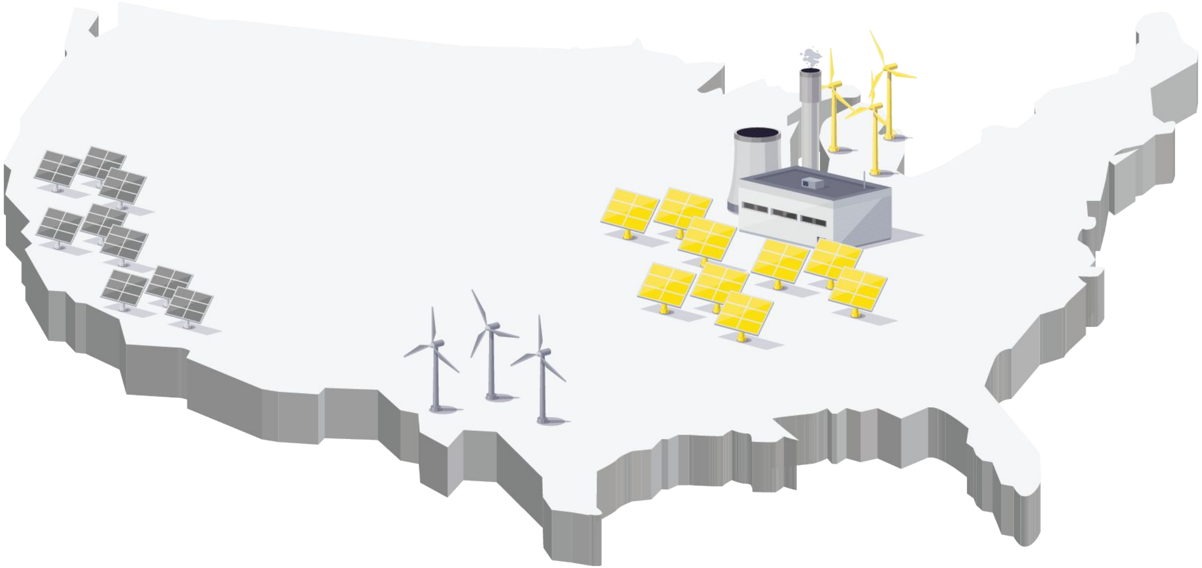
Orientation to Marginal Build Emissions Rates (MBERs)



April, 2025

WattTime

There are *only* three ways to reduce emissions

All the power plant emissions in the world come from only three things. Each power plant's emissions are:

Emissions = Emissions Factor x Capacity x Operation

For example, each ton of coal produces 2000 lbs of $CO2$/MWh. A 500 MW coal plant that operates at 50% with an emissions factor of produces 2000 lbs/MWh x 500 MW x 50% MWh/MW lbs of $CO2$ each hour.

That means it's physically impossible to reduce emissions except in three ways:

1. Do something that reduces the *emissions factor* of polluting power plants
    a. **This generally requires carbon capture and storage, and is likely not relevant to Apple**
2. Do something that reduces the *capacity* of polluting power plants.
    a. **This is called structural change or a "build effect"**
3. Do something that reduces the *operation* of polluting power plants.
    a. **This is called a short-run or "operating effect"**

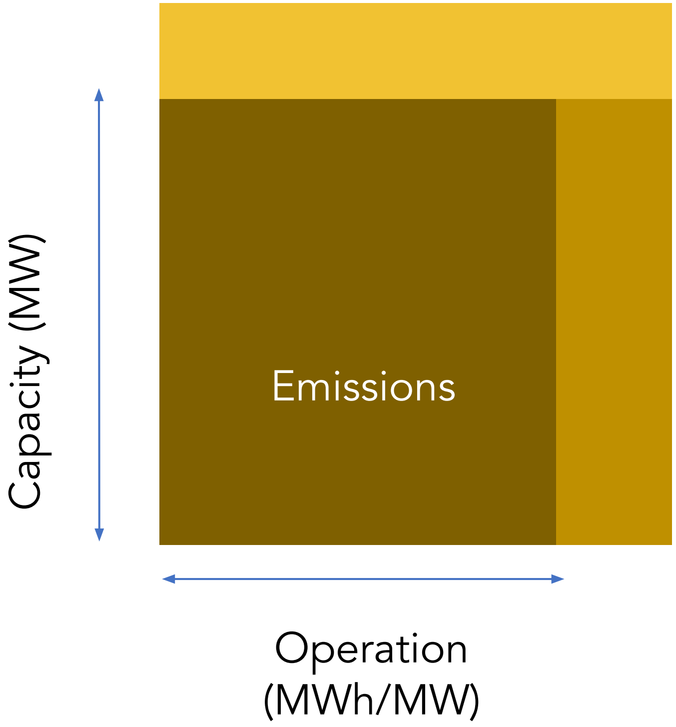
https://rmi.org/insight/assessing-the-impact-of-voluntary-actions-on-the-grid/

All theories of change affect build or operation

All theories of change are designed to affect one of two things.

Build effects (that aim to reduce capacity of emitting power plants):
- Net Peak
- Renewable Energy
- Marginal Build Emissions Rate

Operating effects (that aim to reduce *operation* of emitting power plants):
- Curtailment
- Marginal Operating Emissions Rate



https://rmi.org/insight/assessing-the-impact-of-voluntary-actions-on-the-grid/

Many build margin signals are just *proxies*

There are many signals that people have proposed that may help affect whether the grid will close down more dirty fossil fuel plants, i.e. drive build effects:

- Average emissions
- On peak / off peak
- Renewable fraction
- Wholesale price
- Net load

The hope of each of these signals is that they drive some action that we hope *may* help *indirectly* reduce fossil fuel power plant capacity. What a build margin signal does is attempt to actually measure that change instead of use a proxy for it.

https://rmi.org/insight/assessing-the-impact-of-voluntary-actions-on-the-grid/

How is MBER calculated?

The Greenhouse Gas Protocol and UNFCCC proposed the following method to calculate a MBER:

If you want to know how a grid operator will respond to a change in when or where people use electricity, look at how that same grid operator actually did respond last time.

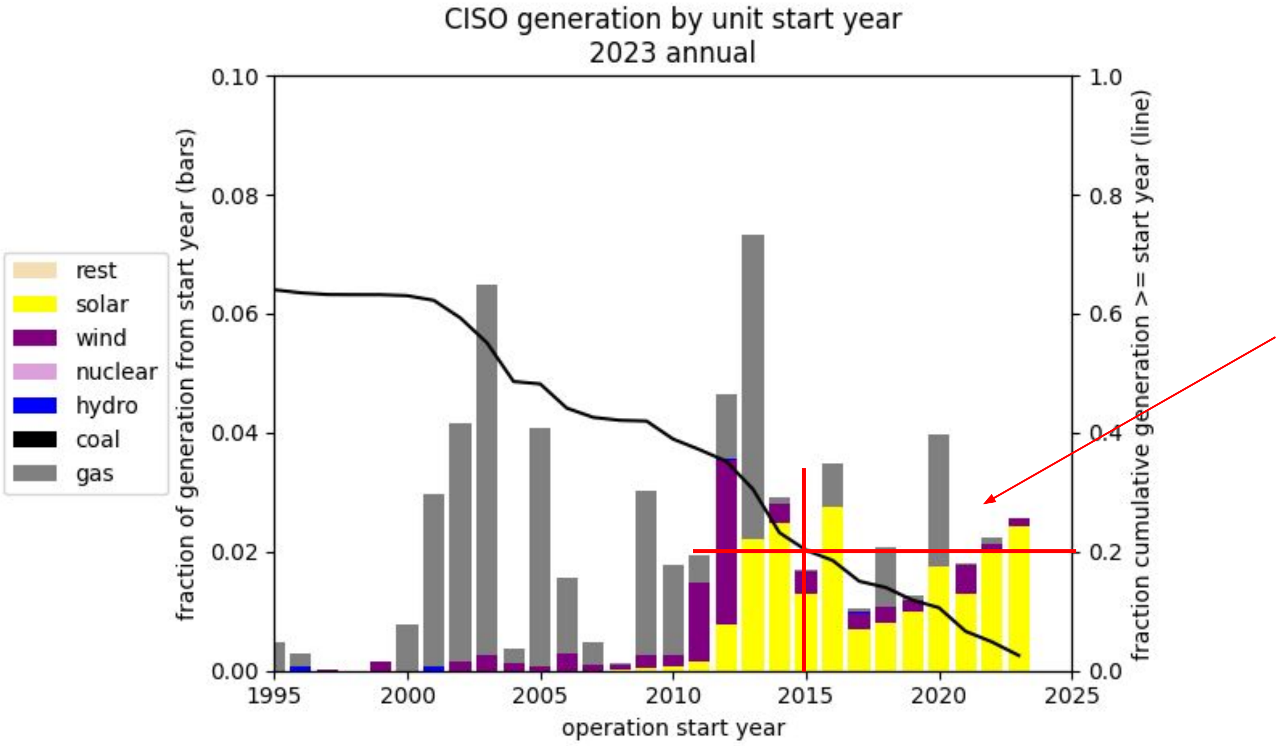
Specifically, for a specific place and time, identify the last 20% of power plants changes grid operators actually did approve. Assume that their next choice will match those choices.

Look at generation coming from the most recent 20% of power plants that have been built. **MBER** is the mean emissions intensity of those power plants.

WattTime, RMI, REsurety, MIT, Princeton, and Open Energy Transition have been investigating the accuracy of this method. So far results suggest that it is more accurate than any other method which has yet been proposed.

https://www.gem.wiki/MBERs_methodology

Example: California ISO



This graph shows what new capacity the California grid operator actually approved.

You can see a dramatic change around 2010.

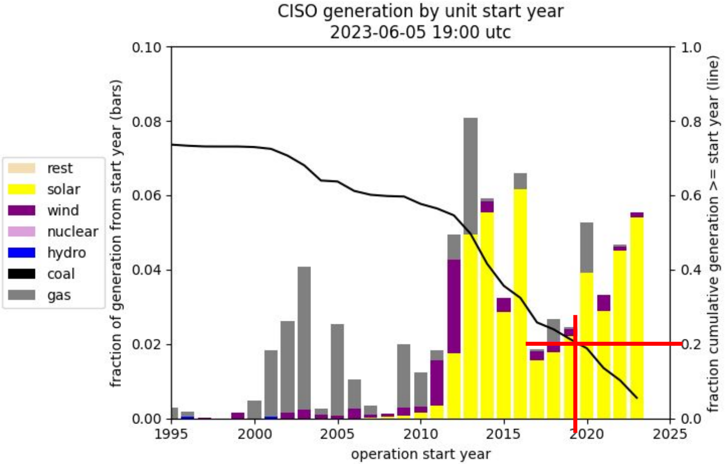
The build margin works by measuring the last 20% of power plants built in California (i.e. those built since 2015).

If you want to predict what the grid operator will do today, this helps.

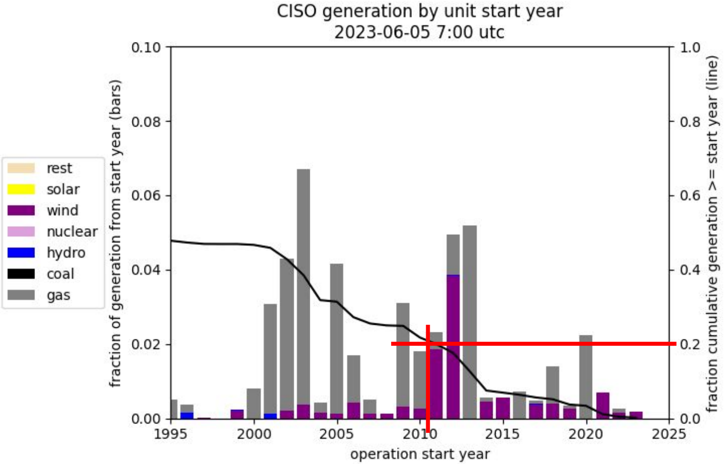
The build margin is the mean emissions rate of those plants, which works out to 86.6kg/MWh.

How this relates to load shifting: *hourly* MBERs

California NOON



California MIDNIGHT



The reason this matters for load shifting is that MBERs vary a *lot* based on time of day and season.

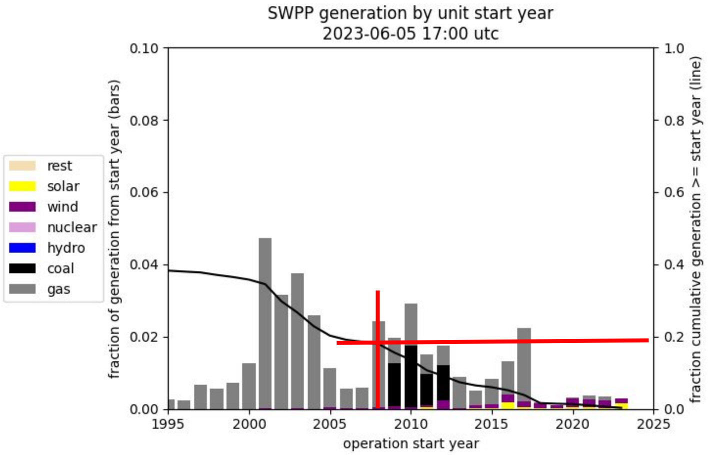
E.g. in California over the last few years, at noon every June 5th nearly 100% of newly built power plants were solar. If you can consistently shift load from midnight to noon on June 5th, you are virtually guaranteeing that the grid will respond by building more solar. On average, their emissions are 25 kh/MWh: not quite zero.

By contrast at midnight on June 5th, the grid has responded to rising load by building a mix of wind and gas. If you can consistently shift load *away* from midnight, you are allowing the grid to build less of, or even shut down, a mix of wind and gas plants. On average, their emissions are 299kg/MWh: a whopping ten times higher.

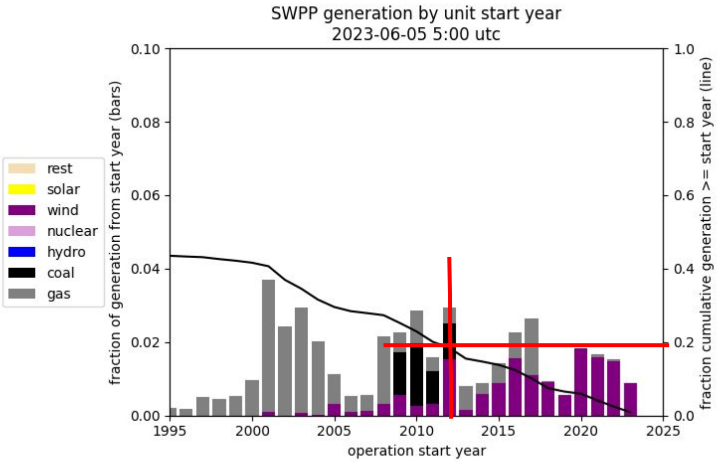
So, shifting 1 MWh from midnight to noon in California today can have a dramatic impact on emissions. And unlike a MOER, it's highly consistent and predictable!

The Build Margin Varies Dramatically by Region

SPP NOON



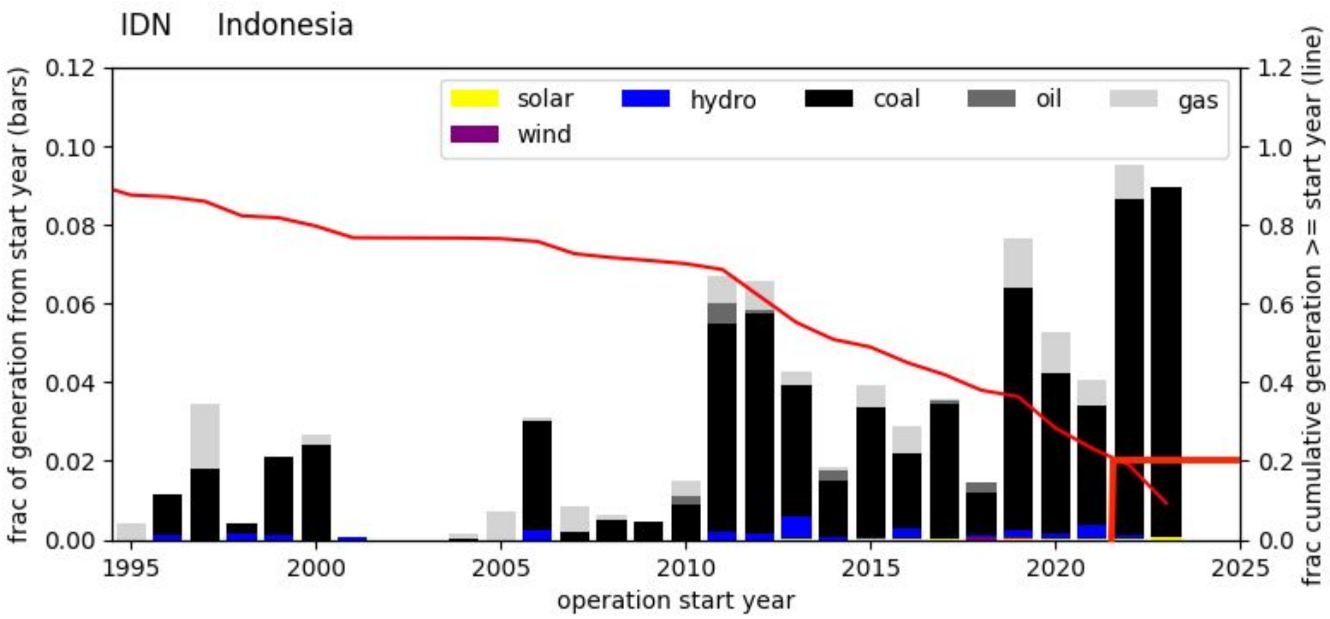
MIDNIGHT



By contrast, SPP is the other way around. There, grid operators have approved barely any solar at all, but huge amounts of night-peaking wind. Further, we can see they are getting away with not building gas plants recently only because demand hasn't actually grown

So in SPP, if you consistently shift electricity from midnight to noon, you'd likely be ensuring grid operators build less wind and more gas, *increasing* emissions. The MBER reflects this–the daytime MBER is 476, *higher* than the nighttime MBER of 172.

The Build Margin Varies Dramatically by Region



But grids vary. For example, in Indonesia, almost every MWh is coal.

This is why it’s so important that Apple includes a build margin in its renewable energy procurement. Other grid regions around the world show significantly different resources that constitute the build margin.

This same approach can be represented as a table, with a cutoff at 20%

operating_year int64	ba_code varchar	start_year int64	cnt int64	mw double	mwh double	co2 double	cum_qty int128	cum_mw double	cum_mwh double	cum_co2 double	cum_mwh_frac double	gte_10 boolean	gte_20 boolean	gte_100 boolean
2023	CISO	2023	47	2595.9	4803384.5	5247964.8	47	2595.9	4803384.5	5247964.8	0.0256	false	false	false
2023	CISO	2022	62	2285.8	4260207.2	96944589.4	109	4881.7	9063591.7	102192554.2	0.0482	false	false	false
2023	CISO	2021	82	1694.6	3377445.0	21425835.1	191	6576.3	12441036.8	123618389.3	0.0662	false	false	false
2023	CISO	2020	67	3350.4	7436573.3	1386065810.8	258	9926.7	19877610.0	1509684200.2	0.1058	true	false	false
2023	CISO	2019	57	1243.6	2412767.6	106923270.6	315	11170.3	22290377.7	1616607470.8	0.1187	true	false	false
2023	CISO	2018	82	1768.1	3963218.6	900979402.0	397	12938.4	26253596.3	2517586872.8	0.1398	true	false	false
2023	CISO	2017	91	977.0	1991402.9	77668892.5	488	13915.4	28244999.2	2595255765.3	0.1504	true	false	false
2023	CISO	2016	127	3377.4	6563702.0	640638147.3	615	17292.8	34808701.2	3235893912.5	0.1853	true	false	false
2023	CISO	2015	152	1656.9	3242577.9	58886492.5	767	18949.7	38051279.1	3294780405.0	0.2026	true	true	false
2023	CISO	2014	168	2898.6	5510490.7	155266045.6	935	21848.3	43561769.8	3450046450.6	0.2319	true	true	false
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2023	CISO	1910	4	12.8	51595.2	0.0	2233	71035.3	187644266.9	35505429825.8	0.9988	true	true	false
2023	CISO	1909	1	2.0	8061.8	0.0	2234	71037.3	187652328.7	35505429825.8	0.9989	true	true	false
2023	CISO	1908	3	10.5	42324.2	0.0	2237	71047.8	187694652.9	35505429825.8	0.9991	true	true	false
2023	CISO	1907	7	30.0	120926.3	0.0	2244	71077.8	187815579.2	35505429825.8	0.9998	true	true	false
2023	CISO	1906	1	2.0	8061.8	0.0	2245	71079.8	187823640.9	35505429825.8	0.9998	true	true	false
2023	CISO	1905	2	2.0	8061.8	0.0	2247	71081.8	187831702.7	35505429825.8	0.9998	true	true	false
2023	CISO	1904	2	2.0	8061.8	0.0	2249	71083.8	187839764.4	35505429825.8	0.9999	true	true	false
2023	CISO	1903	1	1.0	4030.9	0.0	2250	71084.8	187843795.3	35505429825.8	0.9999	true	true	false
2023	CISO	1902	1	1.0	4030.9	0.0	2251	71085.8	187847826.2	35505429825.8	0.9999	true	true	false
2023	CISO	1899	4	3.2	12898.8	0.0	2255	71089.0	187860725.0	35505429825.8	1.0	true	true	true

103 rows (20 shown) 15 columns

WattTime

Marginal Build Emissions Rate Data Sources

- Published by Climate TRACE via WattTime, hosted by Global Energy Monitor (GEM) at https://www.gem.wiki/MBERs

- What's included?
  - Historical, hourly MBERs, downloadable by region
  - Global coverage
  - ISO/BA granularity in the US, country level elsewhere
  - 2022-23
  - Updated annually

The GHG Project Protocol Uses Build Margin

The little-known GHG Project Protocol Guidelines for Grid-Connected Electricity Projects recommends using both operating and build margin.

GHGP “emissions reduced” = Electricity reduced x (w(Build Margin) + (1-w)(Operating Margin))

The guidelines recommend a default weighting of 0.5 for build and operating margin