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Why will capacity markets never achieve equilibrium levels of supply?

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Victor Chung, Managing Consultant (victor @londoneconomics.com)
Julia Frayer, Managing Director (julia@londoneconomics.com)

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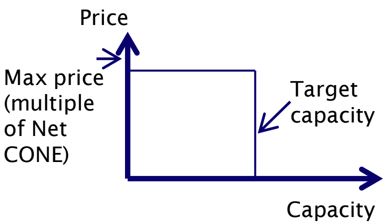
Capacity markets were designed to address the "missing money" problem in mitigated energy markets

- **Market designers and politicians have expressed concerns with reliability risk and energy price volatility with a "pure" energy-only market design**
  - If generators are to recover their long-run marginal cost through an energy-only market, regulators would have to allow generators to offer above short-run marginal in the energy market, which is often not desired
- **Capacity markets procure a target amount of capacity (peak load plus a reserve margin) to meet a specified reliability target – many variations on the design**
- **The procurement target takes the form of an inelastic (vertical) or elastic (downward-sloping) "demand curve" in the capacity market**

Vertical vs. Downward sloping demand curves

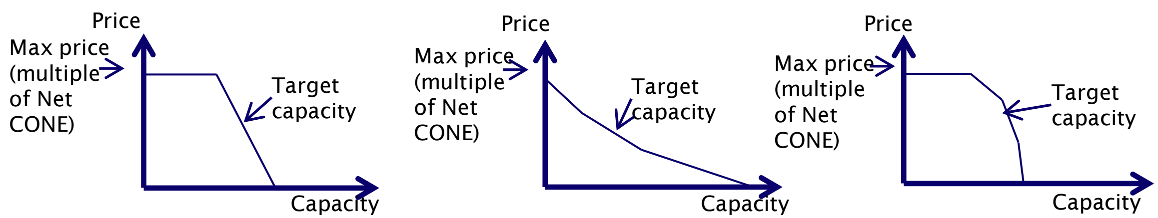


Vertical

- Vertical demand curve can lead to volatile capacity prices
- No incentive to invest until the market is short of target capacity
- Small incremental need for new capacity can be overwhelmed by the size of a single plant

Downward sloping

- Resources can earn capacity payments even when market has surplus capacity above the target
- But the determination of the slope/intercept/cap (overall shape) can become administratively complex



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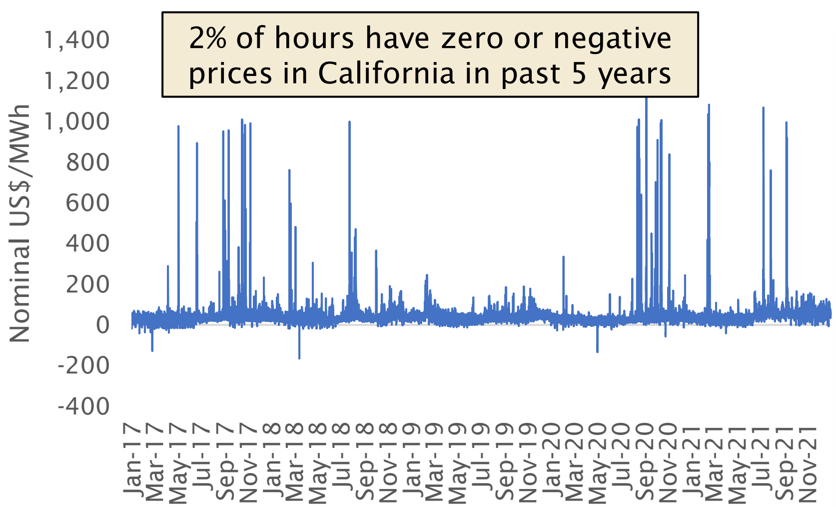
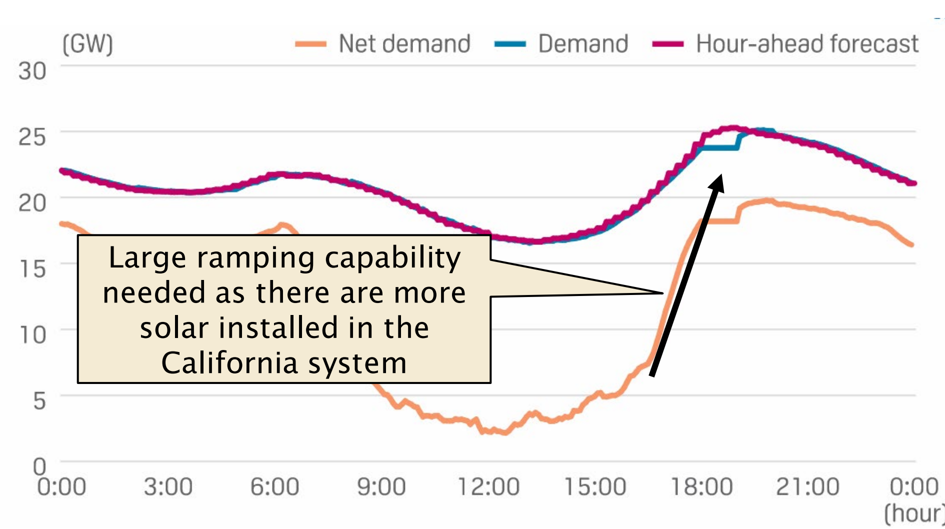
Capacity markets are an important tool for supporting the transition from fossil fuel to carbon-free energy: reliability of electricity service requires non-intermittent generation

- **Energy transition results in large scale deployment of carbon-free resources that are weather-dependent, intermittent, and have a zero short-run marginal cost ("SRMC")**
  - many of the carbon-free investment motivated by opportunities outside the energy and capacity market
  - Intermittent, weather-dependent generation cannot provide a guaranteed level of output all the time, but electricity is typically consumed around the clock – so need for non-intermittent dispatchable resources remains
  - With increasing levels of zero SRMC resources, energy prices may decline, negatively impacting the economics (capacity factor and profit) of other (non-intermittent) resources that have a higher SRMC
  - Capacity markets are therefore needed to provide the economic signals to sustain and support investment in non-intermittent generation in the face of declining (and more volatile) energy prices
- **Energy transition also creates demand for other qualities to maintain reliability – such as ability to quickly ramp up and down to meet net demand changes**

Volatile and occasionally negative energy prices in California



Net Demand resembles a "duck" in California



Source: California ISO

In capacity market with downward sloping demand curves, market designers aim for the price to move and down – to attract new resources, retain existing capacity, and signal retirements

- **Market designers set a target capacity procurement quantity that is needed to meet the required reliability target – usually describe in terms of a reserve margin on peak load**
  - Reserve margin refers to the amount of capacity needed above the forecasts peak load to ensure reliability in situations such as expected maintenance, unexpected outages, and forecast errors
- **Net Cost of New Entry ("CONE") represents the expected incremental revenue (on top of energy and ancillary services market profits) needed to for a new reference resource to enter the market**
  - Such reference resources are typically a peaker, but more recently batteries are also considered
- **Market designers generally set the capacity demand curve to pay resources the Net CONE when capacity supplied is just enough to meet the procurement target**
  - When there is excess capacity, the capacity market should clear at a price below Net CONE, and vice versa

Net CONE and target reserve margin in US centralized capacity markets

Market	Reference technology	Net CONE ($/kW-month)	Target reserve margin @ Net CONE	Delivery year
ISO-NE	Simple cycle gas turbine	$7.47	12.9%	2025-26
NYISO	Simple cycle gas turbine	$7.74	18.9%	2021-22
PJM	Gas-fired combustion turbine	$8.36	14.8%	2023-24
MISO*	Gas-fired combustion turbine	$7.81	8.73%	2022-23

* MISO does not have a downward-sloping demand curve

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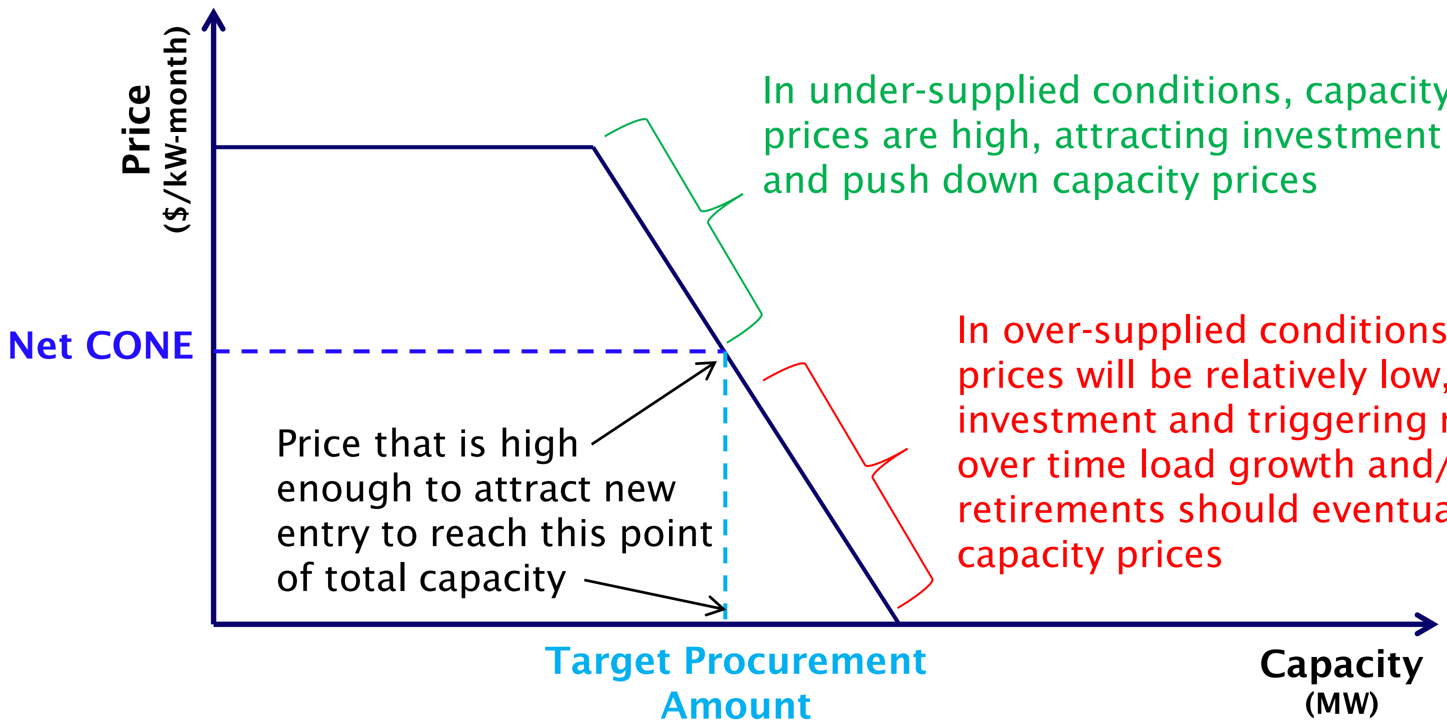
Economic theory predicts that the capacity market should reach equilibrium around Net CONE

A dynamic 'retirement and new entry' cycle is anticipated to occur over time:

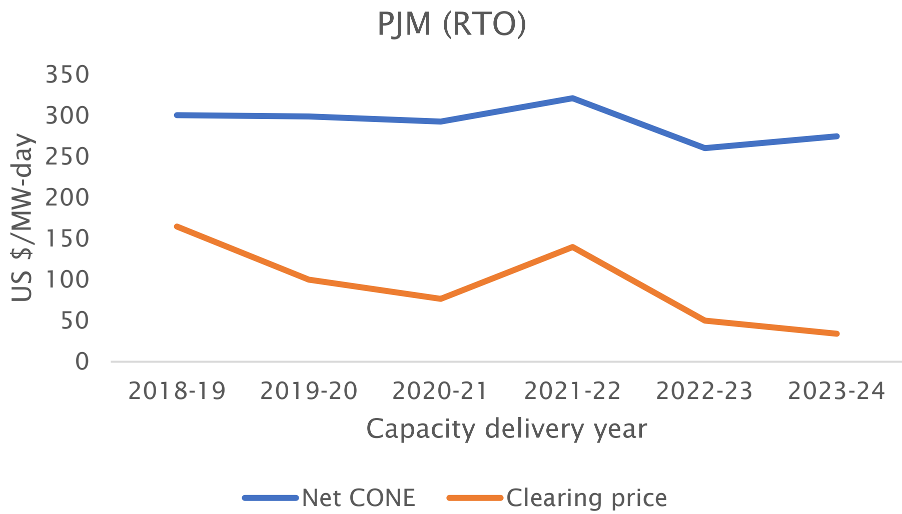
- **When capacity prices are low, existing units that are not earning sufficient profits will retire, and their exit will push up capacity prices in future periods**
- **When capacity prices are high, ceteris paribus, it will become attractive enough for investors to develop new units to enter the market; new capacity will push down capacity prices in future periods**

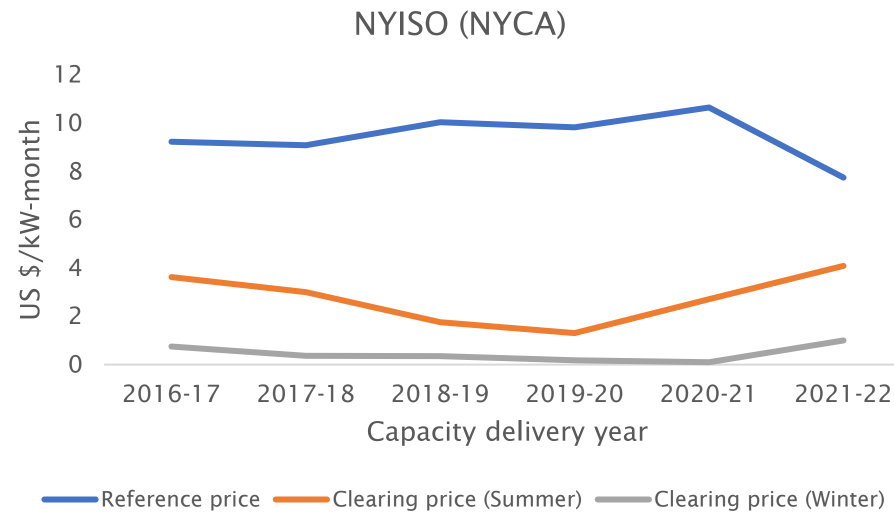
Dynamic process in capacity markets with downward sloping demand curves

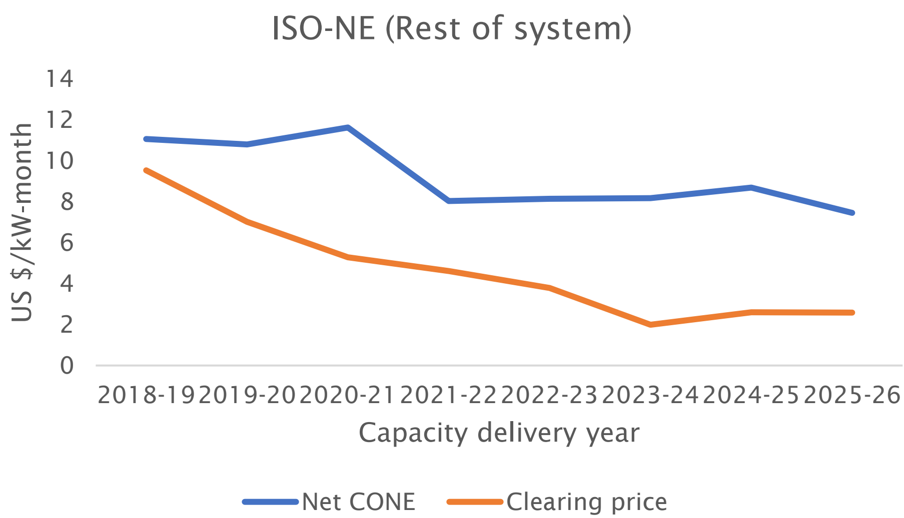


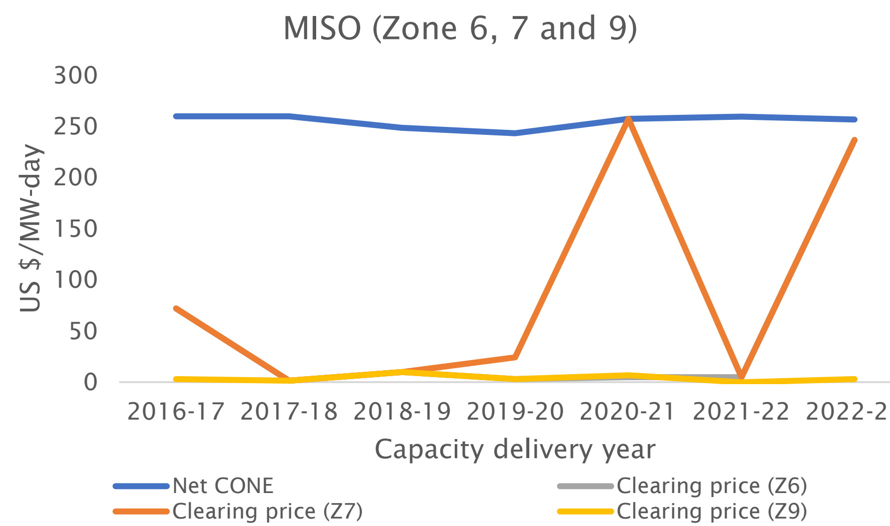
Reality has deviated from theory: capacity markets have consistently cleared below Net CONE in US centralized capacity markets

Historical cleared capacity prices vs Net CONE in US centralized capacity markets









Note: For MISO, participation in the Planning Resource Auction ("PRA") is not mandatory. Prices presented do not include bilateral contract prices
For NYISO, summer season is May - October; winter season is November - April of the following year.

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We observe in the market data that generation units are not retiring, even though the economic conditions and realized profitability indicate that they should retire

- **There are over 15 GW of oil and natural gas generators that ran less than 1% of the time in 2021 – profit contribution from energy sales is minimal for these assets**

Generators with very low capacity factor in US centralized capacity markets

Generators with < 1% capacity factor in 2021	PJM		ISO-NE		MISO		NYISO	
	# plants	MW	# plants	MW	# plants	MW	# plants	MW
Combustion turbine	16	~1,800	24	~900	35	~5,000	11	~650
Oil and gas steam	6	~2,650	4	~3,000	7	~50	1	~1,700

- **Except for MISO Zone 7, many of these generators should not be earning sufficient profits to support their going-forward fixed costs (or avoidable costs) based on the latest capacity auction results**

Modelled missing money for combustion turbine and steam units

$/kW-month	PJM (RTO)			ISO-NE (ROP)			MISO (Zone 7)			NYISO (NYCA)		
	Going-forward cost	Capacity revenue	Missing money	Going-forward cost	Capacity revenue	Missing money	Going-forward cost	Capacity revenue	Missing money	Going-forward cost	Capacity revenue	Missing money
Combustion turbine	1.28	1.03	0.25	3.75	2.59	1.16	1.08	7.17	-6.09	4.58	2.34	2.24
Oil and gas steam unit	2.99	1.03	1.96	5.83	2.59	3.24	2.52	7.17	-4.65	9.17	2.34	6.83

Note: Avoidable costs are based on each ISO or corresponding market monitors' estimation
Capacity prices: PJM 2023-24 RTO, ISO-NE 2025-26 rest-of-pool, MISO 2022-23 Z7, NYISO 2021-22 summer and winter average prices in NYCA
Note that MISO prior auctions have cleared at very low prices (< $1/kW-month), but there is a price spike in Z1-Z7 in the latest auction

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There are several reasons why we are observing low capacity prices: some are the result of market design choices, while others are related to market participant behaviour

Due to market design

- **Market designers are more worried about high capacity prices (which result in high consumer costs) than low capacity prices, which tends to make them overly cautious when it comes to potential exercise of market power**
  - For example, most capacity markets have rules in place preventing resources to retire if such behaviour benefits other resources in the market owned by the same owner
  - Market participants have to go through hurdles in order to prove that the units are not expected to be profitable before they are allowed to retire the units
- **Market designers risk averse: less worried about having higher-than-desired reliability than lower-than-desired reliability**
  - PJM and ISO-NE's demand curves are convex, which result in capacity prices being more elastic in over-supplied conditions as compared to under-supplied conditions
  - Vertical demand curves, such as that in MISO, result in very low capacity prices when market is only slightly over-supplied

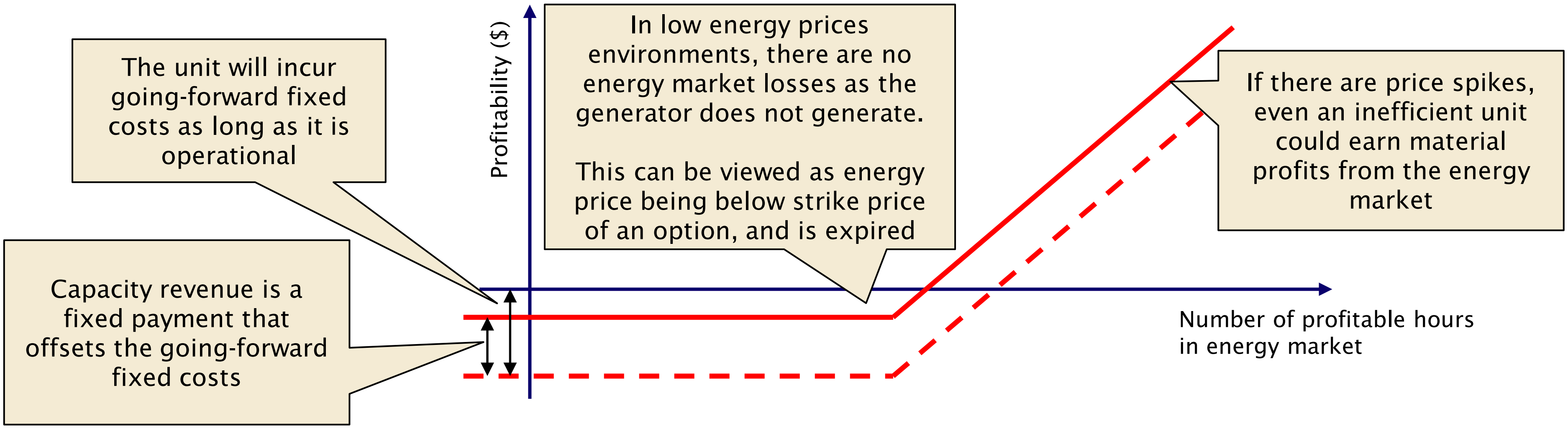
Due to market participant behaviour

- **Retirements are irreversible, while future energy and capacity profits are uncertain**
  - Retirements means permanently giving up the interconnection right, and the decision cannot be reversed by developing a new plant
  - Capacity prices may rise in the future
  - Reward of potential price spike in energy market can be large due to non-linearity of energy prices
- **Interaction between potential retirement candidates can also lead to a "wait and see" approach**
  - game theory outcome where Nash Equilibrium in mixed strategy with low retirement probability

A low capacity factor generator can be considered as a series of call options, the premium being be fixed cost less capacity revenue

- **For generators with very low expected capacity factor, there is no downside when energy prices are lower than expected, but lots of upside when energy price rise**

Illustration of payoff for a low capacity factor generator



- **The downside of carrying this option is limited – the lowest capacity price can go it $0 which means the maximum loss per year is the going-forward cost of the generator**
- **Retirement decision is therefore based on the option value of the unit**

Option value > Going-forward costs – capacity price	➡	Remain online
Option value < Going-forward costs – capacity price	➡	Retire

Game theory analysis shows that retirement delays may be expected, because waiting for other generators to retire first is a viable strategy

- **Capacity revenue of one generator also depends on retirement decisions of other generators, and since one large generator's retirement can influence capacity clearing prices materially, this leads to a "wait and see" attitude**
- **LEI provides a demonstration of the two-player game using PJM 2023-24 annual capacity auction demand curve with a slope of $-0.03/MW-day per MW additional capacity. auction clearing price is $34 MW-day**
- **Two hypothetical 500 MW CT with going-forward fixed costs of $42 MW-day – capacity revenue not enough to cover fixed costs**

Payoff matrix of retirement decision of two hypothetical 500 MW CT in PJM 2023-24 auction

		Unit B: Stay	Unit B: Retire
Unit A	Stay	-8 -8	7 0
Unit A	Retire	0 7	0 0

$34 MW-day capacity payment
- $42 MW-day fixed cost
= -$8/MW-day

If one 500 MW unit retires, capacity price increases to $34/MW-day + ($0.03/MW-day x 500) = $49/MW-day

Profitability of unit remaining online
$49 MW-day capacity payment
- $42 MW-day fixed cost
= $7 MW-day

Retired unit has no costs and no revenue

- **Results in Nash Equilibrium in pure strategies with only one of the CTs retiring**
- **This is less than the retirement quantity predicted using static analysis, where both CTs should retire as they are both unprofitable**

Capacity market's failure in inducing timely retirement of old resources may hinder transition to a low-carbon grid

- **Capacity markets are needed supplement energy revenues, when energy market revenues are capped (and energy prices are not allowed to represent the full value of scarcity**
- **As more intermittent resources are deployed for energy transition, capacity market's role in ensuring reliability becomes ever more important**
- **We observe in that retirements are delayed and deferred because of market design features and behaviour; delayed retirement of old units slows down technological evolution and supply-mix changeover – when there is no retirement, there is no room for new entry**

Further research areas

- **How to adopt capacity market mechanisms to factor in behavioral tendencies and implication of uncertainty (adjust Net CONE, bid caps, etc.)?**
- **What market mechanisms can facilitate timely retirement and new entry?**
- **What market mechanisms can motivate resources with multi-dimensional capabilities that the future grid desires (e.g., fast ramp and dispatchability)?**

A paper exploring the topics presented in this deck will be posted on LEI's website: www.londoneconomics.com

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Appendix: Data sources

- Concentric Energy Advisors, INC., Mott MacDonald. “ISO-NE Net CONE and ORTP Analysis” September 3, 2020
- MISO. “2022/23 PY Planning Reserve Margin and Local Reliability Requirements - Draft Results” September 7, 2021
- Michigan Public Service Commission “2020 MISO Planning Resource Auction Result”
- New York ISO. “Proposed NYISO Installed Capacity Demand Curves for the 2021-2022
- Capability Year and Annual Update Methodology and Inputs for the 2022-2023, 2023-2024, 2024-2025 Capability Years” August 2020
- ISO-NE. “Docket No. ER22-___-000, Filing of Installed Capacity Requirement, Hydro Quebec Interconnection Capability Credits and Related Values for the Sixteenth Forward Capacity Auction (Associated with the 2025-2026 Capacity Commitment Period)” November 9, 2021
- Potomac Economics. “2020 State of the Market Report for the New York ISO Markets” May 2021
- Potomac Economics. “Default Technology-Specific Avoidable Costs” January 20, 2021
- PJM. “Gross Avoidable Cost Rates for Existing Generation and Net Cost of New Entry for New Energy Efficiency”. March 17, 2020
- Todd Aagaard & Andrew N. Kleit. “Too much is never enough: Constructing electricity capacity market demand”. May 1, 2022.