PHIUS + GEB

A Little Abbreviation Goes a Long Way

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Abstract

With climate change impacts increasing, resilience is a topic of concern for communities and utilities alike. Grid-interactive Efficient Buildings (GEB) help connect grid technologies and energy savings across the building sector in order to enable buildings to be more responsive to electric grid conditions, particularly during peak demand or in natural disasters. The GEB concept combines Energy Efficiency (EE) with coordinated Demand Response (DR). However, recent research conducted by the Midwest Energy Efficiency Alliance (MEEA) showed that EE and DR utility programs and policies in the Midwest are currently siloed and not yet reaching their full potential.

The PHIUS+ Passive Building Standard offers substantial energy use reduction over typical construction practices. It can not only provide large energy savings to utility customers but can also contribute to removing stress on the grid during peak demand. By utilizing conservation and passive design methodology, designers can lower and flatten the building's load profiles to enhance the integration of renewable energy into the electric grid.

When combined, PHIUS + GEB can help improve the reliability and resiliency of the grid by significantly reducing demand and stress on the grid and facilitating renewable energy integration. This paper will explore how buildings built to the PHIUS+ standard in Illinois have the potential for increased grid resilience and optimized operation through targeted energy use reduction. It will also highlight the energy savings potential and non-energy benefits.

Electric Grid Background

Basics

The electric grid in the US is made up of three main pieces: generation, transmission and distribution. Most of the existing infrastructure is set up for one-way power flows – from the generation resource distributed via transmission lines to the customer. Electric utility customers in the US expect uninterrupted, 24/7 power supply as a service for their customer fees. Therefore, electric power generation output/supply must match the customer load on a near-instantaneous basis; energy storage is a relatively small part of the system[1].

Generation Resources & Daily Grid Load Profiles

The existing electric grid is made up of a variety of generation resources, most of which heat or burn a fuel source at a high temperature to produce steam and run that through a turbine to produce power. This process inherently has a maximum potential efficiency, which leads to high amounts of energy input as fuel to produce electricity for use in buildings. The raw fuel used to produce electricity is often referred to as 'source energy,' and the US electric grid on average has a conversion factor of 2.8 from Source Energy to Site Energy (EPA 2018). In short, this means 2.8 units of energy are input at the source to yield 1 unit of energy to be used at the site. This value includes all losses: storage, production and transmission – though production accounts for

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[1] http://css.umich.edu/factsheets/us-grid-energy-storage-factsheet

most of the losses. It is a national average, as some grid regions with certain generation resources are more efficient than others.
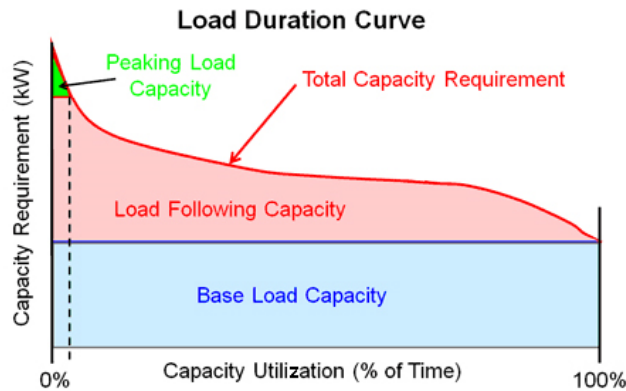

Figure 1: Load Duration Curve for generation resource capacity in the US. 'Base load capacity' is utilized all the time, while 'load following capacity' is partially utilized throughout the year, and 'peak load capacity' is utilized a very small percentage of the year. *Source:* White, L. 2019.

To meet ever-changing demand, grid operators must have an abundant amount and variety of generation resources available as contingency. Our current electric generating capacity is about 2.5 times higher than what is used annually. Much of this is due to the need to meet the peak demand - the grid must be able to satisfy the worst-case condition. There is also the need for redundancy due to inefficiency in existing transmission networks, limitations in flexibility of output, lack of dispatchability and transmission congestion. For example, some generation resources do not or cannot adjust their power output at the rate needed to follow a customer's load profile. These generation stations are often called 'baseload resources' – typically coal fired power plants or nuclear generators.
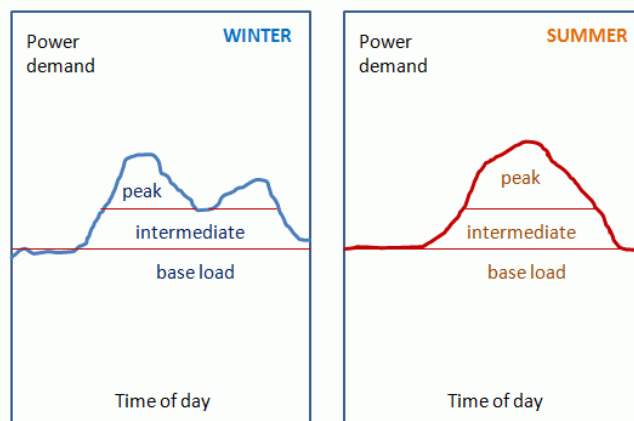

Figure 2: Daily Load profiles on the electric grid, varying by season. Different categories of generation resource types are used to meet the load throughout the day. *Source:* White, L. 2019.

The power demand on the electric grid varies on a wide range of time scales – by the second, hour, day and season. Currently, the highest demand on the grid happens during the summer, typically during the late afternoon/early evening hours when cooling loads in buildings are highest. There is always a baseload demand, covered by the generation resources with

continuous operation non-fluctuating output. Intermediate load starts typically when the daily operations for buildings begin and is met with 'load following capacity.' Annual peak load is typically driven by space conditioning loads while daily peak loads are driven by occupant behavior. The peaks are met by the expensive, rarely-utilized generation resources often referred to as "peaker plants."

Figure 3 below shows a snapshot of how resources are utilized on the New England ISO on March 4, 2020. Notice the baseload is met with a combination of a few resources (Nuclear, Renewables, and 'Other') while the intermediate capacity comes from Natural Gas and Hydro.
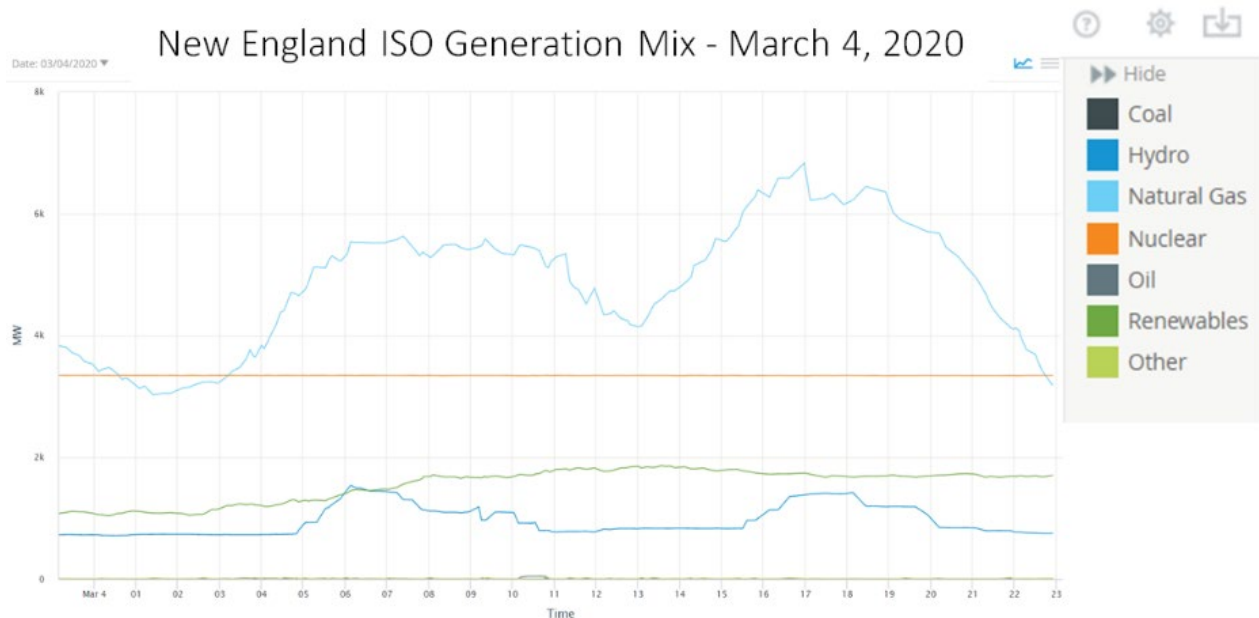

Figure 3: New England ISO Generation Mix on March 4, 2020. *Source:* New England ISO 2020b.

The generation resources are also utilized based on their availability and the price bid into the market. Dispatchable resources (those that can be called upon to follow load) bid into the market at a certain price per unit of energy as shown in Figure 4. As the load on the grid increases (moving to the right on the x-axis), more generation resources are needed to meet the load and the more expensive resources need to be utilized. In the image below, once resource 'E' is called upon, the cost of electricity production increases. There are many other factors, such as transmission, congestion, dispatchability, etc. that may influence price and resources utilized, but in general it results in a fluctuating cost of electricity generation for utilities.

Hourly Carbon Emission Profiles

Due to the variable nature of generation resources being utilized to meet the electrical load at any given time, the marginal carbon dioxide emissions associated with that production is also highly variable. Electricity cost to the utility is generally a good proxy for the carbon intensity of the production, but it is not necessarily a direct match. And many electric customers are on flat rate or time of use supply contract and therefore may not be aware of the fluctuation in cost for the utility to provide power.
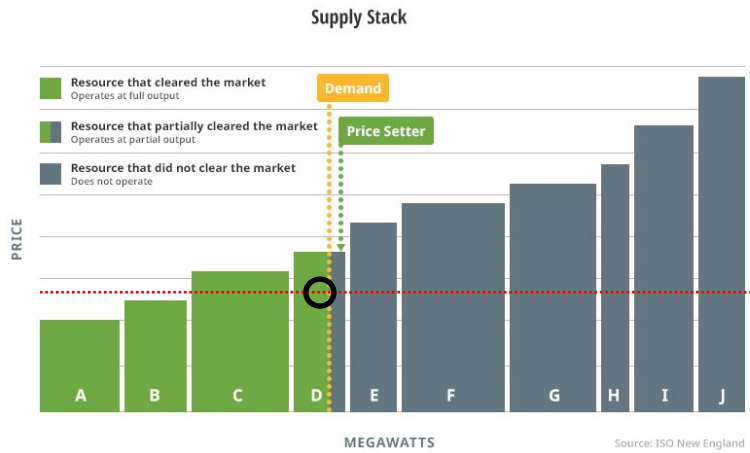
Figure 4: Supply stack from ISO New England, displaying as demand increases, more resources must be called upon to meet that demand which increases cost to generate each marginal unit of energy. *Source: New England ISO 2020a.*

"WattTime", a non-profit tech startup, collects and provides data for hourly marginal carbon emissions on the electric grid for different regions. This helps inform customers of the carbon dioxide emissions impact of using power at different times of the day.

Figure 5 shows an hourly emissions profile for a mid-month weekday for each month in 2019, in Chicago, IL. In terms of total environmental impact for Chicago, reducing energy use becomes much more important in the 'red' hours of the year, relative to the 'green' hours. More on this will be discussed in the Net Zero buildings section below.
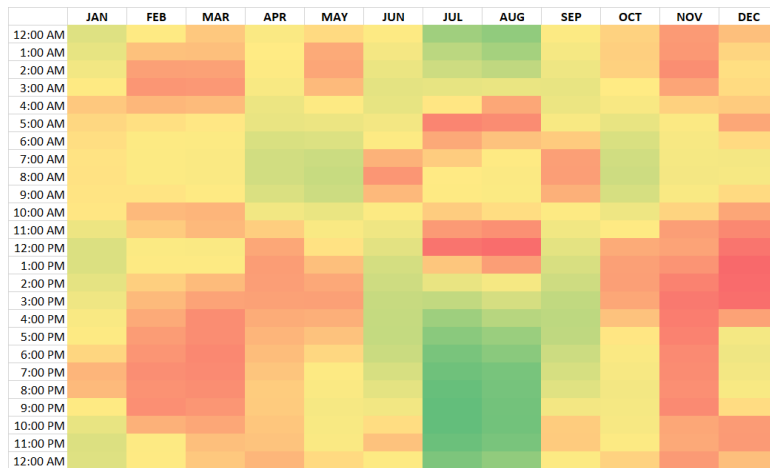

Figure 5: Hourly emissions intensity of electricity generation in Chicago, IL. The hours with the lowest carbon emissions in green, while the hours with the highest emissions are in red. Source: WattTime 2019.

Future Directions for the Grid

While no significant changes were made to the electric grid for decades, there are many changes evolving recently. The current trends are "de-centralizing, digitizing and de-carbonizing." A lot of this change is driven by the fact that customers are not only users of energy but also generators. It is also driven by the need to improve reliability and resilience and reduce environmental impact (i.e. integrate renewable/low-emitting resources into the existing grid).

De-centralizing

De-centralizing generation and transmission/distribution resources can provide improvements to reliability and resilience because it allows for smaller generation and distribution centers closer to where the customers are using it. This means that if there are disruptions or outages due to fallen transmission lines for example, that will only affect a smaller number of customers on the other end. By shortening the length of transmission, it lowers the risk of interrupted power supply. De-centralizing resources has also surfaced naturally as customers become generators of electricity by utilizing rooftop photovoltaics. This also introduces two-way power flows, instead of the older one-way flow model. This effort is also widely referred to as 'DER' or Distributed Energy Resources.

Digitization

Digitization of the power-exchanges on the electric grid has also become somewhat of a necessity given the added complexity of two-way power flow and consumers as suppliers. What was already a complex network of data exchange has become much more complex with intermittent supply from many generation locations. Buildings are also adding equipment that allows the energy use to respond to signals from the grid, more on this in the GEB section below.

Decarbonization

Decarbonization of our electricity generation supply is at the root of much of the current interest in grid evolution. The growing awareness of the negative environmental impact of our existing, aging energy generation resources has come to the forefront. Many jurisdictions are pledging to reduce their emissions, resulting in driving a market for the integration of renewable energy resources into the existing electric grid.

While these changes are happening, the load on the grid is also predicted to increase. Recent studies[2] predict significant increases in the load on the grid due to building electrification and electric vehicles. As discussed above, the current peak demand on the grid happens in the summer evening hours. However, given current trends of electrifying buildings this may not be the case in the future. As electrification of buildings becomes more common, heating loads may cause the highest peak demand on the grid. Currently, most heating loads are covered by gas-fired equipment and therefore do not influence the load on the electric grid. However, some southern electric utility grids are shifting to winter peaks where electric resistance heating is used.

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[2] *Electrification Futures Study* by NREL, 2018, https://www.nrel.gov/docs/fy18osti/71500.pdf; numerous publications by Energy and Environmental Economics (E3), https://www.ethree.com/tools/pathways-model/.

Additionally, as electrification of vehicles becomes more common, the load on the grid will increase and coincident charging of vehicles could create significant unpredictable peaks. Utilities will find mechanisms such as rate structure to incentivize charging at non-peak hours, but the charging load and timing is an unknown variable. This increased electricity demand is happening while also trying to integrate intermittent, clean generation resources. This creates a bigger challenge, but also a larger opportunity, than solving one without the other.

Challenges of Renewable Energy Integration into the Existing Electrical Grid

The existing electrical grid is set up appropriately to dispatch power in a one-directional flow, with the various categories of resources (baseload, load following and peak), and the amounts of each resource available to meet a predicted load. This was appropriate until consumers became producers, and until intermittent, low-cost renewable energy was integrated into the mix. The combination of these new factors is presenting challenges to grid operators.

Intermittency

The first major challenge is that the renewable resources that are becoming more heavily relied on—solar power and wind power—are intermittent. They do tend to work well in tandem, with more sunshine during the day and higher wind speeds at night. But nonetheless they are intermittent and not dispatchable (i.e., not a reliable resource to meet a customer's load at any given time). Therefore, increasing the amount of wind power in a region alone does not necessarily reduce the reliance of the utility on the non-renewable generation resources. Renewable resources have very low operational cost but are typically not dispatchable unless combined with energy storage which can be very costly. One renewable resource that does not fit this description is hydropower, which is dispatchable.

Curtailment

Another major challenge is the utilization of the renewable resources when they are available. Renewable power generation may be curtailed or not utilized due to a variety of reasons. Often it is because the transmission system that brings the generation to the load is not capable of carrying the power. In order to facilitate utilizing all the renewable generation output, significant investment would be needed to upgrade the transmission lines. There are also occurrences where there is system-wide over-supply and it is less costly to curtail the renewable energy than to "turn down" output from another resource.

Net Load Challenges

The last significant challenge ties together the intermittency issue described above and the limitations of ramping up or down the power output of our existing generation resources. Only a small portion of our existing power supply will quickly adjust output to meet a quickly changing load. For example, as shown in Figure 6, the California ISO (CAISO) has a significant amount of solar power in their generation resource mix, so much that 50%+ of the load on the grid can be covered by solar in the peak sunshine hours of the day.
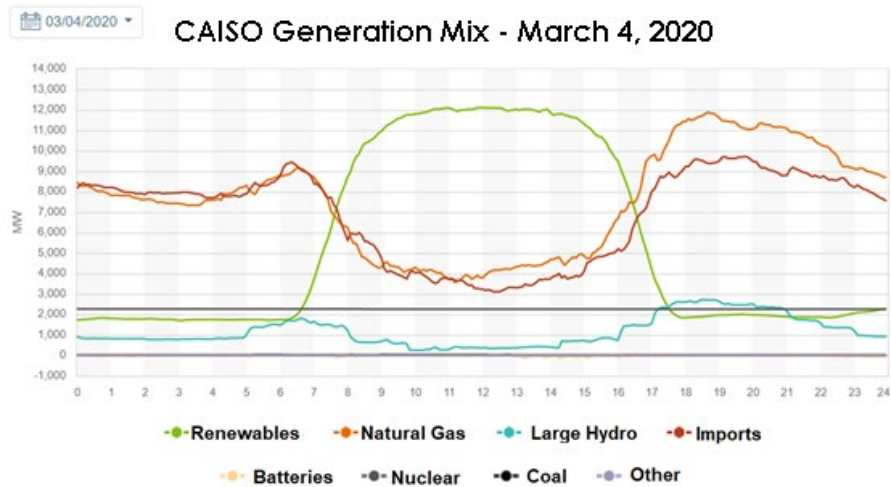
Figure 6: California ISO (CAISO) Generation Resources on March 4, 2020. *Source:* CAISO 2020.

The major operational challenges occur when the sun rises, and when the setting-sun coincides with a typical 'evening peak' of household electricity use. This yields the infamous "duck curve", where the Net Load on the grid has an incredibly steep ramp. This ramp can only be met with quick responding, dispatchable generation resources. Again, these quick responding resources only make up a small percentage of the existing power supply. Figure 7 shows the Net Load on the grid due to the availability of renewable resources during the day, and the ramp required to meet the load as the solar output increases or decreases. As shown in Figure 6 above, the resource utilized to match that ramp is natural gas. These challenges will continue to exist as more renewable energy is integrated into the grid, and it is important for building designers to know how they can help facilitate a smoother integration because they can help shape that load.
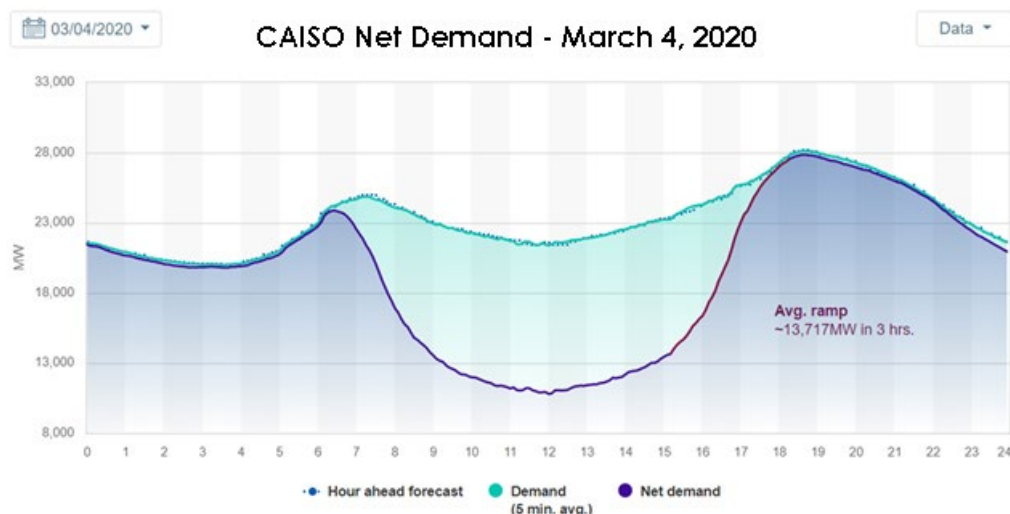

Figure 7: California ISO Net Load March 4, 2020. Average ramp of 13,717 MW in 3 hours. *Source:* CAISO 2020.

Building Programs Background
PHIUS+ Passive Building Standard

Passive building is a design methodology defined by a set of principles that prioritize energy conservation best practices. These principles can be applied to all building typologies -- from single-family homes to multi-family apartment buildings, offices, skyscrapers. Three control concepts shape the design principles: **thermal** control, **radiation** control and **air** control. The underlying passive building principles are (1) High Performance Insulation, (2) Thermal Bridge Elimination, (3) Optimal Glazing, (4) Shading/Daylighting, (5) Envelope Airtightness and (6) Energy Recovery Ventilation. Passive building is associated with lower energy use, specifically lower space conditioning loads. However, the methodology produces other benefits: comfort, improved indoor air quality, durability and resilience.

The PHIUS+ Passive Building Standard was developed as a guideline on "how far to go" with passive building principles. The core of this standard is the design limits set for heating and cooling loads. These were set based on economic optimization for buildings of different sizes and occupant density and are intended to guide the design to the optimal investment in passive conservation measures. The other energy-related design requirement is a maximum limit on net source energy. The source energy limit is not guided by optimization, nor is it guided by economics. It is guided by the ultimate need to reduce global CO_2 emissions. This limit set ambitious goals for reducing source energy use using a combination of conservation measures and renewable energy. The last main performance pillar is airtightness, which takes the form of a pass/fail limit on air leakage at pressure test per square foot of envelope enclosure (PHIUS 2019). PHIUS+ projects also must meet stringent 3rd party quality assurance inspection, testing and commissioning. Residential PHIUS+ projects use Energy Star[3], DOE Zero Energy Ready Home[4] and EPA Indoor airPLUS[5] as pre-requisite programs for their certification.

Grid-interactive Efficient Buildings (GEB)

A Grid-interactive Efficient Building (GEB) is a building that integrates and continuously optimizes Distributed Energy Resources (DER) for the benefit of building owners and occupants, as well as the grid. According to the U.S. Department of Energy (DOE), "A GEB is an energy efficient building with smart technologies characterized by the active use of Distributed Energy Resources (DER) to optimize energy use for grid services, occupant needs and preferences, and cost reductions in a continuous and integrated way…The vision of GEB is the integration and continuous optimization of DERs for the benefit of the buildings' owners, occupants and the electric grid." (DOE 2019) A GEB utilizes analytics and building controls to optimize energy use for occupant patterns and preferences, utility price signals, weather forecasts and available on-site generation and storage. Applications in the building may be controlled, such as HVAC setpoints, lighting and dynamic windows, all optimized to meet both occupant and grid needs.

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[3] https://www.energystar.gov/newhomes/
[4] https://www.energy.gov/eere/buildings/zero-energy-ready-homes
[5] https://www.epa.gov/indoorairplus/about-indoor-airplus

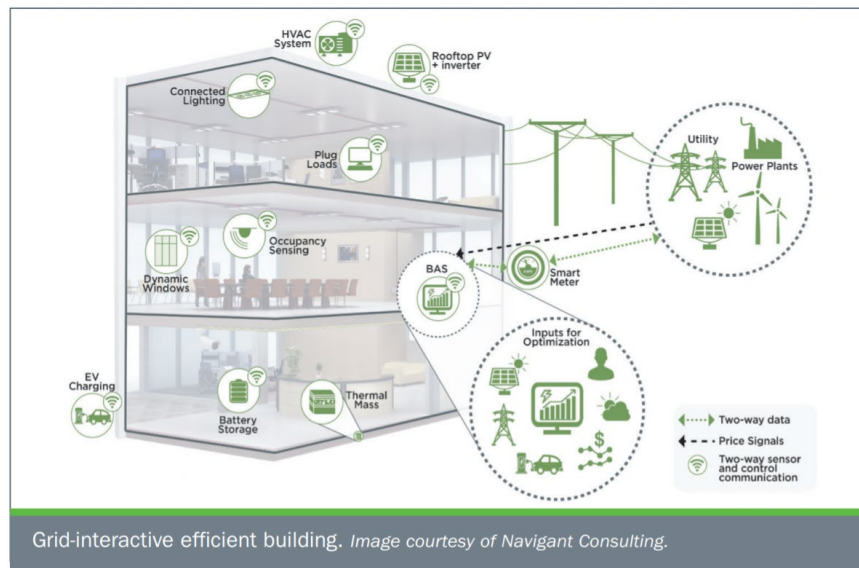Grid-interactive efficient building. *Image courtesy of Navigant Consulting.*

Figure 8. Example Commercial Grid-interactive Efficient Building. The Building Automation System (BAS) utilizes analytics supported by sensors and controls to optimize energy use for occupant patterns and preferences, utility price signals, weather forecasts, and available on-site generation and storage. *Source*: US DOE 2019.

Energy efficiency is key to the concept of GEB. As shown in Figure 9, characteristics of GEB are that the building is efficient, connected, smart and flexible. Efficiency is critical because it helps to reduce overall demand on the grid, minimizing the amount of resources needed to create grid resilience and flexibility and reducing the fuel needed to produce electricity. Energy efficiency "flattens the curve" of peak demand and demand load; very efficient buildings, like PHIUS+ buildings, flatten this curve even more than typical construction.
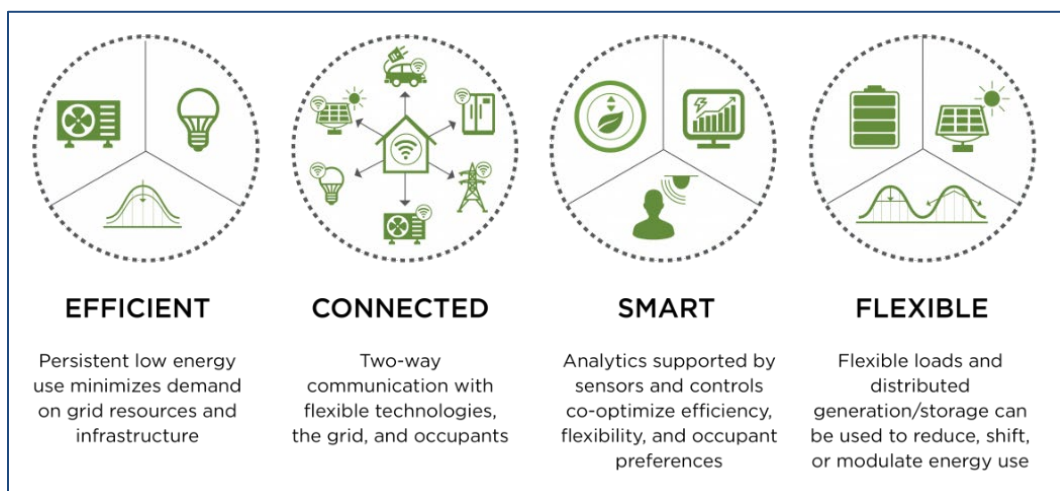

EFFICIENT	CONNECTED	SMART	FLEXIBLE
Persistent low energy use minimizes demand on grid resources and infrastructure	Two-way communication with flexible technologies, the grid, and occupants	Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences	Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use

Figure 9: Characteristics of GEB. *Source:* US DOE 2019.

GEB-related technologies can significantly reduce energy consumption as well. Deployable efficiency technologies may include high efficiency lighting devices, smart appliances, high-efficiency heat pumps, thermal storage, dynamic glazing, advanced sensors and controls, software for optimizing building design and operation and interoperable building communication systems. Many technologies are easily integrated into PHIUS+ buildings.
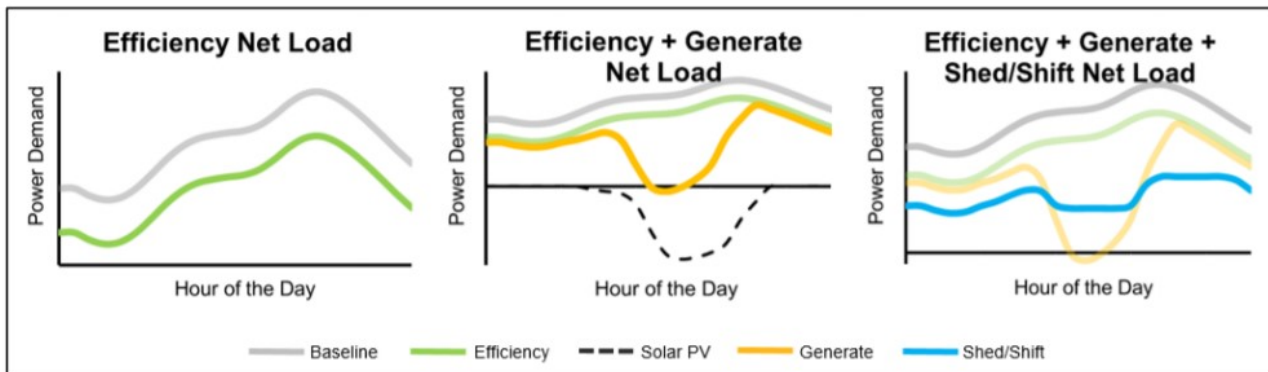

Figure 10. GEB Load Curves. *Source*: US DOE 2019.

Net Zero Buildings

Net Zero is a widely used term in the building industry and an increasingly popular goal for building designers to achieve. There are a variety of definitions[6], each varying slightly[7]. In general, what the definitions all have in common is that they're referring to a building that uses as much energy as it produces by a renewable resource on annual basis – which is why the term 'net' is used. There is a 'netting out' of the building's energy use with renewable energy production over a period of time. A few factors that the definitions do not have in common are metric, boundary and fuel sources.

- **Metric:** Defining what is being accounted for, whether it's source energy, site energy or carbon emissions.
- **Boundary:** Defining where the boundary for renewable energy generation is set: on-site, campus level, community level, etc.
- **Fuel Sources:** Some net zero definitions will allow for the on-site combustion of fossil fuels to be offset with renewable resources, while others will not.

The biggest challenge with most current definitions is that all kilowatt-hours used and generated have the same value on an annual basis. The emissions associated with energy use and the ability to utilize a unit of renewable energy with the current electric grid infrastructure can vary significantly hour by hour. The value of hours is overlooked when accounting on an annual basis.

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[6] Zero-energy(ZE), zero net energy (ZNE), net-zero energy building (NZEB), and net zero building is a building with zero net energy consumption, meaning the total annual amount of energy used by the building is equal to the amount of renewable energy created on the site OR offsite, and sometimes includes net zero carbon emissions as well as energy. In 2015, US DOE published *A Common Definition of Zero Energy Buildings* (https://www.energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf)

[7] There is an ASHRAE Standard under development, ASHRAE 228P, which will provide a standard method of evaluating net-zero energy building performance.

Solar power is becoming less expensive and more attractive to building developers. On-site photovoltaics is the most common approach to achieving a Net Zero, however, there is mismatch between when the solar photovoltaics (PV) produce energy and when the building uses energy.

Case Study

To illustrate PHIUS+GEB in practice, a multifamily case study is used to demonstrate how using PHIUS+ performance standards can provide high levels of energy efficiency, facilitate renewable energy into the electric grid, and when combined with GEB can minimize grid demand challenges. This study was conducted for this paper and modeled using BEopt (EnergyPlus engine).

Building Information

Two different buildings were designed, both to meet Net Zero[8] standards. The only differing factor between the two building was the design approach – one met a minimum code baseline Building America (BA) 2009 benchmark[9] while the other met PHIUS+ 2015 performance targets. Both buildings were all electric. The BA 2009 Benchmark is referred to as the "Baseline" building, while the PHIUS+ 2015 building is referred to as the "Passive" building.

Location: Chicago, IL
ASHRAE Climate Zone: 5A
Type: Multi-Family, 32-unit, 4 stories
Size: 35,000 ft^2
Window to Wall Ratio: 20% (equally distributed)
Energy Use Intensity (EUI): The modeled site EUI for the Baseline building was 33.4 kBTU/ft^{2}yr, while the Passive building was 18.7 kBTU/ft^{2}yr. These values do not include any renewable energy.
On-Site PV: Both buildings achieved Net Zero with an on-site PV array facing south with a 10-degree tilt. The Baseline building needed a 290 kW PV array while the Passive building needed a 159 kW PV array. (Note: the amount of PV needed for each building exceeded the available roof area and thus also utilized additional area to facilitate more PV arrays on-site).

Lower Total Load

The first consideration is the lower annual load of the Passive building, which was about 45% lower than the Baseline building. This reduces the total dependency the building has on the electric grid, even considering there is only a fraction of coincident production and use of power generated by the on-site photovoltaics. PHIUS estimates that for a Net Zero building in Climate Zone 5A, only about 37% of the annual energy being produced could be used coincident with its generation. The remaining 63% would be exported back into the grid (PHIUS 2019). The annual site energy use of the Baseline was 352 MWh/yr and the Passive building was 197 MWh/yr. If estimating that 63% of the annual load is covered by the grid, the Baseline

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[8] Net Zero was defined as a building that uses as much energy as it produces on-site by a renewable resource on annual basis.
[9] https://www.nrel.gov/docs/fy10osti/47246.pdf

building relied on the grid for 99 MWh/yr <u>more</u> than the Passive building. This demonstrates more grid dependence for the Baseline building.

Lower Peak Load

While the lower annual load does reduce grid dependency, the lower peak load has a bigger impact on grid infrastructure needed to support the building. Both buildings peak in January: the Baseline building peak is 132 kW, while the Passive building is 80 kW. When considering that the investment in generation resources is based on meeting that peak load, and then increased by a safety factor for contingency planning, the 52 kW gap in peak between the Passive and Baseline building grows even greater. If considered at a larger neighborhood or city scale, this is significant, and the Passive approach has the impact to reduce up-front investment in generation resources by 40%.
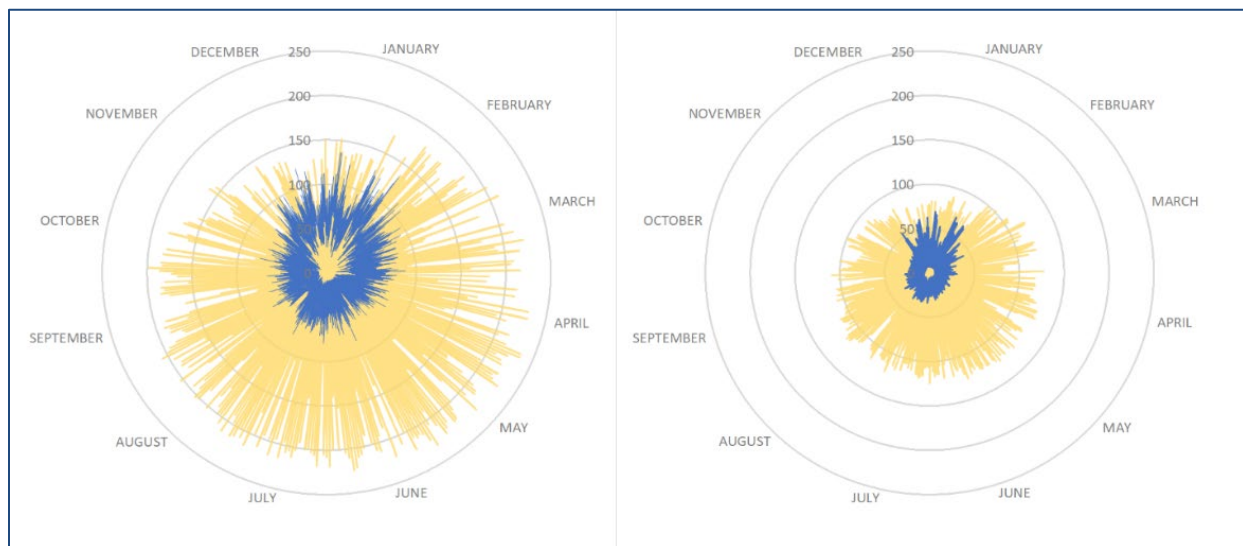

Figure 11: Annual chart reporting hourly building energy use (blue) versus photovoltaic power production (yellow). Baseline building (Left), Passive Building (right).

Reduced Mismatch

As noted above, there is a timing mismatch between on-site solar power generation and energy use. However, when the total annual load and total peaks are reduced, the mismatch is also reduced. By using less energy annually, less PV is needed to reach Net Zero.

In Figure 11, the blue lines show building load and yellow lines show PV production, at the same scale for both charts. Because these were both designed to be Net Zero, the yellow shape (PV) offsets the blue shape (load). The Passive building demonstrates lower total load and PV need. Figure 12 shows the daily building load versus solar energy output in January and July. Again, by reducing the annual and peak loads, the mismatch between production and use is decreased.
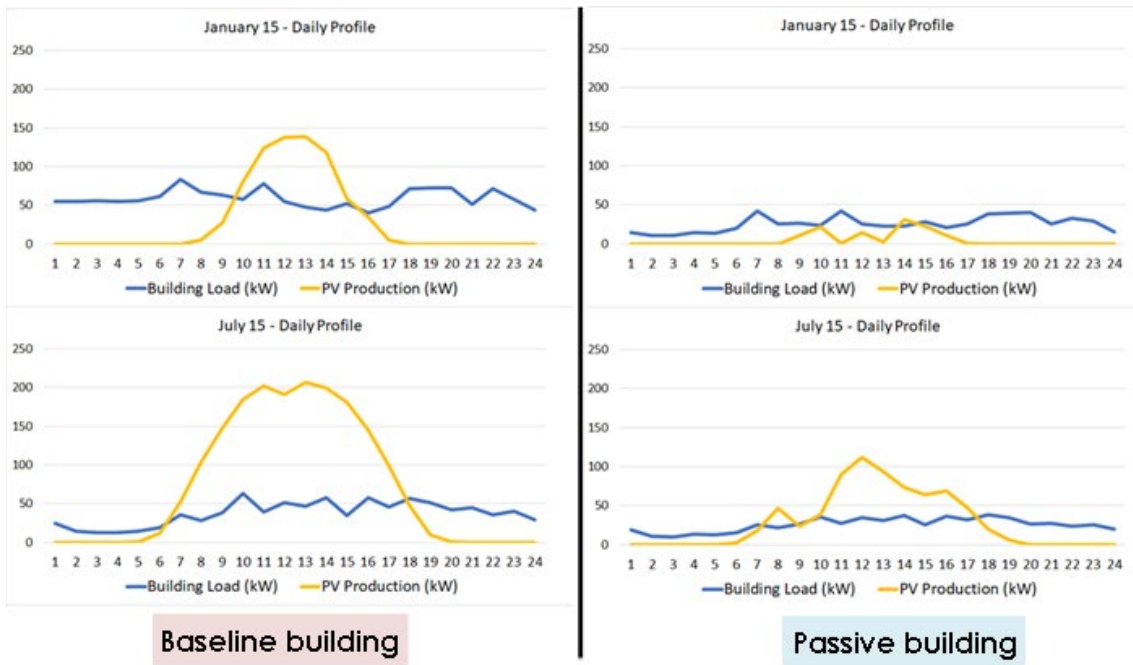
Figure 12: Daily building load profile versus photovoltaic power output on January 15 and July 15. Baseline building (left), Passive building (right).

Net Load/ Ramping Impact

The Net Load on the electric grid with the two different prototypes can be further analyzed by considering their impact at a larger scale. To represent this, it was assumed that 1,000 of these multifamily prototype buildings were on their own microgrid in a modeling exercise. The buildings were built to either Baseline or Passive, and varying percentages of the 1,000 buildings were designed to be Net Zero with the PV array described in the case study description.

The load profile of single day of operation was analyzed: March 31st. Figure 13 shows the total load on the microgrid following the top line from left to right. Then, increasing percentages of the 1,000 buildings designed to be Net Zero were integrated, and the net load after the PV is shown with the different plotted lines, ranging from 0-50%. When 50% of that sample set were made into Net Zero buildings, it is evident there is a significant ramp in the early evening hours, and that ramp is three times steeper for the Baseline building versus the Passive building. The challenge of meeting that ramp is discussed above, and it is much more costly to meet the steep ramp shown by the baseline building.
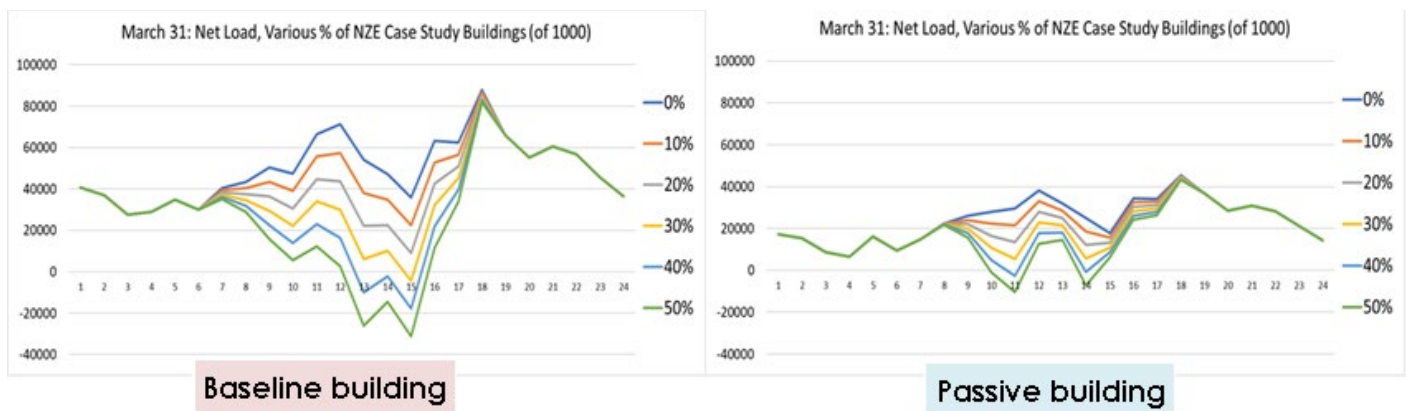
Figure 13: Net Load of 1,000 multifamily buildings with varying percentages meeting Net Zero requirements. Baseline building (left), Passive building (right).

Demand Response Potential

One of the key characteristics of GEB is that it is flexible – it can shed or reduce loads. Buildings are called upon to reduce loads because it is much less costly to shed the load than to call upon other generation resources. Due to their design characteristics, passive buildings inherently can shift or shed space conditioning loads and are able to "float" at a comfortable interior condition for quite a while without active heating or cooling systems. This is where the Passive building really differs from the Baseline building in terms of demand response potential and load shedding.

In order to demonstrate this, load-shed simulations were completed in WUFIplus[10] to investigate the resulting interior conditions if the building turned off any cooling or dehumidification equipment for an evening period (3-8pm) from July 14 - July 21. This period was selected because it is one where significant ramping would be predicted to occur if Illinois continues to integrate PV as a generation resource. The building was slightly "pre-cooled" during the hours prior to the shut-off, and the cooling set-point was 72F. The pre-cooling could utilize excess solar energy in the middle of the day and the building itself can be considered a form of thermal storage as an asset for the grid.

A southwest corner unit (stress-case orientation for summer) was selected from the multifamily Chicago prototype building described above. Two variables were explored: window to wall ratio (20% and 60%) and thermal mass (low mass equating to a wood-framed building and high mass equating to a concrete structure building). All four scenarios meet PHIUS+ performance requirements.

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[10] **WUFI**® is an acronym for Wärme Und Feuchte Instationär—which, translated, means heat and moisture transiency. WUFI software is used to calculate performance of PHIUS buildings.
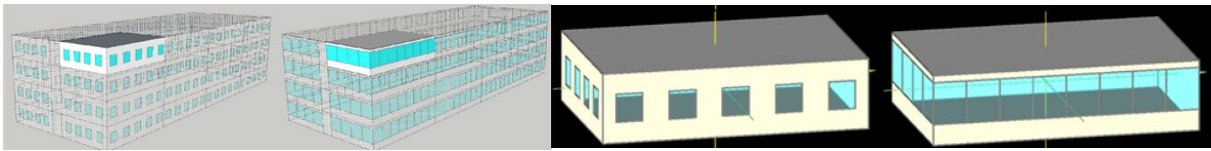
Figure 14: Southwest corner unit visualization for load-flexibility simulation cases. 20% WWR & 60% WWR.

The simulation results showed that the apartment unit that heated up the quickest and the most was the low mass, high window-to-wall ratio case which approaches slightly above 80°F on the warmest day. The best performing case was the high-mass, low window-to-wall ratio building that never got above 74°F inside even without a cooling system for those hours, during one of the warmest weeks of the year in Chicago. This shows that PHIUS+ buildings are inherently flexible. They can shift some or all of their space conditioning loads using smart thermostat sensors or the like, based on grid-signals with little to no effect on occupant comfort.
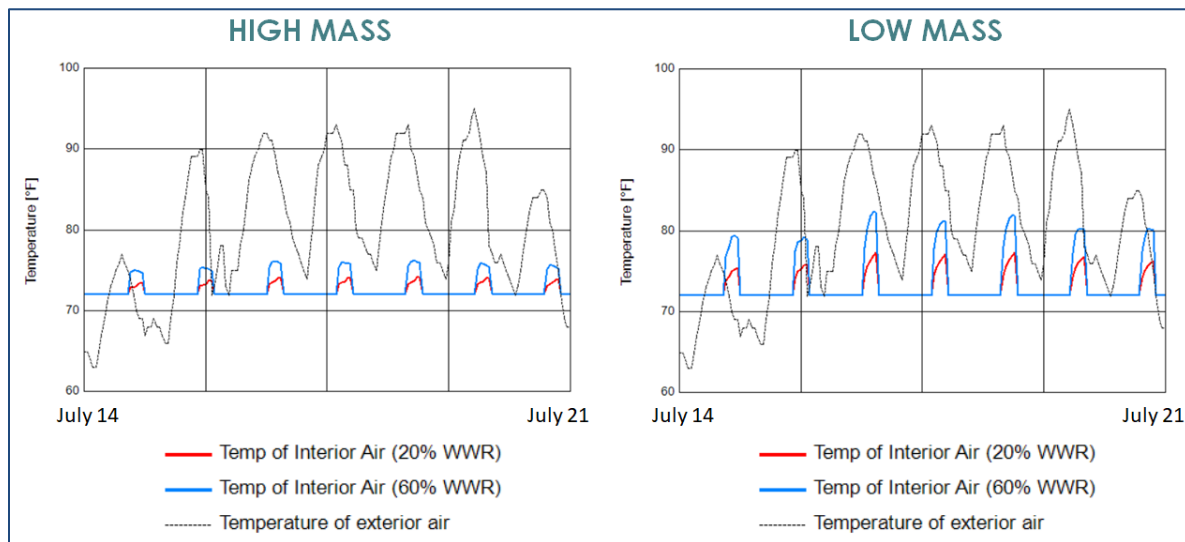

Figure 15: Simulation results for SW corner unit of multifamily passive building in Chicago. Cooling system turned off each day from 3-8pm on July 14-July 21.

Ripple Effect of Conservation

Simple payback analysis is often used to justify the up-front investment in energy saving measures, and sometimes implementing efficiency beyond the simple paybacks doesn't appear to be justified. This type of analysis ignores the building holistically, the generation resources providing power to that building and the transition to a clean energy future. When a building uses one less unit of energy, this savings ripples throughout the whole power supply network. Less generation, less storage and less transmission capacity is needed to carry it through the system. Even though this impact benefits everyone, this ripple effect is felt most directly by utilities and stakeholders interested in climate goals. Utility programs and policy changes that support strong energy efficiency like PHIUS+ and GEB can potentially help accelerate these network-wide savings (see Program and Policy sections).

Looking Forward

As grid resilience and energy efficiency will continue to be key issues for communities, PHIUS and GEB should integrate as well. Combining efficiency with load flexibility can provide significant savings, both in electricity costs and total carbon emissions. In 2019, MEEA studied[11] instances of GEB in the Midwest and found barriers to implementation include:

- Policies silo EE and DR
- Information gap on demand side performance
- Lack of education, training and awareness
- Technology and equipment communication challenges
- Need for transparency and readily available information
- Regulatory requirements for cost-effectiveness and EM&V
- Inadequate communication between utility departments
- Security and privacy concerns

Integration of PHIUS+ and GEB could simultaneously address many of the barriers outlined above and help bring resiliency to communities through policies and programs. Combining efficiency and flexibility allows for targeted conservation and can result in improved reliability and resiliency of the grid. Continuing with the focus on Illinois, below are two suggested options of PHIUS+ and GEB.

PHIUS + GEB Policy

A city in, or the state of, Illinois could revisit the work of the NextGrid stakeholder group, which was created by the Future Energy Jobs Act (FEJA). NextGrid Illinois[12] was an 18-month collaborative initiative managed by the University of Illinois and the Illinois Commerce Commission. The goals of the initiative include developing a final grid modernization report detailing opportunities and challenges and establishing a "21st Century" regulatory model. The group focused on an investigative study to identify, research and develop ideas to help address the issues Illinois' electric grid is facing. The study describes grid modernization benefits and challenges for consumers, utilities and the environment, identifies legal, regulatory and policy revisions needed to support grid modernization and examines the trends and benefits of emerging technologies to help drive the change.

GEB and PHIUS+ could help solve some challenges identified by NextGrid. A city or state could formally designate that the GEB concept helps meet the goals of NextGrid Illinois, and work with the US DOE and Illinois utilities on incorporating Connected Communities[13] projects into Illinois. Because PHIUS+ demonstrates load shifting capabilities and lower peak demand potential, PHIUS+ could be designated as the energy efficiency baseline for GEB and the program recognized in a locally adopted stretch code.

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[11] Some of these preliminary findings are outlined in NEEP's (Northeast Energy Efficiency Partnerships) *Grid-Efficient Interactive Buildings (GEBs) Tri-Region Status Report* from January 2020, https://neep.org/sites/default/files/resources/NEEP%20GEBs%20Report_Final.pdf
[12] https://nextgrid.illinois.gov/
[13] https://www.energy.gov/eere/articles/department-energy-releases-request-information-potential-funding-grid-interactive

Utilities already provide a lot of support of individual components of GEB, but the energy efficiency piece is rarely incorporated with grid-related programs. A pilot program that combines GEB + PHIUS, potentially as a mechanism to support policy initiatives, could be considered. One challenge identified in incorporating GEB is a lack of understanding and training with of installation and integration of GEB technology and equipment. PHIUS+ is a standard that already requires training and quality control to achieve certification; this program could train professionals on aspects of GEB + PHIUS simultaneously. Such a program would combine multiple aspects of GEB, breaking down silos within EE and DR departments and programs, another GEB challenge that was identified. Ultimately, as demonstrated in this paper, utilities would see the benefits of combining GEB and PHIUS+ through load management, peak shaving and the ripple effect of conservation.

Conclusion

While the building stock is increasing at a significant rate, jurisdictions are also targeting significant reductions in carbon emissions and replacing existing generation resources with renewable energy generation. Both deep-energy efficiency and grid-integrated building technologies will be critical for a low-cost transition to a renewable/clean energy future, and the combination of these two is what is needed for the smoothest transition for all parties involved. This combination not only reduces the amount of renewable energy generation resources needed to meet future demands, but also reduces the multiplied effect of redundant/backup contingency resources and ancillary services needed. Utilities that support PHIUS+ and GEB as a unified concept can create a simpler, smoother and more resilient future energy outlook.

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