# MOPR/FRR Sensitivity Analyses of the 2021/2022 RPM Base Residual Auction

The Independent Market Monitor for PJM

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## Introduction

This report, prepared by the Independent Market Monitor for PJM (IMM or MMU), addresses and quantifies the impact of potential MOPR/FRR scenarios on market outcomes in the Reliability Pricing Model (RPM) Base Residual Auction (BRA) (for the 2021/2022 Delivery Year) which was held from May 10 to 16, 2018.[1]

This report addresses, explains and quantifies the market outcomes of applying unit specific Fixed Resource Requirement (FRR) in defined ways.[2]

## Conclusions and Recommendations

The results of the analysis show that removing units and associated load from the markets, as defined by the resource specific FRR approach, significantly reduces capacity market prices when the removed resources did not clear the auction (extra marginal resource). This is not surprising because, in such cases, removing matching load means that the demand curve is shifted while removal of the supply that did not clear does not affect the outcome. The removed supply is offered at prices above the clearing price. In such cases, the price impacts result from the shift of the demand curve to the left without a corresponding shift of the supply curve. The results of the resource specific FRR approach when the removed resources did clear the auction (infra marginal resources) is generally not significant. In such cases, a segment of the supply curve is removed from the supply that cleared and the demand curve is shifted to the left.[3]

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[1] The MMU performs sensitivity analyses for each RPM Base Residual Auction. The MMU has developed an algorithm to replicate the results of Base Residual Auction. The results of the 2021/2022 RPM Base Residual Auction conducted by PJM were replicated using the MMU's approach. The total MW cleared and clearing prices for every constrained LDA using the MMU's algorithm were identical to the corresponding total MW cleared and clearing prices under PJM's method. For details on the clearing process and the MMU's method, see Attachment A to the "Analysis of the 2021/2022 RPM Base Residual Auction Revised," <http://www.monitoringanalytics.com/reports/Reports/2018/IMM_Analysis_of_the_20212022_RPM_BRA_Revised_20180824.pdf> (August 24, 2018).

[2] The values stated in this report for the RTO and LDAs refer to the aggregate level including all nested LDAs unless otherwise specified. For example, RTO values include the entire PJM market and all LDAs. Rest of RTO values are RTO values net of nested LDA values.

[3] See Attachment for illustration through a simple two LDA example of how clearing prices are affected by subsidies for extra marginal and infra marginal resources.

The results show that there are significant price impacts across the range of MW subject to resource specific FRR. There is no safe level and no level of resource specific FRR that would not significantly suppress prices. For example, with only a 2,000 MW level of resource specific FRR, for units that did not clear the auction, the resource specific FRR option reduces rest of RTO prices by 13.4 percent.

PJM's approach would result in a significant increase in capacity prices and in the cost of capacity. Under PJM's proposed repricing method using a two stage auction clearing, the clearing quantities are obtained in the first stage auction where all the subsidized resources are included in the market clearing with offers at $0 per MW-day.[4] The clearing prices are determined in the second stage auction, where the subsidized resources are removed from the supply while the VRR requirements are left unchanged. The sensitivity results show a substantial impact on clearing prices and revenues. Additional high priced offers need to be cleared in the second stage auction in order to the meet the same demand curve with reduced supply. Under PJM's proposal, the additional high priced capacity that cleared in the second stage auction but not the first would not take on any capacity performance obligations despite setting clearing prices and being paid the lost opportunity cost.

**Table 1 Scenario summary of change in rest of RTO market clearing prices: 2021/2022 RPM Base Residual Auction**

| Scenario Description | Rest of RTO Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
|---|---|---|---|---|
| Actual Results | $140.00 | | | |
| FRR for Cost of Service Units | $84.77 | ($55.23) | (39.5%) | 34,114.6 |
| FRR for Units at Risk of Retirement | $70.00 | ($70.00) | (50.0%) | 23,741.1 |
| FRR for Annual Wind and Solar Units | $140.00 | $0.00 | 0.0% | 1,257.1 |
| FRR for 25 percent of Coal and Nuclear Resource MW | $100.21 | ($39.79) | (28.4%) | 18,866.3 |
| FRR for 50 percent of Coal and Nuclear Resource MW | $69.96 | ($70.04) | (50.0%) | 37,732.7 |
| FRR for 100 percent of Coal and Nuclear Resource MW | $25.00 | ($115.00) | (82.1%) | 75,496.2 |
| FRR for 2,000 MW Extra Marginal Supply | $121.21 | ($18.79) | (13.4%) | 2,000.0 |
| FRR for 4,000 MW Extra Marginal Supply | $107.20 | ($32.80) | (23.4%) | 4,000.0 |
| FRR for 6,000 MW Extra Marginal Supply | $93.50 | ($46.50) | (33.2%) | 6,000.0 |
| FRR for 8,000 MW Extra Marginal Supply | $84.77 | ($55.23) | (39.5%) | 8,000.0 |
| FRR for 10,000 MW Extra Marginal Supply | $78.44 | ($61.56) | (44.0%) | 10,000.0 |
| FRR for 12,000 MW Extra Marginal Supply | $69.98 | ($70.02) | (50.0%) | 12,000.0 |
| FRR for Units at Risk of Retirement (PJM's Repricing Method) | $234.67 | $94.67 | 67.6% | 23,741.1 |
| FRR for Units at High Risk of Retirement (PJM's Repricing Method) | $180.62 | $40.62 | 29.0% | 11,777.2 |

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[4]  See Meeting Materials for the Markets and Reliability Committee Special Session: PJM Response to FERC on Capacity Market Reforms, "PJM Proposal including Stakeholder Input", September 11, 2018, <https://www.pjm.com/-/media/committees-groups/committees/mrc/20180911-special/20180911-pjm-proposal-including-stakeholder-input.ashx>.

## *Results*

For this analysis, the reliability requirement is adjusted by the unforced capacity (UCAP) MW of the identified resources, except when simulating PJM's proposed two stage auction clearing because the demand curve is not adjusted in PJM's approach. Based on the mathematical definition of the Variable Resource Requirement (VRR or demand curve), the reduction in the reliability requirement results in a slight change in the slope of the VRR curve and the shift in the VRR curve is not parallel.[5] For this analysis, the resources are matched to the LDA reliability requirement based on the defined modeled LDA of the resource. Unlike the current FRR application where the resources in an FRR plan are not known until closer to the start of the relevant delivery year, the unit specific FRR resources would be identified at the time of the auction. Since the location of the unit specific FRR resource would be identified, the LDA Minimum Internal Resource Requirements are not needed and are not applied in this analysis except in the case of existing FRR plans, and all existing Capacity Emergency Transfer Limits (CETL) are respected.[6]

Table 1 summarizes the results of the sensitivity analyses, using price impacts for Rest of RTO for each sensitivity.

### Impact of FRR for Resources with Cost of Service Regulation

Table 2 shows the results of the 2021/2022 RPM Base Residual Auction if resources with cost of service regulation, including public power resources, had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, cost of service and public power resources accounted for 34,114.6 MW of offered capacity.[7] In the 2021/2022 RPM

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[5]  See Attachment.

[6]  "PJM Manual 18: PJM Capacity Market," Rev. 40 (Feb. 22, 2018) at 225-226. An LDA has a defined import capability, Capacity Emergency Transfer Limit (CETL), to import resources from outside the LDA. FRR entities are allowed to account for this import capability by including resources from outside the LDA in their FRR capacity plan. The Minimum Internal Resource Requirement is defined as the (LDA Reliability Requirement – LDA CETL)/(LDA Preliminary Zonal Peak Load Forecast * FPR). The FRR obligation is multiplied by the LDA Minimum Internal Resource Requirement to determine the reduction in the LDA reliability requirement.

[7]  Unless otherwise specified, all volumes and prices are in terms of unforced capacity (UCAP), which is calculated as installed capacity (ICAP) times (1-EFORd) for generation resources and as ICAP times the Forecast Pool Requirement (FPR) for demand resources and energy efficiency resources. The EFORd values in this report are the EFORd values used in the 2021/2022 RPM Base Residual Auction.

Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ComEd, ATSI, EMAAC, PSEG, and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $55.23 per MW-day to $84.77 per MW-day. The ATSI clearing price would have decreased by $7.32 per MW-day to $164.01 per MW-day. The ComEd clearing price would have decreased by $6.54 per MW-day to $189.01 per MW-day. The EMAAC clearing price would have decreased by $0.73 per MW-day to $165.00 per MW-day. The PSEG clearing price would have decreased by $0.13 per MW-day to $204.16 per MW-day. The BGE clearing price would have decreased by $0.10 per MW-day to $200.20 per MW-day. The DEOK clearing price would have decreased by $11.53 per MW-day to $128.47 per MW-day.

**Table 2 Impact of cost of service and public power units electing resource specific FRR: 2021/2022 RPM Base Residual Auction[8]**

**Scenario 1**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for Cost of Service Units Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
|---|---|---|---|---|---|
| RTO | $140.00 | $84.77 | ($55.23) | (39.5%) | 34,114.6 |
| ATSI | $171.33 | $164.01 | ($7.32) | (4.3%) | |
| ComEd | $195.55 | $189.01 | ($6.54) | (3.3%) | |
| EMAAC | $165.73 | $165.00 | ($0.73) | (0.4%) | |
| PSEG | $204.29 | $204.16 | ($0.13) | (0.1%) | |
| BGE | $200.30 | $200.20 | ($0.10) | (0.0%) | |
| DEOK | $140.00 | $128.47 | ($11.53) | (8.2%) | |

## Impact of FRR for Resources at Risk of Retirement

Table 3 shows the results of the 2021/2022 RPM Base Residual Auction if units at risk of retirement had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, units at risk of retirement accounted for 23,741.1 MW of offered capacity.[9] In

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[8]  The FRR Capacity (UCAP MW) is specified only for the entire RTO to maintain data confidentiality.

[9]  Non-nuclear units that have not recovered avoidable costs from total market revenues in two of the last three years or have not cleared either the 2019/2020 or the 2020/2021 capacity auctions are considered at risk of retirement. The non-nuclear MW at risk are lower than reported in the State of the Market Report because units that have subsequently started the

the 2021/2022 RPM Base Residual Auction, the import constraints for ComEd, ATSI, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ComEd, EMAAC and PSEG import constraints would have remained binding, BGE import constraint would not have been binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $70.00 per MW-day to $70.00 per MW-day. The ATSI clearing price would have decreased by $101.33 per MW-day to $70.00 per MW-day. The ComEd clearing price would have decreased by $6.53 per MW-day to $189.02 per MW-day. The EMAAC clearing price would have decreased by $0.26 per MW-day to $165.47 per MW-day. The PSEG clearing price would have decreased by $0.76 per MW-day to $203.53 per MW-day. The BGE clearing price would have decreased by $130.30 per MW-day to $70.00 per MW-day. The DEOK clearing price would have decreased by $11.53 per MW-day to $128.47 per MW-day.

**Table 3 Impact of units at risk of retirement electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 2**

| LDA | Base Residual Auction | FRR for Units at Risk of Retirement | | | |
| | Clearing Price ($ per MW-Day) | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
|---|---|---|---|---|---|
| RTO | $140.00 | $70.00 | ($70.00) | (50.0%) | 23,741.1 |
| ATSI | $171.33 | $70.00 | ($101.33) | (59.1%) | |
| ComEd | $195.55 | $189.02 | ($6.53) | (3.3%) | |
| EMAAC | $165.73 | $165.47 | ($0.26) | (0.2%) | |
| PSEG | $204.29 | $203.53 | ($0.76) | (0.4%) | |
| BGE | $200.30 | $70.00 | ($130.30) | (65.1%) | |
| DEOK | $140.00 | $128.47 | ($11.53) | (8.2%) | |

## Impact of FRR for Annual Wind and Solar Resources

Table 4 shows the results of the 2021/2022 RPM Base Residual Auction if annual wind and solar units, not including summer or winter seasonal generation, had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, annual wind and solar resources accounted for 1,257.1 MW of offered capacity. In the 2021/2022 RPM Base

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deactivation process or requested deactivation are excluded from the at risk analysis. Nuclear plants at risk are defined to be plants that will not cover avoidable costs based on forward prices. For nuclear plants, avoidable costs consist of NEI operating costs, and capital expenditures. See the 2017 State of the Market Report for PJM, Section 7: Net Revenue.

Residual Auction, the import constraints for ComEd, ATSI, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ComEd, EMAAC, ATSI, PSEG and BGE import constraints would have remained binding.

The RTO clearing price would have remained the same at $140.00 per MW-day. The ATSI clearing price would have remained the same at $171.33 per MW-day. The ComEd clearing price would have decreased by $2.50 per MW-day to $193.05 per MW-day. The EMAAC clearing price would remained the same at $165.73 per MW-day. The PSEG clearing price would have decreased by $0.40 per MW-day to $203.89 per MW-day. The BGE clearing price would have remained the same at $200.30 per MW-day.

**Table 4 Impact of annual wind and solar units electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 3**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for Annual Wind and Solar Units Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
|---|---|---|---|---|---|
| RTO | $140.00 | $140.00 | $0.00 | 0.0% | 1,257.1 |
| ATSI | $171.33 | $171.33 | $0.00 | 0.0% | |
| ComEd | $195.55 | $193.05 | ($2.50) | (1.3%) | |
| EMAAC | $165.73 | $165.73 | $0.00 | 0.0% | |
| PSEG | $204.29 | $203.89 | ($0.40) | (0.2%) | |
| BGE | $200.30 | $200.30 | $0.00 | 0.0% | |

## Impact of FRR for 25 percent of Coal and Nuclear Resource MW

Table 5 shows the results of the 2021/2022 RPM Base Residual Auction if 25 percent of coal and nuclear resource MW had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, coal and nuclear resources accounted for 75,496.2 MW of offered capacity. Thus, 25 percent of coal and nuclear resource MW are 18,866.3 MW.[10] In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $39.79 per MW-day to $100.21 per MW-day. The ATSI clearing price would have decreased by $25.65 per MW-day to $145.68 per MW-day. The ComEd clearing price would have decreased by $31.33 per MW-day to $164.22 per MW-day. The EMAAC clearing price would have remained the

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[10]    This result reflects rounding at the offer segment level.

same at $165.73 per MW-day. The PSEG clearing price would have remained the same at $204.29 per MW-day. The BGE clearing price would have decreased by $39.53 per MW-day to $160.77 per MW-day. The DEOK clearing price would have decreased by $22.75 per MW-day to $117.25 per MW-day.

**Table 5 Impact of 25 percent of coal and nuclear resource MW electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

Scenario 4

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 25 percent of Coal and Nuclear Resource MW | | | |
|-----|----|----|----|----|----|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $100.21 | ($39.79) | (28.4%) | 18,866.3 |
| ATSI | $171.33 | $145.68 | ($25.65) | (15.0%) | |
| ComEd | $195.55 | $164.22 | ($31.33) | (16.0%) | |
| EMAAC | $165.73 | $165.73 | $0.00 | 0.0% | |
| PSEG | $204.29 | $204.29 | $0.00 | 0.0% | |
| BGE | $200.30 | $160.77 | ($39.53) | (19.7%) | |
| DEOK | $140.00 | $117.25 | ($22.75) | (16.3%) | |

## Impact of FRR for 50 percent of Coal and Nuclear Resource MW

Table 6 shows the results of the 2021/2022 RPM Base Residual Auction if 50 percent of coal and nuclear resource MW had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, coal and nuclear resources accounted for 75,496.2 MW of offered capacity. Thus, 50 percent of coal and nuclear resource MW are 37,732.7 MW. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ComEd, EMAAC, PSEG and BGE import constraints would have remained binding, ATSI import constraint would not have been binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $70.04 per MW-day to $69.96 per MW-day. The ATSI clearing price would have decreased by $101.37 per MW-day to $69.96 per MW-day. The ComEd clearing price would have decreased by $116.86 per MW-day to $78.69 per MW-day. The EMAAC clearing price would have decreased by $15.81 per MW-day to $149.92 per MW-day. The PSEG clearing price would have remained the same at $204.29 per MW-day. The BGE clearing price would have decreased by $40.53 per MW-day to $159.77 per MW-day. The DEOK clearing price would have decreased by $54.01 per MW-day to $85.99 per MW-day.

**Table 6 Impact of 50 percent of coal and nuclear resource MW electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 5**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 50 percent of Coal and Nuclear Resource MW | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $69.96 | ($70.04) | (50.0%) | 37,732.7 |
| ATSI | $171.33 | $69.96 | ($101.37) | (59.2%) | |
| ComEd | $195.55 | $78.69 | ($116.86) | (59.8%) | |
| EMAAC | $165.73 | $149.92 | ($15.81) | (9.5%) | |
| PSEG | $204.29 | $204.29 | $0.00 | 0.0% | |
| BGE | $200.30 | $159.77 | ($40.53) | (20.2%) | |
| DEOK | $140.00 | $85.99 | ($54.01) | (38.6%) | |

## Impact of FRR for 100 percent of Coal and Nuclear Resource MW

Table 7 shows the results of the 2021/2022 RPM Base Residual Auction if 100 percent of coal and nuclear resource MW had elected the resource specific FRR option. In the 2021/2022 Base Residual Auction, coal and nuclear resources accounted for 75,496.2 MW of offered capacity. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ComEd and PSEG import constraints would have remained binding, ATSI, EMAAC and BGE import constraints would not have been binding and the MAAC import constraint would have been binding.

The RTO clearing price would have decreased by $115.00 per MW-day to $25.00 per MW-day. The ATSI clearing price would have decreased by $146.33 per MW-day to $25.00 per MW-day. The ComEd clearing price would have decreased by $151.62 per MW-day to $43.93 per MW-day. The MAAC clearing price would have increased by $10.92 per MW-day to $150.92 per MW-day. The EMAAC clearing price would have decreased by $14.81 per MW-day to $150.92 per MW-day. The PSEG clearing price would have decreased by $2.11 per MW-day to $202.18 per MW-day. The BGE clearing price would have decreased by $49.38 per MW-day to $150.92 per MW-day.

**Table 7 Impact of 100 percent of coal and nuclear resource MW electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 6**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 100 percent of Coal and Nuclear Resource MW | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $25.00 | ($115.00) | (82.1%) | 75,496.2 |
| ATSI | $171.33 | $25.00 | ($146.33) | (85.4%) | |
| ComEd | $195.55 | $43.93 | ($151.62) | (77.5%) | |
| MAAC | $140.00 | $150.92 | $10.92 | 7.8% | |
| EMAAC | $165.73 | $150.92 | ($14.81) | (8.9%) | |
| PSEG | $204.29 | $202.18 | ($2.11) | (1.0%) | |
| BGE | $200.30 | $150.92 | ($49.38) | (24.7%) | |

## Impact of FRR for 2,000 MW of Extra Marginal Resources

In order to show the impacts of the selection of the resource specific FRR option by smaller MW levels of extra marginal resources, sensitivities were run at a range of MW levels: 2,000 MW; 4,000 MW; 6,000 MW; 8,000 MW; 10,000 MW; and 12,000 MW. The MW levels of extra marginal resources are assigned to LDAs based on each LDA's share of the reliability requirement.

Table 8 shows the results of the 2021/2022 RPM Base Residual Auction if 2,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $18.79 per MW-day to $121.21 per MW-day. The ATSI clearing price would have decreased by $26.33 per MW-day to $145.00 per MW-day. The ComEd clearing price would have decreased by $6.55 per MW-day to $189.00 per MW-day. The EMAAC clearing price would have decreased by $0.73 per MW-day to $165.00 per MW-day. The PSEG clearing price would have decreased by $19.12 per MW-day to $185.17 per MW-day. The BGE clearing price would have decreased by $19.80 per MW-day to $180.50 per MW-day. The DEOK clearing price would have decreased by $11.53 per MW-day to $128.47 per MW-day.

**Table 8 Impact of 2,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 7**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 2,000 MW Extra Marginal Supply | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $121.21 | ($18.79) | (13.4%) | 2,000.0 |
| ATSI | $171.33 | $145.00 | ($26.33) | (15.4%) | |
| ComEd | $195.55 | $189.00 | ($6.55) | (3.3%) | |
| EMAAC | $165.73 | $165.00 | ($0.73) | (0.4%) | |
| PSEG | $204.29 | $185.17 | ($19.12) | (9.4%) | |
| BGE | $200.30 | $180.50 | ($19.80) | (9.9%) | |
| DEOK | $140.00 | $128.47 | ($11.53) | (8.2%) | |

## Impact of FRR for 4,000 MW of Extra Marginal Resources

Table 9 shows the results of the 2021/2022 RPM Base Residual Auction if 4,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $32.80 per MW-day to $107.20 per MW-day. The ATSI clearing price would have decreased by $26.33 per MW-day to $145.00 per MW-day. The ComEd clearing price would have decreased by $6.45 per MW-day to $189.10 per MW-day. The EMAAC clearing price would have decreased by $1.22 per MW-day to $164.51 per MW-day. The PSEG clearing price would have decreased by $38.21 per MW-day to $166.08 per MW-day. The BGE clearing price would have decreased by $19.80 per MW-day to $180.50 per MW-day. The DEOK clearing price would have decreased by $17.07 per MW-day to $122.93 per MW-day.

**Table 9 Impact of 4,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 8**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 4,000 MW Extra Marginal Supply | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $107.20 | ($32.80) | (23.4%) | 4,000.0 |
| ATSI | $171.33 | $145.00 | ($26.33) | (15.4%) | |
| ComEd | $195.55 | $189.10 | ($6.45) | (3.3%) | |
| EMAAC | $165.73 | $164.51 | ($1.22) | (0.7%) | |
| PSEG | $204.29 | $166.08 | ($38.21) | (18.7%) | |
| BGE | $200.30 | $180.50 | ($19.80) | (9.9%) | |
| DEOK | $140.00 | $122.93 | ($17.07) | (12.2%) | |

## Impact of FRR for 6,000 MW of Extra Marginal Resources

Table 10 shows the results of the 2021/2022 RPM Base Residual Auction if 6,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $46.50 per MW-day to $93.50 per MW-day. The ATSI clearing price would have decreased by $26.33 per MW-day to $145.00 per MW-day. The ComEd clearing price would have increased by $3.55 per MW-day to $199.10 per MW-day. The EMAAC clearing price would have decreased by $9.27 per MW-day to $156.46 per MW-day. The PSEG clearing price would have decreased by $39.12 per MW-day to $165.17 per MW-day. The BGE clearing price would have decreased by $39.53 per MW-day to $160.77 per MW-day. The DEOK clearing price would have decreased by $22.75 per MW-day to $117.25 per MW-day.

**Table 10 Impact of 6,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 9**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 6,000 MW Extra Marginal Supply | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $93.50 | ($46.50) | (33.2%) | 6,000.0 |
| ATSI | $171.33 | $145.00 | ($26.33) | (15.4%) | |
| ComEd | $195.55 | $199.10 | $3.55 | 1.8% | |
| EMAAC | $165.73 | $156.46 | ($9.27) | (5.6%) | |
| PSEG | $204.29 | $165.17 | ($39.12) | (19.1%) | |
| BGE | $200.30 | $160.77 | ($39.53) | (19.7%) | |
| DEOK | $140.00 | $117.25 | ($22.75) | (16.3%) | |

## Impact of FRR for 8,000 MW of Extra Marginal Resources

Table 11 shows the results of the 2021/2022 RPM Base Residual Auction if 8,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $55.23 per MW-day to $84.77 per MW-day. The ATSI clearing price would have increased by $124.67 per MW-day to $296.00 per MW-day. The ComEd clearing price would have decreased by $1.09 per MW-day to $194.46 per MW-day. The EMAAC clearing price would have decreased by $20.73 per MW-day to $145.00 per MW-day. The PSEG clearing price would have decreased by $44.13 per MW-day to $160.16 per MW-day. The BGE clearing price would have decreased by $39.53 per MW-day to $160.77 per MW-day. The DEOK clearing price would have decreased by $32.77 per MW-day to $107.23 per MW-day.

**Table 11 Impact of 8,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 10**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 8,000 MW Extra Marginal Supply | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $84.77 | ($55.23) | (39.5%) | 8,000.0 |
| ATSI | $171.33 | $296.00 | $124.67 | 72.8% | |
| ComEd | $195.55 | $194.46 | ($1.09) | (0.6%) | |
| EMAAC | $165.73 | $145.00 | ($20.73) | (12.5%) | |
| PSEG | $204.29 | $160.16 | ($44.13) | (21.6%) | |
| BGE | $200.30 | $160.77 | ($39.53) | (19.7%) | |
| DEOK | $140.00 | $107.23 | ($32.77) | (23.4%) | |

## Impact of FRR for 10,000 MW of Extra Marginal Resources

Table 12 shows the results of the 2021/2022 RPM Base Residual Auction if 10,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $61.56 per MW-day to $78.44 per MW-day. The ATSI clearing price would have increased by $44.65 per MW-day to $215.98 per MW-day. The ComEd clearing price would have decreased by $8.87 per MW-day to $186.68 per MW-day. The EMAAC clearing price would have decreased by $29.68 per MW-day to $136.05 per MW-day. The PSEG clearing price would have decreased by $50.06 per MW-day to $154.23 per MW-day. The BGE clearing price would have decreased by $19.80 per MW-day to $180.50 per MW-day. The DEOK clearing price would have decreased by $36.87 per MW-day to $103.13 per MW-day.

**Table 12 Impact of 10,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 11**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 10,000 MW Extra Marginal Supply | | | |
|-----|-----|-----|-----|-----|-----|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $78.44 | ($61.56) | (44.0%) | 10,000.0 |
| ATSI | $171.33 | $215.98 | $44.65 | 26.1% | |
| ComEd | $195.55 | $186.68 | ($8.87) | (4.5%) | |
| EMAAC | $165.73 | $136.05 | ($29.68) | (17.9%) | |
| PSEG | $204.29 | $154.23 | ($50.06) | (24.5%) | |
| BGE | $200.30 | $180.50 | ($19.80) | (9.9%) | |
| DEOK | $140.00 | $103.13 | ($36.87) | (26.3%) | |

## Impact of FRR for 12,000 MW of Extra Marginal Resources

Table 13 shows the results of the 2021/2022 RPM Base Residual Auction if 12,000 MW of resources that did not clear the 2021/2022 Base Residual Auction had elected the resource specific FRR option. In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that the ATSI, ComEd, EMAAC, PSEG and BGE import constraints would have remained binding and the DEOK import constraint would have been binding.

The RTO clearing price would have decreased by $70.02 per MW-day to $69.98 per MW-day. The ATSI clearing price would have increased by $19.84 per MW-day to $191.17 per MW-day. The ComEd clearing price would have decreased by $47.46 per MW-day to $148.09 per MW-day. The EMAAC clearing price would have decreased by $30.68 per MW-day to $135.05 per MW-day. The PSEG clearing price would have decreased by $67.78 per MW-day to $136.51 per MW-day. The BGE clearing price would have decreased by $19.80 per MW-day to $180.50 per MW-day. The DEOK clearing price would have decreased by $40.70 per MW-day to $99.30 per MW-day.

**Table 13 Impact of 12,000 MW of extra marginal resources electing resource specific FRR: 2021/2022 RPM Base Residual Auction**

**Scenario 12**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for 12,000 MW Extra Marginal Supply | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $69.98 | ($70.02) | (50.0%) | 12,000.0 |
| ATSI | $171.33 | $191.17 | $19.84 | 11.6% | |
| ComEd | $195.55 | $148.09 | ($47.46) | (24.3%) | |
| EMAAC | $165.73 | $135.05 | ($30.68) | (18.5%) | |
| PSEG | $204.29 | $136.51 | ($67.78) | (33.2%) | |
| BGE | $200.30 | $180.50 | ($19.80) | (9.9%) | |
| DEOK | $140.00 | $99.30 | ($40.70) | (29.1%) | |

## Impact of FRR for Units at Risk of Retirement under PJM's Proposed Repricing Two Stage Auction Method

Table 14 shows the results of the 2021/2022 RPM Base Residual Auction if units at risk of retirement had elected the resource specific FRR option under the PJM's proposed Repricing Method using two stage auction clearing. In the 2021/2022 Base Residual Auction, units at risk of retirement accounted for 23,741.1 MW of offered capacity.

PJM proposed to clear the auction in two stages.[11] In the first stage, all subsidized resources would be entered into the auction at $0 per MW-day. In the second stage, the auction would be cleared after removing the offers of the subsidized resources. The reliability requirement, VRR curves and capacity import limits of every LDA would be kept the same in both stages of the auction clearing. The clearing quantities would be obtained from the solution of the first stage auction. The clearing prices would be set by the second stage of the auction clearing. Any capacity that cleared only in the second stage of auction clearing would be paid a lost opportunity cost in $ per MW-day equal to the difference between the clearing price and offered price, but would not be treated as cleared capacity resources and would not take on any performance obligations.

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[11]   See Meeting Materials for the Markets and Reliability Committee Special Session: PJM Response to FERC on Capacity Market Reforms, "PJM Proposal including Stakeholder Input", September 11, 2018, <https://www.pjm.com/-/media/committees-groups/committees/mrc/20180911-special/20180911-pjm-proposal-including-stakeholder-input.ashx>.

In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that ATSI, ComEd, EMAAC, PSEG and BGE imports constraints would not have been binding and that the MAAC import limit would have been binding. The RTO clearing price would have increased by $94.67 per MW-day to $234.67 per MW-day. The ATSI clearing price would have increased by $63.34 per MW-day to $234.67 per MW-day. The ComEd clearing price would have increased by $39.12 per MW-day to $234.67 per MW-day. The EMAAC clearing price would have increased by $273.31 per MW-day to $439.04 per MW-day. The PSEG clearing price would have increased by $238.75 per MW-day to $439.04 per MW-day. The BGE clearing price would have increased by $238.74 per MW-day to $439.04 per MW-day.

Table 15 shows the impact on the total revenue of the 2021/2022 RPM Base Residual Auction if units at risk of retirement had elected the resource specific FRR option, and the auction were cleared under the market method and PJM's proposed repricing method. The market method is the method used in the first 12 scenarios. Based on actual auction clearing prices and quantities and make whole MW, total RPM market revenues for the 2021/2022 RPM Base Residual Auction were $9,300,877,106.

If units at risk of retirement elected the resource specific FRR, the auction were cleared under the PJM's proposed repricing method and everything else remained the same, total RPM market revenues for the 2021/2022 RPM Base Residual Auction would have been $16,243.440,563. With the estimated cost of subsidies at $846,884,670, and lost opportunity costs at $651,898,639, the total revenues would have been $17,742,223,873, an increase of $8,441,346,767 or 90.8 percent, compared to the actual results.[12]

If units at risk of retirement elected the resource specific FRR, the auction were cleared under the market method (Scenario 2) and everything else remained the same, total RPM market revenues for the 2021/2022 RPM Base Residual Auction would have been $5,536,178,745. With the estimated cost of subsidies at $846,884,670, the total revenues would have been $6,383,063,415, a decrease of $2,917,813,691 or 31.4 percent, compared to the actual results.

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[12] The subsidy for a nuclear unit is equal to net avoidable costs. This is the amount of payment such units would need in order to continue operating in addition to revenues from the energy and ancillary services markets. Actual subsidy payments could exceed this amount. For nuclear units, avoidable costs consist of NEI operating costs and incremental capital expenditures. For non-nuclear units, the subsidy is equal to the unit's offer price in the 2021/2022 RPM Base Residual Action. This is what such units would need in order to continue operating.

Under PJM's proposed two stage auction method, clearing prices would be determined in the second stage of auction clearing, where the subsidized resources are removed from the supply while the VRR requirements are left unchanged. This approach resulted in clearing additional high priced offers in order to meet the same demand with reduced MW of supply. In some LDAs, removal of subsidized resources meant there was not enough supply to intersect the sloped portion of the VRR curve resulting in clearing prices set at the maximum price, or 1.5 times the net CONE of the LDA. Under PJM's proposed clearing method, the additional capacity which only cleared in the second stage of the auction would be paid lost opportunity cost. These resources would not take on any capacity performance obligations despite setting clearing prices and despite being paid the clearing price.

**Table 14 Impact of units at risk of retirement electing resource specific FRR under PJM's proposed method: 2021/2022 RPM Base Residual Auction**

**Scenario 13**

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for Units at Risk of Retirement (PJM's Repricing Method) | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $234.67 | $94.67 | 67.6% | 23,741.1 |
| ATSI | $171.33 | $234.67 | $63.34 | 37.0% | |
| ComEd | $195.55 | $234.67 | $39.12 | 20.0% | |
| MAAC | $140.00 | $439.04 | $299.04 | 213.6% | |
| EMAAC | $165.73 | $439.04 | $273.31 | 164.9% | |
| PSEG | $204.29 | $439.04 | $234.75 | 114.9% | |
| BGE | $200.30 | $439.04 | $238.74 | 119.2% | |

**Table 15 Change in auction revenue due to units at risk of retirement electing resource specific FRR under PJM's proposed method: 2021/2022 RPM Base Residual Auction**

| | $ per Delivery Year | | |
|---|---|---|---|
| | Actual Results | Market Method | PJM Repricing Method |
| Cleared resource revenue | $9,299,504,396 | $5,536,067,785 | $16,243,440,563 |
| Makewhole revenue | $1,372,710 | $110,960 | |
| Estimated cost of subsidies | | $846,884,670 | $846,884,670 |
| Lost opportunity cost | | | $651,898,639 |
| Total capacity revenue | $9,300,877,106 | $6,383,063,415 | $17,742,223,873 |

## Impact of FRR for Units at High Risk of Retirement under PJM's Proposed Repricing Two Stage Auction Method

Table 16 shows the results of the 2021/2022 RPM Base Residual Auction if units at high risk of retirement had elected the resource specific FRR option under the PJM's proposed Repricing Method using two stage auction clearing. In the 2021/2022 Base

Residual Auction, units at high risk of retirement accounted for 11,777.2 MW of offered capacity.[13]

In the 2021/2022 RPM Base Residual Auction, the import constraints for ATSI, ComEd, EMAAC, PSEG and BGE were binding. The results of the sensitivity show that ATSI, ComEd, and PSEG would have remained binding and EMAAC and BGE import limits would not have been binding. The RTO clearing price would have increased by $40.62 per MW-day to $180.62 per MW-day. The ATSI clearing price would have increased by $28.66 per MW-day to $199.99 per MW-day. The ComEd clearing price would have increased by $4.43 per MW-day to $199.98 per MW-day. The EMAAC clearing price would have increased by $14.89 per MW-day to $180.62 per MW-day. The PSEG clearing price would have remained the same at $204.29 per MW-day. The BGE clearing price would have decreased by $19.68 per MW-day to $180.62 per MW-day.

Table 17 shows the impact on the total revenue of the 2021/2022 RPM Base Residual Auction if units at high risk of retirement had elected the resource specific FRR option, and the auction were cleared under the market method and PJM's proposed repricing method. Based on actual auction clearing prices and quantities and make whole MW, total RPM market revenues for the 2021/2022 RPM Base Residual Auction were $9,300,877,106.

If units at high risk of retirement elected resource specific FRR, the auction were cleared under the PJM's proposed repricing method and everything else remained the same, total RPM market revenues for the 2021/2022 RPM Base Residual Auction would have been $10,335,363,667. With the estimated cost of subsidies at $497,957,568, and lost opportunity costs at $86,546,795 the total revenues would have been $10,919,868,029 an increase of $1,618,990,923 or 17.4 percent, compared to the actual results.

If units at high risk of retirement elected resource specific FRR, the auction were cleared under the market method and everything else remained the same, total RPM market revenues for the 2021/2022 RPM Base Residual Auction would have been $6,693,643,385. With the estimated cost of subsidies at $497,957,568, the total revenues would have been $7,191,600,953, a decrease of $2,109,276,153 or 22.7 percent, compared to the actual results.

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[13] Resources at risk of retirement were ranked by the percent of ACR recovered through the energy and capacity markets. For this analysis, the resources at high risk of retirement consist of the 50 percent of resources at risk of retirement with the lowest percent of ACR recovered in the markets.

**Table 16 Impact of units at high risk of retirement electing resource specific FRR under PJM's proposed method: 2021/2022 RPM Base Residual Auction**

Scenario 14

| LDA | Base Residual Auction Clearing Price ($ per MW-Day) | FRR for Units at High Risk of Retirement (PJM's Repricing Method) | | | |
|---|---|---|---|---|---|
| | | Clearing Price ($ per MW-Day) | Change ($ per MW-Day) | Change Percent | FRR Capacity (UCAP MW) |
| RTO | $140.00 | $180.62 | $40.62 | 29.0% | 11,777.2 |
| ATSI | $171.33 | $199.99 | $28.66 | 16.7% | |
| ComEd | $195.55 | $199.98 | $4.43 | 2.3% | |
| EMAAC | $165.73 | $180.62 | $14.89 | 9.0% | |
| PSEG | $204.29 | $204.29 | $0.00 | 0.0% | |
| BGE | $200.30 | $180.62 | ($19.68) | (9.8%) | |

**Table 17 Change in auction revenue due to units at high risk of retirement electing resource specific FRR under PJM's proposed method: 2021/2022 RPM Base Residual Auction**

| | $ per Delivery Year | | |
|---|---|---|---|
| | Actual Results | Market Method | PJM Repricing Method |
| Cleared resource revenue | $9,299,504,396 | $6,687,813,605 | $10,334,838,073 |
| Makewhole revenue | $1,372,710 | $5,829,780 | $525,593 |
| Estimated cost of subsidies | | $497,957,568 | $497,957,568 |
| Lost opportunity cost | | | $86,546,795 |
| Total capacity revenue | $9,300,877,106 | $7,191,600,953 | $10,919,868,029 |

# Attachment

This attachment illustrates the clearing of the Base Residual Auction with a simple example under two scenarios: the subsidized resource was extra marginal in the actual auction and the subsidized resource was infra marginal in the actual auction.

The example capacity market is divided into two locational deliverable areas (LDA): child LDA and parent LDA. Table A 1 shows the assumed parameters for the derivation of the VRR curve.

The X coordinates of the VRR curve are derived using the following formula.[14]

$For\ i \in \{a, b, c\}$

$$X_i = Reliability\ Requirement \times \left(\frac{1 + IRM + Factor_i}{1 + IRM}\right)$$

where

$$Reliability\ Requirement = Peak\ Load\ Forecast * FPR$$

$$FPR = Forecast\ Pool\ Requirement = (1 + IRM) * (1 - Pool\ Wide\ EFORd)$$

$$IRM = Installed\ Reserve\ Margin\ as\ a\ percentage$$

$Factor_i = percentage\ shift\ of\ coordinate\ i$

Figure A 1 and Figure A 2 show the variable resource requirement (VRR) curves for child and parent LDAs. Table A 2 shows the capacity offers for child LDA and Table A 3 shows the capacity offers for the parent LDA. The capacity emergency transfer limit (CETL) between parent LDA and child LDA is assumed as 150 MW.

## *Base Case: No Subsidies*

Figure A 3 shows the clearing of the child LDA. Figure A 4 shows the clearing of the parent LDA. The capacity imports to the child LDA were constrained by CETL resulting in the child LDA price separating from the parent LDA.[15] The clearing price for the child LDA was $65 per MW-day. The clearing price for the parent LDA was $55 per MW-day.

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[14]  "PJM Manual 18: PJM Capacity Market," Rev. 40 (Feb. 22, 2018) at 39.

[15]  For details on the clearing algorithm used for Base Residual Auction, see "Analysis of the 2021/2022 RPM Base Residual Auction Revised,"

## Scenario 1: Subsidy for Extra Marginal Resource

In this scenario, the extra marginal resource C7, offered for $110 per MW-day, received a subsidy and C7 used the resource specific FRR option. The reliability requirements for the child LDA and the parent LDA were reduced by 200 MW, equal to the unforced capacity of the subsidized resource C7. Table A 4 shows the parameters of the shifted VRR curve. Figure A 5 compares the original VRR curve and the shifted VRR curve. The shifted VRR curve was slightly steeper than the original VRR curve as a result of the definition of the X coordinates.

The results show that when the extra marginal resource was removed together with matching load, the clearing price of the child LDA decreased to $43.63 per MW-day from $65.00 per MW-day in the base case. The clearing price of the parent LDA also decreased to $43.63 per MW-day from $55.00 per MW-day in the base case. The capacity imports to the child LDA were not constrained when the extra marginal resource was removed, which resulted in child LDA not price separating from the parent LDA. The lower clearing prices resulted from the left shift of the VRR curve while the supply curve below the clearing price of the base case remained the same. This example shows that when subsidized resources select the resource specific FRR option, and those resources are extra marginal, the result is to reduce the clearing price for the remaining resources offering competitively in the residual auction.

## Scenario 2: Subsidy for Infra Marginal Resource

In this scenario, the infra marginal resource C2, offered for $25 per MW-day, received a subsidy and C2 used the resource specific FRR option. The reliability requirements for the child LDA and parent LDA were reduced by 140 MW, equal to the unforced capacity of the subsidized resource C2. Table A 5 shows the parameters of the shifted VRR curve.

The results show that the clearing price of the child LDA remained the same at $65.00 per MW-day. The clearing price of the parent LDA also remained the same at $55.00 per MW-day. The capacity imports to the child LDA were constrained, which resulted in child LDA price separating from the parent LDA. The clearing prices in the scenario did not change because the removal of the cleared subsidized resource from the supply curve was followed by the left shift of the VRR curve due to the reduction in the reliability requirement. This example shows that subsidizing resources that clear the

<http://www.monitoringanalytics.com/reports/Reports/2018/IMM_Analysis_of_the_20212022_RPM_BRA_Revised_20180824.pdf> (August 24, 2018).

auction results in same prices or slightly higher prices for the remaining resources offering competitively in the residual auction.[16]

**Table A 1 Parameters for VRR curve: Base case[17]**

| | Child (IRM = 15%, RR = 400 MW UCAP) | | | Parent (IRM = 15%, RR = 800 MW UCAP) | | |
|---|---|---|---|---|---|---|
| | Factors | X (MW UCAP) | Y ($/MW-day) | Factors | X (MW UCAP) | Y ($/MW-day) |
| a | -17.13% | 400.0 | 170.0 | -7.19% | 750.0 | 150.0 |
| b | 7.34% | 500.0 | 90.0 | 7.19% | 850.0 | 100.0 |
| c | 80.74% | 800.0 | 0.0 | 86.25% | 1400.0 | 0.0 |

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[16]  In this example, the clearing prices did not change because the flexibly offered marginal resources were same in both the base case and the Scenario 2. However, in general, it is possible for the clearing prices to be slightly higher or equal. This is because of the slight change in the slope of the VRR curve.
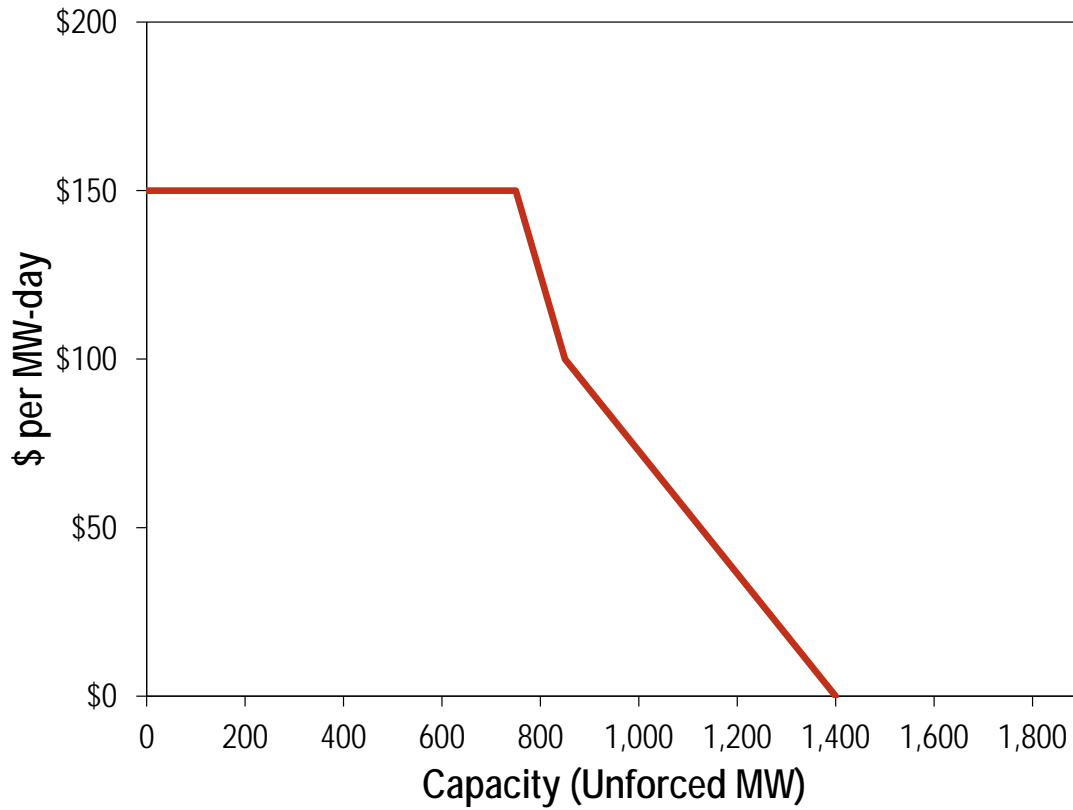
[17]  The factors used in the example are not same as the factors used by PJM in the Base Residual Auction.

**Figure A 1 VRR curve for child LDA**
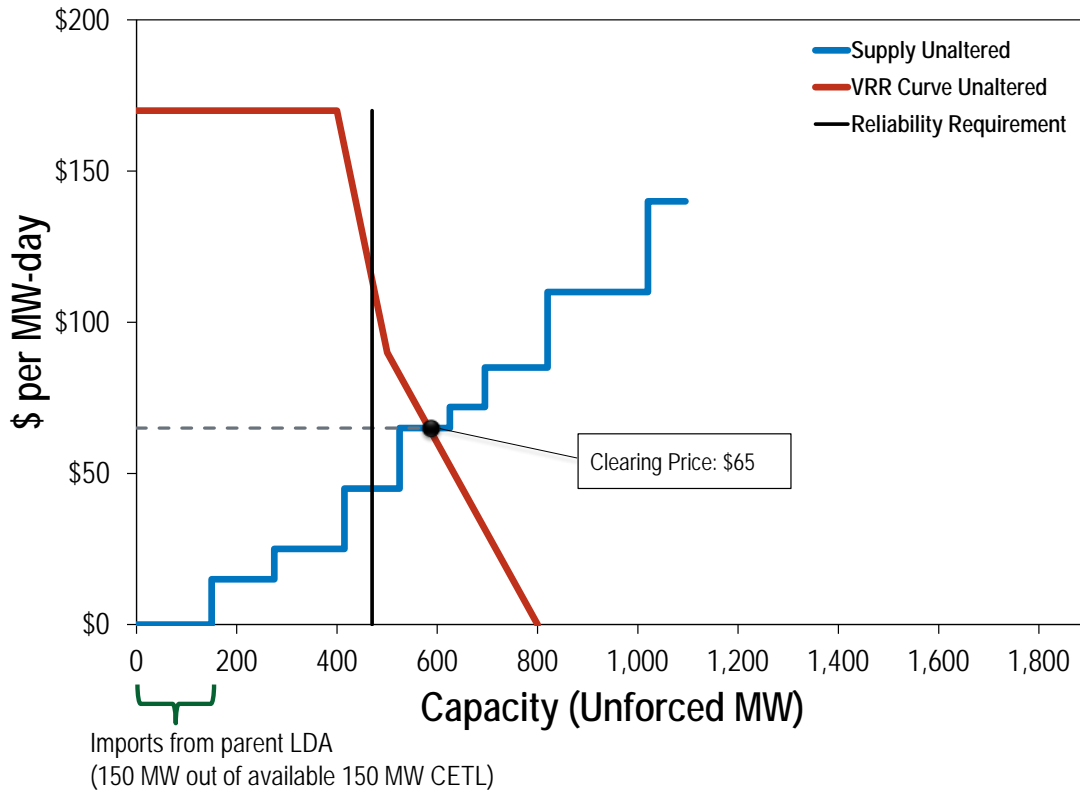
**Figure A 2 VRR curve for parent LDA**



**Table A 2 Capacity offers for child LDA**

|  | Capacity (Unforced MW) | Offer ($/MW-day) |
|---|---|---|
| Res C1 | 125.0 | $15.00 |
| Res C2 | 140.0 | $25.00 |
| Res C3 | 110.0 | $45.00 |
| Res C4 | 100.0 | $65.00 |
| Res C5 | 70.0 | $72.00 |
| Res C6 | 125.0 | $85.00 |
| Res C7 | 200.0 | $110.00 |
| Res C8 | 75.0 | $140.00 |

**Table A 3 Capacity offers for parent LDA**

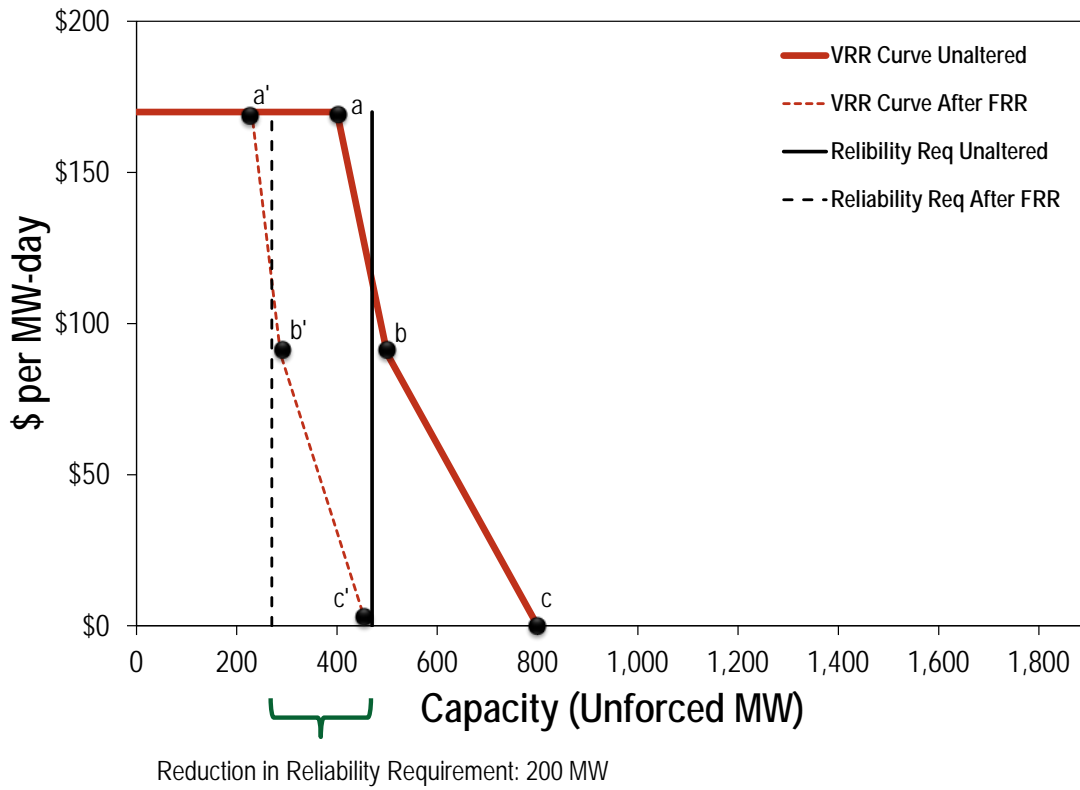|        | Capacity (Unforced MW) | Offer ($/MW-day) |
|--------|------------------------|------------------|
| Res P1 | 150.0                  | $5.00            |
| Res P2 | 200.0                  | $15.00           |
| Res P3 | 160.0                  | $30.00           |
| Res P4 | 95.0                   | $42.00           |
| Res P5 | 240.0                  | $55.00           |
| Res P6 | 195.0                  | $65.00           |
| Res P7 | 110.0                  | $75.00           |
| Res P8 | 50.0                   | $90.00           |

**Figure A 3 Clearing of child LDA: Base case**

**Figure A 4 Clearing of parent LDA: Base case**



(Child LDA's cleared VRR, net of imports: 433.3 MW )

**Table A 4 Parameters for VRR curve: Scenario 1**

| | Child (IRM = 15%, RR = 270 MW UCAP) | | | Parent (IRM = 15%, RR = 600 MW UCAP) | | |
|---|---|---|---|---|---|---|
| | Factors | X (MW UCAP) | Y ($/MW-day) | Factors | X (MW UCAP) | Y ($/MW-day) |
| a | -17.13% | 229.8 | 170.0 | -7.19% | 562.5 | 150.0 |
| b | 7.34% | 287.2 | 90.0 | 7.19% | 637.5 | 100.0 |
| c | 80.74% | 459.6 | 0.0 | 86.25% | 1050.0 | 0.0 |

**Figure A 5 Change in VRR curve of child LDA: Scenario 1**



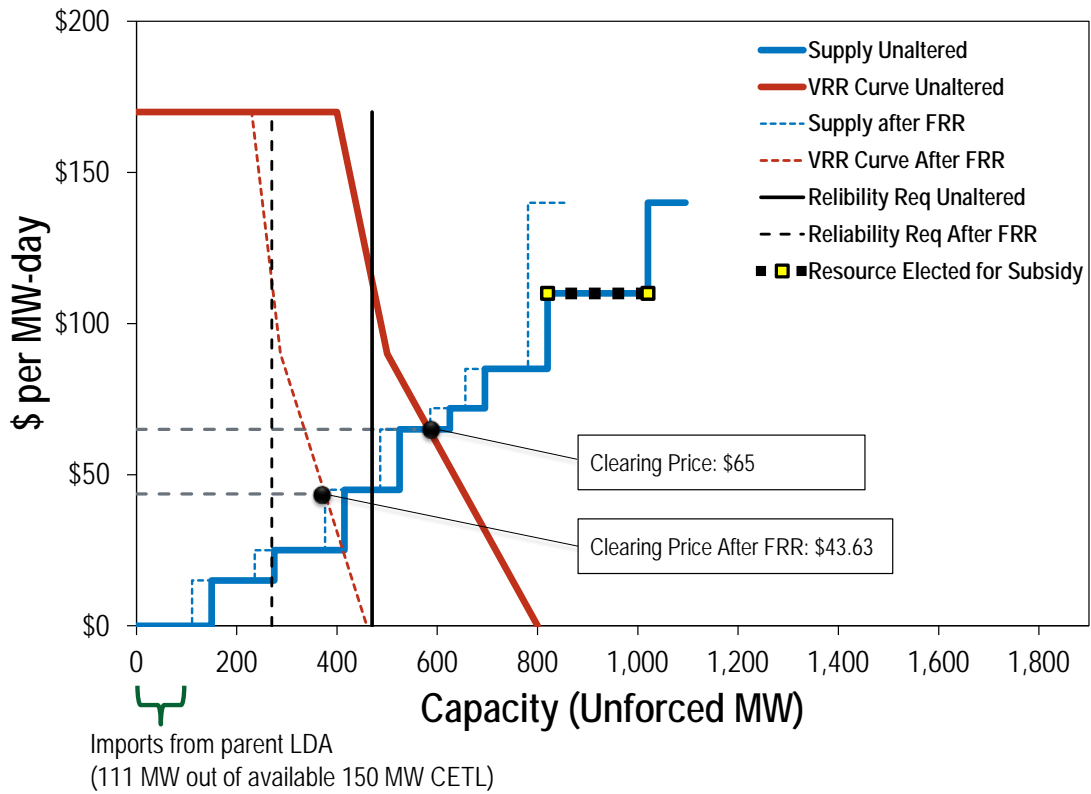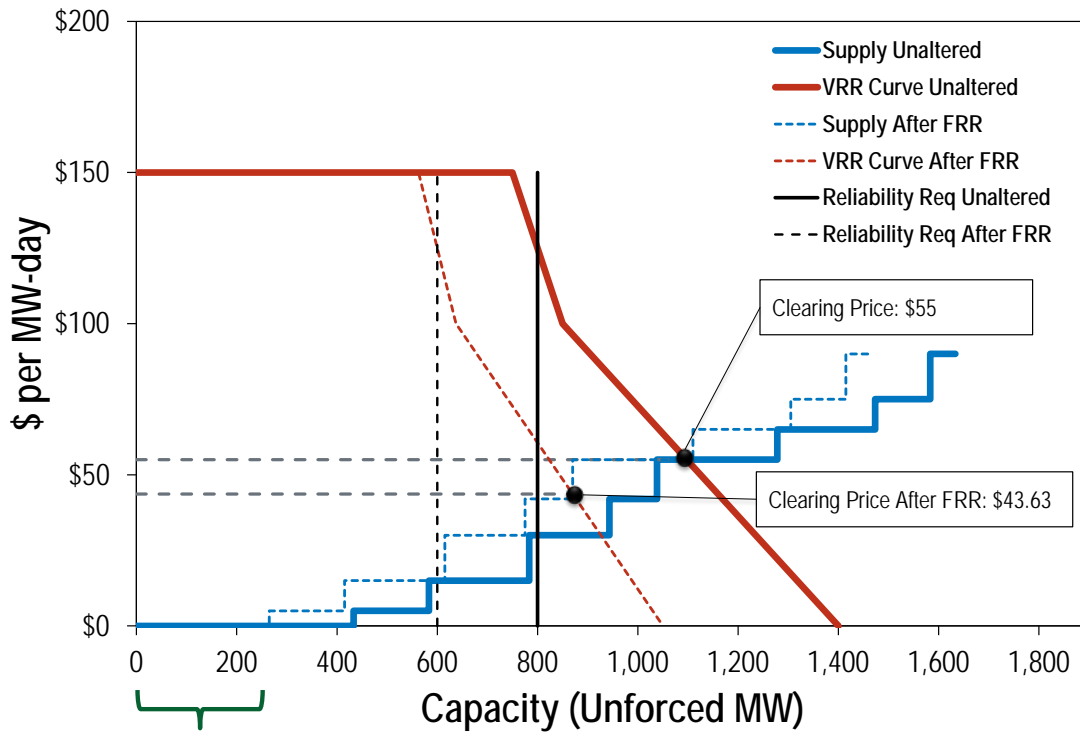Reduction in Reliability Requirement: 200 MW

**Figure A 6 Clearing of child LDA: Scenario 1**

**Figure A 7 Clearing of parent LDA: Scenario 1**



(Child LDA's cleared VRR, net of imports: 265 MW )

**Table A 5 Parameters for VRR curve: Scenario 2**

| | Child (IRM = 15%, RR = 330 MW UCAP) | | | Parent (IRM = 15%, RR = 660 MW UCAP) | | |
|---|---|---|---|---|---|---|
| | Factors | X (MW UCAP) | Y ($/MW-day) | Factors | X (MW UCAP) | Y ($/MW-day) |
| a | -17.13% | 280.9 | 170.0 | -7.19% | 618.8 | 150.0 |
| b | 7.34% | 351.1 | 100.0 | 7.19% | 701.3 | 100.0 |
| c | 80.74% | 561.7 | 0.0 | 86.25% | 1155.0 | 0.0 |

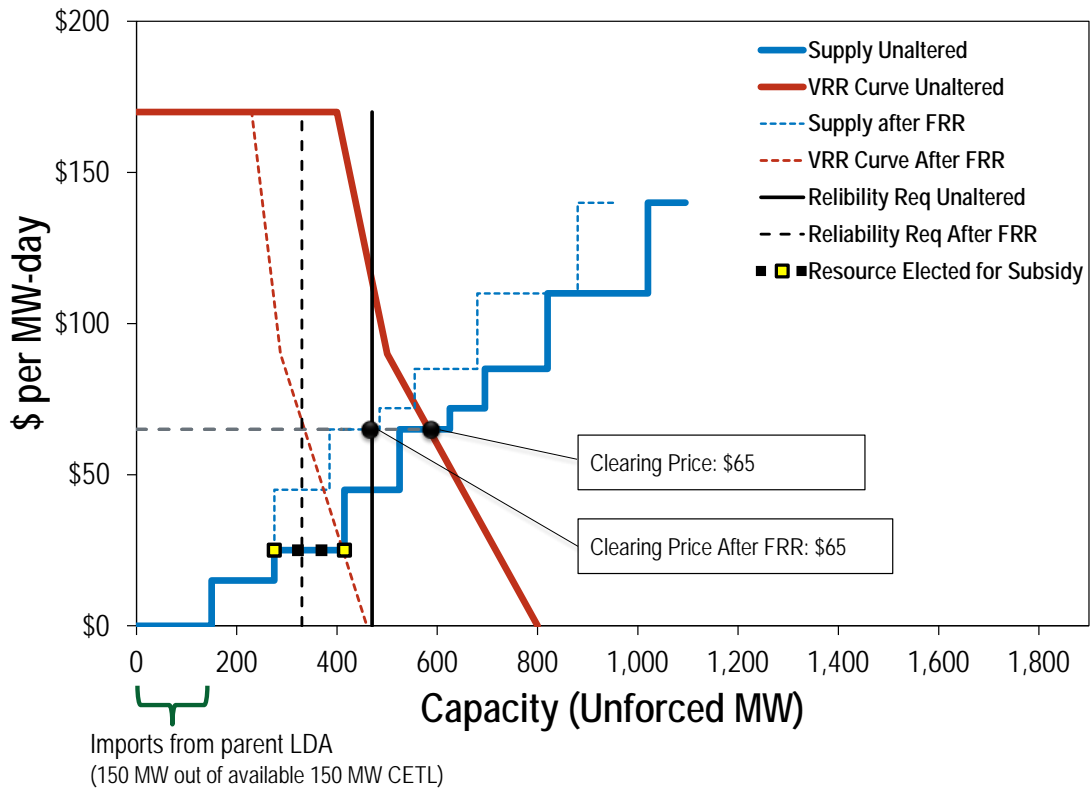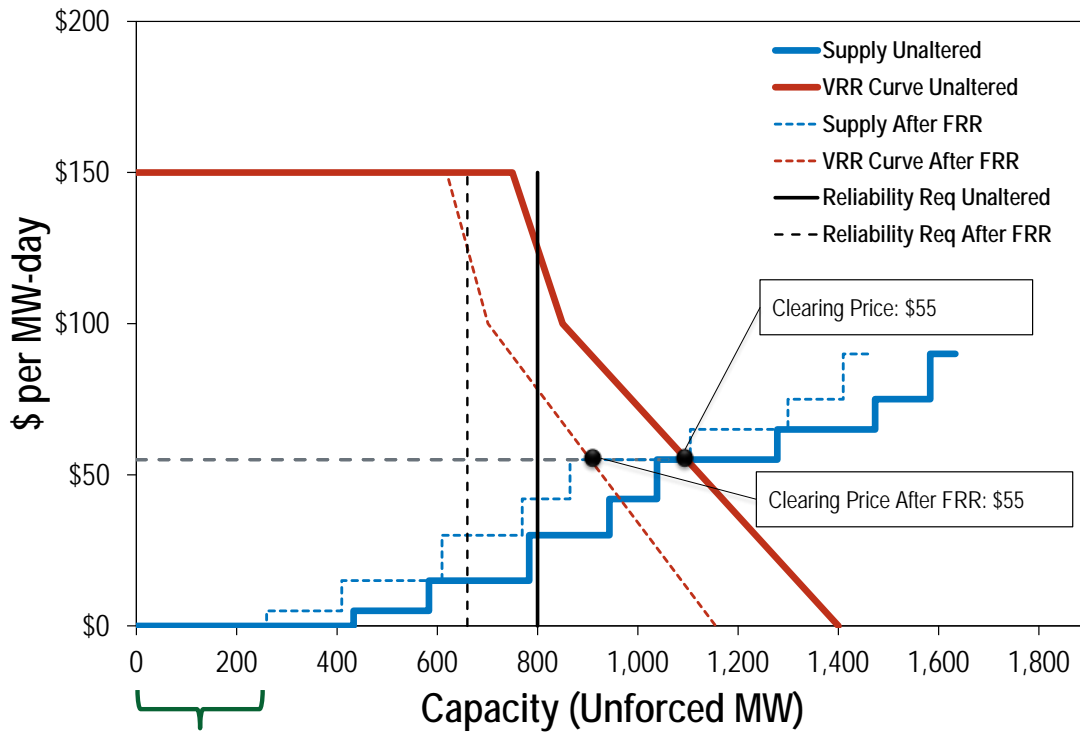**Figure A 8 Clearing of child LDA: Scenario 2**

**Figure A 9 Clearing of parent LDA: Scenario 2**



(Child LDA's cleared VRR, net of imports: 259.6 MW )