TURNING BUILDINGS INTO A SOURCE OF ENERGY

# The grid interactive building

How smart buildings and grids are enabling a forward-looking vision of energy

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# Foreword

This whitepaper identifies the emergence of a new type of building, the 'grid interactive building', at the grid edge (see section 3), where smart buildings meet smart grids. This has been identified by Siemens as a future vision for how commercial buildings, education, industry and healthcare can play an active role in a more decarbonized energy system.

# Index

# 1 Executive Summary

The energy system is changing. The decarbonization of energy is a critical transition that is reshaping all organizations. Driven by climate policy, enabled by the decentralization of energy generation and digitalization of buildings and systems. Decarbonization of energy use is more technically feasible than ever before.

Improved energy efficiency and lower carbon energy use is starting to happen in buildings thanks to technical developments that are helping overcome some of the challenges of decarbonization. The grid that these buildings connect to are also changing and becoming smarter. Improved technology offers new ways for grids and buildings to interact, creating opportunities and benefits for those in the commercial buildings sector.

It is clear that the buildings sector has the potential for significant further improvement, as part of meeting the challenges set out by the United Nations Sustainable Development Goals.

For those looking to futureproof their buildings – from hospitals to university campuses, whether they are new or existing – understanding what is changing in the energy system, in relation to buildings and the grids they connect to, is critical. Further, understanding what the benefits are – for both the organization and the grid, and actions that decision makers can take will help shape how buildings can be made smarter and be a part of a decarbonized society.

This paper will outline some key concepts around the changing low carbon and energy efficiency landscape, and how the grid and smart buildings are starting to work together in new, connected ways as the grid interactive building at the grid edge (see Section 3). It will look at the technology benefits for commercial buildings' energy users in relation to the grid. Lastly, we will outline steps that users could take to realize these smart benefits.

Strategies taken will differ between organizations, but typically will involve specific actions on the energy management side, on the energy demand side and on the energy supply side. For further reading on these broader actions, see our white paper Addressing decarbonization at the grid edge.

In summary, the grid interactive building combines smarter buildings that interact with smart grids to:

- Reduce overall consumption from fossil fuels
- Provide grid stability through changing their energy loads via new technology
- Generate revenue for selling energy demand or generation onsite that is flexible.

This supports a lower carbon, balanced energy grid for all in society.

Expert support from specialist companies who understand buildings can be invaluable, as it can help prioritise the right actions across the business and manage some of the risks around project implementation, performance and financing.

Siemens is well-placed to help its customers with their decarbonization goals, due to its coverage of the complete energy cycle from sustainable power generation over low loss power transmission to intelligent distribution and storage and efficient energy use, especially for large building portfolios. Siemens is also implementing its own decarbonization strategy with a commitment to become carbon neutral by 2030.

# 2 What is driving the need for smarter buildings and smart grids?

Buildings are a major cause of carbon emissions. The global buildings sector represented over 3.1 gigatons (Gt) of direct $CO_2$ emissions[1] in 2019. To put this simply, one gigaton is roughly equal to the mass of 200 million elephants[2]. According to the International Energy Agency (IEA), energy use associated with these emissions is predicted to rise as buildings are increasingly electrified.

Commercial building energy demand or 'loads', such as space heating, cooling and appliances, contribute to this globally especially in Europe, North America, and major cities world-wide. For example, more extreme weather events and climate change are causing an increase in temperature extremes, resulting in increased demand on both heating and cooling.

In the commercial building sector, heating and cooling technologies are increasingly electrified.

Some key progress in emissions from energy has been made in the 2010s, despite energy usage increasing overall. The worldwide decarbonization of the electricity and now increasingly, the heating sector, has made an impact in lowering carbon emissions. A wider awareness on energy efficiency is also having, some, if limited impact. The IEA estimates that building sector energy intensity has been decreasing continuously since 2010 by 0.5-1per cent per year.

In parallel, however, policies and regulations have not continued to rapidly mandate for building energy efficiency globally. The buildings sector is growing worldwide at around 2.5per cent[1], well above the decrease in energy intensity, with new building expansion in emerging markets, and low refurbishment rates in established economies.

Whilst in many countries, new energy efficiency and non-fossil fuel targets for buildings are due to come in in the next decade, there are questions on the stringency and continual improvement of other building energy policies.

Lack of significant change highlights the reasons for why buildings have the potential to have a positive impact on carbon emissions, helping to contribute to mitigating climate change.

# The Energy Reset

“Energy Reset”, one of the five key tenets in Singapore’s Greenplan 2030, has an emphasis on greener infrastructure and buildings, with 2030, and interim, targets.

Aiming to raise standards through the Green Building Masterplan, it will raise energy performance standards and push for adoption of super low energy (SLE) buildings.

Using an “80-80-80 in 2030” principle, 80 per cent of Singapore’s buildings by floor area will be SLE from 2030, and other green buildings are to see an 80 per cent improvement in energy efficiency (over 2005 levels) by 2030.

Combined with a fivefold increase to 5GWp in solar deployment, as well as 200MW of storage after 2025, decarbonizing energy from the grid, as well as buildings is a major policy focus.

It is estimated that non-residential buildings (excluding industry) accounted for around 11 per cent[3] of global emissions. Positive signs can be seen in countries like Singapore[4].

The European Union has identified buildings as being challenging to decarbonize, even after improvements in energy efficiency. Decarbonizing the energy needed for buildings to operate, after energy efficiency measures have been put into place (residual energy needs) is another key issue in the modern buildings sector.

Typically, this relies on energy taken from the grid or generated onsite to be low carbon.

Commercial areas, industries, large buildings, and campuses all have the potential to be important players if they understand their role in energy. To do this, we need to look in greater detail at the specific factors that influence how a commercial building can meet energy needs now and in the future, in a smart way.

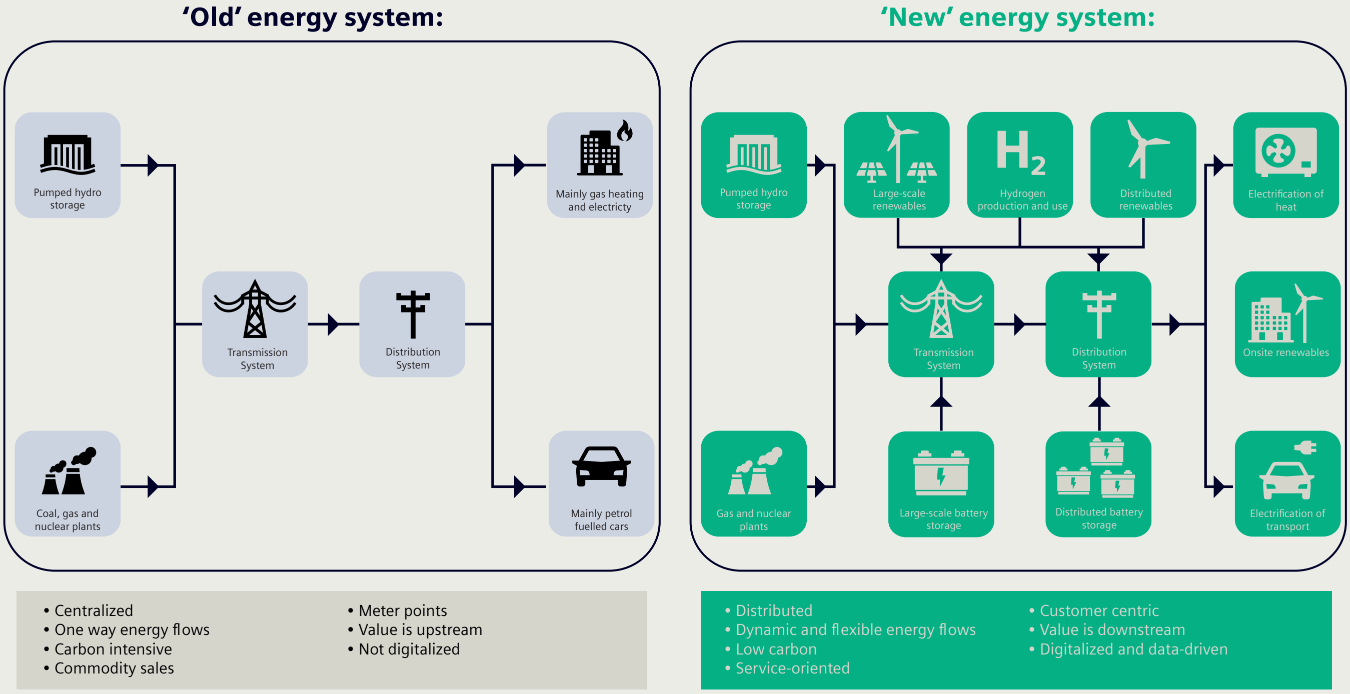



Figure 1: What does the new energy transition mean?

# Three factors driving smarter buildings and energy grids

Three technology factors that make and drive decarbonization feasibility have been identified[5]. How these impact on commercial buildings, such as hospitals, municipal buildings, education, and production facilities, are explored in detail the next section. They can be summarized as:

1. **The transition to a new energy system**, which is generated decentrally and low in carbon, mainly renewables (Figure 1).
2. **New technology**, like storage and flexible energy loads, that help overcome the intermittency[6] issues from increasing amounts of low carbon generation such as wind and solar.
3. **Digitalization of energy and building technology**, allows better control of hardware, technologies and software, allowing buildings to see what is happening internally, and interact with the energy systems they are connected to in new ways.

### What does this mean in more detail?

**How can buildings be part of the transition to a new energy system, which is decentralized and low carbon?**

For buildings, this means a shift from relying only on grid-based power from the grid, and temperature regulation mostly from gas (see Figure 1).

In old energy, the grid is primarily large-scale generation and fossil-based, owned by a few organizations in each region or country, with the value and focus of the power and gas in the upstream generation sources.

Building consumers are at the downstream opposite end, often physically far away from where power is generated, passively consuming what is supplied to them, with little control.

In 'new' energy systems, the power sources are low carbon, like wind and solar, smaller scale and more frequently near the buildings consuming it, sometimes even onsite. There are many more times the amount of low carbon power plants, generating smaller but low carbon electricity. Chemical battery storage, which can be located with onsite renewables to store energy, is also connected to the grid and commercial sites, at a large utility scale and smaller building sized scale.

Buildings with new energy technologies now have the possibility to interact with the grid, rather than just passively draw power down.

Battery storage, together with increasing amounts of fleet and employee electrified vehicles and distributed power generation, creates new power flows feeding into the grid, as well as drawing from it at local levels. Buildings with new energy technologies now have the possibility to interact with the grid, rather than just passively draw power and gas down. The process of interacting with the grid can be called "demand response"

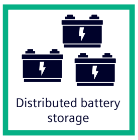
**Demand response** is when an energy user changes their energy demand to better match the needs of the grid and energy system. For example, a building can choose to reduce power taken from the grid by turning off appliances or processes if the grid has production supply constraints. Alternatively, a building can turn up usage, perhaps by running additional processes, when there is too much power in the grid.

Utilities are starting to provide signals and financial incentives to allow commercial end users to do this and be rewarded, creating a new demand response market.

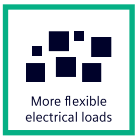
**How can new technology in buildings help overcome the intermittency from those low carbon sources?**

Increasing amounts of low carbon wind and solar in the energy system create challenges around integrating into the wider energy system as their power is intermittent and less controllable than the fossil fuel-based sources that they displace. Those organizations who manage the energy system have done so based on conventional generation and consumption patterns, and with the new energy system, need to change how they do this.

## The electricity grid is getting smarter – it is more controlled, monitored and managed proactively and effectively.








As such, the emergence of new technology that helps manage this intermittency is so important. For future smart buildings, one example is the location of battery storage on site. Where new building energy management systems (BEMS) are installed to understand and control energy within a building, electrical loads in a building can be disaggregated and then potentially turned on and off individually and flexibly. As part of the grid, the building is then able to be part of the demand response market, offering flexible use of its demand-side loads, to reduce strains generated by intermittency on the grid supply-side.

**Digitalization of energy technology allows better control of technologies, buildings and software and allows buildings to interact with the energy systems they are connected to.**

Digitalization of buildings has been rapidly progressing in the last decade, with more and more buildings digitally connected across energy systems, but also ventilation and cooling, building management, security and operational systems. This digitalization of a building means that building managers can see and identify electrical loads, knowing when, where and what power is being used for. This enables them to understand which of their electrical loads they may be able to flexibly turn off or on, and so how much they can participate in putting more power into the system or taking more off – **being an interactive part of the grid**.

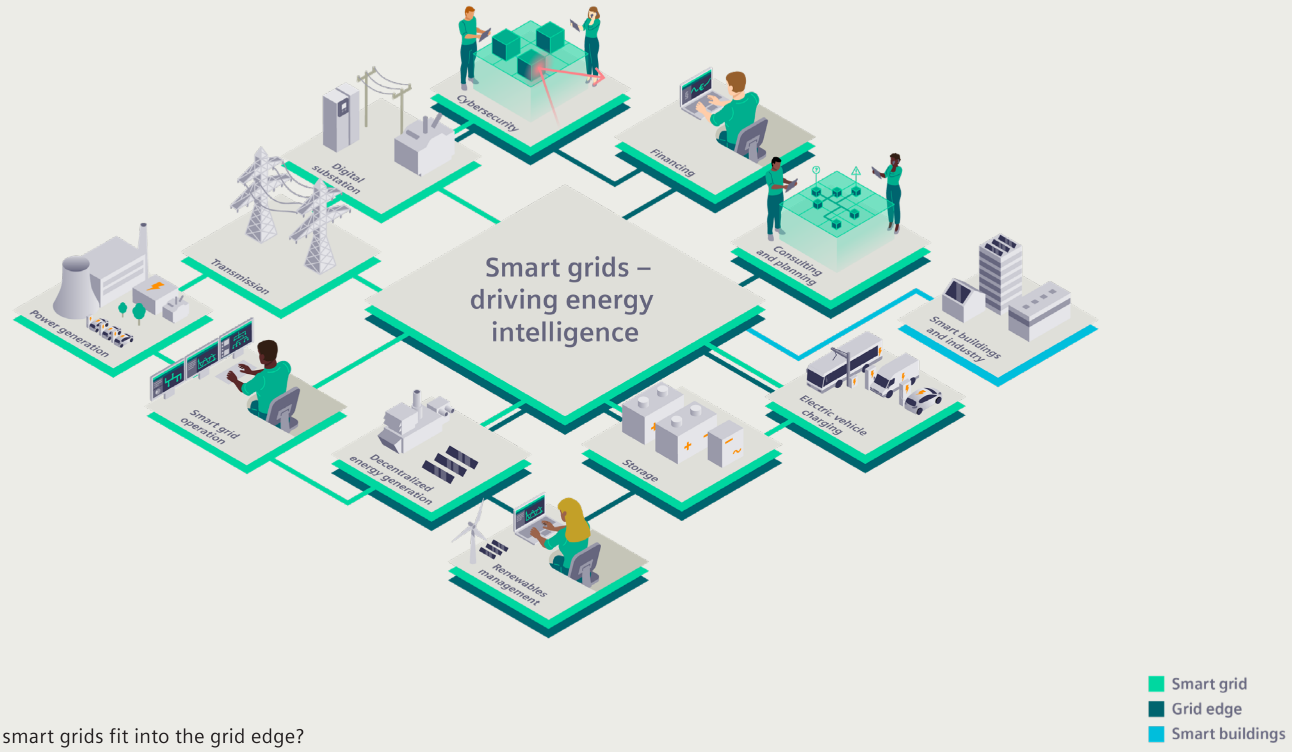



Figure 2: How do smart grids fit into the grid edge?

# 3 The grid edge and smarter buildings

Put simply, the grid edge is where the smart energy grid meets connected energy consumers – and so where energy demand and supply is controlled intelligently and efficiently to create more stable and reliable environments for all in the energy systems.

Significant changes in technology and digitalization in the new energy system has meant two things for buildings:

**The grid is smarter.**
It is controlled, monitored and managed using increasingly digital, rather than, analogue controls and systems. This generates more data and understanding of what is happening on the grid, so that it can be managed more proactively and efficiently (Figure 2).

Example use cases of a smart grid:

- Managing intermittency and multiple directions of new renewable power being connected to the grid. Digital monitoring allows continuous monitoring of variable power quality and electrical frequency, which allows quicker or proactive actions to be taken to keep the grid safe
- Digitalizing ageing grid assets (like transformers) creates better visibility and understanding of challenges and constraints at different points on the grid.

**Energy consumers are more connected, and the smart building has emerged.**
With new technologies, such as renewable energy and energy storage located close to or as part of a building's infrastructure (as well as digitalization and connectivity of energy management inside the building), consumers are becoming smarter and transforming the way they can operate.

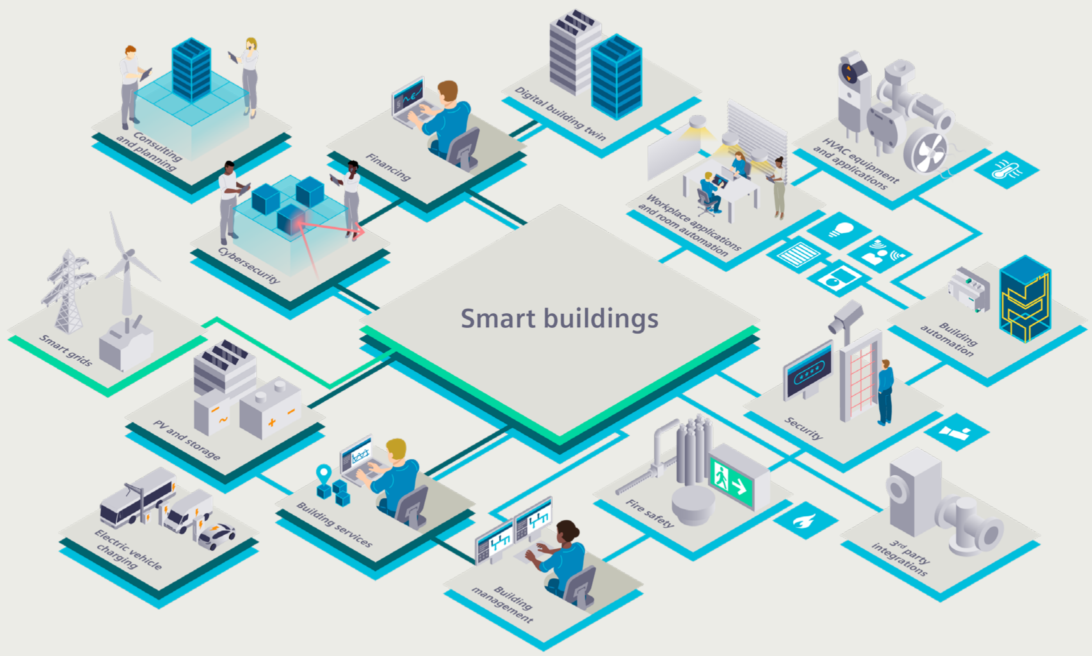



Figure 3: Buildings are more connected, and the smart building has emerged

The external changes in working practices and employee needs can be quite radical, as seen in Covid-19 pandemic. Combining this with the energy system changes means that buildings can be smarter on the inside, more connected, responsive and flexible to the people that use them (Figure 3): This could mean:

- Being able to adapt to usage demands efficiently and sustainability
- Being safe, secure and pleasant places to work
- Enhancing the experience and productivity of users and organizations.

To the outside world, a connected building can help do many things whilst being a comfortable place to work. For example it could:

- Manage its energy needs by optimizing or generating, using and storing its own renewable power on site
- Support the charging of electric vehicles, to enable low carbon transport options for employees

Where the smart grid is connected to smart buildings – **the grid edge – is where electricity system infrastructure meets distributed energy supply and demand**. This meeting is creating opportunities for smart buildings to support the changing grid by optimizing its energy. Industries, infrastructure facilities, campuses, commercial areas, and buildings can reduce their energy consumption, produce their own energy, participate in energy markets, and optimize the performance of their business assets.

**What does a sustainable building of the future look like?** This presents many opportunities in the energy transition for users to re-imagine what a sustainable building will be in the future: we believe that this is the grid interactive building.

# 4 The grid interactive building – what does it look like?

### The grid interactive building – an opportunity to turn buildings into a source of energy

The emerging grid interactive building incorporates newer and smarter technologies.

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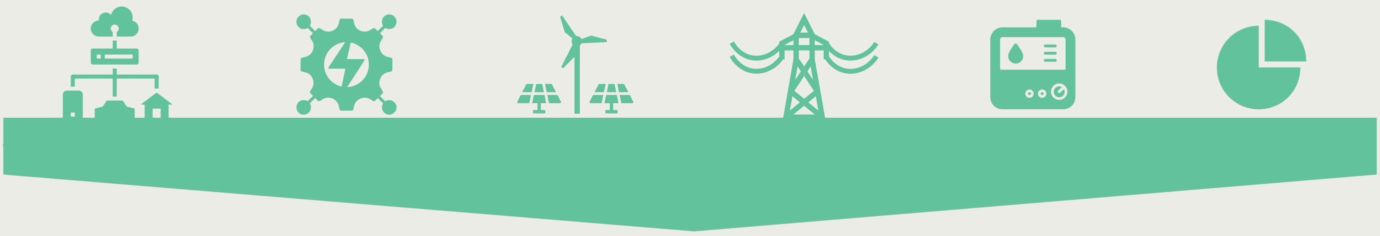
***What is an energy prosumer?*** An energy prosumer both consumes and produces energy, enabling it to take from, and provide power to, the grid. Using control and management systems means that buildings can specify and plan when they do this.

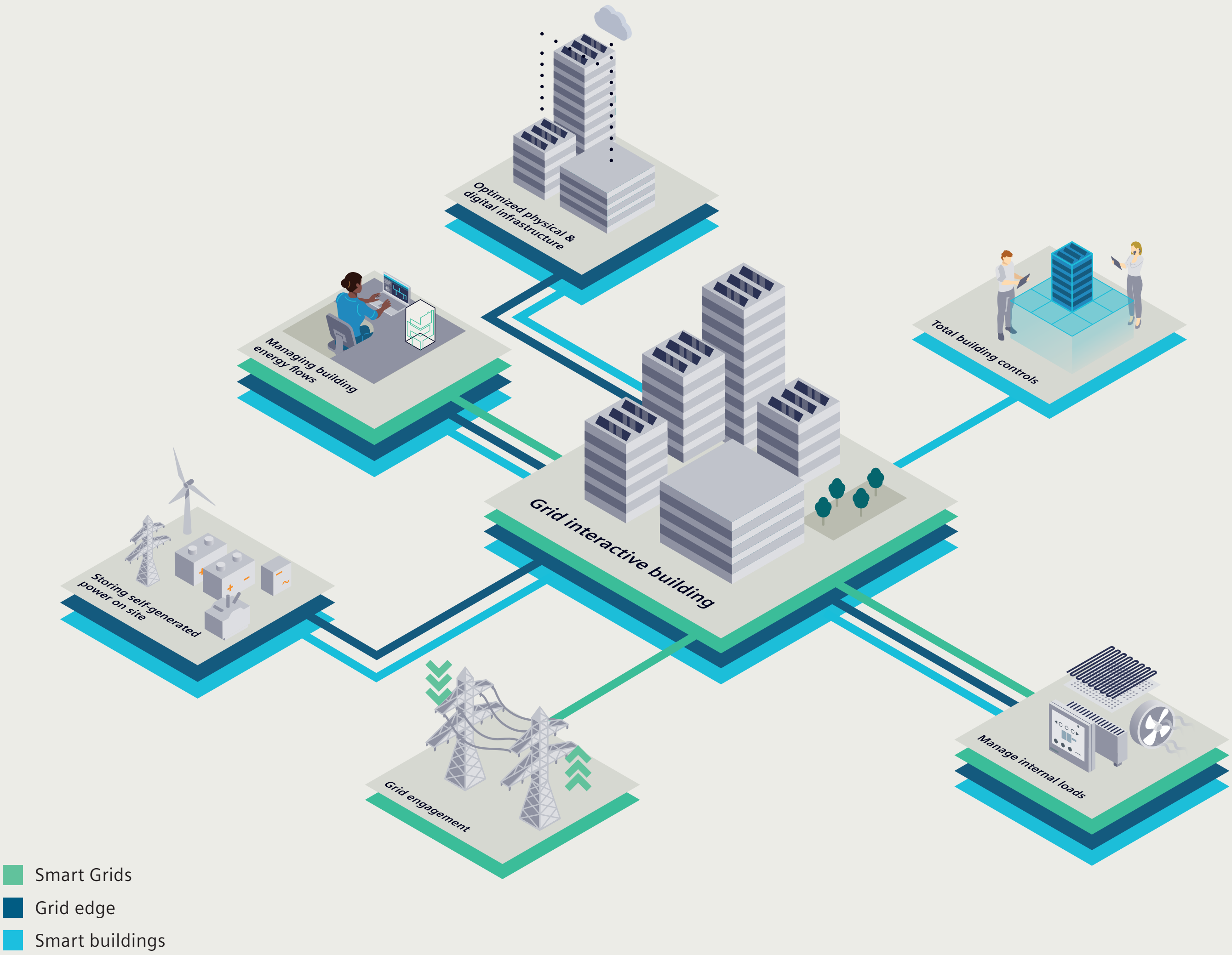
### How can a smart building optimize its energy at the grid edge to be a grid interactive building?

Here are three stages organizations can take to become a grid interactive building:

1. **Load management: This is where all electricity loads within a building footprint are managed. In practice, this means:**
   - Understanding where all loads are located – a critical step for the grid-enabled building
   - Measuring and visualizing these loads at an individual level, and then at a grouped level, using smart controls and software
   - Validating and accepting energy reading and taking internal action to address anomalies/ errors, like fixing or upgrading equipment
   - Continuous analysis to benchmark usage patterns and improve energy efficiency
   - Using automation and enhanced algorithms to predict or suggest more energy efficiency actions to make better decisions. For example, by digitally modelling and simulating energy loads and patterns
   - Connecting all load management into a single view so that energy in single areas or sites can be visualized together.

| 1. Optimized physical & digital infrastructure | 2. Managing building energy flows | 3. Storing self-generated power on site | 4. Grid engagement | 5. Manage internal loads | 6. Total building controls |
|---|---|---|---|---|---|
| Technology such as BEMS, production equipment, IT networks, HVAC are fully digital and connected, so a clear picture of a building is known. This is then monitored, and then optimized for cost or workflow, with the right software. | An energy management system (EMS) is in place tracking with sub-metering of internal loads. Flows of energy within the building, and to the grid are monitored with efficiency actions taken at the right time, place and volume. | On site renewables can be installed, to reduce the need to import grid power and decarbonize energy directly. Excess power that is not needed when generated can be stored on site with battery or hydrogen storage systems, and used to power fleet or employee electric vehicles. | With stored power and grid connection, the building can now act as prosumer to the grid. The customer and grid benefit, both selling and or buying capacity to or from the energy market - depending on the cost tariffs available at a particular time or day. | Combining all facilities that are connected and digital, with a clear picture of energy flows, internal building loads can be optimized for occupants' benefit. This could be smart HVAC systems, intelligent lighting or dynamic windows for ventilation. | Bringing all the building, energy and grid access technologies together, this control system manages the building as a smart interactive asset. Forecasting usage and financials as well managing internal workflow allows grid and building benefits. |
| **Technology Examples** | | | | | |
| Cloud gateways and connected controls | Building & energy management systems | Solar, wind, storage & EV charging design, build and operations | Optimizing grid tariff and demand response markets | Monitoring and optimizing via energy analysis services | Using digital twin or room automation |





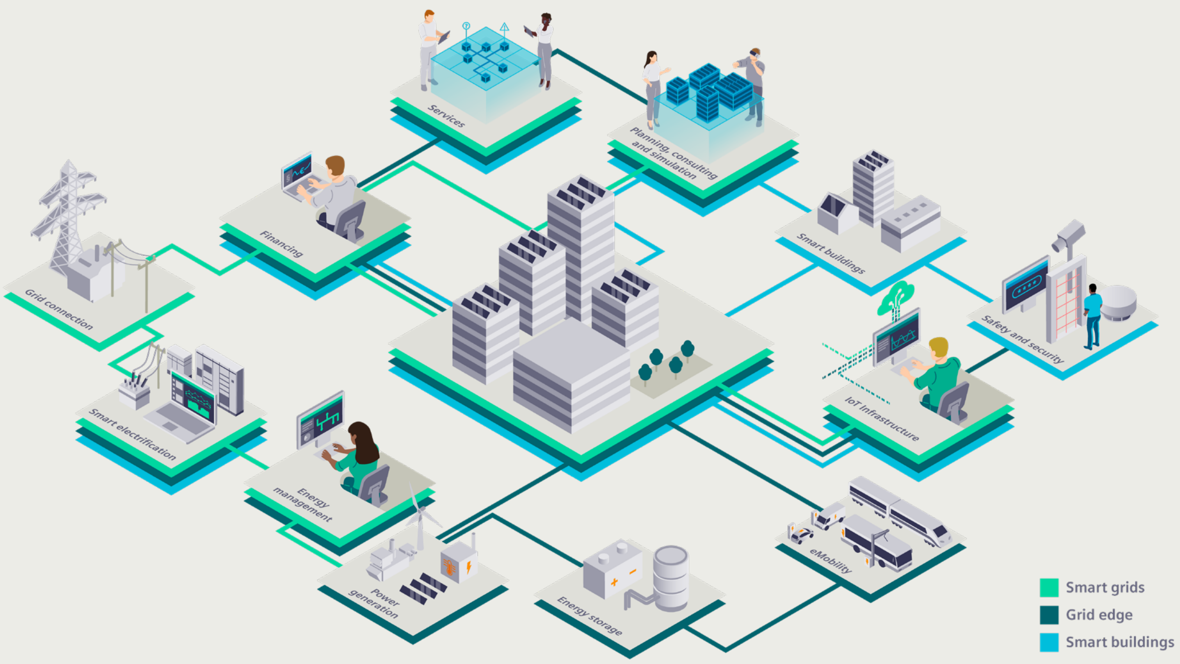



Figure 4: Optimization within buildings and campuses

**2. Optimization within buildings and campuses:**
Once energy is seen at individual building or area levels, organizations can bring together a portfolio of the many buildings within a campus, to have a centralized energy management view.

Rather than one building, optimization enables energy managers to see the impacts across all their loads across all sites, and where the impact of different or new devices and technologies are.

For example, becoming a prosumer, generating and using renewable power onsite, can change the need and pattern of grid energy use, as well as encouraging processes to run when generation is at its peak.

This can then lead to making better decisions on how to optimize energy use and budgets, based on criteria from non-critical processes to financial targets, to operational needs. It can also help with financial or operational decisions on how to introduce new technology.

For example, installing electric vehicle chargers could be seen as helping provide low carbon future fleet and commuting options for employees and the impact on building energy needs can be modeled in advance.

RMIT Melbourne: a grid interactive campus

# Case study: Royal Melbourne Institute of Technology (RMIT), Melbourne, Australia

In 2007, RMIT set out on an ambitious sustainability program to reduce energy and water use and carbon emissions by 25 percent. At the time, the Sustainable Urban Precincts Program (SUPP) was the largest of its kind in the southern hemisphere.

The program represented a commitment of AU$128 million across its three campuses in Melbourne, with Siemens responsible for the works on the City campus.

Targets were set to reduce grid electricity use by 263 million kilowatt hours over eight years and achieve an annual reduction in carbon emissions of 30,000 tons.

## Powering the campus through a local energy solution

A key aim at the campus solution was to become less dependent on mains electricity by installing a local energy supply solution.

A single point of connection was created with the high voltage ring main, integrating three sub-stations and an autonomous cogeneration power system.

The high voltage ring main solution was one of the most ambitious precinct infrastructure upgrades in Australia, with significant technical barriers that needed to be overcome.

Not only does this build resilience to potential grid constraints, it also makes operations much more efficient.

**3. Demand flexibility**

Once an organization understands its loads and the internal patterns and needs and has the ability to make decisions on future technology, it can start to look at a future where it interacts and optimizes with the grid, at a building level.

In open energy markets, smart digital grids are providing signals to end users, via energy tariffs and specific financial incentives at certain times of the day or year when the grid has too little or too much energy to keep it balanced.

## Understanding what the benefits are for both the organization and the grid, and the actions investors can take will help shape how buildings can be made smarter, reduce carbon emissions, provide grid stability and generate revenue.

End users and generators can be encouraged to use more or less to help reduce grid strains and are paid to do so – if they have flexibility in their electricity demand.

In order to participate in demand flexibility, organizations need to know where their demand is, what and when critical energy usage is and have the tools to activate this flexibility.

Smart buildings that are already managing and optimizing loads are better placed to both meet their decarbonized energy needs and help balance the grid.

This is the future vision – the grid interactive building, enabling and enabled by a smart low carbon grid.

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**Benefits for the grid interactive building**

| | | |
|---|---|---|
| To reduce overall consumption from fossil fuel energy sources needed and lower carbon emissions | To support and stabilize the decarbonizing, decentralizing grid by shifting its energy loads and providing storage capacity | To generate revenue for itself by marketing and selling onsite flexible energy demand or generation |

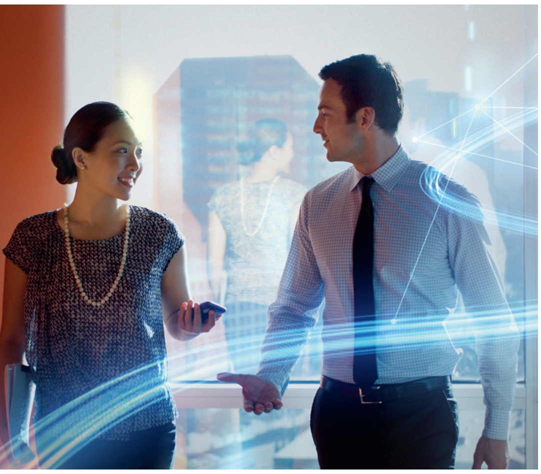
**Benefits for smart grids**

To safely and cost effectively balance electricity provision and grid maintenance to all consumers, in a changing energy system

## The benefits of the smarter grid interactive building

Whilst this vision for buildings is emerging, the aims driving its emergence are key to how we imagine and prepare our buildings now. In the context of decarbonization, grid interactive buildings have three aims:

The macro trends discussed earlier are key to understand the benefits of grid-interactive buildings – for a decarbonized system, that can manage the new technologies that enable decarbonization, and help keep the organization a success – for both employees and revenue opportunities. The grid benefits from buildings helping to take the strain of a changing energy system in a cost effective, safe and low carbon way, helping ideally to keep costs down for all in society.



# 5 What actions can building investors take?

### Benchmark where you are with a provider

The grid interactive building is made of technologies and systems, some of which you may already have in place, but may not be known as they may have been put in piecemeal over the years. Understanding comprehensively what assets and systems you have, and how well they work is critical to building a picture of how far you are from being a grid interactive building.

### Understand and map what your needs are

Consider how the building's use may change over the next 10 years. How might operations and core business aims change and what impact might this have on the use of the business? Will teams be moving to flexible or time-shifted work patterns? How will a focus on indoor air quality and employee well-being translate into how the building's energy is managed and planned for? What carbon or energy efficiency steps do you need to take? Planning these, even though they may change, gives you a basis to review what options there are available to you.

### Review the options

Explore the possibilities with technology providers. The number and scale of technologies and services that are used in the grid interactive building are manifold.

# Conclusion

The grid interactive building offers carbon and people benefits but needs buildings and the grid to have three key components:

### Digitalization

This is key and a prerequisite to ensure interoperability of complex and heterogeneous systems across all buildings and grids and the flows between them. This is essential to achieve a move towards an "all-electrical world". Digital controls, systems and checks ensure that decisions for the benefit of the building and the grid can be made accurately and timely. For example, a digitalized building can be modeled, and using simulation and forecast functions in many systems, help answer strategic questions accurately, before significant investment in other new technologies can be made.

Aiming to use standard software for energy and asset management, which meet current IT requirements, but are adaptable to any potential future needs is central to this.

### Decarbonization

As covered in this paper, there is still a huge opportunity to achieve improvements in primary energy efficiency and play a role in achieving carbon targets and cutting greenhouse gas emissions.

It is likely that political conditions and regulatory environments will continue to encourage organizations to decarbonize. As well as setting targets and supporting policies, this is likely to increasingly focus on enabling measures to modernize facilities. Innovations with new technology and business models are likely to be a result of government policy and support. Financial packages and innovation, (that mean large consumers customers do not need upfront investment), are also being encouraged via government support.

Ensuring that customers understand the policy and regulations that apply to them and which measures are supported is core. Organizations can then examine how business models are now shifting to CAPEX-lite with the options of benefiting cash flow, whilst still decarbonizing.

### Democratization

The grid interactive building decarbonizes buildings through digitalized technologies, and the grid, reducing wider energy strains and supporting the whole energy grid system. Reducing and mitigating stresses and strains of the energy system, cuts costs across the energy system, as well for the building site itself.

This is both the costs of shifting to decarbonized generation sources but also the cost of modernizing energy. Reducing costs across the system is a benefit for all of society. The grid interactive building brings organizations in buildings into a closer relationship with society, supporting all in society impacted by grid costs.

Indirectly, a part of this is providing electrical resilience and so increasing the reliability of the energy system. Using buildings to increase resilience in the energy system is a valuable new contribution in the new energy system, which could not have happened in the old energy system described above.

This localized impact sits against a general political and social consensus of the "Green Deal", made more critical in a post-COVID recovery. Interventions and actions providing the tailwind for a decarbonized and integrated energy system, accelerating the political, scientific and social consensus on climate change.

## Abbreviations

| | |
|---|---|
| BEMS | Building Energy Management Systems |
| C&I | Commercial and Industrial companies |
| EV | Electric vehicle |
| HVAC | Heating Ventilation and Air-Conditioning |
| LED | Light Emitting Diode |
| PV | Photovoltaic |

## Endnotes

1 IEA, Buildings sector energy-related CO2 emissions in the Sustainable Development Scenario, 2000-2030, IEA, Paris https://www.iea.org/data-and-statistics/charts/buildings-sector-energy-related-co2-emissions-in-the-sustainable-development-scenario-2000-2030. Direct emissions exclude indirect emissions from electricity and heat consumption. Indirect emissions in 2019 are 7.0 Gt

2 University of Calgary, https://energyeducation.ca/encyclopedia/Gigatonne#cite_note-1

3 Figure 2. 2019 Global Status Report for Buildings and Construction Towards a zero-emissions, efficient and resilient buildings and construction sector, 2019 IEA/UNEP

4 https://www.greenplan.gov.sg/key-focus-areas/energy-reset

5 Addressing decarbonization at the grid edge, 2020 https://new.siemens.com/global/en/company/topic-areas/smart-infrastructure/energy-and-performance-services/decarbonization-whitepaper.html

6 Renewable energy generation patterns are different to conventional fossil fuels, being more variable. This is known as intermittency and creates issues when the energy is fed into electricity grids for those balancing grids.

### In collaboration with Delta-EE

Delta-EE is a leading European research and consultancy company providing insight into the energy transition.

Their focused research services include Connected Homes, Electrification of Heat, Electric Vehicles, New Energy Business Models and Local Energy Systems. They provide consultancy for clients including network companies, policy makers and utilities. Delta-EE's mission is to help clients successfully navigate the change from 'old' energy to 'new' energy.

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