Valuing Energy Efficiency and Distributed Energy Resources in the Built Environment

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Valuing Energy Efficiency and Distributed Energy Resources in the Built Environment

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ABSTRACT

Traditionally, analytical frameworks that underpin building energy policy have focused on the need to reduce annual energy consumption by assessing the cost and efficiency performance of energy-consuming technologies. Investments in distributed energy resources (DERs) such as photovoltaics (PV) have generally been evaluated independently, but also on a cost and performance basis. However, buildings are rapidly evolving to incorporate technologies that not just consume energy, but also generate, store, and control energy loads. Concurrently, the electric grid is becoming more dynamic and variable due to the increased proportion of electricity production from variable renewable sources. To that end, building energy policy analytical frameworks should be updated to include the interactions between energy efficiency and DERs as well as potential value streams for the grid and building owner that technologies or packages of technologies might offer. As buildings with DERs and controllable loads are able to provide grid services or optimize operations based on electricity rates and grid conditions, the temporal and spatial nature of these technologies should also be incorporated into design decisions. To explore these questions further, the National Renewable Energy Laboratory (NREL) will use a series of building and electric grid models to simulate the design and operation of a neighborhood of buildings under various electricity rates, grid conditions, and potential compensation scenarios. Scenarios of time-sensitive values for future grid services will also be constructed for use in the analysis. New metrics that can be used in building energy policies will also be explored to capture the responsiveness or flexibility of high efficiency buildings with DERs under various electric grid conditions and future scenarios. Initial outcomes will be ready by the Spring of 2019.

Introduction

Buildings, to an increasing degree, can now be controlled for how and when they consume, store, and produce energy. At the same time, the electric grid in which buildings reside is becoming more variable and uncertain. Though buildings with energy efficiency (EE) and DERs, e.g. PV, controllable loads, and thermal and electric storage—also known as SolarPlus buildings (O'Shaughnessy et al. 2017)—can contribute to this variability, they can also help manage it. If this value proposition is captured when new buildings are designed or when investments in existing buildings are considered, the deployment of distributed PV and EE can benefit building owners and the electric system.

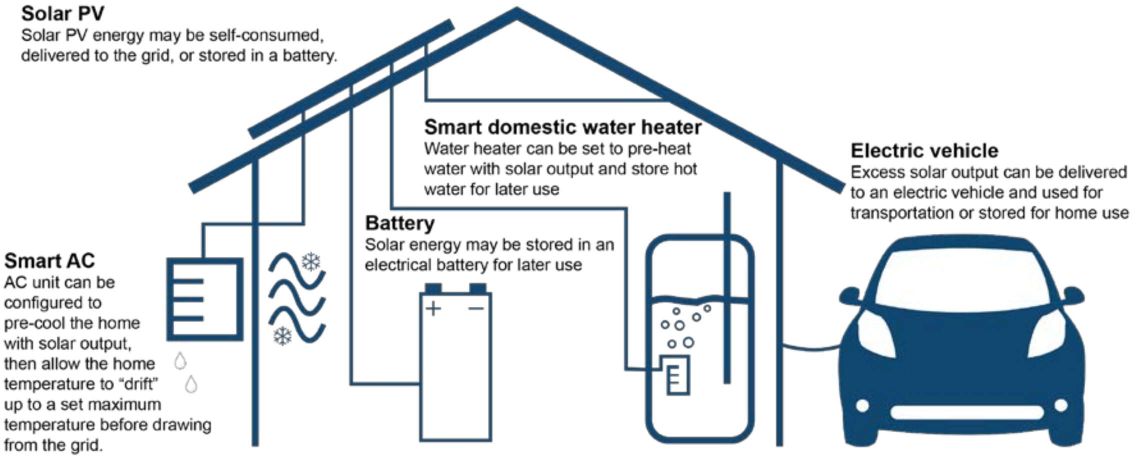

Figure 1. Example of a SolarPlus Home (O'Shaughnessy et al. 2017)

Currently, the analytical approaches that underpin building energy design and policy focus on how to reduce annual energy consumption, and primarily consider the costs of EE technologies (see Figure 1). Similarly, the decision to invest in distributed PV systems generally focuses on the costs of the system for the building owner, and may be dependent upon on the financing and policy incentives available. To date, attempts to incorporate PV into building energy models or analytic frameworks (IECC 2018; U.S. DOE 2018, HERS 2018; HES 2016) have generally focused on the annual load-generation interplay, either having solar PV compete with other efficiency measures or sizing PV when all efficiency measures were implemented.

Additionally, analytic approaches for evaluating technology options in a building have not traditionally incorporated interactions with the electric grid, due to the time disconnect between annual EE modeling which lacks the temporal resolution to sync with grid modeling. With the advent of distributed PV, controllable loads, and storage, incorporating time-sensitivity has become increasingly important to appropriately value these DERs both to the building and the grid. Building policies and consumer interest in zero energy buildings have further created an impetus to specify requirements, guidance, and program design which incorporate grid interaction metrics (NBI 2018; CEC 2017; CPUC 2016; Miller 2018; Woolf et al. 2017).

Considering the grid impacts of investments in building-level DERs and EE is critical as it can lead to system-wide gains in operational efficiency and additional value for building owners when these technologies are appropriately scoped and controlled. However, in the transition to a more value-based paradigm for designing and operating buildings with distributed PV and EE technologies, new analytical frameworks are needed that both (1) incorporate the combined value that a package of technologies may provide a building owner and (2) consider the temporal and spatial interactions with the electric system (see Figure 2). New analytical frameworks or metrics might include enhancements to existing rating systems or metrics which capture the ability of a SolarPlus building to act as a grid asset, e.g. ratio of dispatchable loads versus passive loads.

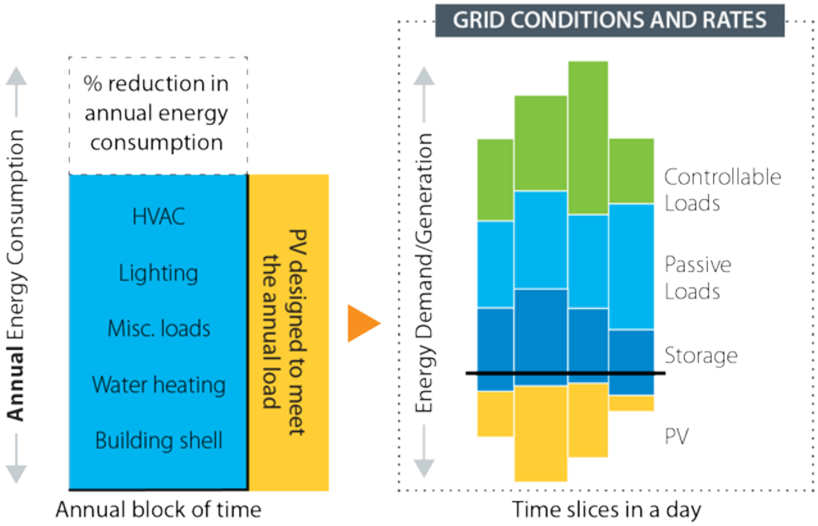

Figure 2: Transition from Current Building Energy Policy Analytic Frameworks to Future Frameworks

Analytical Approaches for Designing, Upgrading, and Operating SolarPlus Buildings

To date, building energy policies and design approaches have primarily focused on reducing the annual energy consumption of the building. To some extent, reducing the impact of building loads on peak demand has been pursued as a secondary goal. Building energy efficiency policies include both mandatory (e.g. appliance standards, audit requirements, and building codes) and voluntary approaches (e.g. incentives, recognition programs, and above code efforts).

Analytical frameworks have been developed to support these energy efficiency policy approaches and assess the effectiveness of technology and policy options both in terms of cost and performance for reducing energy consumption in buildings. Analytical approaches include asset ratings or energy rating indices that are widely used to assess the expected performance of the assets in existing buildings or new building designs. There are several residential and commercial energy rating systems that currently exist. Some examples of residential rating systems include: Home Energy Rating System (HERS), Home Energy Score (HES), Energy Design Rating (EDR), Energy Rating Index (ERI). In more simplistic ratings, buildings might be benchmarked against an annual end-use intensity rating of a comparable building built to a certain building code. There are also more operational or performance-oriented rating systems that consider not just the assets in the building, but also the occupants and function of the building and actual use of energy, e.g. EPA’s Portfolio Manager is a widely used tool.

To date, energy rating systems and other analytical approaches for building energy policy have focused mostly on:

- assessing annual energy consumption
- the interactions between energy efficiency measures
- setting a floor for energy efficiency performance
- using a source energy basis

- the cost-effectiveness of the technologies or measures
- the building compared to benchmarks of like-type buildings (peer comparisons)

However, as buildings incorporate technologies that not just consume energy, but also generate, store and control energy loads, these analytical frameworks may need to be modified with more temporal resolution to assess the cost, performance and interactions between new technology options and potential temporally and spatially-specific value streams that technologies or packages of technologies might offer, especially with respect to the electric grid.

Approaches for incorporating PV into building analytical approaches are emerging. For example, beginning in 2015, the International Energy Conservation Code (IECC) for residential buildings, included a method for incorporating solar photovoltaics into the alternative performance-based compliance path, establishing the energy rating index. The Home Energy Score and RESNET's Home Energy Rating System also include onsite solar generation. However, none of these systems include approaches for assessing the cost, performance and value of flexible loads and storage, or the combined value of PV, storage and flexible loads.

Zero energy buildings (ZEB) — also known as net zero energy or zero net energy building—is a building that exports as much renewable energy as the total energy it imports from other sources on an annual basis. These concepts are being explored in building energy policies and in particular, the requirements, guidance, and program design for ZEBs. New Buildings Institute has also begun to explore these concepts through their GridOptimal Initiative. The National Efficiency Screening Project also released some concepts and approaches for assessing the cost-effectiveness and benefits of DERs in their recent National Standard Practice Manual (Woolf et al. 2017).

However, frameworks for a more robust set of approaches should be explored, the methodologies developed and documented, then tested out both with building energy simulation tools as well as in demonstration or pilot environments. An ideal framework accommodates new and emerging technologies (flexible loads, controls, storage, PV and other DERs), accurately captures sub-system interactions, and establishes metrics for value to the grid. Analytical frameworks could account for:

- Hourly on-site consumption, generation, and storage
- Hourly utility load shapes and value profiles
- Hourly emissions rate profiles
- Interactions between EE, controllable loads, storage, and onsite solar
- Building-to-grid interactions and
- Temporally and spatially sensitive value streams of building and technology activities

In particular, "by combining flexible loads, onsite generation, onsite storage, and advanced supervisory controls, interactive buildings have the potential to provide building owners and utilities with new value streams, such as:

- Maximizing on-site renewable generation
- Minimizing unexpected variability in building net load profiles
- Minimizing or shifting net demand of an individual building based on incentives in utility rate structures
- Ramping up net demand to avoid curtailment of renewable energy

- Managing loads, generation, and storage strategically during demand response events
- Managing loads, generation, and storage strategically and providing energy surety during islanding events
- Responding to utility control signals to provide ancillary grid services." (Kung et al. 2016)

Description of Project

To address these critical needs, the National Renewable Energy Laboratory is undertaking a new project through joint support from the U.S. Department of Energy's Solar Energy Technologies Office (SETO) and Building Technologies Office (BTO). This effort aims to develop initial concepts for new building metrics, use a suite of building-to-grid models to conduct scenario analysis of the interactions between SolarPlus buildings (buildings with PV, EE, and other DERs) and the electric grid, and begin developing time-sensitive values for electricity. This project consists of four major components of interrelated work: 1. Metrics Scoping, 2. Metrics Case Studies, 3. Characterize and Enhance Building-to-Grid Model Interoperability and Capabilities, and 4. The development of a menu of electricity rates and time-sensitive values for the electric grid for use in building energy modeling. Each of these four areas of work are described below.

Metrics Scoping

Through literature review, new analysis and expert engagement, the project team will explore new metrics for buildings with PV, EE, and other DERs that assess the ability for that building to both optimize standalone operations as well as act as a grid asset. Potential metric concepts will be assessed in the Case Studies and findings of the Metrics Scoping work summarized in the final project paper. The methods and results of analysis to construct time-sensitive values for electricity for use in the Case Studies will also contribute to the design of new metrics.

The project team will conduct a literature review of existing metrics and approaches for assessing the ability for buildings with PV, EE, and DERs to play a role as a grid asset, including assessing if current analytical frameworks could be modified or re-envisioned. Based on the literature review, the project team will also conduct internal and external expert engagement to solicit concepts and ideas for new metrics or enhancements to existing analytical frameworks. The project team will also test out the metrics in the Case Studies and begin to understand which metrics are most applicable to certain settings, measure the phenomena that the project team intended, and how measureable the metrics are from a modeled environment. The project team will then capture proposed metrics or analytic frameworks in a final project paper and also identify next steps for future work.

Metrics Case Studies

In order to delve further into the design of new metrics, case studies will be conducted for 1-3 locations in the U.S. to study the interactions between solar PV, energy efficiency and DER technologies in a building given different electricity rates or time-sensitive values and grid conditions. These case studies will allow the project team to study simulated building design and operations using a suite of best-in-class building energy and grid models. Metric design will be informed by assessing the design and operation of buildings with different scenarios of PV, EE, and DER technology cost and performance as well as current and future electricity rates that incorporate more variable grid conditions and needs. Future electricity values will be constructed to reflect bulk power grid needs and other new paradigms for valuing grid services, e.g. transactive energy.

In order to develop metrics, the project team will analyze the design and operation of a group of buildings in 1-3 locations in the U.S. given different scenarios of EE, PV and DER technologies, electric grid conditions and rates. A series of existing models can be linked together to simulate building loads and then optimize the investment in and operation of onsite distributed energy resources given associated grid conditions. This was initially explored in the Solar Plus paper (O'Shaughnessy et al. 2017). The models chosen for the case study analyses represent best-in-class capabilities while also balancing the need for a streamlined set of tools to allow the project team to focus on the primary analysis objectives (see Figure 3). These tools are:

- BEopt/OpenStudio will be used to identify energy efficiency technology packages, establish building load profiles and identify the impact of efficiency measure interactions.
- REopt will identify the cost-optimal set of distributed energy resource technologies, their sizes, and dispatch, given the specific load profiles and tariff price sets.
- ReEDS will be used to establish generation assets at the bulk power scale, considering various future scenarios regarding renewable penetration.
- PLEXOS will produce time-series grid costs for the grid characterizations as established in the ReEDS model; translation from production cost to hourly electric values is described in Task 4.
- IESM will take the established set of technologies and evaluate distribution feeder impacts of these technologies, their expected operation, and potential impacts on building occupant comfort.

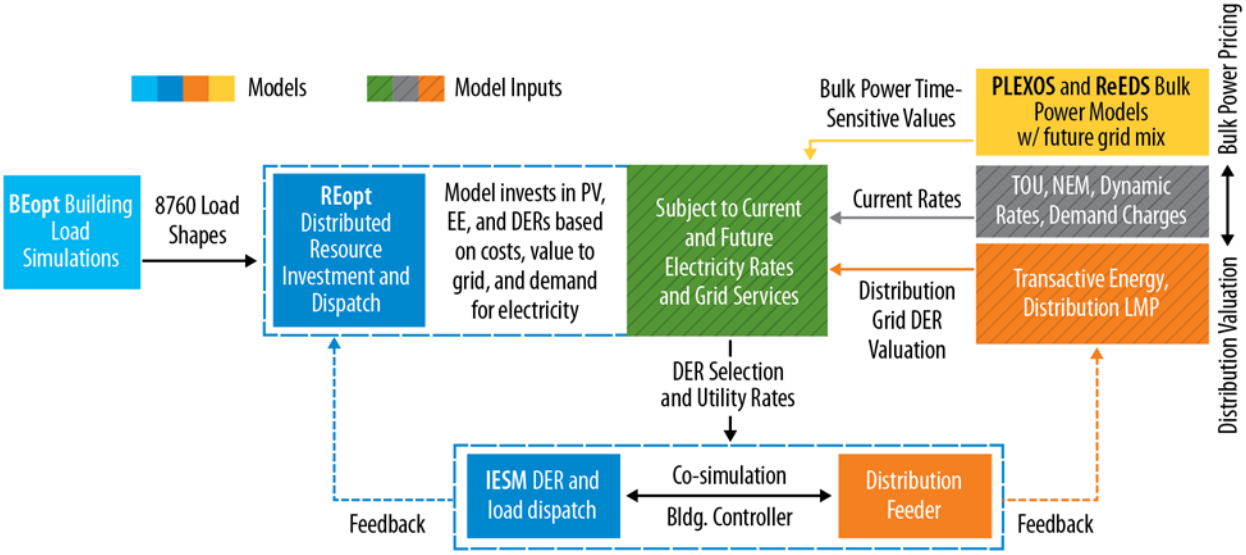

Figure 3: Project Team Modeling and Analysis Capabilities

Finalize Initial Scenarios and Modeling Approach. The first step in the Case Study process is to finalize decisions regarding the scenario design, including the parameters of future policy and market scenarios will need to be determined. The project team will identify location(s) in which to run the case studies for which they have data and that will allow them to properly explore the analysis questions (e.g. DER deployment, policy or regulatory environment) and where they will be able to leverage existing modeling efforts and datasets, including existing or previous agreements with utility partners. The project team will also determine what, if any, model enhancements will be made to support the Case Study analysis, especially closer coupling the BEopt and REopt models together. Lastly, the project team will scope out the landscape of technology investment options including performance, characteristics, and costs as well as future scenarios for customers' electricity charges and compensation schemes.

Prepare Modeling and Conduct Initial Results. Once the parameters of the test case have been finalized, the NREL project team will prepare the data, scenarios and any external analysis needed for the modeling work. Models will then be tested and prepared for conducting integrated modeling runs. Initial scenarios will be run and results analyzed and reviewed. Models will be calibrated, data tweaked and scenarios refined based on initial results. The status of the modeling efforts will be discussed with DOE BTO and SETO, and used to inform the development of metrics in the Metrics Scoping effort.

Review and Refine Modeling Scenarios. Based on review by NREL and DOE and assessment of metric options, additional scenarios will be run and results finalized. Results might be discussed with a small group of external stakeholders or DOE performers working on related projects. Begin summarizing analysis methods and results in short report draft. The status of the modeling efforts will be discussed with DOE BTO and SETO.

Summarize final results in report. The project team will share a draft report with DOE, and then finalize results in report and identify next steps for future work.

Characterize and Enhance Building-to-Grid Model Interoperability and Capabilities

In support of the Case Studies and Metrics Development, the project team may make minor enhancements such that building models can better characterize energy storage, controllable loads and the interactions with PV. The project team will also work to improve the linkages and interactions between the models to more seamlessly pass information back and forth, interlace model decisions, and create more of a feedback loop between the building and grid models. Methods, data and insights will be published where appropriate and modeling or analytic gaps will be noted in the final report.

In particular, the project team is exploring a tighter coupling of the BEopt and REopt models to consider options for more closely coordinating the investment decisions for energy efficiency measures and DERs. The options for more closely coupling BEopt and REopt will consider how and when to send information on building design options from BEopt to REopt, which flexible loads to include in BEopt building design packages, how to incorporate the costs of flexible load options in REopt, how to coordinate the dispatch of flexible loads, storage options and photovoltaic generation against different utility rates, and how closely to integrate the optimization functions of each model.

Additionally, the project will also be manually linking together the building and grid models with data and analysis and will also gather data, methods and insights on how to improve these linkages that might be useful for research institutions, policy analysts, and others to extend this research and build on the executed work. It is expected that during the execution of this project, the project team will identify gaps in the current modeling ecosystem that would enable more efficient or insightful modeling of the interactions between buildings, DER, grid, and markets. The project team will identify either further model enhancements or the need for future models, and will outline these needs in the final project report.

Electricity Rates and Time-Sensitive Valuation

In the future, building owners may be faced with new regulatory or market environments which may impact how buildings are designed and investments in energy efficiency and distributed energy resources are made. To that end, the project team will identify and construct a series of scenarios which reflect current electricity tariffs and potential future electricity rates or compensation structures for electricity customers. Current electricity tariffs may include traditional energy-oriented electricity rates that do not vary with time, different sizes of demand charges, lumpy time-of-use rates, and net metering structures. The NREL Utility Rate Database will be a valuable source of information for the task of gathering existing utility rates from across the country (URDB 2018).

Future electricity rates or compensation scenarios will include more time and location sensitive rates or compensation schemes, e.g. real-time rates and methods for valuing for grid services. The project team will compile a list of existing tariff structures and finalize methods for developing future scenarios of time-sensitive values. In particular, the project team will create a simple hourly electric value tool derived from the outputs of bulk power system models. Based on the California Title 24 Time Dependent Valuation (TDV) approach (Horii et al. 2014), the project team will use the outputs of the NREL Standard Scenarios (Cole et al. 2017) of future bulk power system electricity grid profiles to generate 8760 values for capacity values, energy values, and ancillary service values. These Time Sensitive Values (TSVs) for different regions of the country will be compiled in a database that will then be used in the Case Studies in Task 2 and will be made available publicly for building energy policy analysts and design professionals could use in building energy models. The project team will construct and test out the scenarios in the Test Case and summarize the results of the work.

The overall goals of this effort are to first develop a valuation tool based on exporting the NREL Standard Scenarios results (developed with ReEDS and dGen) to PLEXOS, and then to use the outputs of both models to estimate value components similarly to what is done for TDV. Based on the structure of the Standard Scenarios, the value components will be available for each state or balancing authority on an hourly basis for every other year out to 2050, separately for each scenario. The tool will then accept inputs concerning project location, decision time horizon, discount rates, desired components, and any desired wholesale-to-retail transformations to produce output time series or tariffs that can be used to determine the value of a given EE or DR measure in the whole building context over the investment lifetime. In the later stages of the project, we will layer features related to distribution-level valuation.

Impact of the Project

If successful, this project will identify an initial set of metrics or quantitative approaches that could help the building energy sector to better value the current and future contributions of distributed solar to the value of a building, especially in tandem with other building technologies and in the context of the electric grid. Contributing to a nascent, but growing body of work in this area, the project could provide policymakers, the buildings industry, and the solar industry with options for discussing and quantifying the benefits of solar along with energy efficiency technologies in a common analytical framework.

The project will also identify enhancements that could be made to a suite of building-to-grid models that allow them to better address both the complex interactions between, and potential value of, buildings loads and solar subject to various grid conditions. A beta version of a new tool with hourly electric values representing future power sector scenarios, case study datasets, and increased interoperability within a simulation environment could enable building energy practitioners to conduct their own analyses for jurisdictions across the country. The initial outcomes will be ready by Spring of 2019.

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