New Metrics for Evaluating Building-Grid Integration

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ABSTRACT

Momentum is building for a large-scale transformation of the North American electricity grid. In jurisdictions across the continent, ambitious market and policy efforts are underway to decarbonize the electricity sector, largely by bringing more solar and wind power online. Aggressive vehicle electrification and building decarbonization goals will magnify the challenge. Buildings consumed 71% of US electricity in 2018 (EIA 2020) and will be a critical component of grid transformation efforts.

Since mid-2018, the not-for-profit, multi-stakeholder GridOptimal Buildings Initiative (GridOptimal 2020) has been developing metrics to measure the grid impacts of building features and operating characteristics to support a new design approach that prioritizes better building-grid integration across the building stock.

Standardized metrics that quantitatively define a building's operational performance as a grid asset will catalyze market development for grid-interactive buildings. These metrics can support utility incentive programs, building procurement requirements, guidance and tools for building designers, financial valuation and risk assessment, energy codes, energy/climate policy, and more.

The initiative has developed and tested several open-source building-grid interaction metrics over the past two years, and is now releasing them publicly. To provide context, this paper will describe the building-grid integration market landscape, major policy and program needs, and current key initiatives. The paper provides a detailed explanation of the GridOptimal metrics, including documentation of key building- and grid-side data sources and the calculation methodology across multiple categories (peak demand, passive and active demand flexibility features, carbon, resiliency, and others). To pave the way to market, we include key implementation strategies to use these metrics in programs, projects, and policies.

Introduction and Context

The roles of buildings, renewable energy, and energy storage in the utility industry is changing fast. New near-term solutions are needed to address today's challenges and capitalize on opportunities for market transformation. New Buildings Institute (NBI), in partnership with the U.S. Green Building Council (USGBC), is leading a national coalition committed to better integrating buildings into utility grid management strategies. This project, called the GridOptimal Buildings Initiative, is focused primarily on the **development and deployment of metrics by which building features and operating characteristics that support more effective grid operation and decarbonization can be measured and quantified.** By supporting the adoption of GridOptimal building features, utilities will be able to tap into a new resource to support grid operation while supporting energy efficiency and carbon emission reductions. These metrics are intended to serve as a consistent framework, widely applicable across sectors (residential, commercial, industrial), grid regions, and policy/regulatory contexts.

This paper provides background and context around these issues, introduces the GridOptimal metrics, and discusses the mechanics of those metrics.

Modern Grid Management Challenges

As policymakers and the building community encourage improved building performance and reduced carbon impacts, the electric grid is facing significant new challenges. The rapid proliferation of distributed renewable energy resources creates technical challenges for grid operation. In response to efficiency and climate goals, the building industry is delivering more and more distributed energy generation onto the grid, with little or no regard for how the utilities must respond to the presence of these new distributed resources.

In regions where significant renewable resources have been added to the grid, utilities are facing the need to deeply discount power prices or curtail renewable power resources at peak periods to maintain grid stability. Some grid operators are forced to pay other regions to take their surplus power, periodically resulting in negative electricity prices. These trends threaten to limit the potential for renewable resources to reduce the carbon impacts of grid operation.

How Buildings Can Support Grid Operations

It is illuminating to consider the impacts of individual buildings on the grid through the lens of a building's "grid citizenship." A good grid citizen is a building that contributes to, rather than detracts from, the reliable, safe, and affordable operation of a clean electric grid. Some stakeholders use the term Grid-interactive Efficient Buildings (GEBs), often defined as energy-efficient, grid-connected buildings that use distributed energy resources (DERs) and optimize energy use for grid services (Perry 2019). Everyone agrees that dependable grid operation is a critical priority. However, existing grid management and control systems are struggling to integrate new distributed energy. To maintain grid dependability, utilities must continue to manage and support peak generating capacity, even as more utility generating resources may be forced to remain idle when distributed generating resources are feeding power to the grid.

To fully utilize the rapid increase in distributed generation resources, it is critical that buildings themselves be able to more directly support grid operation by responding to fluctuations in grid load and contributing to broader efforts to manage more diverse grid resources. Some limited progress is being made: some buildings and devices are beginning to incorporate controls enabling short-term load shedding during grid peaks. However, a much more comprehensive approach to integrating building load management with grid operation is needed.

Optimizing Building Grid Interactions is Key to Decarbonization

Achieving aggressive climate goals will be impossible without decarbonizing both buildings and the grid. Building designers, owners, and operators need new tools and knowledge to identify and employ strategies to prioritize building energy use when grid-supplied electricity's carbon impact is low (i.e. when there are more renewables in the generation mix) and to minimize building energy use during expensive, high-carbon peak times. By better aligning building energy usage with low-carbon time periods, buildings can and must play an integral role in enabling the decarbonization of the electricity grid.

As policy-driven efforts to decarbonize (electrify) building heating systems and transportation bear fruit, substantial new demands will be placed on the grid. Buildings can help manage this additional demand through demand flexibility and load shaping, helping to turn a challenge into an opportunity.

Through careful and considered building-grid interaction strategies, multiple distinct but related benefits can be co-optimized, including customer cost, utility grid operations costs, reliability, resiliency, safety, decarbonization, and more.

Building-Grid Integration Market and Policy Landscape

The wholesale transformation of the US energy system is just beginning, and a paradigm shift in building-grid interactions has not yet arrived. While some leading jurisdictions and utilities have enacted policies and programs to enhance energy efficiency and/or grid interactivity, Perry et al (2019) conclude that "no existing programs or pilots qualify as a full-fledged holistic GEB program" at this time. Current approaches tend to prioritize either energy efficiency or grid interactivity, which limits potential benefits for building and grid stakeholders and the potential for buildings to play the enabling role discussed above. Demand response (DR) programs and energy efficiency programs are typical of today's predominant approach: DR programs incentivize limited curtailment of load during events called by a utility or third party, while efficiency programs incentivize energy savings without regard to time of year or location. For a summary of current GEB program and policy approaches, see Perry (2019).

Classifying Building Strategies and Approaches

A wide range of features, strategies, and technologies can enhance a building's grid citizenship. For the purposes of this paper, three distinct categories are defined here.

Permanent Efficiency

Permanent efficiency strategies require no ongoing management, whether automated or manual, and provide efficiency and/or load shape modification. For example: fixed shading, electrochromic glass, and automated blinds can reduce and alter solar heat gain patterns. Enhanced envelope, HVAC, lighting, and other efficiency measures can simultaneously reduce a building's total energy use and minimize the building's grid impacts in terms of time of use.

Demand Flexibility

Through the application of controls and/or other management strategies, buildings can modify the times during which and the magnitude of power they demand or push to/from the grid. For example, smart controls and efficient systems, on their own or in tandem with building features like thermal mass and energy storage, can minimize peak demand and enable buildings to react quickly to grid needs or optimize operations for cost and/or carbon savings.

Dispatchable Demand Flexibility

Dispatchable demand flexibility is a subset of demand flexibility in general. The key difference is in how the strategy is controlled, or dispatched: in this case, the action is taken based on an automated signal sent by the grid operator or other third party entity. Intelligent, grid-integrated communication elements can automatically respond to grid signals. Smart systems and devices, from HVAC to lighting and electric vehicles, can align building energy use with grid operation priorities and renewable energy availability.

Measuring Building-Grid Interactions: Metrics and Mechanics

This paper discusses the process of calculating GridOptimal metrics as follows:

1. **Evaluation methodology:** the calculation process used to evaluate building performance.
2. **Data inputs**: key information sources for the calculation of GridOptimal metrics. Data inputs pertain to the building evaluated and/or the grid in which the building is located.
3. **Metrics:** the results of the GridOptimal metrics, providing quantitative evaluations of building performance across a range of categories.

In general, this paper discusses metrics in the context of a single building – the same scale as a typical electricity meter. All building systems and end uses are combined at this scale. These metrics could be applied at the scale of a single building or a group of buildings.

Evaluation Methodology

The first step in the process is to define the evaluation methodology. GridOptimal combines two basic approaches to holistically evaluate building-grid interactions: load shape and feature set evaluations. In this paper, load shape is used interchangeably with demand profile.

Load Shape Evaluation

GridOptimal metrics apply load shape evaluation calculations for each hour of the year to quantitatively evaluate (score) performance in one of several evaluation categories, which align with the metrics (output categories). Two building demand profiles are entered: the baseline and proposed cases. For each hour of the year, the building's performance is evaluated, generating scores in each output category associated with load shape.

The overall methodology is as follows:

1. **Value each hour of year based on grid conditions and programmatic variables**. Grid conditions, such as load factor or carbon intensity for each hour, are evaluated for all hours of the year. The relative value of each hour is used to assign a weight; the particular weighting methodology is discussed in more detail below. In some cases a percentile or other evaluation threshold is defined. For example, the Grid Peak Contribution metric examines only the 5% of hours with highest total grid demand.
2. **Score each hour based on building performance and importance of each hour**. For each hour, the building load or a dimension thereof is evaluated (specifics vary by metric). These building load evaluations are normalized and weighted to generate an hourly score for each metric, across all 8760 hours in the year.
3. **Roll up all hours across the year, evaluated for each metric**. The hourly scores for each output category, as well as energy demand, cost, carbon, etc. are all summed for the year to generate the summary metrics.

Feature Set Evaluation

The performance of the building's features are scored independently in each output category. For an explanation of the calculation methodology for feature set related output categories, see the Metrics section (each subsection explains how its score is derived).

In general, the feature set evaluation requires external analysis to determine the load modification capability of the building over a particular time frame. In addition, an analysis of what loads in the building are dispatchable (controllable by the utility or a third party) is needed to fully score the building. Other building feature sets are evaluated on a yes/no basis: for instance, either the building is capable of safely islanding itself from the grid and still providing power to all or some circuits, or it is not. Resiliency is evaluated in this manner.

Data Inputs

The second step in the process is to define key data and gather all required data inputs, including information related to the building and to the grid. This distinction between building-side data and grid-side data clarifies what information the user must gather to use these metrics.

- **Building data** means information related to the building's energy/power consumption (usually defined in kW) and to feature sets or capabilities in the building. Building data has to do with what is "behind the meter," that is, on the customer side of the electricity meter.
- **Grid data** means information having to do with the conditions of the electricity grid to which the building is connected. This is driven by the building location. Grid data includes information related to electricity grid system demand (usually defined in MW), marginal carbon emissions information, utility rates, and other system-level information. This distinction also means that grid-side data may remain consistent across the evaluation of multiple buildings, enabling apples-to-apples comparisons across buildings in the same utility territory or other locational evaluation boundaries.

The GridOptimal metrics tool evaluates two versions of a building design: a baseline version and a proposed version. The differences between the two have to do with building design, control strategies, and feature selection. Designers and owners can evaluate "what if" scenarios across multiple buildings by iteratively evaluating multiple proposed cases against the same baseline.

Table 1 provides key information about required data inputs.

Table 1. Data Inputs Summary

Data Input	Side of Meter	Units	Source	Related Metric or Metrics
Grid Total Demand Profile	Grid	kW per hour	8760 grid profile	Grid Peak Contribution
Marginal Carbon Emissions Profile	Grid	Lbs. CO_2 per hour	8760 marginal carbon profile	Grid Carbon Alignment
Building Demand Profile	Building	kW	8760 building profile	Grid Peak Contribution, Energy Efficiency vs. Baseline, Onsite Renewable Utilization Efficiency
Building Onsite Generation Profile	Building	kW	8760 building profile	Grid Peak Contribution, Onsite Renewable Utilization Efficiency, Grid Carbon Alignment
Building Onsite Fuel Consumption	Building	kBtu	8760 model or meter data	Energy Efficiency vs. Baseline
Demand Flexibility	Building	kW, over 15 min, 1 hr, or 4 hrs	Building feature set	Short-Term Demand Flexibility, Long-Term Demand Flexibility, Dispatchable Flexibility
Resiliency	Building	n/a	Building feature set	Resiliency

Grid Total Demand Profile

The total grid demand profile is an 8760 data set and refers to the total load on the grid during each hour of the year. Total load on the grid is typically reported in MW. The default source is the Energy Information Agency Hourly Grid Data Monitor (EIA 2019), but other data inputs may be used. For example, to compare building performance to grid demand at the substation level, a user could input the substation demand profile.

Marginal Carbon Emissions Profile

Marginal carbon emissions refers to the rate at which the emissions associated with electricity consumption will change *on the margin* – that is, from a generation source serving the last, incremental demand added on the system. This is an 8760 data set. Marginal carbon emissions are defined in lbs. of CO_2 emitted per MWh of electricity consumed.

A few marginal carbon emission profile data sources are available. WattTime, a nonprofit subsidiary of the Rocky Mountain Institute, has shared some of its data with GridOptimal. WattTime's data are available for nearly the entire contiguous US at 5-minute granularity (WattTime 2020). Currently, GridOptimal metrics have been calculated using this dataset but NBI expects to use hourly long-range (predicted for the year 2040) marginal carbon emissions profiles derived from NREL's Standard Scenarios. NREL has indicated its intention to provide this data in the 2020 release of its Standard Scenarios. James Mandel (2016) makes a clear case why marginal emissions are more appropriate than average emissions in this application.

Building Demand Profile

The building demand profile (aka load shape) refers to the building's hourly kW energy consumption, at the whole-building level, for each of the 8760 hours in one full year. The building demand profile in this case is a *gross* profile, which means that it includes all site energy consumption, including onsite generation and grid-supplied electricity.

This *gross* demand may be used in part to calculate the *net* building demand. Net building demand refers to the combination of the gross profile and the building onsite generation. Net demand can be negative when the building is exporting energy to the grid.

The **adjusted maximum reference demand (AMRD)** is derived from the demand profile and is defined as the average of net building demand during the 10 highest net demand hours of the year. The AMRD is created to reduce the potential for a single highly anomalous hour to have an undue impact on the evaluation of GridOptimal metrics.

Building Onsite Generation Profile

The building generation profile refers to the pattern of onsite energy generation (that is, the power produced by solar panels or other onsite resources) over all 8760 hours in one year. This is the onsite generation analogue to the load shape. This may be predicted or may be measured; if measured, the data often comes from an inverter or a data dashboard.

Building Onsite Fuel Consumption

The hourly or annual fuel consumption at the building, if any, may be entered in an 8760 format or as a single annual number. The units are kBtu. The most common building onsite fuel source is natural gas but other fuels may be used such as oil, biogas, biomass, etc. Natural gas, hydrogen, or other fuels consumed by fuel cells is included in this category.

Demand Flexibility

In this context, demand flexibility refers to the ability of a building to reduce its power demand during a predefined time period while maintaining an acceptable level of comfort as defined in Section 7.3.4 of ASHRAE Standard 189.1 (ASHRAE 2018). This ability is increasingly important as more intermittent energy (wind and solar, for example) comes online. This metric seeks to evaluate how much a building can reduce its energy demand during the highest-building-demand hour of the year (the building's peak hour). Currently, only downward modification (load shed) is considered. However, the same methodology may be used to measure a building's capability to increase load. This may be useful during times of grid oversupply (i.e. when total energy production on the grid exceeds system demand as on a sunny, windy, temperate day with high renewable energy production and low overall demand).

Demand flexibility may come from energy storage or adjustments to buildings controls, such as temperature setbacks, reduced lighting levels, delaying water heating, etc. Load may be shed or shifted: reduced lighting levels reduces load with no future impact, whereas delaying water heating reduces load during the event period but results in increased load after the event is over. Demand flexibility inherently requires control and metering systems in place in order to perform and measure the demand management.

Dispatchable Demand Flexibility

Dispatchable flexibility measures the *remotely controlled* demand flexibility in the building: that which is automatically controlled by a utility or third party (e.g. aggregation service provider or microgrid controller) rather than simply controllable by the building's local management system.

Buildings with high potential for reducing their energy demand via flexibility can be a great asset to an electricity grid by becoming a reliable source of demand reduction during priority events, such as demand response calls or emergency needs. When some or all of the building's energy storage, interruptible loads, or other load flexibility assets are controlled directly via a utility or third party, the value to grid operations is higher. Demand response aggregators and other entities acting in the interest of the utility grid can more reliably ensure that the flexibility of the building will be available when needed, as compared to voluntary calls or other events requiring action from the building operator.

Resiliency

Buildings may enhance resiliency on both sides of the meter through their features and operations. Within the GridOptimal metrics tool, both types of resiliency (building and grid) are considered. Building resiliency is gauged by the ability of the building to safely island itself from the electricity grid in the event of an outage. Grid resiliency is gauged by the ability of the building to contribute to the restart of grid operations after an outage through soft-start capabilities.

An Overview of Selected Metrics and Their Calculation Methodology

The GridOptimal metrics spreadsheet tool performs calculations to evaluate building performance across a range of output categories, which are described here. The relative importance, or weight, of each output category has not been universally defined, precluding the combination of all output scores into a single overall score. Currently, the GridOptimal output categories are not combined into a single overall score: rather, each output category stands alone.

All output categories are scored on a percentage basis, from 0% to 100%; scores of greater than 100% are possible in some categories. Comparisons are not necessarily comparable across categories. That is, a score in one category may not indicate the same degree of achievement or performance as the same score in a different category.

Table 2. GridOptimal Metrics Summary Table (note: all metrics use unitless scores)

GridOptimal Metric v1	**What it Measures**
Grid Peak Contribution	Degree to which building demand contributes to load on the grid during system peak hours
Onsite Renewable Utilization Efficiency	Building's consumption of renewable energy generated onsite (not exporting to grid) over a year
Grid Carbon Alignment	Degree to which the building demand contributes to upstream (grid) carbon emissions over a year
Energy Efficiency vs. Baseline	Percent better than code (annual total energy use)
Short-Term Demand Flexibility	Building's ability to reduce demand (shed) for 1 hour
Long-Term Demand Flexibility	Building's ability to reduce demand (shed) for 4 hours
Dispatchable Flexibility	Building's ability to automatically reduce demand (shed) for 15 minutes, controlled by utility/ third party
Resiliency	Building ability to island from grid and/or provide energy for critical loads for 4-24 hours; motor soft start capability to help grid restart after outage

This paper provides an overview of the first version of these eight GridOptimal metrics. Further details, including documentation of the development of recommended credit thresholds (i.e. scores considered creditworthy for utility programs and rating systems such as LEED), are available at the GridOptimal webpage (GridOptimal 2020).

Grid Peak Contribution

The Grid Peak Contribution score defines how much this building's load contributes to peak loads on the grid, during grid peak hours. To calculate this score, only the top 5% (highest load) of all peak hours are considered. Other peak hours (the other 95%) are not counted for this purpose. During each of these highest peak hours, the building's demand (kW) is divided by its AMRD, which results in the calculation of a grid peak load factor for the building. The average of these factors during the top 5% of hours defines the building's grid peak contribution. Because lower grid peak load factors are desirable, the scores are then inverted so that higher scores are better (in line with other output categories).

The following graphic shows normalized 2017 grid demand in the ISO-Northeast grid region. The top 5% of hours are shown in red. These hours, and only these, would be used to calculate the Grid Peak Contribution metric.

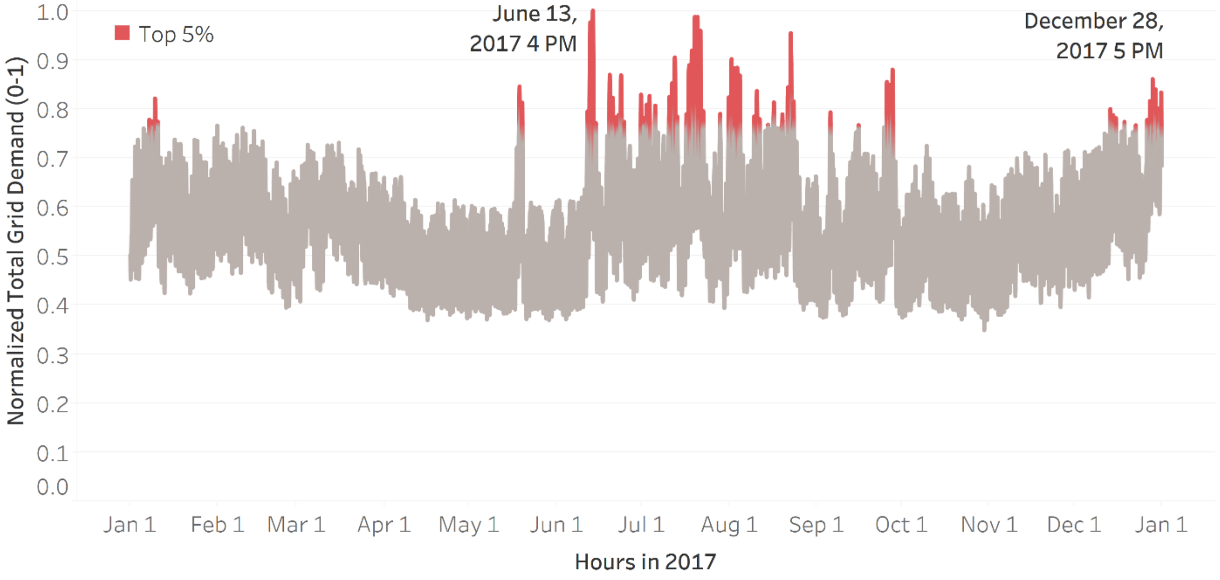

Figure 1. The top 5% of hours in 2017, used to calculate Grid Peak Contribution (Source: ISO-New England).

Onsite Renewable Utilization Efficiency

The Onsite Renewable Utilization Efficiency score measures a building's ability to consume energy generated onsite. The generation profile of onsite generation (e.g. through solar PV panels) is compared to the building's demand profile. A higher Onsite Renewable Utilization Efficiency indicates that the building can consume more of its own energy instantaneously, on the building side of the meter.

During hours in which the building produces more energy than it consumes, energy is exported to the grid, unless energy storage (e.g. batteries or thermal energy storage systems) absorb the excess energy generation. These grid exports are totaled over the year and divided by the total annual onsite renewable generation energy.

The score is then scaled down by how much of the annual energy load is offset by onsite renewables: 100% of annual load offset equals 100% potential credit, scaling linearly down to zero. For example, consider a building with onsite renewables that annually produce energy equal to 100% of annual energy consumption, and the facility consumes 100% of that energy onsite (no exports to the grid), the score would be 100% * 100% = 100%. However, if the same building consumed only 50% of that energy onsite (half of all energy produced onsite is exported to the grid, the score would be 100% * 50% = 50%. The best performance therefore represents a zero energy building that does not export any energy to the grid.

Grid Carbon Impact

The Grid Carbon Impact measures the alignment between the building's net demand profile and the marginal carbon on the grid over all 8760 hours of the year. These two data sets have different metrics: the building's net demand profile is measured in kW and marginal carbon is measured in lbs. of CO_2 per kWh. To perform this evaluation, both the building net demand profile and the marginal carbon emissions profile are normalized to a unitless fraction of their relative maxima, resulting in a 0-1 factor for each hour of the year. These fractions are then multiplied, resulting in a unitless product. These products are averaged over the year. The scores are then inverted so that higher scores are better (in line with other output categories) and converted to a percentage score.

A perfect score in this case is not realistically achievable. To achieve a perfect score, a building would have to either use no net power or use power only during hours of the year with zero marginal carbon emissions – for all hours of the year. Nevertheless, this score represents the combined impact of building load and marginal grid carbon for each hour of the year.

Energy Efficiency vs. Baseline

The value of energy efficiency is explicitly recognized by the inclusion of the Energy Efficiency vs. Baseline output category. The building's gross Energy Use Intensity (EUI) is calculated as the sum of all energy consumption (electricity, gas, district energy, and other sources) divided by the building size (gross square feet). The units are in kBtu/sf/yr. This calculation is performed using the building's *gross* demand profile, including all energy consumption regardless of whether the energy was generated onsite or delivered through the grid. This is compared to a baseline and the score is the ratio of the two: percent better than code.

The baseline, as a default, is derived from modeling of a code-equivalent building. Alternate baselines or targets may be used, such as zero energy EUI targets (NBI 2019).

Short Term Demand Flexibility

A building's short term demand flexibility score is defined as the percentage of its AMRD that it is able to shed over a one-hour period. This is measured on the building's peak day: the day during which the building's highest hourly demand occurs. The building must be able to shed at least 10% of its AMRD to get any credit in this category. Additional credit is available as the building's load shedding capability increases, up to 50% of maximum reference load. A score of 100% indicates that the building can shed 50% of its AMRD for one hour; scores of greater than 100% are possible. This adjustment has been made to increase resolution and to make the scale more useful to most projects.

Long Term Demand Flexibility

The long term demand flexibility category is very similar to short term demand flexibility, with the exception that the time period over which the building must be capable of shedding load is four hours long. The same scaling has been applied: the minimum shed is 10% and a score of 100% indicates that the building is able to shed 50% of its AMRD for 4 hours[1].

Dispatchable Demand Flexibility

The calculation methodology of the dispatchable demand flexibility score is structurally similar to short and long term demand flexibility score. The time period is 15 minutes rather than one hour or four hours. In addition, there is a requirement related to how dispatchable demand flexibility is controlled: to get credit, dispatchable demand flexibility must be capable of activation (dispatch) by an automated signal from a utility or third-party service provider (such as a demand response aggregator or the controls architecture of a Distributed Energy Resource Management System (DERMS: a microgrid).

The same scaling has been applied: the minimum shed is 10% and a score of 100% indicates that the building is able to shed 50% of its AMRD over a 15 minute long period, directly, automatically, and remotely controlled by the utility or a third party.

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[1] This metric could easily be modified in a particular application to focus on longer time frames.

Resiliency

GridOptimal metrics include a simple indicator to measure the building's capability to perform a limited set of specified resiliency-related capabilities. In this context, resiliency is considered both from the perspective of the building (islanding related components) and of the grid (soft start). Each score gets one point, which translates to 25% credit. A perfect score is 4, which is equivalent to 100%.

1. **Islanding Capability:** The building's solar, storage, or other energy-providing systems have a smart inverter with an automatic transfer switch that is capable of safely islanding the building (temporarily disabling the building's connection to the grid) and enabling all or designated high-priority circuits in the building to remain online during a power outage. If the building is part of a DERMS (microgrid), these capabilities may be present at the DERMS level instead of the individual-building level. If this capability is present one point is awarded.
2. **Islanding Capability, 4 Hour:** The building or DERMS is capable of supplying energy to designated high-priority circuits (i.e. minimum needs to remain habitable in an emergency) in the building during a power outage for at least four (4) hours on the day during which the building's highest hourly demand occurs. Combustion fired backup generation equipment may not be used to meet this requirement.
3. **Islanding Capability, 24 Hour:** The building or DERMS is capable of supplying energy to designated high-priority circuits in the building during a power outage for at least 24 hours on the day during which the building's highest hourly demand occurs. Systems are in place to ensure that the building can recharge batteries or other energy storage using onsite generation resources. Combustion fired backup generation equipment may not be used to meet this requirement.
4. **Soft Start:** The building or DERMS has the ability to ramp up power demand gradually after a power outage. By staging or slowly ramping up motors, such as HVAC fans and pumps during a restart of building operations after a power outage, the spike on the grid associated with many motors coming online all at once is mitigated. This facilitates restarting the local electricity grid after an outage. If at least 50% of the whole-building's combined nameplate motor capacity is capable of soft start mode, one point is awarded.

Additional Outputs

GridOptimal metrics may be leveraged to investigate topics outside the specific categories discussed here. NBI is using these additional categories to explore additional options for GridOptimal implementation. For example, the estimated marginal carbon emissions attributable to building operations can be calculated by multiplying the marginal carbon emissions factor by the building's demand profile for each hour of the year and totaling all hourly impacts. This can help users understand the emissions implications of choices related to design, configuration, equipment, and operations. Similarly, by inputting utility rates (flat, time of use, or real-time pricing models are possible) a user may compare energy cost impacts of a baseline building against one or more proposed cases. Currently GridOptimal does not include adders for power quality, service fees, etc. but could be configured to do so.

Next Steps: Deployment of Metrics for Buildings, the Grid, and the World

The metrics described in this paper are intended to provide tools for a wide range of stakeholders to measure and improve building-grid interactions. The ability to quantify specific building performance parameters and capabilities in a coordinated, consistent manner has been a major gap, impeding forward progress on enhanced building-grid integration. Buildings have the potential to either enable or hinder progress toward grid transformation and decarbonization.

These metrics may be applied in a variety of ways. In the immediate future, the GridOptimal Buildings Initiative is working to develop a pilot credit proposal for the Leadership in Energy and Environmental Design (LEED) rating system. The authors and other GridOptimal members are working to define utility program criteria to bring a more holistic approach to building-grid utility programs. Representatives of some leading jurisdictions have contributed to the development of these metrics and/or are exploring how to leverage them for code and policy applications. Members of the design community (architects, engineers, builders, owners, etc.) are interested in applying these metrics to enhance grid-integration outcomes in their own projects.

The authors hope that by publicly documenting these GridOptimal metrics, stakeholders on both sides of the meter will gain valuable tools to maximize benefits on both sides of the meter while ensuring that buildings help, not hinder, the transformation of the electricity system.

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