PJM Reference Unit

Issues to Consider on the Frame H CT

Presented on behalf of The P3 Group

July 6, 2018

Just Energy / Just Experts

Contents

Objective: Review the proposed Frame H CT with respect to FERC reference unit evaluation criteria

Agenda:

- FERC Criteria
- Likelihood of development in PJM
- Ability to develop cost and revenue estimates
- Appropriate demand curve
- Next Steps

FERC evaluation criteria does not support use of the Frame H CT

FERC's focus is on allowing for necessary new entry at low cost

In the FERC decision regarding ISO-NE's reference unit, FERC indicates that it used three criteria to evaluate the reference level selection:

(1) Is it likely to be developed in the market?

(2) Can cost and revenue estimates be developed with confidence?

(3) Does the reference unit result in a demand curve that allows for entry without unnecessary costs?

> "The criteria should produce demand curves such that a developer sponsoring **efficient and needed new entry** has a reasonable opportunity to recover the full costs of the new resource from . . . markets over its useful life." (emphasis added)

Source: 161 FERC ¶ 61,035 UNITED STATES OF AMERICA FEDERAL ENERGY REGULATORY COMMISSION, ISO New England Inc. Docket No. ER17-795-000 ER17-795-002, ORDER ACCEPTING FILING, Issued October 6, 2017, paragraph 38.

Apply FERC's criteria to assess use of a Frame H CT as the reference unit

FERC Criteria

By FERC's criteria, PJM should not be using a Frame H CT

(1) **The Frame H is NOT being developed as a CT in PJM** – There is not a single example of a Frame H CT in PJM. In contrast, developers are implementing multiple technologies ranging from combined cycle units (Frame F and Frame H), single-cycle combustion turbines (Frame F) and aeroderivatives. Other locations are pursuing reciprocating engines.

(2) **Frame H cost and revenue estimates cannot be verified –** There is no experience in how Frame H technology ramps and operates at partial load. There are only two being built nation-wide as brownfield developments – none in operation in the U.S.. Industry has been reluctant to implement a Frame H as a combustion turbine due to lack of commercial experience in ramping and availability. Brattle only applies historical prices, which does not reflect actual projected operations going forward.

(3) **Results in an inappropriate demand curve –** Size is no longer the driving factor for new developments. Flexibility, modularity and smaller sizes are more attractive in PJM and in markets ahead of PJM with respect to integration of renewables.

Using the Frame F allows for more flexibility; the Frame H squeezes that out

Issues to Consider on the Frame H CT

LIKELIHOOD OF DEVELOPMENT IN PJM

Likelihood of Development in PJM

There is no evidence that a Frame H CT will be developed in PJM

- **No experience with the Frame H as a single unit in PJM**
  - Review of the queue in PJM
  - Review of experience in other Northeast markets
  - Review of other development databases

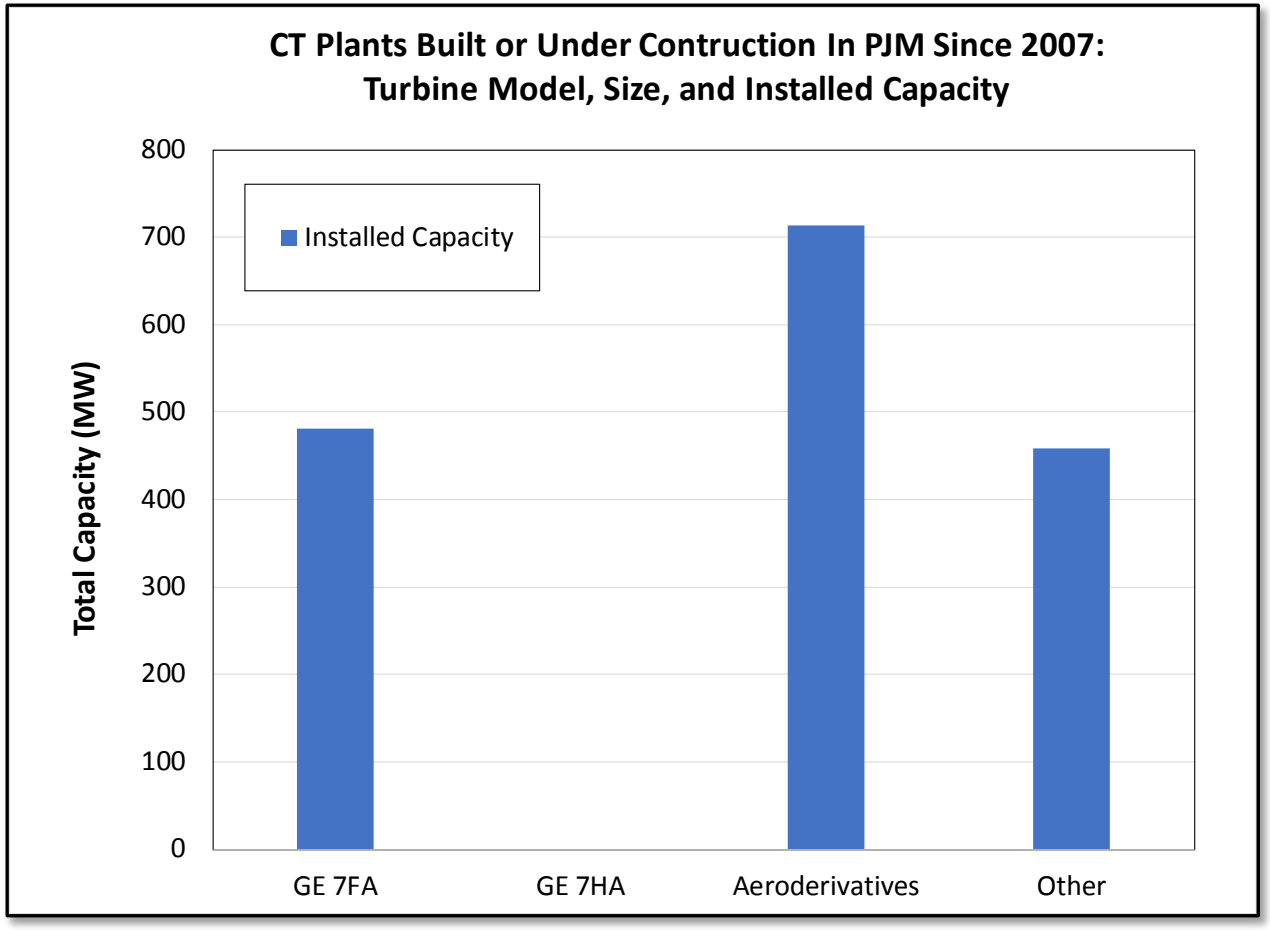
- **Untested quick-start response**
  - Industry research
  - Conversations with developers

- **Increasing need in the market for flexibility**
  - Need for smaller, more modular units
  - Higher integration of renewables anticipated in PJM
  - PJM initiatives in developing frequency market
  - Experience in other markets that see a rising use of reciprocating engines, aeroderivatives and other peaking technologies

There is no support for using a Frame H CT as the reference unit in PJM

Likelihood of Development in PJM

PJM has multiple peaking technologies, but not a Frame H CT



Number of CT Plants Built or Under Construction Since 2007: PJM vs US

Model	PJM	US
GE 7FA	3	26
GE 7HA	0	2
Aeroderivatives	12	147
Other	8	88
Total	**23**	**263**

Source: Summary table of Ventyx data, Brattle Report

Frame H technology has only been used in a CC configuration in PJM, not as a CT

Likelihood of Development in PJM

Nearby markets are not using Frame H as a CT

Turbine Model:	GE 7FA		GE 7HA	
ISO	CC	CT	CC	CT
ISO-NE	674	0	1,485	350
NYISO	1,619	0	480	0
MISO	361	220	0	0
Total	2,654	220	1,965	350

CC = Combined Cycle
CT = Combustion Turbine (single unit)

- NYISO currently uses a GE 7FA CT as the reference unit
- ISO-NE – where a single Frame H CT is being built -- currently uses a GE 7HA CT as the reference unit
  - Existing brownfield site
  - Under construction
  - Operational 2019

Although the GE Frame 7HA is being built in CC configuration across multiple markets, why shouldn't it be the reference unit?

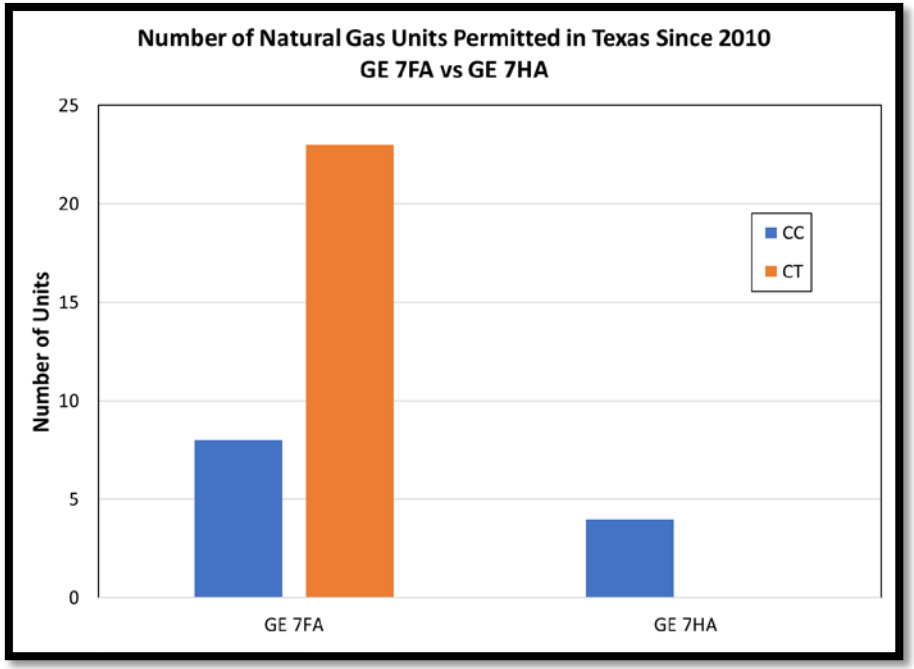
- Inconsistent with previous reference unit specification
- Less stable given volatility of potential energy and ancillary services revenues
- Does not reflect a unit that relies almost exclusively on capacity market revenues
- Too efficient in PJM to allow for new entry of more flexible technologies

Canal 3(MA) is on an existing site – there are no greenfield developments proposed

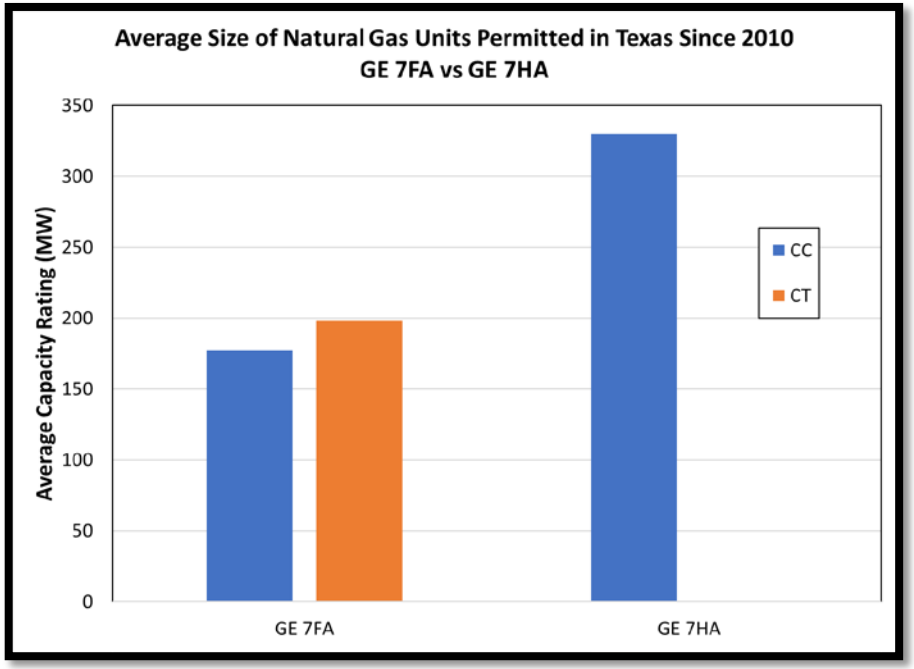
Likelihood of Development in PJM

CASE STUDY: ERCOT has been implementing GE 7FAs as CTs

Number of Permitted Units



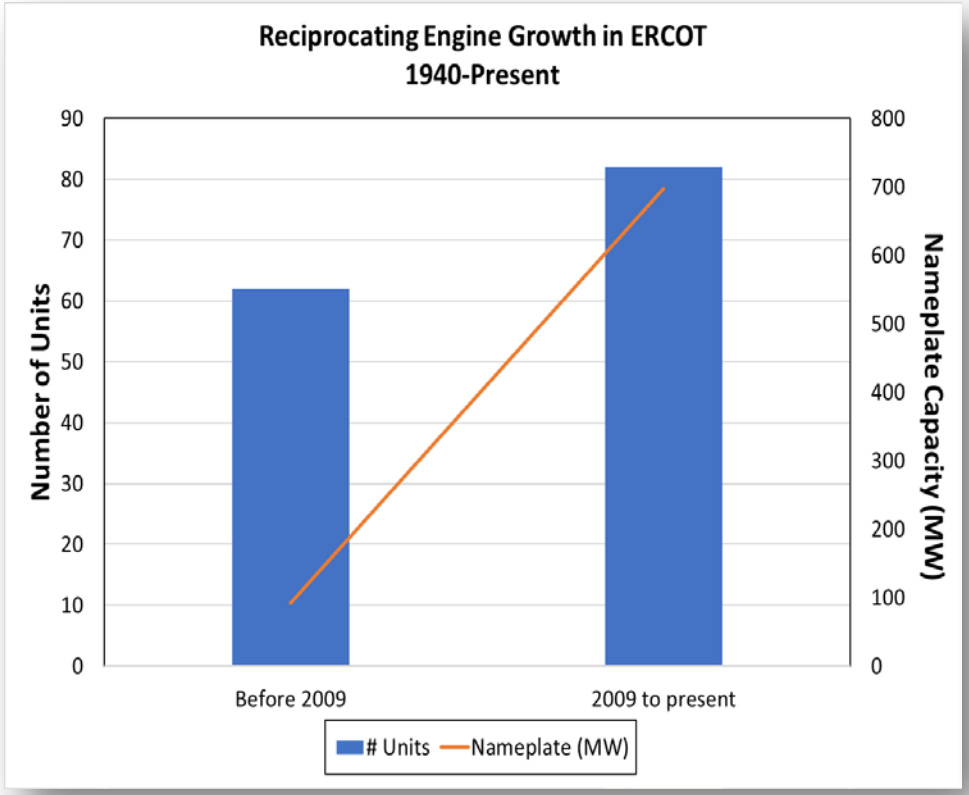
Average Size



Source: Analysis of Texas Permitted Natural Gas Projects https://www.tceq.texas.gov/.../permitting/air/memos/turbine_lst.xlsx

Although the GE 7HA is common in a CC configuration, there are no Frame H CTs

CASE STUDY: ERCOT also has seen increases in reciprocating engines



- In recent years wind generation has taken over in Texas, making them the leading state for wind generation in the US
- The intermittent output of wind has resulted in a large demand for flexible, reciprocating engines across the state

PJM may follow a similar trend as the states work to meet their renewable goals

Issues to Consider on the Frame H CT

ABILITY TO DEVELOP COST AND REVENUE ESTIMATES

Conversation with EPRI: Frame H for CT Has Unproven Operational Flexibility

There are many reasons why the **Frame H is not being used** in a combustion turbine configuration

- Larger generation capacity may be difficult to employ fully
- Decreased efficiency with partial loads at less than full output
- New technology without track record of operating experience as a CT
- Unproven flexibility:
  - Ramp-up/Ramp-down times
  - Frequency of multiple cycles during day
  - Availability response time
- Competition with smaller and more flexible alternatives (e.g., Frame F CT, aeroderivatives and reciprocating combustion engines)
- High capital and variable operating costs

Source: Energyzt conversation with contact at EPRI

Unproven flexibility makes it very difficult to estimate longer term costs

Ability to Develop Cost and Revenue Estimates

Brattle recognizes the difficulty in assessing costs and revenues

"**For CTs, there are too few representative existing resources to make a meaningful comparison**, but we believe PJM's approach and assumptions are reasonable.

. . .

Although futures are not liquid beyond one year and do not cover all locations, we propose an approach to extend the available market data further forward and to other locations. **This approach does not work well for CT plants, however, because their dispatch does not closely match any observable forward-traded product.**"

- Brattle Report, pp. v - vi

ISO-NE used a dispatch model to project energy prices and AS revenues

Issues to Consider on the Frame H CT

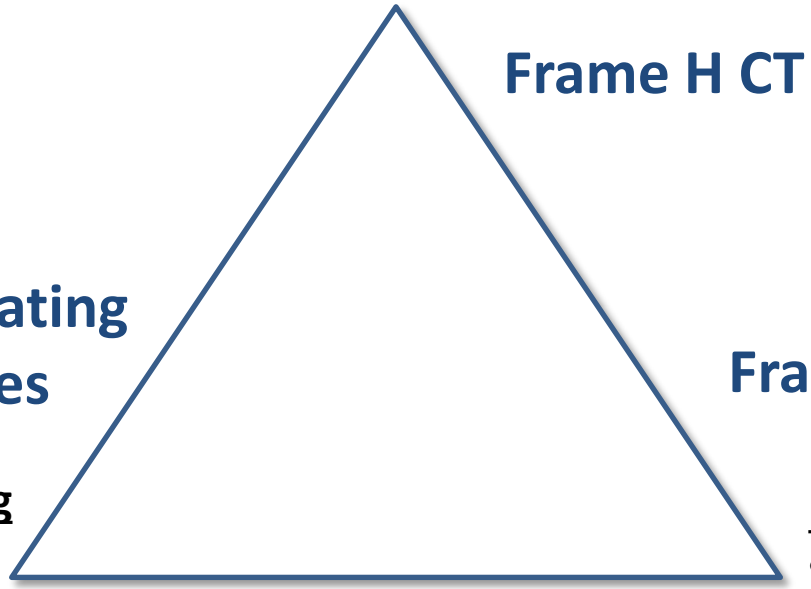
APPROPRIATE DEMAND CURVE

Appropriate Demand Curve

Natural gas generating technologies offer different qualities

Cheaper = More Efficient

- Lower overall cost
- Fuel efficient
- Higher operating profit



Faster = Quicker Ramping

- Qucker start-up times
- Fast ramp-up and ramp-down rates

Better = Reliability

- Commercially proven technology
- Higher availability rates

Each technology provides alternative features that markets increasingly require

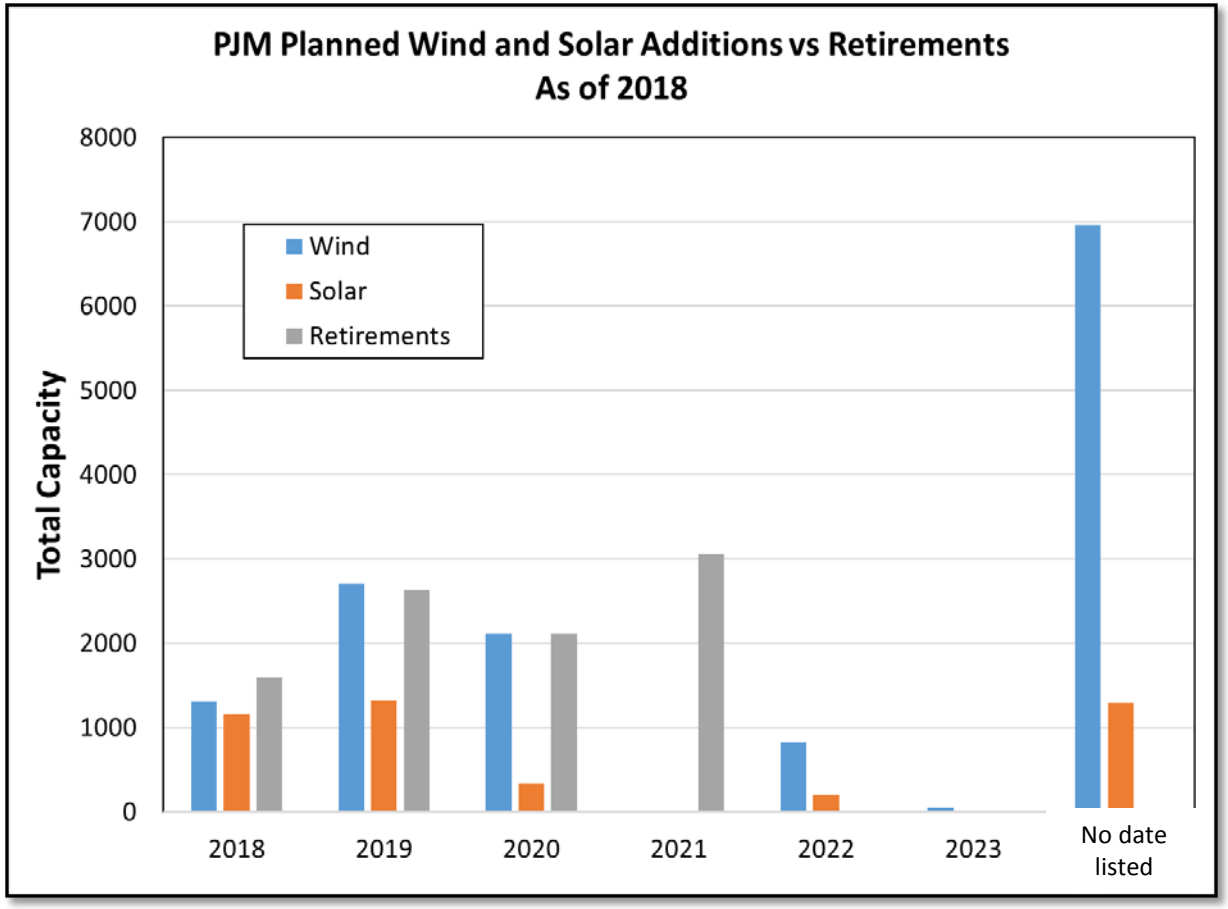
Appropriate Demand Curve

Conversations with Developers: The grid paradigm has shifted

- H-Frame gas turbines are designed for **large, base load combined cycle (CC) applications** to meet needs that were once viewed as grid requirements
  - High efficiency with heat rates less than 7000 Btu/KWh
  - Quicker start capabilities and improved cooling capabilities, make it an ideal intermediate or baseload unit
  - The H-frame is larger than the F-frame
- **The grid paradigm has shifted** with the increase in renewables (wind, solar, bio mass) and potentially electricity storage
  - The larger CCs are at a competitive disadvantage
  - There are more flexible alternatives such as aeroderivatives and natural gas internal combustion engines
  - Speed ramp-up and ramp-down properties are as important as higher efficiency characteristics
- **Availability and how quickly a unit can be called upon** is becoming a more important characteristic in order to make into the bid stack

Sources: Phone conversations with Energyzt connections at Federal Power Company, GEUS (Greenville Electric Utility System), and TClean Energy Technology Associates, June 29, 2018

PJM is experiencing a "paradigm shift" with new renewables



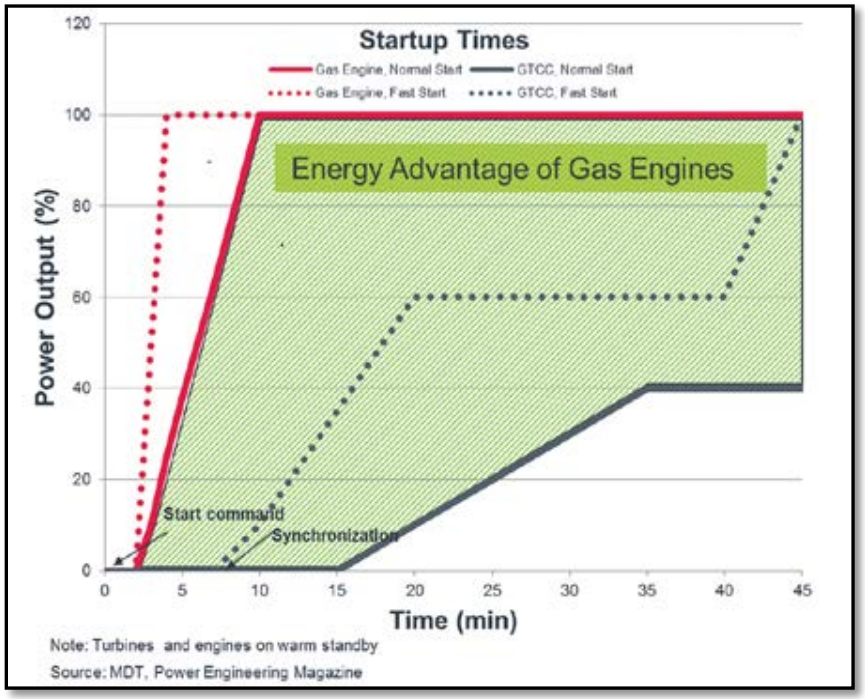
Source: PJM Queue, cross-checked with Ventyx data

The mid-2020s will see a need for smaller units and proven flexibility

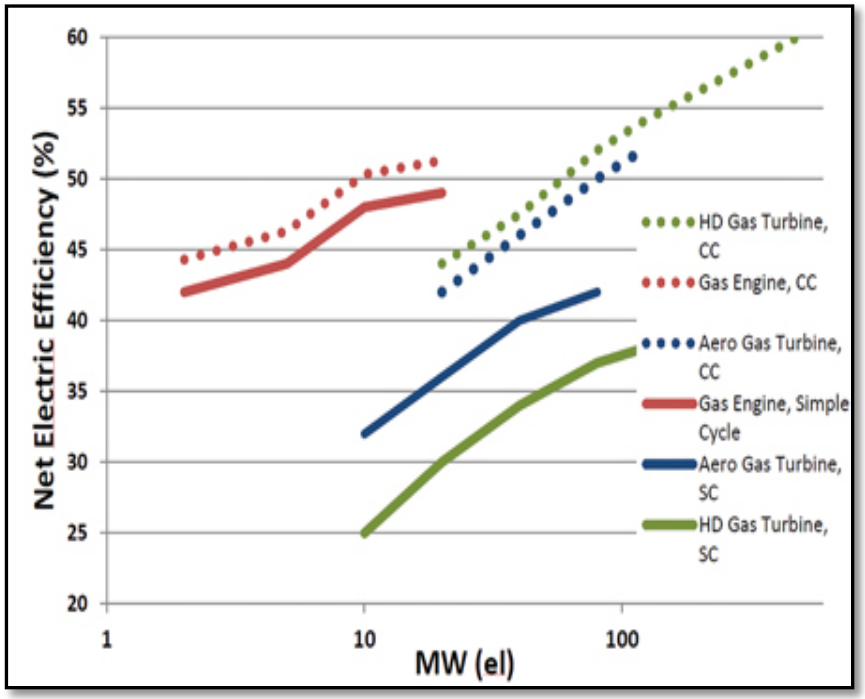
Appropriate Demand Curve

Other technologies offer faster start-times

Startup Times



Net Plant Efficiency

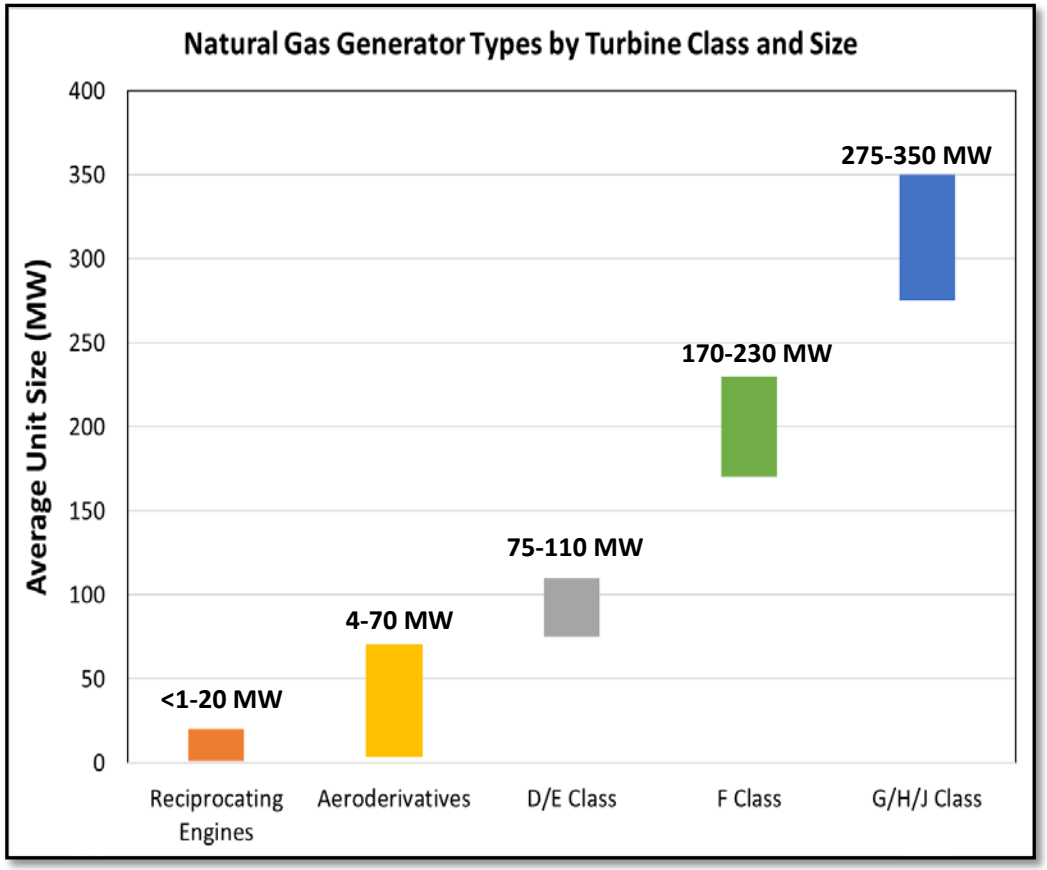


Source: https://www.power-eng.com/articles/print/volume-121/issue-6/features/reciprocating-engine-generator-technology.html

The Frame F CT offers a proven flexibility bridge to new technologies

Appropriate Demand Curve

Other technologies offer smaller sizes and modularity



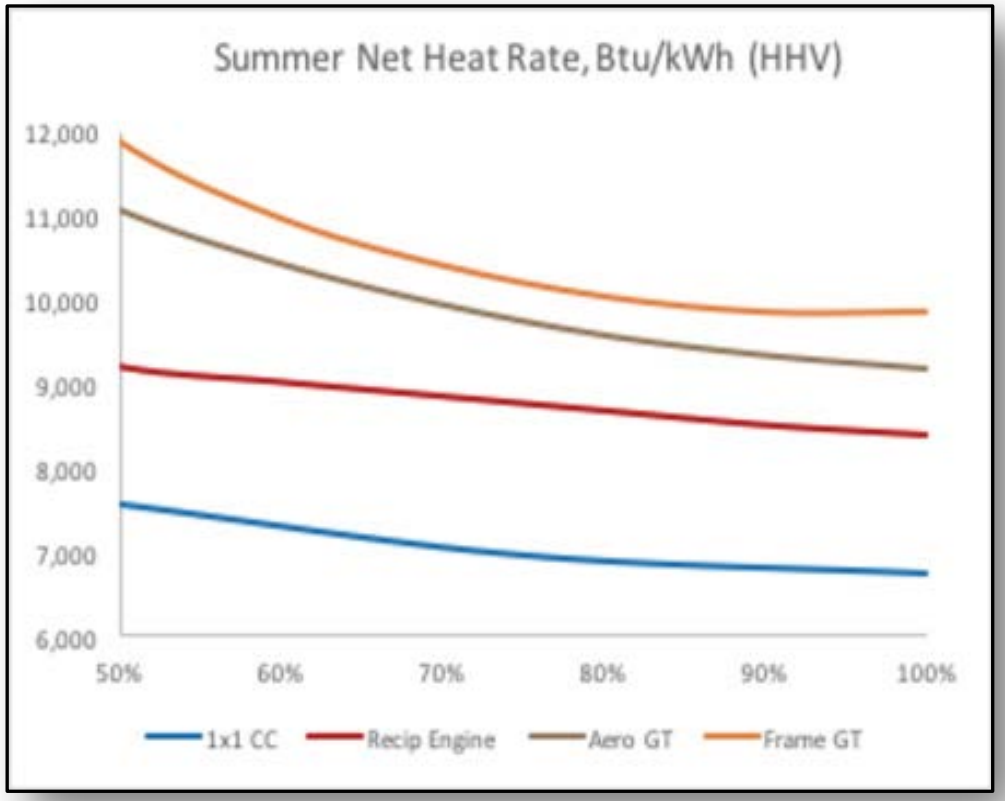
Class	Example Models
D/E-Class	• GE 7F • Siemens SGT6 • Mitsubishi H-100
F-Class	• GE 7F.03-.05 • Siemens SGT6-5000F • Mitsubishi M501 F
G/H/J-Class	• GE 7HA.01-.02. • Siemens SGTg-5000F • Mitsubishi M501J
Aeroderivative	• GE LM6000 • Siemens SGT-A65 • Mitsubishi FT4000
Reciprocating Engines	• Wartsila RT-flex96C • GE Jenbacher

Source: https://www.power-eng.com/articles/print/volume-121/issue-6/features/reciprocating-engine-generator-technology.html

Modularity and smaller size are an advantage in a changing market

Appropriate Demand Curve

Size is no longer an indication of efficiency



Flexibility with multi-unit designs

- Output scalability and load following without sacrificing efficiency
- 95% availability rate common among new models
- Minimized impact of maintenance or unplanned outages

Source: https://www.power-eng.com/articles/print/volume-121/issue-6/features/reciprocating-engine-generator-technology.html

Don't sacrifice flexibility for size and assumed efficiency

Appropriate Demand Curve
View of Consultants: Key trends favor flexibility

"... there are a handful of key trends that stand out in the industry—power density and efficiency, **fuel flexibility, integration with renewables, and the incorporation of telemetry**"

- Director of Product Management, Aggreko

"In the last five to seven years, because of performance enhancements on the heat rate, with the quick-start capability, and penetration of renewables**, utilities are using reciprocating technology** more often. It's become **more competitive with simple-cycle gas turbines**."

- Senior Manager at ICF International

Source: http://www.powermag.com/quick-starts-high-efficiency-grid-balance-engines-on-an-up-cycle/?pagenum=1

The market increasingly is valuing other qualities beyond economies of scale

Appropriate Demand Curve

Despite higher prices, Aeros can compete with the Frame F CT curve

ISO-NE 2017
Analysis of Net CONE

Table 2: Net CONE Summary for Candidate Reference Technologies (2021$)

Reference Technology	Installed Capacity (MW)	Installed Cost (000$)	Installed Cost ($/kW)	ATWACC (%)	Fixed O&M ($/kW-mo)	Gross CONE ($/kW-mo)	Revenue Offsets ($/kW-mo)	Net CONE ($/kW-mo)	Net CONE ($/MW day)
1x1 7HA.02 (CC)	533	$598,958	$1,124	8.1	$5.01	$15.62	$5.62	$ 10.00	$ 329
1x0 7HA.02 (CT)	338	$304,179	$900	8.1	$3.21	$11.35	$3.31	$ 8.04	$ 254
2x0 LM6000 PF+ (Aero)	94	$198,363	$2,110	8.1	$6.96	$25.98	$3.63	$ 22.35	$ 735
1x0 LMS100PA (Advanced Aero)	103	$174,644	$1,696	8.1	$5.75	$21.03	$3.67	$ 17.36	$ 571

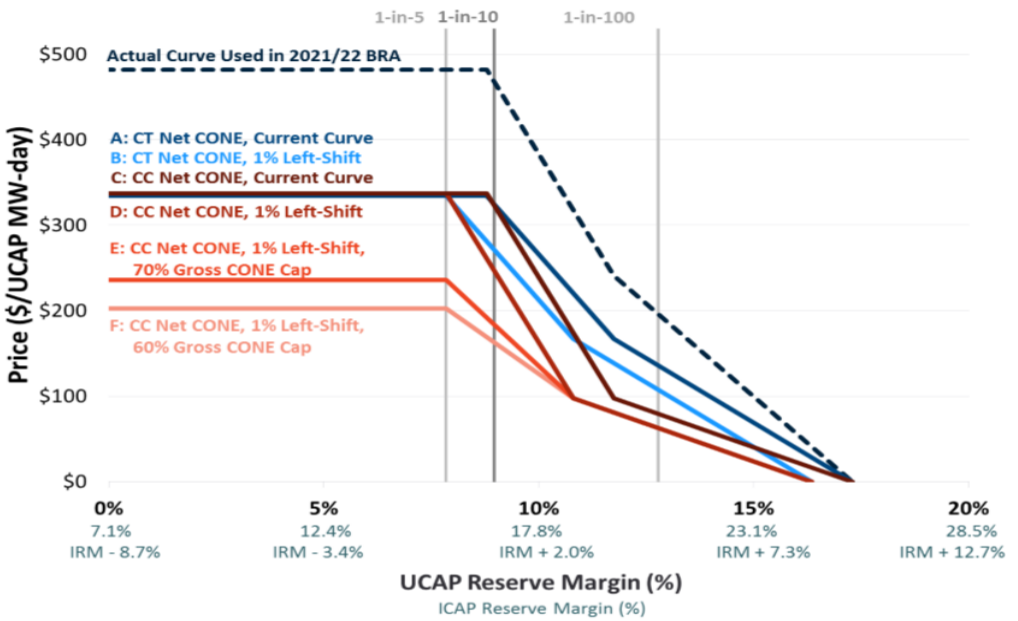
Source: Concentric Energy Advisors report, "ISO-NE CONE and ORTP Analysis: An evaluation of entry cost parameters to be used in the Forward Capacity Auction to be held in February 2018 ("FCA-12") and forward, January 13, 2017

Adopting the Frame H CT would make it harder for aeros to compete

Appropriate Demand Curve

Moving to a Frame H significantly decreases the VRR curve

Figure 20
Candidate System VRR Curves



Notes and Sources:

CC and CT curves are based on the level-nominal estimates of Gross CONE with major maintenance in VOM, our recommendation to use the median LDA E&AS margin as the RTO value, and apply PJM's backward-looking E&AS methodology for the CT estimate and forward-looking approach for the CC estimate.

2021/22 BRA curve uses unadjusted values posted in the 2021/22 BRA parameters, PJM (2021/22).

Source: Brattle report, "Fourth Review of PJM's Variable Resource Requirement Curve," April 29, 2018, http://pjm.com/-/media/library/reports-notices/special-reports/2018/20180420-pjm-2018-variable-resource-requirement-curve-study.ashx?la=en

The proposed curves make it very difficult for other technologies to compete

Next Steps

- **Survey:** Develop an official survey of developers and lenders on different technologies
  - Technology of choice
  - Impact of increasing regulatory risk
  - Cost of capital

- **Next Session:** Presentation on critique of discount rate

QUESTIONS?

Sources

Turbine Comparisons

- https://www.power-eng.com/articles/print/volume-121/issue-6/features/reciprocating-engine-generator-technology.html
- https://www.power-eng.com/articles/print/volume-120/issue-11/features/turbines-vs-reciprocating-engines.html
- https://www.power-eng.com/articles/print/volume-121/issue-11/features/comparing-aeroderivatives-and-reciprocating-engines-for-fluctuating-power-demand.html
- http://www.powermag.com/quick-starts-high-efficiency-grid-balance-engines-on-an-up-cycle/?pagenum=2
- https://www.skyglobalpartners.com/power-producers-turning-to-reciprocating-engines/
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ISO Queue Data

- PJM: https://www.pjm.com/planning/services-requests/interconnection-queues.aspx
- ISO-NE: https://irtt.iso-ne.com/reports/external
- NYISO: https://www.nyiso.com/public/markets_operations/services/planning/planning_resources/index.jsp
- MISO: https://www.misoenergy.org/planning/generator-interconnection/GI_Queue/

Texas

- https://www.greentechmedia.com/articles/read/ercots-summer-peak-demand-forecast-new-investment-generator-profits-no-blac%23gs.j08n9Kg
- https://www.eia.gov/electricity/data/eia860/