1_27_21.pdf
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- Northwest Power and Conservation Council's Seventh Power Plan

  (https://www.nwcouncil.org/energy/powerplan/7/plan)
- Using Integrated Resource Planning to Encourage Investment on Cost-Effective Energy

  (https://www4.eere.energy.gov/seeaction/publication/using-integrated-resource-planning-encourage-investment-cost-effective-energy-efficiency)
- Best Practices in Electric Utility Integrated Resource Planning -
  Examples of State Regulations and Recent Utility Plans
  (http://www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf)
- Practicing Risk-Aware Electricity Regulation: What Every State Regulator Needs to Know

  (http://www.raponline.org/knowledge-center/practicing-risk-aware-electricity-regulation-what-every-state-regulator-needs-to-know/?sf_action=get_results&_sft_topic=energy-resource-planning+integrated-resource-planning)
- LBNL – Resources on Integrated Resource Planning (https://emp.lbl.gov/projects/utility-resource-planning)

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