

# The Value of Reciprocating Engines in the Future ERCOT Market

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THE **Brattle** GROUP

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**This presentation explores the value of flexible generation in an ERCOT context.**

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# Acknowledgement

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**I would like to thank the following individuals for their assistance:**

- Pablo Ruiz of the Brattle Group
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- Hank He of Tabors Caramanis Rudkevich

## Overview (1)

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**Higher levels of variable renewables (wind and solar) require greater flexibility in the remainder of the system.**

**Natural gas generation can provide that flexibility.**

**Three natural gas generation technologies that are available today:**

- Frame gas turbines (in simple-cycle (CT) or combined-cycle (CC) configurations).
- Aero-derivative gas turbines.
- Reciprocating engines.

**Reciprocating engines are by far the most flexible.**

**In addition to natural gas technologies, storage and some types of demand response can also provide needed system flexibility.**

## Overview (2)

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In this study we investigated system costs and investor returns when new frame-type units are added to meet demand, and when a mix of frame and reciprocating engines are added.

The study was performed for the ERCOT market for 2022.

For this analysis we used Polaris Systems Optimization, Inc.'s *Power System Optimizer* (PSO) model running in the Newton Energy Group's p-Cloud Analytics modeling environment, a cloud-based environment that allows the user to run PSO cases quickly and at low cost.

## Major Findings

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**Wärtsilä engine plants are economic in the ERCOT market. Our analysis shows that reciprocating engines plants have better economic performance from an owner's point of view than CC or CT plants.**

**Adding Wärtsilä engine plants rather than CT plants also benefits customers in terms of significantly lower wholesale prices (8% real-time price reduction in 2022 with 100 reciprocating engines replacing CTs).**

**The analysis also showed that under the conditions evaluated, CC units were not competitive with CT units. The heat rate advantage of CCs did not outweigh the capital cost advantage of CTs.**

# Natural Gas Technology Characteristics

Technology	Ramp rate	Start Time	Minimum Load	Start Cost	Efficiency	Capital Cost
Frame Simple Cycle	Moderate	Slow	Moderate	High	Low	Low
Frame Combined Cycle	Moderate	Slow	Moderate	High	High	High
Aeroderivative	Fast	Moderate	Moderate	None	Moderate	Moderate
Reciprocating Engines	Very Fast	Very Fast	Low	None	Moderate	Moderate

Frame and aero technologies are most cost effective in large sizes (about 200 MW for frame CT; about 600 MW for frame CC; and about 100 MW for aero).

Reciprocating engines are 8-18 MW each, and are combined into plants with multiple independently operated engines, usually in 200 MW plant sizes.

- Pearsall in ERCOT has 202 MW in 24 x 8.4 MW Wärtsilä engines.
- Red Gate in ERCOT has 225 MW in 12 x 18.8 MW Wärtsilä engines.

**Independent operation provides flexibility and high reliability.**

**Wärtsilä has a total of 2.7 GW installed in the US.**

## Study Design

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**We started with a 2022 case that we evaluated for the Texas Clean Energy Coalition<sup>1</sup> and:**

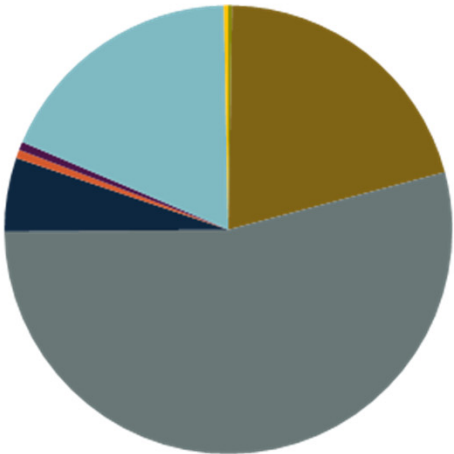
- Modified the coal retirements for consistency with the EPA's 2014 Regulatory Impact Analysis of the CPP (Option1 State), retiring about 8.9 GW of existing coal.
- Specified renewable penetration consistent with current renewable trends in ERCOT: about 10 GW of solar PV and 24 GW of wind. The resulting system has about 28% of its energy needs met by variable renewable resources.
- Used natural gas prices consistent with the Energy Information Administration's Annual Energy Outlook 2015 Reference Case (about \$5.25/MMBtu in 2015 dollars).

<sup>1</sup>

[http://www.brattle.com/system/publications/pdfs/000/005/013/original/Exploring\\_Natural\\_Gas\\_and\\_Renewables\\_in\\_ERCOT\\_Part\\_III\\_Shavel\\_Weiss\\_Fox-Pennerf.pdf?1401907416](http://www.brattle.com/system/publications/pdfs/000/005/013/original/Exploring_Natural_Gas_and_Renewables_in_ERCOT_Part_III_Shavel_Weiss_Fox-Pennerf.pdf?1401907416)

# ERCOT Resource Mix

## ERCOT 2016



## BRATTLE 2022 CASES

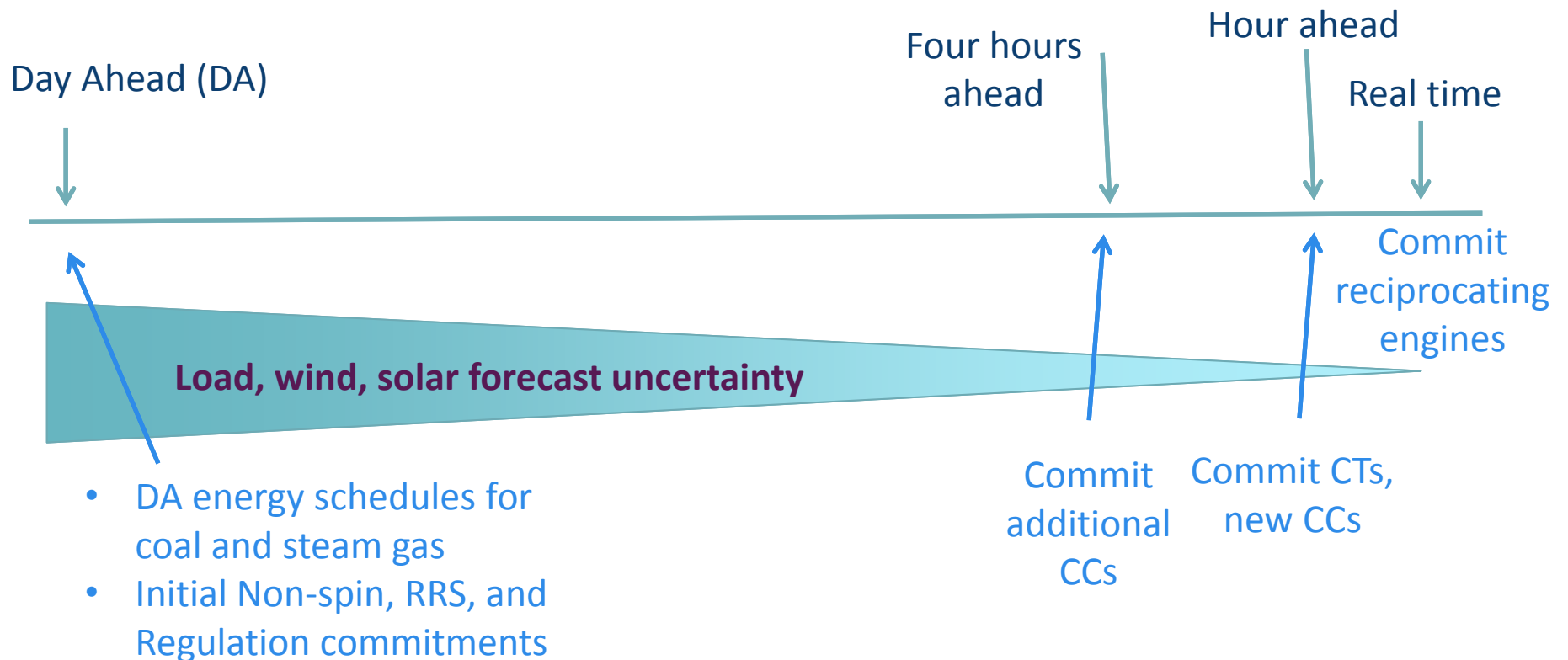


- Biomass
- Coal
- Gas
- Nuclear
- Other
- Hydro
- Wind

Sources: ERCOT's Report on the Capacity, Demand and Reserves in the ERCOT Region, December 2015 and the Brattle 2022 Cases.

# Modeling the ERCOT Market Using PSO

We set up PSO to accurately simulate the ERCOT operators commitment and dispatch decisions, and the co-optimization of energy and ancillary services.



## Base Case

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**We added 25 modern, flexible F-class CTs (5,900 MW of MW nameplate units and 4,550 MW summer rating) to achieve an energy-only balance consistent with the ERCOT market design.**

**In the base case, the existing Wärtsilä engine plants are forecasted to earn \$161/kW-yr from energy and ancillary services, which is 60% more than required for entry (about \$100/kW-yr is required for entry). We estimate an implied rate of return of about 22% if no more engines plants are added in ERCOT.**

**The analysis also showed that under the conditions evaluated, CC units were not competitive with CT units. The heat rate advantage of CCs did not outweigh the capital cost advantage of CTs.**

## Scenario Specifications

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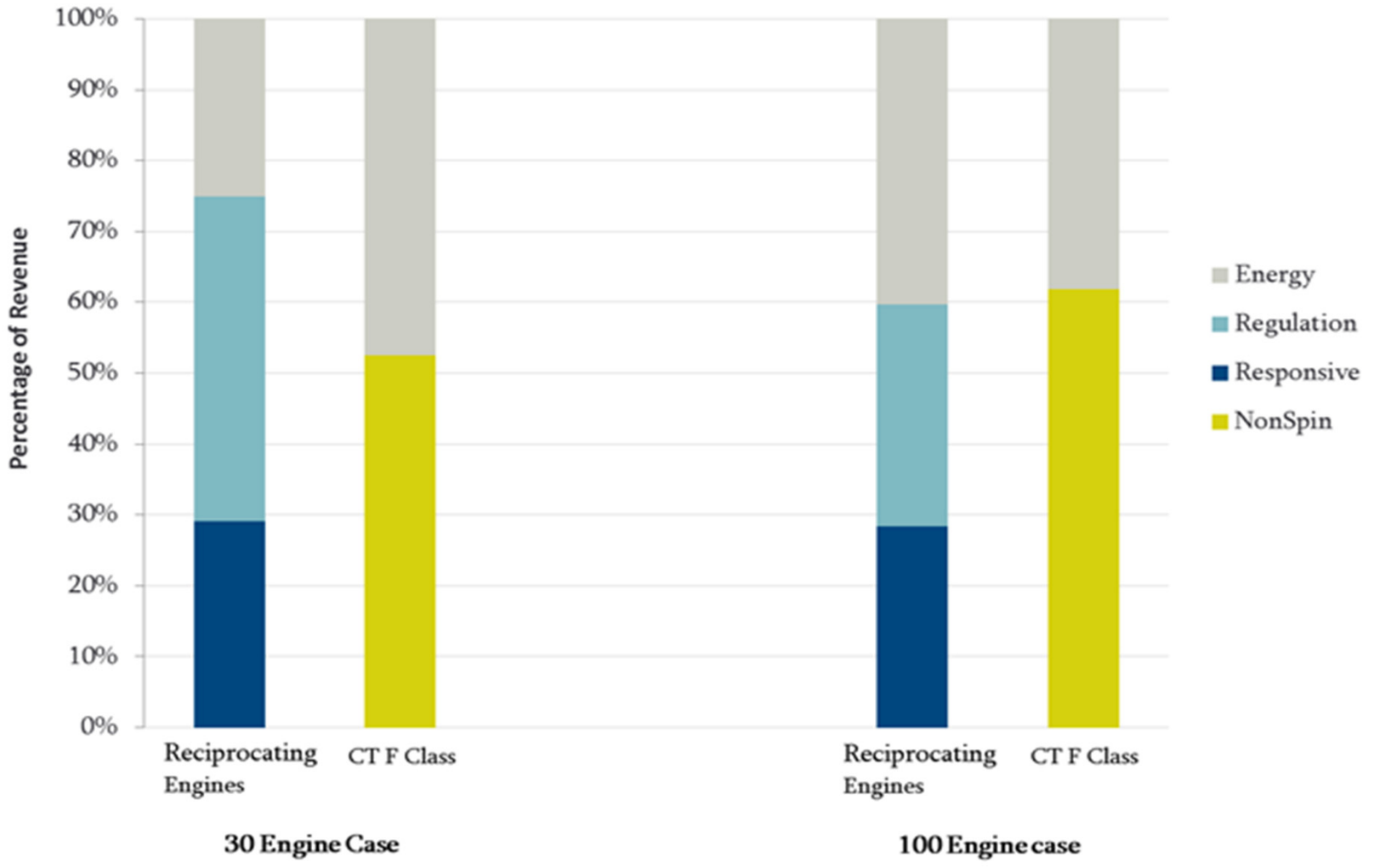
We added 18.4 MW reciprocating engine plants to replace CT units, while maintaining an energy-only capacity balance. We ran two cases:

- 30 Engine Case: 552 MW of engines.
- 100 Engine Case: 1,840 MW of engines.

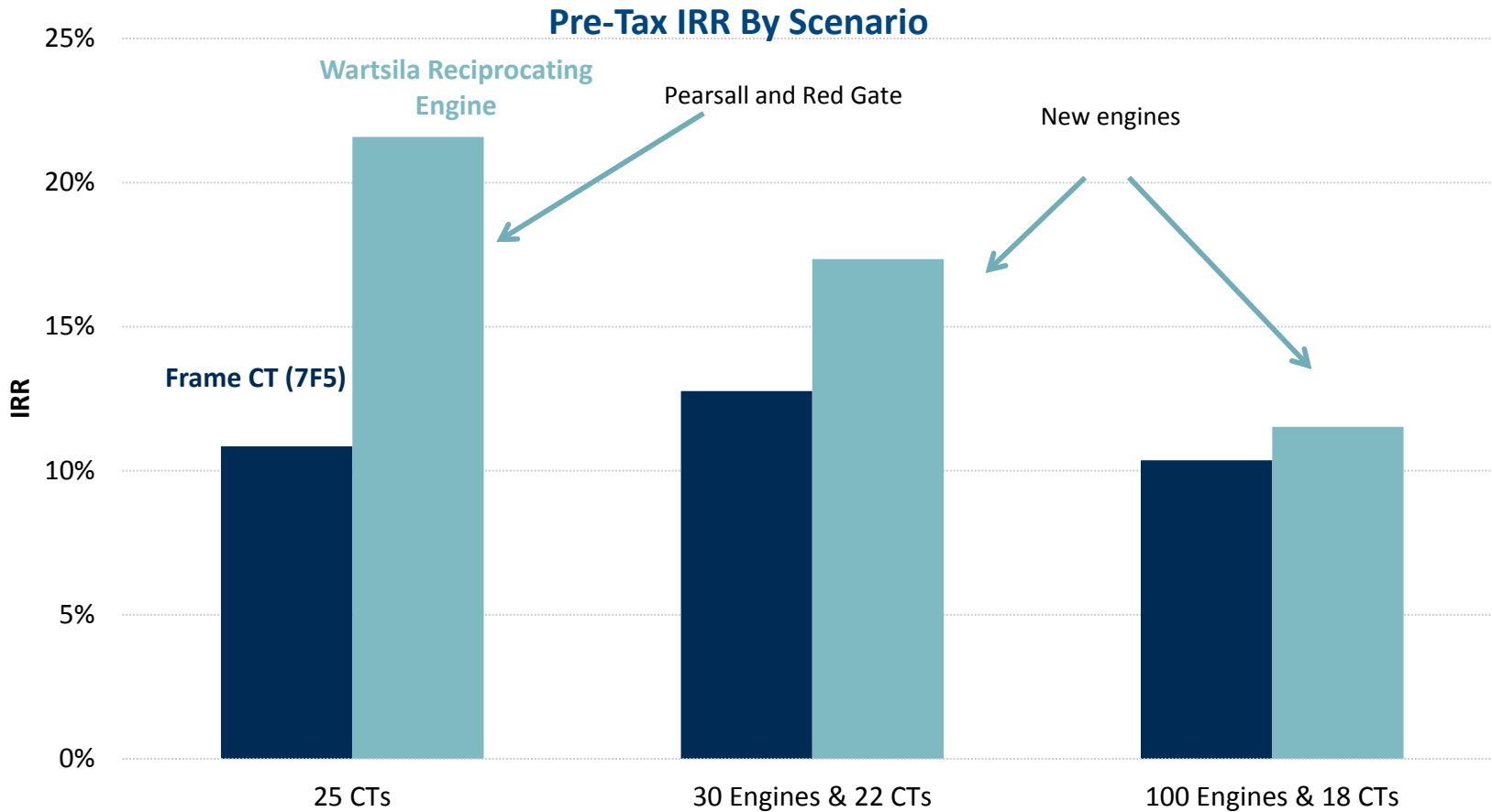
## Results - Summary

Case		Base	30 Engines	100 Engines
Configuration		25 CTs	30 Engines & 22 CTs	100 Engines & 18 CTs
Day Ahead Price	\$/MWh	\$50.42	\$50.01	\$48.59
Real Time Price	\$/MWh	\$ 47.16	\$ 46.21	\$ 43.54
Real Time Price Difference	%		2.02%	7.83%
Real Time Production Cost	Million \$	\$8,342	\$8,311	\$8,247
Production Cost Difference	%		0.4%	1.1%
<b>CT F-Class</b>				
Capacity Factor	%	5.9%	5.4%	4.3%
Hours of Operation	Hours	862	779	618
Average Number of Starts		123	114	95
Market Earnings	\$/kW-yr	\$80	\$88	\$78
Required Market Earnings	\$/kW-yr	\$80	\$80	\$80
<b>Reciprocating Engines</b>				
Capacity Factor	%	5.4%	4.3%	6.5%
Hours of Operation	Hours		1,977	2,438
Average Number of Starts			2,376	1,876
Market Earnings	\$/kW-yr	\$161 (Red Gate and Pearsall)	\$138	\$106
Required Market Earnings	\$/kW-yr	\$100	\$100	\$100

# Results – Sources of Revenue



# Results – Investment (1)



Source: Brattle Analysis, assumes constant energy margins and FOM over 20 years.

## **Results – Investment (2)**

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**Our analysis shows that under projected 2022 conditions, investment in Wärtsilä reciprocating engine plants would be expected to yield excellent returns ranging from 12% to 17% depending on the number of stations installed. This estimate assumes 2022 projections continue for 20 years.**

**As one would expect, as more engines are added, the rate of return declines to more normal market levels (about 12% in the 100 Engine Case).**

## **Results – Prices and Production Costs**

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**The addition of engines reduces both day-ahead and real-time prices significantly. With 100 engines, real-time prices are almost 8% lower.**

**This is very important since in the ERCOT market most customers are exposed to wholesale prices.**

**Production costs decline as engines are added since they are more efficient than the CTs that they replace and have no start-up costs.**

## Results – Unit Operation

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**Engines operate about 25% of the hours providing energy, regulation and responsive reserves. They start about 2,000 times per year compared with CTs that only start about 100 times per year.**

## New Gas Unit Cost and Performance Parameters

	Configuration	Nameplate Capacity (MW)	Heat rate (Btu/kWh)	Min load (%)	VOM (\$/MWh)	FOM (\$/kW)	Startup cost (\$/MW)	Startup time (minutes)	Ramp rate (MW/min)	Min up time	Min down time	Capital Cost (\$/kW)
Combined Cycle (7F5)	2x1	639	7,010	50.0%	2.00	14.9	45	60	50	4 hours	4 hours	1000
Frame CT (7F5)	N/A	236	10,000	40.0%	1.00	7.1	65	10	50	1 hour	2 hours	650
Wärtsilä Reciprocating Engine	18V50SG	18.4	8,072	20.0%	3.50	7.0	0	5	80% per min	1 min	5 mins	850

## For Further Information Please Contact

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Dr. Shavel is an energy economist with over 30 years of experience in the energy industry, specializing in the economics and operations of the U.S. electric power system, generation and transmission investment, and environmental strategy. He has performed work for a wide range of clients, including generation and transmission companies, natural gas pipelines, marketers, developers, industry research groups, and as federal agencies.

Dr. Shavel has broad experience developing models of North American power systems, including the Integrated Planning Model by ICF International. He has also directed significant assignments for major electric utilities, independent transmission companies, RTOs, independent power producers and private equity on matters such as coal plant retirements, fuel price forecasting, the benefits of new transmission lines and power plant valuation.

Prior to joining Brattle, Dr. Shavel was a Vice President at Charles River Associates (CRA). While at CRA, he led the development of the National Energy and Environment Model (NEEM) and contributed to its integration with the Multi-Region National Macroeconomic Model.

# About The Brattle Group

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The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governments around the world. About half of our work is in energy and utility-related planning, regulatory and litigation support.

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