JISEA Joint Institute for Strategic Energy Analysis

Valuing Nuclear in Energy Modeling

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GAIN Webinar

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NREL Transforming ENERGY | COLORADO SCHOOL OF MINES EARTH • ENERGY • ENVIRONMENT | COLORADO STATE UNIVERSITY | MIT Massachusetts Institute of Technology | Stanford University | University of Colorado Boulder

Overview of Topics

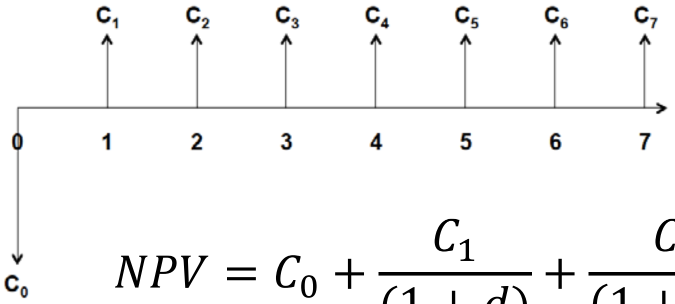
1. Basics of Techno-Economic Analysis
2. Integrated Energy Systems
3. Nuclear Innovation: Clean Energy Future initiative
4. ReEDS Long-term Energy Planning Scenarios

Techno-Economic Analysis: The Basics

- Levelized Cost of Electricity (LCOE)

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

- Discount Rates: How you value present vs. future value, governments may use 2-4%, companies may use 20-25% (highly industry dependent). Discount rates are related to the ‘hurdle rate’, or the internal rate of return that is important to attract investor interest.
- Net Present Value and Internal Rate of Return



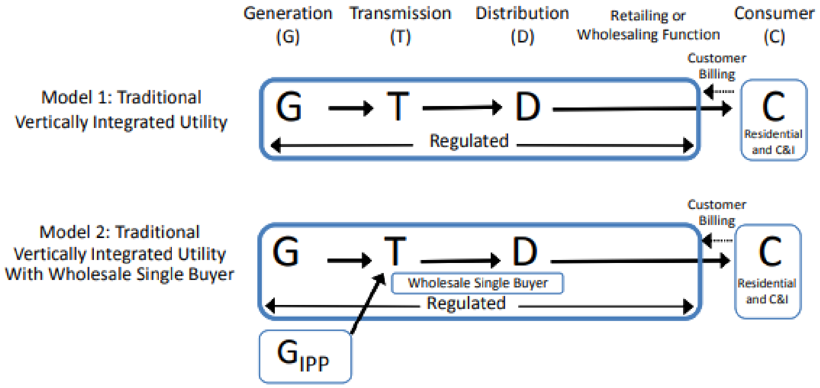
$$NPV = \sum_{i=0}^{N} \frac{C_i}{(1+d)^i}$$

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

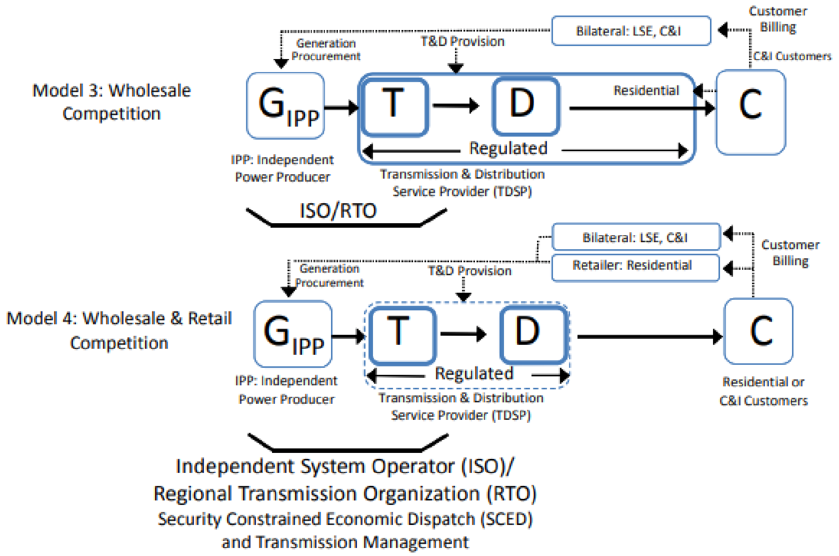
$$0 = \sum_{i=0}^{N} \frac{C_i}{(1+IRR)^i}$$

Techno-Economic Analysis: The Basics

Vertically Integrated



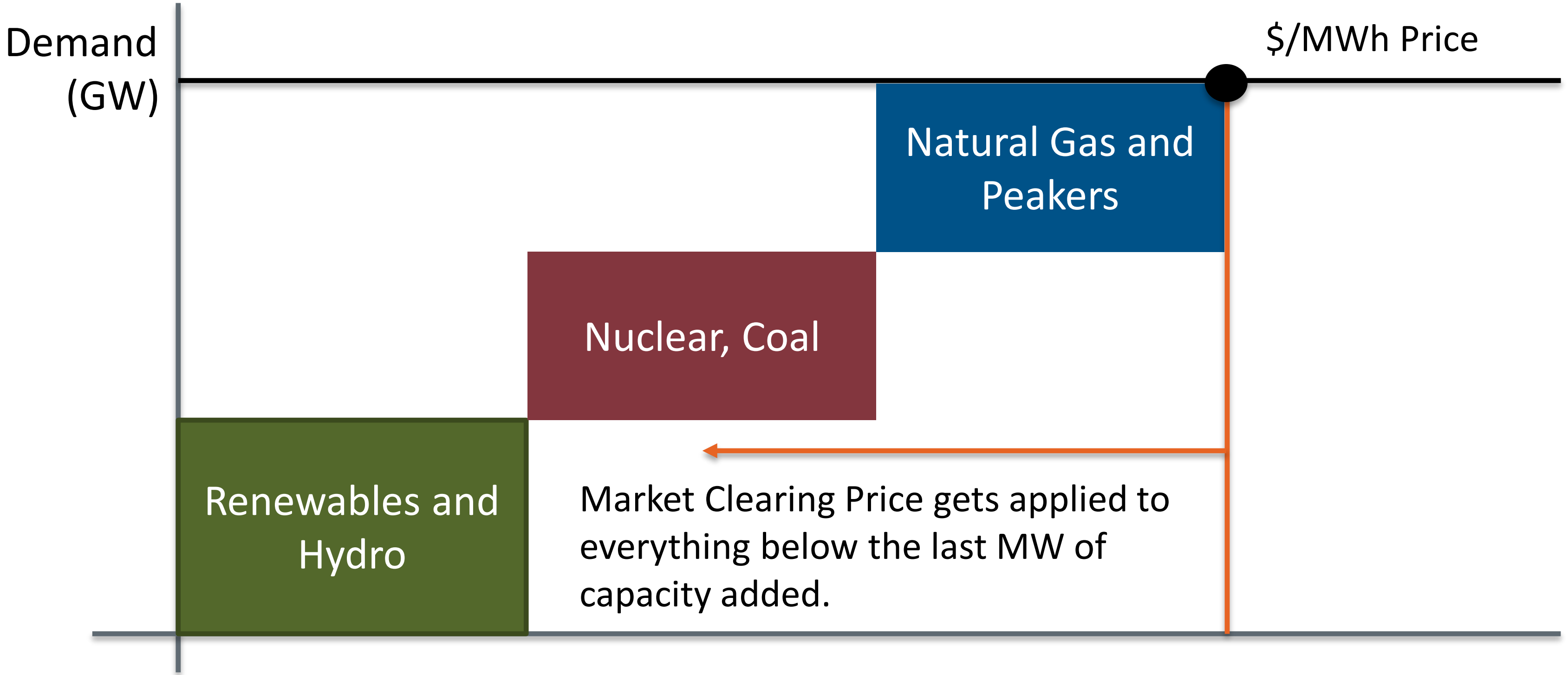
Competitive



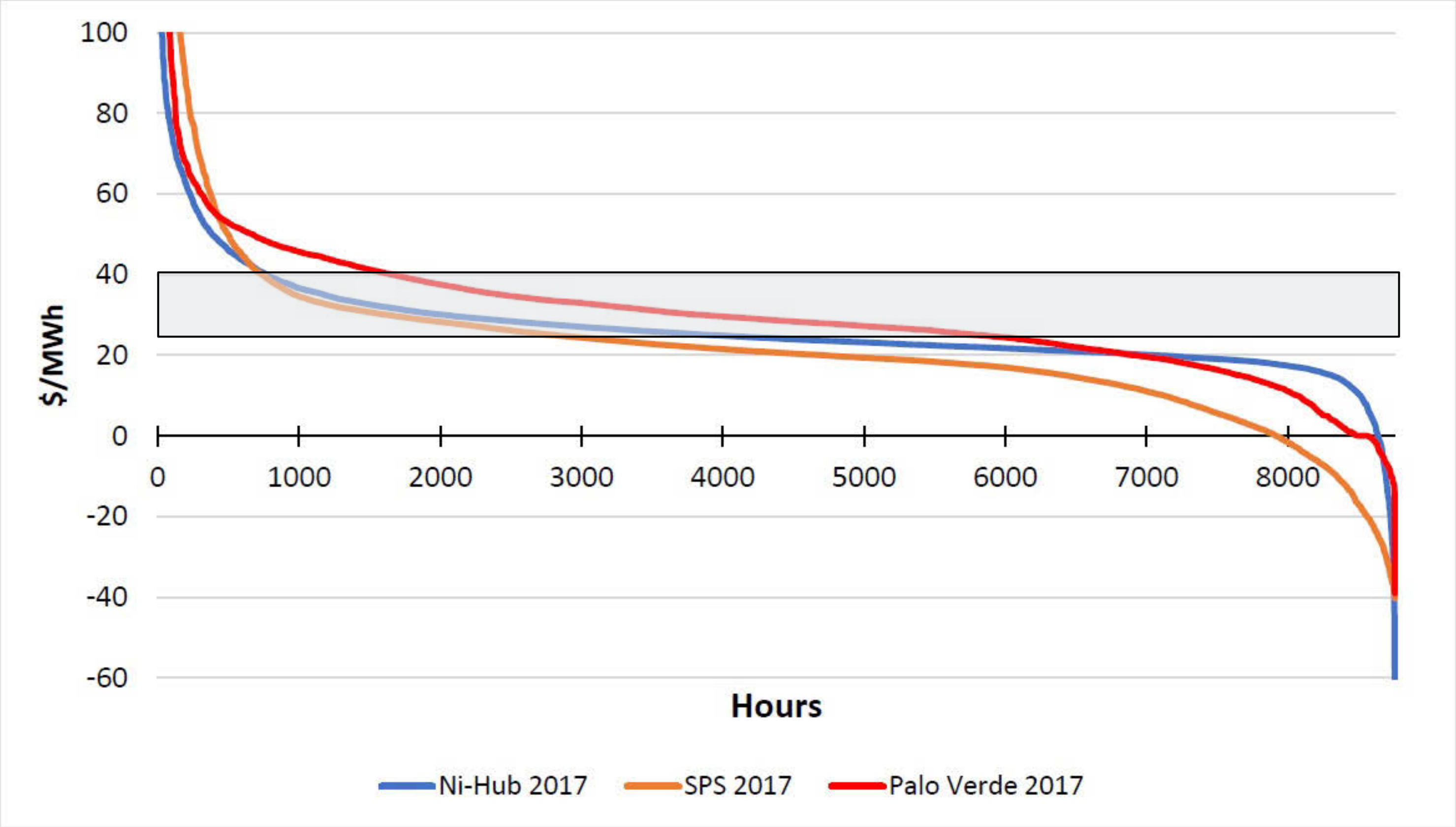
http://sites.utexas.edu/energyinstitute/files/2016/09/UTAustin_FCe_History_2016.pdf#:~:text=Historically%2C%20a%20vertically%20integrated%20utility%20in%20the%20U.S.,service%20commission%20%28PSC%29%20%28see%20Figure%203%2C%20Model%201%29.

Techno-Economic Analysis: The Basics

Market Clearing Price



Integrated Energy Systems



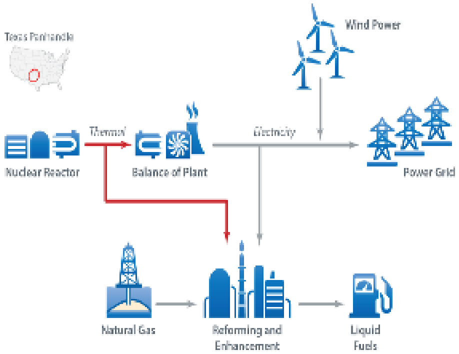
Some nuclear power plants may sell energy at a loss 35% or more of the hours in a year depending upon their technology, scale, location, and market.

Figure created by NREL (Daniel Levie) based on publicly available price data

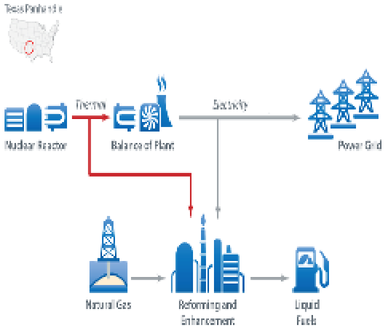
Integrated Energy Systems

Identify optimal configurations and internal dispatch under various product prices

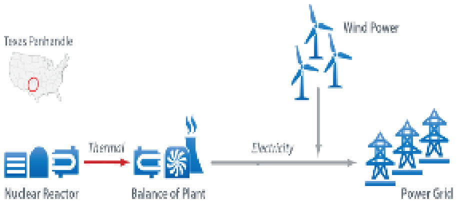
Full Configuration



Partial Configuration



Another Partial Configuration

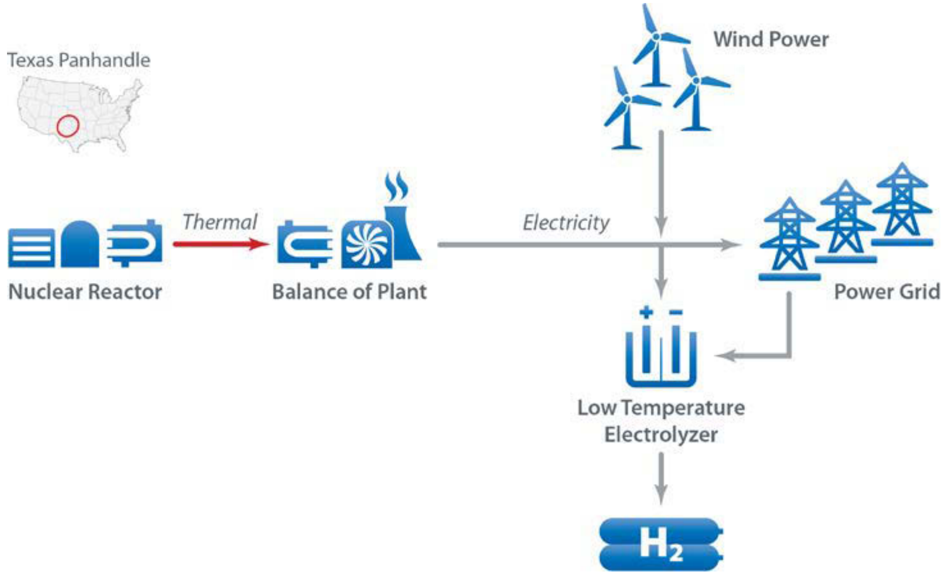


Other configurations: (1) nuclear-generated electricity only and (2) wind only

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 products more often than their higher capital cost configurations
- This flexibility increases the number of profitable situations

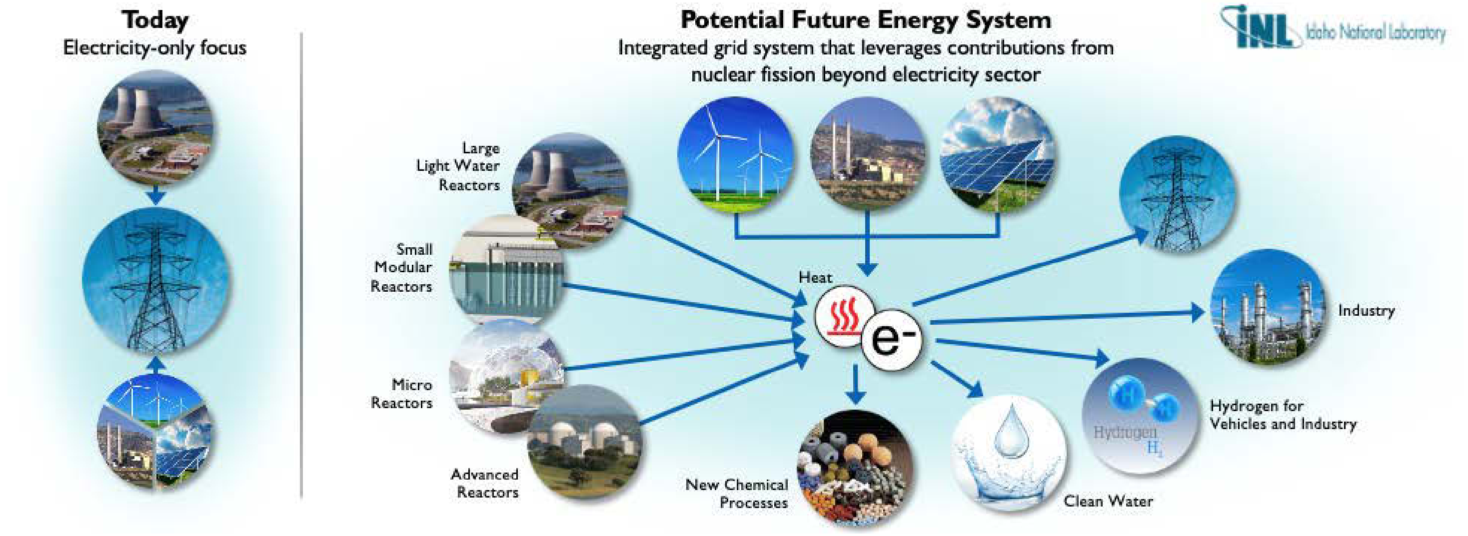
Source: Ruth, Mark, Cutler, Dylan, Flores-Espino, Francisco, and Stark, Greg. *The Economic Potential of Nuclear-Renewable Hybrid Energy Systems Producing Hydrogen* (2017). NREL/TP-6A50-66764. http://www.nrel.gov/docs/fy17osti/66764.pdf

Flexible Nuclear Campaign

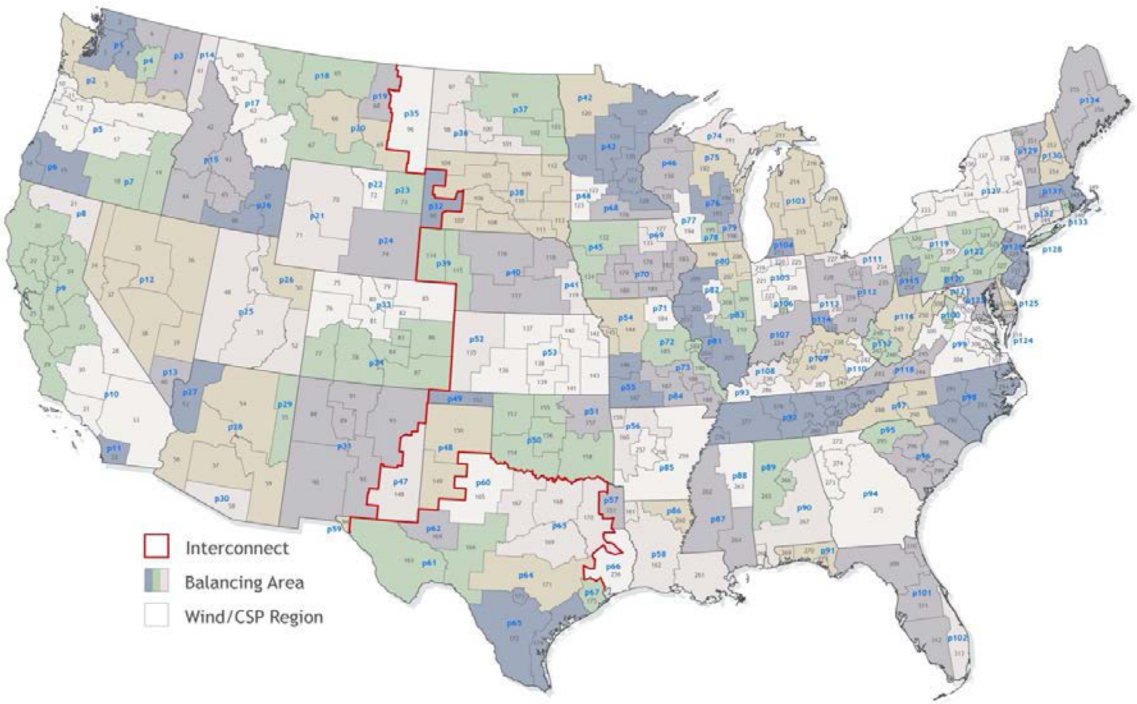
The Flexible Nuclear Campaign seeks to highlight the roles that flexible nuclear energy can play in clean energy systems.

NICE Future
Nuclear Innovation: Clean Energy Future
An Initiative of the Clean Energy Ministerial

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?

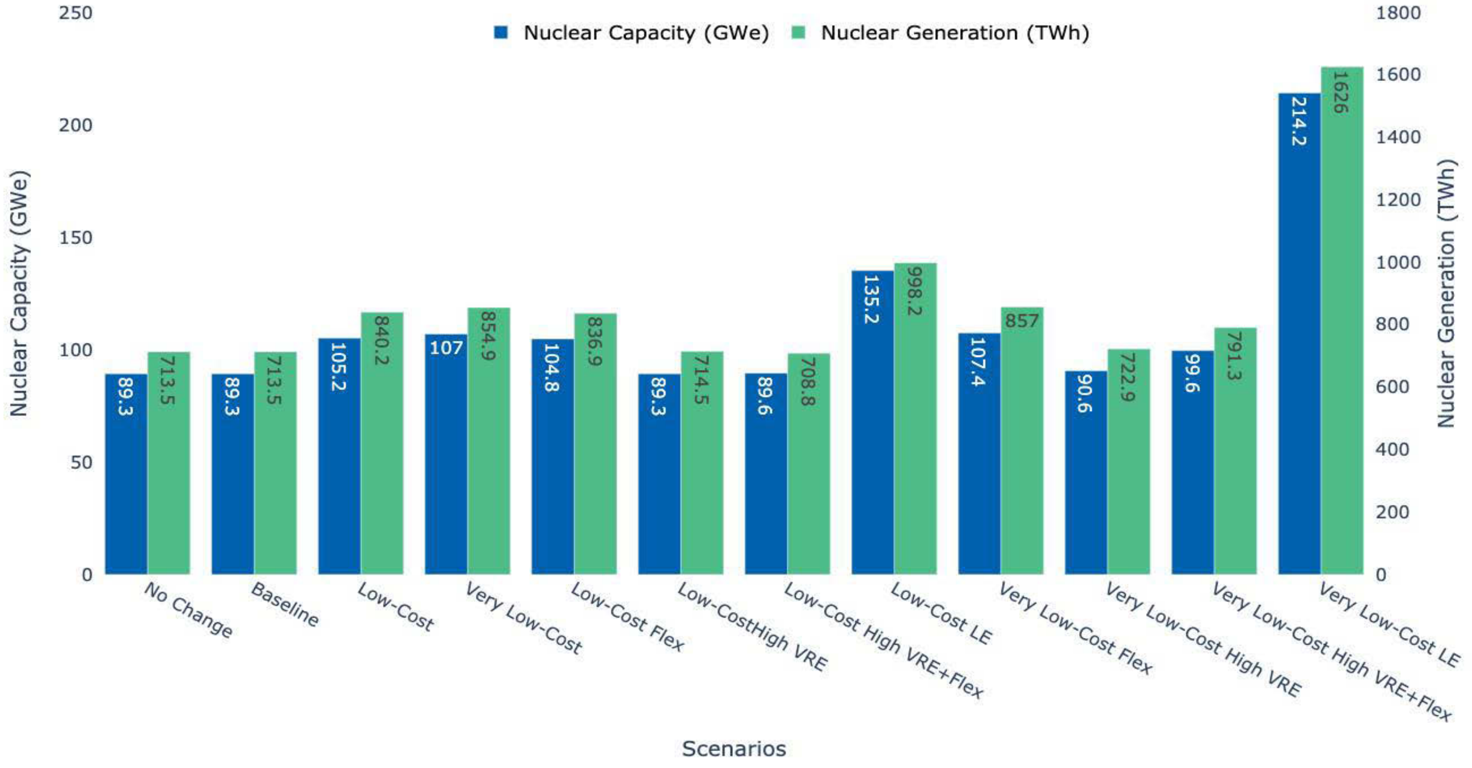
- Base case (with 80-year life extension)
- Capital Cost Reduction

	Natural Gas	Onshore Wind	Solar (Utility PV)	Nuclear Today	Nuclear Price Reductions
Overnight Capital Cost ($/kW)	$899/kW	$1,360/kW	$956/kW	$6200/kW	$1500/kW (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: Model requires 95% emissions reduction by 2050, no policy mechanism suggested, only changes energy mix with low-emissions technologies.

NREL. 2019. “2019 Annual Technology Baseline.” Golden, CO: National Renewable Energy Laboratory. https://atb.nrel.gov/.

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 shows three areas where nuclear energy significantly expands:
    - Very low-cost reductions achieved
    - A low emissions scenario
    - Flexibly operating in tandem with RE
- Renewable energy, due to its variable nature, is relatively insensitive to cost.
- There are many non-economic factors in the energy system. Security, resilience, etc. that are not reflected in our model.
- Does not include non-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 clean energy systems future where renewable energy and nuclear energy work together to support global decarbonization goals
  www.nice-future.org

Questions or Comments:

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NREL/PR-6A50-79408

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