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February 14, 2019

The Honorable Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E. Room 1A
Washington, D.C. 20426

Re: *PJM Interconnection L.L.C., Docket Nos. ER19-105-000 and ER19-105-001*
Responses to Deficiency Letter re: Periodic Review of Variable Resource Requirement Curve Shape and Key Parameters

Dear Secretary Bose:

PJM Interconnection, L.L.C. ("PJM") hereby responds to the letter of the Federal Energy Regulatory Commission's ("Commission") Office of Energy Market Regulation issued on January 15, 2019[1] seeking additional information concerning the filing it submitted on October 12, 2018, as amended on October 26, 2018.[2] PJM appreciates the opportunity to further clarify the proposed revisions.

I. RESPONSE TO DEFICIENCY LETTER

1. PJM has elected a simple-cycle combustion turbine reference resource utilizing the H-class turbine, as opposed to the F-class turbine previously used. While Brattle's review of recent orders for GE turbines shows that future combined cycles are almost exclusively using the H-class turbine, Brattle also notes that the simple-cycle H-class configuration has not been constructed or planned for construction in PJM.[3] PJM states that this configuration is under construction in ISO New England and has been proposed by the California Independent System Operator.[4] Given the nascent stage of commercial operation and limited

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[1] *PJM Interconnection, L.L.C.*, Deficiency Letter, Docket Nos. ER19-105-000 and EL19-105-001 (January 15, 2019) ("Deficiency Letter").

[2] *PJM Interconnection, L.L.C.*, Transmittal Letter, Docket No. ER19-105-000 (October 12, 2018)("PJM Transmittal"); *PJM Interconnection, L.L.C.*, Amendment to Extend Time for Action, Docket No. ER19-105-000 (October 26, 2018).

[3] PJM Transmittal at 17 and Brattle 2018 CONE Study at 14-15 and 17.

[4] PJM Transmittal at 17 and Brattle 2018 CONE Study at 14-15 and 17.

> *operational history of this configuration, please provide more detail explaining how the costs of this reference resource were determined as relevant to PJM's market.*

PJM Response

PJM's experts developed the cost of new entry ("CONE") value for PJM's proposed reference resource – the GE 7HA turbine – using industry data in the same manner and with the same vigor that was previously employed to develop the CONE for the reference resource in PJM over the last decade. The analysis, detailed in the CONE Study that accompanied PJM's filing,[5] includes a bottom-up analysis of the capital costs to build the plant in PJM. Specifically, Brattle explained that

> [W]e conduct a comprehensive, bottom-up analysis of the capital costs to build the plant: the engineering, procurement, and construction (EPC) costs, including equipment, materials, labor, and EPC contracting; and non-EPC owner's costs, including project development, financing fees, gas and electric interconnection costs, and inventories. We separately estimate annual fixed operation and maintenance (O&M) costs, including labor, materials, property taxes, and insurance.[6]

Table 9 of the 2018 CONE Study shows the Plant Capital Costs for the CT reference resource with a 2022 online date. The recommended CONE for PJM's proposed reference resource is shown in Table 19 of the 2018 CONE Study. For ease of reference, PJM is including excerpts from the 2018 CONE Study showing the tables as Attachment A to this response.

Brattle explains that all equipment and material costs are estimated by the consulting firm Sargent & Lundy ("S&L") in 2017 dollars using S&L proprietary data, vendor catalogs or publications.[7] For inputs such as labor costs specific to the simple-cycle configuration of the GE

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[5] *See* PJM Filing, Attachment E, Exhibit 2 (2018 CONE Study) at iii-iv.

[6] *Id.*

[7] *Id.* at 21.

7HA turbine, S&L developed the costs based on its experience with similarly sized and configured facilities.[8]

GE has been developing the next model combustion turbine, the 7HA, began commercial operation in the U.S. in 2008.[9] In 2014, GE introduced the latest generation of 7HA combustion turbine. Also in 2014, PJM's independent market monitor began using the GE 7HA to determine the net revenues for a new combustion turbine in its State of the Market report.[10] The next few years saw increasing orders and new builds of H frames over F frames in the U.S. In PJM, all of the combined-cycle plants that cleared the most recent three capacity auctions (2019/2020, 2020/2021 and 2021/2022 Base Residual Auctions) were based on the GE 7HA combustion turbine technology.

The GE 7HA turbine provides a reasonable representation of the reference resource in PJM for several reasons primarily due to the superior efficiencies of this model. First, the H-frame model is exceedingly more efficient than the F-frame model. Thus, it is more attractive to investors and developers, which further supports PJM's reasonable expectation that the H-frame model will be utilized in development of both simple- and combined-cycle plants in to the future.[11] Specifically, as detailed in Table 1, the GE H-Frame turbines have faster start times, faster ramp rates, larger turn down, and higher efficiency[12] compared with the F-frame turbines.

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[8] *Id.* at 21 and Appendix B.

[9] https://etn.global/wp-content/uploads/2018/09/ADVANCEMENTS-IN-H-CLASS-GAS-TURBINES-FOR-COMBINED-CYCLE-POWER-PLANTS-FOR-HIGH-EFFICIENCY-ENHANCED-OPERATIONAL-CAPABILITY-AND-BROAD-FUEL-FLEXIBILITY.pdf

[10] https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2014/2014-som-pjm-volume2-sec7.pdf

[11] See *ISO New England Inc. and New England Power Pool Participants Committee*, 147 FERC ¶ 61,173, at P 32 (2014)(Commission accepted reference unit, in part, due to the expectation that it would be developed in the future); see also ISO New England Inc., 161 FERC ¶ 61,035, at P 38 (2017).

[12] Comparison of GE 7F.05 and 7HA.02, available at: https://www.ge.com/power/resources/tools/product-comparison/turbine-

In turn, these improved parameters result in lower emission levels. Additionally, the increased turbine size and modularity results in significantly shorter installation times.[13] Finally, as reported in the Gas Turbine World's 2018 GTW Handbook, the genset cost (i.e., the cost of the combustion turbine with generator) of the 7HA.02 at 198 $/kW is 14% less expensive than the 7F.05 at 228 $/kW.[14]

Table 1. Comparison of GE H-Frame and F-Frame Turbines[15]

	7F.05	**7HA.02**	Delta
Intro Year	2009	2014	
ISO Base Load (MW)	243	384	58%
Heat Rate (Btu/kWh)	8570	8009	-7%
Turndown-Min load (%)	43	25	-42%
Ramp Rate (MW/min)	40	60	50%
Startup Time (min)	11	10	-9%
Efficiency (%)	39.8	42.6	7%
Genset Price ($/kW)	228	195	-14%

The superior economics of the H-frame over the F-model support the reasonable conclusion that this model or others with similar costs and performance are likely to be built in

compare?prodid1=010&cycleType1=Simple_Cycle&hzType1=60%20Hz&prodid2=012&cycleType2=Simple_Cycle&hzType2=60%20Hz

[13] GE 7HA.01/.02 Gas Turbine, available at https://www.ge.com/power/gas/gas-turbines/7ha

[14] Gas Turbine World Handbook, January 2018 Vol. 33, Pequot Publishing Inc.

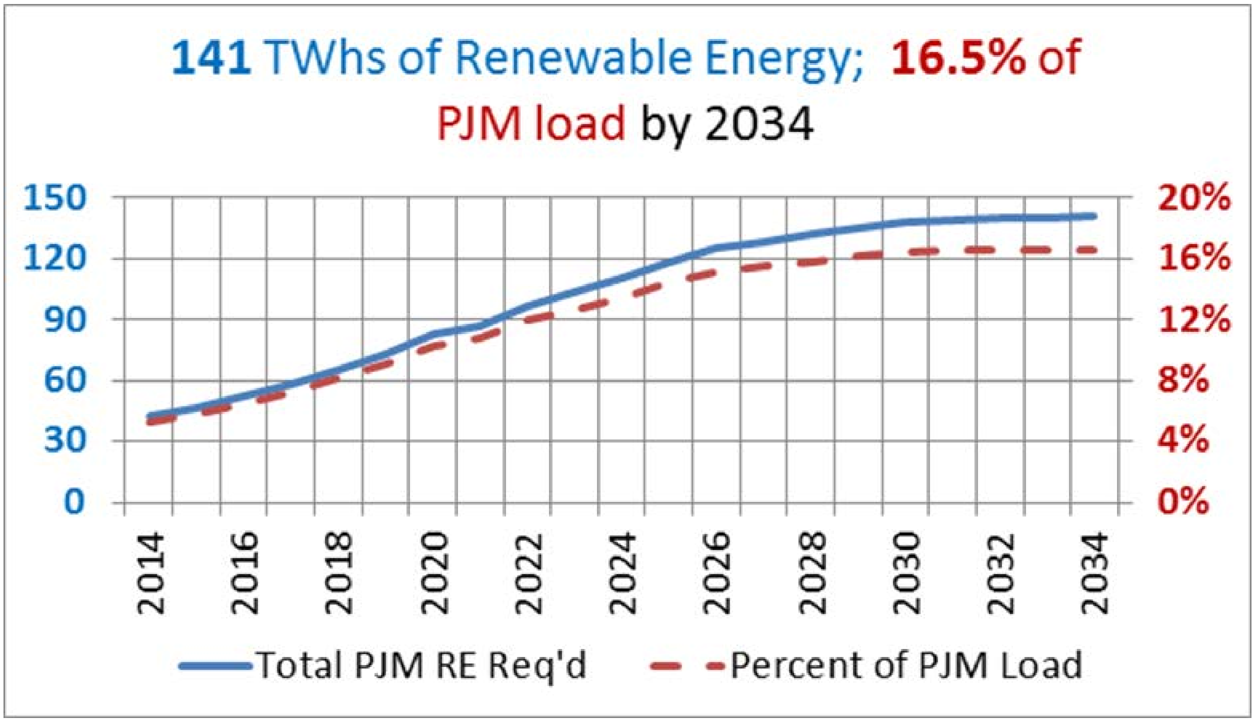
[15] Data based on information from Gas Turbine World Handbook, January 2018 Vol. 33, Pequot Publishing Inc. and Comparison of GE 7F.05 and 7HA.02, available at: https://www.ge.com/power/resources/tools/product-comparison/turbine-compare?prodid1=010&cycleType1=Simple_Cycle&hzType1=60%20Hz&prodid2=012&cycleType2=Simple_Cycle&hzType2=60%20Hz

PJM in the future.[16] Additionally, ignoring the fact that a more efficient, cost-effective simple-cycle unit is commercially available in PJM than the F-frame, could result in an over-procurement of capacity; unnecessarily increasing costs.

PJM anticipates that the modularity, flexibility, and economics of the GE 7HA turbine is expected to become increasingly important with the growth of intermittent resources. As shown in Figure 1 below, renewable resources are expected to generate approximately 30 more terawatt hours in 2022 than they do today due to state policies (increasing from 8% of load to 12% of load). Wind resources alone are expected to increase by approximately 9,000 MW by 2022. The average capacity factor of combustion turbines in PJM has increased 6.5 percent in the past decade, coinciding with the increase in the percentage of PJM generation from intermittent resources from 3.6% to 5.9%. The H-frame combustion turbine specifications are better suited to respond to the increase in intermittent resources in PJM markets than the smaller slower responding F-frame or for that matter, banks of costlier reciprocating engines because of their superior economics.

[16] See *ISO New England Inc. and New England Power Pool Participants Committee*, 147 FERC ¶ 61,173, at P 32 (2014)(Commission accepted reference unit, in part, due to the expectation that it would be developed in the future); see also ISO New England Inc., 161 FERC ¶ 61,035, at P 38 (2017).

Figure 1.[17]



[17] This chart is based on data from PJM's 2019 load forecast and relevant aggregate state renewable energy mandates.

2) *The Gross Cost of New Entry (CONE) values proposed in PJM's filing assume that certain major maintenance costs are recovered as variable operating and maintenance through energy market offers. Specifically, PJM states the operating costs at issue are expenses related to consumable materials used during plant operations and the maintenance costs at issue are expenses a Market Participant incurs as a result of electric production.*[18] *Explain how Net CONE changes, or not, depending on whether these costs are recovered in the energy market or capacity market.*

PJM Response

As shown in Table 2, and explained below, the Net CONE does not materially change regardless of whether major maintenance costs are recovered in the energy market or the capacity market.

Table 2. Calculation of Net CONE

		Major Maintenance Expenses in Energy Market	Major Maintenance Expenses in Capacity Market included as Fixed Costs
A	Gross CONE ($/MW-Year)	$107,175[19]	$126,025[20]
B	Variable O&M ($/MWh)	$6.93[21]	$1.10[22]
C	Net EAS ($/MW-Year)	$20,431	$39,688
D = (A - C)	Net CONE ($/MW-Year)	$86,744	$86,337
E= (D/365) / (1-0.0589)	Net CONE ($/MW-Day) (UCAP)[23]	$252.53	$251.34

[18] PJM Transmittal at 17 and Brattle 2018 CONE Study at 14-15 and 17.

[19] *See* Table 1 of PJM Quadrennial Review Filing.

[20] *See* Table 2 of PJM Quadrennial Review Filing.

[21] Quadrennial Review Filing at 20.

[22] *Id.*

Table 2, above, shows the gross CONE, Net Energy & Ancillary Services ("EAS") offset and the resultant Net CONE for the proposed reference resource for two different assumptions: Major Maintenance costs recovered in the energy market and major maintenance costs recovered in the capacity market.

The first column shows these values for the proposed reference resource where major maintenance costs are assumed to be included in the energy market via variable operations and maintenance costs ("VOM"), whereas, the second column shows these values for the proposed reference resource where the major maintenance costs are assumed to be included in the fixed costs (i.e. Gross CONE) in the capacity market. As expected, the Gross CONE value in the second column (inclusion of maintenance costs in capacity market) includes major maintenance and corresponds with a higher Gross CONE value than the first Column (inclusion of maintenance costs in energy market). Table 2 also shows that the VOM value in the second column does not include the major maintenance and is therefore less than the VOM value in the first Column.

Since VOM is included as part of the total cost-based offer used to determine the annual Net EAS of the proposed reference resource, a lower VOM corresponds with higher Net EAS revenues. That is because a resource with lower cost-based offers will be dispatched more often than one with higher offers. Therefore, the second column shows higher Net EAS revenues than the first column in this simulation.

Because of this off-setting effect, the resultant Net CONE values are nearly identical regardless of whether major maintenance costs are included in the energy or capacity market.

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[23] Determined using the system-wide EFORd value from the 2018 Base Residual Auction conducted for the 2021/2022 Delivery Year.

II. CORRESPONDENCE AND COMMUNICATIONS

Correspondence and communications regarding this filing should be sent to the following individuals:

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III. SERVICE

PJM has served a copy of this filing on all PJM members and on all state utility regulatory commissions in the PJM Region by posting this filing electronically. In accordance with the Commission's regulations,[24] PJM will post a copy of this filing to the FERC filings section of its internet site, located at the following link: http://www.pjm.com/documents/ferc-manuals/ferc-filings.aspx with a specific link to the newly-filed document, and will send an e-mail on the same date as this filing to all PJM members and all state utility regulatory commissions in the PJM Region[25] alerting them that this filing has been made by PJM and is available by following such link. PJM also serves the parties listed on the Commission's official service list for this docket. If the document is not immediately available by using the referenced link, the document will be available through the referenced link within 24 hours of the filing. Also, a copy of this filing will be available on the FERC's eLibrary website located at the following link: http://www.ferc.gov/docs-filing/elibrary.asp in accordance with the

[24] *See* 18 C.F.R. §§ 35.2(e) and 385.2010(f)(3).

[25] PJM already maintains, updates, and regularly uses e-mail lists for all PJM members and affected state commissions.

Commission's regulations and Order No. 714. PJM also served this on each person designated on the official service list maintained by the Commission for this proceeding.

IV. CONCLUSION

Wherefore, PJM requests that the Commission accept this response to the Commission's deficiency letter.

Respectfully submitted,

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On behalf of
PJM Interconnection, L.L.C.

CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document upon each person designated on the official service list compiled by the Secretary in this proceeding.

Dated at Audubon, this 14th day of February 2019.

/s/ *Chen Lu*

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Attachment A

Table 9: Plant Capital Costs for CT Reference Resource in Nominal $ for 2022 Online Date

	CONE Area			
	1	2	3	4
	EMAAC	SWMAAC	Rest of RTO	WMAAC
Capital Costs (in $millions)	*352 MW*	*355 MW*	*321 MW*	*344 MW*
Owner Furnished Equipment				
Gas Turbines	$74.4	$74.4	$74.4	$74.4
SCR	$26.6	$26.6	$0.0	$26.6
Sales Tax	$6.7	$6.1	$4.7	$6.4
Total Owner Furnished Equipment	**$107.7**	**$107.1**	**$79.1**	**$107.4**
EPC Costs				
Equipment				
Other Equipment	$25.7	$25.6	$28.5	$25.7
Construction Labor	$43.5	$31.8	$31.0	$37.6
Other Labor	$16.5	$15.3	$12.9	$16.0
Materials	$6.6	$6.5	$6.5	$6.6
Sales Tax	$2.1	$1.9	$2.2	$2.0
EPC Contractor Fee	$20.2	$18.8	$16.0	$19.5
EPC Contingency	$22.2	$20.7	$17.6	$21.5
Total EPC Costs	**$136.8**	**$120.5**	**$114.8**	**$128.9**
Non-EPC Costs				
Project Development	$12.2	$11.4	$9.7	$11.8
Mobilization and Start-Up	$2.4	$2.3	$1.9	$2.4
Net Start-Up Fuel Costs	$2.6	$1.7	$0.2	$0.6
Electrical Interconnection	$7.8	$7.8	$7.1	$7.6
Gas Interconnection	$29.1	$29.1	$29.1	$29.1
Land	$0.4	$0.7	$0.3	$0.5
Fuel Inventories	$3.0	$3.0	$2.7	$2.9
Non-Fuel Inventories	$1.2	$1.1	$1.0	$1.2
Owner's Contingency	$4.7	$4.6	$4.2	$4.5
Financing Fees	$8.0	$7.5	$6.5	$7.7
Total Non-EPC Costs	**$71.4**	**$69.2**	**$62.6**	**$68.3**
Total Capital Costs	**$316.0**	**$296.8**	**$256.5**	**$304.7**
Overnight Capital Costs ($million)	**$316**	**$297**	**$257**	**$305**
Overnight Capital Costs ($/kW)	**$898**	**$836**	**$799**	**$886**
Installed Cost ($/kW)	**$938**	**$874**	**$835**	**$925**

Table 19: Recommended CONE for CT Plants in 2022/2023

				Simple Cycle			
				EMAAC	SWMAAC	Rest of RTO	WMAAC
	Gross Costs						
[1]	Overnight	*$m*		$316	$297	$257	$305
[2]	Installed (inc. IDC)	*$m*		$330	$310	$268	$318
[3]	First Year FOM	*$m/yr*		$5	$9	$6	$4
[4]	**Net Summer ICAP**	***MW***		**352**	**355**	**321**	**344**
	Unitized Costs						
[5]	Overnight	*$/kW*	= [1] / [4]	$898	$836	$799	$886
[6]	Installed (inc. IDC)	*$/kW*	= [2] / [4]	$938	$874	$835	$925
[7]	Levelized FOM	*$/kW-yr*	= [3] / [4]	$16	$24	$18	$15
[8]	**After-Tax WACC**	***%***		**7.4%**	**7.5%**	**7.4%**	**7.4%**
[9]	Effective Charge Rate	*%*		10.1%	10.1%	10.0%	10.0%
[10]	**Levelized CONE**	***$/MW-yr***	= [5] x [9] + [7]	**$106,400**	**$108,400**	**$98,200**	**$103,800**
	Prior Auction CONE						
[11]	PJM 2021/22 CONE	*$/MW-yr*		$133,144	$140,953	$133,016	$134,124
[12]	Escalated to 2022/23	*$/MW-yr*	= [11] x 1.028	$136,900	$144,900	$136,700	$137,900
	Difference between Updated CONE and Escalated Prior Auction CONE						
[13]	Escalated to 2022/23	*$/MW-yr*	= [10] - [12]	($30,400)	($36,500)	($38,600)	($34,000)
[14]	Escalated to 2022/23	*%*	= [13] / [12]	-22%	-25%	-28%	-25%

Sources and notes:

PJM 2021/22 parameters escalated to 2022/23 at 2.8% annually, based on S&L analysis of escalation rates for materials, turbine and labor costs.

CONE values expressed in 2022 dollars and ICAP terms.