LBMP Carbon Impact ($LBMP_C$)

Calculation and Transparency

This presentation was reposted on 11/16/2018.The revisions impact the calculations at slide 19, and in Appendix I. These, as well as other ministerial revisions are shown as noted below.

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SENIOR MARKET DESIGN SPECIALIST – ENERGY MARKET DESIGN

Reposted – Revisions shown in red font

Integrating Public Policy Task Force (IPPTF)

October 29, 2018 Rensselaer NY

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Agenda

- Definition and Purpose
- Background
- Marginal Resources
- Example – No Congestion
- Example – Single Transmission Constraint with Two Marginal Units
- Appendix I: Example – Two Constraints with Three Marginal Units
- Appendix II: Draft $LBMP_C$ Formulation

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Definition and Purpose

- $LBMP_C$ is an estimate of the impact of carbon pricing on LBMPs.
- This presentation will describe:
  - How the NYISO intends to calculate $LBMP_C$
  - How the NYISO will provide $LBMP_C$ transparency to stakeholders

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Definition and Purpose

- The $LBMP_C$ is needed for the following reasons:
  - Allocate carbon credit to LSEs
  - Charge/credit imports/exports the $LBMP_C$, respectively.
    - Note that most internal generators are not charged the $LBMP_C$; instead, the majority of resources will be assigned a carbon charge reflective of their actual emissions.
  - Apply a carbon charge to applicable wholesale market suppliers with NYSERDA REC contracts*
  - Provide market transparency regarding $LBMP_C$

*For further information, please see "Carbon Pricing: Treatment of Existing REC Contracts," presented at the October 11, 2018 IPPTF meeting at the following link: http://www.nyiso.com/public/webdocs/markets_operations/committees/bic_miwg_ipptf/meeting_materials/2018-10-11/20180924%20NY%20REC%20Resources.pdf

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Background

- The NYISO straw proposal envisions including carbon pricing within the wholesale energy market using the existing offer structure.
  - The NYISO market software will not automatically calculate a carbon component of LBMP, since the carbon charge will be included with fuel and other relevant costs when bid into the current structure.
- The NYISO intends to develop an ex post calculation to estimate the LBMP carbon impact. This value is an estimate due to:
  - Uncertainty of marginal units' precise emissions rates
  - Under certain market conditions, it is difficult to identify the marginal unit(s) due to product trade-offs (Energy, spin, regulation), and time interval trade-offs involved in the NYISO's look-ahead when considering the next MW of supply.
- Identified marginal units and their expected emissions would be used to estimate the LBMP carbon impact.

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Background

- The NYISO's carbon reference level for the share of the marginal resource bid(s) associated with their anticipated carbon charge will be used to calculate the LBMP Carbon Impact ($LBMP_C$).
  - If the marginal resource is subject to the Regional Greenhouse Gas Initiative ("RGGI"), then the net Social Cost of Carbon ("SCC") will be utilized to determine the carbon reference level for the resource.
    - Such resources will ultimately be charged the net SCC for emissions.
  - If the marginal resource is not subject to RGGI, then the SCC will be utilized to determine the carbon reference level for the resource.
    - Such resources will ultimately be charged the SCC for emissions.
  - If the marginal resource is carbon free or qualifies under the Clean Energy Standard ("CES"), then the NYISO will utilize a $0.00 carbon reference level for the resource.
    - Such resources will ultimately not be charged for emissions.
- The NYISO will post a single $LBMP_C$ for each zone and proxy bus.

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Marginal Resources

- **The marginal resource(s) and system constraint(s) determine the LBMP today.**
  - Those marginal resources and system constraints will be used for the ex post $LBMP_C$ calculation.

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Marginal Resources

- **The NYISO will require adequate marginal resources to calculate $LBMP_C$.**
  - In the event there are not enough marginal resources to calculate $LBMP_C$, *e.g.*, when the demand curve is marginal, the NYISO is considering persisting the $LBMP_C$ from the most recent interval where $LBMP_C$ could be determined.
    - For example, if marginal resources had set the price in interval t, and only the reserve demand curve sets price in the next interval, t+1, then the NYISO would set the $LBMP_C$ in interval t+1 equal to the $LBMP_C$ in interval t.
- **The NYISO is currently considering the impact of this approach, and is open to stakeholder feedback.**

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Examples - Background

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Examples - Background

- The NYISO will use the power balance equation and transmission constraint equations to determine $LBMP_C$ for the zone j.*

$$\text{power balance: } \sum_{i=1}^{M} (DF_i * P_i) = DF_j$$

$$\text{transmission constraint } k \in NC\text{: } \sum_{i=1}^{M} (GF_{i,k} * P_i) = GF_{j,k}$$

$$LBMP_{c,j} = \sum_{i=1}^{M} CB_i * P_i$$

M = The set of Marginal Resources

NC = The set of binding transmission constraints

$GF_{i,k}$= Shift factor for resource i on constraint k (the Shift Factor measures the increment of constraint flow for an incremental injection at resource i and a corresponding withdrawal at the Reference Bus)

DF_i = The delivery factor for bus i to the system Reference Bus

CB_i = The reference level estimated net carbon charge from the bid of each marginal resource

P_i = Resource i energy injection

*The formulation for the calculation of LBMP is discussed in Market Administration and Control Area Services Tariff (MST) section 17.1 – LBMP Calculation

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Example – No Congestion

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Example – No Congestion

Resource	Estimated Net Carbon Charge	Shift Factor*	Delivery Factor**
Marginal Generator 1	$5.00/MWh	1	1.05

Zone	Delivery Factor for the Zone
1	0.95

$1.05P_1 = .95$ } Power balance equation set equal to the delivery factor for Zone 1

*Please see the definition of "Shift Factor" in the NYISO Market Administration and Control Area Services Tariff (MST) section 2.19 Definitions – S.
**Please see the treatment of Delivery Factors throughout MST section 17.1 – LBMP Calculation

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Example – No Congestion

Resource	Estimated Net Carbon Charge	Shift Factor	Delivery Factor
Marginal Generator 1	$5.00/MWh	1	1.05

Zone	Delivery Factor for the Zone
1	0.95

$1.05P_1 = .95$ — Power balance equation set equal to the delivery factor for Zone 1

$P_1 = 0.904$ — Solve for P_1

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Example – No Congestion

Resource	Estimated Net Carbon Charge	Shift Factor	Delivery Factor
Marginal Generator 1	$5.00/MWh	1	1.05

Zone	Delivery Factor for the Zone
1	0.95

$1.05P_1 = .95$ — Power balance equation set equal to the delivery factor for Zone 1

$P_1 = 0.904$ — Solve for P_1

($5*0.904)= $4.52 $LBMP_C$ for Zone 1

- The $LBMP_C$ across zones will differ only due to losses in this example, as there is no congestion. The delivery factor for the zone reflects the losses.

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Example – Single Transmission Constraint with Two Marginal Units

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System Congestion

- **One or more transmission constraint can develop, causing congestion.**
  - At least two resources must be marginal if a transmission constraint develops, one on either side of the constraint.
    - It is possible that more than one resource can be margina on either side of the constraint.
      - This is because resources can have similar costs to relieve a constraint.
- **A resource's Shift Factor, as developed by the market software, represents the percent effectiveness of this resource in resolving a constraint.***

*For a definition of Shift Factor, please see Market Administration and Control Area Services Tariff (MST) section 2.19 MST Definitions - S

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Example – Single Transmission Constraint with Two Marginal Units

Resource	Estimated Net Carbon Charge	Shift Factor	Delivery Factor
Marginal Generator 1	$5.00/MWh	.85	1.05
Marginal Generator 2	$10.00/MWh	.60	1.10

Zone	Delivery Factor for the Zone	Zone Shift Factor on the Constraint
1	0.95	0.30

- **To determine the $LBMP_C$ of Zone 1 (continued):**
  - Calculate the $LBMP_C$

$1.05P_1 + 1.10P_2 = 0.95$

$.85P_1 + .60P_2 = 0.30$

Power balance equation and transmission constraint equations for two unknowns

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Example – Single Transmission Constraint with Two Marginal Units

Resource	Estimated Net Carbon Charge	Shift Factor	Delivery Factor
Marginal Generator 1	$5.00/MWh	.85	1.05
Marginal Generator 2	$10.00/MWh	.60	1.10

Zone	Delivery Factor for the Zone	Zone Shift Factor on the Constraint
1	0.95	0.30

- **To determine the $LBMP_C$ of Zone 1 (continued):**
  - Calculate the $LBMP_C$

$1.05P_1 + 1.10P_2 = 0.95$

$.85P_1 + .60P_2 = 0.30$

Power balance equation and transmission constraint equations for two unknowns

$P_1 = -0.786$

$P_2 = 1.614$

Solve for the two unknowns, P_1 and P_2

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Example – Single Transmission Constraint with Two Marginal Units

Resource	Estimated Net Carbon Charge	Shift Factor	Delivery Factor
Marginal Generator 1	$5.00/MWh	.85	1.05
Marginal Generator 2	$10.00/MWh	.60	1.10

Zone	Delivery Factor for the Zone	Zone Shift Factor on the Constraint
1	0.95	0.30

- **To determine the $LBMP_C$ of Zone 1 (continued):**
  - Calculate the $LBMP_C$

$1.05P_1 + 1.10P_2 = 0.95$

$.85P_1 + .60P_2 = 0.30$

Power balance equation and transmission constraint equations for two unknowns

$P_1 = -0.786$

$P_2 = 1.614$

Solve for the two unknowns, P_1 and P_2

($5*-0.786)+($10*1.614) = $12.21 $LBMP_C$ for Zone 1 — Solve for the zonal $LBMP_C$

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Market Transparency of $LBMP_C$

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$LBMP_C$ Posting

- **The NYISO is targeting the following post for $LBMP_C$; however, the ultimate implementation will depend on whether the posting is technologically possible and necessary for market information:**
  - Compute and post the zonal $LBMP_C$ for RTD and RTC intervals, as well as RTC and RTD look-ahead intervals, to provide information for transactions.
  - Use the binding RTD interval (nominally 5-minutes) to determine the carbon credit allocation, import/export settlements, REC resource settlements, and provide further market transparency.
  - Post the zonal $LBMP_C$ at a 5 minute granularity*
    - When the posting occurs will depend on the time required to calculate $LBMP_C$.
    - The NYISO is targeting posting as soon as possible after the completion of each market run.

*The NYISO intends to provide a posting granularity similar to the current real-time zonal LBMP postings: http://www.nyiso.com/public/markets_operations/market_data/pricing_data/index.jsp

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Appendix I: Example – Two Constraints with Three Marginal Units

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A*	Carbon Impact to Constraint Cost ($)B
1	0.95		

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$$.85P_1 + .60P_2 + 0P_3 = -1$$

$$0P_1 + 0P_2 + .75P_3 = 0$$

$$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$$

Power balance equation and transmission constraint equations for three unknowns

*This is the carbon impact to Constraint Cost ($) in the real-time limiting constraints posting at the following link:
http://www.nyiso.com/public/markets_operations/market_data/power_grid_data/index.jsp

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B
1	0.95		

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = -1$

$0P_1 + 0P_2 + .75P_3 = 0$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -3.605$

$P_2 = 3.442$

$P_3 = 0$

Solve for the three unknowns, P_1, P_2, and P_3

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B
1	0.95	16.39	

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = -1$

$0P_1 + 0P_2 + .75P_3 = 0$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -3.605$

$P_2 = 3.442$

$P_3 = 0$

Solve for the three unknowns, P_1, P_2, and P_3

$(\$5*-3.606) + (\$10*3.442) + (\$15*0) = 16.39$

Solve for the carbon impact on the Shadow Price of the Constraint A

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B
1	0.95	16.39	

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = -1$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$

Power balance equation and transmission constraint equations for three unknowns

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B
1	0.95	16.39	

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = -1$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -3.147$

$P_2 = 4.459$

$P_3 = -1.333$

Solve for the three unknowns, P_1, P_2, and P_3

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B
1	0.95	16.39	8.85

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = -1$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 0$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -3.147$

$P_2 = 4.459$

$P_3 = -1.333$

Solve for the three unknowns, P_1, P_2, and P_3

$(\$5*-3.147) + (\$10*4.459) + (\$15*-1.333) = 8.85$

Solve for Carbon impact on the Shadow Price of the Constraint B

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	Carbon Impact to Constraint Cost ($)A	Carbon Impact to Constraint Cost ($)B	Zone Shift Factor Constraint A	Zone Shift Factor Constraint B	*Carbon Impact to Congestion, Constraint A*	*Carbon Impact to Congestion, Constraint B*
1	0.95	16.39	8.85	0.20	0.70	3.27	6.19

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

- To determine the $LBMP_C$ of Zone 1:

$0.20*16.39 = 3.27$ } Calculate the carbon impact to congestion due to constraint A

$0.70* 8.85= 6.19$ } Calculate the carbon impact to congestion due to constraint B

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	*Carbon Impact to Congestion, Constraint A*	*Carbon Impact to Congestion, Constraint B*	*Carbon Impact to Energy*
1	0.95	3.27	6.19	

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = 0$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 1$

Power balance equation and transmission constraint equations for three unknowns

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	*Carbon Impact to Congestion, Constraint A*	*Carbon Impact to Congestion, Constraint B*	*Carbon Impact to Energy*
1	0.95	3.27	6.19	

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = 0$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 1$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -1.967$

$P_2 = 2.786$

$P_3 = 0$

Solve for the three unknowns, P_1, P_2, and P_3

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	*Carbon Impact to Congestion, Constraint A*	*Carbon Impact to Congestion, Constraint B*	*Carbon Impact to Energy*
1	0.95	3.27	6.19	$18.03

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

$.85P_1 + .60P_2 + 0P_3 = 0$

$0P_1 + 0P_2 + .75P_3 = 0$

$1.05P_1 + 1.10P_2 + 1.20P_3 = 1$

Power balance equation and transmission constraint equations for three unknowns

$P_1 = -1.967$

$P_2 = 2.786$

$P_3 = 0$

Solve for the three unknowns, P_1, P_2, and P_3

$(\$5 * -1.967) + (\$10 * 2.786) + (\$15 * 0) = \$18.03$

Solve for Carbon impact on energy

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Example – Two Transmission Constraints with Three Marginal Units

Zone	Delivery Factor for the Zone	*Carbon Impact to Congestion, Constraint A*	*Carbon Impact to Congestion, Constraint B*	*Carbon Impact to Energy*	*Carbon Impact to Losses*
1	0.95	3.27	6.19	$18.03	–0.90

Resource	Estimated Net Carbon Charge	Shift Factor Constraint A	Shift Factor Constraint B	Delivery Factor	Constraint
Marginal Generator 1	$5.00/MWh	.85	0	1.05	A
Marginal Generator 2	$10.00/MWh	.60	0	1.10	A
Marginal Generator 3	$15.00/MWh	0	.75	1.20	B

- **Determine $LBMP_C$ of Zone 1, continued:**

18.03 * (0.95-1)=–0.90 Carbon impact to losses } Solve for Carbon impact on losses

18.03 + -0.90 -(3.27+6.19) = $7.67/MWh is the zonal $LBMP_C$

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Appendix II: Draft $LBMP_C$ Formulation

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Draft $LBMP_C$ formulation

- The NYISO posted a draft $LBMP_C$ formulation with today's meeting materials.

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- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policy makers, stakeholders and investors in the power system

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