



Valuing Nuclear in Energy Modeling

Jordan Cox

GAIN Webinar

3/2/21

Overview of Topics

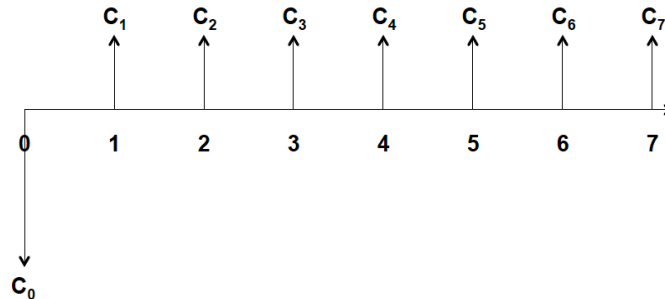
1. Basics of Techno-Economic Analysis
2. Integrated Energy Systems
3. NICE Future Initiative
4. ReEDS Long-term Energy Planning Scenarios

Techno-Economic Analysis: The Basics

- Levelized Cost of Electricity (LCOE)

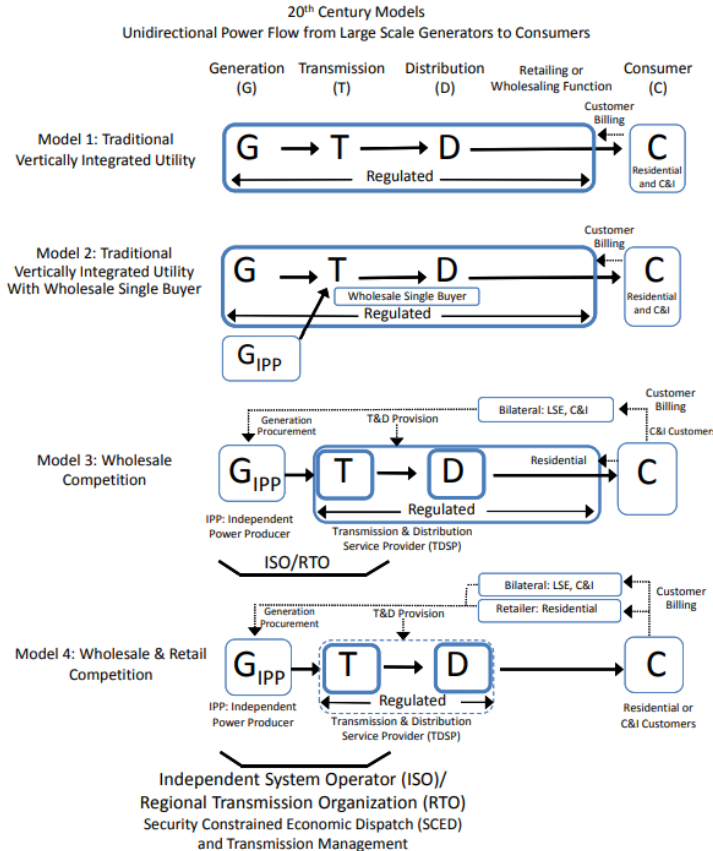
$$LCOE = \frac{\text{Overnight Capital Cost} \times \text{Capital Recovery Factor} + \text{Fixed O\&M Cost}}{8760 \times \text{Capacity Factor}} + \text{Fuel Cost} \times \text{Heat Rate} + \text{Variable O\&M Costs} \rightarrow \$/MWh$$

- Discount Rates: How you value present vs. future value, governments use 2-4%, companies use 20-25%. Discount rates are related to the 'hurdle rate', or the internal rate of return that is important to attract investor interest.
- Net Present Value



$$NPV = C_0 + \frac{C_1}{(1+d)} + \frac{C_2}{(1+d)^2} + \frac{C_3}{(1+d)^3} + \frac{C_4}{(1+d)^4} + \dots$$

Techno-Economic Analysis: The Basics



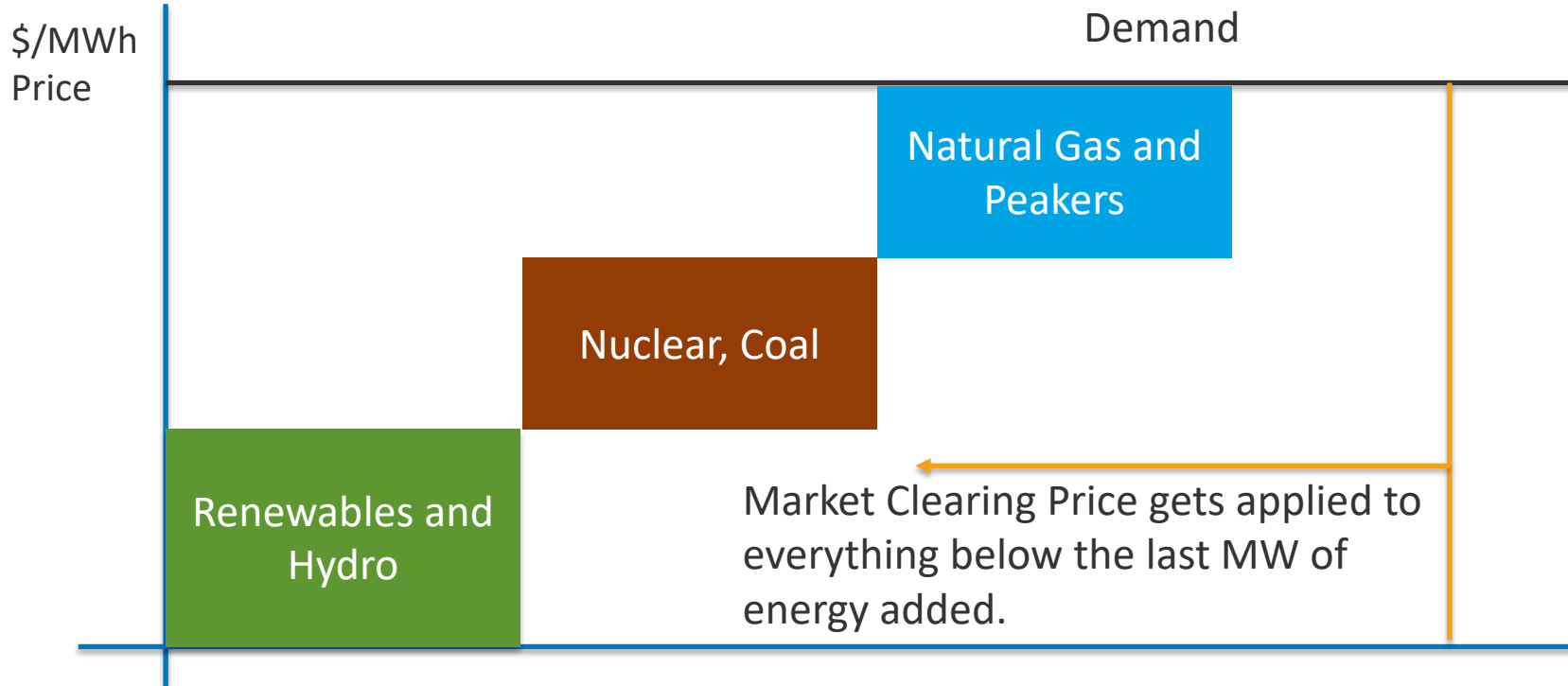
Vertically Integrated

Competitive

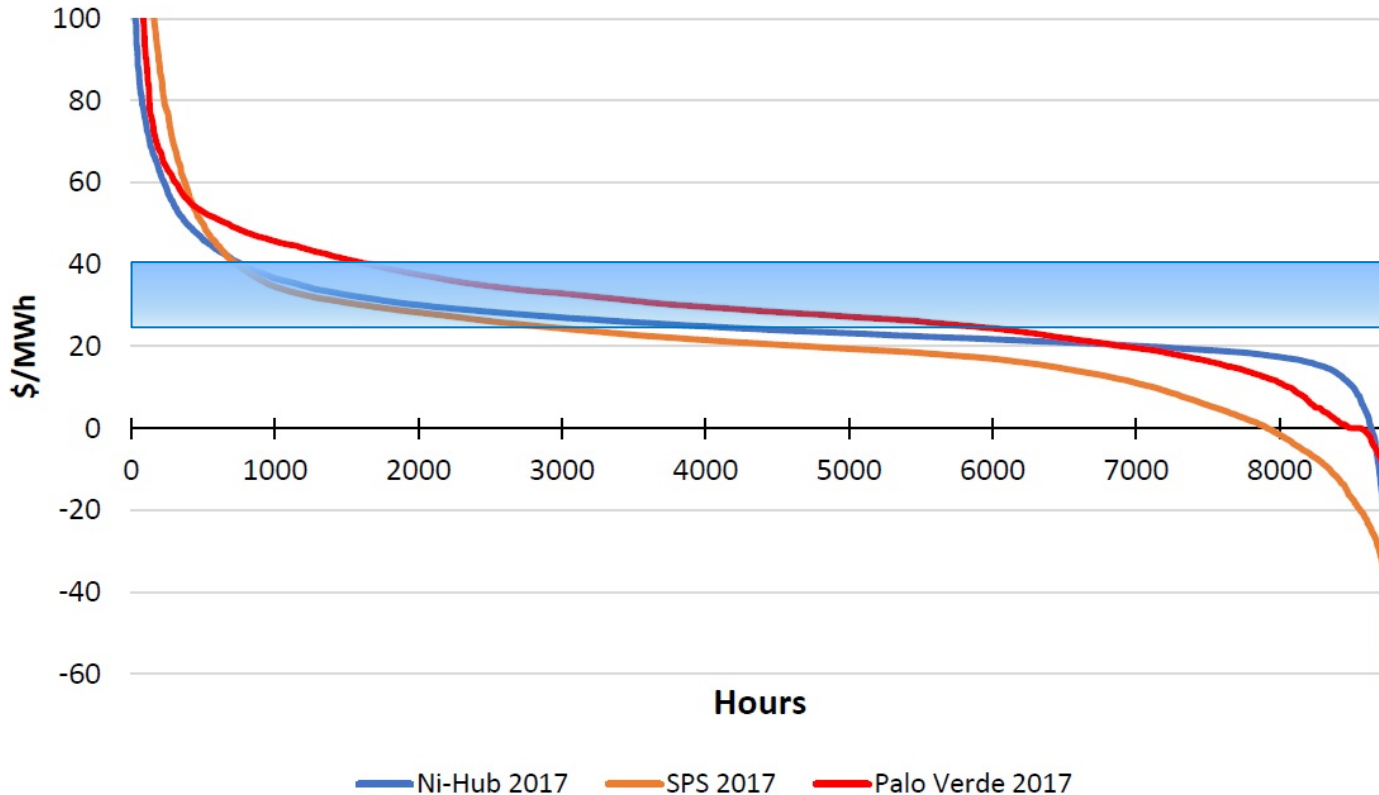
http://sites.utexas.edu/energyinstitute/files/2016/09/UTAustin_FCe_History_2016.pdf#:~:text=Historically%2C%20a%20vertically%20integrated%20utility%20in%20the%20U.S.,service%20commission%2028PSC%29%20%28see%20Figure%203%2C%20Model%201%29.

Techno-Economic Analysis: The Basics

Market Clearing Price



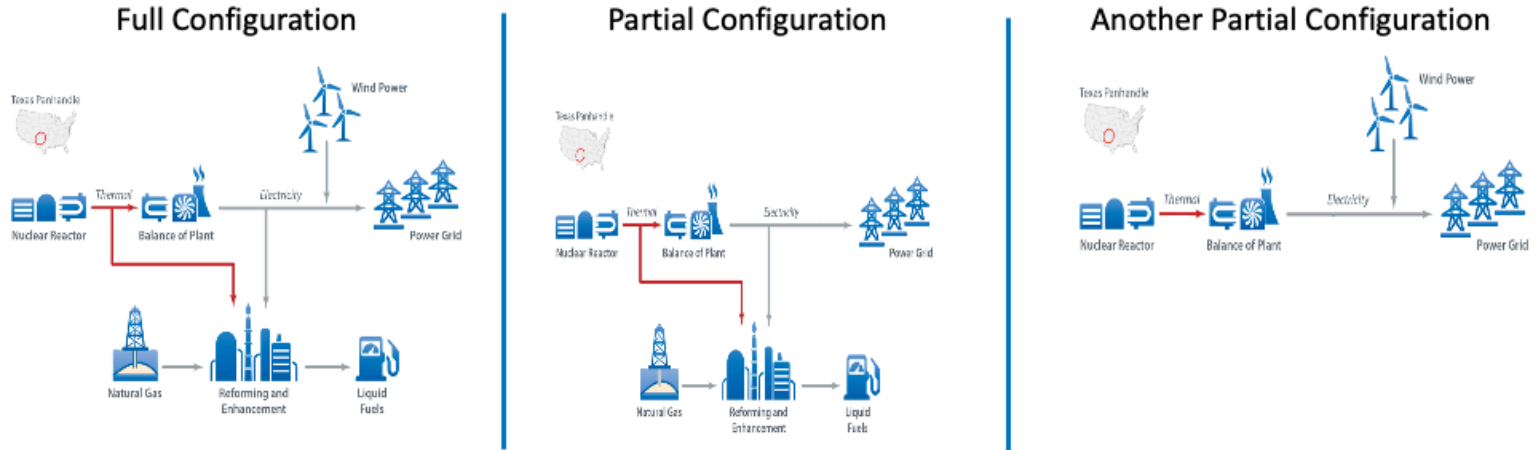
Integrated Energy Systems



Some nuclear power plants may sell energy at a loss 35% or more of the hours in a year depending upon their technology, scale, location, and market.

Integrated Energy Systems

Identify optimal configurations and internal dispatch under various product prices

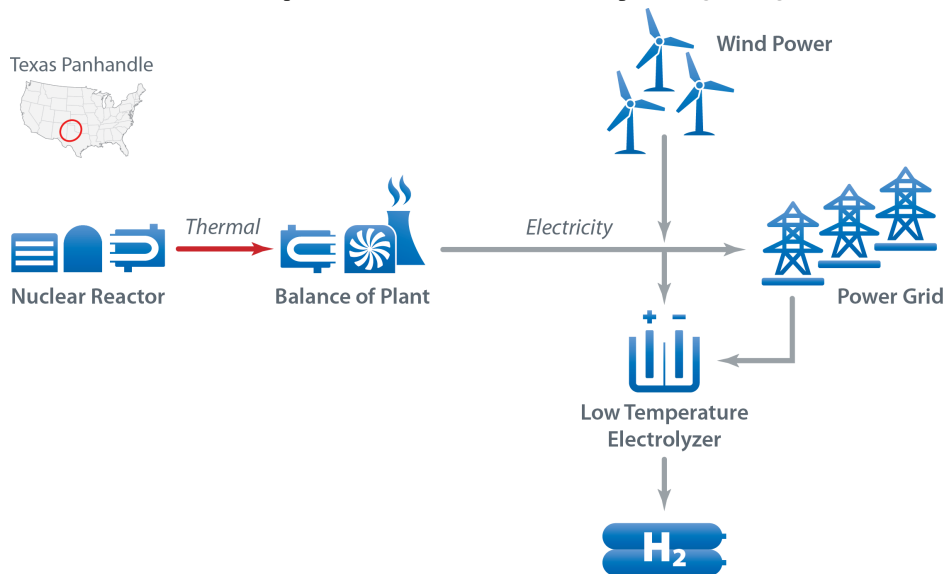


Other configurations: (1) nuclear-generated electricity only and (2) wind only

Source: Ruth, Mark, Cutler, Dylan, Flores-Espino, Francisco, Stark, Greg, Jenkin, Thomas, Simpkins, Travis, and Macknick, Jordan. *The Economic Potential of Two Nuclear-Renewable Hybrid Energy Systems*, 2016. NREL/TP-6A50-66073. <http://www.nrel.gov/docs/fy16osti/66073.pdf>

Integrated Energy Systems Conclusions

Low Temperature Electrolysis (LTE)



- Lower capital cost industrial processes are more likely to utilize their flexibility to switch between electricity and the industrial product more often than their higher capital cost configurations
- This flexibility increases the number of profitable situations

Source: Ruth, Mark, Cutler, Dylan, Flores-Espino, Francisco, and Stark, Greg. *The Economic Potential of Nuclear-Renewable Hybrid Energy Systems Producing Hydrogen* (2017). NREL/TP-6A50-66764.

<http://www.nrel.gov/docs/fy17osti/66764.pdf>

Flexible Nuclear Campaign



NICE Future

Nuclear Innovation: Clean Energy Future

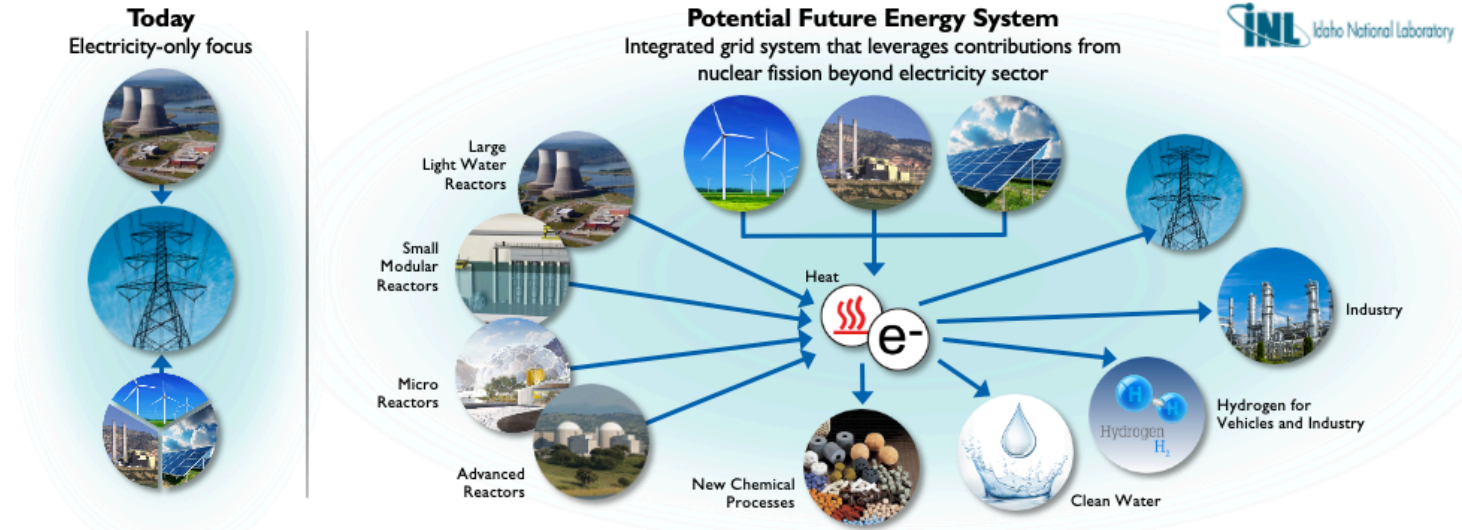
An Initiative of the Clean Energy Ministerial

The Flexible Nuclear Campaign seeks to highlight the roles that flexible nuclear energy can play in clean energy systems.

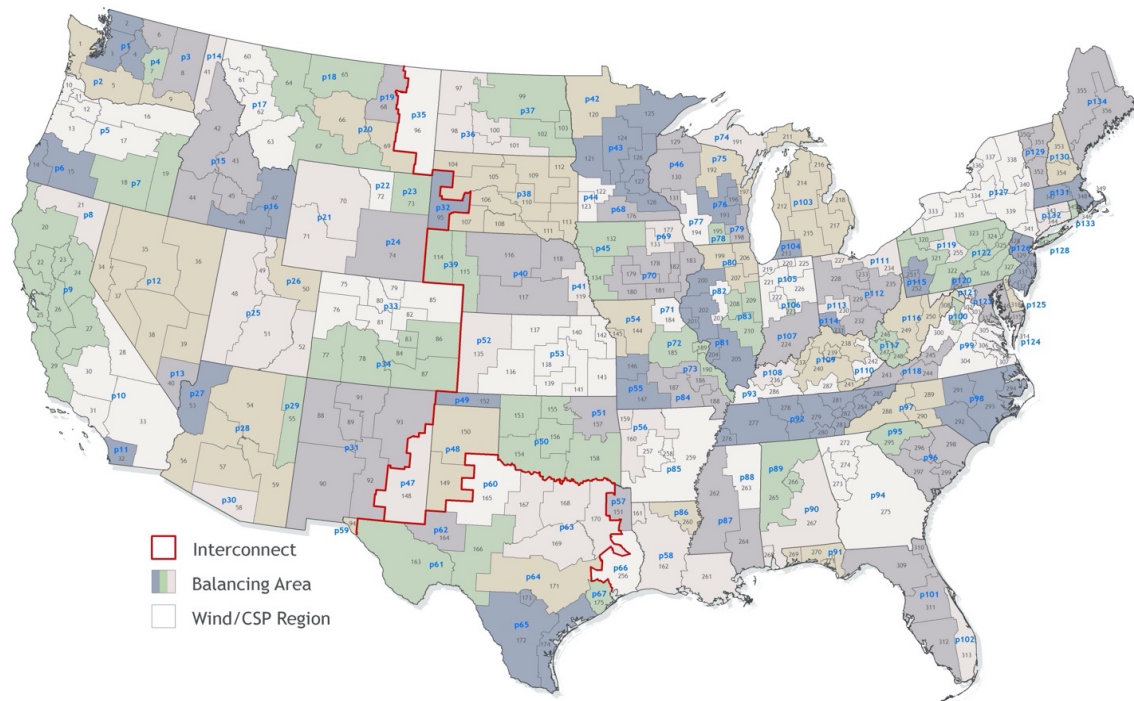


FLEXIBLE NUCLEAR CAMPAIGN
FOR NUCLEAR-RENEWABLES INTEGRATION

A CAMPAIGN OF THE CLEAN ENERGY MINISTERIAL



Long-Term Energy Planning Scenarios



The Regional Energy Deployment Model (ReEDS)

- Divides the country into balancing regions.
- Meets demand with an optimized least-cost energy mix.
- Assumes perfect knowledge and rational behavior.

Brown, Maxwell, Wesley Cole, Kelly Eurek, Jon Becker, David Bielen, Ilya Chernyakhovskiy, Stuart Cohen, et al. 2020. “Regional Energy Deployment System (ReEDS) Model Documentation: Version 2019.” *Renewable Energy*, 140.

Long-Term Planning Scenarios

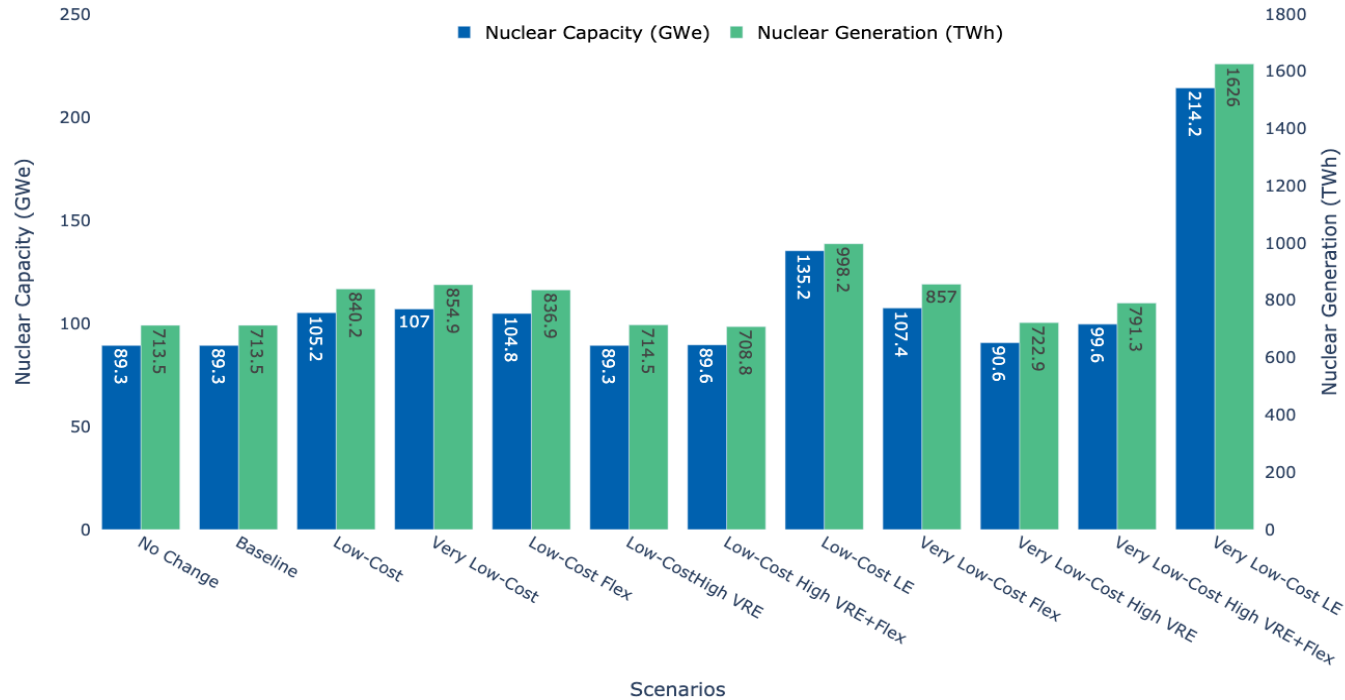
What variables change the overall deployment of nuclear energy from now through 2050?

- Base case (with 80 year life extension)
- Capital Cost Reduction

	Natural Gas	Onshore Wind	Solar (Utility PV)	Nuclear Today	Nuclear Price Reductions
Overnight Capital Cost	\$899	\$1,360	\$956	\$6200	\$1500 (Very low) - \$5000/kW

- Flexible Nuclear Energy: Nuclear Energy can ramp 100% per hour and receive ramping payment but cannot divert energy to an alternative product
- High VRE penetration: Renewable energy prices decreases faster than expected.
- Flexible Nuclear + High VRE
- Low Emissions: It is required that we reduce carbon emissions by 95% by 2050

Long-Term Planning Results



Cox, Jordan, Shannon Bragg-Sitton, John Gorman, Gordon Burton, Megan Moore, Ali Siddiqui, Takeshi Nagasawa, et al. "Flexible Nuclear Energy for Clean Energy Systems," September 2020, 155.

Long-Term Planning Conclusions

- Energy models do not model the world precisely but give us starting points to understand how to economically meet future energy system demands. `
- The modeling presented here showed two areas where nuclear energy significantly expands:
 - Very low cost reductions achieved
 - A low emissions scenario
- Renewable energy, due to its variable nature, is relatively insensitive to cost. It changes by some GW, but goes to approximately 60% of the primary electricity supply or more.
- There are many non-economic factors in the energy system. Security, resilience, etc. that are not reflected in our model.
- Does not include not-electric applications.

Future Work

- Upcoming publications will further focus on the price points and non-electric products that lead to nuclear deployment.
- Also working on the Renewable Energy Optimization Model (REopt Model) to implement small scale nuclear in a distributed fashion and maximize economic value.
- The NICE Future initiative continues to promote a future where renewable and nuclear energy work together in a clean energy system.

www.nice-future.org

Questions or Comments:

jcox@nrel.gov

www.nrel.gov

