The Stochastic Energy Deployment Systems (SEDS) Model

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Outline

- **Motivation(s)**
- **Model Description**
- **Sample Results**
- **Next Steps**

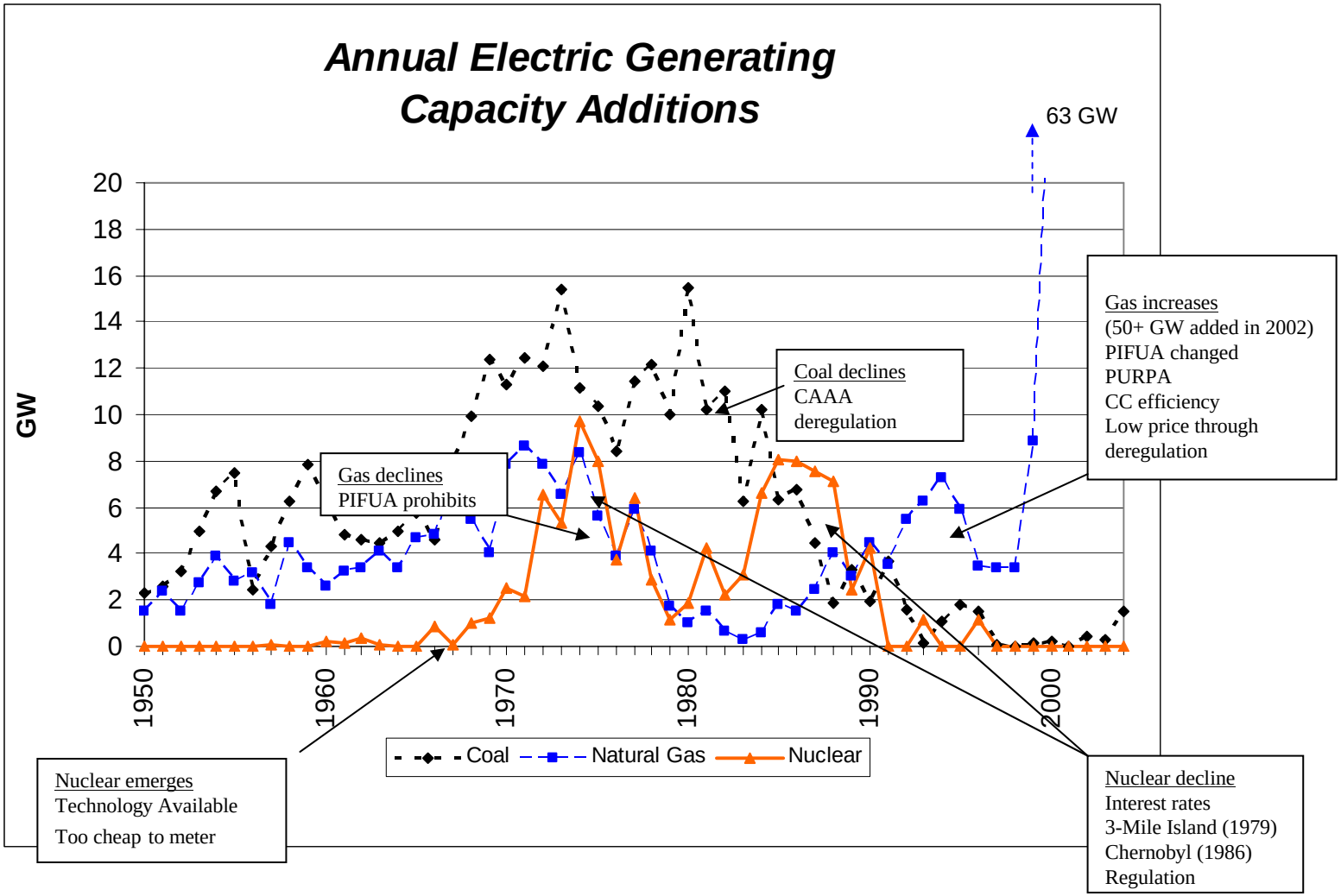
Who Needs ANOTHER Energy Model?

- **The SEDS "project" is a model and a strategy, aimed at rectifying multiple ills**
  - Models are the tools we love to hate
  - Black boxes and distrust
  - Market imperfections of the "modeling market"
  - Hard wired and hidden assumptions (>> more distrust)
  - Slow-to-glacial run time
  - Modelers' are not always subject experts
  - False precision of inputs – parameter uncertainty
  - False precision of relationships, dynamics or drivers - framing or model uncertainty
  - False precision of outputs(>>more distrust)

Models Are Most Useful IF:

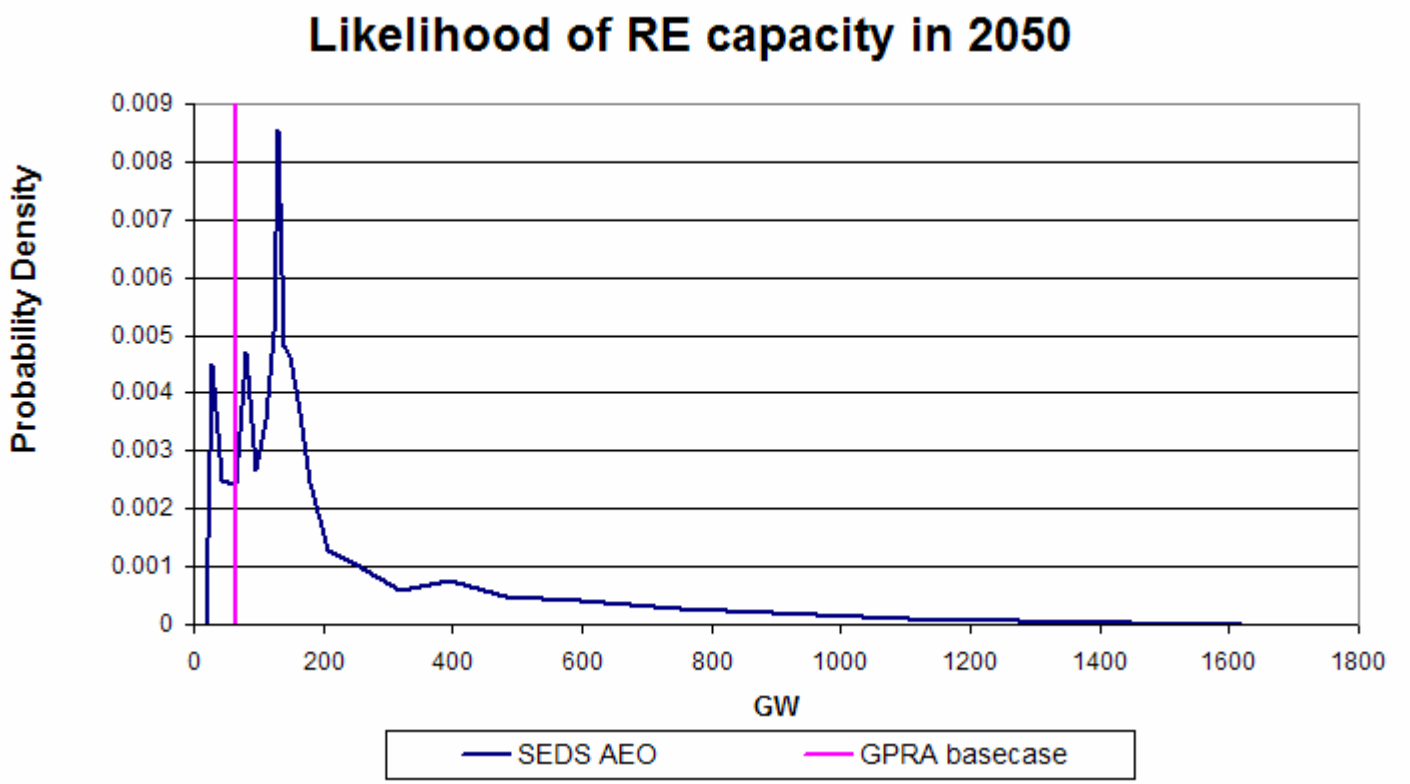
- **They are widely vetted**
  - Requires development/use by a wide community
- **They are widely used**
  - By decision-making staff
  - Requires user-friendliness, quick run time, easy input, transparency/trackability, well-documented, easy access, inexpensive software
- **They are flexible - able to accommodate:**
  - Market diversity
  - Changes
  - Constraints
- **They are built with specific uses in mind**
  - Markets, technologies, policies, metrics
  - Major drivers emphasized

The World is Stochastic



What Might a Stochastic Model Show You?

- **Incorporating uncertainty into an energy market model conveys significantly more information than a single point estimate**



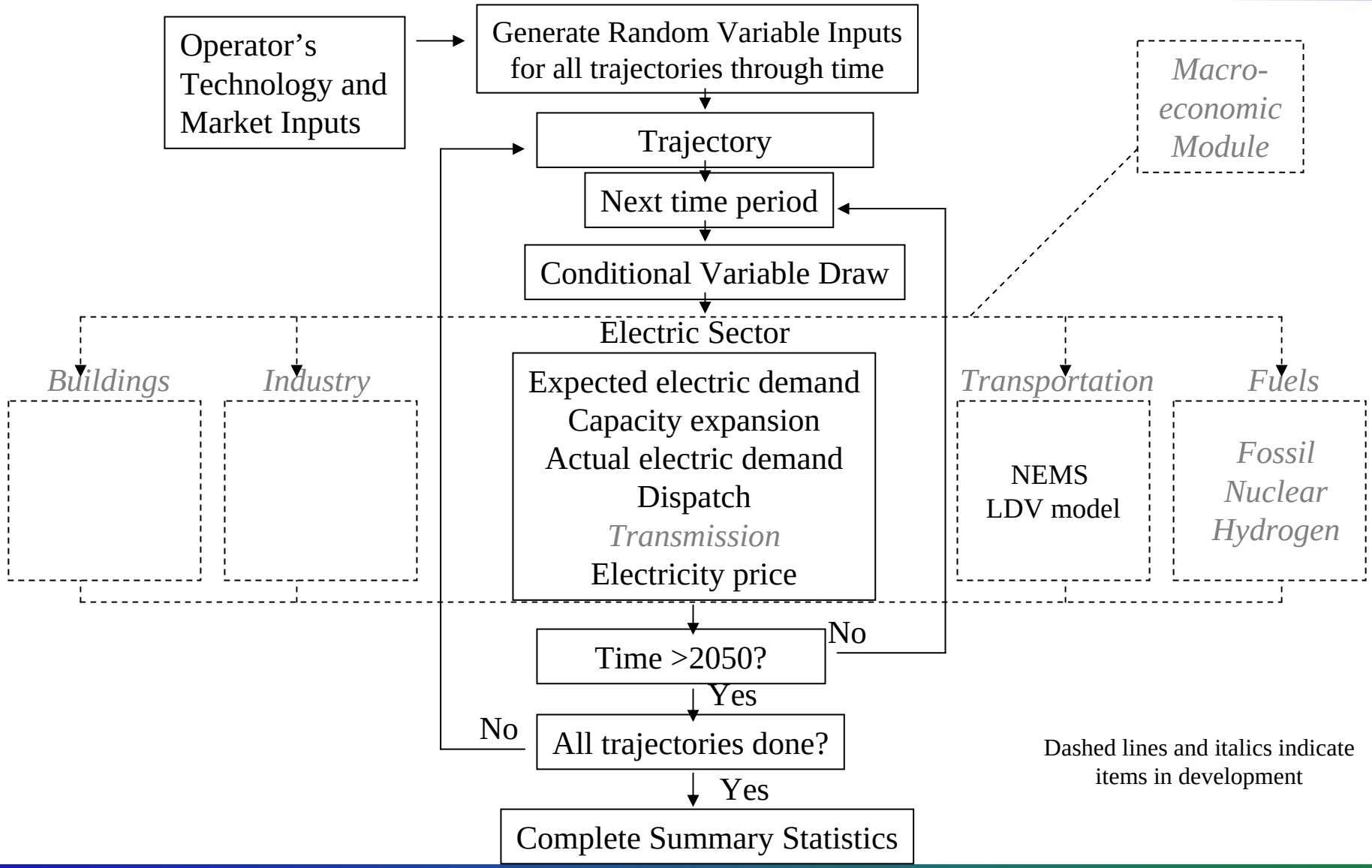
Project Objectives

- **"..develop an energy modeling capability that explicitly takes into account the uncertainties that we all know exist.."**
- **Focus on the major market drivers keeping SEDS "relatively simple."**
- **"..facilitate the on-site direct use of SEDS" by DOE staff and others.**
- **Bring a wide range of modelers into the development process to ensure quality and wide-spread use.**

SEDS General Description

- Model of U.S. energy markets: currently only electric sector capacity expansion and alpha version of light duty vehicle transport
  - All major electric prime mover types – coal, gas, nuclear, hydro
- 2010 to 2050 in 5-year increments
- Explicit treatment of uncertainty with Latin Hypercube simulation
- Simulation – not optimization, lack of foresight
- Single national region
- Engineering/economic costs and efficiencies
- Endogenous technology change through learning curves
- Base, intermediate, and peak power markets
- Logit market share for new capacity
- Renewable energy supply curves
- Least cost dispatch
- Planned and economic plant retirements

SEDS Modules and Routine



Uncertain Major Market Drivers in SEDS

- **Policy/environment**
  - Climate change
  - Production Tax Credit
  - Nuclear builds = f (climate change, Yucca Mtn, etc.)
- **Fossil fuel prices**
  - Natural Gas, Oil and Coal
- **Technological advances (e.g $/kW, capacity factor)**
  - Due to R&D
  - Due to learning
- **The Economy**
  - Electric demand
    - Growth
    - Elasticity

Simulation – Not Optimization

- No knife-edge responses
- Logit market share algorithm
- Capable of capturing non-optimal behaviors
- Relatively quick run times

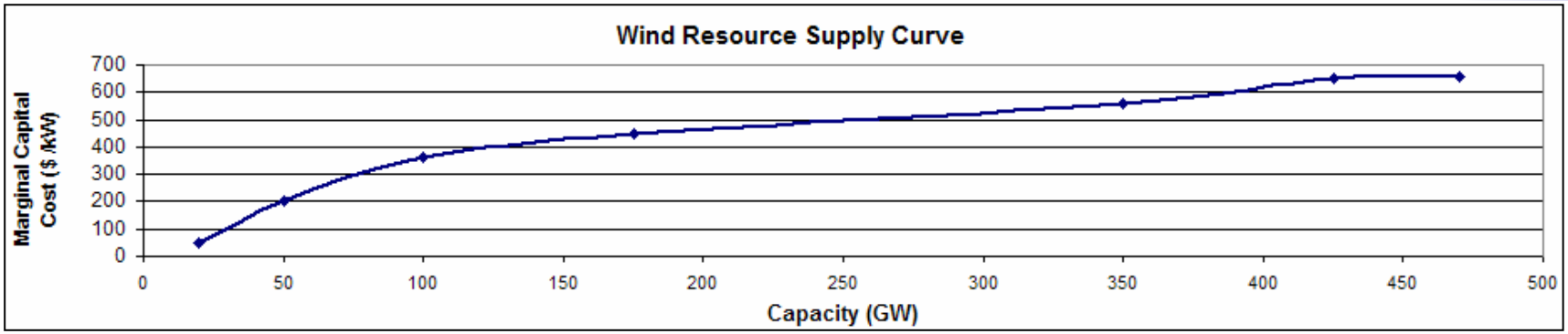
Lack of Foresight

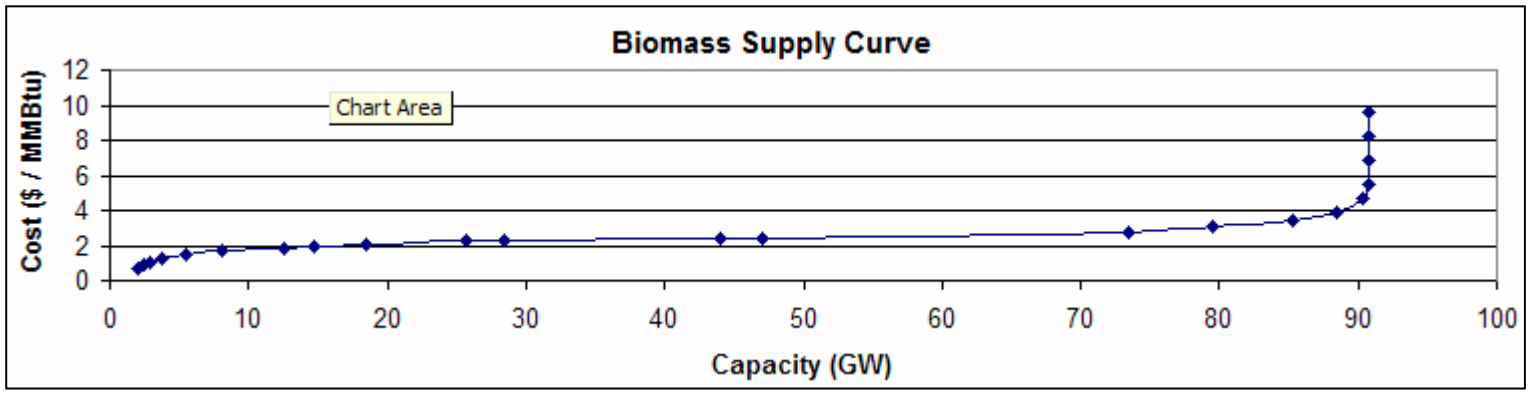
- **Especially important in a stochastic model**
  - Don’t want modeled investors to know the outcome of future uncertainties
- **Doesn’t know:**
  - Future fuel prices
  - Future technology improvements
  - Future policies
  - Future loads
    - Build to model’s expectations – dispatch to model’s reality

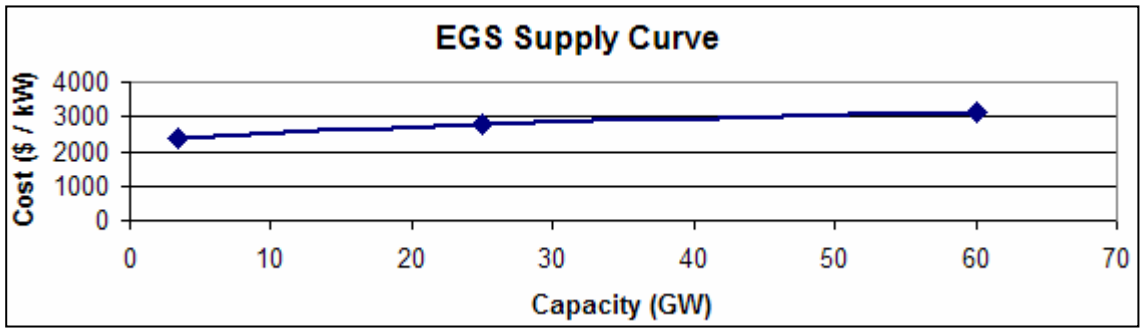
Regions in SEDS

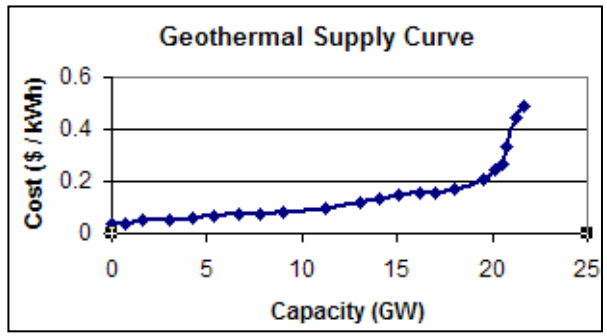
- **For transparency and quick run times, SEDS electric market has a single national region, but:**
  - We're investigating the tradeoffs associated with having more electric regions
  - Single electric region may be feasible because:
    - Logit market share captures diversity
    - Supply curves capture renewable energy heterogeneity
    - May be able to incorporate some reduced form version of optimal power flow modeling using response surface or neural network
  - Other sectors could have more regions, even if electric sector retains only one region

Renewable Resource Curves









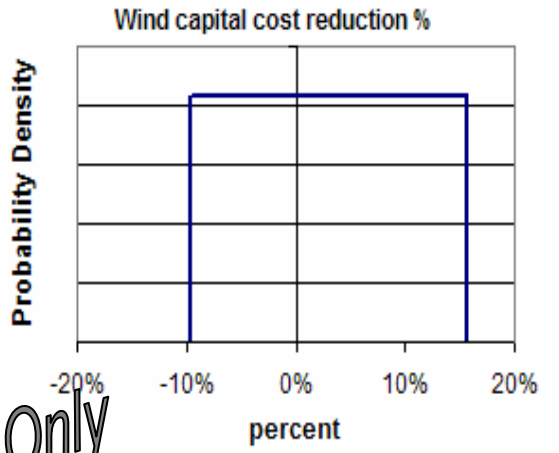
Analytica software environment

- **Designed explicitly for uncertainty analysis**
  - Operable in deterministic or stochastic mode
  - Easy to input different probability distributions
  - Correlated inputs
  - Conditional probabilities
  - Bivariate distributions
  - Many forms of uncertainty related outputs
    - Confidence intervals
    - Statistics – mean, mode, median, std deviation, min, max
    - Spearman correlation
- **Built for self documentation**
  - Graphical portrayal of functional relationships
  - Function boxes show equations, inputs, outputs, descriptions, relationships
- **No-cost, run-only version easily downloadable from net**

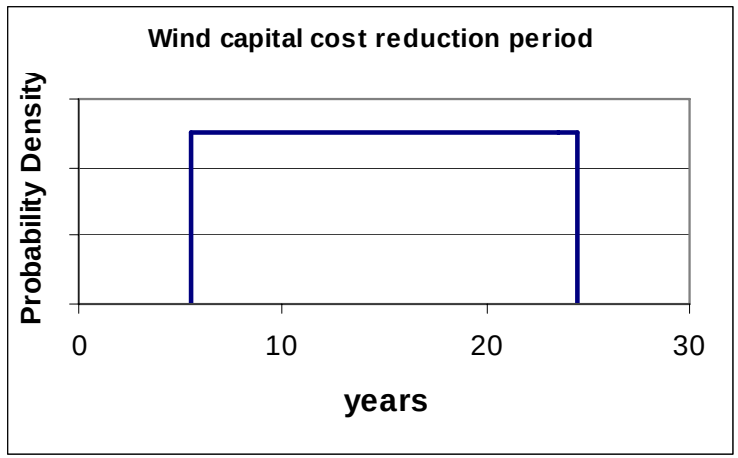
Technology Cost & Performance

- **Uncertainty in Capital Cost and Efficiency**

- **Each uncertainty modeled through two random variables**
  - Ultimate improvement
  - Time to ultimate improvement
    - linear improvement over time

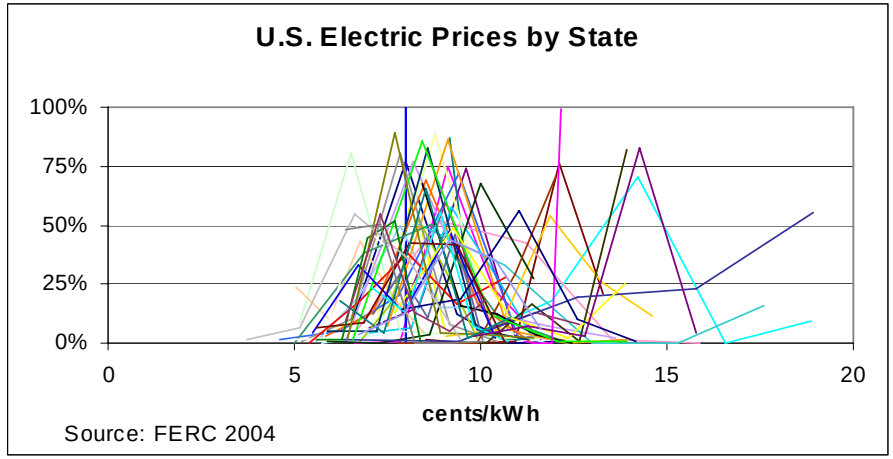


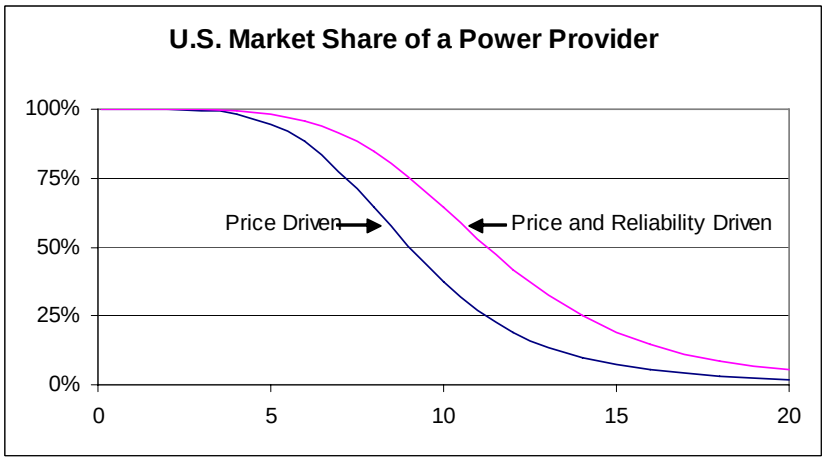
Illustrative Results Only



Market Diversity – Logit Market Share

- **Market prices are widely divergent across the U.S.**



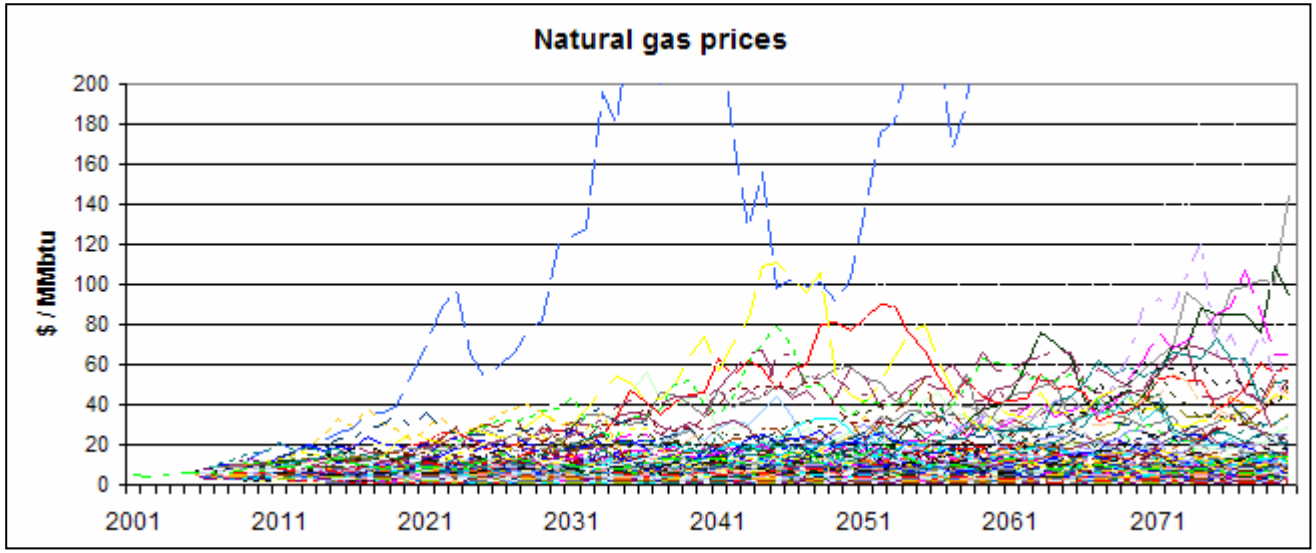


- **Multinomial logit can use more than just price to estimate market share, e.g. reliability, ramp-rate**

Modeling Fuel Price Uncertainty

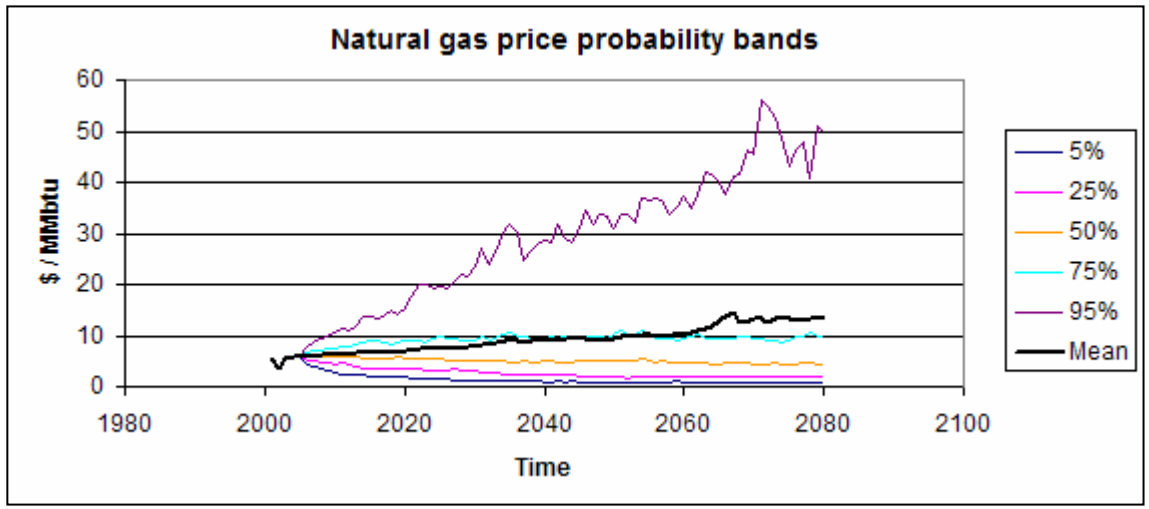
- **Eventually, modeled fuel prices will reflect resource depletion, new sources, refining, distribution and uncertainties**
- **Currently, uncertainty in fuel prices expressed through uncertainty in an annual price growth multiplier g_t [$P_t = (1+g_t)P_{t-1}$]**
- **Oil price determined by three random variables**
- **Gas and coal prices determined by uncertainty in their annual price growth multipliers and correlation with oil price**

Sample Stochastic Input – Natural Gas



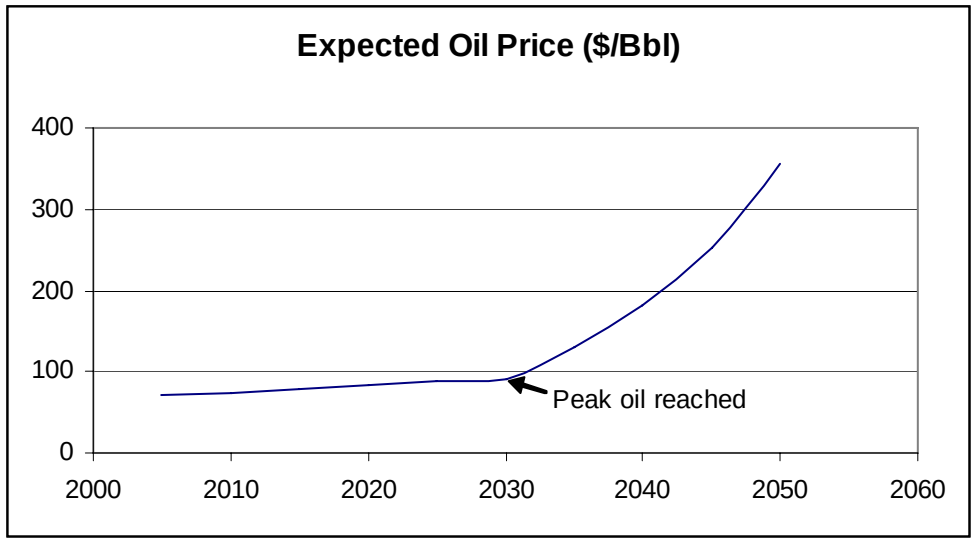
- The evolution of Natural gas price pathways" over time are simulated using Monte Carlo simulations

- Inputs and outputs are easily shown using using bands (or confidence intervals)



Oil Price Uncertainty

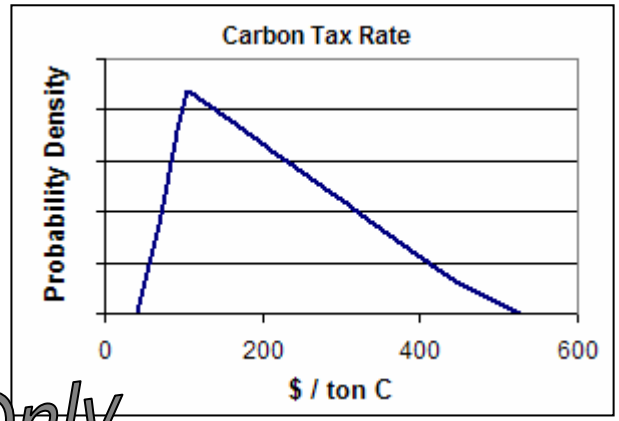
- **Annual price growth before "Peak Oil"**
- **Time to "Peak Oil"**
- **Annual price growth after "Peak Oil"**
- ***Later version will have representation of world oil market based on D. Greene***



Illustrative Results Only

Modeling Carbon Value Uncertainty

- **Size of carbon tax**
- **Start date for implementation**
- **Ramp-up time**



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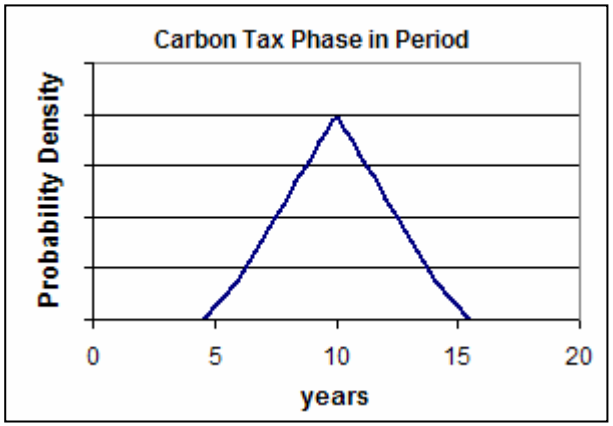
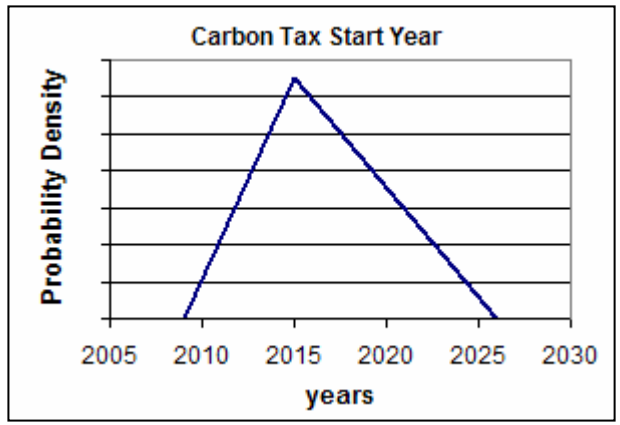
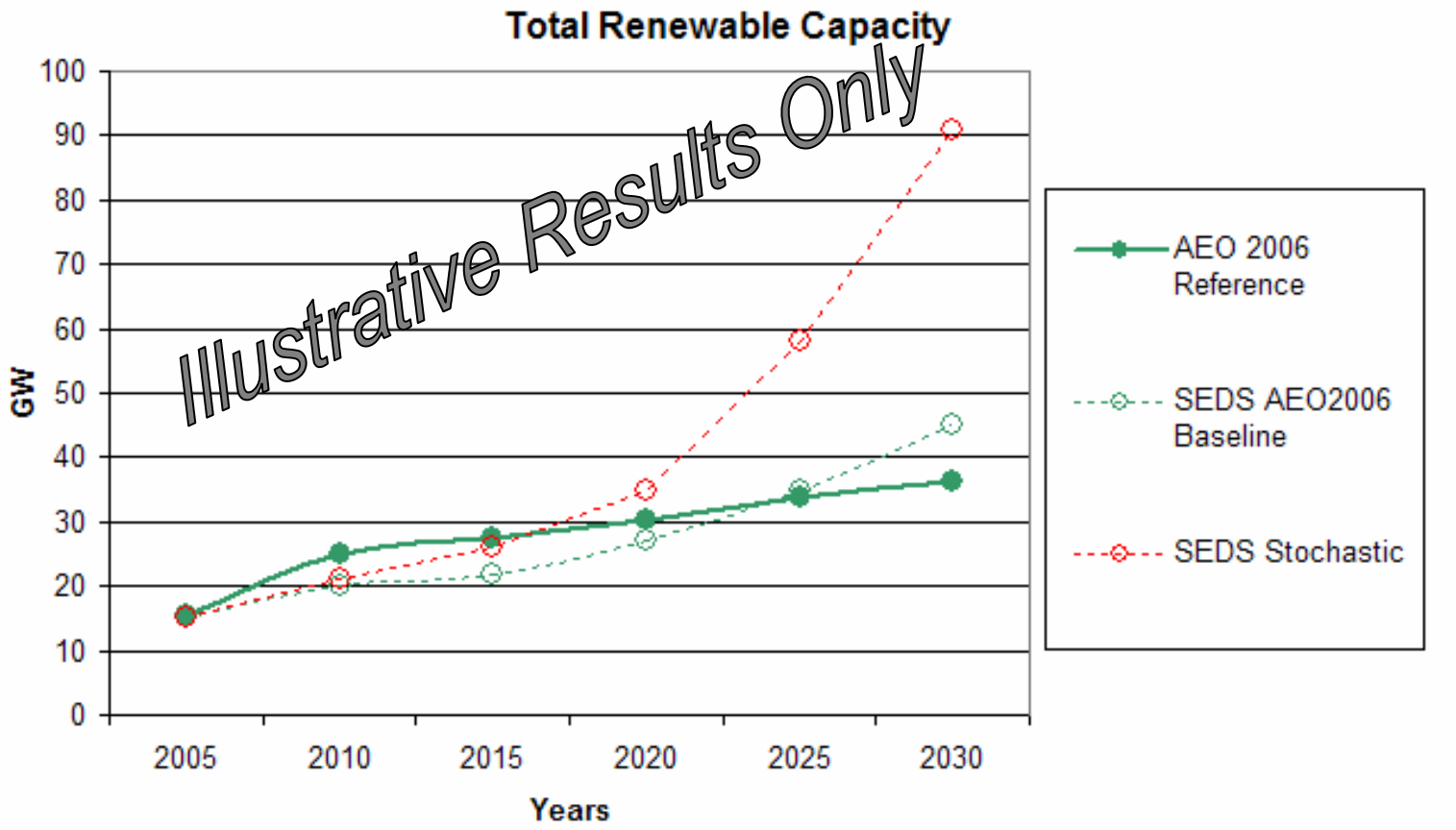




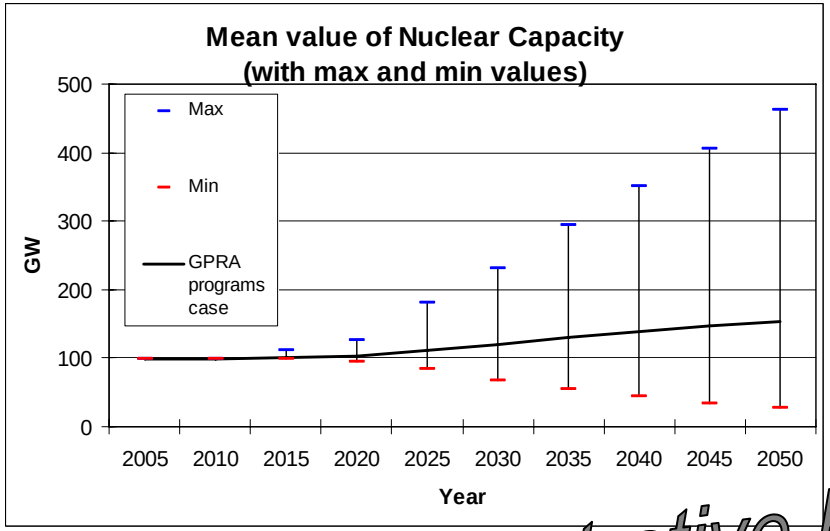
Renewable Capacity

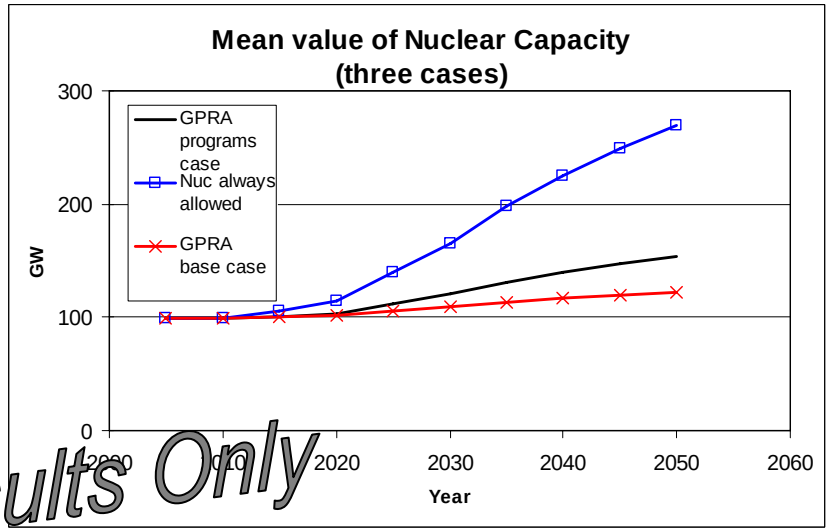
- **A stochastic model's projection can yield insights not visible with deterministic models**



Sample Results

Nuclear Capacity





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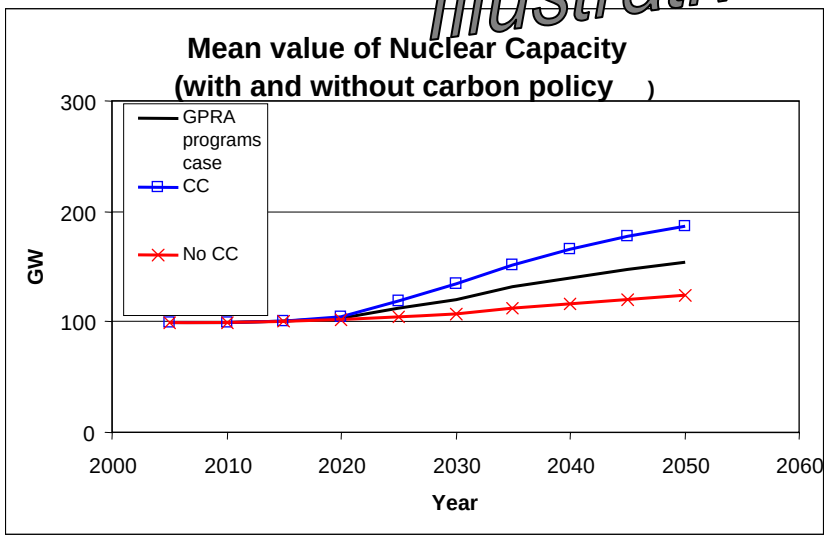
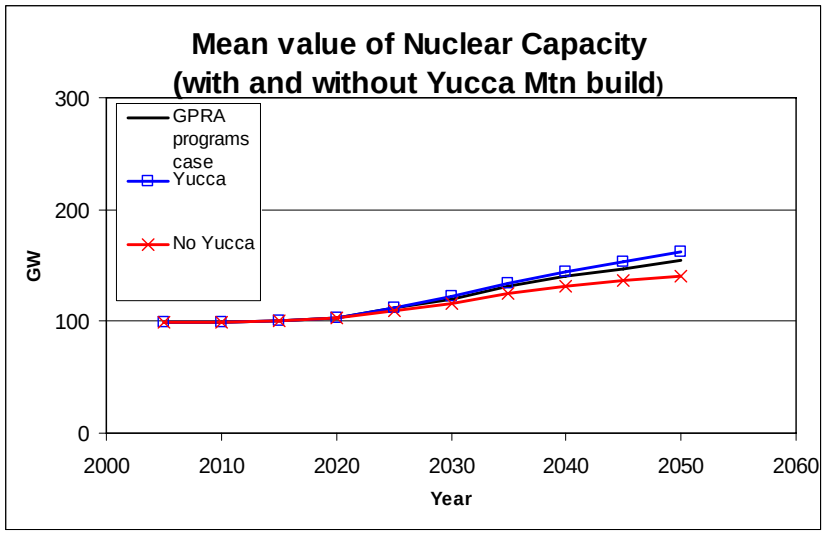
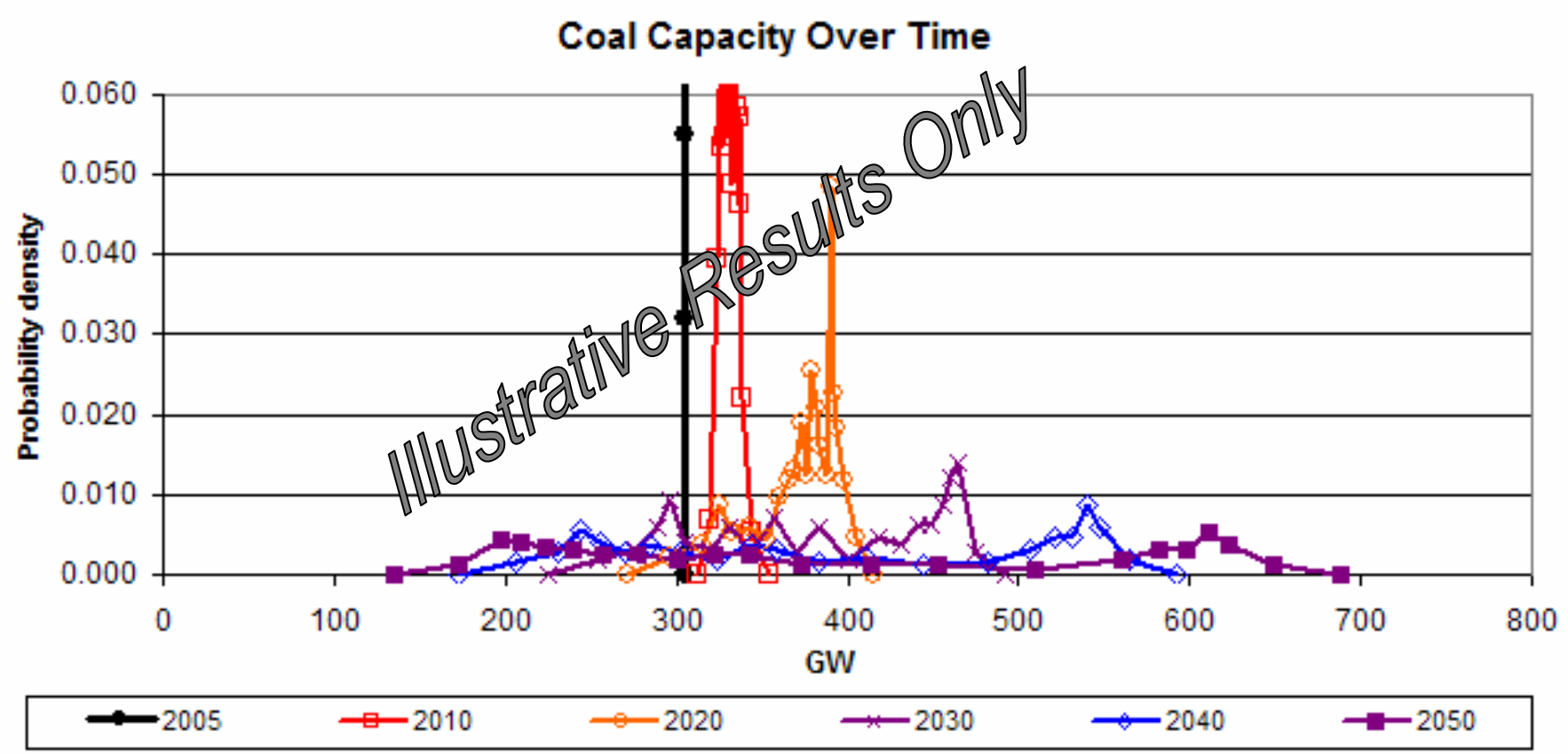


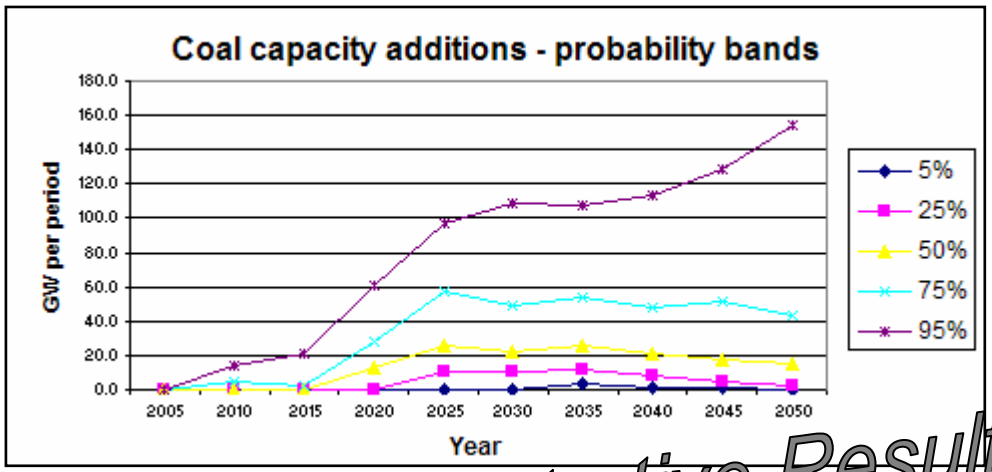


Coal Capacity

- **Uncertainty Increases with Time**
- **A Bimodal Energy World Driven by Carbon Policy Uncertainty**



Information Presentation Variety



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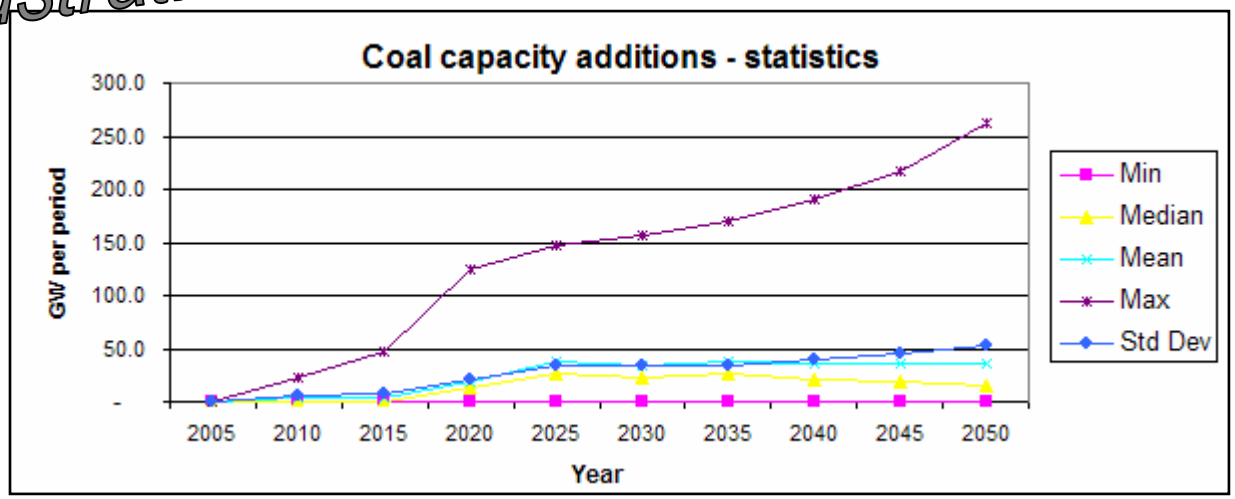

Next Steps and Potential Collaboration

- Investigation of important uncertainties (NETL)
- Macroeconomic Module (LBNL/ANL)
- Liquid and Gas Fuels (ANL/ NETL)
- Residential and Commercial Sectors (LBNL/PNNL)
- Industrial Sector (LBNL/PNNL)
- Transportation Sector (ORNL/NREL/ANL)
- “Lite” vs. “Full” versions
- Regionalization or representation of regionalization’s effects
- Hydrogen
- Transmission (LBNL)
- Nuclear Fuel Cycle (BNL)
- Option value