Changing Building Design for a Changing Electrical Grid

Electricity generation from wind and solar is poised to surpass fossil fuel generation in the next 30 years. You can future-proof the buildings you design today to save money and carbon later on.

by Ruby Theresa Nahan

Lord Aeck Sargent's design for Myron Boon Hall at Warren Wilson College in Asheville, North Carolina, serves as a powerful example of what designers can do now to future-proof buildings.

Photo © Tzu Chen Photography

Renewable electricity generation has nearly doubled in the last 10 years. Ninety percent of that increase came from wind and solar generation (source: U.S. Energy Information Administration (EIA)). Costs have also declined rapidly. Oftentimes solar and wind generation is the cheapest option for new or replacement generation capacity (source: BloombergNEF (BNEF)). This capacity includes wind and solar generation and electric storage assets owned by utilities ("utility scale") and those that are not owned or managed by utilities ("distributed energy resources" or "DERs," which include net-zero-energy buildings).

Electricity generation from wind and solar is often termed a "Highly Variable Renewable Energy" generation asset, or "VRE" because electricity generated from these assets varies by time of day and season. Generally, solar electricity is most productive during the day, especially in the summer, and wind generation at night, especially in the spring (source: EIA). Of course, both solar and wind are dependent on daily, even hourly, local weather as well. The existing electricity sector—utility business models and grid infrastructure—were not designed for VREs. Building design and operation have also not been designed to optimize VREs.

When high penetrations of VRE generation occur, the grid goes out of balance. The shape of the net-load curves—the difference between electricity demand and VRE generation—in areas with high penetrations of VREs provides an easy visualization of the challenges, fondly referred to as "the zoo." California has a "duck curve." "Nene" the native goose is in Hawaii. Texas has an armadillo, and there's an alligator in the upper Midwest. Each of these areas is a little different in terms of the degree of the problem, but they all illustrate a period of time in the late afternoon and early evening when electricity demand cannot be met by VRE generation. Utilities are forced to quickly ramp up "peaking generators" to address the mismatch between the profile of peak electricity *generation* by VREs and the typical afternoon/evening peak *demand* profile coming mostly from buildings. Utilities are required to meet that demand for electricity no matter the cost or the environmental and climate impacts. Their peaking generators are usually the most expensive, and sometimes the dirtiest, generation assets they have. Certainly, they are dirtier and more carbon intensive than VREs.

The problems illustrated by Hawaii's Nene and California's duck curve are even worse. Their net-load curves have bellies, which show that during some seasons, VRE generation is actually greater than demand in the middle of the day. Hawaii has no place to send that excess electricity, but California "curtails" it (sells it, gives it away, or pays to get rid of it). As utilities balance consumer and regulatory demand for low-carbon VRE electricity generation, they will be looking for rate structures and a variety of customer programs that incentivize building design and operation strategies to free the zoo animals and "flatten" those net-load curves.

Buildings and the Grid

Utilities have been grappling with grid challenges exemplified by the zoo for a while, and now it's time for the building design community to enter the fray. Whereas green building design strategies such as LEED ratings and net zero energy have done a lot to reduce carbon emissions from the buildings sector, there is much more to be done. In fact, Mark Frankel, technical director, New Buildings Institute (NBI), says, "The first inkling of problems [with the grid] came with NZEBs." Net-zero-energy buildings (NZEBs) reduce electricity demand through both efficiency and photovoltaics (PV), but they still require utilities to provide 24/7 grid infrastructure for storage and power when needed, and their operations are not necessarily compatible with optimal grid operations. Cara Carmichael, principal, Rocky Mountain Institute (RMI), notes that NZEBs have increased 700% in the last seven-year period. But there is no preference for when energy is used: PV generation does not match peak demand, so it's not helping the grid.

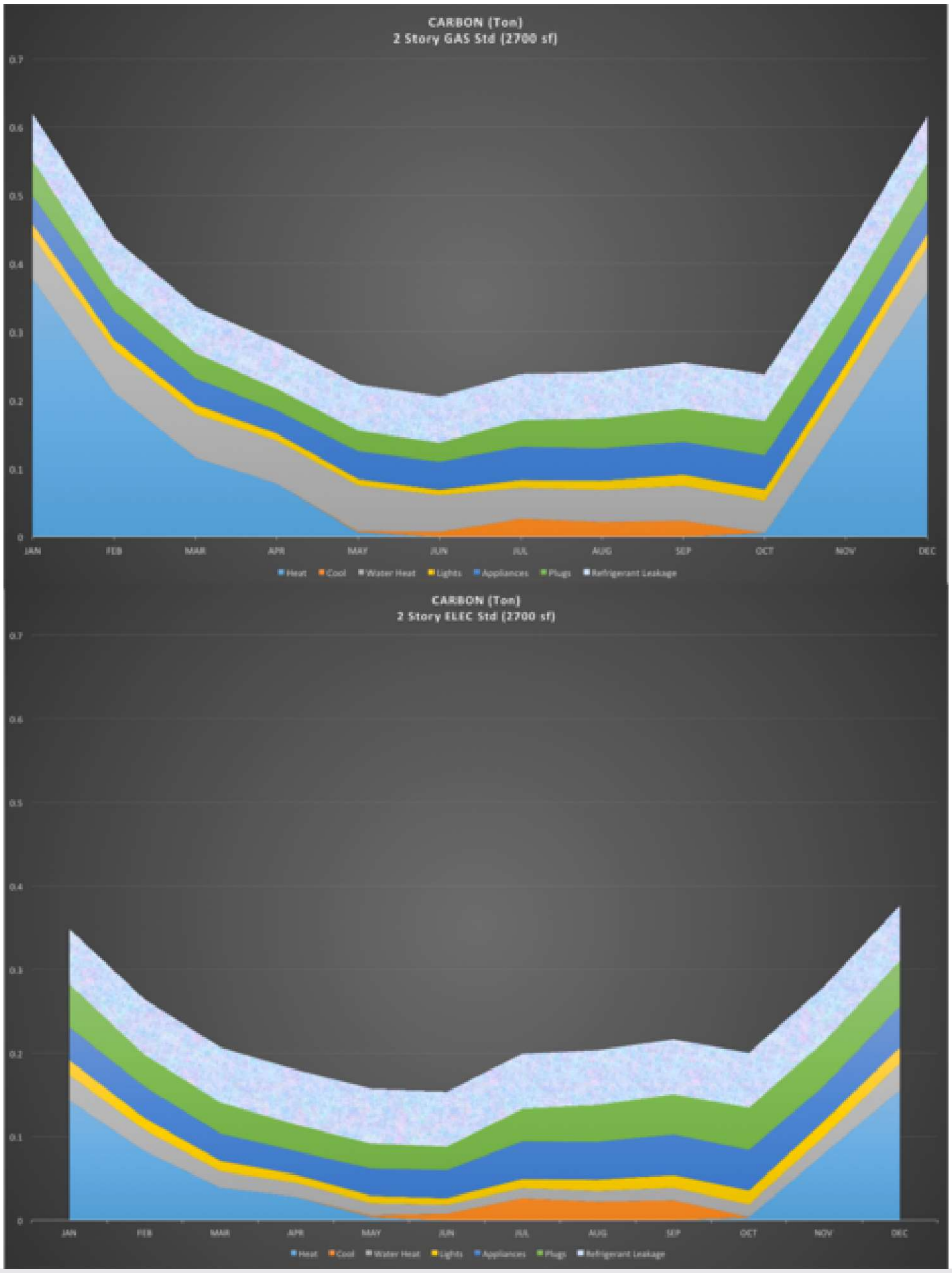
Designers can rethink some priorities to support building-to-grid harmonization and play a critical role in de-carbonizing the electric grid through design and operation of "grid-friendly" buildings.

Concepts for Designing Grid-Friendly Buildings

To take full advantage of VREs, buildings have to change their demand patterns. Frankel says, “The value and carbon intensity of electricity is highly variable over time. Annual energy use is old thinking. Now we have to think about when electricity is used in a day and by season and ask ourselves as designers, ‘What can I do about it?’”

To answer Frankel’s question, a review of some basic electricity billing concepts is helpful. Charges from the utility typically consist of total usage over the billing period in kWh. Charges can also include *demand charges* in kW, which reflect the greatest amount of electricity required during a specific time period. Think about how much electricity is demanded all at once during a hot afternoon in a full office building, for example. *Time-of-use (TOU) rates* reflect different costs per kWh, depending on the time of day the electricity is used. These rate structures are designed to enable utilities to pay for generation and infrastructure that is only required relatively infrequently (e.g., hot afternoons), and to encourage electricity use when it’s cheapest for the utility to deliver it. Many commercial building owners are already paying these types of rates, and utilities are likely to create new incentives and pricing, including expanding TOU rates and demand charges to more customers in the future.

Designing and operating buildings to respond to these rate structures by minimizing use of electricity and/or maximizing export of renewable electricity to the grid, typically during late afternoon or early evening (although that can vary by season and location) will reduce carbon emissions and the cost of demand charges and time-of-use (TOU) rates right now. It will also save money for more customers in the future. Shanti Pless, senior research engineer, National Renewable Energy Laboratory (NREL), provides an example with TOU rates, “Utilities may give you economic incentive to care about 5 to 9 p.m. more than you care about energy you save at night or in the middle of the day. Or, for that matter, the electricity you produce in the middle of the day, as you would in the case of an NZEB.”



Carbon intensity of two residences built in accordance with California's Title 24, one of the more stringent energy codes in the country. The graphs demonstrate the lower carbon intensity of the all-electric home. And this is without PV, storage, or any efforts toward load shifting and flexibility.

Source: California Energy Commission

Carmichael notes that for some current building owners up to 60% of total electricity costs are actually demand charges, so "there is significant opportunity" to think about changing design priorities now. RMI performed an analysis for the U.S. General Services Administration (GSA) showing that up to one-third of GSA's annual operating costs could be reduced cost effectively within bundles of measures that focus on demand management and reduction. And, those bundles have a less than five-year payback in six locations across the United States. She noted that these bundles "are slightly different from what architects and buildings owners traditionally think of first, because designers and owners usually focus on annual consumption."

Scott Shell, FAIA, principal, EHDD, notes that building designers will need to think differently about seasonal building electricity demand as well. For California, where there is a lot of solar in the summer but not during the short, rainy days of winter, his “hypothesis is that winter energy will become more valuable than summer energy. That’s the exact opposite of what we’ve always taught here, where we always focused on reducing summer cooling.”

Beyond seasonal differences, the local VRE asset mix can also be quite different from place to place. That changes the time of day when renewable electricity is abundant and, therefore, influences pricing and carbon intensity. A utility with predominantly wind assets, for example, might be less carbon intensive and charge a lot less at night than a utility with predominantly solar, which will charge less and be less carbon intensive during the day. Therefore, Shell notes that because of both local climate and generation mix, his winter energy hypothesis may not apply in other places.

Grid-friendly buildings are also designed to “smooth out the load” with building demand flexibility. This can be accomplished with passive and active design strategies as well as operations. Both e-storage with batteries and using electricity to “recharge” thermal storage will play an important role. Electric vehicles (EVs) play a limited role now, but their future role in demand flexibility is probably big.

Demand flexibility may be especially encouraged by pricing structures. According to Frankel, “Designing buildings with load flexibility has big value. If the utility changes its pricing structure, the building owner won’t get hit with unexpected high prices.” Flexibility is also key to reducing carbon emissions as it enables utilities to minimize their higher-carbon generation capacity or keep it offline completely.

Change the time of peak demand to better match generation from VREs. Smooth out the load. Great concepts, but how does that happen? Fear not; many of the design strategies to realize these general concepts are already well known to designers.

Energy efficiency from a different perspective

Energy efficiency is still important, but harmonizing buildings and the grid adds a new twist—from saving energy all the time to using it when VREs are producing and saving it when electricity prices and carbon emissions are high. Experts offer different recommendations to reach appropriate energy savings and about which baseline to use for comparison:

- **Architecture 2030 Zero Code** starts with ASHRAE 90.1-2016 for minimum compliance, then offers a predictable path to advancing energy efficiency through more stringent standards (e.g., 2018 International Green Construction Code (IgCC), ASHRAE Standard 189.1-2017).
- **LEED 4.1** requires minimum compliance with ASHRAE 90.1-2016.
- Carmichael recommends targeting **50% better than ASHRAE 90.1-2016.**
- The **Commercial Buildings Energy Consumption Survey (CBECS)** provides a good baseline, which is also what Architecture 2030’s ZeroTool uses. Mara Baum, AIA, health + wellness sustainable

design leader at HOK, recommends 50% energy savings over the CBECS baseline as a starting point (as available and appropriate for the building type).

Passive design—more important than ever

Designers have the greatest potential to impact energy efficiency through passive design. Multiple experts also recommend it for grid-friendly design as it results in a building that either heats up or cools down slowly and therefore reduces the overall peaks and troughs of electricity demand, while also shifting them in time. Five essential elements from the Passive House approach are essential to grid-friendly design:

- excellent insulation
- reduction of thermal bridges
- air-tight enclosure
- high-performance windows
- heat-recovery ventilation

Go all-electric

RMI's 2018 report *The Economics of Electrifying Buildings*, underscores the importance going all-electric to shift electricity demand in time and support high penetrations of VREs on the grid.

- If you're designing for a new build, build electric.
- If you're designing for a retrofit, replace with electric.
- Use heat pump space and water heating. Heat pump options that operate effectively at lower outdoor temperatures are becoming more prevalent.
- Use electric cooking and clothes drying.

There are other reasons to make the all-electric switch too. Shell notes that California has committed to carbon neutrality by 2045, which will require replacing natural gas equipment with electric equipment in buildings. In new construction, it is less expensive to build all electric than to install both gas and electric infrastructure, and retrofitting from gas to electric later is more costly and difficult. Many California jurisdictions are incentivizing all-electric construction. Some are considering requiring all-electric designs and banning new gas hookups. It does not make sense to invest in and maintain gas infrastructure that becomes obsolete in a low-carbon energy system.

Update your thinking about solar

Solar is still very, very important, especially in areas of the United States where the percentage of VRE generation continues to be low. Brendan Owens, P.E., senior vice president at the U.S. Green Building Council (USGBC), notes, "PV in Indiana, on average, can have a carbon dividend three times that of a similar installation in California."

California homebuilder City Ventures benefits from market differentiation by offering a number of solar, all-electric townhomes.

Photo: City Ventures

To design grid-friendly solar buildings, it may be necessary to update conventional thinking about orientation of PV panels. Pless recommends you "assume that you want the building to maximize energy efficiency and generation back to the grid during those hours when electricity is the most expensive." Evaluate the economics beyond typical south-facing PV by considering:

- southeast-facing solar to provide generation earlier in the day,
- west-facing solar to provide generation later into the afternoon,
- dual-axis or single-axis tracking to maximize output from the time the sun comes up until it sets, and
- façade solar, which can also be a cost saver because it replaces siding materials.

To determine the value of various solar options, consider:

- current pricing programs (existing and in pilot),
- forecasts that look at future trends for generation capacity and how that may impact rate structures, and
- renewable power purchasing programs, which may be a better option than onsite solar for some projects, especially as utilities increase installed VRE capacity and develop new programs.

Add storage

To solve the mismatch between peak VRE generation and peak demand, battery storage will become essential. Fortunately, battery storage costs are expected to drop significantly in the next 20 years (source: BNEF), so payback for PV with storage may happen more quickly than you think.

Battery storage has the potential to offer the following costs savings by:

- reducing the size of a PV system,
- lowering demand charges—recent NREL and McKinsey & Company reports suggest storage is cost-effective for owners with demand charges above $9 to $15 per kW, and
- shifting consumption to optimize TOU rates.

If you're already designing an NZEB or considering solar, compare the economics of PV plus storage to those of a tracking system to determine which is the better investment.

Solar plus storage systems that can "disconnect" from the grid (e.g., via a physical switch or software), can also provide resilience. The value of that resilience may justify the cost of such a system. NREL's *Valuing the Resilience Provided by Solar and Battery Energy* sheds light on this topic.

The Boulder Commons commercial development in Boulder, Colorado, features PV on the roof and southeast façade. The rooftop solar is pitched slightly to the east and west to shed snow and minimize self-shading. PV on the façade is used as shading and as a rain screen instead of cladding.

Photo: Boulder Commons

Storage doesn't just mean batteries. Using thermal storage as an alternative to batteries, or using both, can be considered on a case-by-case basis. As noted earlier, a passive building can use off-peak or high-VRE generation to charge thermal storage, using the building itself as a battery. Ice systems work similarly. Off-peak electricity is used to nearly freeze a water and ethylene or propylene glycol mix in a storage container then fans and heat exchangers are used to deliver cooled air to conditioned space. Because batteries can still be expensive in some areas, it might be cheaper to charge thermal anytime renewable base power is cheap and plentiful. Batteries can still be used to run pumps and fans, if needed.

Master planners also need to think about community-scale solar, especially if the PV systems are ground mounted, as tracking systems usually are. Where will the PV system go? Will it include storage now or in the future? It all requires space and infrastructure, so the aesthetic considerations are really important. Jim

Nicolow, FAIA, LEED Fellow, Lord Aeck Sargent, says, “As architects, we tend to want to try to fix everything at the scale of the building, and that scale isn't necessarily optimal. Sometimes renewables should be at the municipal scale, or at least somewhere you can change the orientation to get the most ideal outcome.”

If you can’t make solar work, go “solar-ready:”

- Design building massing and orientation, equipment rooms, and systems to accommodate future PV interconnect/disconnect infrastructure and storage.
- Consider locating EV charging near the equipment room, planning for EV-ready and EV-capable electrical systems, and ensuring space in electrical rooms for future battery system integration.

NREL published a *Solar Ready Buildings Planning Guide* in 2009. This guide still emphasizes south-facing PV and considers battery systems primarily for uninterrupted power, so you will need to add your own updated thinking as you use it.

Designers should recognize that even if PV isn’t in the budget today, it will likely become cost effective soon and in some places, it already is. According to Shell, the 2019 California energy code requires PV and dramatic energy reductions for new homes. To be included in the energy code, a new measure must have first passed a stringent cost-effectiveness test showing that including PV on a new home results in lower monthly costs (mortgage plus utility) for the homeowner. For future consideration, solar plus battery was also found to be cost effective.

Design for demand flexibility

Experts offer a number of strategies to move the time of day of building peak demand on the grid. A general approach includes:

- reducing overall energy use,
- using thermal storage and/or energy storage (batteries), and
- using controls that provide the ability to shift and deliberately choose when particular demands are met.

There are more specific demand flexibility strategies for HVAC, water heating, lighting, and plug loads.

HVAC:

- Electrify and use the best-sized and most energy-efficient equipment.
- Heat and cool off-peak, for example:
  - begin preheating or cooling at 5 a.m.,
  - take a break during morning peak demand,
  - resume after 9 a.m., and

- take another break during evening peak demand.

- Apply a similar concept to central chilling: use off-peak or renewable electricity to make ice that offsets energy-intensive cooling loads during periods of peak demand.
- Use heat recovery systems.
- Apply zone space temperature setback schedules.
- Use controls for equipment staging.
- Increase air filtration to reduce outside air needs.
- Use demand control ventilation.
- Apply static pressure reset control strategies.
- Use chilled water and hot water pumping pressure reset for demand response.

Water heating:

- Electrify with heat-pump technology.
- Use the tank water heater as a thermal battery.
- Heat water when VRE electricity is more abundant.
- Don't heat water during times of peak demand, which could mean heating all night and not during the day at all, or heating anytime except during morning and afternoon/evening peak demand hours.

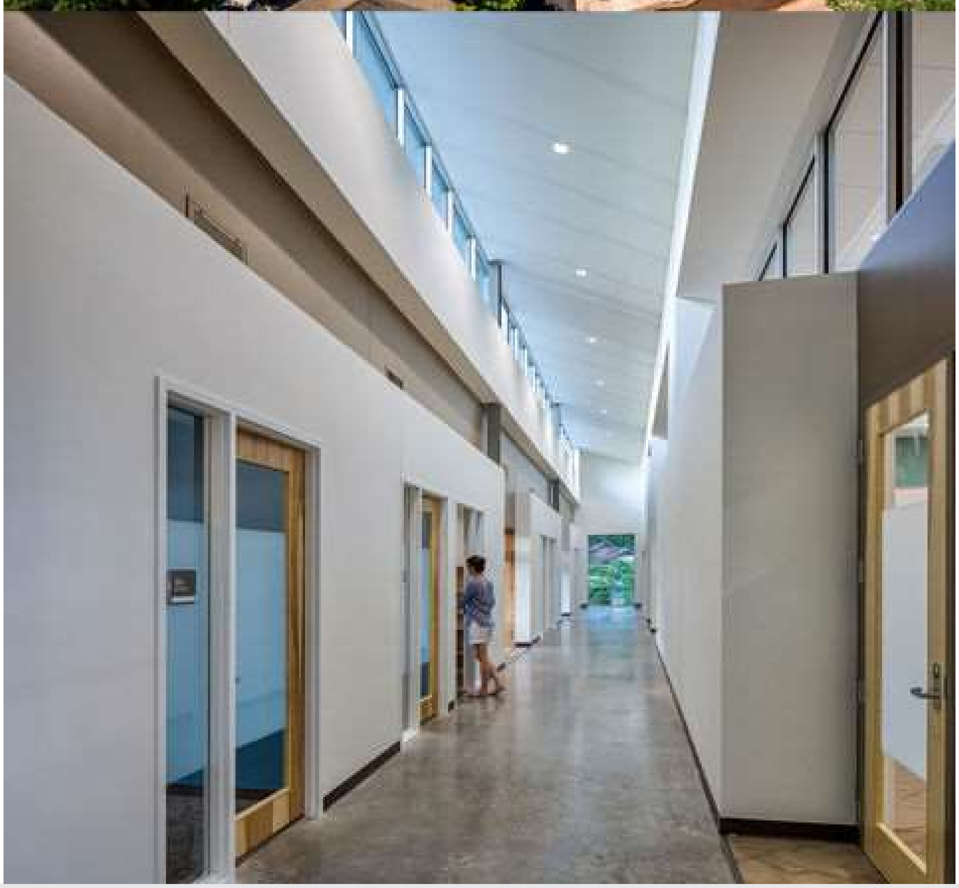
Lighting:

- Incorporate good passive design.
- Develop programming to optimize use of perimeter daylighting.
- Use LEDs.
- Use occupancy sensors.

Plug loads:

- Stage laptop battery charging.
- Manage with "smart" home/building strategies.

Carmichael stresses the importance of plug loads, especially in buildings that are already super-efficient. "In an NZEB, plug loads are typically 30% to 60% of energy use, and they can be difficult to control." Shell cites data from the California Energy Commission that shows plug loads in an office building in Los Angeles consuming 48% of electricity demand. That's almost half the total demand, and yet designers often don't consider plug loads and only focus on the other 52%.



Myron Boon Hall, completed in 2018, incorporates several passive design best practices: elongation on the east-west axis, minimal east and west glazing, external overhangs and shading devices, clerestories, and interior glazing to maximize daylighting. The construction budget for the project did not support installation of solar, but the firm deliberately designed a solar-ready building with a large, unobstructed south-facing roof designed to support rooftop PV. According to Jim Nicolow, "We understand the future came fast, and the college is already soliciting proposals to install solar."

Photo © Tzu Chen Photography

Given the long list of energy-efficiency measures and the need to control the timing of demand, it's no surprise that Carmichael also recommends having "a robust system in the building that ensures individual controls on end-uses and also allows those controls to interact. Then, start looking at loads in unison and their staging dynamics. That will provide a lot of load flexibility that will be a benefit today with current rate structures all across the country, but also enable you to future-proof the building." These measures and controls should be designed to operate as seamlessly as possible without occupant involvement or even awareness.

Automated demand response (ADR) is a powerful tool in demand flexibility and will likely play a big role in balancing the grid as low-carbon VRE generation capacity grows. Automated demand response requires an agreement with the utility and communication technologies associated with building systems or building automation systems. It enables the utility to get an automated response from the building to reduce or shut down specific equipment if there is an event on the grid (e.g., a price or carbon spike, or a potential brown or black out). ADR is typically managed with Internet of Things (IoT) systems that need to become part of the design process. Many utilities are beginning to offer ADR programs. Pacific Gas and Electric Company (PG&E) in California has a series of videos that explain ADR generally as well as their specific ADR program for "offices and high tech."

ADR can pose a significant cultural challenge for some building owners. Using IoT as a path to "let the utility into the building" to reduce heating or cooling or have some control over other equipment is not what people are used to. Large commercial and industrial customers are usually the first participants in ADR programs as they use a lot of energy and already have controls built in that enable communication among different equipment. But moving forward, utilities are more likely to offer ADR programs to residential customers, and both residents and the utility will be able to control major residential loads (e.g., heating and cooling, hot water, kitchen appliances, washer-dryer, and EVs) through web-based applications.

Electric vehicles

Electric vehicles are mobile batteries. Charging infrastructure is most often connected to and has big implications for a building's electrical system. While not charging, that battery is spending a lot of time parked near a building, and the energy in it has incredible potential. The demand implications and the opportunities for load flexibility, demand response, and "dispatchable" stored power (power that can be ramped up very quickly) make EVs interesting to building owners and utilities alike. RMI published a report about EVs as distributed energy resources that includes information about required infrastructure, implications for the grid, and more.

Pless notes that right now the load flexibility opportunities offered by EVs to residential and multifamily buildings are especially good, and that some utilities "really love workplace charging" because that new load gives them a chance to sell excess renewable electricity during the day that they otherwise would have lost. Pless continues, "This new idea of when you use electricity is becoming very specific to architects who have to design parking infrastructure." It could be a really key opportunity to justify controls and IoT infrastructure to prevent tenants using uncontrolled charging during the morning or evening peak or to spike demand, especially in jurisdictions that require EV charging stations in workplace or other new parking areas.

PG&E notes that the storage in EVs may also play a big role in ADR. Currently in the United States we don't have "grid-operable cars" but there are new technologies abroad. Nissan has had a "Leaf to Home" program in Japan since 2012. It features power control system (PCS) technology that supports charging the vehicle as well as communication between the EV battery and the home's power system, allowing the storage to provide electricity during a blackout or for demand response. There have also been media reports of Nissan and other auto manufacturers working on vehicle-to-grid (V2G) technologies, which would support EVs being able to back-feed electricity to the grid.

Even though it may take time to realize some EV opportunities, controlling when EVs put demand on the grid to optimize pricing, generate electricity, and reduce carbon is here today. Sonoma Clean Power offers a program right now: buy an EV, get a free charger, and use their "GridSavvy" program to "help us move toward a cleaner grid and improve the electricity grid's performance under times of stress." NREL is also currently piloting a large scale EV workplace charging system that uses charge session information to minimize facility demand charges and electrical infrastructure upgrade costs, as well as to prevent local grid stress.

Learn about the broader energy system

There's value in trying to get a sense of where the local grid's fuel mix and grid infrastructure are headed. Colorado's electricity sector is a lot dirtier than California's is today, for example. But a big utility in Colorado announced it is retiring two coal-fired power plants early and replacing them with VRE generation. (Because it's cheaper.) They will also be "carbon free" by 2050. That should get any designer thinking about how the building they're designing today will interact with that utility in coming years. Designers don't necessarily have to "speak utility," but it's a good idea to find someone, probably an engineering consultant, who does or can at least learn to.

Summary of Strategies

Nicolow thinks about architecture and grid-friendly buildings this way: "This is coming to the built environment, and it's a way to have a big impact as a designer on de-carbonizing the grid. From a risk-avoidance perspective, to future-proof your practice, you need to figure out a way to do this if you want to stay a leader." Here is a final list of strategies for you to keep in mind as you move your own practice toward grid-friendly building design.

Energy efficiency, passive solar, and all-electric

Commit to the design strategies that are clearly in the designer's purview: **passive design** and energy efficiency **at or beyond ASHRAE 90.1-2016**. For new buildings, go **all-electric**. For retrofits, replace with all-electric.

Solar + storage

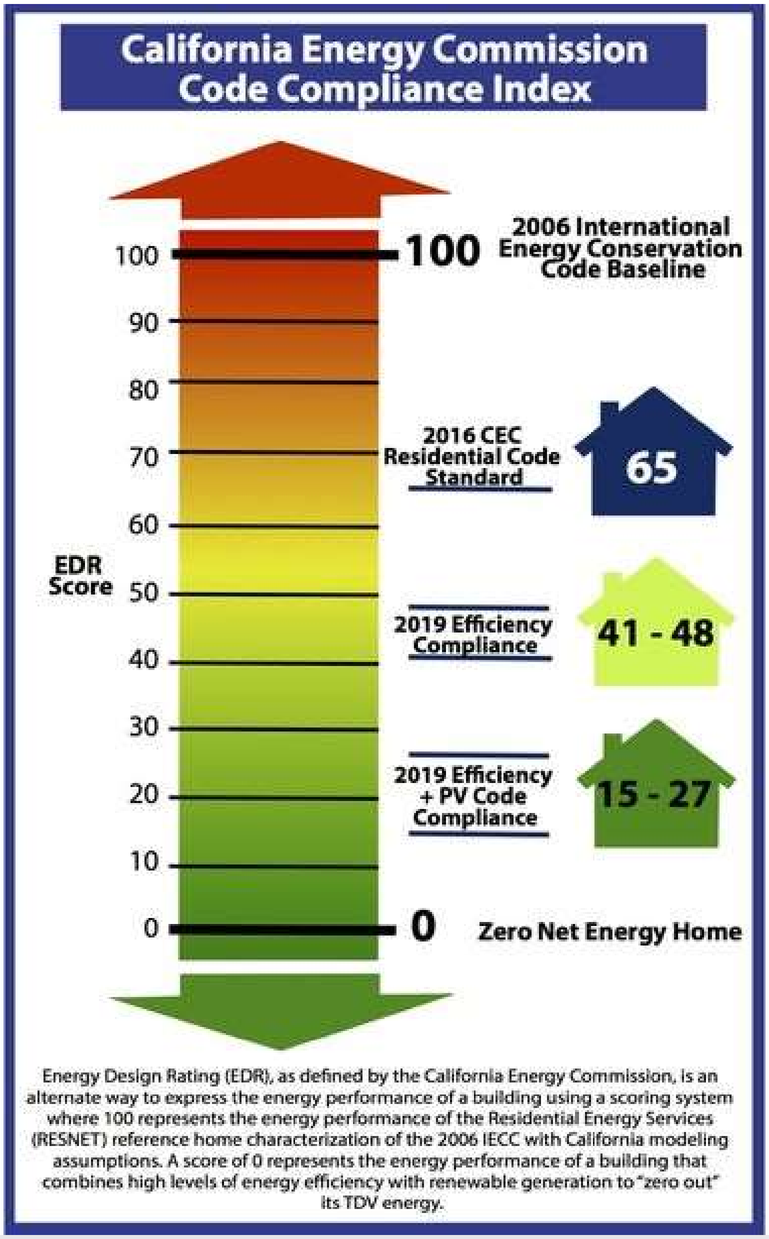
Use **solar + storage systems to optimize for lowest-carbon generation**: minimize use of electricity during peak demand and maximize use of VRE generation when it is plentiful (solar during the daytime and wind at night). If you're already fluent in the language of NZEBs, this is a strong foundation. As Nicolow puts it, "Add storage, controls that support dynamic shifting of loads, and some thought about carbon impacts based on the local grid mix, and you're on your way to a grid-friendly building."

Demand flexibility

Pair passive design with all-electric, energy-efficient HVAC, water heating, lighting, appliances, and more. Combine that with **interoperable controls and control strategies** for operations that optimize demand-charge and TOU pricing today, and that provide flexibility for inevitable utility incentive and pricing changes in the future.

Cultural changes

If passive solar design and energy efficiency (how much, when, and where) are important to grid-friendly design, then it should come as no surprise that **energy modeling** from the earliest phases of design through post-occupancy is essential. Frankel says, "A key starting point for grid-optimal buildings is to model operational patterns, not just annual energy use. Understanding the pattern is critical to designing a building with a flattened demand curve and flexible demand."



California's Title 24 Energy Code demonstrates a steady march toward low- to no-carbon energy use for new residential construction. Energy-efficiency requirements have become steadily more stringent, and the latest version of the code requires PV.

Source: California Energy Commission

Using an **integrative design approach** is also essential. Frankel shares his experience: "I've been a consultant for a GridOptimal building pilot project. The whole design team is realizing that the knowledge we need is really diverse. Looking at carbon reduction versus annual energy savings and future-proofing for utility rate structures is a new realm. The roles of the electrical and mechanical engineers and operations on the design team are even more important. There are new questions to ask in this kind of design approach, and they are critical to getting answers."

Carmichael thinks design of grid-friendly buildings presents **opportunities for integrated project delivery** (see the guide from The American Institute of Architects) because "it puts skin in the game for every stakeholder" to engage in the integrative design process, collaborating, setting goals and targets, and defining M&V for the project. It's a shared risk and reward pool, so if the design team—designers and engineers—does its job well, they can make more money."

Carmichael says good **controls and control strategies aligned with lease structures** are also important. She points to the NZEB office building RMI leases. All the leases for that building include a set "energy budget" for plug loads, and if tenants exceed it, they get charged. RMI's lease structure very intentionally has cost benefits from storage reside with the building owner. The owner could have a really strong business case to do energy arbitrage to avoid peak demand charges and incorporate storage. Presumably, use of the storage capacity in EVs would be open for discussion as part of the storage plan.

Resources to Support Grid-Friendly Buildings

Programs

LEED 4.1 has a variety of incentives rewarding grid harmonization strategies. It includes a dedicated grid harmonization credit, rewarding projects with up to two points for implementing ADR, load flexibility, and management strategies. Credits for optimization of energy performance and renewable energy have also been updated to encourage energy use informed by grid conditions. Owens says, "Changes in the v4.1 language are encouraging the design community to have a more integrated discussion about energy systems. In previous versions, energy-related decisions were compartmentalized—energy efficiency in one credit, renewable energy onsite in another, and then green power. If the design did good things in these three places, it received points, but the synergies weren't as apparent. Version 4.1 is eliminating silos, and rewarding integration and systems thinking."

GridOptimal, a partnership between the New Buildings Institute and USGBC, is working to create a metric that measures and rewards a building's operational performance as an asset to the grid. Such a metric may be used by utilities for incentives and as requirements in climate policies. Future building codes may also be affected. Frankel encourages the design community to "stay tuned" for guidance. Currently, NBI is in discussion with at least eight utilities and is also talking with four jurisdictions about how code can make buildings more grid responsive.

Online resources and publications

BuildingGreen

- Doing Daylighting Right
- How to Make Integrated Project Delivery Work for Your Project
- Natural Ventilation
- Passive Solar Heating

McKinsey

- *The New Economics of Energy Storage*

NREL

- *Identifying Potential Markets for Behind-the-Meter Battery Energy Storage: A Survey of U.S. Demand Charges*
- *Solar Ready Buildings Planning Guide*
- *Valuing the Resilience Provided by Solar and Battery Energy Storage Systems*

PG&E

- ADR for Office and High Tech (web page and video)

RMI

- *Electric Vehicles as Distributed Energy Resources*
- Grid-Integrated Energy Efficient Buildings
- *The Economics of Electrifying Buildings*

Sonoma Clean Power

- Drive EV and GridSavvy (web pages)

U.S. Department of Energy

- Grid-Interactive Efficient Buildings
- Buildings and the Grid blog series
    - Buildings and the Grid 101: Why Does it Matter for Energy Efficiency?
    - Buildings and the Grid 101: Challenges
    - Buildings and the Grid 101: It Matters, But How Much?
    - Buildings and the Grid: Helping Commercial Buildings Get Smarter
    - Buildings and the Grid 101: Opportunities and Challenges from HVAC, Water Heating, and Appliances
    - ASHRAE, Buildings, the Grid, and Resources to Face the Challenges
    - Buildings and the Grid 101: How Are Building Technologies Office Partners Researching and Validating in the Field?