TEXAS
The University of Texas at Austin

WHAT STARTS HERE CHANGES THE WORLD

2017 Energy Policy
Research Conference

epi Energy Policy Institute

The Cost of Policy Uncertainty in Electric Sector Capacity Planning

Implications for Instrument Choice

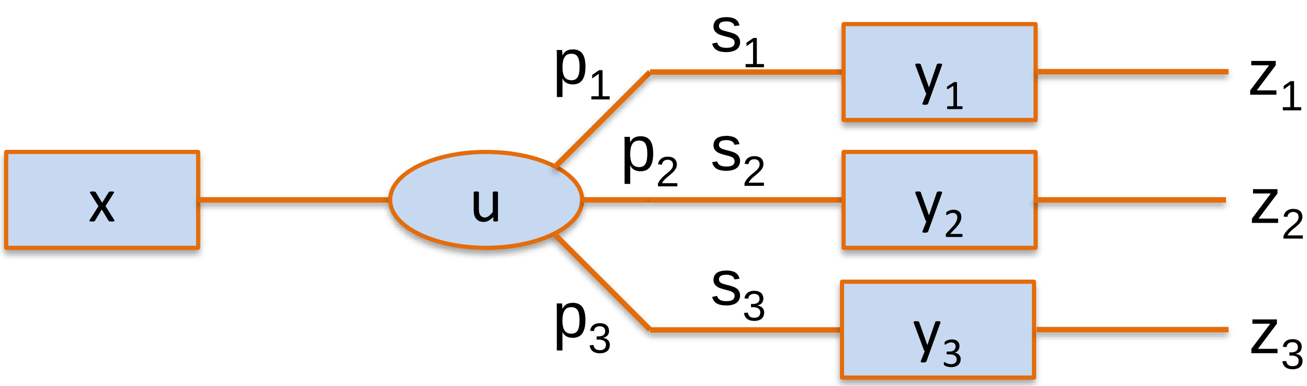
Dr. Benjamin D. Leibowicz
Assistant Professor
Graduate Program in Operations Research and Industrial Engineering
Graduate Program in Energy and Earth Resources
Department of Mechanical Engineering
The University of Texas at Austin

Dealing with Uncertainty

- Generation assets have long service lives, over which a number of relevant factors are highly uncertain.
  - Energy commodity prices, policies, electricity demand, etc.

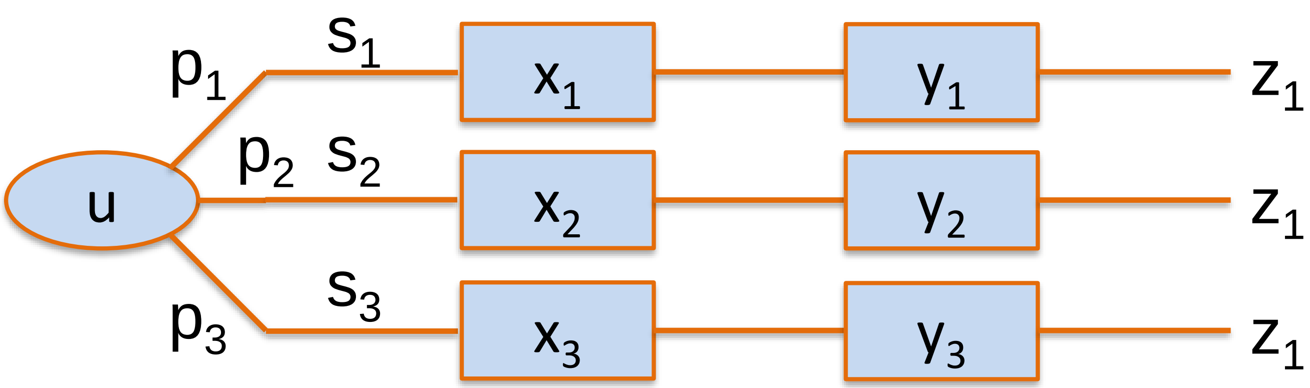
- There are several methodologies for making power sector investment decisions under uncertainty.
  - For example: sensitivity analysis, scenario analysis, Monte Carlo simulation, decision analysis, stochastic programming.

Stochastic Programming



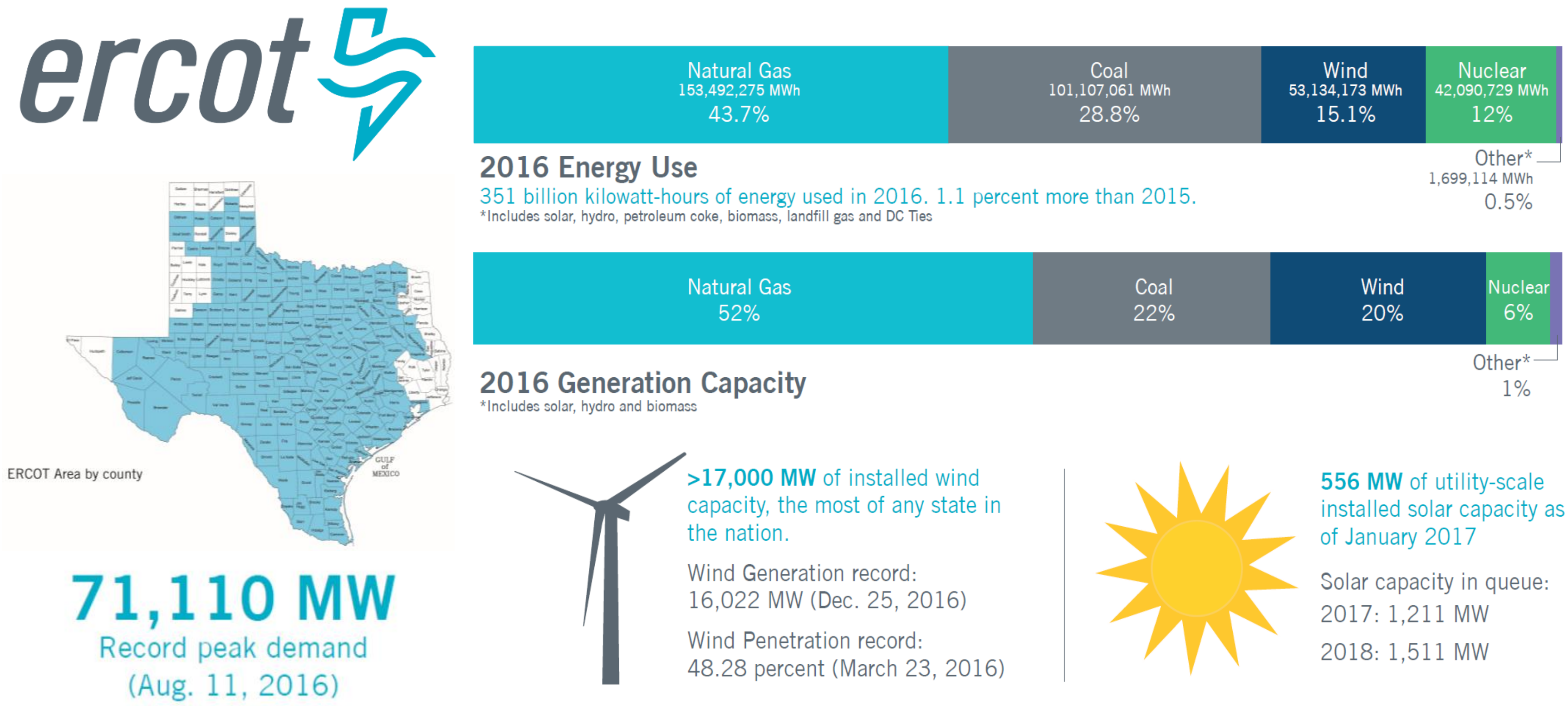
- Determine the optimal near-term hedging strategy *x* and state-dependent recourse decisions *y* that maximize (or minimize) the expectation of objective value *z* over all states of the world *s*.
- Hedging incorporates generality and flexibility.

Perfect Information

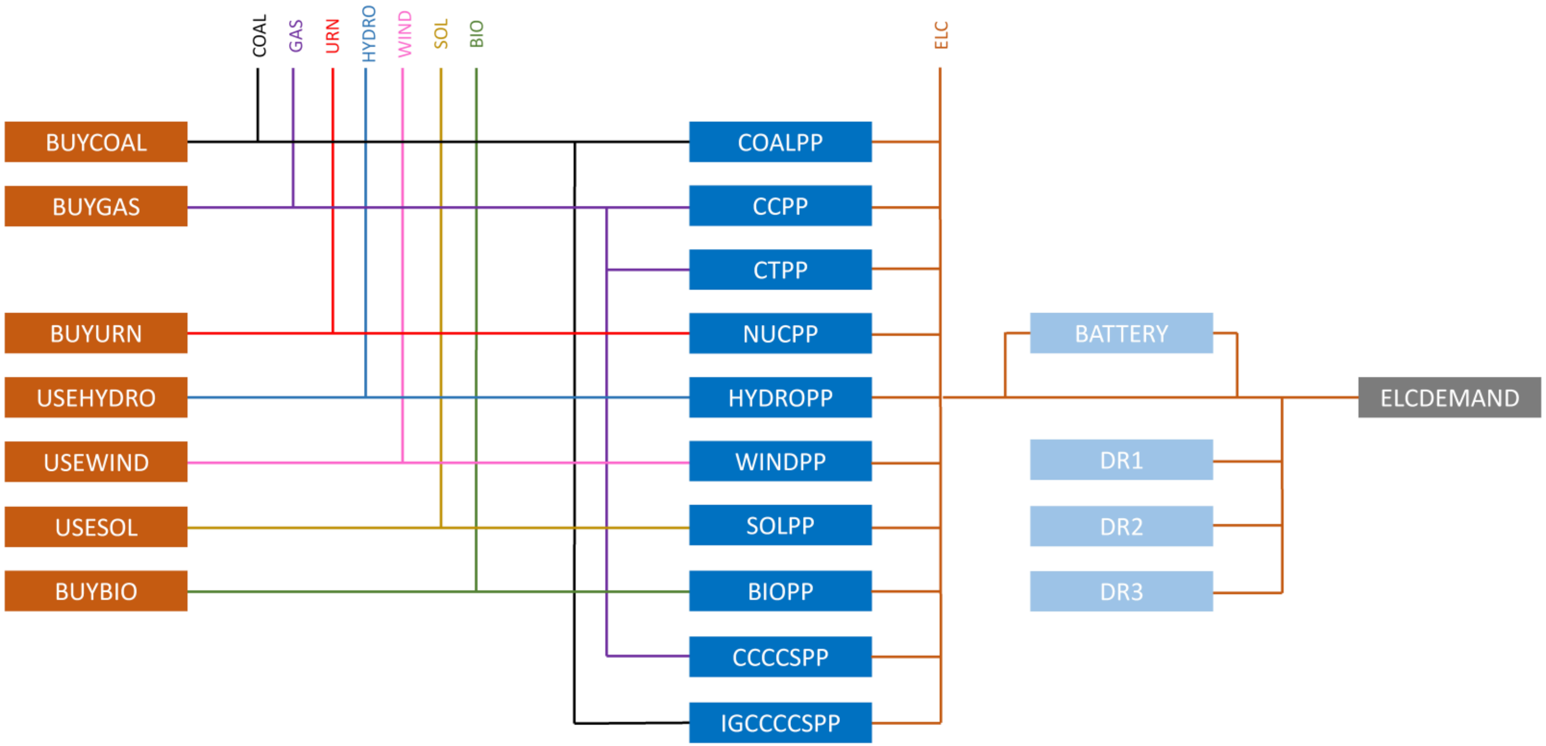


- If we know from the start which state of the world will occur, we can perfectly tailor all decisions to that state.
- Suppose the objective is cost minimization.
- Expected value of perfect information (EVPI) tells us how much less costly our perfect information solution is, on average, than our stochastic solution.

Capacity Planning in ERCOT



OSeMOSYS Model for ERCOT



- Minimize total generation system costs over 2016–2040.
- Dispatch computed for ten representative timeslices parameterized using hourly load, wind, and solar data.

Climate Policy Uncertainty

- Reformulate OSeMOSYS as a two-stage stochastic program to determine the optimal near-term hedging strategy under climate policy uncertainty.
- Consider three alternative instruments.
  - Carbon tax, carbon cap, renewable portfolio standard.
- Five possible policy levels for each instrument.
  - No policy, Weak, Moderate, Strong, Very strong.
- Calibrate the instruments so that, in a deterministic setting, they all lead to the same minimized cost objective value at each policy level.

Most Relevant Literature

- Energy modeling based on stochastic programming:
  - Using MARKAL: Kanudia and Loulou (1998), Kanudia and Shukla (1998), Heinrich et al. (2007), Hu and Hobbs (2010), Usher and Strachan (2012), Bistline and Weyant (2013)
  - Using other models: Krukanont and Tezuka (2007), Keppo and van der Zwaan (2012), Bistline (2015)

- Instrument choice:
  - Weitzman (1974), Palmer and Burtraw (2005), Fischer and Newell (2008), Goulder and Schein (2013)

Calibrated Policy Instruments

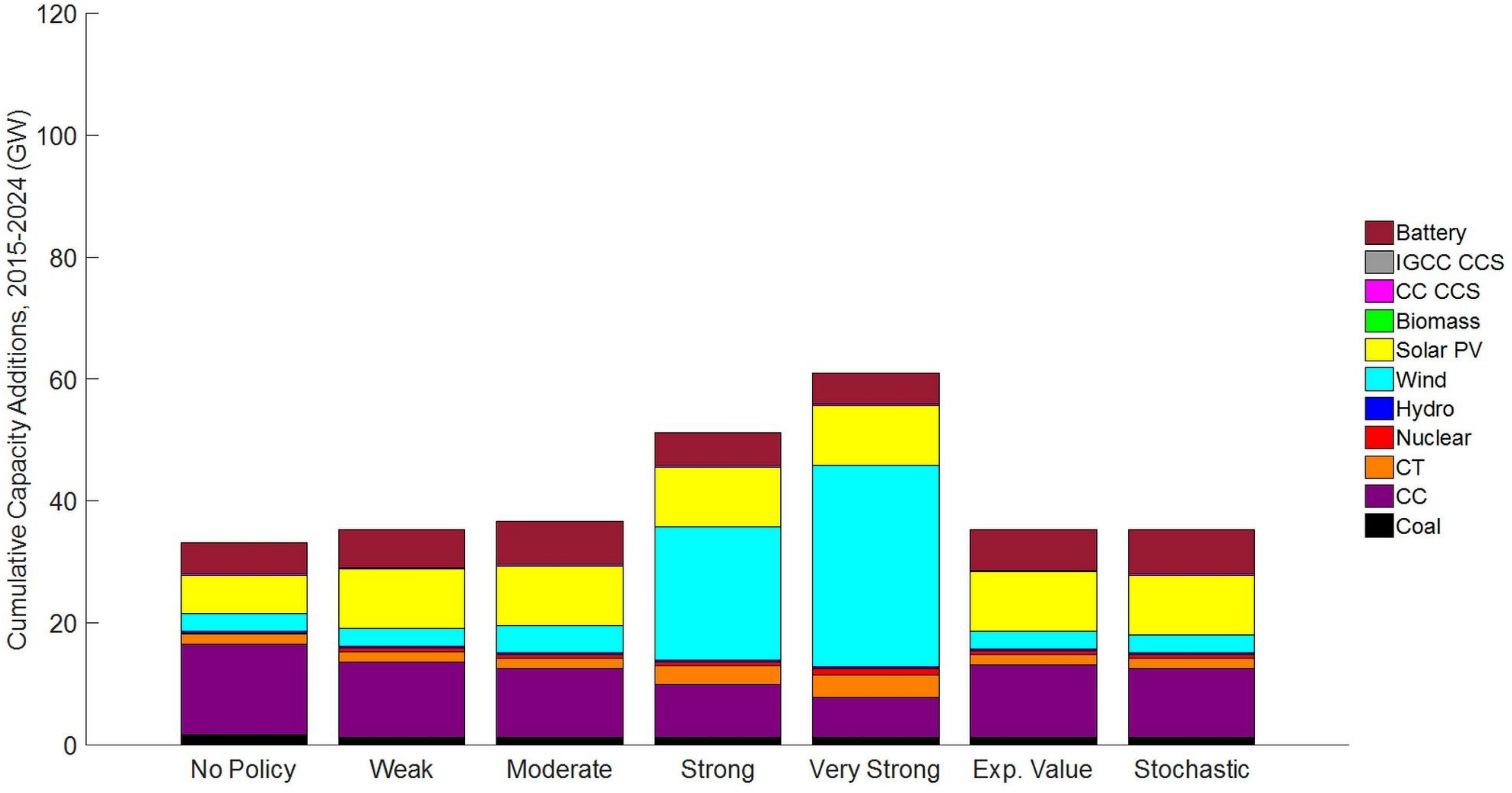
Policy Level	**Probability**	**Tax** ($\$/tCO_2$)	**Cap** ($MMtCO_2$)	**RPS** (%)	**Cost** ($Billion)
No Policy	0.2	0	159.3	12.5	216.6
Weak	0.4	20	72.1	56.3	235.7
Moderate	0.2	40	33.9	77.2	251.4
Strong	0.1	60	16.9	86.2	260.5
Very Strong	0.1	80	12.9	89.8	265.0

- This carbon tax distribution is based on a survey of 14 utilities in the Western U.S. (Bistline, 2015).
- The other instruments are calibrated to result in the same minimized cost objective values.

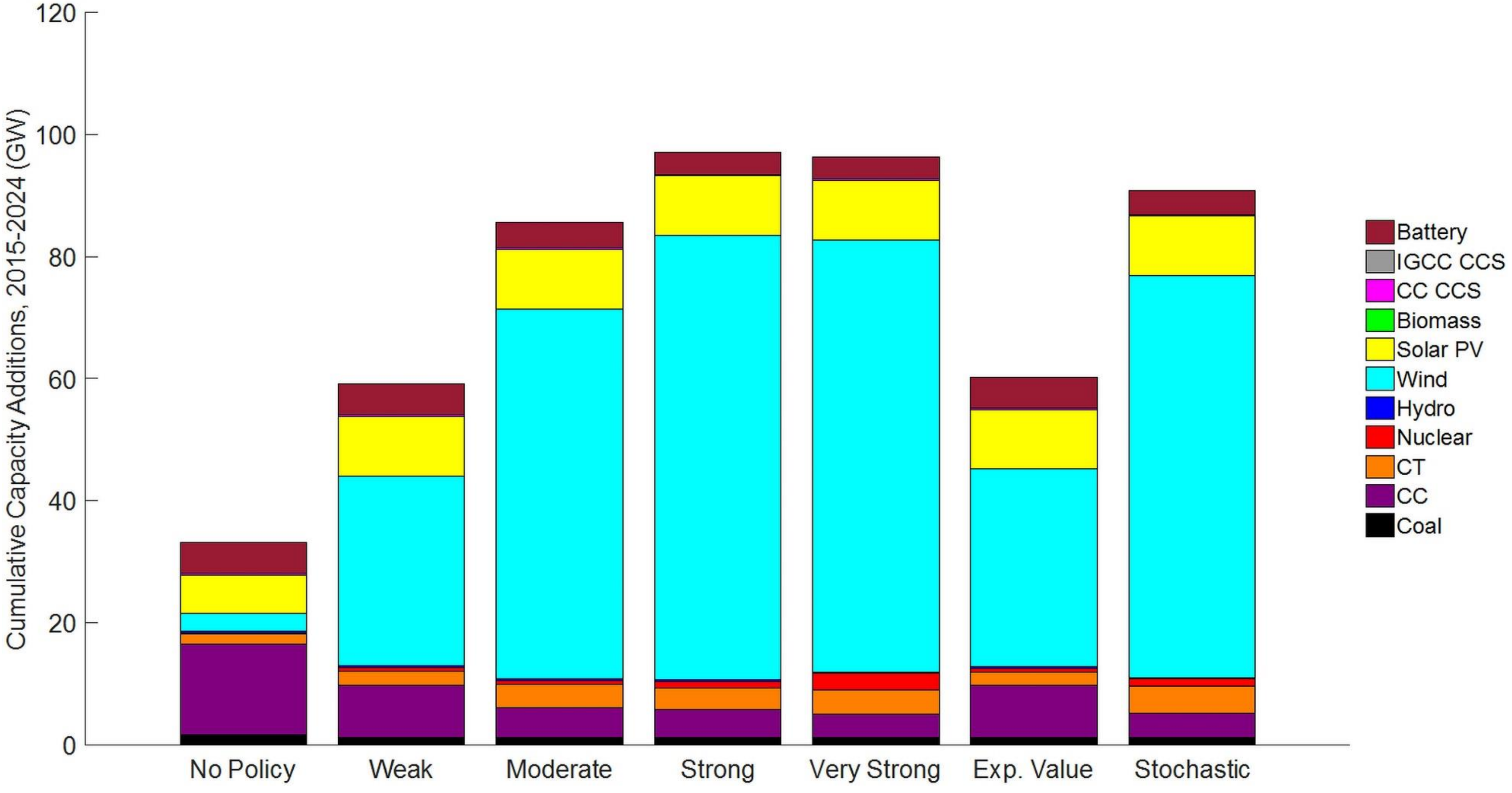
Summary of Findings

- Facing an uncertain carbon tax, the optimal hedging strategy is a wait-and-see approach.
  - Delay action as much as possible, then accelerate decarbonization if the tax turns out to be high.
- Facing an uncertain carbon cap or RPS, the optimal hedging strategy is a prepare-for-the-strictest approach.
  - Decarbonize aggressively in the near term, and accept the unnecessary cost this entails if the policy turns out to be weak.
- The cost of policy uncertainty is higher under a cap than a tax, and highest under an RPS.

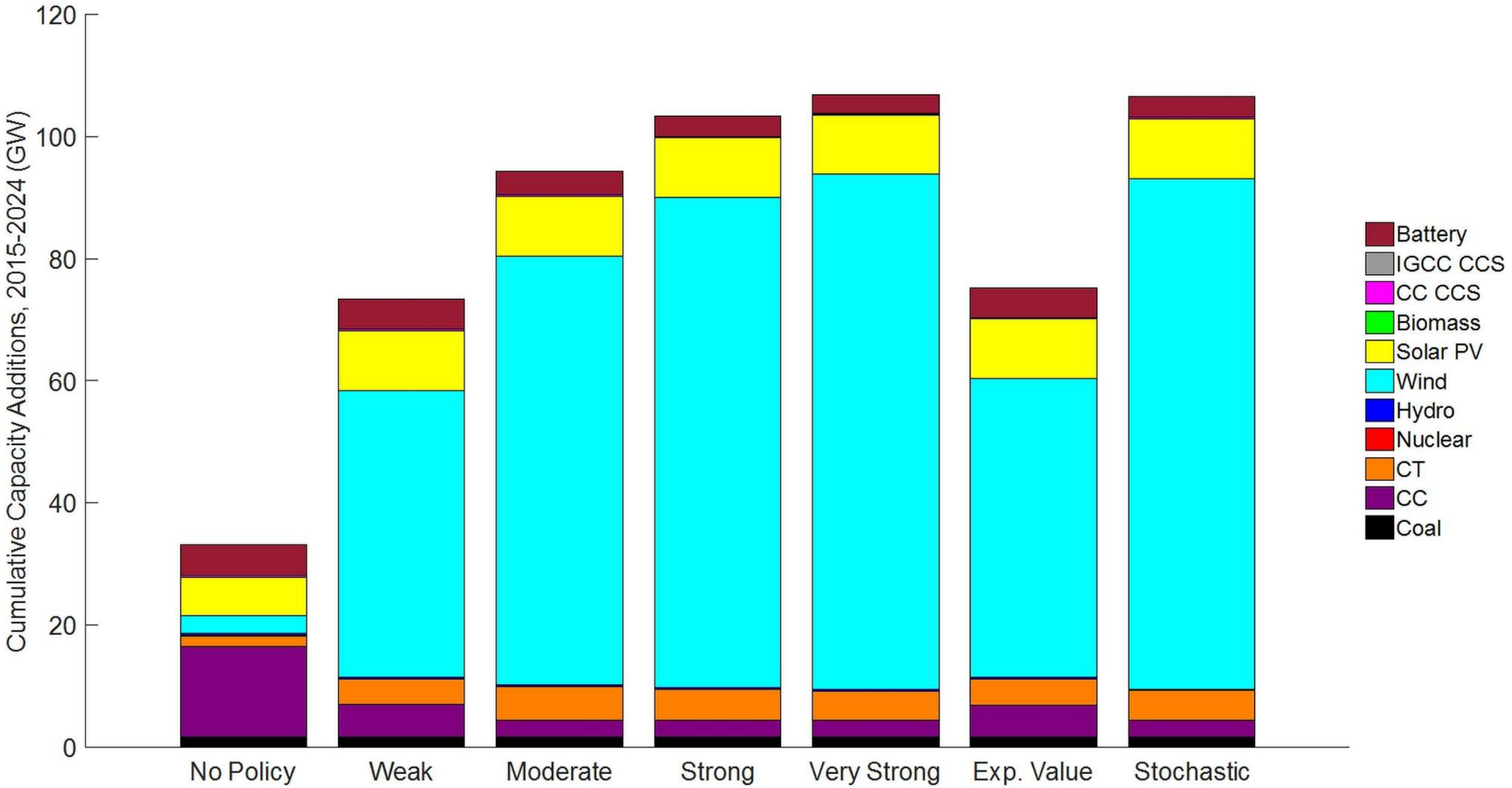
Hedging Under a Carbon Tax



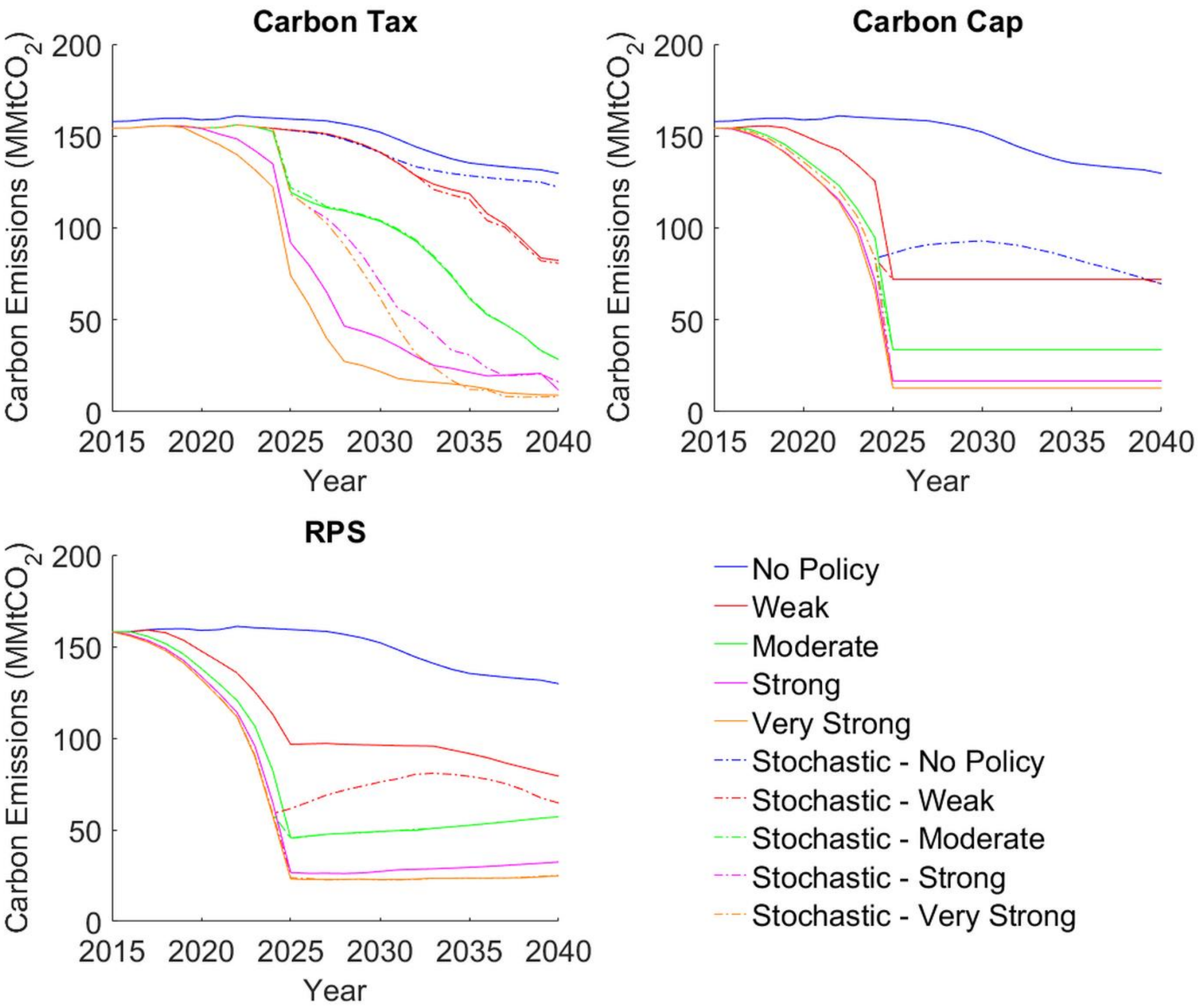
Hedging Under a Carbon Cap



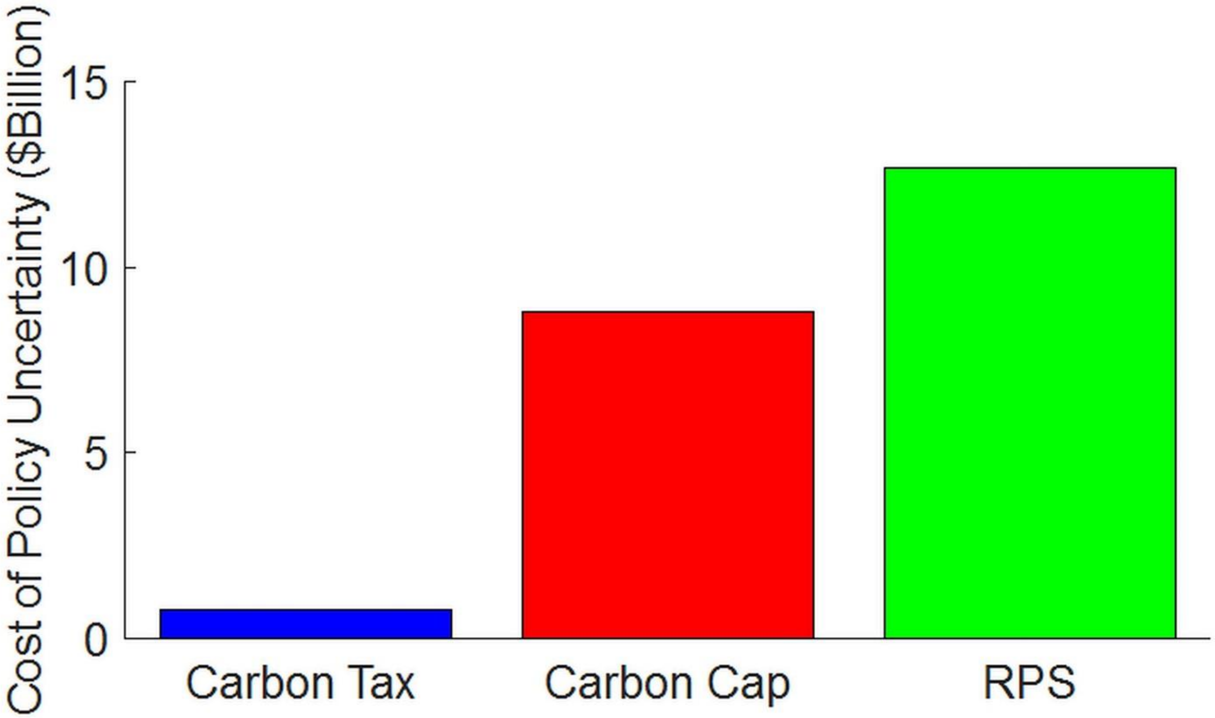
Hedging Under an RPS



Carbon Emissions



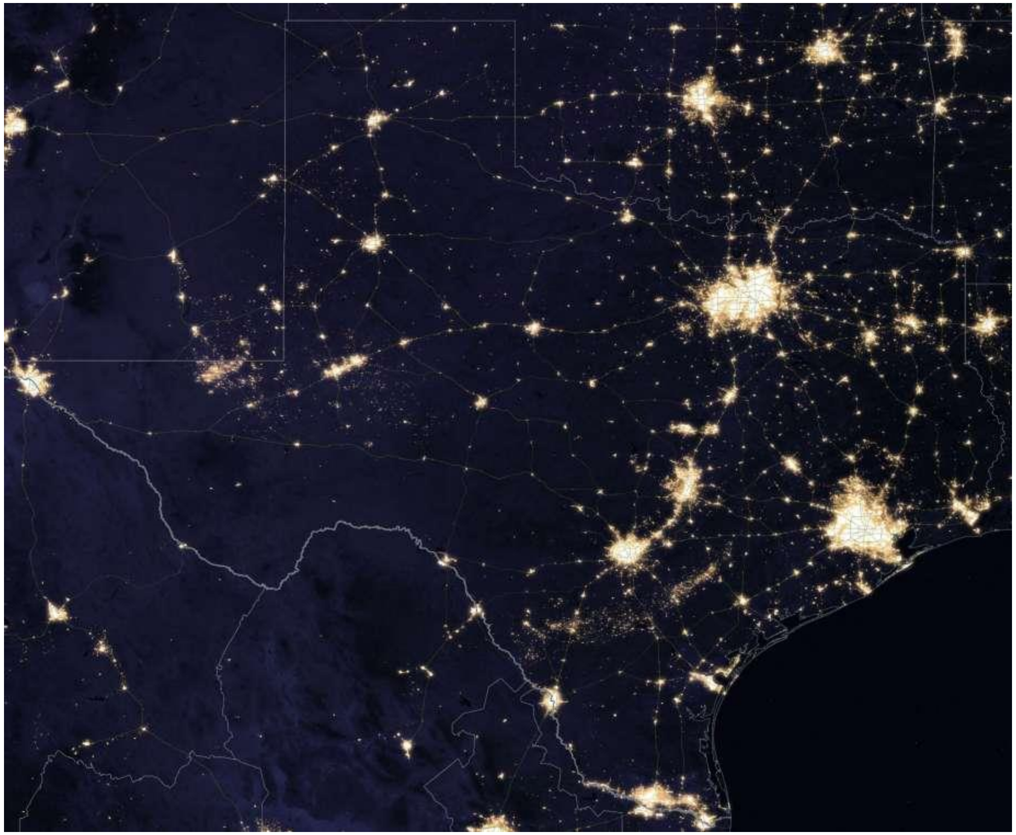
Cost of Policy Uncertainty



Takeaways

- Policy uncertainty is costly in the electric sector, so commitments to long-term policies are valuable.
- Some degree of policy uncertainty is inevitable, and from the perspective of electricity decision making, this favors price-based over quantity-based instruments.
- Price-based instruments offer greater flexibility because they affect parameters of the objective function, rather than constraints that restrict the feasible region.

The End



The University of Texas at Austin
Operations Research and Industrial Engineering
Cockrell School of Engineering

energy institute
THE UNIVERSITY OF TEXAS AT AUSTIN

Literature Cited

- Bistline, J.E., 2015. Electric sector capacity planning under uncertainty: Climate policy and natural gas in the US. Energy Economics 51, 236–251.
- Bistline, J.E., Weyant, J.P., 2013. Electric sector investments under technological and policy-related uncertainties: A stochastic programming approach. Climatic Change 121 (2), 143–160.
- Fischer, C., Newell, R.G., 2008. Environmental and technology policies for climate mitigation. Journal of Environmental Economics and Management 55 (2), 142–162.
- Goulder, L.H., Schein, A.R., 2013. Carbon Taxes Versus Cap and Trade: a Critical Review. Climate Change Economics 4 (3), 1–28.
- Heinrich, G., Howells, M., Basson, L., Petrie, J., 2007. Electricity supply industry modelling for multiple objectives under demand growth uncertainty. Energy 32 (11), 2210–2229.
- Hu, M.C., Hobbs, B.F., 2010. Analysis of multi-pollutant policies for the U.S. power sector under technology and policy uncertainty using MARKAL. Energy 35 (12), 5430–5442.
- Kanudia, A., Loulou, R., 1998. Robust responses to climate change via stochastic MARKAL: The case of Quebec. European Journal of Operational Research 106 (1), 15–30.
- Kanudia, A., Shukla, P. R., 1998. Modelling of Uncertainties and Price Elastic Demands in Energy-environment Planning for India. Omega 26 (3), 409–423.
- Keppo, I., van der Zwaan, B., 2012. The Impact of Uncertainty in Climate Targets and CO2 Storage Availability on Long-Term Emissions Abatement. Environmental Modeling and Assessment 17, 177–191.
- Krukanont, P., Tezuka, T., 2007. Implications of capacity expansion under uncertainty and value of information: The near-term energy planning of Japan. Energy 32 (10), 1809–1824.
- Palmer, K., Burtraw, D., 2005. Cost-effectiveness of renewable electricity policies. Energy Economics 27 (6), 873–894.
- Usher, W., Strachan, N., 2012. Critical mid-term uncertainties in long-term decarbonisation pathways. Energy Policy 41, 433–444.
- Weitzman, M.L., 1974. Prices vs. Quantities. Review of Economic Studies 41 (4), 477–491.