Planning for the evolution of the electric grid with a long-run marginal emission rate

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Agenda

1. Discuss recent study
2. Discuss NREL’s Cambium database
3. Q & A
What is the point of this talk?

What metric is most suitable for estimating the emissions consequences of an electric-sector intervention?

If I install a heat pump, what electric-sector emissions will be induced?

If an energy efficiency measure is adopted, what emissions will be avoided?

What are the emission differences from charging my electric vehicle during the day versus during the night?
3 Types of Emission Metrics

**Average Emission Rates**
Average emission rate of all generation in a given region
*Examples: eGRID*

**Short-run marginal emission rate**
Emission rate of the next unit of electricity *considering the grid’s structure as fixed*
*Examples: AVERT, WattTime, REsurety, ElectricityMap, Carbonara, et cetera*

**Long-run marginal emission rate**
Emission rate of the next unit of electricity *considering the grid’s structure as variable*
*Examples: NREL’s Cambium, CPUC Avoided Cost Calculator*
How did we test the 3 metrics?

The Method
1. Calculate each metric using power system models
2. Define a set of load shapes
3. Use each metric to estimate the emissions induced by each load shape
4. Put each load shape directly into the model and see what emissions are induced
5. Compare the two values
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\[ X = 284 \text{ kg of CO}_2 \text{ per MWh} \]
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215 kg of CO₂ per MWh
How did we test the 3 metrics?

**The Method**

1. Calculate each metric using power system models
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| Method 1 | Method 2 |
|----------|----------|
| 284 kg/MWh | 215 kg/MWh |

Error of +69 kg of CO₂ per MWh
How did the three metrics perform?

How well does each metric perform?

The estimations from a well-performing metric would fall on the diagonal parity line.

The metric **overestimated** emissions.

The metric **underestimated** emissions.
How did the three metrics perform?

How well does each metric perform?

The estimations from a well-performing metric would fall on the diagonal parity line.

![Graph showing Observed Mixture vs Estimated Mixture for Short-run Marginal Emission Rate. The graph includes a scatter plot with a diagonal line indicating parity. The x-axis represents the observed CO$_2$ emissions rate (kg/MWh$_{enduse}$), and the y-axis represents the estimated CO$_2$ emissions rate (kg/MWh$_{enduse}$).]

- Observed Mixture
- Estimated Mixture

The chart shows the comparison between observed and estimated emission rates, with categories for Wind and Solar, Hydropower, Natural Gas, Coal, Other, and Nuclear.
How did the three metrics perform?

How well does each metric perform?

The estimations from a well-performing metric would fall on the diagonal parity line.

Short-run Marginal Emission Rate

Average Emission Rate

Observed Mixture

Estimated Mixture

Wind and Solar

Natural Gas

Hydropower

Coal

Other

Nuclear
How did the three metrics perform?

**How well does each metric perform?**

The estimations from a well-performing metric would fall on the diagonal parity line.

- **Short-run Marginal Emission Rate**
- **Average Emission Rate**
- **Long-run Marginal Emission Rate**

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**Observed Mixture**

- Wind and Solar
- Hydropower
- Coal
- Other
- Nuclear

**Estimated Mixture**

- 1.0
- 0.5
- 0.0
How did the three metrics perform?
How did the three metrics perform?

How well does each metric perform?

The estimations from a well-performing metric would fall on the diagonal parity line.

- **Short-run Marginal Emission Rate**
- **Average Emission Rate**
- **Long-run Marginal Emission Rate**

Observed Mixture

Estimated Mixture

- Wind and Solar
- Hydropower
- Natural Gas
- Coal
- Other
- Nuclear
How did the three metrics perform?

How well does each metric perform?

The estimations from a well-performing metric would fall on the diagonal parity line.
What if the average and short-run metrics are also calculated from projections of the future?

SRMER and AER Calculated From First-year Values

- Short-run Marginal Emission Rate
- Average Emission Rate
- Long-run Marginal Emission Rate

All Metrics Calculated From Full 20-year Timeframe

- Short-run Marginal Emission Rate
- Average Emission Rate
- Long-run Marginal Emission Rate
Conclusions

**Short-run marginal emission rate:**
- Does not comprehensively reflect the consequences of an intervention
- In our study, often significantly overestimated induced emissions
- Integrating SRMER over time does not capture full consequences

**Average emission rate:**
- Mean error was less than short-run metrics, but this was mostly by happenstance
- Did not capture diurnal trends well in our nation-wide analysis

**Long-run marginal emission rate:**
- Outperformed both the other two metrics, but still not perfect
- See caveats on the next slide!
Discussions and Limitations

General comments:
• For unexpected or unplanned interventions, a phased short-run/long-run approach would likely be appropriate
• The LRMER metric is only as good as the underlying model
• This study only examined a priori planning assessments, but the concepts likely apply to many real-time operational decision as well
• We only examined CO₂, but the concepts here apply to other emissions as well

Limitations of our study:
• Our scenarios had curtailment occurring ~1% of the time (and often in locations with relatively little load) – SRMER might perform better when there is significant curtailment
• This paper only examined our “Mid-case” projection of the future
• This paper only examined performance when the future unfolded as expected
• This paper only examined the nation as a whole
NREL’s Cambium Project

NREL’s annually-released data sets contain hourly emission, cost, and operational metrics for modeled futures of the U.S. electric sector

Website for updates: https://www.nrel.gov/analysis/cambium.html

Workbooks with LRMER data: https://data.nrel.gov/submissions/183
Scenario Viewer and Data Downloader: https://scenarioviewer.nrel.gov/

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Questions?

Website for updates: https://www.nrel.gov/analysis/cambium.html

Workbooks with LRMER data: https://data.nrel.gov/submissions/183

Scenario Viewer and Data Downloader: https://scenarioviewer.nrel.gov/

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