Carbon Pricing Impacts on the LMP

CPSTF

October 24, 2019

Schedule

- **August Meeting:** Reviewed the basics of economic dispatch and the three border adjustment options.
- **Today:** In preparation for the November meeting, we will review the impacts of carbon pricing on the LMP.
- **November Meeting:** Both CAISO and NYISO will present their carbon pricing programs/proposals.

Disclaimer

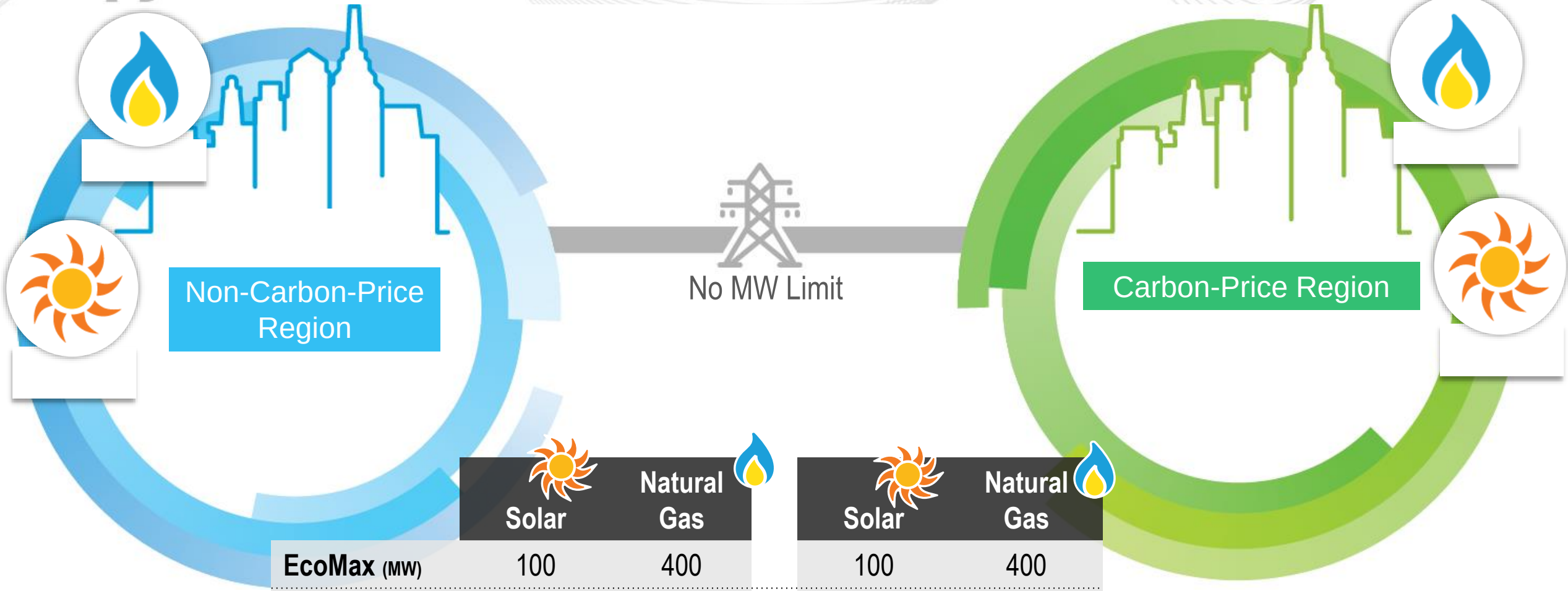
- **Disclaimer:**
  - PJM **does not** favor one border adjustment option over another and is solely providing this information to support stakeholder discussions
  - The examples used are **solely** intended to help illustrate the concepts presented and are not intended to be a representation of actual system conditions

Carbon Pricing Impacts on the LMP

- Both CAISO and NYISO have programs/proposals where a carbon price impacts the LMP
- The meaning and use of the carbon component of the LMP and the impact of the carbon price to the LMP that they calculate are fundamentally different due to the differences in their respective programs/proposals
- PJM may need to include elements of both to implement a border adjustment for a carbon price for only a subset of states
- An example from the August meeting will be used to illustrate the differences

Example 3:
One-Way Border Adjustment
Net Import to Carbon-Price Region

Example System



	Non-Carbon-Price Region		Carbon-Price Region	
	Solar	Natural Gas	Solar	Natural Gas
EcoMax (MW)	100	400	100	400
Offer ($/MWh)	0	30	0	20
Offer with Carbon ($/MWh)	0	120	0	100

Unit Emissions Rates

- It is assumed that the carbon price is 1 $/short ton.

- Natural gas generators have the following emissions rates:
  - Natural Gas Generator in the carbon-price region = 80 short ton/MWh
  - Natural Gas Generator in the non-carbon-price region = 90 short ton/MWh

Carbon-Price Region Emissions Obligation

- Note:
  - Assume the natural gas generator in the carbon-price region is located in State A
  - The natural gas generator in the carbon-price region has an obligation to pay State A for its carbon emissions at a rate of 80 $/MWh
  - This financial transaction takes place outside of the market and the grid operator's settlement process

One-Way Border Adjustment Dispatch Rules

- Generators located in the carbon-price region
  - Dispatched using offers that include the cost of carbon

- Generators located in the non-carbon-price region
  - When associated with serving load in the non-carbon-price region
    - Dispatched using offers that do not include the cost of carbon
  - When associated with serving load in the carbon-price region
    - Dispatched using offers that include the cost of carbon

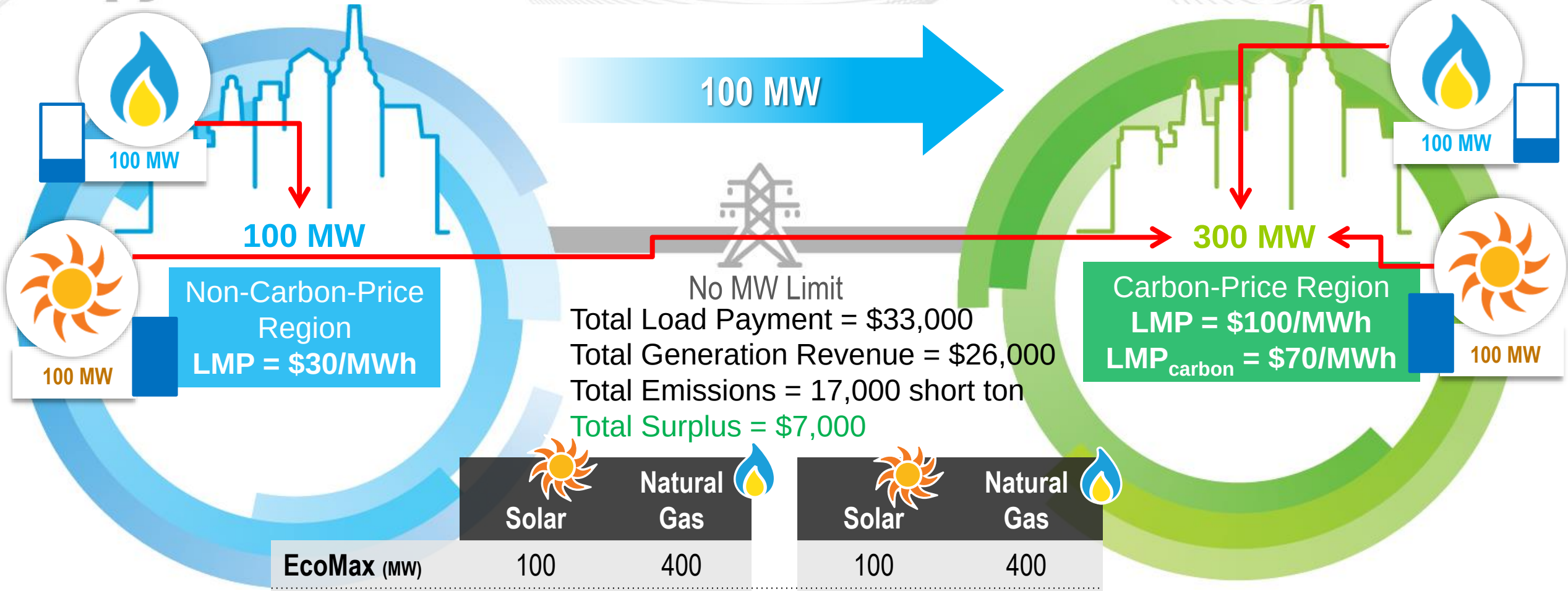
Border Adjustment Constraint

- To implement the border adjustment in economic dispatch, a net imbalance energy import allocation constraint is added to the optimization problem (using CAISO's formulation)

- The shadow price of this constraint is what CAISO has referred to as the Greenhouse Gas (GHG) price or marginal GHG compliance cost and is what was referred to as the carbon component of the LMP in the August meeting examples

- The shadow price represents the marginal cost to the carbon-pricing region due to the border adjustment constraint

Example 3: Net Import – One-Way Border Adjustment



Total Load Payment = $33,000
Total Generation Revenue = $26,000
Total Emissions = 17,000 short ton
Total Surplus = $7,000

	Solar	Natural Gas	Solar	Natural Gas
EcoMax (MW)	100	400	100	400
Offer ($/MWh)	0	30	0	20
Offer with Carbon ($/MWh)	0	120	0	100

Example 3: Load Payments and Generator Revenues

$$Load\ Payments = 100MW \times 30\$/MWh + 300MW \times 100\$/MWh$$
$$= \$33{,}000$$

$$Generator\ Revenues = 200MW \times 30\$/MWh + 200MW \times 100\$/MWh$$
$$= \$26{,}000$$

$$Surplus = Load\ Payments - Generator\ Revenues = \$33{,}000 - \$26{,}000$$
$$= \$7{,}000$$

Example 3: Settlement

- Revenue Adequate:
  - Total Load Payments > Total Generator Revenue
  - Surplus $7,000 is allocated back to the carbon-price-region

- In the carbon-price-region, the natural gas generator is dispatched using an offer that includes the cost of carbon
  - Carbon revenue collected by State A:

    (100$/MWh – 20$/MWh) * 100MW * 1h = $8,000

Settlement: LMP Components

- The LMPs in each region can be broken down into the following components:

$$LMP_{Carbon-Price\ Region} = LMP_{Energy} + LMP_{Loss} + LMP_{Congestion}$$

$$LMP_{Non-Carbon-Price\ Region} = LMP_{Energy} + LMP_{Loss} + LMP_{Congestion} - LMP_{Carbon}$$

- Note: LMP_{Carbon} is determined from the optimization as a result of solving the economic dispatch problem
- Note: LMP_{Energy} is the same for all nodes and includes the impacts of LMP_{Carbon}

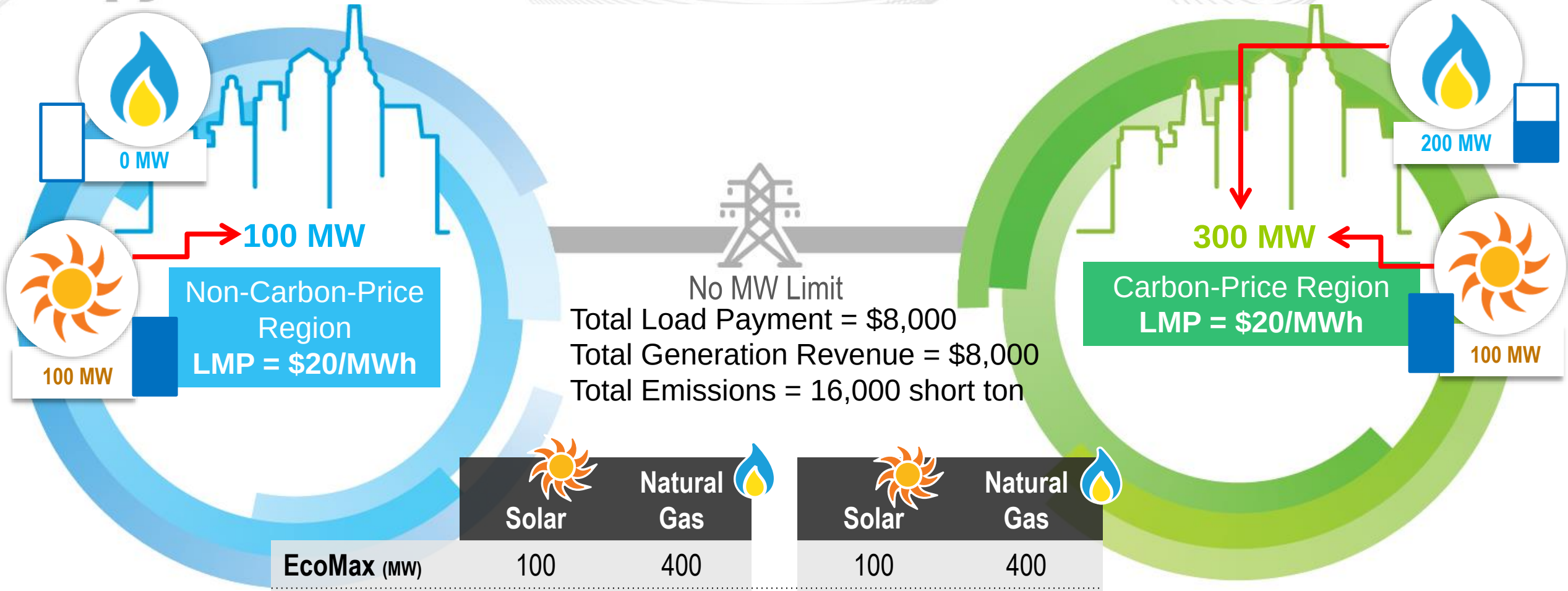
Carbon Price Impact to the LMP

- The carbon component of the LMP as just described is not the same thing as the impact of the carbon price to the LMP!

- The impact of the carbon price to the LMP is not automatically determined by solving the economic dispatch problem.

- To determine the impact, the counterfactual case without a carbon price must be solved.

Example 3a: No Carbon Price



	Solar	Natural Gas	Solar	Natural Gas
EcoMax (MW)	100	400	100	400
Offer ($/MWh)	0	30	0	20
Offer with Carbon ($/MWh)	~~0~~	~~120~~	~~0~~	~~100~~

Example 3a: Load Payments and Generator Revenues

$$Load\ Payments = 100MW \times 20\$/MWh + 300MW \times 20\$/MWh$$
$$= \$8{,}000$$

$$Generator\ Revenues = 100MW \times 20\$/MWh + 300MW \times 20\$/MWh$$
$$= \$8{,}000$$

$$Surplus = Load\ Payments - Generator\ Revenues = \$8{,}000 - \$8{,}000$$
$$= \$0$$

Example 3a: Settlement

- Revenue Adequate:
  - Total Load Payments = Total Generator Revenue

- Without a carbon price, the LMP in both regions is $20/MWh.
  - Impact of the carbon price on the LMP:
    - Carbon-Price Region = $100/MWh - $20/MWh = $80/MWh
    - Non-Carbon-Price Region = $30/MWh - $20/MWh = $10/MWh

  - These values are different from the carbon component of the LMP in Example 3, which was calculated to be $70/MWh

NYISO Carbon Impact to the LBMP Proposal

- NYISO will not have a carbon component of the LBMP since every Market Participant in NYISO is subject to the carbon price and can include carbon emissions costs in their economic offers
- NYISO is proposing to use an *ex post* calculation to estimate the carbon impact to the LBMP
- The value will be calculated after-the-fact by using the set of marginal resources during each interval and the reference level estimated net carbon charges for these resources

NYISO Proposed Use of the Carbon Impact to the LBMP

- The carbon impact to the LBMP is needed to:
  - Allocate their carbon credits to LSEs
  - Adjust the LBMPs for external imports and exports (we will discuss approaches for dealing with external imports and exports at the December meeting)
  - Provide market transparency

- Note: Generators in NYISO will be charged based on their actual emissions, not on the calculated carbon impact to the LBMP

Key Takeaways for PJM

- The carbon component of the LMP is not the same thing as the impact of the carbon price to the LMP

- Depending on stakeholder discussions, it is possible that both a carbon component of the LMP and the impact of the carbon price to the LMP may need to be used to implement a border adjustment for a carbon price in a subset of PJM states