The Future of Buildings: Integrating with the Power Grid of Tomorrow

2018–2019 ASHRAE President Sheila Hayter and National Renewable Energy Laboratory Associate Laboratory Director for Energy Systems Integration Juan Torres lead a panelist discussion at the "Building our New Energy Future" workshop. *Photo by Werner Slocum, NREL 55880*

Traditional interactions between the built environment and the electric utility industry are changing rapidly. Rather than a one-way flow of electricity where utilities produce and transmit the electricity that buildings then consume, buildings are becoming efficient energy consumers that can dynamically adjust loads to ensure grid-provided energy is used effectively. Buildings are transitioning to now be at the intersection of forecasting loads and demand response, forecasting and control of output from distributed generation and renewable energy systems, and the optimal dispatch of energy storage. Because residential and commercial buildings consume 74.7% of the electricity generated in the United States,[1] grid-integrated buildings represent an important solution to addressing challenges facing the power sector. In addition to the electric power grid, buildings will be increasingly interactive with water, transportation, and telecommunications networks, and will also more strongly affect surrounding buildings and other civic infrastructure.

To address some of these quickly evolving grid-interaction needs, building and grid industry experts convened at the "Building our New Energy Future" workshop held at the National Renewable Energy Laboratory[2] (NREL) in Golden, Colorado, in March 2019. Cohosted by NREL and ASHRAE with the support of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, the two-day workshop included building owners, building

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[1] U.S. Energy Information Administration. 2019. "Electric Power Monthly." https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_01.
[2] More information about NREL can be found at https://www.nrel.gov/.

and grid consulting engineers, utility operators, equipment and controls manufacturers, and staff from U.S. government and private sector stakeholder groups. The goal of the workshop was to examine current, emerging, and needed research priorities essential to enabling a new energy-efficient future.

Four key topical areas were discussed, addressing current and emerging research needs:

- *Grid Services: How can buildings help the grid?*
- *Energy Efficiency: Expanding the capabilities of existing solutions*
- *Energy Storage: The power of space, temperature, and time*
- *Integration and Interoperability: Bringing it all together.*

These discussions sparked conversation on bridging the gap between the grid industry and the building science community. Following are key takeaways and opportunities for research and analysis that were identified in each priority area.

Grid Services: How can buildings help the grid?

Overall, the building industry and the greater community of buildings professionals have made great progress in integrating energy efficiency into building science. The next goal is to figure out how to make buildings more flexible, which means lowering energy load peaks through energy efficiency and demand response. Demand response (shifting demand to different times of the day) can have many benefits, including maximizing the benefit of on-site renewable energy systems to offset building loads. Renewables are expected to have the fastest growth in the electricity sector, providing almost 30% of power demand by 2023.[3] Another integral part of building flexibility is making better predictions about building load profiles by anticipating future load curves, and then lowering and smoothing out those curves.

Eventually, dynamic load control should be part of the solution to combat expected growth in energy consumption. However, buildings are supposed to serve occupants and the activities that take place within the building, and improving grid services is ultimately about what the consumer needs. This means better understanding occupancy behavior and reducing energy consumption while maintaining comfortable, safe, productive, and healthy indoor environments.

The next step is figuring out how to ensure the conversation about how buildings can support the grid gains momentum—we may not know exactly where the future of buildings is headed, but the value of flexibility is something definitive that we can point to for critical future success in grid service needs.

Buildings on the Grid: The questions we should be asking

What are the right performance metrics for a grid-integrated building?

For compliance with ASHRAE 90.1, a baseline energy cost budget is established specific to the size and program of the building and prescriptive requirements of ASHRAE 90.1. The design efficiency is expressed as percent better than ASHRAE 90.1, such as "30% better than ASHRAE 90.1-2016." Metrics are also set on percent annual energy from on-site renewable energy or

[3] International Energy Agency. "Renewables 2018: Market Analysis and Forecast from 2018 to 2023." https://www.iea.org/renewables2018/

percent annual carbon reduction, but almost always on an annual-average basis with cost savings estimated according to the rate schedule and with carbon and other emissions savings based on annual-average multipliers. Grid integration of buildings demands a more exacting approach, with the cost-savings to the utility and emissions based on megawatts of power exactly when and where rather than annual total megawatt-hours of energy. Cost savings should be based on the impact that load control, distributed generation, or storage dispatch of a building has on utility operations. Similarly, estimates of emissions savings should be based on which power plant is turned down in response to building action. Regulators will require that data be made available, but sophisticated software and "big data" platforms will also be required to implement this higher level of reporting performance metrics.

How much does cost really drive implementing grid services into buildings?
The bottom line in the buildings industry is the cost to operate buildings. As technology becomes available for dynamic building load control, such as smart building systems, more attention is given to utility rate structures that can encourage a desired building load profile. Because cost is key to implementing grid services, it will be used as a driver. New rates need to be a win-win for both the utility and the users. Despite the definite influence of cost, utilities are not completely driven by rates. If the value can be proven to the utility, then there is a higher chance of the utility implementing it to contribute to the good of the system and institution. Right now, utilities are especially interested in grid services that save energy or have a long-term benefit to the building.

What can buildings really do for the grid?
A wave of digital technologies and connected devices offering two-way communication with the grid is projected to equate to $1.3 trillion worldwide in new annual industry revenue by 2030.[4] Whichever grid services are added to a building, the comfort, productivity, and convenience of the indoor environment cannot suffer because of the additions. Grid services should be supporting these building priorities. A flexible building should be able to incorporate energy efficiency, energy storage, and on-site generation. One aspect that is not well known is how fast buildings can respond to adjust their load profiles. What the grid needs, and how the building should be planning for those needs, is not currently well understood.

Energy Efficiency: Expanding the capabilities of existing solutions
Continuing to make buildings more energy efficient is important for creating grid-interactive buildings. Resilience (making buildings that can withstand events that can disrupt the building's ability to perform as intended and then be able to recover quickly after disruptions occur) should be at the forefront of design and innovation when creating a more energy-efficient building. To achieve greater energy efficiency and resiliency goals, we need to make integrated building design a necessity. Resilience plans often enumerate all the threats to a building and take measures to avoid or recover from each threat, but it is impossible to foresee every type of threat. "Design principles" for resilience are a way to mitigate this. These principles include diversity of supply, redundancy, interconnectivity, and interoperability.

[4] Strother, N., and M. Lawrence. 2016. "IoT and the Future of Networked Energy: A Platform for Enhanced Energy Cloud Applications, Services, and Business Models." *Navigant Research*.

Integrated building design begins with an integrated design, construction, and commissioning team. With integrated building design, a team has ownership over the delivery and design of the project. This process encourages achieving a demand control target by moving away from the prescriptive strategies that building designers often follow. Instead of relying on these routine strategies, the true project fundamentals can take a front seat in the process.

Once a successful building project resulting from a truly integrated building design, construction, and commissioning process is completed, then the building performance must be measured. This performance information will be the basis of the communication between the building operation and the grid. However, understanding what metrics should be measured and ensuring the metrics are useful for both the building and grid operation are still not well defined.

Energy Efficiency Solutions: The questions we should be asking
How do we encourage an integrated design process?
When it comes to making real changes to the energy efficiency of a building, those responsible for operating the building need to feel they have the ability and responsibility to be a part of the solution. Currently, there is little opportunity for building designers and grid providers to strategize toward a combined goal. Encouraging these conversations will result in better solutions where buildings and the grid operate as a single system.

Energy Storage: The power of space, temperature, and time
Energy storage can help optimize buildings' use of electrical and thermal energy, in addition to making it possible for buildings to use more renewable energy whether or not the renewable energy generation is occurring when the building needs the energy. Storage is one way to help make buildings flexible so that the building loads more closely match the electrical.

As we shift into thinking about making buildings more flexible so they behave like electric energy storage or thermal energy storage systems, we should keep in mind that electrical energy storage is something that the grid already understands and knows how to value. There are several challenges on the building side that need to be addressed, including the fact that buildings cannot be simple batteries with energy capacities because building load profiles change over time.

Energy storage—specifically electrical energy storage—brings cybersecurity to the table as a prominent challenge. Cybersecurity is something buildings will have to account for and will undoubtedly be an area where there will always be vulnerabilities. This means we have to start thinking differently about how building control systems are designed to ensure both the building and its occupants are secure and ensure the grid is protected from security breaches through building systems.

Energy Storage: The questions we should be asking
What are the reasons for a building to integrate electrical energy storage?
Battery technology is improving, and economies of scale are contributing to a downward trend in cost.[5] There is also an aspect of resiliency that interests both consumers and utilities. For example, if a building can ride out a power outage, then the building is accommodating its

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[5] ASHRAE. 2019. "Building our New Energy Future." https://www.ashrae.org/File%20Library/About/Leadership/new_energy_future_web_061518.pdf.

occupants. For some consumers and utilities, greenhouse gases are a strong enough driver to start looking for a change.

What are the greatest challenges facing thermal energy storage?
While battery storage will allow us to store electrical energy from renewables, thermal energy storage can help level energy loads in buildings. Water and ice thermal storage is well understood, while new storage technologies are emerging (eutectics, and so on). Traditionally, the economics of thermal storage has been driven by rebates and time-of-use rates. Going forward, there needs to be a more integrated and stable approach to allow long-term planning. Integrating thermal storage operation with short-term grid load profiles is the key to improving energy use while delivering resiliency—research is needed to understand what the planning parameters are and over what window of time are they reliable, and then the research results need to be packaged into clear applications for building design professionals as well as building and grid operators.

Integration and Interoperability: Bringing it all together
We are starting to see the emergence of the building-to-grid phenomenon as more and more smart homes and interconnected buildings are developed. This also means that controls and integration are becoming even more critical to building a grid-friendly building.

A great example of a building that showcases integration and interoperability is the Powerhouse Brattora in Trondheim, Norway. It encompasses all the key factors of a futuristic building that integrates buildings on the grid. The building's geothermal heat pump system generates more heat than it needs so it can share excess heat with other nearby buildings. The on-site photovoltaic system capacity is large enough that it can charge 200 electric vehicles a day and generate two times as much energy as it consumes. All systems within the Powerhouse Brattora building are digitally integrated, helping to make this building the world's northernmost energy-positive building.[6]

As buildings become more integrated with the grid, the need for standards to guide this integration also increases. Data gathered from both the grid and buildings sides of the meter are available for conducting the analysis needed to create standards. Data analytical tools should be used to figure out what the data are telling us, which means machine tools that can help do those analytics should be developed. Once the analytics are completed, then the resulting metadata can be represented in universal standards. It is important that the buildings and energy industries work together to create these standards.

Integration and Interoperability: The questions we should be asking
How will integration and interoperability make operating buildings easier?
Building owners and operators are the key stakeholders that should be involved in these integration and interoperability conversations, and they are becoming more willing to pay for the interoperability of their buildings. However, as buildings' integration and interoperability increase, so does the complexity of buildings. We should be making it easier to operate buildings, instead of giving people even more intricate tools. Through control and automation, operating buildings can become easier.

[6] Snøhetta, "Powerhouse at Brattørkaia." https://snohetta.com/projects/60-powerhouse-at-brattorkaia.

Are people investing in the right controls to take advantage of these lucrative opportunities for integration and interoperability?
Large organizations are beginning to invest in sophisticated building control systems having the ability to support integration and interoperability. What is needed is to figure out how to bring the right controls to a smaller scale and make these systems more affordable. Meeting this goal requires partnership across sectors. The business process also needs to adjust to bring the right controls to the right buildings.

How do we maximize efficiencies and get still get our fair share?
An important aspect of maximizing our efficiencies is making sure occupants are aware of how their decisions impact building energy load profiles. Education on smart technology is key to making sure we are not consuming energy we do not need to be consuming. For example, for residential buildings, automating connected appliances and systems in a choreographed way saves energy, reduces strain on the grid, and could save homeowners on their energy bills. Yet every homeowner may not have those same concerns, so perhaps a more ideal solution is making the complexities of smart technology in the background for users by taking out the need for users to interface with the system. We should be optimizing in the background based on complex economics, but all the consumer should see is the bill.

Looking Forward
There are information gaps that we need to remedy in order to take advantage of the new energy future and predict the needs of buildings tomorrow so as to make decisions today. Industry (both the buildings and energy industries) and the research community must work together to define questions and determine the tools and resources that need to be developed to transform the market. We need the full engagement of the entire utility, energy, and buildings industries, with all their unique perspectives, to keep the conversation going about these areas of need and push the envelope of innovation and possibilities.

The next step is continuing the conversation between the buildings and energy industries and working together to make progress toward a more integrated and energy-positive future. We should all focus on becoming aware of the challenges facing the grid industry and building science community, becoming engaged in the conversation and sharing our expertise with one another, and prioritizing these conversations now. The future isn't so far off—a lot of these challenges are already affecting the way we design, create, integrate, and talk about buildings.