2020 Project:
Locational Marginal Pricing of Capacity
Implementation Issues and Market Impacts

Pallas LeeVanSchaick
Potomac Economics
Market Monitoring Unit

Installed Capacity Working Group
March 10, 2020

Overview of Presentation

- Review of C-LMP Project deliverables and schedule
- Key market design concepts
- Overview of MARS simulation tool used to evaluate C-LMP outcomes
- Comparison of prices and consumer payments under current design and C-LMP:
  - ✓ At LOE conditions with identical supply
- Answers to key implementation questions regarding:
  - ✓ Monotonicity of MRI curves and appropriate step size
  - ✓ Methodology for computation of ideal CRI
- Next steps

C-LMP Project Deliverables and Schedule

C-LMP Project Scope and Deliverables

The NYISO defined the *Locational Marginal Pricing of Capacity* project as part of the 2020 Market Project Candidate list. This project is scheduled for completion in Q1.

NYISO's *2020 Market Project Candidates* document:

- *Project Objective(s) & Anticipated Deliverable(s)*
  - ✓ *The objective for this project would be to consider a capacity pricing framework where the clearing price at each location is set in accordance with the* ***marginal reliability value of capacity at the location****.*
  - ✓ *The deliverable for 2020 is Issue Discovery.*

POTOMAC ECONOMICS

C-LMP Project Scope and Deliverables

NYISO's *2020 Market Project Candidates* document:

- *Project Justification – This proposal **could**:*
  - ✓ *Reduce the costs of satisfying resource adequacy needs,*
  - ✓ *Facilitate more efficient investment and retirement decisions,*
  - ✓ *Be more adaptable to changes in resource mix (i.e., increasing penetration of wind, solar, and energy storage), and*
  - ✓ *Simplify market administration.*

C-LMP Project Schedule

<u>Project Schedule:</u>

- January 21 – Kickoff presentation
- February 6 & 19 – Presentation of proposed conceptual design
- March 10:
  - ✓ Review findings on key implementation issues
  - ✓ Present example of market impact analysis based on 2019/20 LCR case at LOE conditions, including estimated prices and consumer payments
- March 26:
  - ✓ Sum-up proposal, results, and conclusions
  - ✓ List of unanswered questions for future research

Key Market Design Concepts

Key Market Design Concepts: Review of MRI & CRI

- Marginal Reliability Impact (“MRI”, ΔLOLE/MW)
  - ✓ The estimated reliability benefit (i.e., reduction in the annual loss of load expectation (“LOLE”)) of adding an amount of perfect capacity to an area
  - ✓ Measured by adding perfect capacity to MARS simulation and calculating improvement in LOLE per MW added
- Cost of Reliability Improvement (“CRI”, $/ΔLOLE)
  - ✓ The estimated net capital investment cost of an amount of improvement in LOLE
  - ✓ Based on estimated net cost of new investment from the DCR study (net CONE) and the MRI of capacity in each area

POTOMAC ECONOMICS

Key Market Design Concepts: Review of Market Processes

- Demand Curve Reset and Annual Updates
  - ✓ Determine system ‘ideal’ CRI during DCR, update annually
  - ✓ CRI is determined using net CONE and MRIs at LOE conditions. ‘Ideal’ CRI reflects optimal capacity allocation.
- Monthly Spot Auction
  - ✓ Determine MRI for each zone and resource type in as-found system at time of auction
  - ✓ Calculate clearing price for each zone and technology:
    - $\text{C-LMP}_{zt}\ (\$/\text{MW}) = \text{MRI}_{zt}\ (\Delta\text{LOLE}/\text{MW}) \times \text{CRI}\ (\$/\Delta\text{LOLE})$
  - ✓ Similar formulas are used for C-LMP of load, imports, UDRs and internal transmission interfaces

For detail, see 2/6/2020 and 2/19/2020 ICAPWG presentations

Key Market Design Concepts: Review of Key Questions – Implementation

- As the amount of supply increases, the MRI should have a stable, downward-sloping shape to reflect diminishing reliability value as capacity is added in a location
  - ✓ MRI is estimated by adding small amounts of perfect capacity and calculating change in LOLE or LOEE.
    - – Smaller step sizes better capture marginal effects
  - ✓ How much could the step size be reduced while ensuring prices are monotonic as supply is increased? Would this be different if MRI is based on LOEE instead of LOLE?
- The DCR process would need to estimate an 'ideal CRI' that will be used in calculating market prices
  - ✓ What is the best approach to calculating ideal CRI?

POTOMAC ECONOMICS

Key Market Design Concepts: Review of Key Questions – Market Outcomes

- How would C-LMP affect market outcomes compared to the current rules?
  - ✓ Prices for generation, load, imports and transmission
  - ✓ Consumer costs (including congestion revenue adequacy)
  - ✓ Relative prices across zones
- This presentation compares estimated outcomes under LOE conditions
  - ✓ MMU will also present in Q1 on outcomes where suppliers respond to the modified pricing method
  - ✓ Future presentations could address market outcomes in other scenarios

POTOMAC ECONOMICS

MARS Simulation Tool for Evaluating C-LMP

POTOMAC ECONOMICS

MARS Simulation Tool: Overview

- The MMU maintains a tool that simulates GE-MARS results for LOLE and LOEE
  - ✓ Inputs hourly supply margin and load data from MARS runs provided by NYISO
  - ✓ Replicates ten EOP steps in each hour to determine if loss of load event occurs
  - ✓ Additional supply can be added or shifted to evaluate impact on hours when loss of load occurs in MARS run
- Simulation of change in LOLE and LOEE after addition of capacity allows estimation of MRI

MARS Simulation Tool: Comparison of Simulation vs. MARS Results

- The MMU's simulation tool has the capability of altering capacity margins in targeted areas in the pre-EOP stage
  - ✓ This allows the MMU to estimate how capacity additions affect LOLE in a manner that is consistent with the logic of MARS
- Benchmarking with MARS results shows accuracy of replication within 1% of MARS LOLE (e.g. 0.01 × 0.1 LOLE)
  - ✓ Most deviations seem to occur due to level of precision and solution tolerance used in MARS run
  - ✓ Increasing the number of MARS iterations causes results to converge with MMU simulation
- Details of EOP procedures included in simulation can be found in the Appendix

Prices and Consumer Impacts

POTOMAC ECONOMICS

Prices and Consumer Impacts: Current Design vs. C-LMP

- MMU estimated prices and consumer payments by zone under the current capacity market design and C-LMP proposal
  - ✓ Current design prices based on Net Cone values
  - ✓ C-LMP prices calculated from estimated MRI and CRI values
- Assume LOE conditions and identical supply in both approaches
- These results reflect LOLE at LOE conditions and not today's as-found system
  - ✓ Other scenarios could be analyzed for future presentations

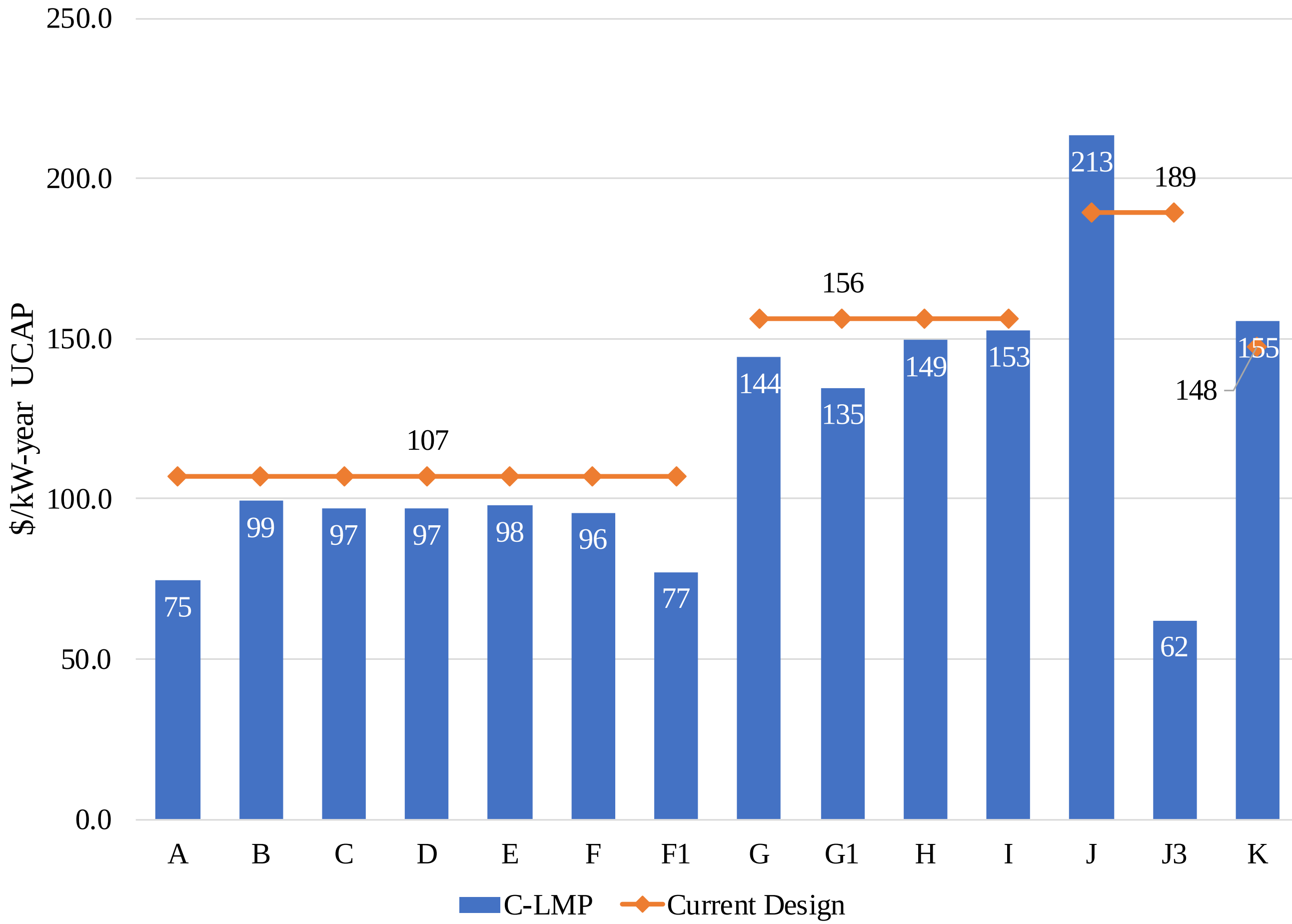
Current Design – Price and Cost Calculation

- Assumes system at LOE using existing demand curves
  - ✓ Supplier UCAP prices are locality net CONE values
- Total payments to generation calculated from:
  - ✓ ICAP Net CONE by locality for 2019/20 capability year
  - ✓ UCAP supply from MARS Final 2019 LCR case
    - – Adjusted to LOE conditions
  - ✓ Derating factors for 2019 Summer
- Costs allocated to load zones based on share of coincident peak in NYCA or locality from 2019 Gold Book

C-LMP – Price and Cost Calculation

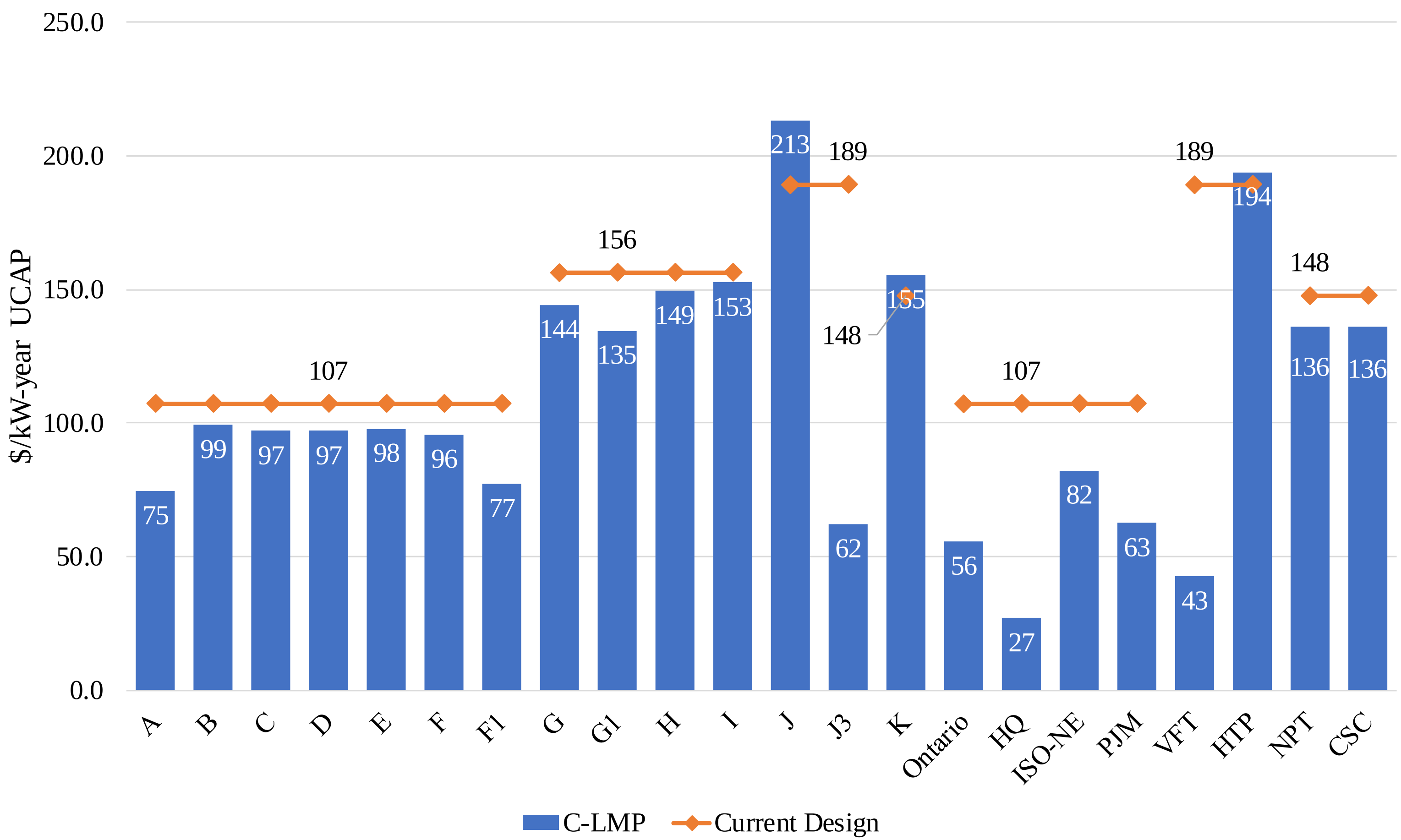
- Supply, load, and transmission topology are based on the 2019/20 MARS LCR case
- Total supply identical to Current Design assumption – only difference is in the pricing methodology
- Estimate MRI at each location for generation, load, imports and transmission using MARS simulation tool and 50 MW step size
- Estimate ideal CRI using demand curve net CONE
- Calculate C-LMP prices using formula:
  - ✓ $GenPrice_z = GenMRI_z \times CRI$
  - ✓ $LoadPrice_z = LoadMRI_z \times CRI$
  - ✓ $ImportPrice_z = ImportMRI_z \times CRI$
  - ✓ $TxPrice_i = TxMRI_i \times CRI$

Comparison – Generator Prices at LOE

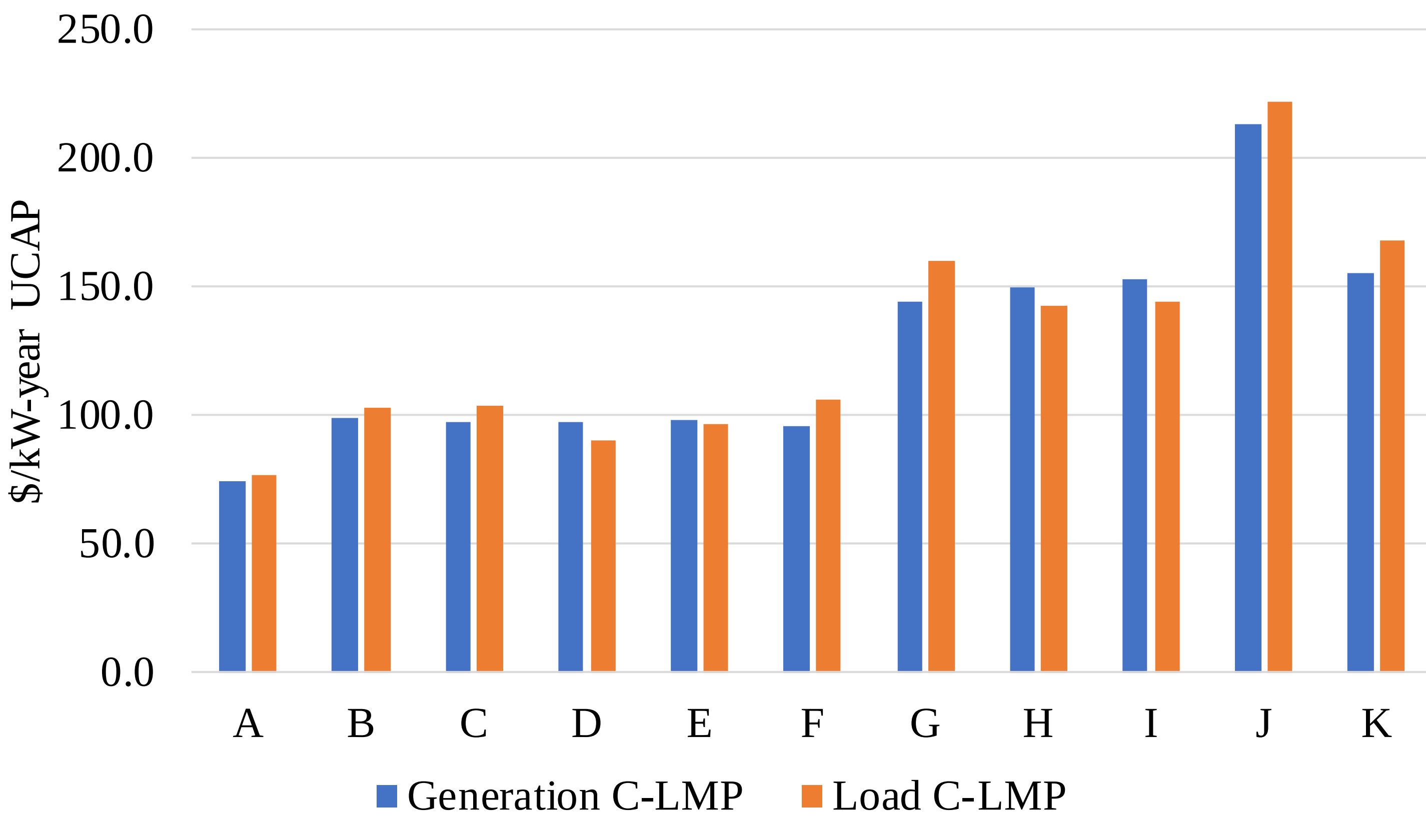


POTOMAC ECONOMICS

Comparison – Prices to Suppliers at LOE



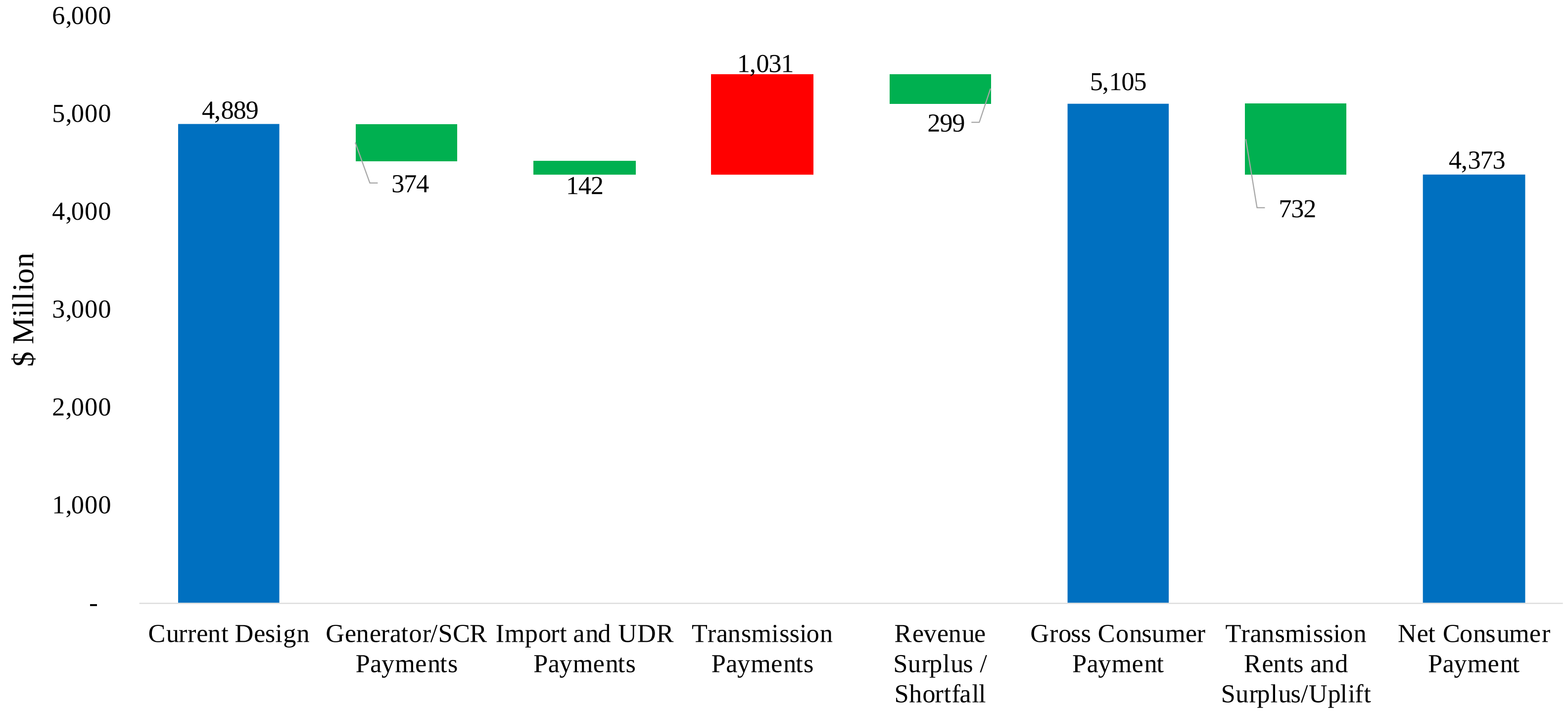
Generation and Load C-LMP



- Load price typically exceeds generator price due to higher MRI as 1 MW of load has larger impact on reliability than 1 MW of perfect capacity.

POTOMAC ECONOMICS

Comparison – Consumer Payments



- Net consumer payments fall by $516M in LOE case after accounting for transmission revenues and uplift

Prices and Consumer Impacts of C-LMP: Conclusions

- Regional C-LMP prices diverge from current design due to variations in MRI across zones and subzones
  - ✓ MRI is highest in locations where new capacity is most effective at reducing LOLE
  - ✓ The largest price impacts are reductions in deliverability-constrained areas, such as Staten Island (J3) and the West zone
- Expected consumer costs are lower under C-LMP
  - ✓ Primary source of savings is elimination of overpayment to resources in non-deliverable areas
  - ✓ Payments to imported capacity and UDRs is reduced to reflect the lower reliability value of imported capacity
  - ✓ Payments to owners of constrained transmission lines offset embedded costs ultimately borne by ratepayers
- C-LMP is not always revenue adequate

POTOMAC ECONOMICS

Prices and Consumer Impacts of C-LMP: Revenue Adequacy

- Nodal markets with marginal cost pricing are not strictly revenue adequate
  - ✓ The energy market also has revenue surpluses/shortfalls
- This analysis found a $299M revenue shortfall at LOE
- Potential drivers of shortfalls include:
  - ✓ Compensating UCAP supply as 'perfect capacity'.
    - – Some resource types (e.g., large generators) could have lower actual MRI and compensation
  - ✓ Inconsistent derating factors between MARS & UCAP market
  - ✓ Two percent EFORd assumption used to calculate payments to transmission lines and UDRs likely overstates MW-limit for interfaces with dynamic limits and forced deratings.

POTOMAC ECONOMICS

Evaluation of Step Size and Monotonicity of MRI Curves

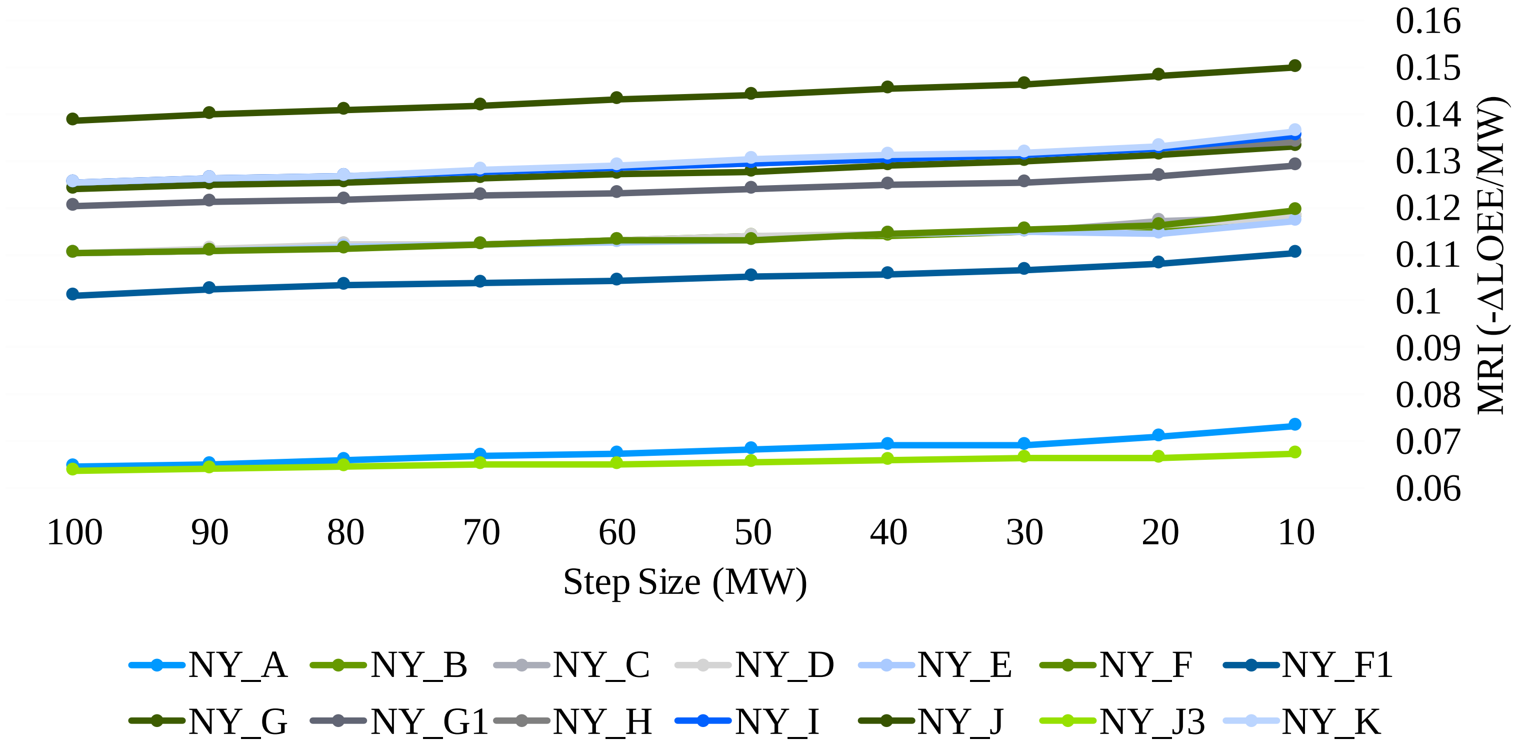
POTOMAC ECONOMICS

Step Size and Monotonicity of MRI Curves

- Zonal MRI should decline as capacity is added to that zone
  - ✓ Reflects diminishing marginal value of adding capacity in a given location
- In practice, LOLE is not a strictly convex function of supply
  - ✓ Results are based on a probabilistic simulation
  - ✓ Loss of load hours at LOE conditions are rare and may only be affected after multiple small increments of capacity
- Using larger capacity increments (steps) to assess MRI can help ensure that prices will be monotonic with supply
  - ✓ MRI calculation should use steps that are small enough to reflect marginal value but large enough to make MRI monotonic

POTOMAC ECONOMICS

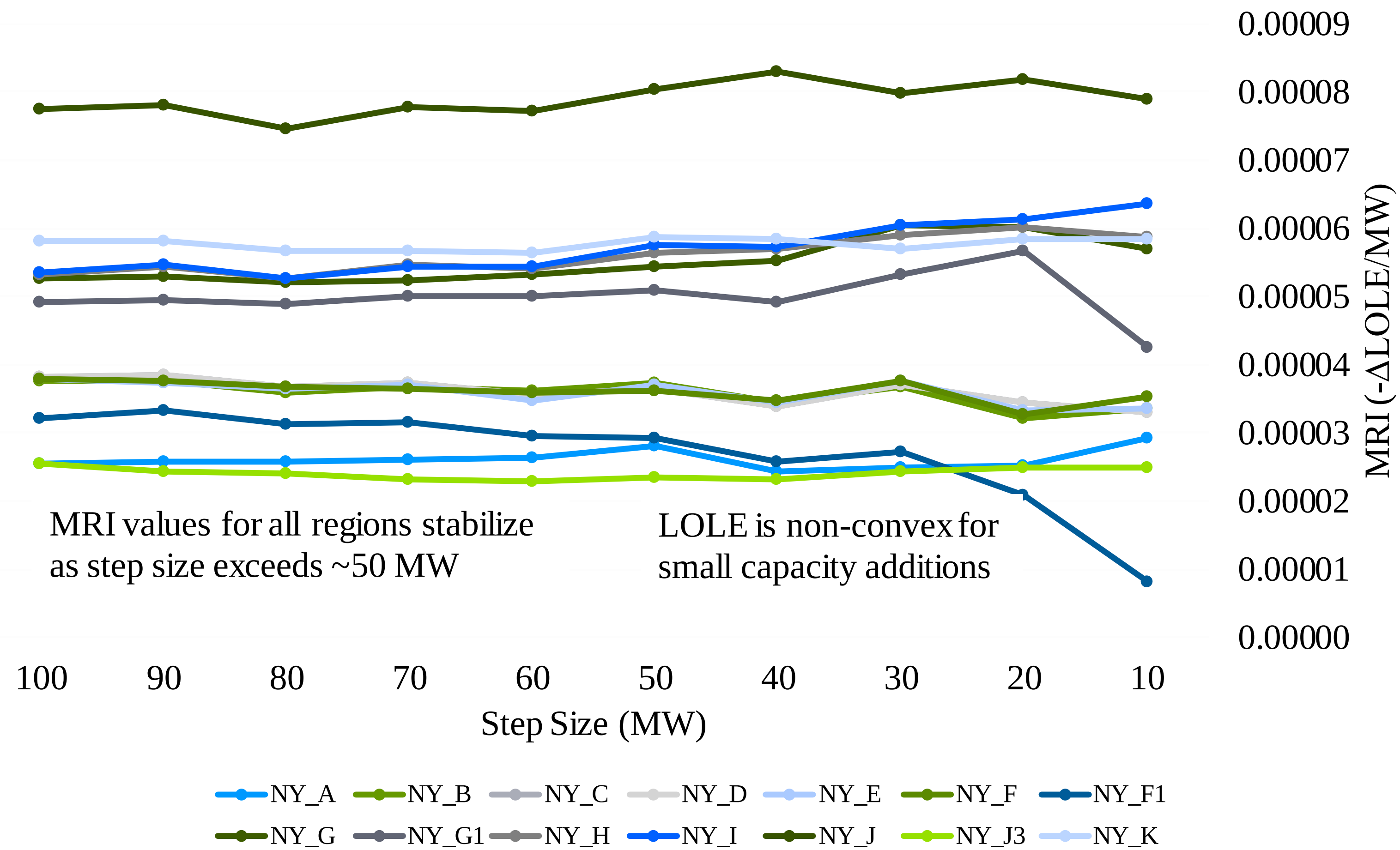
Step Size Results – LOEE



- MRI measured from LOEE is always declining at small step sizes because lost energy in MWhs is a convex function of supply
- If MRI was measured in LOEE terms, small step size (~20 MW) could ensure monotonicity

POTOMAC ECONOMICS

Step Size Results – LOLE



POTOMAC ECONOMICS

LOLE Step Size Discussion

- Very small steps produce inconsistent MRI results as LOLE may respond differently to each small increment of capacity
- When step size of at least 50-60 MW is used, the change in LOLE per MW added is more stable and monotonic
  - ✓ A step size in this range should still be small enough to capture marginal impact of new supply
- Nodal energy pricing is also not strictly monotonic for small changes of supply or load
  - ✓ For example, an incremental increase in demand can reduce price if it causes an additional generator commitment

POTOMAC ECONOMICS

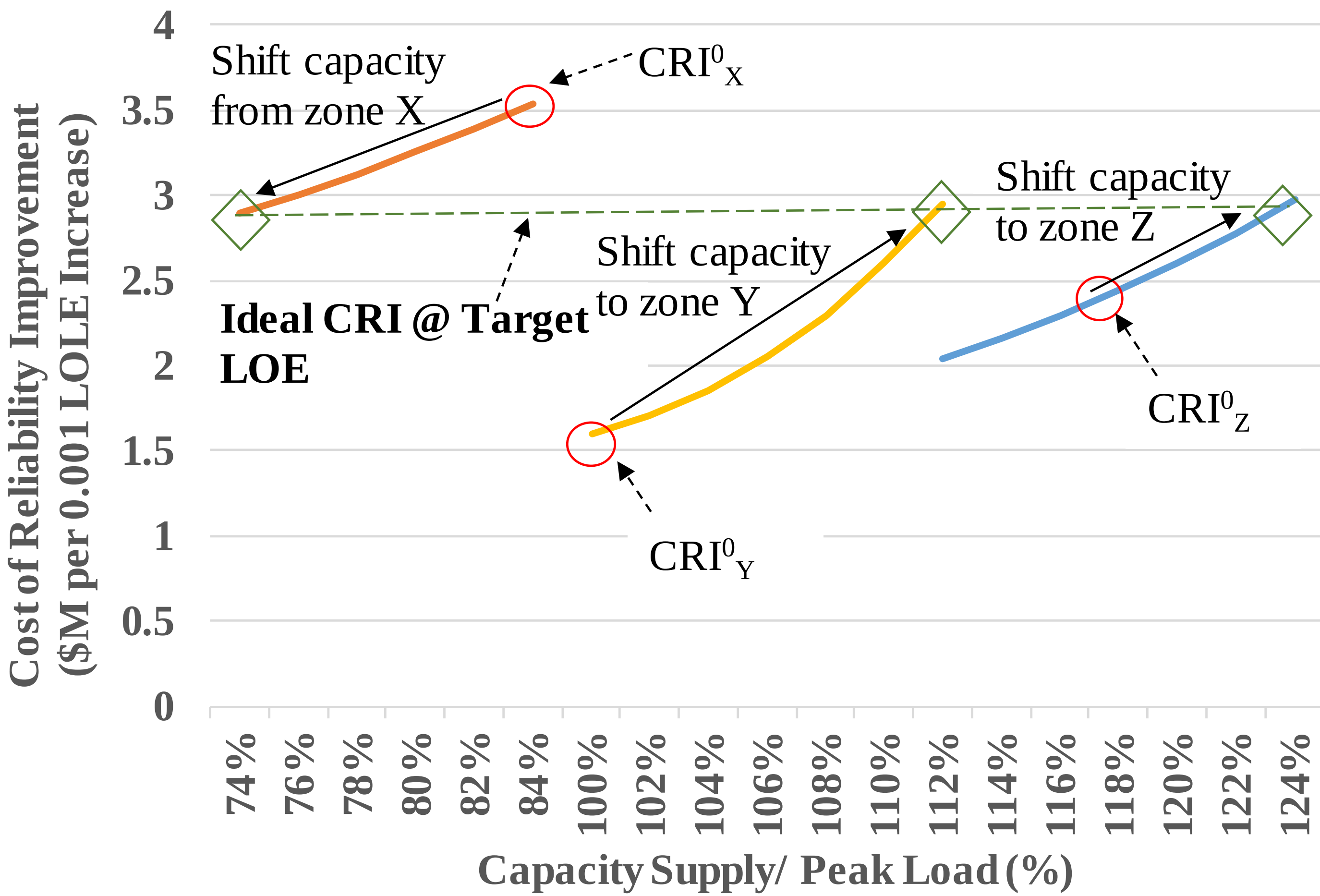
Ideal CRI Methodology and Results

POTOMAC ECONOMICS

Computation of Ideal CRI – Overview

- 'Ideal' CRI reflects the systemwide marginal cost of improving reliability when capacity is optimally allocated across zones
- Basic outline of approach:
  - ✓ Begin with system at LOE in MARS run
  - ✓ Compute MRI^0 and CRI^0 in each zone using net CONE curves
    - – Some zones will have a lower CRI (ratio of net CONE to MRI) than others, indicating that new capacity can improve system reliability more cost-effectively there
  - ✓ Shift capacity from high-CRI zones to low-CRI zones
    - – This will increase CRI in the zone where capacity is added and reduce CRI in the zone where capacity is removed
  - ✓ Repeat until CRI is equal in all zones and LOLE is at LOE conditions
    - – This solution satisfies LOLE criteria at minimum cost

Ideal CRI Illustration



Use of Ideal CRI vs. LCR Optimizer

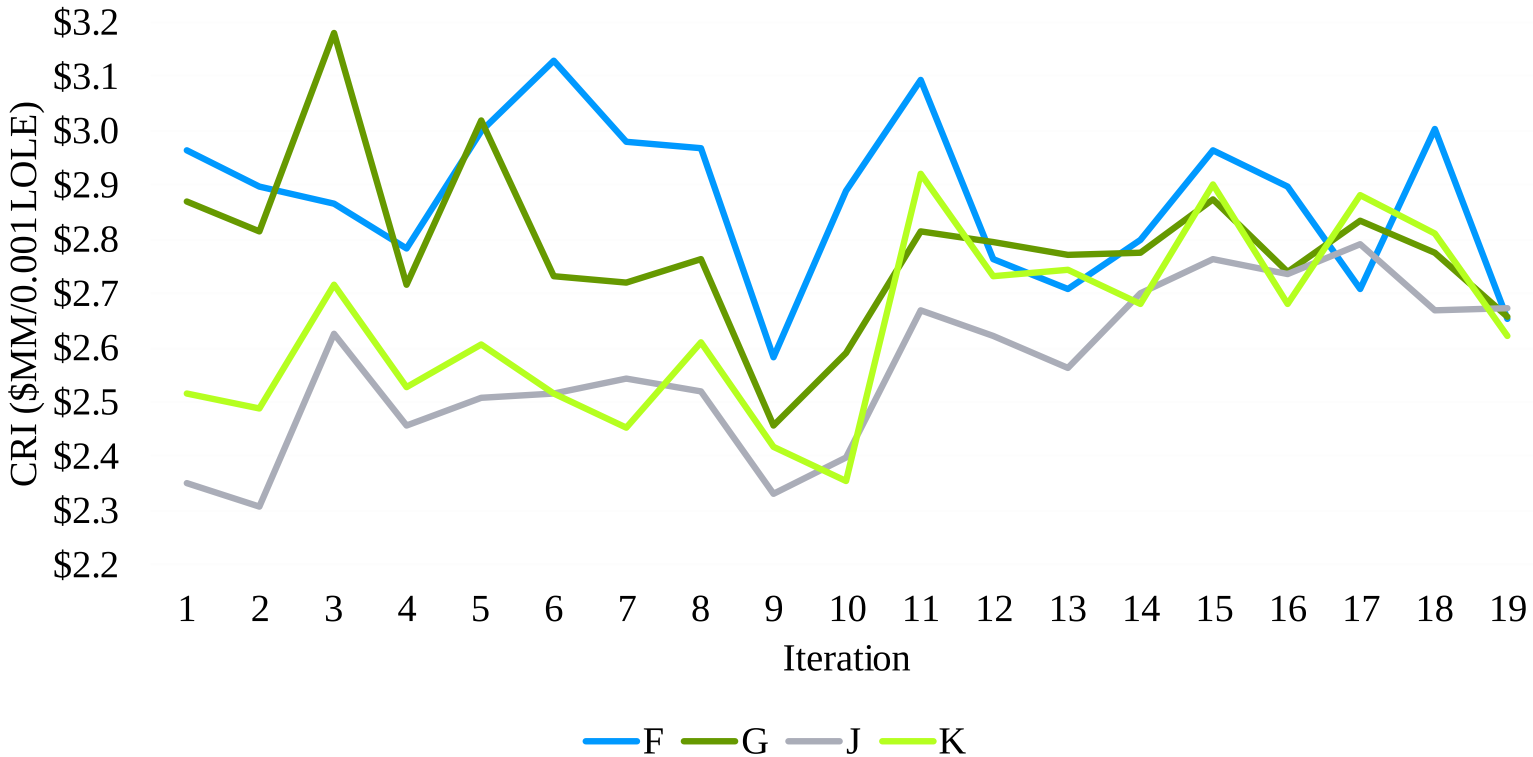
- Ideal CRI would be determined in DCR process and updated annually
- Role of CRI in C-LMP market solution is analogous to role of Net Cone in Demand Curves
  - ✓ Sets price benchmark to incent new entry when new capacity is needed for reliability
- Capacity 'shifts' in algorithm are only used for calculation of system-wide ideal CRI and do not determine a locational requirement of capacity
- Function of CRI is not comparable to LCR Optimizer
  - ✓ LCR Optimizer minimizes total payment by changing locational requirements used in demand curves
  - ✓ Ideal CRI is a systemwide value to be multiplied by zone/resource MRIs. Its value does not bias relative payments between zones

Algorithm for Computing Ideal CRI

- Algorithm approaches ideal CRI iteratively
- Each iteration adds and removes capacity based on initial CRI and MRI values. Amounts are targeted to converge zonal CRIs without reducing reliability criteria (e.g., LOLE) below starting LOE level
  - ✓ MRI and CRI are treated as linear for this purpose, and small shifts in capacity are used to avoid large deviations from estimated impact
- Based on LOLE or LOEE, the MRI and CRI are recalculated after each iteration. If reliability criteria was reduced, the next iteration will attempt to restore it by adding or shifting capacity
- MMU's run time to solve for the ideal CRI is approximately 15 hours
  - ✓ Solution time is reduced by defining a 2% tolerance for CRI convergence
  - ✓ This should be manageable since the ideal CRI is calculated only once per year.

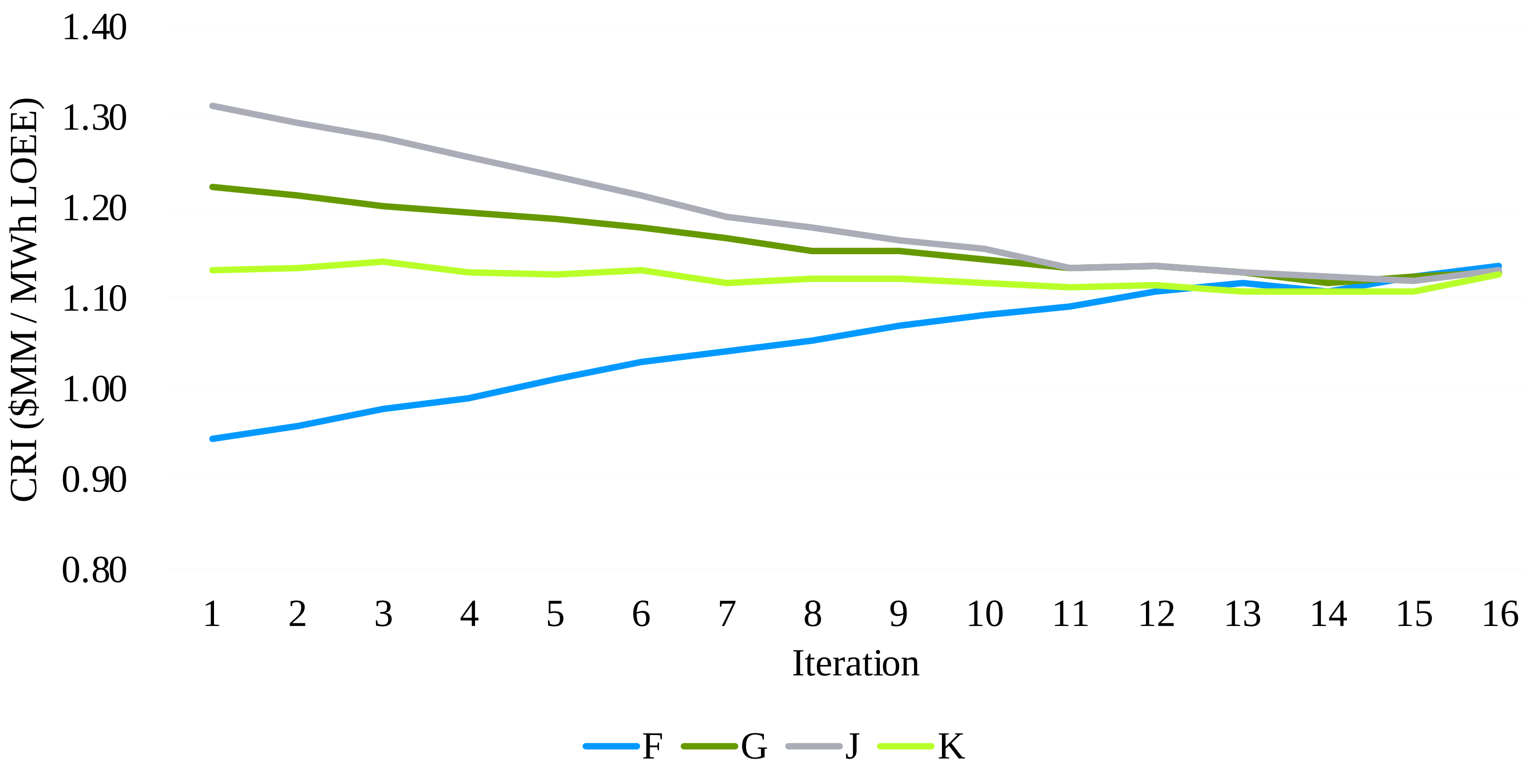
POTOMAC ECONOMICS

CRI Convergence Example – LOLE



- In each iteration, capacity is shifted from high-CRI zones to low-CRI zones until CRIs converge within maximum difference of 2%
- Each shift is subject to condition of not increasing LOLE above LOE level

CRI Convergence Result – LOEE



- In each iteration, capacity is shifted from high-CRI zones to low-CRI zones until CRIs converge within maximum difference of 1%
- Each shift is subject to condition of not increasing LOEE above LOE level

POTOMAC ECONOMICS

Next steps

Next Steps – 2020 Q1

- In the March 26 presentation, the MMU will:
  - ✓ Summarize proposal,
  - ✓ Discuss additional NYISO processes that may be affected, and
  - ✓ Answer some outstanding questions.

Key Questions to Be Evaluated Future

- Future projects could estimate how the design would change prices, consumer costs, and other market outcomes:
  - ✓ Under high renewable penetration, high battery storage penetration, and other changes in resource mix
  - ✓ Under a broad set of conditions (e.g., capacity surplus, inaccurate Net CONE, if SAF is utilized, etc.)
- Future efforts would be needed to assess:
  - ✓ The overall impact on the NYISO's administration of planning and market processes
  - ✓ Impact on the BSM process
  - ✓ Speed and efficiency of the Interconnection process

POTOMAC ECONOMICS

Key Questions to Be Evaluated Future

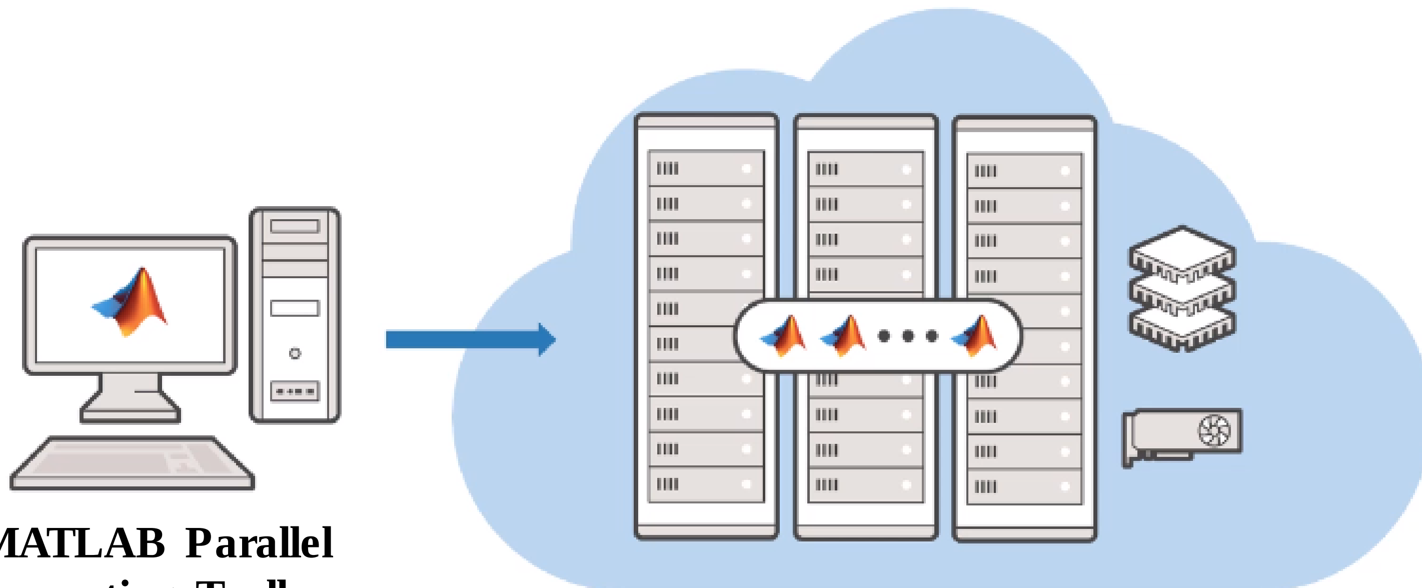
- ✓ How would the C-LMP framework affect the incentives for a generator that may not be fully deliverable over the project life?
- ✓ What algorithm could be used to perform iterations necessary to calculate LOLE[A] for as-cleared system in each monthly capacity auction?
- ✓ What is an appropriate method for allocating transmission rents, surpluses, and shortfalls?

Appendix

MMU MARS Simulation Tool

Description of Simulation Tool

- Our simulation tool employs MATLAB Parallel Server and 90 high-performance CPUs from Amazon AWS Cloud Computing Services.



MATLAB Parallel Computing Toolbox

MATLAB Parallel Server + Amazon AWS Cloud Computing

MARS EOP Simulation Procedure

- The tool uses pre-EOP stage results from a GE-MARS case, which:
  - ✓ Uses the same network topology and transfer limits.
- Then, consistent with GE-MARS, it simulates each of following EOP steps sequentially:
  - ✓ EOP 1 – Allocation of capacity for system operating reserves
  - ✓ EOP 2-4 – Deployment of SCR load, SCR gen, and EDRP
  - ✓ EOP 5 – Reduction of voltage for reduced load
  - ✓ EOP 6 – Deployment of 30-minute reserves
  - ✓ EOP 7-9 – Additional voltage reduction for load, voltage-related load curtailment, and public appeals for load reduction
  - ✓ Pool-to-Pool Assistance – Pools with surplus capacity to assist pools with deficiency

MARS EOP Simulation Procedure

  - ✓ EOP 10 – Deployment of 10-minute reserves
  - ✓ EOP 11 – Small adjustments for LCR settings
- EOPs 1-9 are NYCA-only self-assistance steps
  - ✓ EOP assistances are deployed only for areas within NYCA
  - ✓ Wheeling-through outside pools is not allowed
- The "Pool-to-Pool Assistance" has 11 assisting steps defined by a priority list
- EOP 10 and 11 each have two separate steps:
  - ✓ Self Assistance – assisting NYCA areas without wheeling-through outside pools; then
  - ✓ System Rebalance – for any remaining areas with surplus capacity to assist other deficient areas (including all regions)

POTOMAC ECONOMICS

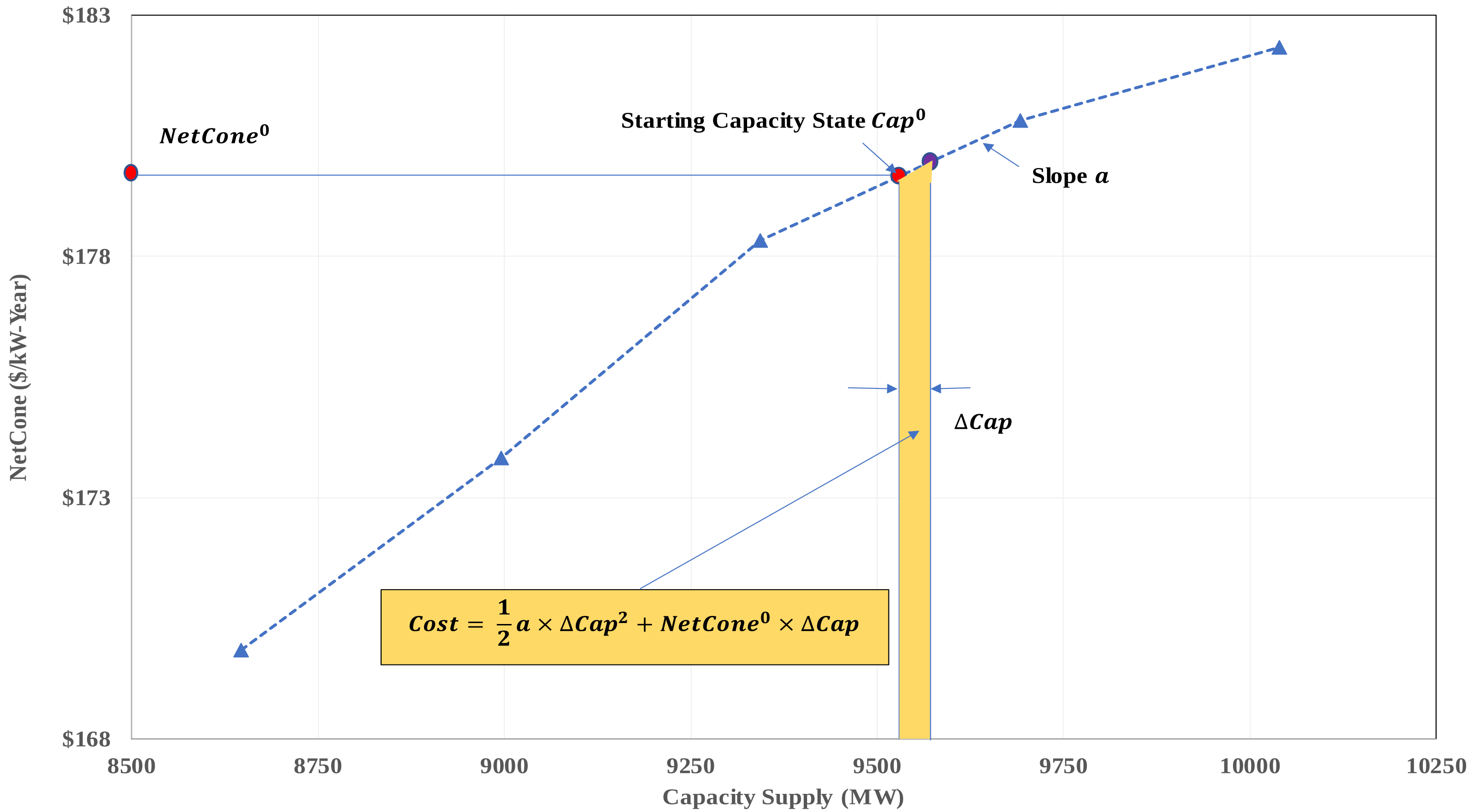
MARS EOP Simulation Procedure

- In each of these EOP steps (including Pool-to-Pool), reserve sharing is used to allocate available surplus capacity
  - ✓ This is done in proportion to the deficiency of receiving areas.
  - ✓ Transmission limitations are respected
    - – Constrained areas may have different reserve sharing ratios than un-constrained areas.
- The MMU's simulation tool has the capability of altering capacity margins in targeted areas in the pre-EOP stage
  - ✓ This allows the MMU to estimate how capacity additions would affect LOLE in a manner that is more consistent with the logic of MARS

POTOMAC ECONOMICS

Algorithm to Find Ideal CRI

Calculation of Incremental Capacity Cost



- Assumes piecewise linear Net Cone curve

Formulation of Cost-Minimization Based Ideal CRI

- Objective Function: $Min\ \sum_i Cost_i = \sum_i (\frac{1}{2} a_i \times \Delta Cap_i^2 + NetCone_i^0 \times \Delta Cap_i)$ (1)
- Subject to:

$$LOLE^0 + \sum_i MRI_i^0 \times \Delta Cap_i \leq LOLE^{Target} \quad (1.1)$$

$$-stepSize \leq \Delta Cap_i \leq stepSize \quad (1.2)$$

$$\sum_i (\Delta Cap_i + Cap_i^0) \geq IRM \quad (1.3)$$

$$\sum_{j \in L} (\Delta Cap_j + Cap_j^0) \geq Minimum\ LCR_L \quad (1.4)$$

- Constraint (1.1) maintains LOLE criterion
- Constraint (1.2) bounds the problem within a reasonable range to maintain the convexity of (1)
- Where $MRI_i^0 = \frac{LOLE_i - LOLE^0}{stepSize}$
- Constraint (1.3) maintains NYCA IRM requirement
- Constraint (1.4) maintains minimum LCR requirement for G-J, J, and K

Iterative Process to Find Ideal CRI