Two LBNL Methods for Estimating the Emissions Avoided due to Renewable Energy Generation

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A New Plant's Effect on the Future Emissions from a Power Pool

- **When a new plant begins operations, it impacts emissions in two ways.**
  - **It may affect the operations of plants that are relatively responsive to changes in load.**
  - **It may offset the need for another generation source that would have been built in its place.**
- **The first impact referred to as operating margin (OM) effect, the second as the build margin (BM) effect.**

Average vs. Marginal Emissions Rates

- Determining the emissions rate of offset electricity: Average vs. Marginal Emissions Rates
  - Is the average rate of all plants on the grid a good estimate?
  - No, it does not reflect the way new projects actually affect emissions.
  - We need to estimate emissions offset at the **margin** by new generation.
  - This matters because average and marginal rates can vary tremendously.

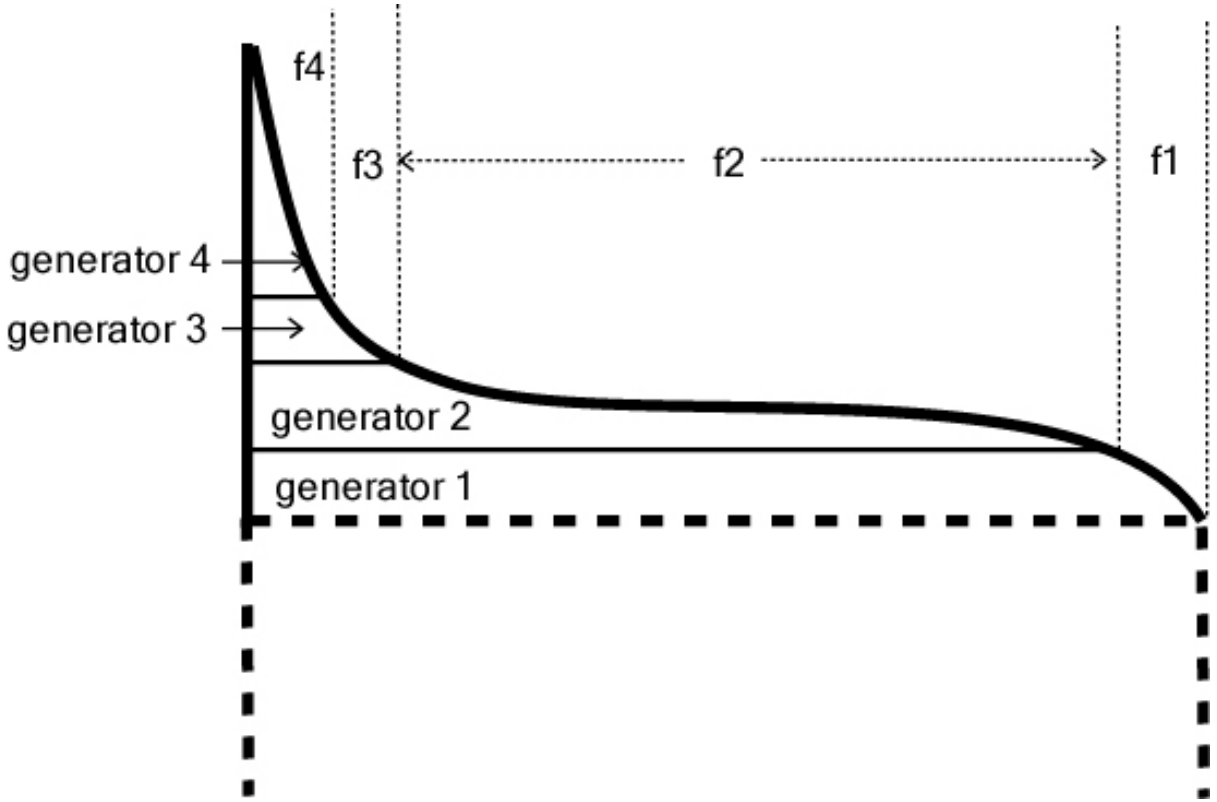
Two Methods Devised by LBNL to Estimate Avoided Emissions

- Marginal Avoided GHG – Power Sector (MAGPWR)
  - This is a load duration curve model designed to calculate the OM for a given grid.
  - It is best suited to smaller projects thought to affect primarily the operating margin.
- MBase Electric
  - This a more comprehensive tool that produces both BM and OM outputs.
  - However, the modeling of the OM is less sophisticated than MAGPWR.

MAGPWR Methodology

- Construct a load duration curve from a chronological load curve.
- Fill the curve from the bottom up with plant-level or resource-level data beginning with highest capacity factor units first.
  - If generating costs are known, cost data may be used instead to stack by plant or fuel type.
- Calculate the weighted OM based on the amount of time each resource operated on the margin.

Marginal Avoided GHG – Power Sector (MAGPWR)



MBase Methodology

- Plants are separated into three cohorts to produce three different margins.
  - Recent baseload plants
  - Recent load following plants
  - All load following plants (may want to exclude some pondage hydro used for load following0
- The generation and corresponding emissions from these plants can be averaged or ranked into percentiles to yield three types of margins
  - Baseload BM
  - Load following BM
  - OM
- These three margins can be combined in various ways according to a project's expected impact on future emissions.

Case Study #1
5 MW Landfill Gas

- MAGPWR – Assume project affects OM use rate given by MAGPWR.
- MBase – Since LFG provides firm baseload power, assume effect is primarily on baseload BM.
  - If no capacity credit is assumed, may want to use OM.
  - A combined margin can also be used.

Case Study #2
100 MW Wind Farm

- MAGPWR – Assume offset generation is entirely from OM and use the MAGPWR factor.
- MBase – Since wind is intermittent (non-firm), assume effect is primarily on OM and use MBase OM rate.
  - Capacity credit may be given to some share of the wind farm and generation up to that point can be credited with baseload BM.

Case Study #3
1000 MW Wind Farm for RPS

- MAGPWR – Not well suited for this project due to lack of ability to model build margin effect.
- MBase – Divide generation into (statistically) firm and non-firm shares and estimate avoided emissions using corresponding baseload BM and OM rates.
- The fact that this is for an RPS is a separate question.
  - Emissions **are** avoided, but whether they count for a given crediting program is purely a policy question. Using agreed-on definitions of additionality, they would not.

Use of MAGPWR and MBase for Criteria Pollutants

- Sure, why not?
- If emissions of these pollutants are correctly matched to plants, both tools could be modified to produce NO_x and SO_x rates.
- However, if dealing with a capped emissions market, emissions may never be truly avoided unless permits are retired as a result.

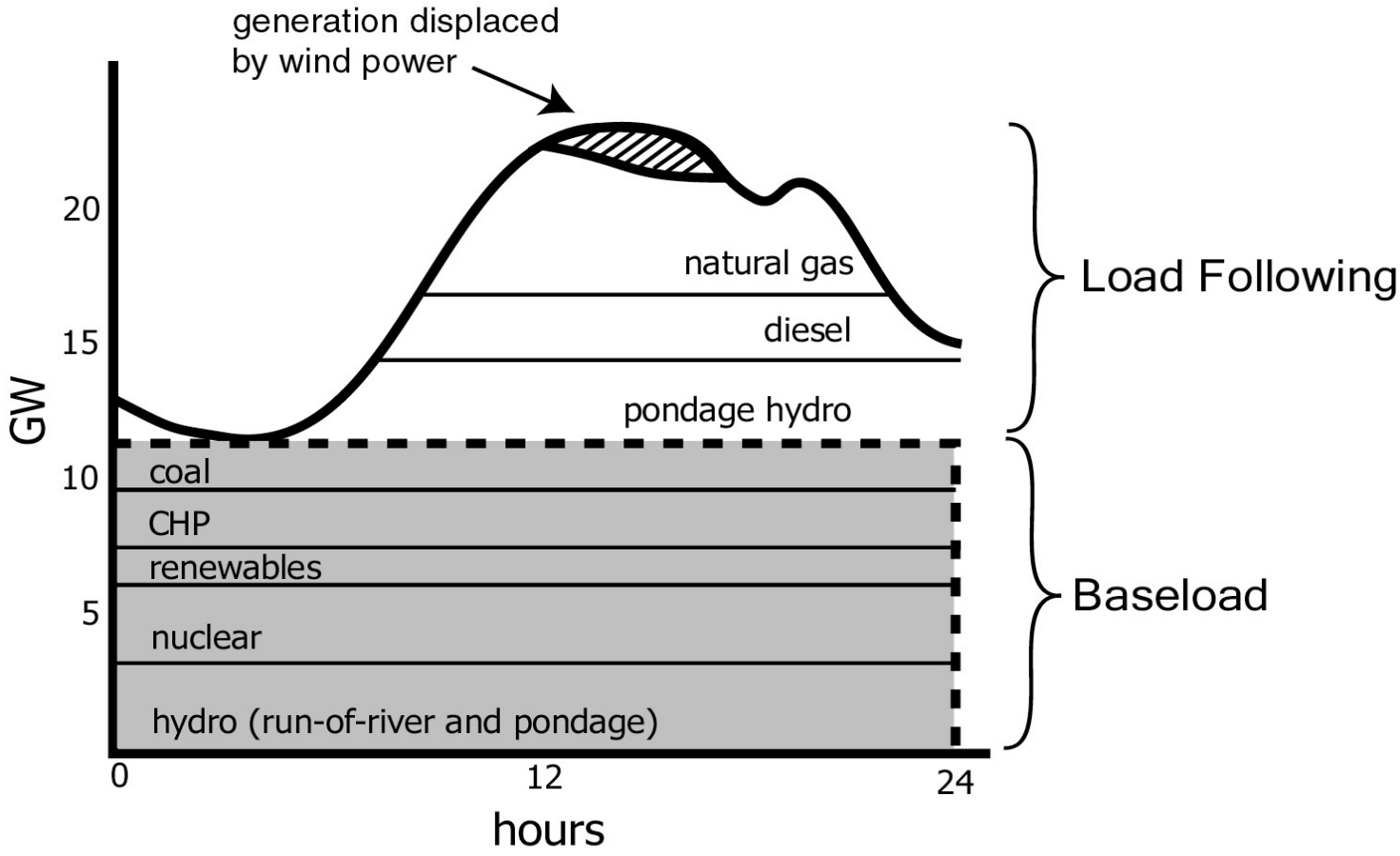
Which Marginal Emissions Rate?

- There are two kinds of marginal effects on emissions: **Build Margins** and **Operating Margins**.
- The build margin represents the effect of a new plant on offsetting the need for other plants that would have been built.
- The build margin emissions rate is likely to differ from the average rate for two reasons.
  - Conversion technologies are improving, generating more electricity from less fuel.
  - The average fuel mix may change, e.g. combined cycle natural gas plants may begin to replace coal plants.
- The operating margin represents the effect of a new plant on the operations of existing power plants.
  - Operating marginal emissions rates are likely to differ from the average because…

Marginal Demand Is Met by Different Technologies at Different Times

- Baseload plants are designed to operate at high capacity factors and provide power day and night.
- Load following plants provide additional power as needed throughout the day.
- Emissions rates of the generators serving the two load types may differ substantially.
- Whether a plant is baseload or load-following may be determined by economic, physical, or contractual factors.
  - Economic: high cost vs. low cost
  - Physical: thermal vs. solar
  - Contractual: take or pay clauses

Displacement of Load Following Power by Renewable Electricity



California: Average vs. Operating Marginal Emissions Factors, 1999

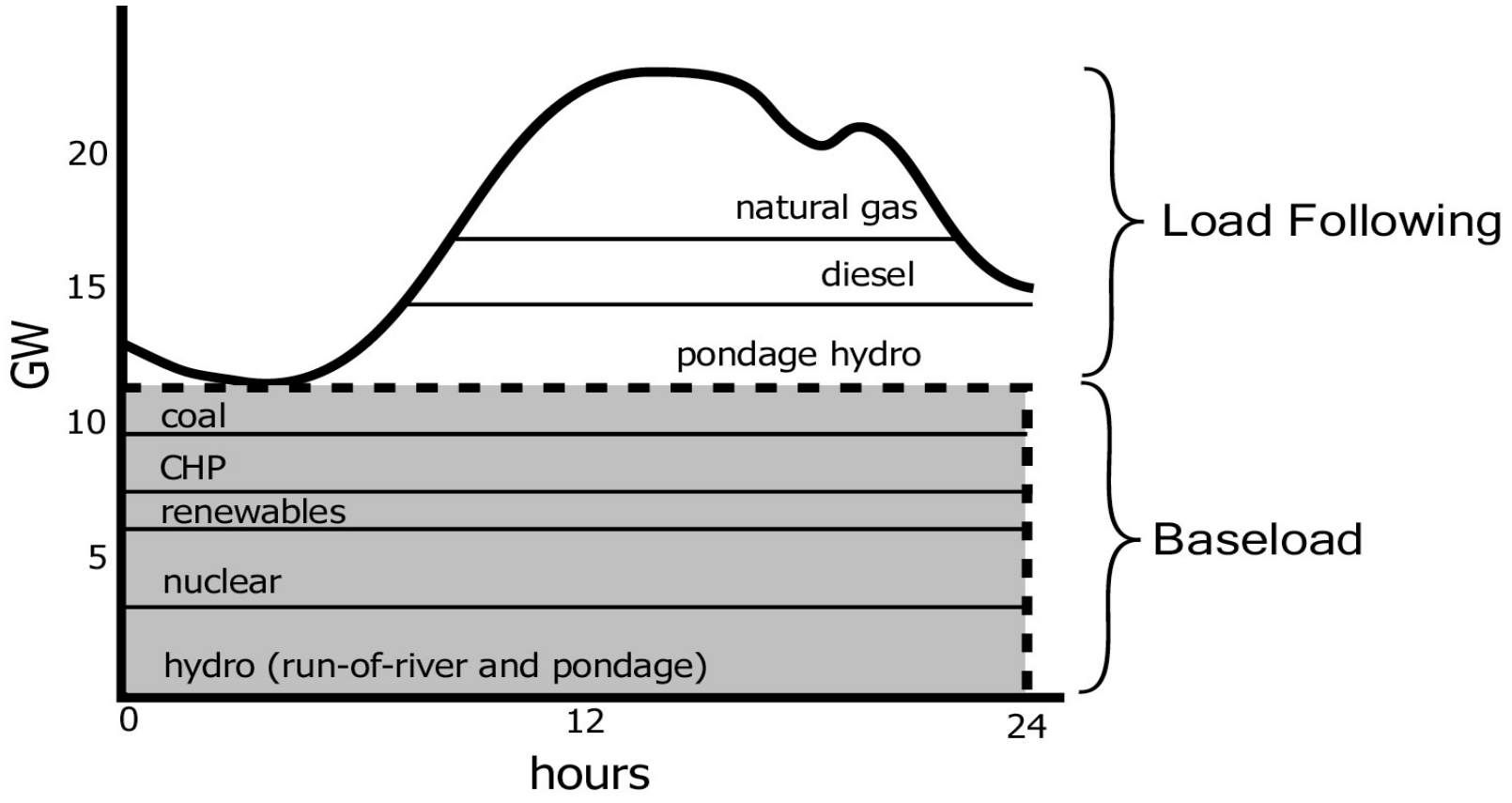
Calif. Grid Region	Average Emissions Rate kgC ($kgCO_2$)/kWh	(Operating) Marginal Emissions Rate kgC ($kgCO_2$)/kWh
Southern California Edison	.131 (.481)	.215 (.789)
San Diego Gas and Electric	.146 (.536)	.181 (.664)
Pacific Gas and Electric*	.063 (.233)	.140 (.518)
California Independent System Operator**	.101 (.374)	.193 (.714)
Los Angeles Dept. of Water and Power	.207 (.766)	.199 (.736)

* Includes Sacramento Municipal Utility District
** Includes irrigation districts and municipal utilities

Which Margin should be Used for Performance Standards?

- Most generation technologies produce “firm” power, i.e. power that is reliably available and dispatchable (controllable).
- Since these sources are dependable, it is assumed they offset the need for other capacity additions. (This may be a single large plant, or the cumulative impact of several smaller plants.)
- If a plant is meant for baseload or load following operations, the average characteristics of the offset capacity may differ.

Which Part of the Load will a New Plant Offset?



Which Margin should be Used for Performance Standards? (2)

- Some generation sources (such as wind farms) produce power intermittently. This is referred to as “nonfirm” power.
- Since this power is not dispatchable, it cannot offset needed capacity.
- Power from intermittent sources is assumed to primarily affect the operations of existing (and future) load following stations (operating margin effect).

Taxonomy of Projects and MERs

- These considerations result in three project types based on their effect on the future path of emissions.
- Each of these three project types is assumed to mostly affect plants of three distinct reference groups.
- Thus, for each project type there is a corresponding set of reference case plants used to construct the appropriate MERs.

Taxonomy of Projects and MERs

Will renewable project provide firm or non-firm power?

	Non-firm	Firm
Types of renewables	wind, solar	geothermal, biomass, lfg
Impact of project?	Operating margin	Build margin
What "reference case" to use?	Emissions rate of marginal dispatch plants in geographic region	Emissions rate of recent benchmark firm plants in geographic region (baseload vs. load-following)

Choosing Reference Case Plants for Build Margins

- Geographic scope: state, national, or power pool?
  - Generally, the power pool. These are the plants whose emissions will be offset.
  - However, the presence of large interties blurs the definition of “power pool”.
- Load specificity: baseload or load following?
  - The difference between baseload and load following can be fuzzy.
  - What capacity factor defines “baseload”? 60%, 70%?
  - Plants operations may change with fuel prices or demand.
  - Hydro plants may be baseload in one season and load following in another.

Choosing Reference Case Plants for Build Margins (2)

- Vintage: how old can a plant be before it is not considered "recently built"?
  - If too restrictive, the sample of plants may not be representative of resources available to the power pool.
  - If too lenient, older plants may not match the efficiencies and fuel sources of plants built in the near future.
  - A Berkeley Lab analysis of grids in the U.S. and some developing countries suggests roughly five years as a limit.
- Stringency: weighted average, top 25%, top 10%, or best plant? (more of an additionality or eligibility question)

Methods and Time Frames for Calculating Operating Margins

- Operating margins can be calculated on a periodic basis using models or actual generation data.
  - Complex power system operation models
  - Simplified Load Duration Curve approaches
  - Average of all load following generators
- New plants with different generation profiles may need seasonal or time-of-day factors to improve accuracy since operating margins change between
  - On-peak and off-peak periods
  - High load and low load seasons (e.g. summer vs. winter)
  - High hydro and low hydro seasons

MBase Approach to Calculating Marginal Emissions Rates

- Berkeley Lab has developed a spreadsheet tool, referred to as MBase, that calculates a variety OM and BM rates from plant level generation and fuel consumption data.
- The MERs consist of simple averages of total emissions divided by total generation for the cohort of reference plants used.
- MBase is available at http://ies.lbl.gov/mbase

Evaluation of MBase and MAGPWR Approaches

- Accuracy
  - OM: high for MAGPWR, medium for MBase
- Practicality
  - High practicality when plant-level data available. In the U.S. these data are easily available from public sources, but for greater accuracy detailed dispatch tables may be needed to guide the modeling.
- Transparency
  - Crystal clear. Calculations in spreadsheets are easily verified, MAGPWR is somewhat more complex.
- Conservativeness
  - Choosing higher stringency levels in MBase can increase conservativeness for BM.

For Further Information

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