Universität Basel
Wirtschaftswissenschaftliche Fakultät
WWZ

FoNEW
Forschungsstelle für Nachhaltige Energie- und Wasserversorgung

State and Federal Nuclear Support Schemes in Dynamic Electricity Market Conditions: Insights from NYISO and PJM

Muhammad Bah
University of Basel, Switzerland

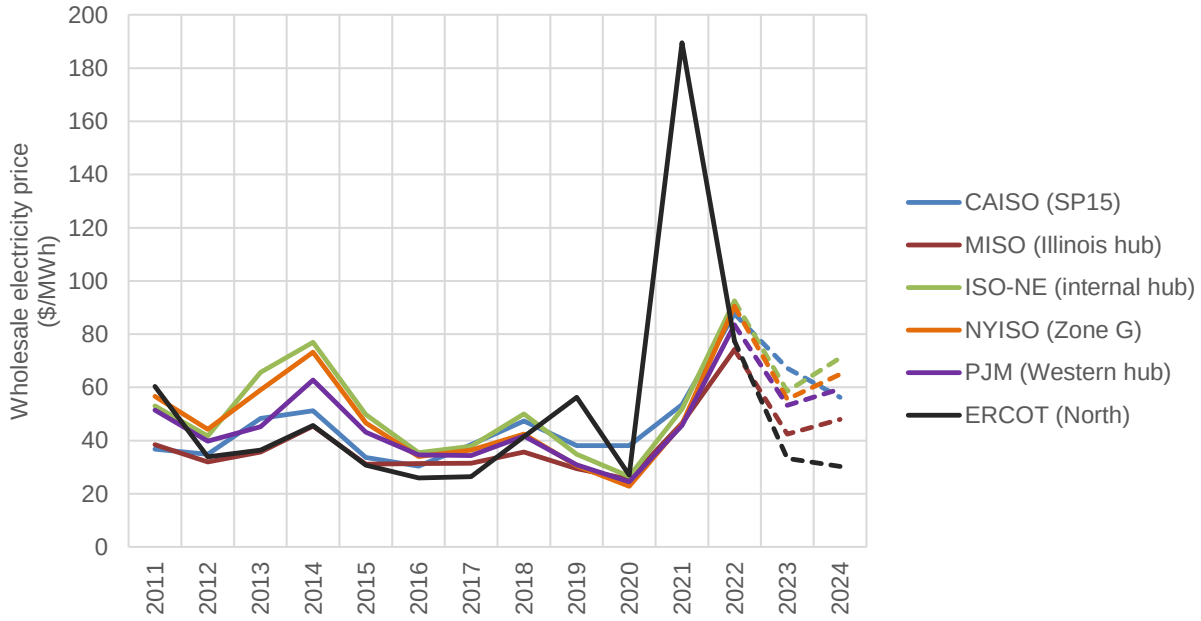
18th IAEE European Energy Conference Milan 2023
Session: Nuclear Energy Some Experiences
July 25, 2023

Outline

1. Motivation
2. State level support schemes
3. Federal level support schemes
4. Methods and Data
5. Results
6. Policy implications

Nuclear Support Schemes
Motivation

- Low wholesale market prices over the past decade
- Thirteen nuclear reactors (10.2 GW) retired between 2009 and 2022.
- Rapid introduction of nuclear support schemes at state and federal levels.
- **Rationale?**
  - *State level*:
    - Meeting medium to long term climate targets
    - Keeping emissions low
    - Nuclear as a bridging technology
  - *Federal level*:
    - Keeping NPPs online and climate targets



Source: Bah (2023)

Objectives

1. Test whether out-of-market support schemes for NPPs were justified in wholesale electricity markets

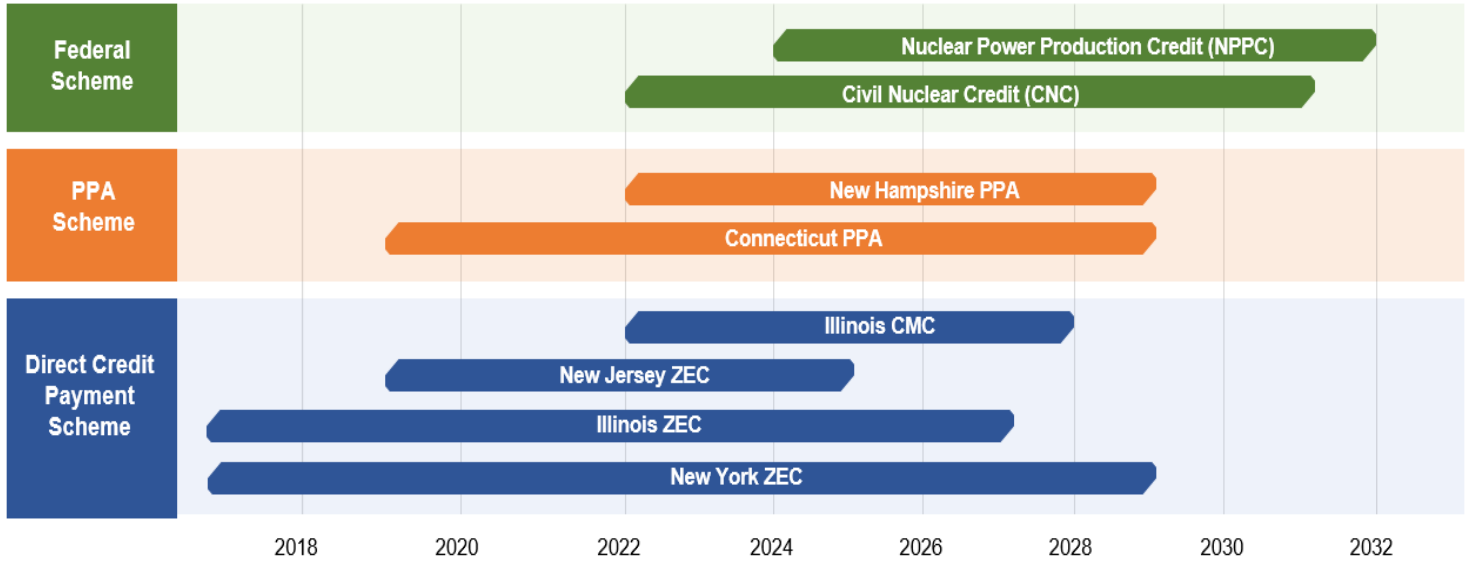
2. Quantify the potential profit magnitude for NPPs in a dual state and federal support scheme environment

3. Provide policy suggestions on redesigning support schemes to meet the policy objective of keeping only financially vulnerable plants online

Nuclear support schemes
State level

- **Direct Credit Payment Scheme:** New York, Illinois and New Jersey
- **Power Purchase Agreements:** Connecticut and New Hampshire
- Covers **19 operating reactors**
- Total capacity of **19.4 GW** (~ 20% of nationwide nuclear capacity)

Timeline of state and federal support schemes for existing U.S. NPPs



Nuclear support schemes
Federal level

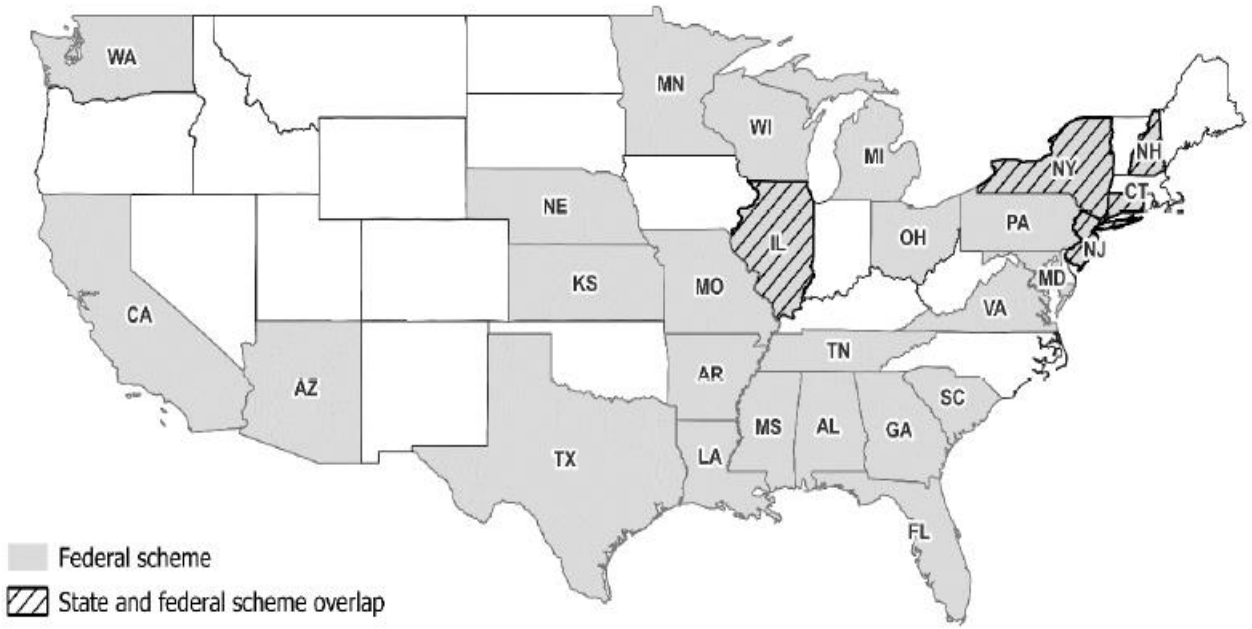
Civil Nuclear Credit (CNC)

- Approx. $6 billion over 10 years (2022-2031)
- ***First round***: targeted NPPs with announced shutdown dates before 2026
- ***Second round***: expanded eligibility to all NPPs projected to shutdown in 2027 including NPPs that shutdown before Nov. 2021
- Credit price determined through sealed bids

Nuclear Power Production Credit (NPPC)

- Introduced in 2022 Inflation Reduction Act (IRA)
- Only operating NPPs eligible
- Nine-year coverage (2024-2032) estimated at $30 billion (JCT, 2022)
- Credit value: $3/MWh to $15/MWh and adjusted in relation to NPPs gross revenues

State and Federal nuclear support scheme coverage in the U.S.



Source: Bah (2023)

Methods and Data

New York

- Three active NPPs (or 4 reactors)
- Nuclear accounts for 9% of state installed capacity
- Lucrative subsidies

PJM

- Nuclear accounts for 17% of total installed capacity in PJM.
- State subsided plants located in Illinois and New Jersey (12 reactors)

Timeframe

- Five-year ex-post time frame from 2017-2021
- Corresponds to the earliest introduction of state support schemes
- Representative sample of electricity market developments

Data

- Historical annual plant generation data
- Average zonal day-ahead market prices
- Plant specific capacity market prices
- Average operating costs (fuel & O&M)
- Published state credit prices
- Assumptions on federal support credit prices

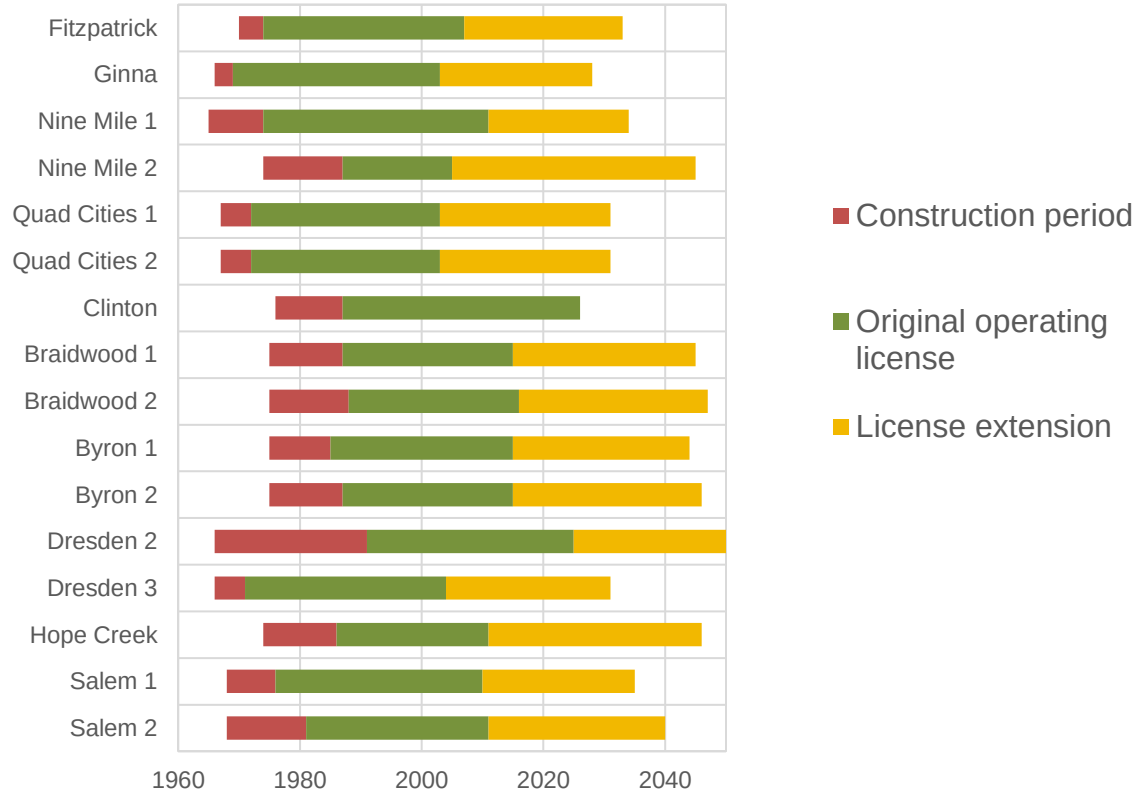
Methods and Data
Assumption space

- **Exclusion of fixed costs**
  - Capital costs are treated as sunk and have no influence on going-forward decisions of NPPs (DEEP and PURA, 2018)
  - Reactors constructed between mid-1960s and mid-1970s
  - Fifteen out of sixteen reactors were granted 20-year NRC license extensions
  - NEI capital cost data cannot be disaggregated into individual components.

- **Federal scheme**
  - NPPs are eligible to apply for federal schemes

- **Capacity market**
  - NPPs cleared capacity market over sample period

Reactor construction and license extensions



Results
NYISO

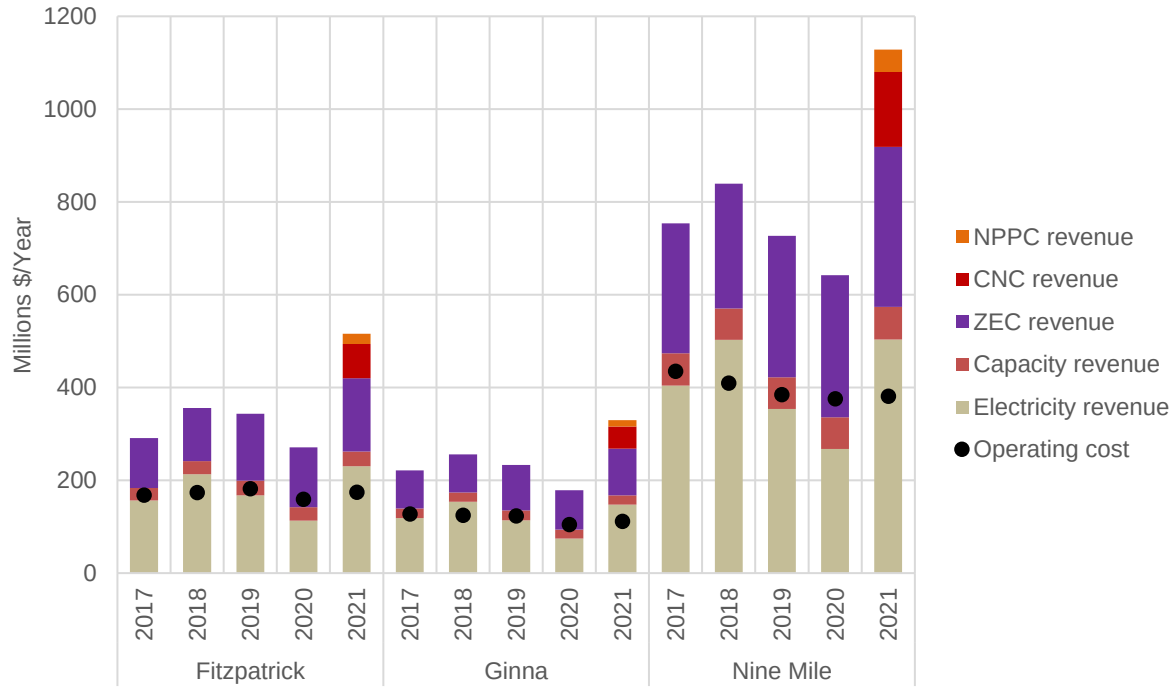
- NPPs were able to cover their total operating costs over entire sample

- Low price environment 2017:
  - Net profit market only revenues~$11.2 million (Ginna) to $38.6 million (Nine Mile)
  - With a ZEC scheme ~$93.3 million (Ginna) to $313.3 million (Nine Mile)

- High price environment 2021:
  - Combined market and ZEC revenues far exceeded operating costs
  - If NPPs are eligible for a single federal support (CNC), profits range from $202 million to $699.1 million

- Over long periods of time, NPPs are economically viable. In certain moments, NPPs draw on state support.

Profitability estimates of nuclear power plants in NYISO.



Notes: Although Clinton is located in Illinois, it is part of the MISO market. The ZEC program for Hope Creek and Salem began in 2019.

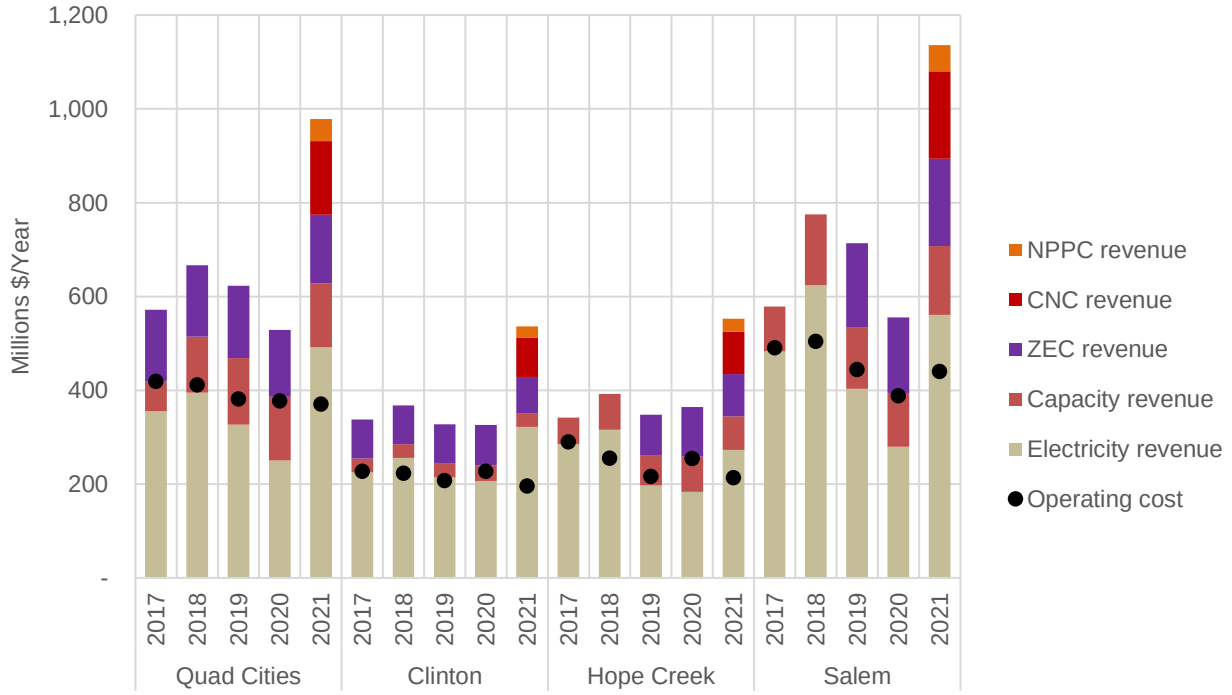
Results
PJM Market

- Similar trends observed in the PJM market

- Findings consistent with independent expert reports;
  - "*Hope Creek and Salem are able to sufficiently cover their operating costs from 2019 to 2021… should not be eligible for state support*" (Monitoring Analytics, 2019)
  - PJM Power Provider Group: collective evidence will find that NPPs in "Salem County are solidly profitable and extremely unlikely to close in the next four years - even in the absence of a ZEC payment" (NJBPU, 2018, p. 3)

- If state and single federal scheme co-exist ~Profits range from $311.5 million (Hope Creek) to $640.4 million annually (Salem)

Profitability estimates of nuclear power plants in PJM

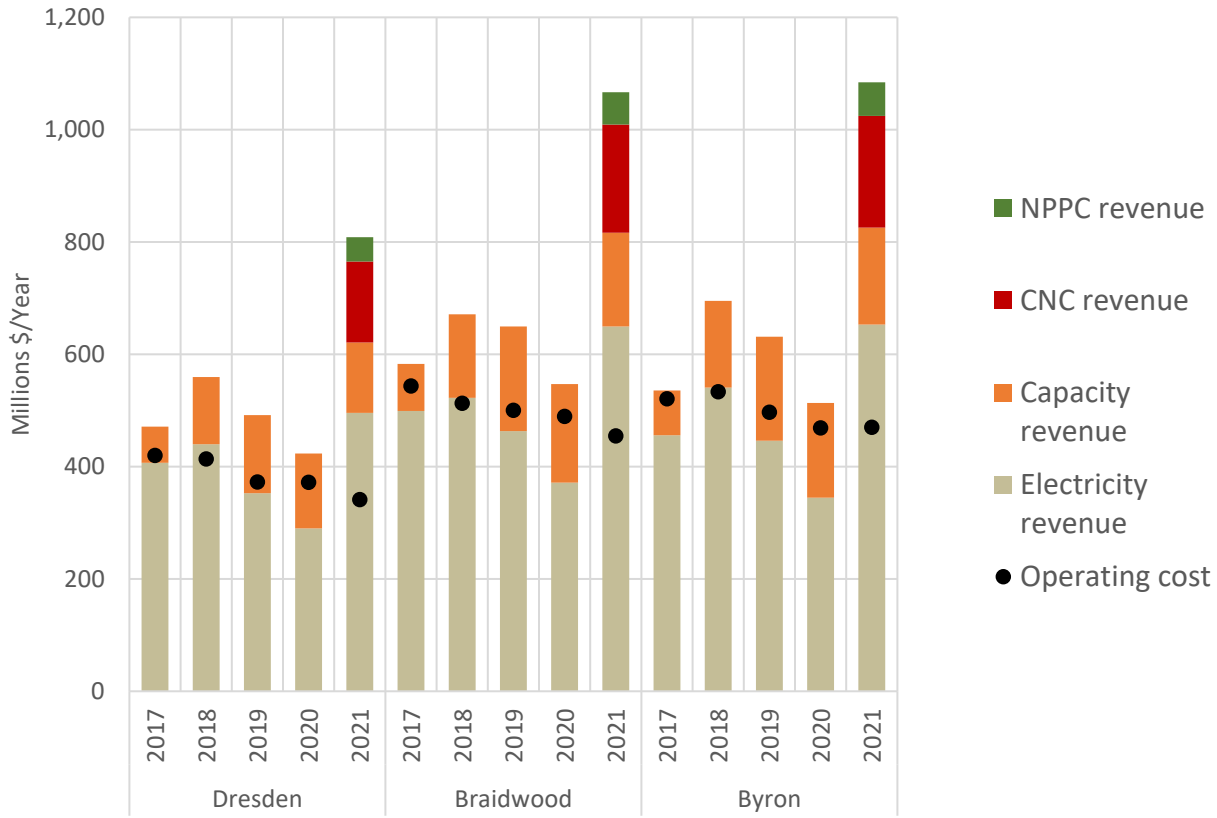


Notes: Illinois NPPs (Quad Cities, Clinton), New Jersey NPPs (Hope Creek, Salem). ZEC program for Hope Creek and Salem started in 2019

Results
Robustness tests: Illinois Carbon Mitigation Credits (CMC)

- A sub-set of NPPs in Illinois were granted subsidies (CMC) starting June 2022
- Allows for comparison with Quad Cities and Clinton that were subsidized under the ZEC scheme in 2017
- NPPs were financially robust between 2017 and 2021 like their subsidized counterparts
- NPPs would remain economically viable without the CMC scheme

Profitability estimates of NPPs in PJM (Illinois) subsidized under the CMC scheme.



Results
Ex-post assessment of uncertainty

- Cost estimations
  - Exclusion of fixed costs, lowers cost estimates
  - Additional robustness test conducted including fixed costs and results are broadly in consistent
  - Profitability estimates could potentially change depending on the source of cost data

- Federal support scheme selection

- Nuclear and renewal support comparison

Conclusion

Insights

- NPPs are in an economically viable condition to operate without support schemes in place.
- Based on the profitability assessments, and given current and projected improvements in wholesale market prices, there is no economic justification for the introduction of federal support scheme

Policy implications
What should be done?

Co-existence of state and federal support schemes

- **Federal schemes**
  - should disqualify NPPs already subsidized at the state level from applying
  - e.g. CNC does not explicitly prohibit state subsidized NPPs from applying
  - Disqualify rate-regulated NPPs from applying for federal funding

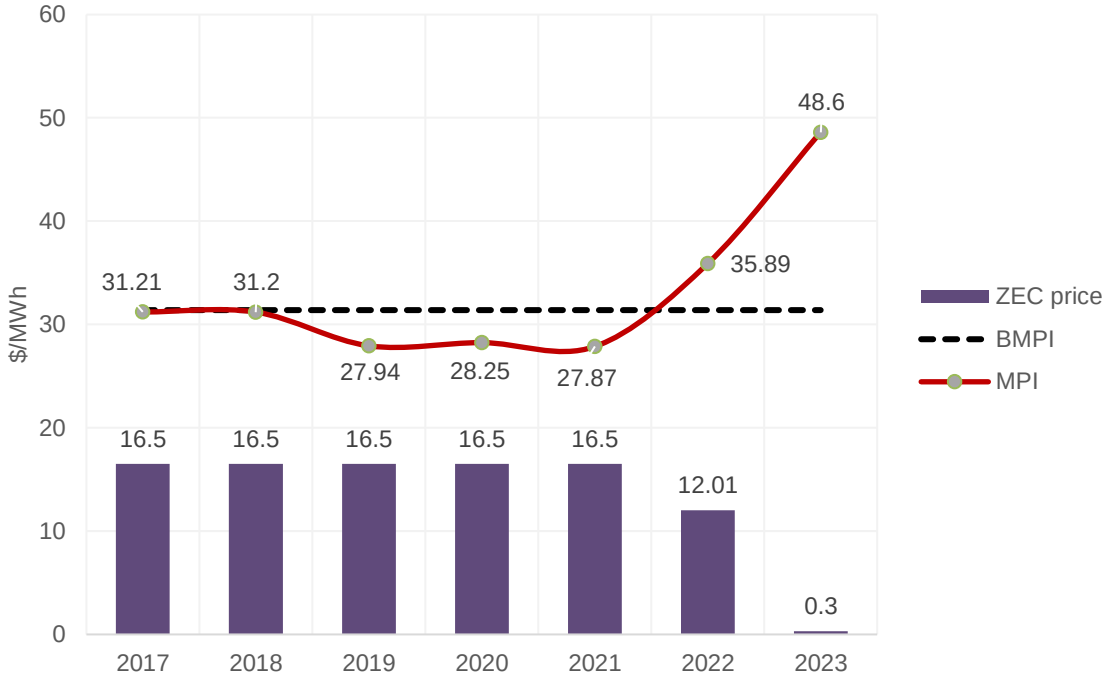
- **State level**,
  - regulators should activate or include clauses that automatically rescinds support once NPPs chosen for federal funding

Policy implications
What should be done?

Dynamic electricity markets

- Regularly revise state credit prices
- Typical approach of state regulators is to set a threshold market price level with a reference market price.
- Discrepancies exist across state schemes
  - New York ZEC: Threshold revised once over entire 12-year program period
  - Illinois ZEC: Fixed upper threshold
- Solution: Flexible threshold and market price index that is revised regularly (e.g. monthly)

Illinois ZEC payment results



Notes: BMPI: Baseline Market Price Index. MPI: Market Price Index. The BMPI is fixed at $31.40/MWh while the MPI is adjusted annually

Final words

- Collective body of evidence suggests that there are other agendas behind the support schemes

- Reasons
  - Large corporation lobbying
  - Present administration intends to spur investments in nuclear which necessitates stronger financial signals
  - States face multiple policy choices as they work on energy transition targets ~ keeping nuclear online with expensive subsidies represent a pragmatic short-term solution while renewables ramp up.

University of Basel

Thank you!

Muhammad Maladoh Bah

Research Center for Sustainable Energy and Water Supply (*FoNEW*)
Faculty of Business and Economics, University of Basel

muhammadmaladoh.bah@unibas.ch

References

Bah, Muhammad Maladoh. 2023. “State and Federal Nuclear Support Schemes in Dynamic Electricity Market Conditions: Insights from NYISO and PJM.” WWZ Working Paper. https://edoc.unibas.ch/93914/.

Cebulla, Felix, and Mark Z. Jacobson. 2018. “Carbon Emissions and Costs Associated with Subsidizing New York Nuclear Instead of Replacing It with Renewables.” Journal of Cleaner Production 205 (20): 884–94. https://doi.org/10.1016/j.jclepro.2018.08.321.

Haratyk, Geoffrey. 2017. “Early Nuclear Retirements in Deregulated U.S. Markets: Causes, Implications and Policy Options.” Energy Policy 110: 150–66. https://doi.org/10.1016/j.enpol.2017.08.023.

Joskow, Paul L. 2006. “The Future of Nuclear Power in the United States: Economic and Regulatory Challenges.” MIT-CEEPR Series 06-019WP. MIT Center for Energy and Environmental Policy Research (CEEPR). https://dspace.mit.edu/handle/1721.1/45065.

Lovins, Amory B. 2013. “The Economics of a US Civilian Nuclear Phase-Out.” Bulletin of the Atomic Scientists 69 (2): 44–65. https://doi.org/10.1177/0096340213478000.

———. 2017. “Do Coal and Nuclear Generation Deserve Above-Market Prices?” The Electricity Journal. https://doi.org/10.1016/j.tej.2017.06.002.

———. 2022. “US Nuclear Power: Status, Prospects, and Climate Implications.” The Electricity Journal 35. https://doi.org/10.1016/j.tej.2022.107122.

Monitoring Analytics. 2019. “Analysis of NJ Zero Emissions Certificate (ZEC) Applications.” Monitoring Analytics, LLC.

NJBPU. 2018. “Comments of the PJM Power Providers Group.” State of New Jersey Board of Public Utilities. https://www.nj.gov/bpu/agenda/zec1.html.

Richards, James, and Wesley J. Cole. 2017. “Assessing the Impact of Nuclear Retirements on the U.S. Power Sector.” The Electricity Journal 30 (9): 14–21. http://dx.doi.org/10.1016/j.tej.2017.10.007.

Szilard, Ronaldo, Phil Sharpe, Edward Kee, Edward Davis, and Eugene Grecheck. 2016. “Economic and Market Challenges Faacing the U.S. Nuclear Commercial Fleet.” INL/EXT-16-39951. Energy Systems Strategic Assessment Institute. https://www.osti.gov/biblio/1364498.

Back-Up

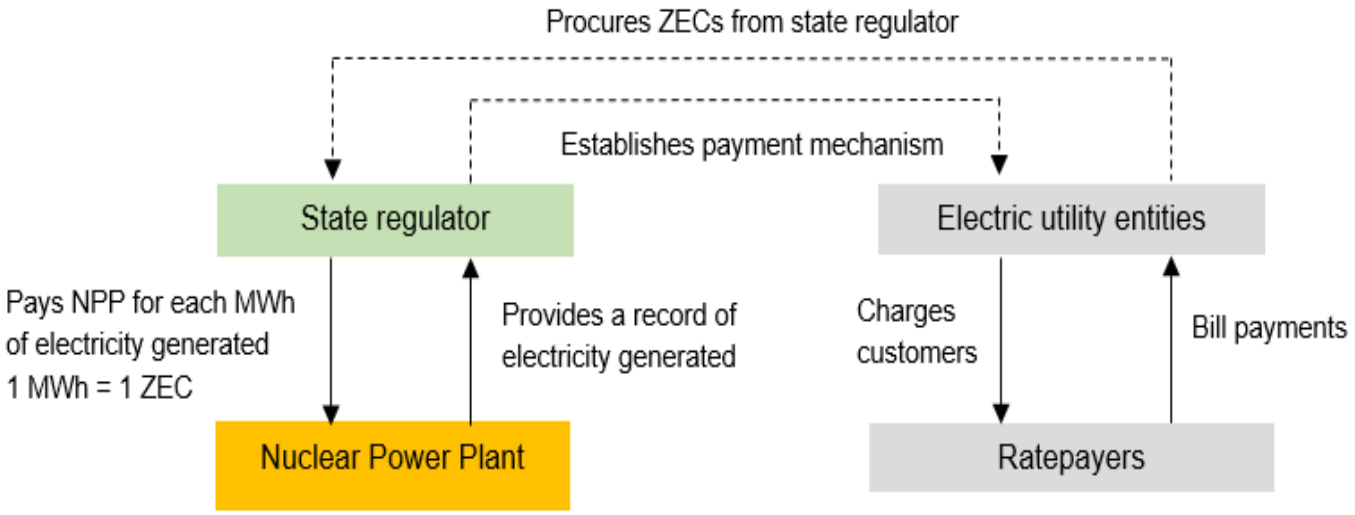
Active state level support schemes

Overview of state subsidy schemes

Reactor	Capacity [MW]	State	Market	Age[a]	License expiry	State support scheme	Coverage	Majority Ownership
Fitzpatrick	813	New York	NYISO	47	2034	ZEC	2017-2029	Constellation (Exelon spin-off)
Ginna	560	New York	NYISO	52	2029	ZEC	2017-2029	Constellation
Nine Mile 1	613	New York	NYISO	53	2029	ZEC	2017-2029	Constellation
Nine Mile 2	1,277	New York	NYISO	34	2046	ZEC	2017-2029	Constellation
Quad Cities 1	908	Illinois	PJM	49	2032	ZEC	2017-2027	Constellation
Quad Cities 2	911	Illinois	PJM	49	2032	ZEC	2017-2027	Constellation
Clinton	1,062	Illinois	MISO	35	2026	ZEC	2017-2027	Constellation
Braidwood 1	1,194	Illinois	PJM	34	2046	CMC	2022-2028	Constellation
Braidwood 2	1,160	Illinois	PJM	34	2047	CMC	2022-2028	Constellation
Byron 1	1,164	Illinois	PJM	37	2044	CMC	2022-2028	Constellation
Byron 2	1,136	Illinois	PJM	35	2046	CMC	2022-2028	Constellation
Dresden 2	894	Illinois	PJM	52	2029	CMC	2022-2028	Constellation
Dresden 3	879	Illinois	PJM	51	2031	CMC	2022-2028	Constellation
Hope Creek	1,172	New Jersey	PJM	36	2046	ZEC	2019-2025	PSEG
Salem 1	1,169	New Jersey	PJM	45	2036	ZEC	2019-2025	PSEG
Salem 2	1,158	New Jersey	PJM	41	2040	ZEC	2019-2025	PSEG
Millstone 2	869	Connecticut	ISO-NE	47	2035	PPA	2019-2029	Dominion
Millstone 3	1,210	Connecticut	ISO-NE	36	2045	PPA	2019-2029	Dominion
Seabrook	1,246	New Hampshire	IOS-NE	32	2050	PPA	2022-2029	NEXTERA
Total	19,395							

Notes: [a] Age calculated as of 2022. ZEC: Zero Emission Credit, CMC: Carbon Mitigation Credit, PPA: Power Purchase Agreement. Customer rate cap applied in New York, Illinois and New Jersey schemes.

ZEC Mechanism and New York credit price



Tranche	Period	ZEC price ($/MWh)
Tranche 1	4/2017-3/2019	17.48
Tranche 2	4/2019-3/2021	19.59
Tranche 3	4/2021-3/2023	21.38
Tranche 4	4/2023-3/2025	23.56
Tranche 5	4/2025-3/2027	25.00
Tranche 6	4/2027-3/2029	26.26

Nuclear plant average operating costs ($/MWh)

Year	Fuel	Operations	Total operating costs
2017	6.76	20.43	27.19
2018	6.47	20.12	26.59
2019	6.15	18.55	24.7
2020	5.76	18.27	24.03
2021	5.55	18.07	23.62
Source: (NEI, 2017, 2020, 2021, 2022)			

O&M Categories

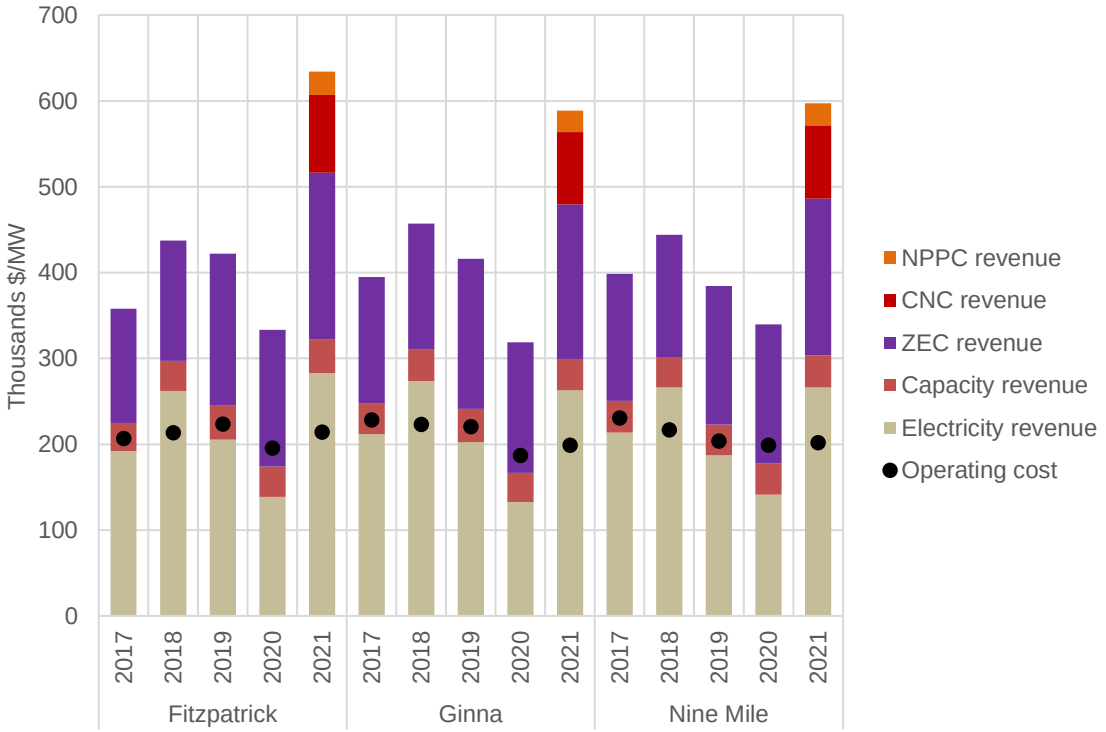
- Engineering
- Fuel management
- Training
- Loss prevention
- Operations
- Work management
- Materials and Services
- Support Services

Fixed costs categories

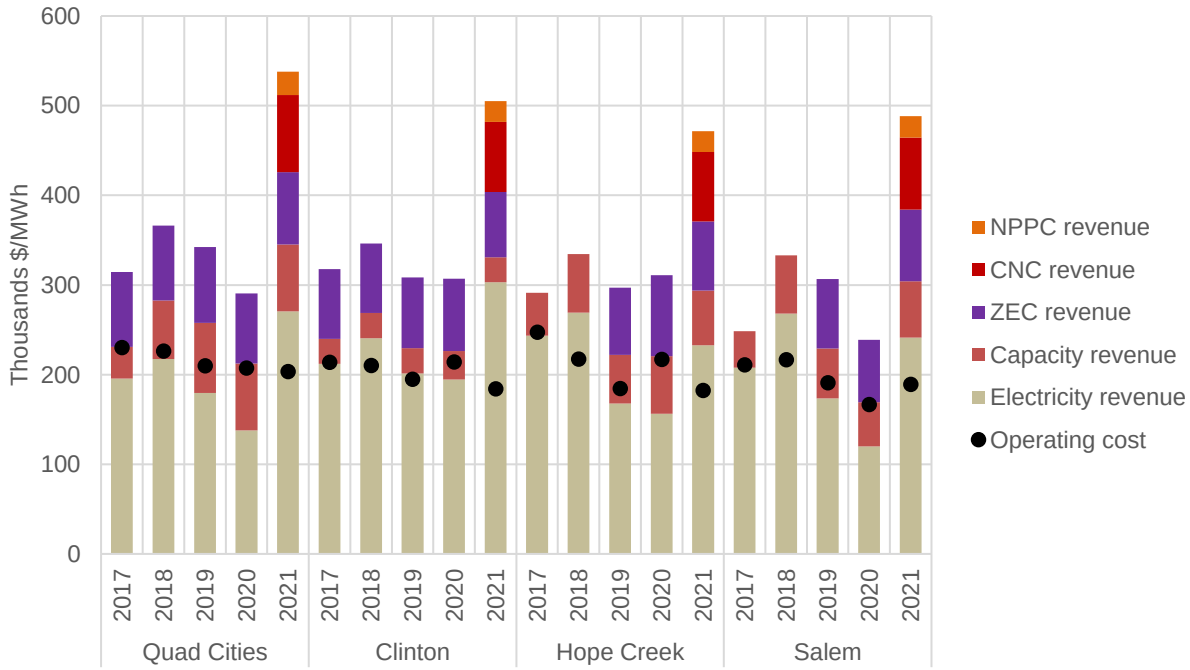
- Capital spares
- Information technology
- Regulatory
- Enhancements
- Infrastructure and sustaining

Policy assessment relative estimates

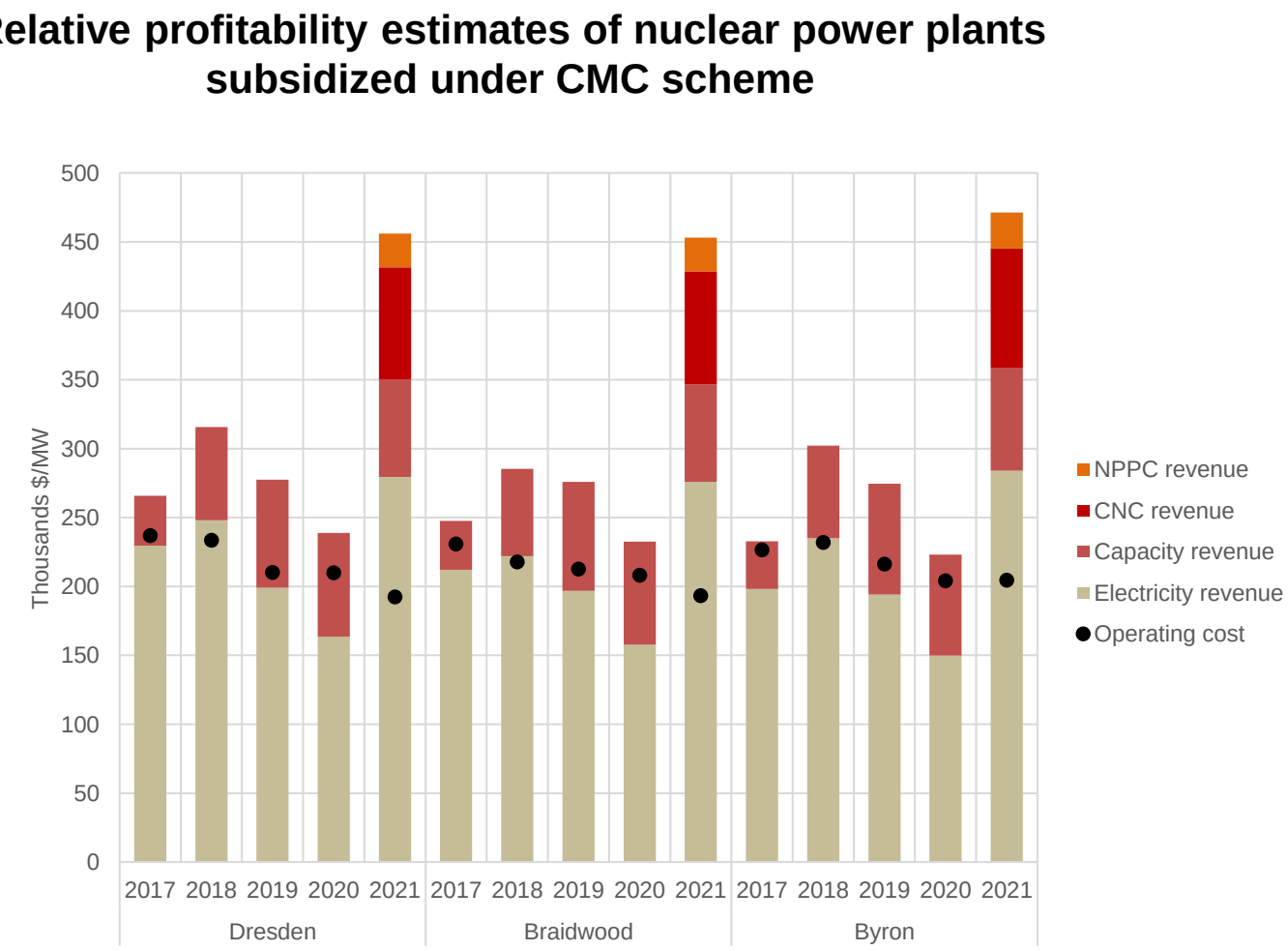
Relative profitability estimates of nuclear power plants in NYISO.



Relative profitability estimates of nuclear power plants in PJM.

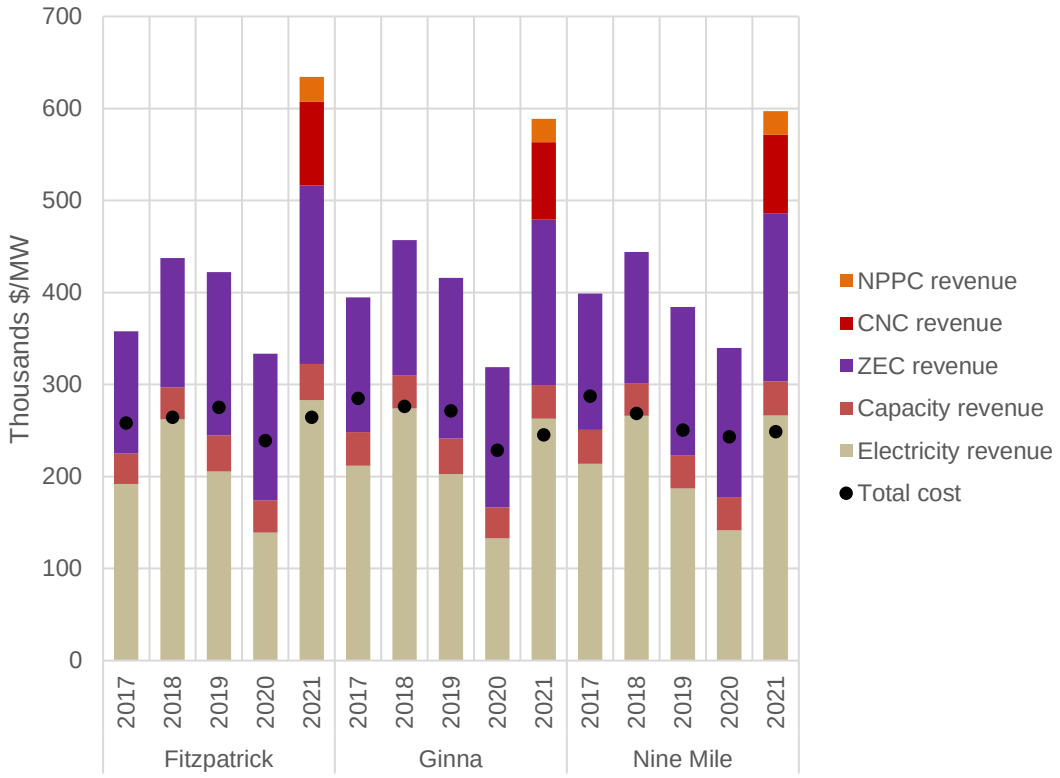


Policy assessment relative estimates



Robustness tests: Including fixed costs

Relative profitability estimates of nuclear power plants in NYISO with fixed costs



Relative profitability estimates of nuclear power plants in PJM with fixed costs