

How a Home Energy Management System Improves Sustainability and Resiliency

White Paper 515

Version 1

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Executive summary

The residential segment represents a large percentage of the world's electricity consumption – 29%. This consumption is continuing to grow with the electrification of vehicles (i.e. EVs) and adoption of heat pumps for heating homes. Solutions are emerging to reduce the CO₂ impact, such as onsite solar generation, energy storage, and demand response programs. With sustainability becoming a top-of-mind criteria to mitigate global warming, energy supply and demand in the home must be managed accordingly. In this paper, we discuss the sustainability and resiliency challenges that arise in operating a sustainable home and describe how a home energy management system (HEMS) that links the supply and demand can address these challenges. Builders that understand these trends and requirements will be best equipped to help homeowners ensure critical systems are available and lower their carbon footprint and energy cost.

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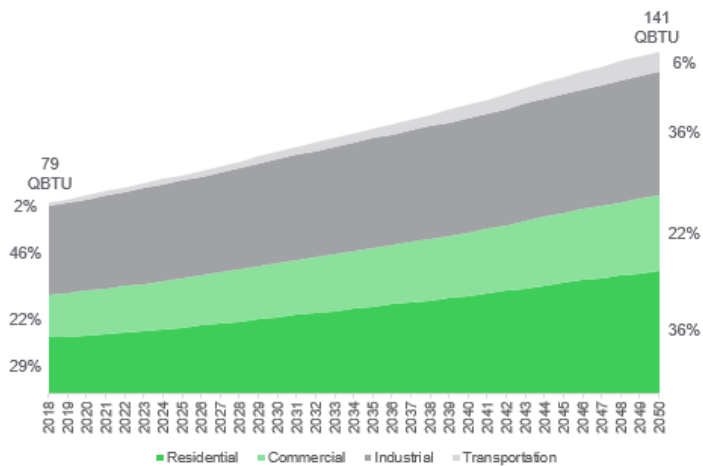
Introduction

The residential segment is a leading contributor to overall global electricity consumption and is one of the biggest carbon dioxide emitters. **Figure 1** illustrates residential buildings are the 2nd biggest sector for *electricity* consumption today (29%) and will be tied for 1st at 36% by 2050 when electricity consumption is forecasted to be 15,000 TWh or 51 QBTU, which represents a growth of 120% from 2018. There is a common misperception that since homes are small in footprint relative to commercial and industrial buildings, it ranks much lower on environmental impact, but the reality is collectively, the global electricity consumed by residential is greater than commercial buildings and is a close second to the industrial segment.¹

Figure 1

Global electricity final consumption forecast by sector, 2018-2050,

Source - International Energy Outlook 2019 (EIA)



Home buyers are increasingly focused on sustainability objectives. A new study conducted by E.ON Energy found that **89% of prospective buyers want sustainable homes** that are kind to the planet.² In the US, the percentage of dedicated green single-family homebuilders has grown from 18% in 2014 to 21% in 2019.³ “Green” homes focus on many aspects of sustainability. The common strategies that builders focus on include:

- **Reducing energy use** – more efficient appliances, more insulation, tighter building envelope, LED lighting, using daylight in the design, etc.
- **Using renewable energy** – installing solar systems and onsite energy storage to maximize [self-consumption](#)
- **Optimizing grid consumption** – [demand side management](#) and flexibility based on CO₂ footprint and price of grid electricity (kWh)
- **Conserving building materials** – using recycled/reclaimed/reused building materials, minimizing construction waste, prefabricated components
- **Conserving water resources** – rainwater collection and re-use, water-conserving plumbing, drought-resistant landscaping
- **Improving indoor air quality** – environmental measures like ventilation systems, filtration

In this paper, we focus on the first three, which center around **energy use and its associated carbon emissions**. With sustainability and resiliency being a priority and technologies continuing to advance, we are seeing many changes in the energy supply and demand for homes, making them much more complex to manage. We discuss these trends and challenges that arise for homeowners and then

¹ IEA, [Electricity consumption by sector, World 1990-2019](#)

² E.ON, [Sustainable solutions beat gardens as the most desirable feature for homebuyers](#)

³ NAHB SmartMarket Brief, [Green Single Family & Multifamily Homes 2020](#)

describe how a home energy management system that links the supply and demand can address these challenges.

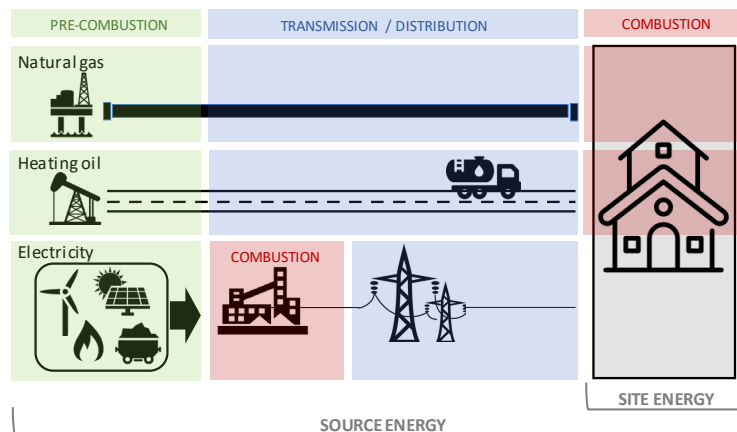
Builders that understand these trends and requirements will be best equipped to help homeowners take control of their loads, ensure critical systems are available, and reduce their carbon footprint and energy cost.

Trends in energy supply

Historically, energy supply for residential buildings was very simple, and one directional. Consumers purchased electricity generated by their utility provider. They also acquired natural gas and/or oil, in many cases, for specific home loads like space heating ventilation air conditioning (HVAC), cooking, and water heating. The CO₂ emissions that resulted were based off the [emissions factors](#) of those energy sources and amounts consumed⁴ (See [Figure 2](#)).

Figure 2

Historically, residential buildings relied primarily on energy from electricity, heating oil, and natural gas from utility providers



There are four key trends related to energy supply which are causing energy management challenges for homeowners:

- **Lower carbon electricity from grid** – Utilities are shifting their generation sources to greener approaches (solar, wind, nuclear) which decreases the emissions from electricity purchased.
- **Increasing risk and impact of grid-supplied power outages** – there has been an increase in electricity outages by utility providers, bringing resiliency needs to the forefront.
- **Varying rate structures** – Utilities are applying varying rate structures, based on energy demand at different times of the day as well as seasonally.
- **Onsite generation & storage** – Homes are generating their own electricity with renewables and storage, a shift towards net-zero emissions while being self-sustaining and selling excess back to the grid (a “[prosumer](#)” mindset).

Below we discuss these four trends in greater detail.

Lower carbon electricity from grid

The 2020 global mix of electricity generation is illustrated in [Figure 3](#), which equates to a CO₂ emissions of 544 kg CO₂/MWh⁵ of electricity consumed. This

⁴ Schneider Electric White Paper 504, [Factoring Carbon Pricing into Business Decisions: A Building Heating Case Study](#)

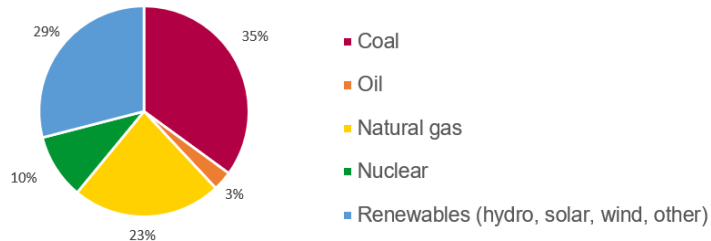
⁵ Schneider Electric TradeOff Tool, [Building Heating Method Comparison Calculator](#)

electricity generation mix is very localized and can vary greatly depending on your location and time of day, but regardless, it is a significant lever for your CO₂ emissions.⁶ Each year, utilities are shifting this mix more and more towards renewables to reduce the emissions per MWh⁷, with the end goal of creating net-zero carbon emissions from generation. **Because the utility's renewable mix varies with time of day, and is evolving year over year, it becomes challenging for the homeowner to know how best to power their loads to maximize the CO₂ benefit of the utility's green energy sources.**

Figure 3

2020 global electricity generation mix

Source - [IEA](#)



Increasing risk and impact of grid

In some parts of the world, such as in Australia and USA, there has been **an increase in electricity outages**, bringing resiliency needs to the forefront. A report by the US Department of Energy cited **weather-related** power outages as the leading cause of power outages. Events like wildfires and other extreme events are in some cases driving utilities to intentionally shut power off for public safety. The DOE report and the Pew research both also acknowledge an **aging infrastructure** as part of the problem.⁸ In some areas, strategies include intentional brownouts to help utilities avoid rolling blackouts; and yet others are mandating reductions in energy consumption to help meet the needs of the entire energy grid for that area. **These types of events are putting resiliency on the priority list and driving interest and demand for onsite generation.**

Varying rate structures

In an effort to drive behavior that flattens the demand curve (so utilities can avoid firing up costly peaker plants), some utilities are now shifting from fixed residential electricity rates to time of use (TOU) rates, sometimes referred to as time-varying rates (TVR). The price of electricity varies depending on the time of day and the season. Your energy bills are determined, in part, by when you use electricity and how much you use. If you're able to adjust your energy use based on time of day, day of the week, it can help lower your bill. **To do this effectively, homeowners must have a good understanding of their load profile and have the ability to shift or reduce key loads.** Some examples of countries implementing this are below:

- California, USA has TOU as their default rate structure now.⁹
- In Italy, TOU rates have been mandatory since 2010 for all low-voltage residential customers.¹⁰

⁶ IEA, [Global electricity generation mix by scenario, 2018, Stated Policies and Sustainable Development Scenarios 2040](#) Note, emissions used to construct the electrical plant are excluded from these values.

⁷ IEA, [Net-zero by 2050, A Roadmap for the Global Energy Sector](#)

⁸ Energy Professionals, [Power Outages on the Rise in the US](#)

⁹ Southern California Edison, [Time-of-use Rate Plans](#)

¹⁰ ECEEE Summer Study Proceedings, [Evaluation of the effects of a tariff change on the Italian residential customers subject to a mandatory time-of-use tariff](#)

- South Australia’s SA Power Networks (SAPN), which serves around 1.7 million customers, has recently proposed offering default TOU rates for residential customers with interval meters starting in July 2020.¹¹
- In France, regulations will oblige the utility providers to impose tariffs to their consumers.¹²

Onsite generation & storage

Onsite solar (PV) generation

Solar generation is the most commonly deployed onsite generation in residential buildings. **Figure 4** illustrates the steady growth of these PV installations around the world.

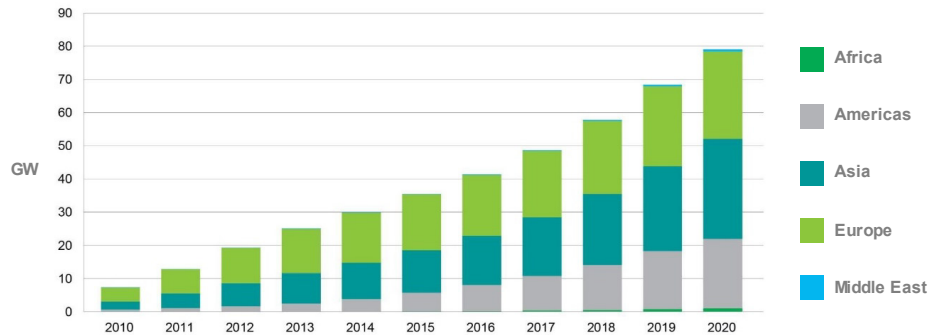


Figure 4

Residential solar installations

Source - [PV Europe](#)

While in many locations, this is done *by choice* in an effort to go “green” and save energy expense in the long run, there are some locations beginning to implement policies that *mandate* solar as part of new residential construction or include them in [tariff designs](#) and rebates as an incentive. For instance,

- California, USA has established a solar mandate – “a building code that requires new construction homes to have a solar photovoltaic system as an electricity source.”¹³ This code went into effect on January 1, 2020.
- Germany – “In 2018, the German city of Tübingen introduced a requirement for solar PV to be installed on roofs of buildings wherever cost-effective, with municipally led leasing options for those unable to self-finance the systems.”¹⁴
- 10 states in the USA are looking to pass legislation over the next 2 years requiring solar on new construction similar to California. “The coordinated national campaign will advocate for a solar home requirement in at least 10 states: Colorado, Maryland, Massachusetts, Michigan, Minnesota, Nevada, New Mexico, North Carolina, Pennsylvania and Texas.”¹⁵

While many homes install rooftop solar panels to have a clean energy source, this creates a challenge in balancing supply and demand. Power generation from solar panels peaks during the day when the sun is out, however, oftentimes, energy consumption peaks during morning and evening hours. **When users are connected to a utility grid, solar panels, and have onsite energy storage (discussed later), managing and controlling what loads get what source of electricity, and when, becomes more complex.**

¹¹ SA Power Networks, [Tariff Structure Statement Part B, Dec 10, 2019](#)

¹² French-Property.com, [French Electricity Tariffs](#)

¹³ EnergySage, [An overview of the California solar mandate](#)

¹⁴ SolarPower Europe, [EU Market Outlook For Solar Power / 2019 - 2023](#)

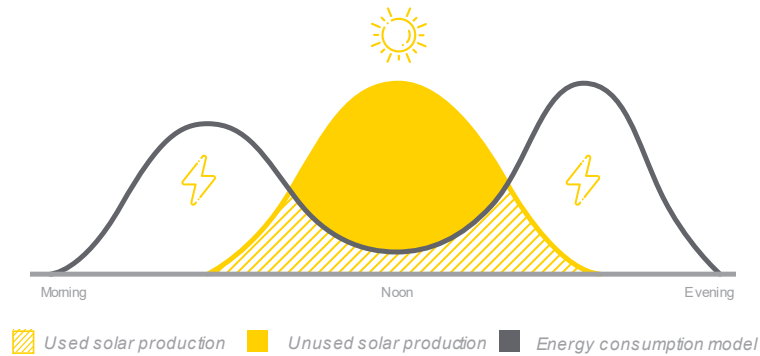
¹⁵ Solar Power World, [Environment America calls for 10 states to pass mandates for solar](#)

Onsite energy storage

Because of the intermittent nature of energy generation from PV installations (see **Figure 5**), onsite energy storage (e.g. lithium-ion batteries) is important for storing any excess energy generated, to use when the supply from the PV is less than the demand (consumption). Without energy storage, system operators may need to curtail the homeowner's PV generation, reducing its economic and environmental benefits.

Figure 5

Typical residential energy consumption profile vs. solar generation over a day

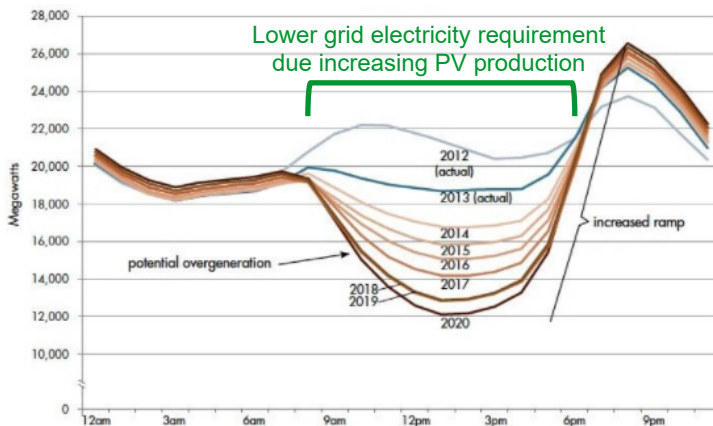


Without wide adoption of onsite energy storage, as solar adoption increases, it also becomes increasingly challenging for *utilities* to balance the grid's supply and demand. "This is due to the increased need for electricity generators to quickly ramp up energy production when the sun sets and the contribution from PV falls."¹⁶, as **Figure 6** illustrates. This could stress the grid and impact the resiliency of grid-producing electricity.

Figure 6

California utilities "duck curve" challenge as onsite solar adoption increases

Source - [Office of Energy Efficiency & Renewable Energy](#)



Onsite generation with storage provides homeowners with the added benefit of keeping loads running during a utility power outage, such as those caused from weather or accident events. While these are generally deployed as standalone battery systems, as technology continues to advance, we can envision further integration. For example, an electric vehicle (EV) battery could become the home's backup energy source (referred to as "vehicle to home" or **V2H**). In fact, Ford's electric F-150 has this capability which "enables the pickup truck to act as a reserve of energy storage for homes during their most crucial times".¹⁷ This onsite power generated could even be exported to the grid (referred to as vehicle to grid or **V2G**). This **prosumer behavior further adds to the complexity in managing the home's energy**, as it is dependent on available capacity, pricing, and the grid's demand to purchase the excess energy.

¹⁶ Office of Energy Efficiency & Renewable Energy, [Confronting the Duck Curve: How to Address Over-Generation of Solar Energy](#)

¹⁷ Green Cars, [Ford F-150 Lightning EV Can Power Your House](#)

Trends in energy demand

In addition to the supply trends just mentioned, we are also seeing some key trends on the energy consumption side for residential buildings. These include:

- **All-electric shift** – Homes traditionally used mixed energy sources (gas, oil, electricity) for loads in the home, but this is shifting to all electric.
- **New load types** – Technology is enabling new load types in the home such as EVs, “smart” devices, and energy-efficient rated appliances.
- **Increasing consumption due to work-from-home practices** – In addition to the new loads, we are seeing an increase in household energy consumption driven largely by work-from-home (WFH) practices.

All-electric shift

As utilities shift towards cleaner generation sources for electricity, using electricity in homes for loads like **HVAC**, water heating, and cooking becomes a lower carbon alternative compared to fossil fuels like natural gas, coal, and oil. Therefore, with the objective of reducing CO₂ emissions, there is a growing trend towards “100% electric” homes. **This leads to a significant increase in electricity consumption, as loads like HVAC and water heating are “heavy loads” in the home.** Increasingly, we see legislation banning the use of non-electric sources. Examples include:

- San Francisco, USA – A recent building code ordinance requires that new residential building construction be all electric on or after June 1, 2021. “All indoor and outdoor space-conditioning, water heating, cooking, and clothes drying systems must be all-electric.”¹⁸
- Massachusetts, USA – The towns of Brookline, Arlington, Lexington, Concord, and Acton have all passed measures asking legislature “to allow them to prohibit the installation of fossil fuel infrastructure in new construction”.¹⁹
- United Kingdom – “Natural gas boilers and all other forms of fossil fuel heating will officially not be permitted in new homes from 2025 on.”²⁰

New load types

In addition to shifting to “all-electric” consumption, new load types are increasingly becoming standard in homes – specifically, EVs, efficient loads, & “smart” devices.

Electric vehicles

The global EV market is growing at a rapid rate because of its potential to decrease CO₂ emissions²¹. As homeowners make the shift from gas-fueled to electric vehicles, they must consider the implication on their home’s energy consumption profile, as these EVs must be charged.

Figure 7 illustrates the mix of electricity consumption of a typical household without EVs compared to one with EVs. **The chart illustrates a significant shift in load mix, and EVs becoming the largest electricity consumer in the home, at 41% of the total.** Because of this, **it is crucial to understand your charging requirements based on the vehicle(s) owned, expected driving distances, electricity rate**

¹⁸ City & County of San Francisco, [All-Electric New Construction Ordinance](#)

¹⁹ Energy News Network, [Massachusetts cities try new legal path toward banning new fossil fuel hookups](#)

²⁰ H&V News, [Government confirms 2025 new build ban on all existing boilers](#)

²¹ If EV charging uses utility electricity instead of onsite solar, the mix of electricity generation impacts the CO₂ footprint.

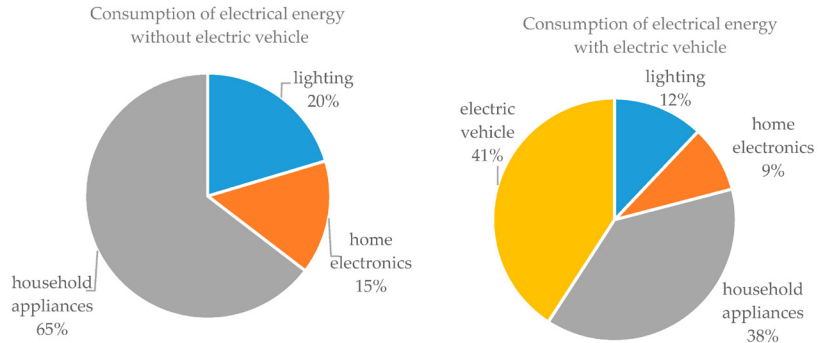
structure, etc. in order to optimize charging times to reduce cost and carbon impact.

Homeowners may also face difficulties while integrating new heavy loads like EVs due to the home’s power limits, requiring a change of their electrical installation (i.e. switching to 3PH circuits) which is both costly and challenging to manage. Although highly variable, based on the factors mentioned above and your household’s baseline electricity consumption, EVs can increase an electric bill by more than 30%.²²

Figure 7

Residential electricity consumption breakdown with and without EVs in residential buildings

Source - [MDPI](#)



Energy-efficient loads

Many load types in households have improved in efficiency over time. An ongoing trend in managing consumption and the associated cost and carbon footprint is to replace old inefficient systems with more efficient systems. One simple example is replacing old lighting with LED lighting, or old appliances with energy-efficient (e.g. Energy Star) appliances.

Smart devices

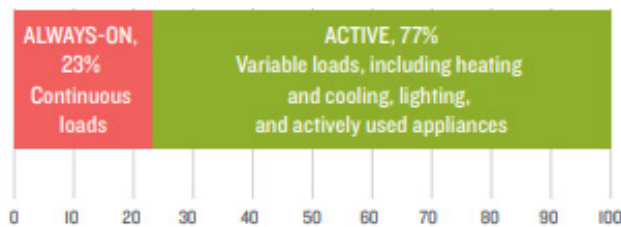
Digital technology trends like artificial intelligence, big data, and internet of things (IoT) are driving an explosion of “connected” and “smart” devices in the home. From lighting, to appliances like refrigerators and washers/dryers, security/doorbells, and exercise equipment, the list goes on and on. While not the biggest energy consumers in the home, these new connected loads leverage connectivity, sensors, and data to provide the homeowner with important insights on their energy usage to make informed and/or automated decisions that reduce energy. Note, however, these reductions are not at the same magnitude as the large consumers we previously discussed like HVAC, heat pumps, pool pumps, and EVs.

With advancement in technologies, many home devices and appliances require an energy supply, not only for their intended function, but also when switched to off, low-power, standby, or sleep mode. **These “always-on but inactive” devices can have significant consequences, responsible for 23% of the energy consumption in residential buildings, according to recent study (Figure 8).** This is an additional challenge towards achieving efficiency and sustainability goals.

Figure 8

Always-on loads represent 23% of residential energy consumption in Northern California

Source - [NRDC](#)



²² The Driven, [How much will an EV add to the average household electricity bill?](#)

Increasing consumption due to work-from-home practices

According to the IEA, in April 2020, around one-third of the world population was in complete lockdown due to the Covid pandemic, and houses became an office for employees and a classroom setting for students. This situation forced about 59% of employees to work from home and changed the pre-pandemic pattern of energy usage in residential buildings²³.

Before the pandemic, residential electricity consumption was high early in the mornings and lower during the day, with peaks in the evening. During the pandemic, electricity demand elevated more later in the morning, and remained steady at an increase of 16% during working hours, leading to an overall increase in electricity consumption²⁴, by running systems such as air conditioners, lighting, and appliances during work hours. For example, average energy usage for an HVAC unit increased by 25% in the month of April 2020 compared to the same month for the years 2017-2019²⁵. According to IEA, in one workday, the energy consumption of a residential building with individuals working remotely from home rose by 7-23% compared to one day when those individuals work at their companies' offices. The exact increase varied depending on several factors such as the size of the home, climate zone and season, and other household appliances such as computers, printers, lights. For example, a desktop computer, alone, can increase the homes energy consumption by 0.1kWh per hour or 0.8kWh over an 8-hour workday²⁶, which translates to almost 3% of a typical home's daily consumption of 28.9kWh²⁷.

Figure 9 illustrates the increase in residential consumption during the pandemic in the USA, along with the associated decrease in commercial consumption. Many companies learned through this pandemic that flexible work-from-home practices could be effective. There is also significant evidence that employees prefer that flexibility. In fact, according to a McKinsey & Company survey, today more than 50% of the global workforce prefers to work from home three days per week or more.²⁸

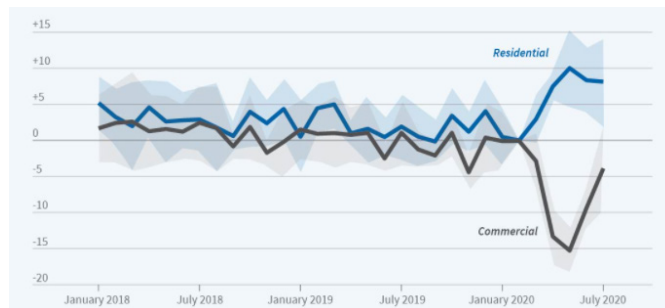


Figure 9

Increased residential electricity and the associated decrease in commercial consumption, during the Pandemic

Source - [National Bureau of Economic Research](#)

As a result of the effectiveness and interest level, we are seeing an increase in companies announcing changes to their policies allowing employees to work longer term from home in varying capacities. **This means we can expect the increased residential energy consumption in a typical home to remain, which has a direct impact on the home's carbon emissions.**

²³ IEA, [Working from home can save energy and reduce emissions. But how much?](#)

²⁴ NBER, [Working from Home's Impact on Electricity Use in the Pandemic](#)

²⁵ ScienceDirect, [Review analysis of COVID-19 impact on electricity demand for residential buildings](#)

²⁶ OVO Energy, [Average electricity usage in the UK: how many kWh does your home use?](#)

²⁷ Electricity Plans, [What Is A Kilowatt-hour \(kWh\) And What Can It Power?](#)

²⁸ McKinsey & Company, [What employees are saying about the future of remote work](#)

Home energy management systems

As the above sections describe, the home's energy supply and demand are changing, with the presence of onsite renewables, energy storage, varying rate and tariff structures, new load types, increased electricity demands, and so on. This makes it significantly more challenging to monitor, control, and optimize the home for sustainability and resiliency.

When builders and homeowners seek to achieve sustainability and resiliency objectives, they often reference the need for a "smart home". A smart home, according to the Oxford Dictionary, is "a home equipped with lighting, heating, and electronic devices that can be controlled remotely by phone or computer." There are two distinct components to smart homes that sometimes confuse homeowners:

home automation and **energy automation**.

- **Home automation** - Lighting control, shutter control, security system management, door-entry-system control, smart thermostats, entertainment systems, etc. Systems like Google Home or Amazon Alexa are examples that fit in this category.
- **Energy automation** – Optimization of energy use, carbon footprint, and energy cost, through the convergence of home automation, control of onsite energy generation and storage, and control/automation of large loads; Energy automation is achieved through a Home Energy Management System (HEMS).

While home automation is helpful towards improving sustainability and resiliency objectives, there is a larger opportunity for savings and emissions reduction. For example, smart thermostats can be used to reduce heating and cooling energy consumption, and in some cases even be connected and controlled by the utility (through signal transmitters) based on real-time peaks in demand, but this is one of many devices interacting (either directly or indirectly) in a home. Manual coordination of these will typically result in suboptimal energy consumption. A human can try to perform the coordination of (1) the shades going up/down to maximize the sunlight and heat source, (2) turning down the heating set point and dimming or turning off the lights, and (3) checking the weather forecast to see if the sun will be out, and if not, pre-heating the house so they don't get hit with the high tariffs at 4pm., This simple example shows how complex this coordination can become. We believe a more comprehensive platform (HEMS) is needed that can perform these tasks in a coordinated way *automatically*. In this section we clarify what we mean by a HEMS, and describe what functions and attributes to look for.

What is a home energy management system (HEMS)?

A home energy management system is a comprehensive technology platform made up of both hardware (the energy center, where all energy flows converge) and software (smart algorithms) that enables the homeowner to minimize energy consumption & cost, minimize carbon footprint, and ensure resiliency, through insights, orchestration, and control/automation of energy sources (supply) and key loads (demand). A HEMS combines home control/automation, energy sources, and loads (like the EV charging system), to not only lower the home's consumption and carbon emissions but also to enable the consumer to be a "prosumer", where they can leverage their produced clean energy to sell back to the grid and optimize ROI.

There are 6 key functions of a home energy management system. These are summarized in **Table 1** and then later described through examples.

Table 1*6 key functions of a home energy management system*

Function	Description	Why important
Real-time power & energy monitoring & visualization	Provide a clear view of power & energy usage and trends of key devices in the home's electrical network	Spot the inefficiencies that increase your consumption; leverage insights to reduce use
Device on/off notification	Inform you when devices are powered on or off	Ensure resiliency of critical loads and identifies potential failures
Orchestration of energy sources	Determine the optimal energy source to supply to the loads, based on homeowner's priorities (e.g. cost, CO ₂)	Optimize self-consumption of solar and storage
Load control leveraging available energy sources	Turn loads on/off based on availability & costs of energy sources like solar; participate in demand response programs	Run loads when you can leverage lowest CO ₂ emissions energy sources and/or off-peak pricing; Ensure power contract limits are not exceeded
Load control leveraging weather insights	Notify you of the best action according to weather conditions	Optimize energy consumption based on weather conditions; loads can be adjusted based on forecasted weather events
Energy bill & CO₂ tracking, notification & insights	Suggest the best time of use by responding to price & carbon signals in real time	Set the usage limits to avoid high tariffs and ensure CO ₂ footprint is minimized through smart consumption

Real-time power & energy monitoring & visualization

Real-time monitoring and visualization of the power consumption (kW) and energy use (kWh) is an essential first step in managing your energy. Having data on a device by device level allows you to spot the biggest and most inefficient loads in the home. The heaviest loads are generally the HVAC system (i.e. heat pumps), water heater, and EV charging, along with pool pumps for homes with swimming pools. Although not all loads are on their own dedicated circuits, it is important that you're able to identify each load, whether it be a plug and socket, electric oven, or EV, to take the proper steps toward energy efficiency improvement. This can be accomplished with a system that recognizes the distribution and energy use profiles through analytics.

Device on/off notification

A HEMS should notify the homeowner when specific devices/loads change state from on to off or off to on. This is an important element of ensuring resiliency. For example, this can help by informing you there is a power outage and you have to switch to a backup source; or there is a specific appliance that has failed; or an overloaded circuit or electrical faults that caused loads to shut down.

Orchestration of energy sources

With multiple energy sources to choose from, a system must orchestrate what source is supplied and at what time. The system optimizes self-consumption of solar and storage, to help the homeowner achieve a faster payback of their investment. Two examples of how energy source orchestration can help are:

- Based on demand peaks on the electric grid and the availability of onsite solar, switch to the best source to reduce CO₂ emissions and/or cost.
- Lower your temperature set point by 2 degrees to increase the runtime from battery energy storage by 4 hours.

Load control leveraging available energy sources

The system should prioritize green energy sources, ensuring power-hungry appliances and devices, such as EVs, consume most of their energy from onsite solar or other decarbonized energy sources. For example, while it may seem logical to charge the EV overnight because charging between 10pm – 6am can save on electricity costs, it may not be the lowest CO₂ option since solar is not available during night hours. Because this is not always intuitive, a system that controls and automates these decisions and tradeoffs (based on homeowner priorities) between the emissions factors, costs, and available sources is necessary in this complex environment. The system must also manage the consumption of key loads to ensure total consumption does not exceed the power limit contracted with the utility provider.

Load control leveraging weather insights

Weather data and insights can be instrumental in effective load control, based on relationships with different loads. For example, an effective system should be able to orchestrate based on sensor data to close the shades/shutters to prevent the indoor temperature from spiking and lower AC set point to save energy. It should also take into account the weather forecast to know to charge your home battery and EV ahead of the scheduled time(s) when a storm is on the horizon or know to turn the lights off when sufficient sunlight is coming through windows during peak daylight.

Energy bill and CO₂ notification and insights

A HEMS plays an even more important role in energy cost management in countries where utilities have imposed time of use (TOU) tariffs and where homeowners have installed battery storage to power their homes with stored electricity when tariffs are high. The system does this by responding to price signals in real time, notifying users of the best time of use and cheapest energy per hour, providing the homeowners with information to take actions that minimize their energy expenses. Users can access and analyze their usage, energy bills and benchmark it with their past bills or similar buildings nearby. These practices also prove advantageous for utility companies as shifting demand from peak times to off-peak periods naturally reduces strain on the electrical grid infrastructure. The system should also report on CO₂ emissions – at both appliance and home level; and track progress over time, driving behavior towards energy and overall CO₂ emissions reduction.

Homeowners are increasingly participating in demand response programs. These programs “provide an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.”²⁹ The HEMS should help orchestrate this by automatically load shedding/shifting.

An example of a system that performs these 6 key functions is the Schneider Electric Wiser Energy Center. This system goes beyond multiple discrete smart devices and becomes the brain that enables orchestration of the three elements of the home: energy sources (onsite and utility), key loads (e.g. EV system), and the control/automation system (as **Figure 10** illustrates). **A home with such a system could save 20% on the annual electricity bill.**³⁰

Although not listed above as a key function, there is a clear trend towards further interaction with the grid. More and more, homeowners are choosing to not only support their own loads with onsite energy, but also to generate income by selling the excess solar energy generated to the utility provider. In fact, it was under this assumption that many homeowners justified the expense of their solar installations. In

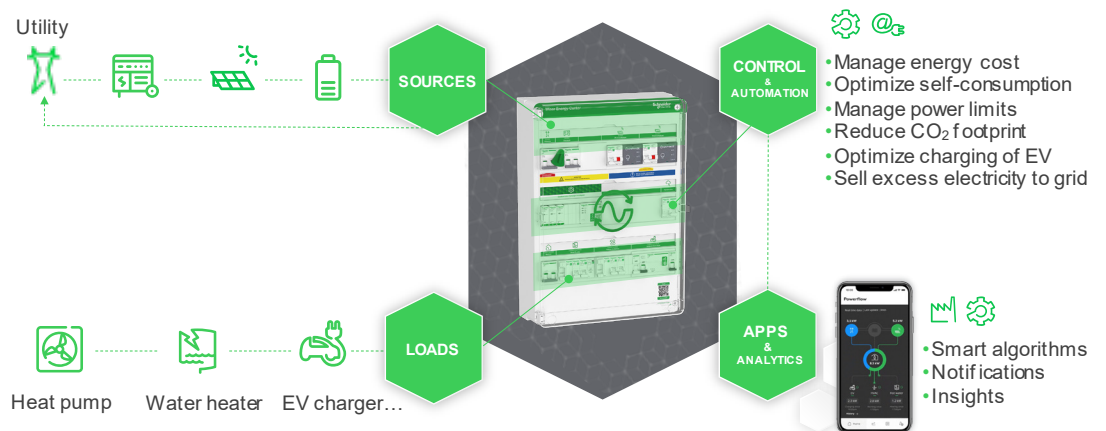
²⁹ Energy.gov Office of Electricity, [Demand Response](#)

³⁰ Sense, [The Biggest Sense Savings in 2019](#)

In addition to monetizing solar electricity, in the near future, homeowners will also be able to sell the energy stored in battery energy storage systems (including EV batteries). A home energy management system will need to coordinate this prosumer activity as this trend continues.

Figure 10

Conceptual architecture of a home energy management system



Attributes of an effective home energy management system

A home energy management system with the following 5 attributes, we believe, is best suited to fulfill the key functions just described.

- Leverages artificial intelligence (AI) and machine learning
- Integrates with multiple communication protocols for flexibility
- Stores information securely
- Installs quickly and simply
- Enables cost-effective energy retrofits to future-proof the home

Leverages artificial intelligence (AI) and machine learning

By leveraging AI and machine learning, an effective HEMS should get smarter as it learns energy usage patterns over time. This enables the home to become autonomously managed. AI can also help identify specific device loads in the home. This is important because most home devices today are not connected to the internet and they act as individual components, not part of a complete system. Even if these devices are connected, they often lack the ability to communicate their power consumption. How can we then know when to use them, charge them, to take control of our electricity? A HEMS with AI and machine learning technology can look at all the power in a home and identify key devices and loads that drive consumption.

Integrates with multiple communication protocols for flexibility

Interoperability is critical. An effective system should integrate with all the common software interface devices such as google assistant, amazon home Alexa, and phone apps that bring the smart home applications and power together to make homes more efficient, resilient, and convenient to monitor for users. This system should have wireless connection to the internet and be able to monitor and control devices regardless of their communications protocols. A system that supports protocols such as Wi-Fi, Zigbee, Bluetooth Low Energy (BLE), and Matter, as well as supporting Cloud APIs will provide more flexibility and interoperability. It is also essential that a HEMS can connect and interoperate with the onsite generation/battery energy storage systems, as well as with the grid.

Stores information securely

A home energy management system collects massive amounts of data about energy usage, communication between devices, and scheduling. The information about the devices that are being monitored, energy supply, and demand behavior can reveal personal routines to phone/applications or web services remotely or locally. Without effective security in place, the beneficial attribute of integration with multiple communication protocols, increases the risk of a data breach or even manipulation of your energy.

A proper HEMS should have a comprehensive level of security to prevent any data breach or system manipulation by encrypting all the data. It should inform users of any malicious activity and only allow authorized users to access the information gathered by the system.

Installs quickly and simply

A system that can be installed easily and quickly means less cost and quicker ROI. Electrician work is minimized helping to ensure the homebuilder can complete the project on time and avoid penalties due to extended delivery dates.

Some home energy management systems today look like the **top image in Figure 11**. It is unorganized, unstandardized, and made up of separate parts and pieces that aren't designed to work together. A well-integrated, standard system, on the other hand, like that in the **bottom image of Figure 11**, significantly simplifies the installation process, saving time, and avoiding risk of downtime due to human error. A single integrated panel that controls and communicates wirelessly has the added benefit of saving wall space and avoiding the unappealing aesthetics of wall clutter. The smaller space requirement also means the homebuilder can offer homes with optimized configurations.

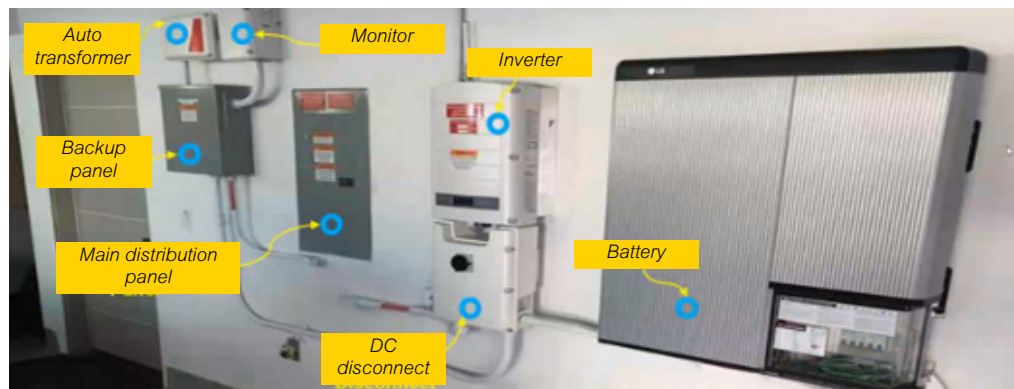
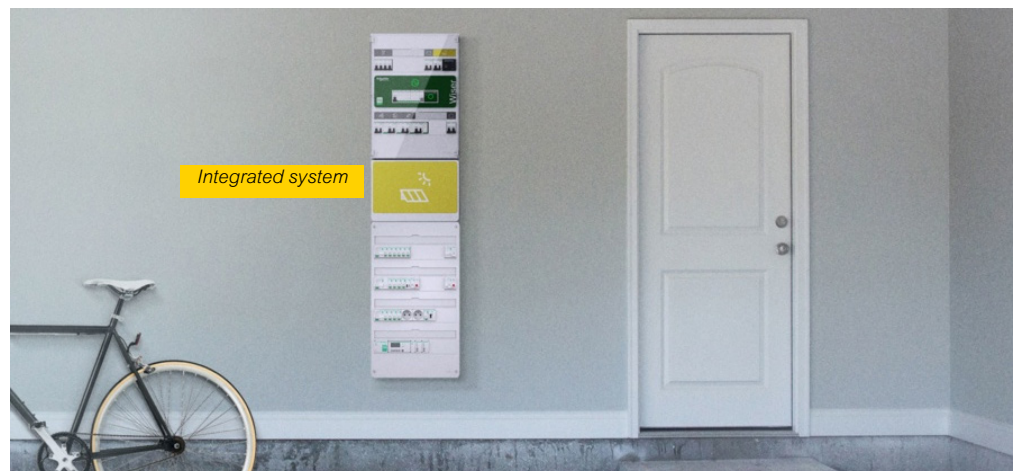


Figure 11

Comparison of an unorganized, disparate system (top) vs one that is simple, standardized, and integrated (bottom)



Guidance for builders

Enables cost-effective energy retrofits to future-proof the home

Not all homes have solar panels, generators, battery energy storage, EV charging systems, etc. at the time the home is built. In fact, most do not. There is a high likelihood, however, that many will require these types of upgrades down the road. This becomes an issue with disparate energy management systems which can't retrofit very easily. Therefore, an effective HEMS must enable home upgrades without major inconvenience of wiring changes to the home, downtime, and cost. It should eliminate the need for costly additional equipment, which usually requires a licensed electrician, and be simple, safe, and modular to upgrade in under an hour. A system with the electrical infrastructure already in place to receive solar and/or EV enables this integration. Homebuilders then have the opportunity to build future-proof homes that are equipped with not only the basic requirements but also the infrastructure to allow for upgrades when requested by the home buyers or even some years later after occupancy.

To get to the global net-zero goal, homebuilders, mortgage providers, and homeowners need to be empowered by the right technologies and solutions. Many homebuilders are already implementing various "green" practices, but installation of a HEMS where everything converges in one standardized panel is not yet common. Implementing this, however, enables builders to add significant value to the home, with minimal additional man-hours and cost. For a minimal capital cost investment, it provides some key selling points. Specifically, it helps them:

- meet current and future "green" regulations and certifications
- reduce energy usage and energy expense by 20-30%
- increase home sale and rental values
- differentiate their homes to provide a competitive advantage
- demonstrate commitment to environmental, social & governance (ESG) goals

Meet current and future "green" regulations and certifications

As we previously discussed, there is a growing shift towards regulations in certain parts of the world around "green" homes, such as the requirement for all-electric loads and solar installations. As these evolve, homes must comply to them. In addition, there are a number of optional certifications for residential buildings that builders and/or homeowners can obtain to demonstrate and verify the "green" performance of the home. Obtaining these can directly impact the interest level in the home, reflects on your business' construction processes as being sustainable, and can increase the value of the home (described later). Two examples are:

- Leadership in Energy and Environment Design (LEED) certificate by US Green Building Council (USGBC)³¹
- Green Star certificate by the Green Building Council Australia (GBCA)³²

To obtain these certifications, the home needs to meet certain criteria such as being fully electric, having proper insulation and ventilation, using EVs, demonstrating energy efficient systems, and being powered by renewables. The LEED certificate is a point system where the more green practices you implement, the higher the point total. "Energy and atmosphere" accounts for 38 out of the possible 110 points. A HEMS that effectively tracks energy usage, predicts solar and other onsite energy availability, and controls loads enables the home to more easily implement the

³¹ US Green Building Council, [LEED Credits](#)

³² Savings.com.au, [Green Building Council Australia releases world-first Green Home certification](#)

green practices to achieve these points since the system is standardized, all-in-one, and flexible to changes.

Reduce energy usage and energy expense by 20-30%

Reduction in energy usage not only plays an important role in GHG emissions but also has a big impact on the financial strategy of the household. The upfront capex of implementing many of the green practices is quickly paid back due to the substantial energy savings. According to USGBC, “LEED homes use less energy and water, which means lower utility bills. On average, certified homes use 20 to 30 percent less energy than non-green homes, with some homes saving up to 60 percent.”³³ Having a HEMS for the comprehensive control of energy helps ensure this reduction in energy and expense is realized.

Increase sale and rental values

Buildings that are equipped with “green” practices are getting very popular and many homebuyers are showing greater interest in investing in homes that are more sustainable. According to the European Commission, better energy performing residential buildings increase the sale value up to 14% and rental value up to 5.2%³⁴. It’s often assumed that green technologies come at a cost premium. But the increase in value to the homeowner at time of sale easily exceeds the cost of the green technology improvements. In addition, in some countries, financial entities are now offering better mortgage conditions if the home is equipped with a high energy performance rating.

Differentiate their homes to provide a competitive advantage

By offering a home with an integrated HEMS, the homebuilder can distinguish their homes from the competition. As green homes become increasingly desirable, this differentiation will become even more crucial.

Demonstrate commitment to environmental, social & governance (ESG) goals

Building homes that are sustainable helps demonstrate the homebuilders’ own commitment to sustainability and ESG goals. Large builders and developers, in particular, usually measure their own ESG performance. Integrating HEMS to improve energy performance ratings can help them achieve their own internal commitments.

³³ US Green Building Council, [LEED certification for residential](#)

³⁴ European Commission, [The Macroeconomic and Other Benefits of Energy Efficiency](#)

Conclusion

Residential buildings represent a significant percentage of the world's energy and CO₂ emissions. With sustainability and resiliency being top-of-mind, and “smart” technologies continuing to advance, there are many changes happening in the energy supply and demand for homes. The supply is no longer a fixed-rate feed from a utility provider, rather it is an interconnection of sources, including those generated and stored onsite such as solar panels and battery energy storage. Demands in the home are also evolving, including a shift to all-electric homes, new load types like EVs, and an overall growth in consumption due to an increase in work-from-home practices. These changes make energy in the home much more complex to manage.

We believe a more comprehensive platform is needed that manages from grid to plug to ensure resiliency and sustainability. A home energy management system or HEMS fills this need. This system interlinks the energy supply and demand, allowing the homeowner to gain insights on their energy status and consumption as well as more control and automation of their energy sources and devices. Specifically, a HEMS must be able to monitor energy in real-time, alert to device power status, orchestrate varying energy sources, control loads based on available energy sources and weather insights, and provide energy insights based on cost and CO₂ emissions. We believe fulfilling these functions effectively requires a system that (1) leverages AI, (2) integrates with multiple communication protocols for flexibility and interoperability, (3) stores information securely, (4) installs quickly and simply, and (5) enables cost-effective retrofits as needs of the home evolve.

A homebuilder that implements a home energy management system is positioned to meet current and future “green” regulations and certifications, reduce energy use and expense by 20-30% for their home buyer, and increase the sale and rental value of homes by up to +14% and 5.2% respectively. Implementing HEMS also helps differentiate the builder's homes to provide a competitive advantage, and demonstrates their own commitment to environmental, social & governance (ESG) goals.



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