Tabors Caramanis Rudkevich

What Does it Take to Achieve Carbon Neutrality in the Electric Network?

Presented to:

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Presenter: Hank He

Co-authors: Alex Rudkevich, Richard Tabors, Xindi Li, Ninad Kumthekar, Chen Ling. (TCR)

Russ Philbrick (PSO)

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Agenda

Pursuit of Green Energy and Carbon Neutrality	*What it means to be carbon neutral?*
Locational Marginal Emission Rate	*Definition and computation of LMER*
NYISO Case Study	*Modeling nodal LMER in a NYISO back cast simulation and study the effectiveness of different decarbonization strategies*

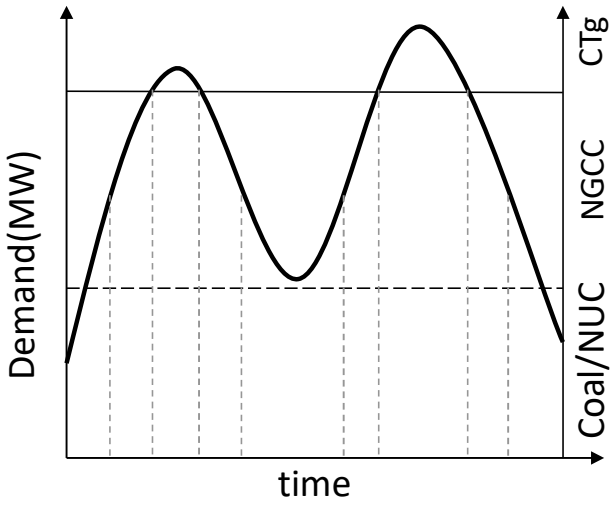
Pursuit of Carbon Free Electricity and Carbon Neutrality

- There has been a growing appetite for 100% carbon free energy in local government and private sector
  - Nine states and more than 100 cities and communities
  - 200+ enterprise energy buyers have engaged in some level of carbon offsetting
- However, a true definition of carbon neutrality has yet to be defined
  - Most popular strategy is to match REC with load either annually or hourly
  - However, that is not true carbon neutrality
- True Carbon Neutrality means 0 net carbon emission

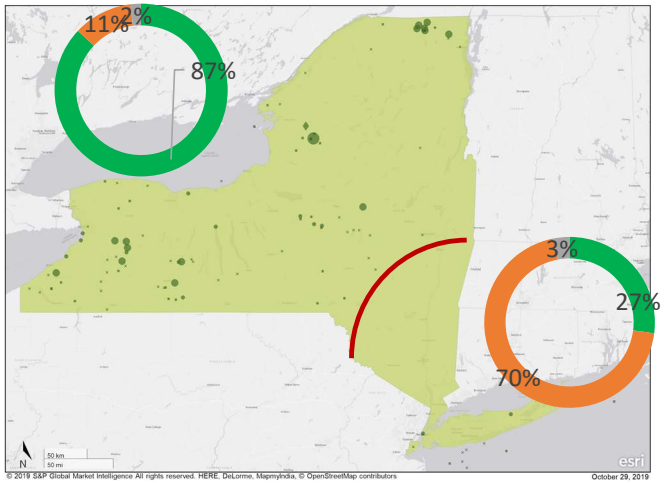
Electrons are not Created Equal (From a Carbon Perspective)

- Factors Impacting Emission Rates

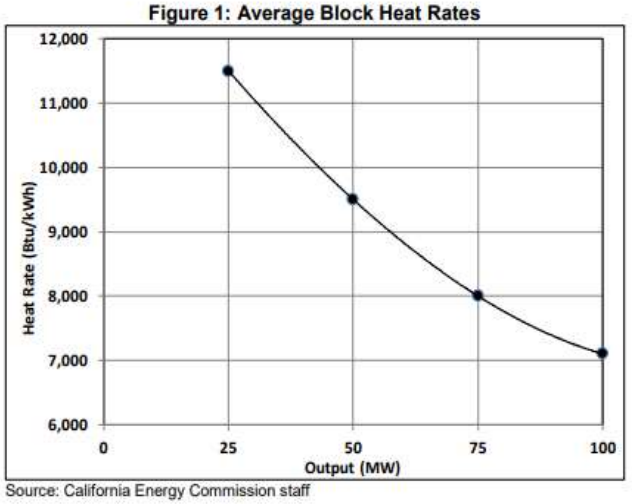
Temporal Impact



Locational Impact



Asset Data Impact



Source: California Energy Commission staff

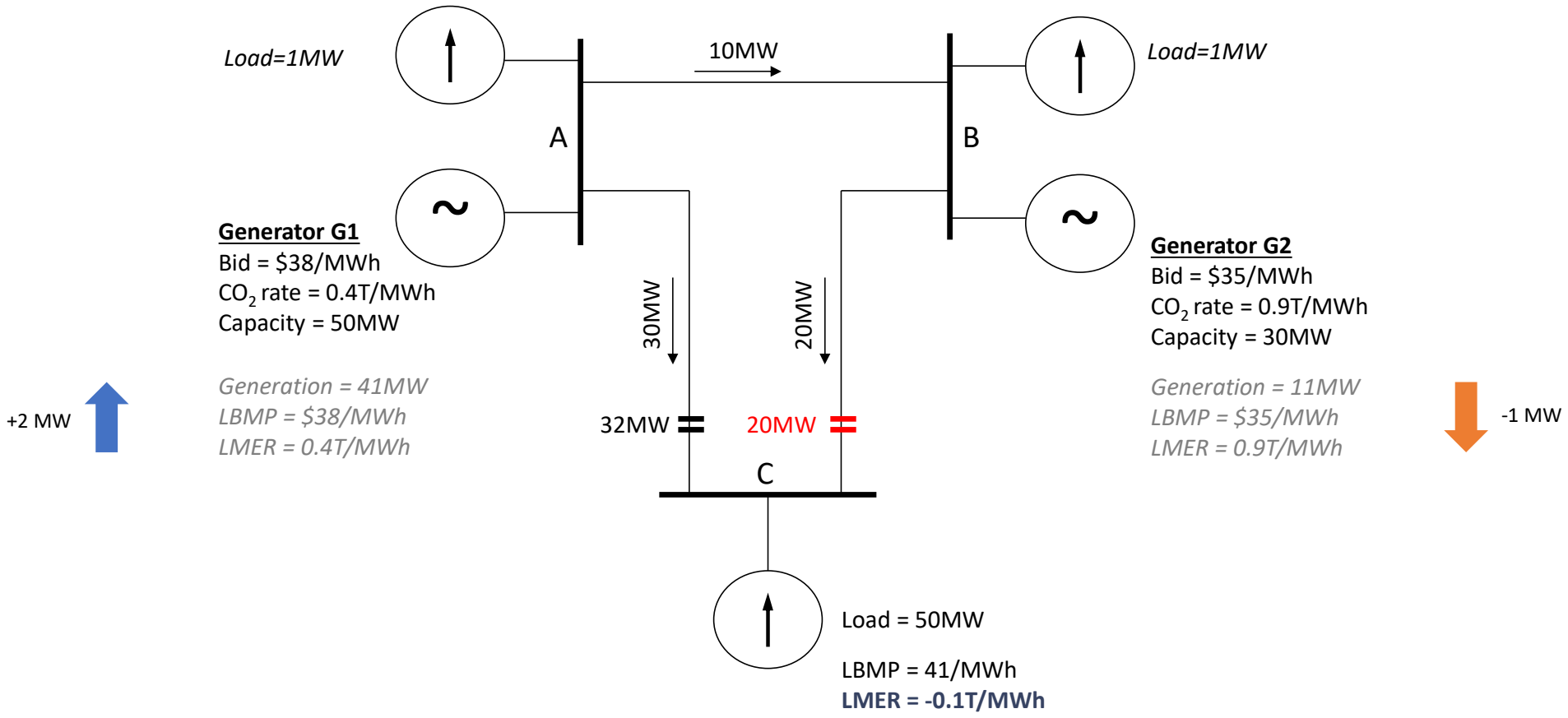
Locational Marginal Emission Rate Definition

$$LMER_{node} = \frac{\Delta(CO_2)_{system}}{\Delta(Demand)_{node}}$$

Change in system CO_2 emissions for an incremental MW of load at

1. A given location; and
2. A given time

LMER Can be Determined from Marginal Unit and Binding Constraints



Computation of LMER in a Large System

- The Grid is much more complex than the example:
  - Marginal for energy vs. marginal for reserves
  - Inter-temporal constraints for energy limited hydro and pumped storage
  - Effect of optimized phased shifters

- Nodal LMER can be derived by changing emission price:

LBMP changes in response to small variations in CO_2 Price in proportion to LMER at that location	$$LMER = \frac{\Delta LBMP}{\Delta CO_2 Price}$$

Computation Approach of LMER

$$LBMP = Cost_{production} + Cost_{carbon}$$
$$= Cost_{production} + LMER * Carbon\ Price$$

Case 1 : $$LBMP_1 = Cost_{production} + LMER * Carbon\ Price_1$$

Case 2 : $$LBMP_2 = Cost_{production} + LMER * Carbon\ Price_2$$

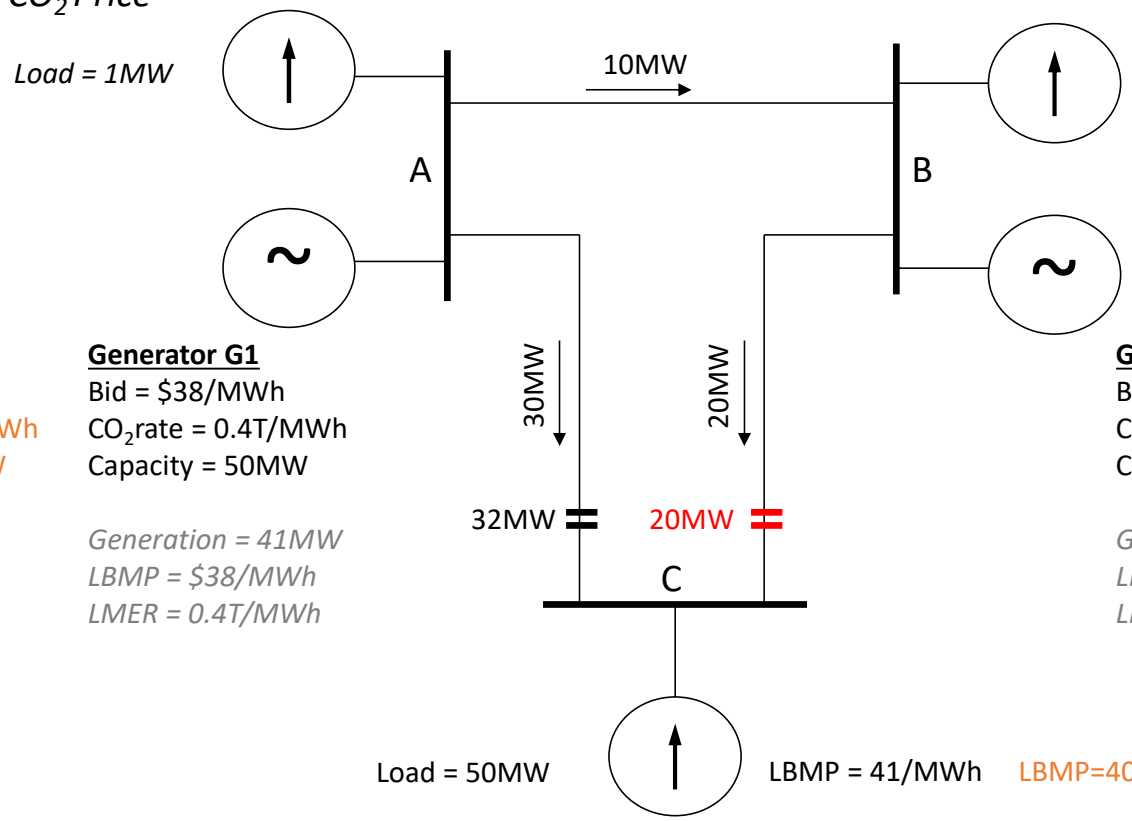
$$LBMP_2 - LBMP_1 = LMER * Carbon\ Price_2 - LMER * Carbon\ Price_1$$

$$LMER = \frac{LBMP_2 - LBMP_1}{Carbon\ Price_2 - Carbon\ Price_1}$$

Computational Approach to MER Calculation – an Example

Scenario1: \$0/ton CO_2 Price

Scenario2: \$1/ton CO_2 Price



Generator G1
Bid = \$38.4/MWh
CO_2rate = 0.4T/MWh
Capacity = 50 MW

Generator G1
Bid = \$38/MWh
CO_2rate = 0.4T/MWh
Capacity = 50MW

Generation = 41MW
LBMP = \$38/MWh
LMER = 0.4T/MWh

Generator G2
Bid = \$35/MWh
CO_2rate = 0.9T/MWh
Capacity = 30MW

Generation = 35MW
LBMP = \$20/MWh
LMER = 0.9T/MWh

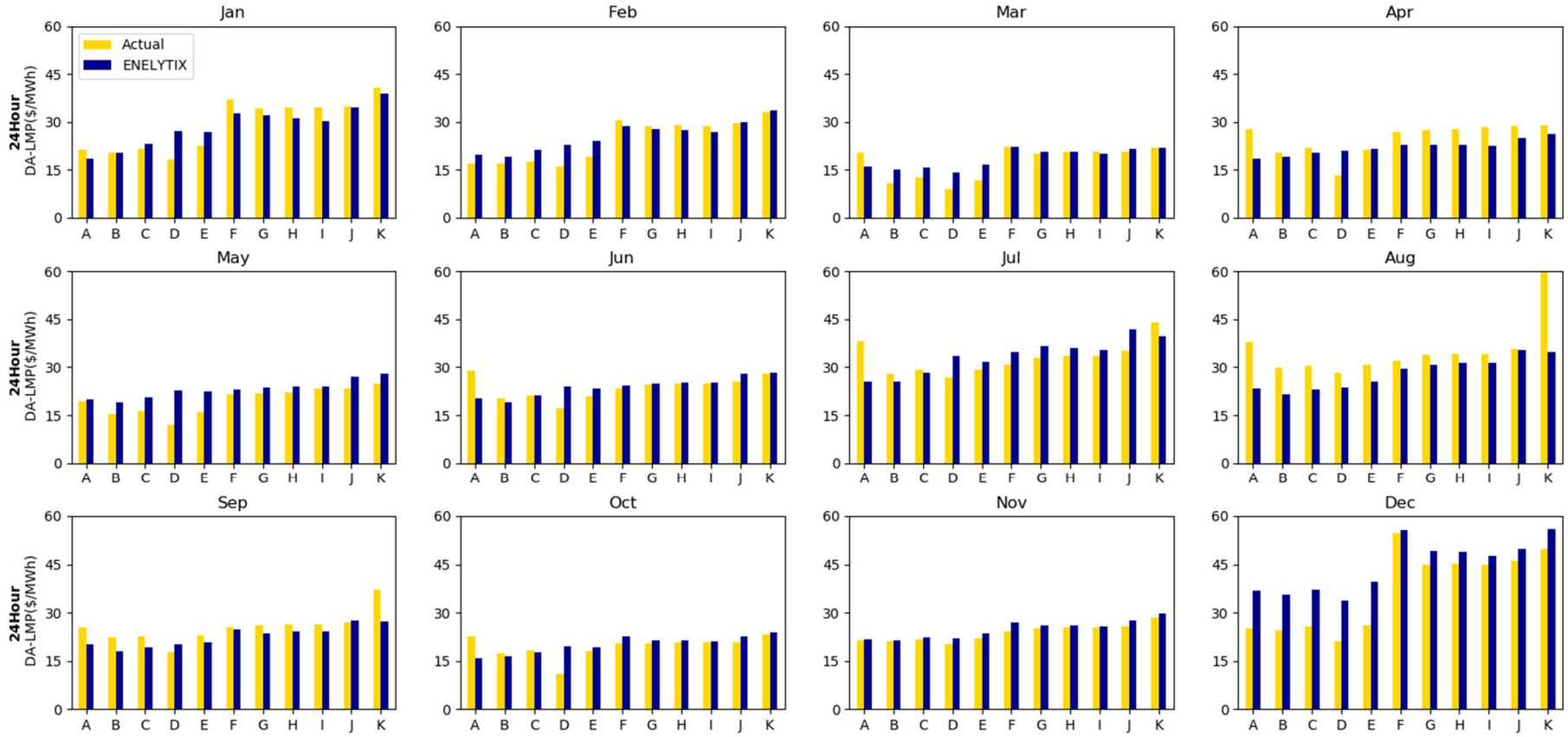
Generator G2
Bid = \$35.9/MWh
CO_2rate = 0.9T/MWh
Capacity = 30 MW

$$LMER = \frac{(40.9 - 41)\frac{\$}{MWh}}{(1 - 0)\frac{\$}{ton}} = -0.1\,{}^{ton}/_{MWh}$$

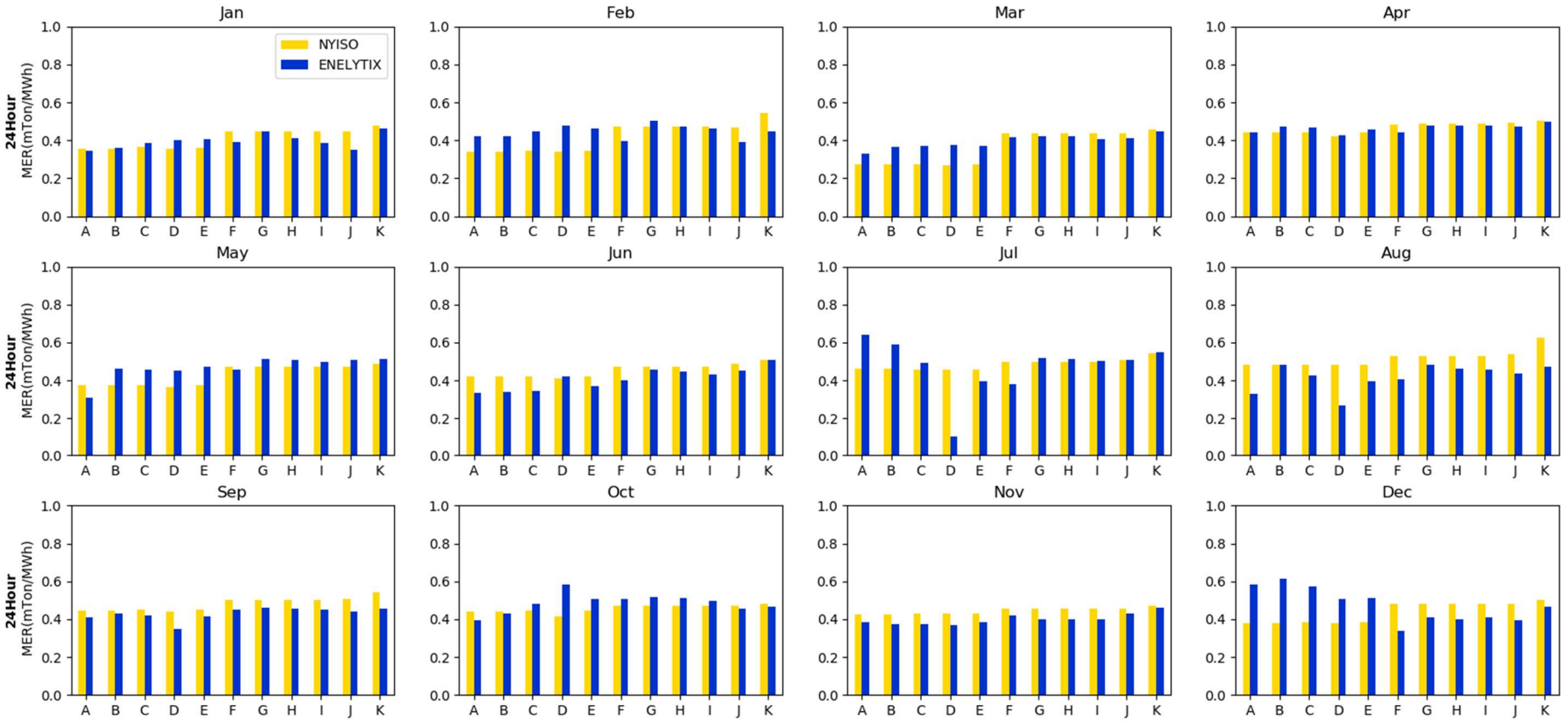
A Case Study for NYISO

- Start with a NYISO back cast simulation
  - Nodal SCUC and SCED model ENELYTIX® powered by PSO
    - Historic NYISO data
    - Fuel prices
    - Transmission constraints
    - Asset data
    - Interchanges
    - …
- Examine net carbon footprint of a small load under different decarbonization strategies
  - A hypothetical load in N.Y.C following zonal shape (8.76GWh/year)

Model was Calibrated with Historic Zonal Prices



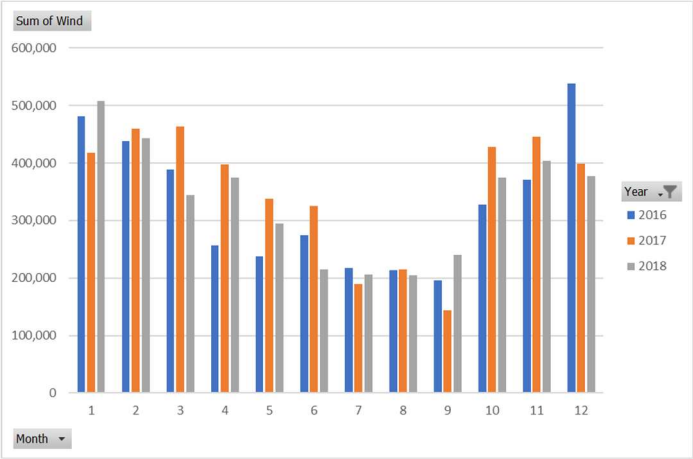
LMER Benchmarked Against NYISO Study for 2016



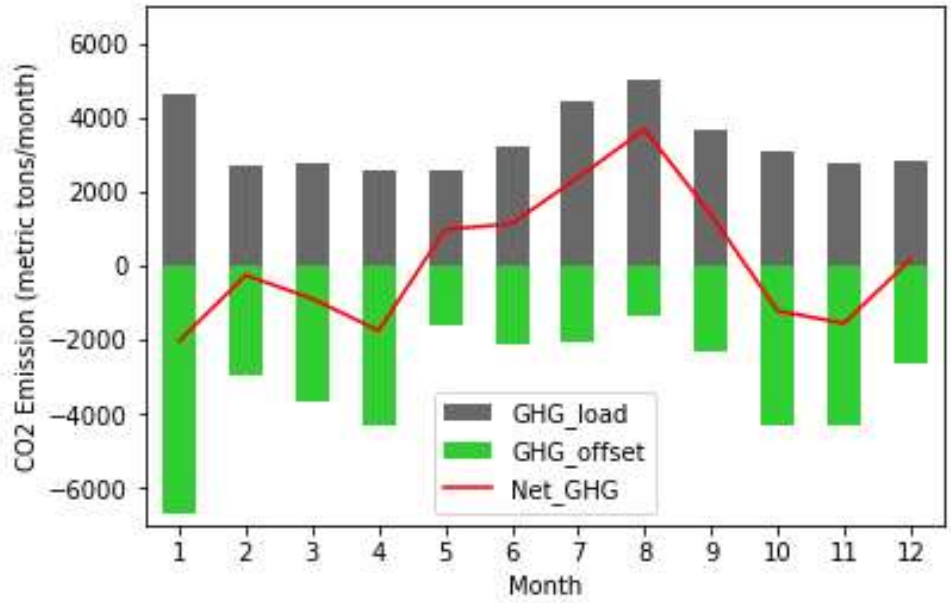
Annual MWh Matching Strategy Still Leaves a Large GHG Footprint

- Results:
  - Net emission: 2,045 ton/year
  - Balanced by a large wind plant in upstate

- Wind production is low in the summer when LMER is high and load is high



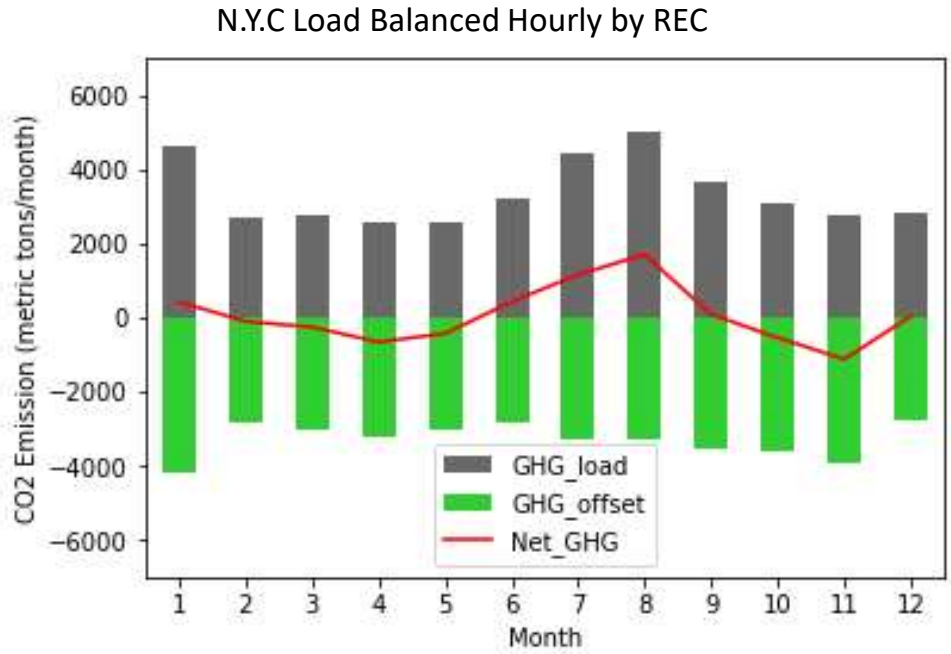
N.Y.C Load Balanced by Annual REC



Hourly Matching is not Cost Effective

- Results:
  - Net emission: 787 ton/year
  - Hourly balance could not be achieved even with all NYISO wind and PV plants
    - Total wind generation was less than 10 MW for more than 200 hours in 2018(NYISO)

- Net positive carbon driven by locational difference in LMER
  - Upstate resource vs. N.Y.C load

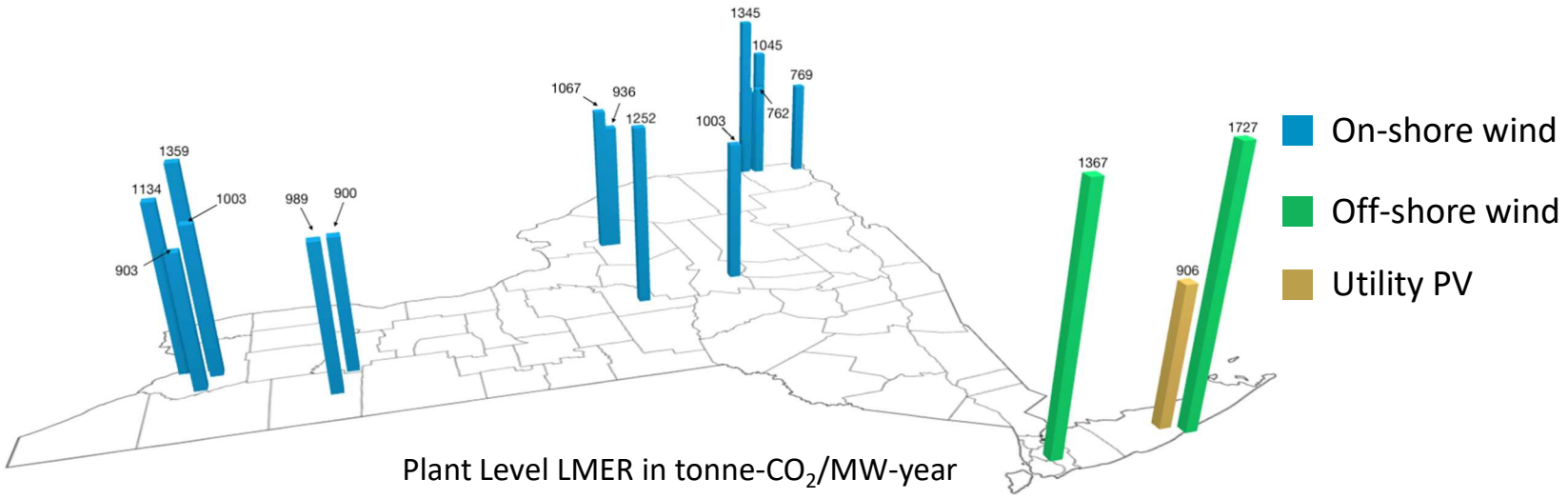


Use LMER to Achieve True Carbon Neutrality

- Nodal LMER allows us to measure how much energy is needed to offset the load's carbon footprint
  - 87,600 MWh/year
  - 40,334 tons-CO_2/year

Power Plant	Type	Plant Capacity	Plant Carbon Offset (tonne/year)	Plant MW Required to Neutralize Load
Long Island Solar Farm	Utility PV	31.5	28,539	NA
Moses Niagara (Fleet)	Hydro	2860	6,979,103	16.5
St Lawrence - FDR (Fleet)	Hydro	1088	3,212,120	13.7
Maple Ridge Wind 1	Wind	231	246,489	37.8
Marble River Wind	Wind	215.5	225,332	38.5
Wethersfield Wind Power	Wind	126	126,473	40.2

LMER Enables a Wide Range of Carbon Management Options



Plant Level LMER in tonne-CO_2/MW-year

- By quantifying carbon intensity of load and generators on a nodal basis, LMRE enables a wider range of decarbonization strategy that is efficient both economically and operationally:
  - Carbon offset in other emission areas (i.e. Transportation, heating etc.)
  - Use LMER to quantify carbon offset capability of transmission projects

Tabors Caramanis Rudkevich

300 Washington Street, Newton MA, 02458

Hank He

hhe@tcr-us.com

Aleksandr Rudkevich

arudkevich@tcr-us.com

Richard Tabors

rtabors@tcr-us.com