APPLYING THE CONSEQUENTIAL EMISSIONS FRAMEWORK FOR EMISSIONS-OPTIMIZED DECISION-MAKING FOR ENERGY PROCUREMENT AND MANAGEMENT

CEBI
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The accompanying ***Guide to Sourcing Marginal Emission Factor Data*** includes supplemental information about sources of marginal emissions factor data, the different methodologies used to estimate these factors, and a discussion of the strengths and limitations of these data.

AUTHOR & ACKNOWLEDGMENTS

Author

Gregory Miller was a 2021–2022 fellow with the Clean Energy Buyers Institute and recently earned his Ph.D. in energy systems from the University of California, Davis. He is currently the research and policy lead at Singularity Energy.

Acknowledgments

The author thanks these individuals for their time and expertise to review this paper. Inclusion on this list does not indicate endorsement of the paper's conclusions.

- Avi Allison, Microsoft
- Matt Clouse, U.S. Environmental Protection Agency
- Olivier Corradi, Electricity Maps
- Hallie Cramer, Google
- James Critchfield, U.S. Environmental Protection Agency
- Mark Dyson, RMI
- Neil Fisher, Northbridge Group
- Pieter Gagnon, National Renewable Energy Laboratory
- Elaine Hale, Ph.D., National Renewable Energy Laboratory
- Alan Jenn, Ph.D., University of California, Davis
- Todd Jones, Center for Resource Solutions
- Holly Lahd, Meta
- Kevin Novan, Ph.D., University of California, Davis
- David Luke Oates, Ph.D., REsurety
- Sarah Penndorf, Google
- Ian Quirk, Apple
- Adam Reeve, REsurety
- Henry Richardson, WattTime
- Wenbo Shi, Ph.D., Singularity Energy
- Colby Tucker, U.S. Environmental Protection Agency
- Thomas Zadlo, PJM Interconnection

The author would like to recognize individuals at the Clean Energy Buyers Institute who supported this work and made it possible, especially Josh Kaplan, Laura Vendetta, Kyla Aiuto, Sarah Mihalecz, Rupak Thapaliya, Priya Barua, Bryn Baker, and Misti Groves. Also thank you to Monica Gordon and Sue Kim for their contributions to the design, layout, and editing of this paper.

INTRODUCTION

Energy customers today are trying to integrate a wide array of next-generation considerations into their clean energy procurement decision-making: time-coincident matching with load, indirect avoided emissions impacts, land use and habitat impacts, life cycle environmental impacts, social justice and equity concerns, and local community engagement.[1] Although indirect avoided carbon emissions impact is just one of many metrics that an energy customer might consider, the Clean Energy Buyers Institute (CEBI) has witnessed a growing interest among energy customers in maximizing impact through this metric, in what many see as the decisive decade for swift climate action.

The two greenhouse gas (GHG) emissions accounting frameworks that exist today for a scope 2 inventory, or the indirect emissions from purchased electricity, heat, steam, or cooling, are the location-based and market-based frameworks. These frameworks apply an attributional emissions framework to attribute total power sector emissions to each user of the grid based on their electricity consumption and electricity and environmental attribute purchases. Although the attributional framework is an important tool for tracking emissions reductions and managing carbon budgets, it was neither designed nor intended to provide a perspective on the indirect consequence of a specific decision or project on avoided or future power sector emissions. The consequential emissions framework adds to the toolbox by providing insight into the future emissions impact of a specific project activity on power sector emissions, making it useful for impact-based decision-making.

This guide builds off of the learnings from CEBI's ***Next Generation Carbon-Free Electricity Procurement Activation Guide,*** which shares the market evolvements needed to enable a broader suite of next-generation procurement options, such as procurement that maximizes the location- and time-based decarbonization potential of CFE procurement. This guide is also a continuation of CEBI's *Accelerating the Decarbonization Impact of Energy Procurement* primer and aims to help energy customers build an understanding of the effective application of the consequential emissions framework as a decision support tool (rather than its use for emissions offsets or avoided emissions claims). To help illustrate the framework in action, this paper traces an example of a clean energy procurement decision that a hypothetical company makes using the consequential emissions framework.

This paper strives to present a factual and practical discussion of the consequential emissions framework by synthesizing the most up-to-date guidance, research, knowledge, and perspectives on this topic. However, there is not yet an agreed-upon standard for applying this framework to decision-making, and through our months- long process of engaging with experts on this topic while writing this paper, we found that there is a need to continue alignment on this framework across the energy customer community as our collective understanding of the framework continues to evolve.

This paper was primarily written for participants in the U.S. voluntary clean energy market and has two intended audiences and purposes:

1. Organizational decision-makers — to help decide if and how to use consequential emissions impact as a metric to guide an organization's electricity sourcing or management strategies.

2. Organizational analysts — to help understand how to quantify consequential emissions impact and apply it to clean energy decision-making.

Defining the terminology

A wide variety of terms are used in connection to the consequential emissions framework: consequential emissions, avoided emissions, marginal emissions, displaced emissions, incremental emissions, and "emissionality." In this paper, we describe how the consequential emissions framework can support emissions-based decision-making through the use of marginal emissions factors to estimate the **consequential or marginal impact** of an action.

The consequential emissions framework seeks to establish and then quantify the causal relationship between an energy management or procurement decision and a change in indirect emissions from the power sector, relative to a counterfactual baseline in which the intervention did not occur. The broader consequential framework originated in the field of life cycle assessment as a method for quantifying how environmental impacts would change in response to an activity (in contrast to the attributional framework, which quantifies the environmental impact of the activity itself).

The avoided emissions impact is the metric optimized when making a procurement or energy management decision when using the consequential emissions framework. The goal is to maximize avoided indirect emissions (if a decision results in a reduction in consequential emissions), or to minimize induced indirect emissions (if a decision would increase consequential emissions). These emissions impacts are "indirect" because they occur at power plants that are generally neither owned nor controlled by the decision-maker. This impact can be quantified either through calculating the difference between modeled power sector emissions both with and without the intervention, or by using pre-calculated marginal emission factors.

Marginal emissions factors (MEFs), also referred to as marginal emissions rates, are the calculation factors that are most commonly used in the estimation of consequential emissions impact. They are called marginal factors because they generally describe the GHG emission rate (kilograms or pounds [lb] CO_2 per megawatt-hour [MWh]) of the marginal power generation source(s) that would change output or be built in response to a decision. This paper identifies four primary types of MEFs (operating, short-run, build, and long-run) that relate to different types of power system responses. Pre-calculated MEFs are more available and convenient for decision-making, so they are more commonly applied than custom marginal emissions modeling in the voluntary climate action context. Although MEFs are most commonly used for consequential analysis, in certain cases grid average emissions factors may reasonably approximate the consequential response of a power system to a decision.[2]

Avoided or induced emissions?

Different types of projects can either avoid or induce consequential emissions from the electrical grid:

In general, the types of project activities that may **avoid emissions** either generate electricity (like building a new solar farm) or reduce consumption of electricity (like energy efficiency or demand response).

In general, the types of project activities that may **induce emissions** are those that increase consumption of electricity (like electrification).

Certain project activities like energy storage and load shifting can either **avoid or induce emissions**.

However, the overall consequential impact also depends on considering the baseline emissions and direct emissions of the activity. For example, electrifying a vehicle fleet may induce indirect power sector emissions, but avoids direct emissions from the gas-powered vehicles being replaced. Or, for example, operating an on-site diesel generator avoids indirect power sector emissions, but induces direct diesel emissions from the on-site generator.

THE CONSEQUENTIAL EMISSIONS FRAMEWORK AS A DECISION SUPPORT TOOL

The consequential emissions framework generally seeks to establish and then quantify the causal relationship between an activity and an indirect change in emissions from the power sector, relative to a counterfactual baseline in which the intervention did not occur. This broader framework can be applied as either a decision support tool (which is covered in this paper) or as a method for making a unique, reportable claim to a specific volume of avoided emissions. For decision-making, the framework is used to compare the relative consequential emissions impacts of two or more options, rather than to quantify and convey ownership of the total global or direct emissions impact of a project activity, which is the focus of reporting and claims. The steps for applying the consequential framework in each context differ, so the steps presented in this paper for decision-making would not necessarily be appropriate for making a reportable claim to avoided emissions. Note that the indirect emissions impacts of an activity estimated during the decision-making phase are not likely to match the activity's actual indirect emissions impacts calculated retrospectively for claims or reporting, because of the differences in methodology, scope of analysis, and uncertainty about the future. The following table summarizes the key distinctions between these two applications of the consequential emissions framework.

APPLICATION OF THE CONSEQUENTIAL EMISSIONS FRAMEWORK:

	Decision-making	Claims/Reporting
Focus of this paper	Yes	No
Purpose/ motivation	Compare the relative impact of two or more options to choose the option that reduces indirect power sector emissions more rapidly than otherwise would happen	Quantify the indirect emissions impact of a single project activity to make a unique and accurate claim to indirect emissions reductions to reduce reported indirect emissions
Time frame	Typically future/prospective decisions	Typically retrospective analysis of an activity
Types of consequential emissions considered	Indirect grid emissions impact	Global emissions impact, including direct, life cycle emissions of the project activity itself and indirect (marginal) power sector emissions
Impact testing	Optional, but still important	Required
Monitoring/ verification	Unnecessary	Required
Existing standards/ guidance	None	*The GHG Protocol for Project Accounting* and *Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects.*[3,4] *Making Credible Renewable Electricity Usage Claims.*[5]

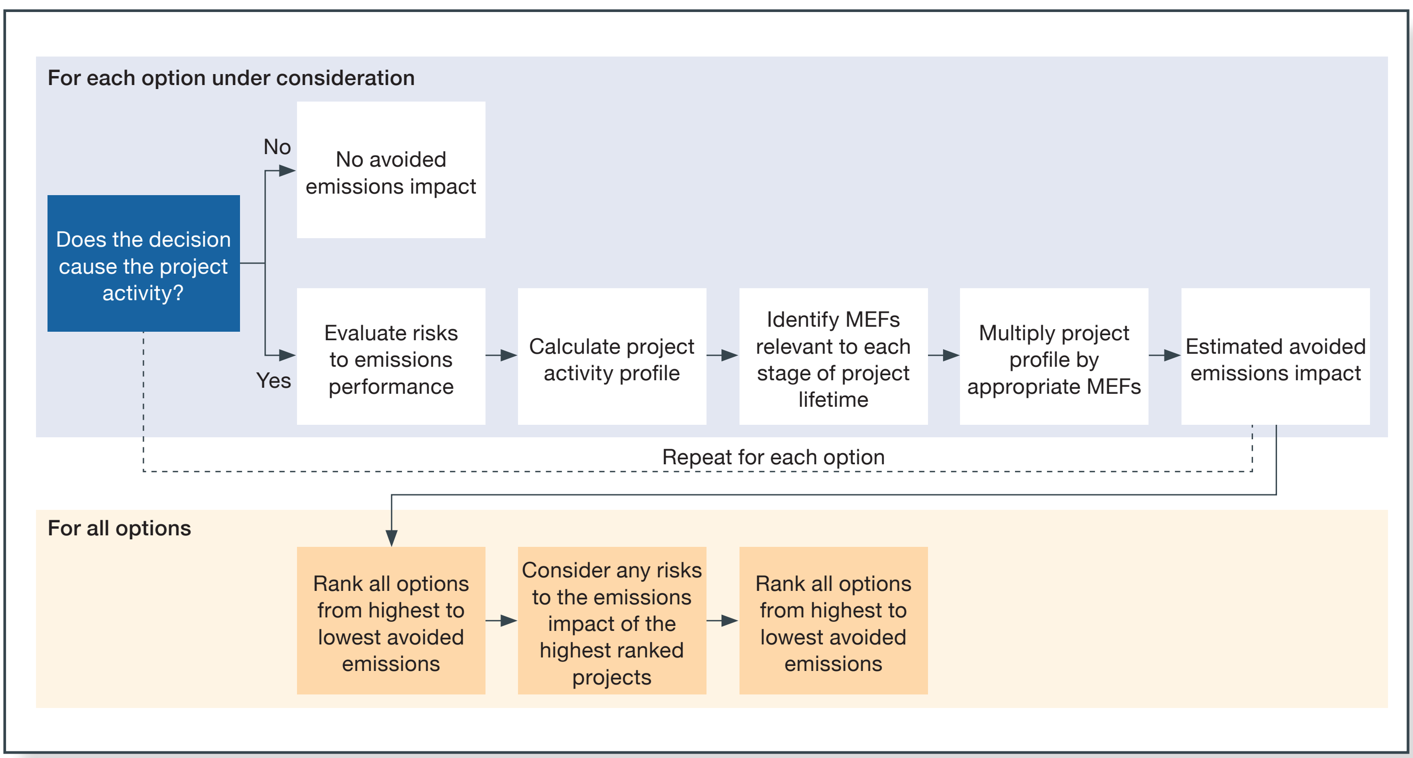
Any user of the consequential emissions framework is essentially seeking to answer two questions: “Is my decision going to have an emissions impact?” and “If so, how much?” By asking these questions, decision-makers can make informed choices to understand indirect emissions impacts. However, the specific steps used to answer these two questions will differ depending on the use case. To use the consequential framework as a decision support tool, follow these steps:

01 Evaluate whether the activity will lead to new and permanent emissions reductions.

02 Estimate the incremental energy profile of the project activity.

03 Determine which types of MEFs are relevant to the project activity.

04 Calculate and compare the consequential, indirect emissions impact for each option.



STEP 1: Evaluate whether an activity will lead to indirect emission reductions that otherwise wouldn't have happened

Because the goal of using the consequential emissions framework for decision-making is to maximize a decision's indirect avoided emissions impact, first consider whether a decision will have any impact at all, or whether there are risk factors that could erode its avoided emissions impact. This step is the most subjective aspect of applying the consequential emissions framework, and each decision-maker may execute this step differently, depending on the rigor with which they want to ensure that their decision is causing new and meaningful indirect emissions reductions. Although the following considerations are not directly reflected in quantification of avoided emissions impact, if deciding between multiple options with a similar avoided emissions impact, these questions can help a decision-maker understand whether an option has a greater risk of not realizing the intended indirect emissions impacts.

Does my decision cause new, incremental indirect emissions reductions?

In the consequential framework, it is important to consider whether your decision causes the project activity that affects grid emissions. In general, a project activity is the actual project, program, or activity that affects a power system response, such as a new wind farm, energy efficiency measure, or electric vehicle (EV) charging. But a decision or an action is what causes the project activity to occur (for example, by signing a power purchase agreement, investing in an efficiency upgrade, or implementing a policy).

Often, this causal relationship is straightforward: Your decision to invest in a light-emitting diode (LED) lighting retrofit causes the LED retrofit to occur, and this retrofit reduces energy consumption. However, in other cases, especially regarding energy sourcing decisions, this causal relationship may not always exist. For example, a decision to procure clean energy from an existing generator generally does not directly cause more clean energy generation (the project activity), and thus will not lead to new emissions reductions (although sometimes it could be impactful to procure from an existing generator that would otherwise retire and be replaced by an emitting generator). So, for energy sourcing decisions, a simple way to evaluate this is to ask whether or not your decision will result in new clean energy generation.

Would these indirect emissions reductions have happened anyway?

When a decision-maker has limited resources (financial or otherwise) to take climate action, it is important to ensure that those resources are being used efficiently to maximize emissions impact. Thus, even when a decision causes new indirect emissions reductions, one should consider whether these emissions reductions might have happened anyway, whether or not the decision-maker spends their resources. For example, just because you sign a PPA for a new clean energy project doesn't necessarily mean that it wouldn't have been built anyway, especially if there are other energy customers in line who would be willing to sign the same contract. Although in practice these other buyers would likely then sign a different contract, resulting in a similar capacity of clean energy ultimately being built, if these other buyers are not considering emissions in their decisions, the alternate contracts they sign might not result in similar overall emissions impacts. While this is subjective, a decision-maker can ask whether their decision goes above and beyond what would have happened in common practice.

What is the risk that these indirect emissions reductions will not be permanent?

In certain cases, voluntary climate action can interact with climate regulations such as cap-and-trade programs or renewable portfolio standards in a way that can cancel out the intended power sector emissions reductions of the voluntary action.

When a project activity is located in a region with a cap-and-trade program, such as the Regional Greenhouse Gas Initiative, California's Cap and Trade Program, and the European Union Emissions Trading System, there is a risk that the indirect emissions reductions at the marginal generator caused by the activity may allow for increased emissions at other times or at other generators, resulting in no net emissions reductions in the long term. In cap-and-trade programs, a regulatory cap is set on total emissions, and emitters must buy and trade emissions allowances to cover all their emissions. When the emissions cap is binding, taking an action that reduces power sector emissions may free up emissions allowances that can be used to pollute at a later time or be sold to another emitter that allows them to emit more.[6–9] This risk can be mitigated by purchasing and retiring cap-and-trade allowances equivalent to the estimated emissions impact of a decision or reporting the activity as a voluntary set-aside in the cap-and-trade program (if such set-asides exist).[10]

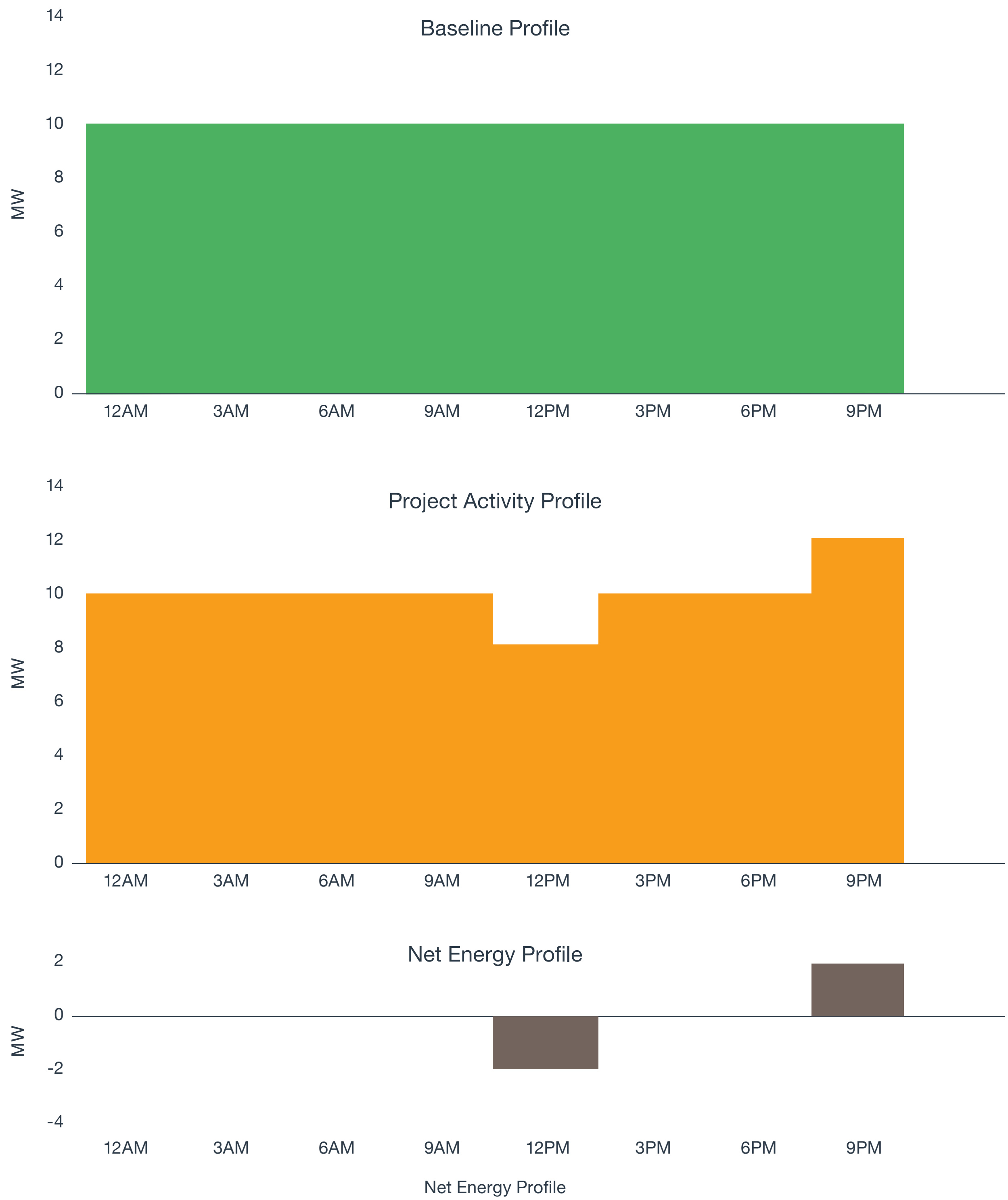
Another risk to the long-term avoided emissions impact of a new clean energy project occurs when an energy customer engages in renewable energy certificate (REC) swapping or REC arbitrage. When procuring clean energy located in a state with a renewable portfolio standard (RPS), the price of these "compliance-grade" RECs may be higher than RECs from voluntary markets because there are differences in eligible supply that can qualify for each market. Thus, some energy customers will sell their project's RECs for use in the local RPS and buy cheaper RECs from other (often existing) sources, arbitraging the value between the two types of RECs. However, if the RECs that were sold away are now used to help meet compliance with the RPS targets, this reduces the amount of clean energy that the local utility would have otherwise been mandated to procure. Engaging in this type of REC swap means that the voluntary clean energy procurement is no longer incremental to the amount of clean energy procurement that was mandated to happen anyway. To reduce this risk, energy customers would want to ensure that any compliance-grade RECs they sell are ultimately retired in a voluntary market, or avoid REC swapping altogether.

STEP 2: Estimate the net energy profile of the project activity

Calculating the indirect avoided emissions impact of an activity involves multiplying its net energy profile by the relevant MEFs. The marginal carbon intensity of the grid is constantly changing, and accurately estimating the indirect avoided emissions impact requires understanding of when a project activity affects the power sector operations, so that in each time period, its net energy profile can be multiplied by the appropriate MEF.

A net energy profile is generally represented by the hourly or sub-hourly energy generation or demand profile of an activity over its entire lifetime relative to (or net of) some baseline. For example, if the project activity is a new solar PV array, then the incremental energy profile would be represented by the estimated generation profile of the array over the 25 years of the project's lifetime. Or, if the decision pertains to when to shift load at a data center the next day, the net energy profile would be a single 24-hour period that represents the difference between the shifted load profile and the baseline load profile (see figure 1 for an example).

FIGURE 1. Over the course of a day, a data center consumes a flat 10 megawatts (MW) of electricity in all hours, representing the baseline profile. If the operator of this data center shifts some of its electricity demand from daytime to nighttime, the data center now consumes 8 MW from 12 PM to 3 PM, and 12 MW from 9 PM to midnight, with all other hours staying the same. This would represent the project activity profile. The net demand profile is the difference between the two, showing a 2 MW decrease from 12 PM to 3 PM and a 2 MW increase from 9 PM to midnight.



The overall length of this profile is an important characteristic when determining which MEFs are relevant to the project activity. In the data center example, if this were a temporary load-shifting decision that only applies to the next day, this net demand profile would be only one day long. If this were a permanent load-shaping decision that would be repeated every day for the next year, then the profile would be one year long, showing the repeating 24-hour net demand pattern every day of the year.

There may not be a single net energy profile for a project. To account for the uncertainty in the future generation or energy consumption of the project activity, it may make sense to calculate multiple net energy profiles so a range of potential impacts can be reflected in your analysis.

STEP 3: Determine which MEFs are relevant to the project activity

Once the project's net energy profile has been estimated, the next step involves determining what types of MEFs should be used to estimate the avoided emissions impact, based on how the power system is likely to respond to the specific type of activity. Although MEFs are commonly thought of as a single concept, there are actually many different types of MEFs that are relevant to different timescales or types of grid response. This paper identifies four primary types of MEFs: operating, short-run, build, and long-run. Before explaining how to choose the appropriate factor, it is first helpful to understand some background on how power systems respond to incremental changes in demand or generation.

Understanding marginal power system response

The dynamics of marginal emissions are understood through the science of power systems engineering and can be understood based on a few basic principles:

01 To maintain reliable delivery of electricity through a power grid, there must always be enough supply capacity available to meet demand.

02 This supply capacity must be dispatched to closely balance the electricity demand at all times.

03 Any project activity that disrupts this balance (whether in the short run or long run) generally requires a response from some part of the system to restore the equilibrium.

In power systems, the concept of "marginality" refers to the order in which power generators are dispatched to meet load. Generators are generally dispatched in order of lowest to highest cost, so the "marginal generators" are those with the highest cost needed to meet demand. In the simplest of terms, when demand decreases, the marginal generators will decrease output (and thus emissions), and if demand increases, the marginal generators will increase output (in some cases, however, decreasing demand can increase emissions, if power flow conditions require further rebalancing using a dirtier generator).[11]

Although the dynamics are slightly different, this concept plays out in both the short run and long run. In the short run, plugging in an EV increases demand, which requires certain generators to increase supply proportionally to maintain balance. The specific generators that respond to these actions change often and depend on factors such as the generator's marginal cost and operational characteristics, power flow over the transmission network, and the characteristics of the net demand profile. In the long run, adding new load, such as building a new data center in a region, may require the construction of a new power plant if there is not already enough capacity available to meet this future demand.

Multiple planning and operational processes, occurring over multiple timescales, work in concert to make sure that the grid always remains balanced. A project activity can affect the grid on multiple timescales and thus could have different marginal impacts over time. Understanding these timescales is important for selecting which type of marginal emission factor relates to a project activity. These timescales, from longest-term to shortest-term, are:[12]

Grid infrastructure decisions (Planning timescale — years ahead):

To ensure that there is enough generation capacity available to meet future electricity demand around the clock (and especially during peak demand times), grid planners must make decisions years in advance to build or retire capital assets on the grid, such as generators, energy storage, or transmission capacity. These decisions are based on long-term planning forecasts of anticipated demand, grid planning studies, and generator and load interconnection requests.

Generator commitment decisions (Scheduling timescale — hours to days ahead):

Because some generators take a long time to start up or shut down, grid operators will schedule or "commit" them to operate in certain hours the next day. In liberalized markets, these decisions are typically made as part of the day-ahead market. Commitment decisions are made based on a combination of short-term load forecasts, generator maintenance schedules, and supply offers and demand bids made by generators, load serving entities, and demand aggregators.

Generator dispatch decisions (Real-time timescale — minutes to hours ahead):

Decisions about the level at which each committed generator should be dispatched are typically made in real-time energy markets, minutes to hours ahead. These decisions are made based on short-run forecasts of demand and variable renewable generation and monitoring real-time grid conditions at the transmission level. Because changes in real-time market dispatch are typically not made more frequently than every five minutes, any grid response in the real-time market to an intervention would typically occur on a five-minute lag.

Automatic balancing and regulation (Instantaneous timescale — seconds or less ahead):

The final level of balancing is based on automated or physical processes that can respond on the order of seconds or less to any imbalances on the grid. For example, some generators have governors or automatic generator controls that respond to measured deviations in the electrical frequency of the grid. Other types of responses result from simple physics, such as the inertial response of a spinning generator. This type of balancing, which consists of regulation and frequency response services, represents the initial response of the grid to any intervention that affects the supply–demand balance.[13]

Understanding these different grid responses is important in the context of estimating indirect marginal emissions because generally different types of generators (which use different fuels and thus have different emission rates) will respond on different timescales.[13,14] As figure 2 illustrates, different types of resources were marginal in day-ahead and real-time energy markets in the California ISO in 2018. Even within ancillary services, different types of resources might provide "regulation up" (responding to an increase in demand) versus "regulation down" (responding to a decrease in demand).

FIGURE 2, part 1. In CAISO in 2018, the types of generators that were on the margin on the average day changed by time of day and depended on the grid planning timescale. The resources that provide instantaneous regulation up and down differ from the resources that are marginal in real-time markets and day-ahead markets.[15,16]

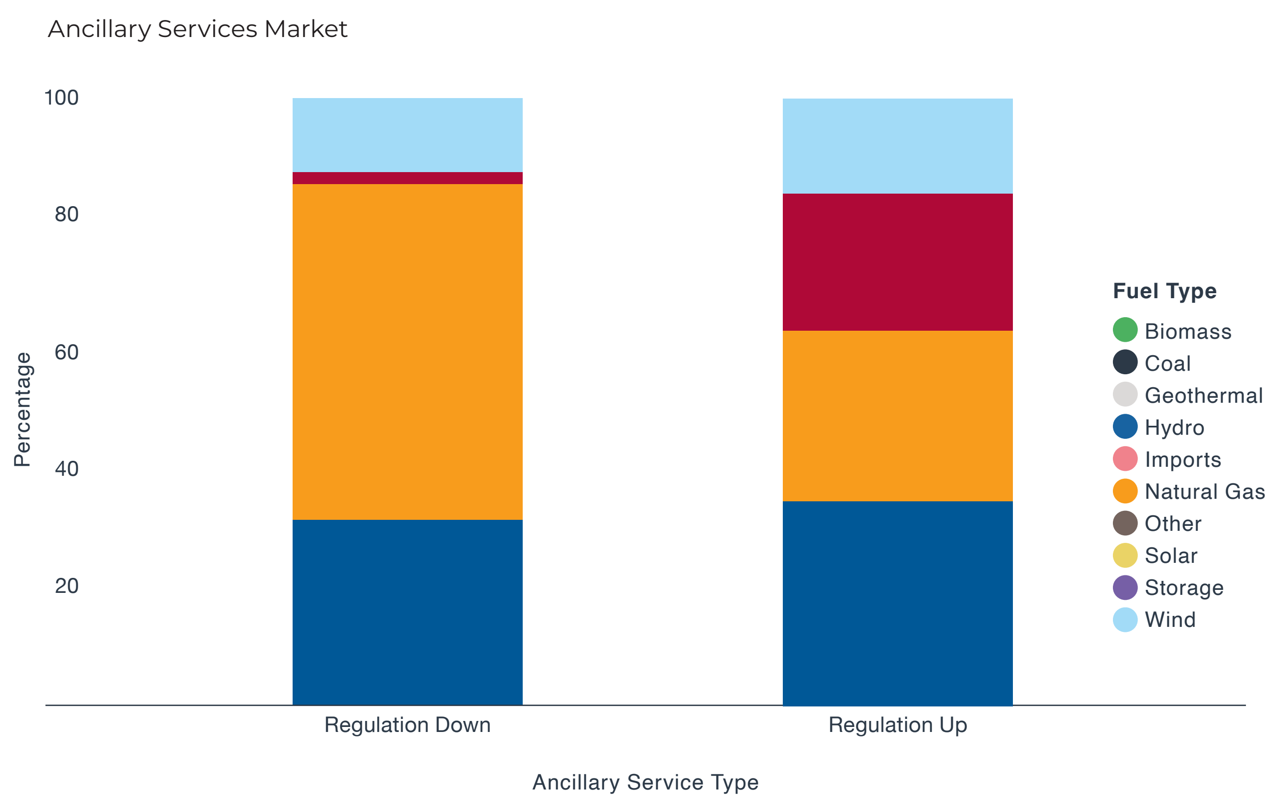


FIGURE 2, part 2

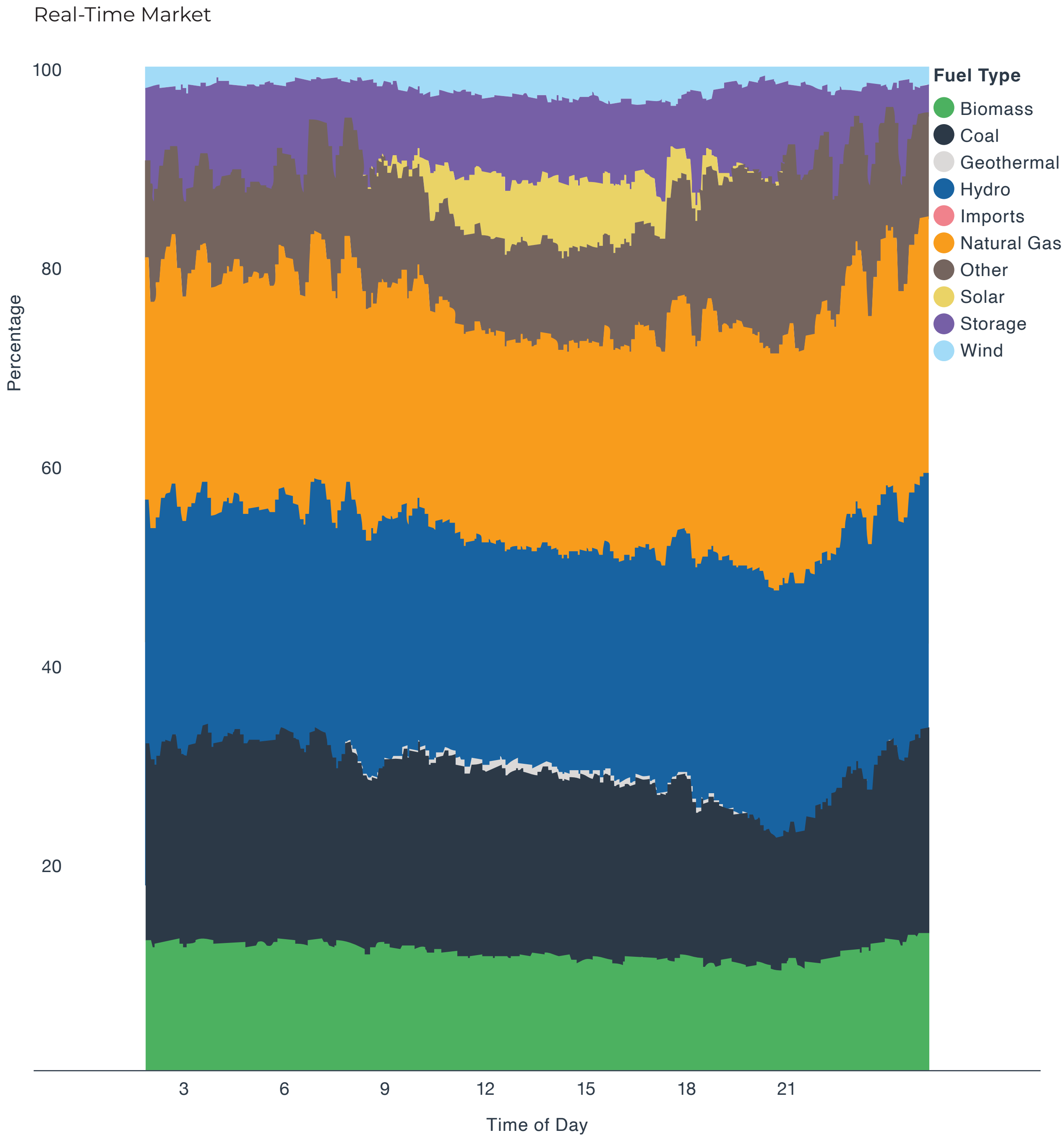
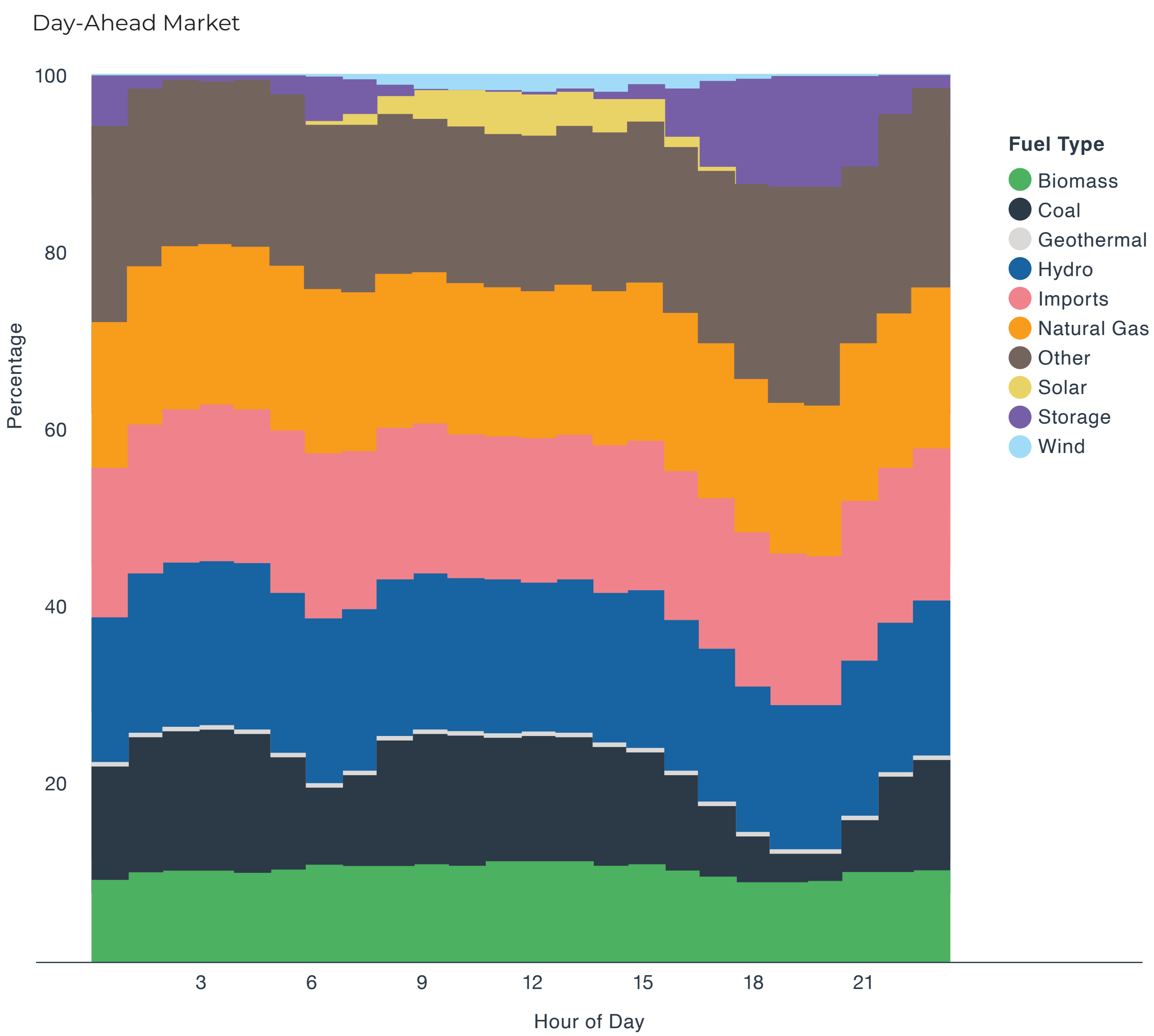


FIGURE 2, part 3



The four primary types of MEFs

This paper identifies four primary types of MEFs that correspond with different types of marginal power system response to an intervention.

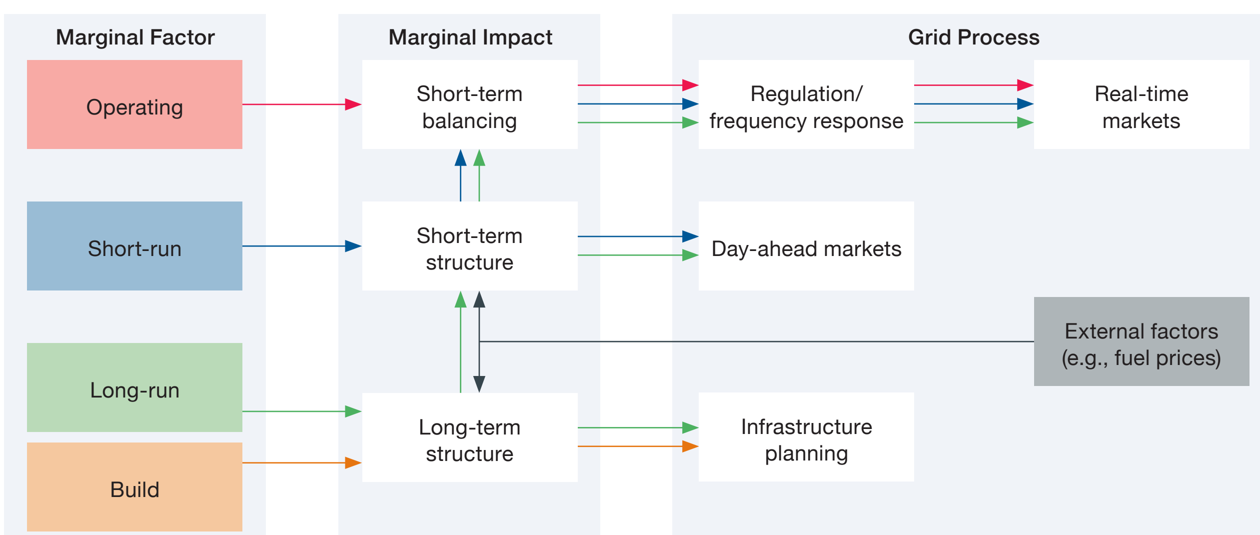
An **operating factor (OMEF)** describes the impact of an unpredictable intervention on the short-term balancing of the grid. Operating factors only describe the grid as it exists, literally, today: it assumes that generator commitment decisions and the fleet of generators itself are fixed.[4,17–19] This is why operating factors are often calculated dynamically and provided on a minute-by-minute or day-by-day basis for real-time optimization of energy use, rather than published ahead of time for use in estimating the lifetime impact of an intervention that might last for years.

A short-run factor (SRMEF) describes the impact of a more predictable intervention on the dispatch and commitment of existing generators (generally corresponding with real-time and day-ahead markets). Like the OMEF, the SRMEF describes the impact of an intervention on the operation of the grid, treating the generator fleet as mostly fixed, but, unlike the OMEF, it reflects limited systematic change (such as changing fuel prices or scheduling decisions).[17,20]

The build factor (BMEF) describes the average emission rate of the next generator that would be expected to be added to or retired from the current generation fleet in response to a consistent and predictable activity.[4,17,21] However, the build factor does not actually describe how the addition or retirement of that marginal generator impacts the operation of the grid, and the resulting emissions impact of that structural change. Thus, a BMEF may be a useful heuristic for decision-making (for example, answering "will shifting more load to midday help more solar get built?"), but it may be less useful for accurately quantifying the consequential emissions impact of a decision.

Finally, a long-run factor (LRMEF) describes the impact of a consistent and predictable intervention on both the structural evolution of the grid (that is, infrastructure addition and retirement decisions) and the impact of that structural evolution on the operation of the grid.[17,20] An important aspect of the long-run factor is that it assumes that the intervention actually causes the structural change (as opposed to short-run factors, which assume that any short-run structural changes result from external factors).[17,20] While long-run factors describe both structural and operational responses of the grid, they should not be thought of as a "combined" factor. The operating response reflected in a LRMEF describes the operating response only once the structural response has occurred. So, for example, if it takes five years for an activity to cause a structural grid response, the LRMEF would describe the emissions impact of the activity only after Year 5 — the first five years of the project activity would be reflected by a separate SRMEF.

FIGURE 3. **This diagram shows the marginal impacts and grid processes that each type of marginal emission factor describes.**



Determining the relevant MEFs for a project activity

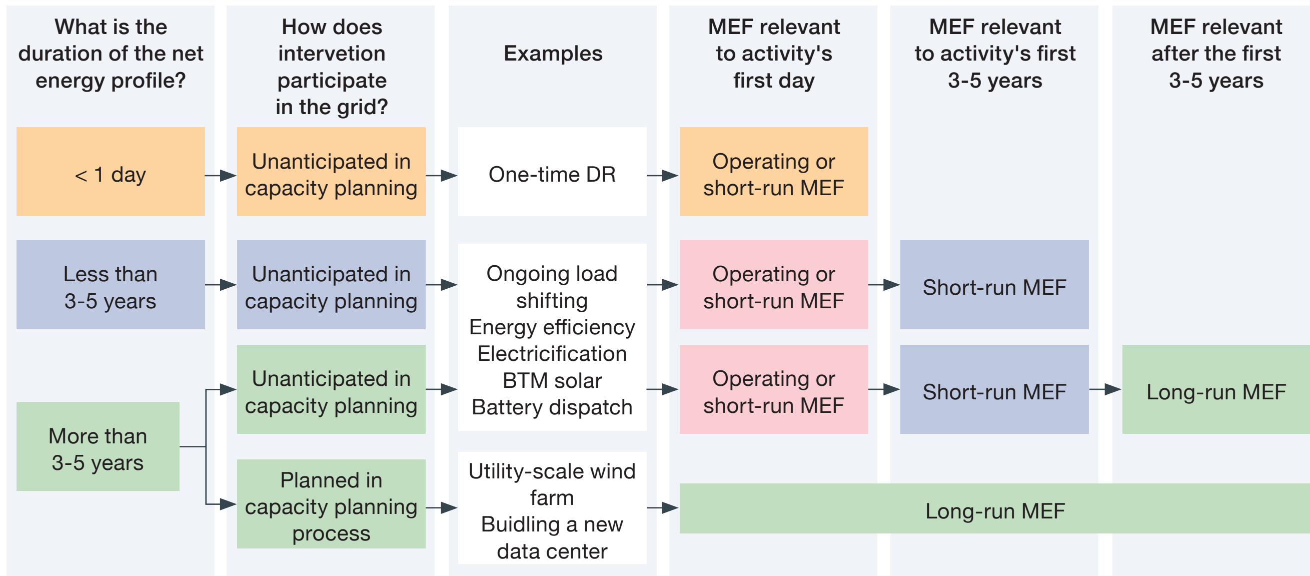
Because each type of factor represents emission impacts on different timescales, one or more of these factors could be used to estimate the impact of a single project activity over its entire lifespan. One can determine which factors are relevant to an activity by considering the duration of the activity's net energy profile and how the project activity formally participates in grid processes.

The duration of the net energy profile informs how permanent and predictable the project activity is and how the power system will respond to it. In general, a short-lived or transient decision will result in only an operating or short-run marginal response from the power system, while a long-lived decision or pattern of decisions can cause a long-run marginal response. Based on the various grid operation and planning timescales explained above, a general rule of thumb that can be used to determine the relevant MEF for each part of a decision's lifespan is: Operating MEFs best describe decisions lasting less than a day because they will only affect short-term grid balancing; short-run MEFs best describe decisions lasting less than several years; and long-run MEFs best describe the impacts lasting more than several years (generally more than three to five years) because this is how long it takes grid planning processes to effect structural change in response to an intervention.[21–23]

For long-lived decisions (those lasting more than three to five years), considering how the activity participates in formal electricity market or planning processes, and thus becomes known to grid operators and planners, is important to understand whether the activity will have an immediate or delayed long-run impact. Certain planned project activities, if they are large enough or connect directly to the transmission grid (like utility-scale generators or large industrial facilities), may participate in formal capacity planning processes years before being implemented, such as RTO planning studies or interconnection queues, and thus may result in structural change immediately upon commencement. The second category of non-participating project activities does not participate in any energy markets or planning processes, so grid operators only learn of these activities by detecting any imbalances they cause in real-time, or by observing changes in patterns that affect future forecasts of load or supply. For these project activities, there is generally a three- to five-year lag between when the activity commences and when the grid will structurally adapt to it. Thus, it would be appropriate to use a short-run factor for the first three to five years of a project activity, and then switch to a long-run factor for the remaining project life. Figure 4 illustrates how to select the appropriate MEF for each part of a project's lifetime.

There are certain cases when even a short-lived or dynamic decision, if part of a repeating pattern of ongoing short-lived decisions, may have the potential to effect some long-run structural change.[2] For example, the emissions impact of dynamically scheduling when an EV fleet charges each night after it is plugged in would be best described using an operating MEF. However, even though the specific charging times for the fleet change every day, if it is plugged in during the same time window every day, over time this could result in an average pattern of increased demand during those times, which could reasonably be described using a long-run MEF after the first three to five years. However, there is not yet an established method for how the relative operating and long-run impacts of such repeating, dynamic decisions should be weighed, or how the net energy profiles for each effect would be calculated.

FIGURE 4. **This diagram illustrates how to determine which marginal emissions factors are relevant to different types of project activities and to which timescale each is relevant.**



Identifying sources of MEF data

Once the appropriate types of MEFs have been identified, it will be necessary to identify a specific source of marginal emissions factor data to use in the analysis. There are many sources of marginal emissions factor data, each of which estimates these factors differently.

To aid readers in identifying and evaluating these different sources, the accompanying *Guide to Sourcing Marginal Emission Factor Data* will be helpful. The important takeaways from this guide are that each estimate of MEFs may differ from the others, and multiple sources should be used if possible; each MEF relates to a specific time period; all MEFs involve some uncertainty; and many pre-calculated MEFs are provided as “one size fits all” for all interventions, even if different types of interventions can cause different types of emissions impacts.

STEP 4: Calculate and compare the avoided emissions impact of each option

To estimate the avoided emissions impact of each option, one must first estimate the project activity’s net energy profile (Step 2) and identify the relevant MEFs by which each part of the net energy profile should be multiplied. It is important that when multiplied, the two multipliers are matched in both time and space. If you are considering different wind farms, one in Texas and one in New York, the Texas net generation profile should be multiplied by a MEF for the grid region or node where the wind farm is located in Texas, and likewise for the New York project. Similarly, the wind farm’s net generation in a specific hour should be multiplied by the MEF for that same hour (if time-specific factors are not available, use a factor that most closely matches when the activity is occurring).

It is important to use the relevant MEF for each part of the project's lifetime, which may require using multiple different types of MEFs for a single project activity. For example, if you are considering a commercial-scale rooftop solar array that may be unanticipated in grid planning processes, a short-run MEF would be multiplied by the first three to five years of the net generation profile, and a long-run MEF would be multiplied by the remaining net generation profile.

Hour of day	Net demand profile (MWh)	Operating MEF ($lbCO_2$/MWh)[24]	Emissions impact ($lbCO_2$)
1	0	466	0
2	0	660	0
3	0	932	0
4	0	932	0
5	0	932	0
6	0	932	0
7	0	932	0
8	0	932	0
9	0	932	0
10	0	932	0
11	0	932	0
12	0	932	0
13	−2	389	−778
14	−2	855	−1,710
15	−2	932	−1,864
16	0	932	0
17	0	932	0
18	0	932	0
19	0	932	0
20	0	466	0
21	0	466	0
22	2	855	1,710
23	2	696	1,392
24	2	460	920

Total Emissions Impact: −330

The total avoided emissions impact is the sum of the product of the net energy profile and MEFs for each time interval of the project's lifetime. The table on this page illustrates a simple example of this calculation for a potential load-shifting decision.

When starting these calculations, it is important to choose a sign convention and stick with it (in other words, whether a negative emissions impact represents a decrease or an increase in indirect emissions). Because this example shows a demand-side intervention, the result of −330 pounds (lb)CO_2 indicates that the decision would avoid 330 $lbCO_2$. However, were we examining a generation project, where net generation is represented as a positive number, avoided emissions would be shown as a positive number. If comparing supply-side and demand-side interventions side by side, it is important to use a consistent sign convention (for example, where generation is represented as negative demand, or demand is represented as negative generation), to avoid confusion about which options avoid indirect emissions and which might induce indirect emissions.

This is important because at certain times the marginal emission factor could be negative (meaning that a reduction in demand actually leads to an increase in emissions, or vice versa). For example, because of re-dispatch of generators required to respond to constraints on power flow, a reduction in energy demand may cause a relatively cleaner natural gas plant to reduce output, but require a dirtier coal plant to increase output, leading to a net increase in emissions.[25]

Finally, when estimating indirect avoided emissions impacts, one should consider the effect of uncertainty. This means that the calculated emissions impact of each option should never be a single number, but rather a range of estimates that should reflect any uncertainties in the net energy profile or the marginal emissions factor itself (although data providers do not always publish uncertainty ranges for their estimates).

Depending on the context of the decision-making process, it may help to consider normalized emissions impact metrics in addition to, or instead of, total avoided emissions. For example, if the decision-maker has a set budget for all of their climate action programs, and the options under consideration cost different amounts, they may wish to maximize the indirect avoided emissions impact per dollar spent. Or, if a decision-maker is trying to achieve an energy procurement goal that requires the company to buy a certain volume of total energy, they may wish to maximize the avoided emissions per MWh generated by each project.

EMISSIONS-BASED RENEWABLE ENERGY PROCUREMENT EXAMPLE

To demonstrate the consequential emissions framework in action, below is a hypothetical example of a U.S. company seeking to maximize the avoided emissions impact from the electricity it procures to meet its 100% clean energy goal. In 2022, the company issues a request for proposals for 100 MW of clean energy capacity anywhere in the United States. They receive offers for virtual power purchase agreements to buy both the energy and RECs from these eight projects:

Capacity	Technology	Location	Commercial operation date
100 MW	Solar	Southern California	2024 (New build)
100 MW	Solar	New York	2024 (New build)
100 MW	Solar	South Dakota	2024 (New build)
100 MW	Solar	Louisiana	2024 (New build)
100 MW	Wind	Western Pennsylvania	2024 (New build)
100 MW	Wind	Illinois	2024 (New build)
100 MW	Wind	Oregon	2024 (New build)
100 MW	Wind	West Texas	2018 (Existing merchant plant)

The company's energy manager asks her energy analyst to evaluate which project the company should contract with to maximize the avoided emissions impact of its procurement.

STEP 1 IN ACTION: Evaluating potential risks to the emissions impact of each project

As a first step, the analyst considers whether each project will lead to new emissions reductions that wouldn't have otherwise happened, and whether there is any risk that the emissions reductions would not be permanent or incremental. Note that because this step can be subjective, and because this is meant to be illustrative, readers should not interpret this hypothetical analyst's judgments as generalizable conclusions.

The analyst first considers whether each project will lead to new, incremental emissions reductions by examining whether each project represents new clean energy generation. Because most projects have a future operational date and have not yet been built, she judges that these projects would cause new emissions reductions. However, the West Texas wind offer comes from an existing merchant generator that began operation in 2018. While this project would have started displacing grid emissions when it was first built, their company's emissions-based procurement goal is to effect new emissions reductions, so she removes this project from consideration.

Next, she evaluates whether there is a risk that each project would be built anyway, even if the company didn't choose that project. To evaluate this, she looks at voluntary clean energy market conditions and grid interconnection queues in each region to better understand whether each resource is being built as a matter of common practice. Although this is subjective, she is trying to determine where a project would likely not be built if the company didn't sign the contract.

Finally, she considers the risk that any indirect emissions reductions would not be permanent because there may be interactions with regulatory programs in the regions where each project is located. To do so, she evaluates whether each project is located in a region with cap and trade or with an active renewable portfolio standard.

After completing this step, she develops the following table to help her energy manager understand the potential emissions impact risks of each project:

Example evaluation of risk factors for the projects being considered by the analyst. Note: This is an illustrative example based on a hypothetical analyst's subjective judgment, and these risk factors should not be interpreted as generalizable for similar real-world projects.

PROJECT	NEW EMISSIONS REDUCTIONS	LIKELIHOOD OF BEING BUILT ANYWAY	RISK TO IMPACT FROM CAP AND TRADE	RISK TO IMPACT RECS SWAPPED (PROJECT IN STATE WITH ACTIVE RPS)	OVERALL RISK TO EMISSIONS IMPACT
CA Solar	Yes	High	Yes	Yes	High
NY Solar	Yes	Med	Yes	Yes	Med-High
SD Solar	Yes	Low	No	No	Low
LA Solar	Yes	Low	No	No	Low
PA Wind	Yes	Med	No	No	Med-Low
IL Wind	Yes	Low	No	Yes	Med
OR Wind	Yes	Med	Yes	Yes	Med-High
TX Wind	No	High	No	No	High

STEP 2 IN ACTION: Estimating the net generation profiles for each project activity

Because renewable generation varies by time of day and season, the analyst will need to use hourly time series data that represent this variability to calculate net generation profiles. Estimating the exact generation patterns over the 25-year lifespans of each project would be difficult, so the analyst represents each year of the project activity using historical wind and solar resource data from eight different years (2007–2014), which will help represent the uncertainty in generation patterns due to weather. To estimate generation profiles for each of the four projects, the analyst uses the National Renewable Energy Laboratory's (NREL) System Advisor Model software to simulate this generation for each resource year (although she could ask the project developers for these different profiles).

For the seven new projects, the net energy profile represents the estimated generation from each project. Because the Texas wind project is existing and not at risk of shutting down, the baseline generation profile is the same as the project activity profile, so the net generation profile is zero (meaning a decision to procure energy from this project will have zero consequential emissions impact).

STEP 3 IN ACTION: Determining the relevant MEFs

Because all of these projects are utility-scale wind and solar projects, the analyst determines that using a LRMEF would be appropriate to use for the entire lifetime of the project, because these projects would likely participate in local capacity planning processes and effect structural change from day one. However, to reflect any potential uncertainty that this structural change would not happen right away (and because this is an illustrative example), she chooses to calculate the marginal emissions impact of the first five years of each project activity not only using a LRMEF, but also using SRMEFs. For LRMEFs, she uses data from NREL's Cambium model. Cambium provides LRMEFs for five different future scenarios (Mid Case, Low Renewable Energy Cost, High Renewable Energy Cost, Grid Decarbonization by 2050, and Grid Decarbonization by 2035), so she uses all five of these to reflect how uncertainty about the future might affect her analysis. For short-run factors, she uses the same five scenarios for the SRMEF data provided by Cambium, as well as the project-specific MEFs from AVERT and the non-baseload MEFs from eGRID. By using factors from multiple different sources, she can reflect how uncertainty in different types of MEF estimates might affect her analysis. By incorporating three different sources of uncertainty (from clean energy generation patterns, different MEF estimation methodologies, and uncertainty about the future), and comparing whether they all lead to the same decision outcome, she can better understand the certainty that the project she recommends will, indeed, lead to the greatest amount of indirect avoided emissions. For this illustrative example, these specific MEFs were chosen because they are free and publicly available.

STEP 4 IN ACTION: Calculating and comparing the options

Now that the analyst has estimated the net generation profiles for each project and collected the relevant MEFs she will use for each project, it is time to calculate the range of possible indirect avoided emissions impacts. For the first five years of each project lifetime, she will multiply the net generation profile of each project by 12 different MEFs: five different scenarios for the Cambium LRMEF, five different scenarios for the Cambium SRMEF, the AVERT SRMEF, and the eGRID SRMEF. For the final 20 years of each project's 25-year lifespan, she will multiply the net generation profiles by the five different LRMEFs representing each Cambium scenario. She will then add the impact from the first five years to the impact from the final 20 years to arrive at the range of total avoided emissions impacts for each project.

The figure on the following page shows the results of these calculations for the first five years of the project life, the final 20 years of the project life, and the range of total estimated indirect avoided emissions over the entire life of the project. The analyst notes that the Pennsylvania wind project appears to be the most likely project to avoid the greatest amount of emissions. Consulting her risk table that she developed during Step 1, she sees that this project has relatively low emissions impact risk. Thus, she feels confident recommending this project from an emissions-based procurement standpoint.

However, her energy manager comes back to her a week later to tell her they have determined that the Pennsylvania and Illinois wind projects are not financially viable for the company to procure from, and asks her to recommend a different project. Her analysis shows that the next best two projects are the Oregon wind and Louisiana solar projects, although there is not a significant difference between the range of estimated avoided emissions impacts for the two projects. In situations like this, the analyst's risk evaluation might play a larger role: She notes that several factors cause her to judge that there is a medium-high risk that the indirect emissions impacts of the Oregon wind project could be eroded. Thus, she decides to recommend the Louisiana solar project, because it has a low risk.

This example demonstrates why it is important to consider multiple MEF estimates: The relative rank ordering of each project will not always be the same, so relying on a single source of MEF data might result in a different decision than if multiple sources were considered together. In this example, because the Pennsylvania wind project had the highest capacity factor (and thus the greatest amount of generation) of the projects, it consistently ranked as the best project across all MEF scenarios. If the analyst were considering projects that generated roughly the same amount of electricity, or using a metric normalized by the number of megawatt-hours, the highest-ranked project might not always be consistent. In such cases, it may be necessary to consider weighting the different estimates based on a subjective estimate of their relative quality (the accompanying MEF sourcing guide includes several factors that may be considered to help judge quality).

FIGURE 5. Avoided Emissions Impact for Each Project's First Five Years of Operation (2024–2028)

These figures show the range of total avoided emissions for the first five years (top), last 20 years (middle), and entire lifetime (bottom) for each project being considered. Depending on the marginal emissions factor used, the total magnitude of avoided emissions can range significantly. Each box plot in the bottom panel represents 480 different scenarios for each project (8 resource years x 12 MEFs for the first five years and x 5 MEFs for the final 20 years).

CONCLUSION

The consequential emissions framework is an important decision support tool for guiding a range of decarbonization decisions, from energy efficiency and clean energy procurement to real-time battery charging and demand response decisions. Analyzing the marginal emissions impact of decisions can help provide a well-rounded perspective on an organization's climate impact, alongside its GHG inventory.

For those who are ready to take the next step in applying this framework to support their decision-making, the accompanying *Guide to Sourcing Marginal Emission Factor Data* is intended as a resource to help energy customers identify specific sources of marginal emissions factor data and provide additional background about how these factors are calculated.

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Thank You!

Address
Clean Energy Buyers Institute (CEBI)
1425 K St. NW, Suite 1110, Washington, DC 20005

Phone
1.888.458.2322

Email / Web
info@cebi.org
www.cebi.org

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