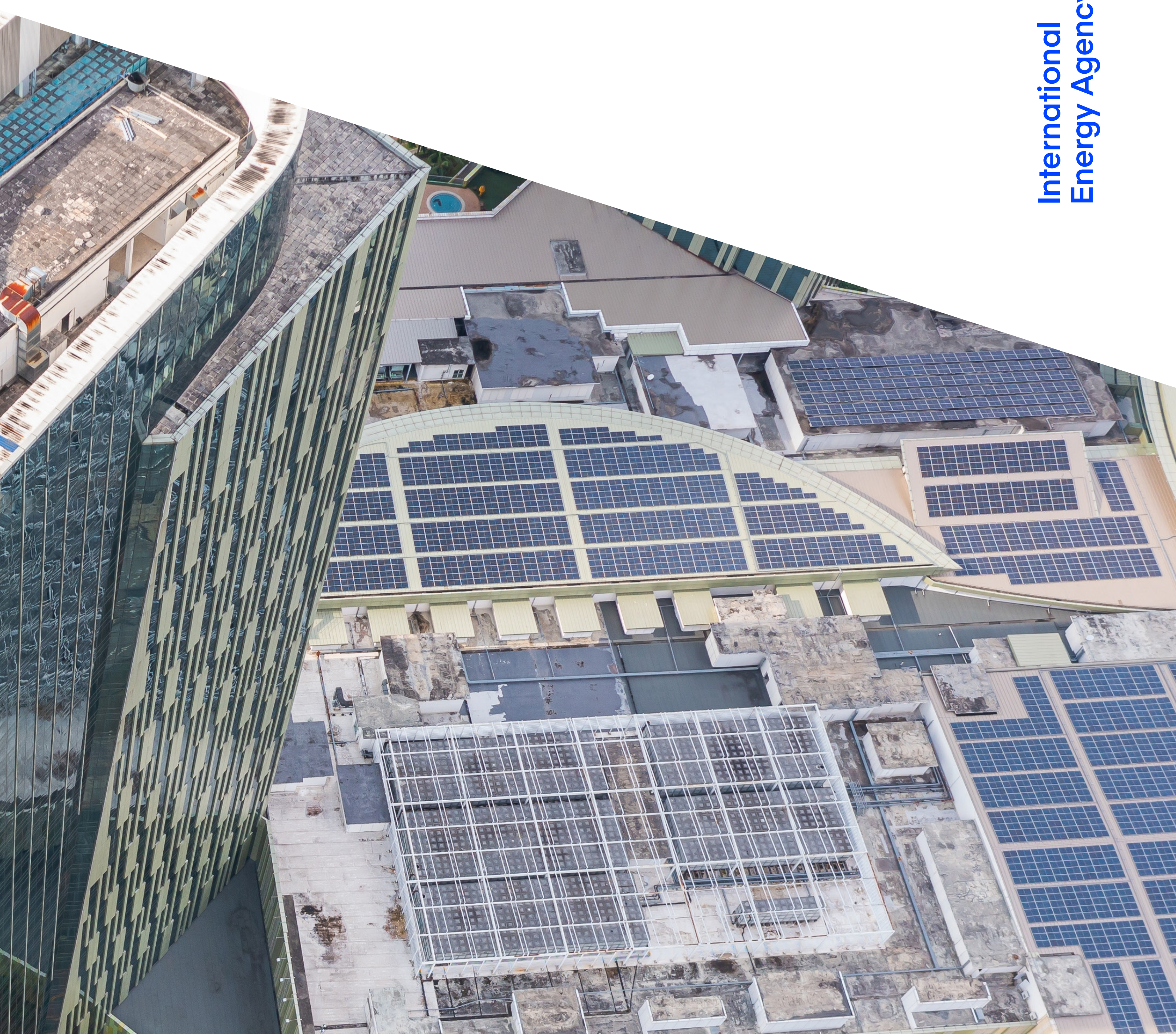
# Efficient Grid-Interactive Buildings

## Future of buildings in ASEAN

International Energy Agency



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# Abstract

A future with net zero emissions requires scaling up improvements in energy efficiency, electrification of end uses and renewable energy generation. For the Association of Southeast Asian Nations (ASEAN), a growing population and rising standards of living will massively increase future energy demand. Mitigating growing electricity demand and integrating renewable energy into electricity generation will therefore be paramount for the region's clean energy transition and avoid lock-in of additional fossil fuel generation. The intermittent nature of variable renewable energy and increasing deployment of distributed energy resources are putting additional pressure on existing grids. In response to these challenges, this report explores the opportunities and challenges for efficient grid-interactive buildings in the ASEAN region.

Such buildings are becoming a crucial element for the global ambition to attain net zero emissions, as they can combine enhanced energy efficiency, advanced smart digital technologies and decarbonised electricity generation. This integration creates the potential for buildings to shift from energy-intensive consumers to low-carbon prosumers, empowered by digital technologies that can offer flexibility benefits to the electricity grids. With the ability to produce, consume, store, sell and buy energy, buildings become active participants in the building-to-grid ecosystem.

Drawing on relevant international trends and best practices, the current report lays out an analytical framework to assess a variety of factors that can enable a building to become energy efficient and grid-interactive. The framework is used to analyse the current situation in countries of the ASEAN region. The report provides policy-oriented recommendations and guidelines tailored to different stages of the process for adopting efficient grid-interactive solutions in buildings. These recommendations can support ASEAN policy makers in their policy development to create an energy-efficient and grid-interactive built environment, contributing to a cleaner and more sustainable energy future.

# Acknowledgements, contributors and credits

This report was developed by the International Energy Agency (IEA) Energy Efficiency Division in the Directorate of Energy Markets and Security. It was authored by Ksenia Petrichenko, Andika Akbar and Ian Hamilton, with key contributions from Natalie Kauf and Silvia Laera. Melanie Slade, senior programme manager of the Emerging Economies (E4) programme, provided the overall guidance. Keisuke Sadamori, Director of the Energy Markets and Security Division and Brian Motherway, Head of the Energy Efficiency Division, provided strategic direction.

Special thanks go to the IEA's Digital Demand-Driven Electricity Networks Initiative (3DEN) on electricity grid modernisation and digitalisation, particularly Vida Rozite, Brendan Reidenbach and Emi Bertoli for their invaluable feedback for the development of the analytical framework.

Valuable inputs, comments and feedback were provided by several IEA colleagues in alphabetical order): Heymi Bahar, Piotr Bojek, Clara Camarasa, Nicholas Howarth, Vida Rozite, Jonathan Sinton, and Anthony Vautrin.

The work benefited from the expertise, collaborative support and stakeholder engagement provided by the ASEAN Centre for Energy (in alphabetical order): Vu Trong Duc Anh, Shania Esmeralda Manaloe, Rio Jon Piter Silitonga, Septia Buntara Supendi, and Beni Suriyadi.

The authors would like to thank a number of international experts, including those from the Association of Southeast Asian Nations (ASEAN) countries for their valuable inputs and support during the data collection process and review of the report (in alphabetical order): Alam Awaludin (Perusahaan Listrik Negara [PLN], Indonesia), Steven Beletich (Beletich Associates), Gnan Bora (Ministry of Mines and Energy, Cambodia), Andrew P. Catayong (Department of Energy, Philippines), Oum Chansophea (Ministry of Mines and Energy, Cambodia), Alex Chong Chia Chuan (Nanyang Technological University, Singapore), Hoang-Anh Dang (Hanoi University of Science and Technology, Viet Nam), Halil Haron (Tenaga Nasional Berhad [TNB], Malaysia), Kartina Hasim (TNB, Malaysia), Chalermluk Jitrumpueng (Department of Alternative Energy Development and Efficiency, Thailand), Daniel Collin Jornales (Department of Energy, Philippines), Myat Thet Khaing (Ministry of Electric Power, Myanmar), Agnes Koh (Energy Market Authority, Singapore), Regina Lee (Energy Market Authority, Singapore), Rodel S. Limbaga (Department of Energy, Philippines), Naing Naing Linn (Ministry of Industry, Myanmar), Wisaruth Maethasith (Department of Alternative Energy Development and Efficiency, Thailand), Kumareshan Mardappan (Energy Commission, Malaysia), David Morgado (Asia Development Bank), Sanjib Kumar Panda (National University of Singapore), Mohammad Asri bin Puasa (Department of Electrical Services, Brunei Darussalam), Kritika Rasisuddhi (Electricity Generating Authority of Thailand [EGAT]), Anouphanh Simmachanthavong (Electricité Du Laos, Lao PDR), Phonepasong Sithideth (Ministry of Energy and Mines, Lao PDR), Evi Wahyuningsih (independent consultant, Indonesia), Radityo Cahyo Yudanto (Ministry of Energy and Mineral Resources, Indonesia).

Special acknowledgement goes to the following members of the IEA Technology Cooperation Programme on Energy Buildings Communities for their feedback and inputs to the report provided under the guidance of Malcolm Orme (in alphabetical order): Noel Chin (Building and Construction Authority, Singapore), Rongling Li (DTU – Technical University of Denmark), Meli Stylianou (Natural Resources Canada), Stephen White (Commonwealth Scientific and Industrial Research Organisation [CSIRO], Australia).

Thanks also to the IEA Communications and Digital Office (CDO) for their help in producing this publication, especially to Poeli Bojorquez, Curtis Brainard, Jon Custer, Astrid Dumond, Merve Erdil, Isabelle Nonain-Semelin, Clara Vallois, Therese Walsh.

Thanks to Erin Crum for her work copy-editing this report.

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# Executive summary

## Efficiency and flexibility are key for the clean energy transition

Energy efficiency is crucial for reducing emissions, enhancing the resilience and reliability of the energy system, and improving the well-being of people in support of the clean energy transition. In the member states of the Association of Southeast Asian Nations (ASEAN) (Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam), energy consumption has doubled since 2000, fuelling a regional economy that is two and half times larger than it was in 2000 with a current population of over 660 million. Energy efficiency therefore has an important role to play in this region.

In 2022, the global rate of energy efficiency improvement accelerated to just over 2% as the energy crisis increased costs and encouraged the improved management of energy. This followed several years of slowing global progress, including in the ASEAN region, where intensity improvements slowed from around 3% per year achieved between 2010 to 2015 to 1% per year from 2015-2020. However, to achieve global net zero emissions by 2050, global efficiency improvements need to double to 4% per year by 2030 with a tripling in annual efficiency-related investment.

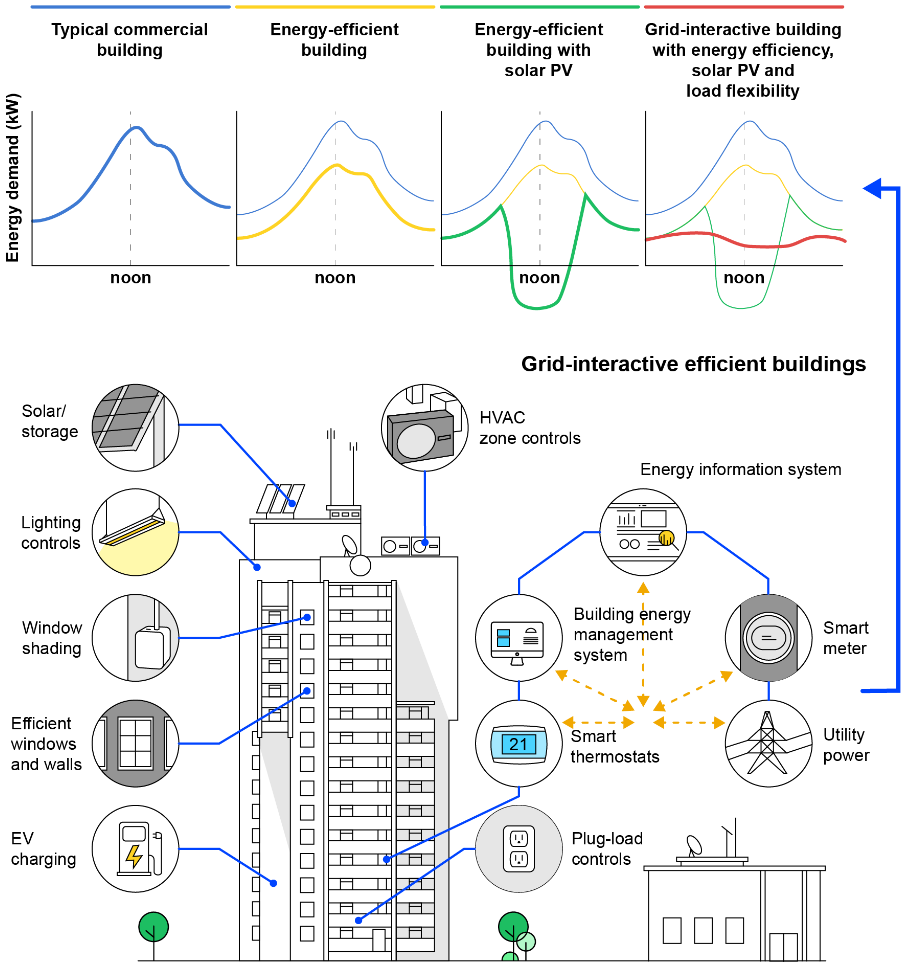
While the ASEAN average annual energy intensity is slightly below the world average, the slowdown in energy intensity improvements observed globally over the second half of the last decade was also experienced in the ASEAN region, with an annual rate of 2.8% per year from 2010 to 2015 slowing to 0.9% from 2015 to 2020. In 2021, energy intensity in the region actually worsened, rising by half of a percentage point following exceptionally strong growth in industrial energy demand. Although increased access and use of electricity for clean cooking is reducing, the reliance on polluting fuels is still around 30%. Increasing energy access in Southeast Asia is crucial for improving the quality of life and reducing people's exposure to pollution.

A future with net zero emissions also requires scaling up renewable energy such as wind and solar. These energy sources will, however, also increase intermittency within the electrical grid due to their variability and dependency on weather conditions. The grids will also be put under pressure by an increasing number of distributed energy resources, such as distributed solar PV and storage systems, electric vehicles (EVs), smart meters, and other connected equipment and devices.

# Grid-interactive buildings provide flexibility services and other benefits

Buildings offer a unique place where many distributed energy resources could be installed and connected to the grid or rely on the off-grid electricity supply, particularly for ASEAN where electricity demand is expected to increase due to growth in electricity use for space cooling and other appliances. Efficient grid-interactive buildings are energy-efficient buildings that have high-performance building envelopes and design as well as efficient appliances and equipment. They are also smart, optimising energy performance through the use of sensors and controls and intelligent analytics. These buildings are equipped with sensors and meters that can send and receive signals to respond to the grid and are flexible, meaning that energy loads can be optimised through behind-the-meter generation, demand response and energy storage.

**Efficient grid-interactive buildings: Technologies and demand flexibility benefits**

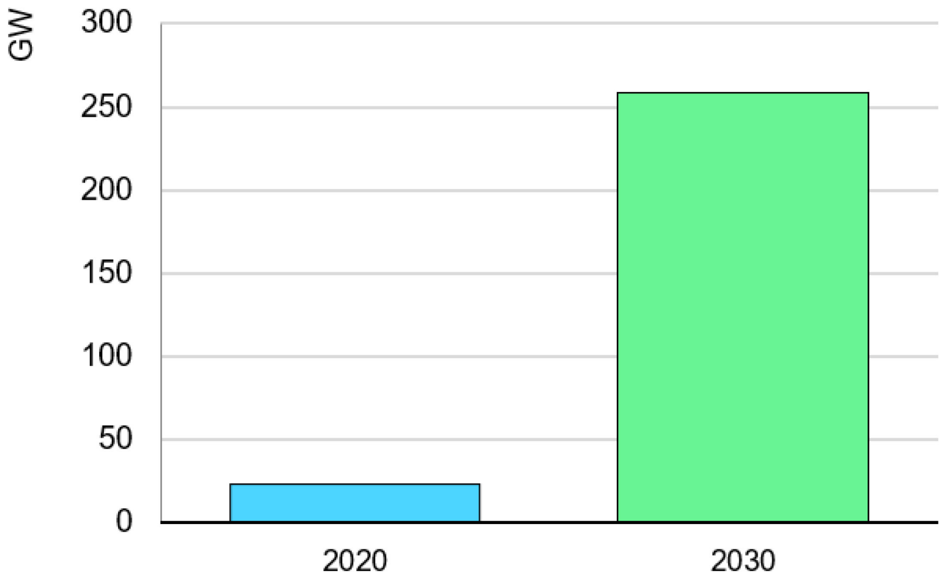





Notes: kW = kilowatts; HVAC = heating, ventilation and air conditioning.
Source: IEA (2022), Unlocking the Potential of Distributed Energy Resources.

These features, alongside smart solutions applied on the grid's side, can help increase power system flexibility by taking advantage of power demand variation and greater input of variable renewable electricity generation. To be in line with pathway to net zero emissions, by 2030 the global power system flexibility needs to more than double and the availability of demand response in buildings to increase more than tenfold by that time. Adoption of efficient grid-interactive buildings can lead to significant energy savings and peak demand reductions.

**Global demand response availability in buildings at times of greatest flexibility needed by 2030, within the Net Zero Emissions by 2050 Scenario**






Notes: GW = gigawatts; TWh = terawatt-hours.
Source: IEA (2023), Tracking Demand Response.

This report presents a novel analytical framework developed by the IEA that assesses key enablers for adoption of efficient grid-interactive buildings.

This framework is intended to provide a methodology to assess the policy readiness of countries to enable efficient grid-interactive buildings and future-proof their buildings sector efficiency policy. While this methodology could be applied to any country, the IEA applies this framework through this report to the example of ASEAN member states. ASEAN was chosen for this analysis because of the rate at which the Southeast Asian region is growing and developing the buildings sector as well as the region's high potential for energy efficiency improvement. It was also chosen due to the IEA's long-standing partnership with ASEAN member states and regional institutions, as well as an in-depth expert knowledge of the region. The high-level recommendations and group-specific guidelines offered in this report are presented in the context of the ASEAN region; however, the framework is intended to be able to be used as a standalone global methodology, which could be applied to any jurisdiction.

## Efficiency, decarbonisation, smartness and building-to-grid interaction are key for efficient grid-interactive buildings

Within the framework for efficient grid-interactive buildings the identified enablers are grouped into four categories: energy efficiency, decarbonisation, smartness and building-to-grid interaction.

The key enablers for *energy efficiency* are i) high-performance building envelopes and ii) energy-efficient appliances and equipment. Building envelopes as well as the HVAC, water heating and lighting systems determine buildings' energy demand and impact thermal comfort, indoor environmental quality and safety. Beyond building energy codes, which address the efficiency of the building itself, improving the energy efficiency of appliances and equipment is key, including setting minimum energy performance standards and other supporting policies, spurring innovation, and investing in technology.

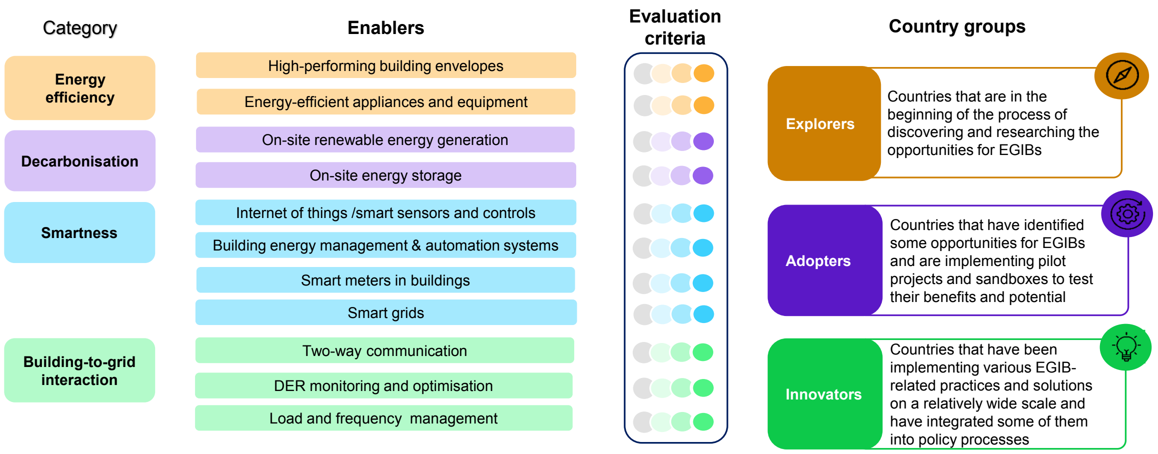
The key enablers for buildings *decarbonisation* are i) on-site or nearby renewable energy generation and ii) on-site energy storage. Distributed variable renewable energy generation can help to significantly decarbonise energy used in buildings. Buildings can also have energy storage, such as battery systems, to help integrate variable renewable energy generation, and mitigate fluctuations in energy supply and demand.

The key enablers for *smartness* are i) the internet of things; ii) building energy management and automation; iii) smart meters in buildings; and the development of iv) smart grids. The internet of things is a network of connected equipment, sensors and devices in buildings that communicate with one another, collect and analyse data from key building equipment to optimise energy performance. The internet of things can be integrated using building energy management systems to control parameters of the indoor environment and a building's energy consumption. Smart meters can collect and store data on actual energy consumption in buildings on an hourly or more detailed basis. Smart meters can help to collect real-time data on energy use in buildings on a very detailed basis. Smart grids and their enabling solutions help optimise system operations, reduce costs and increase generation efficiency.

The key enablers for *building-to-grid interaction* are i) two-way communication; ii) distributed energy resource monitoring and optimisation; and iii) load and frequency management. Building-to-grid interaction requires interoperability, meaning both sides can communicate with each other. Equipment and appliances need to be able to respond automatically to signals from the grid by changing electricity consumption or production. Open communication protocols can help establish interoperability and automated control to manage voltage and quality fluctuations that could be caused by distributed energy resources. Advanced metering infrastructure can enable real-time data collection and analysis, demand response, and outage detection. Digital tools can help not only manage individual distributed energy resources but also aggregate them into a single entity controlled and operated as a unified system, such as a virtual power plant, which can monitor and manage electricity generation, consumption and storage across multiple sites. Load and frequency management strategies can support this through demand response programmes, dynamic electricity tariffs and smart charging for EVs.

Based on the assessment of a country's context for each of the enablers, the country can be placed into one of the three groups: Explorers, Adopters and Innovators, depending on the stages of adoption of efficient and grid-interactive technologies and policies.

**Assessment framework on enablers for efficient grid-interactive buildings**






Notes: DER = distributed energy resources; EGIBs = efficient grid-interactive buildings.

## Growing energy demand increases the need for efficiency and flexibility in ASEAN buildings

Buildings operations account for close to one-third of the global final energy consumption and for 27% of total energy sector emissions. Electrification of end uses, e.g. space heating and transport, is driving electricity demand growth further. In the buildings sector, improving energy efficiency of building envelopes and of appliances and equipment can significantly lower energy demand. In 2020, the ASEAN buildings sector represented around 4% of global buildings demand and emissions and around 5% of global electricity demand in buildings, though these numbers are likely to grow.

In 2022, ASEAN electricity demand grew by 5.5% and is expected to increase 4-6% per year until 2025, largely due to increasing standards of living alongside population growth and rapid urbanisation. Growth in buildings electricity demand represents almost 50% of total electricity growth in ASEAN by 2025 from 2020. Additional demand will largely be in the buildings sector and is likely to be met by fossil fuels. Higher appliance ownership and an increased demand for cooling could drive up energy demand in Southeast Asia by 15% in 2030 and 60% in 2050. Space cooling will also account for almost 30% of peak electricity demand in the region by 2040, up from around 10% in 2017, and will require about 150 GW of additional generation capacity to meet the peak levels.

## Enablers for efficient grid-interactive buildings are present in ASEAN, but need to be scaled up

Several ASEAN member states have already adopted some form of building energy codes, but their implementation could be scaled up to achieve larger energy efficiency improvements. Buildings in ASEAN that were certified with green building schemes demonstrated energy use intensities 20-70% lower than that of comparable uncertified buildings. All countries in the region now have some form of minimum energy performance standards and labelling policies for air conditioners and some other types of appliances either in force or under development. However, countries need to increase their stringency, scope and enforcement. Moreover, aligning with the recommended harmonised levels of minimum energy performance requirements for air conditioners in the region can drive more substantial energy savings and environmental benefits.

ASEAN's commercial and residential deployment of solar PV is estimated to almost triple from 2022 to 2027. However, to enable this deployment, countries must invest in grid infrastructure, simplify permitting procedures, create ambitious targets and attract international investment. The use of energy storage in buildings is limited but there are some projects to that indicate potential for growth in several ASEAN countries, such as recent investments in battery storage in Singapore.

In many ASEAN countries, electricity tariff structures are primarily flat with a fixed rate. However, dynamic tariffs, such as varying time-of-use tariffs, could help reduce peak demand and encourage consumers to reduce energy bills and even carbon emissions. Demand response programmes are increasing and are typically implemented by utilities offering financial incentives for specific groups of customers to reduce their consumption during peak hours.

## Digital technologies and enablers are key for supporting the uptake of efficient grid-interactive buildings

While there are not currently many policies mandating the use of smart digital technologies in buildings, some countries have taken initiatives to promote digitalisation of buildings through adoption of smart meters and smart grid pilots. Despite being in its infancy stage, the ASEAN building digitalisation market is expected to grow significantly. Several ASEAN countries are rolling out programmes to support the uptake of smart meters, mainly driven by the utilities, to improve data collection and accuracy of billing. In 2022, it is estimated that the total number of smart meters installed across ASEAN was around 30 million. The use of smart inverters for solar PV systems is currently limited; however, there are several pilot projects in the region under way. Smart charging for EVs in buildings could help reduce energy bills and carbon emissions while offering flexibility benefits to the grid, but it is rarely used across the region.

## ASEAN governments are recognising the need for modernised grids and standards

Improvements are needed for transmission and distribution infrastructure, including the expansion of high-voltage transmission lines and the development of smart grid technologies. Recognising this, many countries in ASEAN have developed smart grid plans to improve their grid capacity and the reliability of electricity supply. The ASEAN Power Grid will establish cross-border transmission lines that interconnect the ASEAN member states.

While building automation as well as communication protocols and technologies are increasingly being used, there are no policies to mandate their installation. Interoperability between buildings and the grid is currently very limited in the ASEAN region. Advanced metering infrastructure offers important potential for measuring, collecting, analysing and controlling energy distribution and usage, but is not common for most ASEAN countries. A promising trend in the integration of distributed energy resources in the ASEAN region is the emerging deployment of virtual power plants and peer-to-peer solar energy trading projects, for example in Malaysia, the Philippines, Singapore, Thailand and Viet Nam.

## Grid reliability of existing power systems creates challenges for consumers

Power supply reliability, which can be defined as the ability of an electrical system to consistently provide electricity to consumers without interruptions or significant fluctuations in voltage or frequency, presents challenges for many ASEAN countries. Weather events, outages, electricity theft and affordability concerns all contribute to disruptions, increased and variable costs due to energy market changes, and compromised living conditions for end users. Strengthening the power grid's resilience through infrastructure upgrades, better monitoring tools and advanced analytics supported by digital solutions can reduce the frequency and duration of interruptions in power supply.

## ASEAN countries are exploring solutions for efficient grid-interactive buildings

The assessment of status and opportunities for efficient grid-interactive buildings in ASEAN across the enablers has shown that most of the countries in the region have begun exploring different ways of improving energy efficiency in buildings and testing various smart and digital technologies, while the implementation of building-to-grid interactive solutions remains limited and is taking place only in a few countries in the region and at a relatively small scale.

This report is intended to provide a pathway for countries to be able to develop their own pathways to further enable efficient grid-interactive buildings in support of their energy transition objectives. While none of the countries assessed in this report fall into the Innovator category, this category provides an aspirational vision for ASEAN countries and may be applicable to other countries globally that are more advanced in their implementation of enabling solutions for efficient grid-interactive buildings.

**Recommendations for ASEAN countries based on the assessment of enablers for efficient grid-interactive buildings**

| | **Explorers** | **Adopters** |
|---|---|---|
| | Countries that are in the beginning of the process of discovering and researching the opportunities for EGIBs | Countries that have identified some opportunities for EGIBs and are implementing pilot projects and sandboxes to test their benefits and potential |
| | **Brunei Darussalam**, **Cambodia**, **Lao PDR**, **Myanmar** | **Indonesia**, **Malaysia**, **Philippines**, **Singapore**, **Thailand**, **Viet Nam** |
| **Energy efficiency** | Develop and implement building energy codes with mandatory EE requirements<br>Introduce MEPS and supporting policies for appliances (can be voluntary first) | Make regular updates and more stringent mandatory EE requirements in building energy codes and MEPS |
| **Decarbonisation** | Introduce voluntary requirements for on-site solar PV in buildings<br>Promote battery storage systems | Introduce mandatory requirements for onsite renewable generation and storage |
| **Smartness** | Develop voluntary smart buildings standards and requirements for smart solutions | Adopt and implement smart buildings standards and requirements for smart solutions in large buildings |
| **Building-to-grid interaction** | Conduct feasibility study on open interoperability standards and grid-readiness requirements in building energy codes and MEPS<br>Develop pilot projects for demand response and virtual power plants | Introduce voluntary requirements for grid-readiness which transition to mandatory<br>Develop mandatory requirements for demand-response readiness in MEPS, scale up virtual power plant projects |



Note: EE = energy efficiency; MEPS = minimum energy performance standards.

To ensure robust policy making, the IEA recommends countries adopt a policy package approach for policy development that combines regulation, information mechanisms and incentives. Countries should also create favourable conditions and support mechanisms for uptake of efficient grid-interactive buildings. These include investing in research and development, conducting data collection and analysis, developing training programmes and certification schemes for building professionals, and updating public procurement policies. Furthermore, policy makers can support modernisation of the grids and encourage grid operators to better enable grid-interactive buildings by adopting solutions that support communication between the grid and buildings, as well as other distributed energy resources.

# Buildings and the grid as an ecosystem

## Energy efficiency and energy flexibility are key for the clean energy transition

Energy efficiency is crucial for the clean energy transition through its ability to reduce carbon emissions, enhance resilience and reliability of the energy system, and improve well-being of people and societies.

In 2022, the global rate of energy efficiency improvement reached just over 2% per year – twice the average over the previous five years due to the effect of global energy cost variations and high prices in addition to progress on policy development. Since the start of the global energy crisis, countries representing over 70% of the world's energy consumption have introduced new or strengthened energy efficiency policies. However, in order to bring global greenhouse gas emissions close to net zero by 2050, which is needed to limit the global warming to 1.5° C degrees, the global rate of efficiency improvement needs to double to around 4% per year on average this decade. This improvement will also require a tripling in annual efficiency-related investment, from USD 600 billion today to USD 1.8 trillion.

A future in which there are net zero emissions also requires scaling up utilisation of variable renewable energy sources such as wind and solar. Southeast Asia has considerable renewable energy potential, but these fuel sources currently meet only around 15% of energy demand, mainly through hydropower and still-limited use of solar PV and wind. These energy sources, while providing clear decarbonisation benefits, will also increase intermittency within the electrical grid due to their variability and dependency on weather conditions. Electricity grids will also be put under pressure by an increasing number of certain types of distributed energy resources (DERs), such as distributed solar PV systems and storage systems, electric vehicles (EVs) with no dispatch capability, and demands from heat pumps and other connected equipment and devices. Buildings, both residential and non-residential, offer a unique place where many DERs could be installed and connected to the grid or off-grid electricity supply. This makes buildings a key player in the energy system's modernisation.

Unmanaged deployment of DERs, however, can cause unintended stress on the power system, such as reverse flows in distribution feeders due to excess generation or mass disconnections due to grid instability. The adoption of DERs connected to the grid can require grid reinforcements, increase uncertainty in net demand forecasts, and present challenges for power system planning and operation, which can potentially impact operational viability. There are risks to electricity grids when there is a lack of appropriate planning and deployment tools for visibility, monitoring and management of large-scale DER deployment, which can exacerbate financial challenges for utilities.

# Modernisation of power systems is crucial for the clean energy transition

The increase in electricity demand will surpass energy consumption, especially in emerging markets and developing economies, with a projected increase of over 2 600 terawatt-hours (TWh) by 2030, equivalent to five times Germany's current demand. Yet the global electricity systems face challenges such as inefficiencies, losses, congestion, outages and climate-related damage. For the Association of Southeast Asian Nations (ASEAN), growth in buildings electricity represents almost 50% of total electricity growth by 2025 from 2020. Therefore, the need to strengthen and modernise grids is urgent, particularly in emerging markets, where consumption is expected to grow three times faster than in advanced economies. The unprecedented rise in cooling demand further contributes to this trend.

Clean energy sources, such as the uptake of wind and distributed solar PV systems, continues to increase across many grids, providing clear decarbonisation benefits. However, unmanaged PV deployment across the building stock can cause unintended stress on the local power system.

EVs are a key part of decarbonising the transport system but increase pressure on the electricity grid and electricity use associated with buildings through on-site charging. In regions with robust grids, EVs can achieve a high level of penetration without adverse effects. However, in areas where transformers are already overloaded, even low levels of EV uptake could cause disruptions. For example, adding an EV to a typical household of four people in Germany could increase the household's peak electricity demand by 70%.

Modernisation of power systems allows for the optimisation of energy use through the implementation of smart grids,[1] advanced sensors and data analytics. This makes it possible to monitor and manage energy consumption in real time, identify and reduce energy losses, and minimise energy waste. Digital solutions can enhance electricity supply management, lower overall demand and optimise electricity use during peak times. These technologies aid demand management and electrification, and minimise unnecessary grid expansion while ensuring grid

[1] Smart grids are electricity networks that use digital technologies, sensors and software to better match the supply and demand of electricity in real time while minimising costs and maintaining the stability and reliability of the grid.

stability, affordability and avoiding localised outages amid rising cooling demands and increased air-conditioner usage globally.

Smart grids act to improve the efficiency of energy production by reducing transmission losses and integrating renewable energy sources through actively and intelligently matching generation with energy demand and matching producers with consumers. Modernising power systems can improve their resiliency and reliability by increasing their flexibility, enabling faster response times to outages, reducing curtailment of renewable energy and providing backup power during emergencies. This flexibility is particularly important in the face of extreme weather events, which are becoming increasingly frequent and severe due to climate change. In emerging markets and developing economies, frequent electricity outages result in reduced operational capacity for businesses, leading to additional expenses for backup power generation.

# Grid-interactive buildings provide flexibility services and other benefits

Managing electricity demand growth is increasingly challenging due to the rising level of urbanisation, economic development and improved living standards driving high energy demand, particularly for electricity, and especially in emerging economies and developing countries. Buildings, in terms of their operations, account for close to one-third of the global final energy consumption and for 27% of total energy sector emissions. The ASEAN buildings sector represents around 4% of global buildings demand and emissions and around 5% of global electricity demand in buildings.

Electrification of space heating along with growing air conditioner and appliance ownership, particularly in emerging markets such as ASEAN, are key sources of increased electricity consumption. Cooling alone is expected to add 2 800 TWh to global electricity use by 2050. Due to the impacts of climate change, heatwaves are expected to become more frequent and intense, further increasing cooling needs. By 2040, the increased demand for cooling could raise annual electricity demand by 10%, with a significant daily difference in air-conditioning load. Access to adequate cooling remains limited for most, with only 10% of households having air conditioners in India and Indonesia compared with over 90% in the United States and Australia. It is expected that increased urbanisation and rising standards of living will significantly raise the demand for space cooling in emerging markets in the coming years as well.

In the buildings sector, improving energy efficiency of building envelopes as well as appliances and equipment can lower energy demand and reduce related GHG emissions. For example, almost half of the increase expected in the electricity use for space cooling could be offset by energy efficiency improvements of the cooling equipment.

Buildings offer opportunities for cost-effective demand-side management to help balance demand with supply over time, integrate variable renewable energy (VRE) and optimise its use, and shift the electricity loads away from the times when the grid is the most stressed and the most expensive to operate and electricity generation produces the highest amounts of GHG emissions. Digitalisation, data management and other smart technologies (e.g. smart meters, smart sensors and controls) enable consumers to provide flexibility to the grid through controlling and adjusting buildings operations and energy usage in response to the signals from the grid, making buildings not only energy efficient but also grid-interactive.

**Efficient grid-interactive buildings**

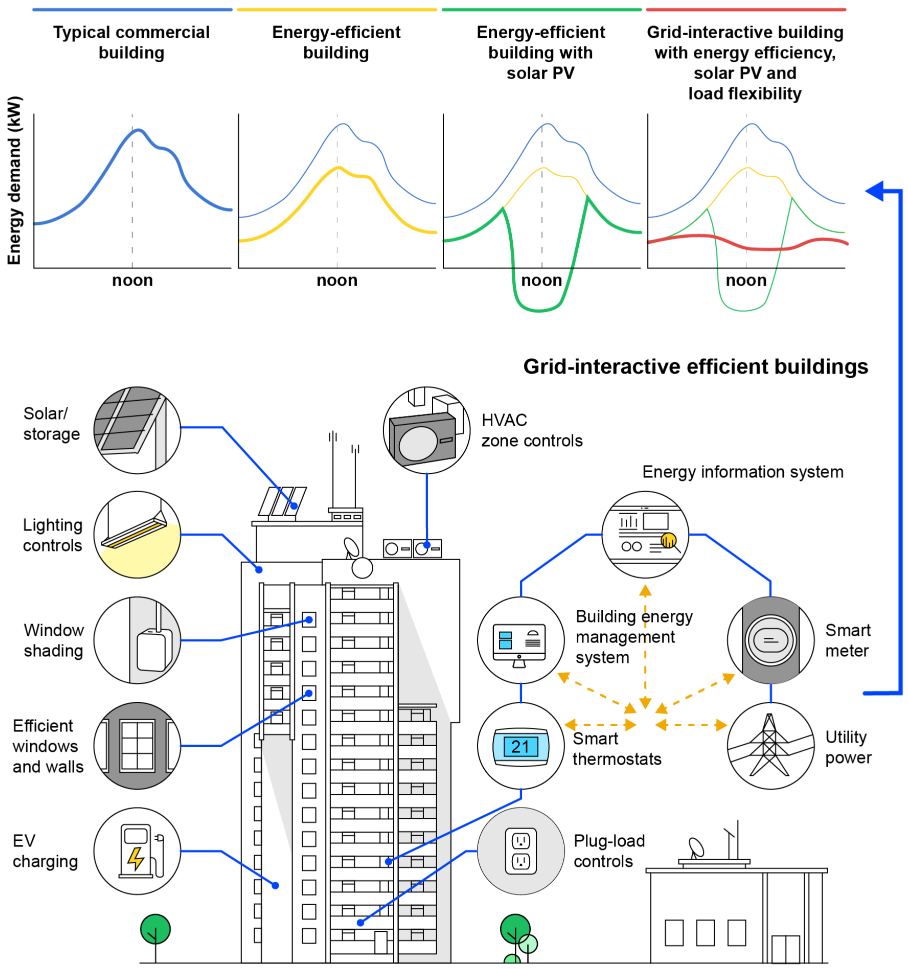
Efficient grid-interactive buildings (EGIBs) are energy-efficient buildings with grid-connected smart technologies characterised by the active use of DERs to optimise energy use and energy flexibility for supporting grid services, occupant needs and preferences, and cost reductions in a continuous and integrated way.

EGIBs can be characterised by the following attributes:

- **efficient**: includes high-quality building envelopes and windows, high-performance appliances and equipment, and optimised building designs and operation to reduce final energy consumption and peak demand
- **smart**: the ability to operate based on analytics supported by sensing and optimised controls that are necessary to manage multiple behind-the-meter DERs in ways that are beneficial to the grid, building owners and occupants
- **connected**: the ability to send and receive signals that are required to respond to needs of the grid
- **flexible**: the ability to dynamically shape and optimise building energy loads and through responsive operation, behind-the-meter generation, EVs, batteries, water storage tanks, building thermal mass and other forms of energy storage.

A combination of improved energy efficiency with flexibility benefits and decarbonisation of electricity supply is making EGIBs an important aspect of a future with net zero emissions, presenting significant potential for buildings to transition from energy-intensive consumers to energy-efficient and low-carbon prosumers supported by digital technologies that can enable them to produce, consume, store, sell and buy energy as a part of the building-to-grid (B2G) ecosystem.

**Efficient grid-interactive buildings: Technologies and demand flexibility benefits**

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Notes: kW= kilowatt; HVAC = heating, ventilation and air conditioning.
Sources: IEA (2022), Unlocking the Potential of Distributed Energy Resources.

Grid and building digitalisation provides the opportunity to optimise electricity production and consumption between buildings and the grid in an efficient and integrated manner. B2G interactions create opportunities for buildings to generate new value streams with energy services, reduce energy costs through optimised use of resources, and alleviate congestion in the distribution grid through flexible energy operations.

Well-established interactions between buildings and the grid enabled by digital tools for automated communication and control can optimise the use and generation of electricity at specific times and at different levels across numerous DERs, and provide demand flexibility to the grid, while still meeting occupants' needs for comfort and productivity as well as reducing their utility bills.

**Demand flexibility**

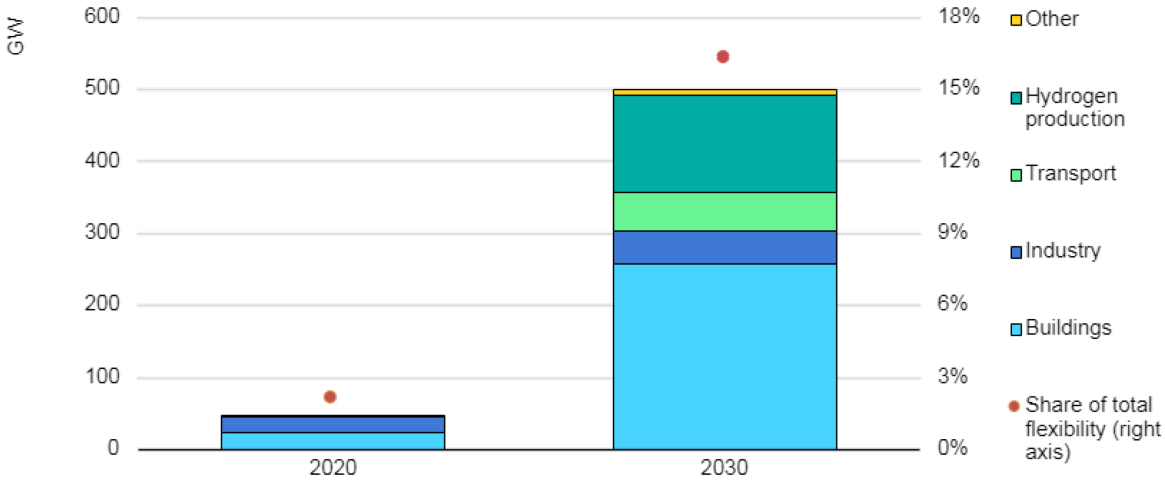
Demand flexibility can be defined as a portion of the demand that could be reduced, increased or shifted during and/or for a specific period of time to provide flexibility benefits to the grid (can also be referred to as demand response) that may include:

- facilitate the integration of VRE by adjusting load profiles to match VRE generation
- reduce peak load and seasonality
- stabilise grid frequency
- reduce electricity generation costs.

Utilisation of these benefits together with smart solutions applied on the grid's side help increase power system flexibility, as the ability of the grid to respond in a timely (often hour-to-hour) manner to variations in electricity supply and demand is also crucial for the decarbonisation of the electricity generation in line with the IEA Net Zero Emissions by 2050 (NZE) Scenario. Achieving net zero emissions at a global scale requires power system flexibility to more than double by 2030. Buildings accounted for about half of the demand response available in 2020 globally. By 2030 the amount of available demand response needs to increase more than ten-fold in order to be in line with NZE Scenario.

Demand response programmes can be applied alternatively through implicit demand response methods such as adopting time-varying electricity tariffs to encourage peak-load reductions, energy bill reductions and even carbon emissions reductions. Generally, time-varying electricity tariffs, particularly those that offer significant price differences between peak and non-peak hours, can optimise the electricity cost savings for buildings' occupants. Additionally, the time-varying tariffs can also reduce GHG emissions by applying higher rates when GHG emissions production is high and vice versa.

**Demand-response availability at times of highest flexibility needs and share in total flexibility provision in the Net Zero Emissions by 2050 Scenario, 2020 and 2030**

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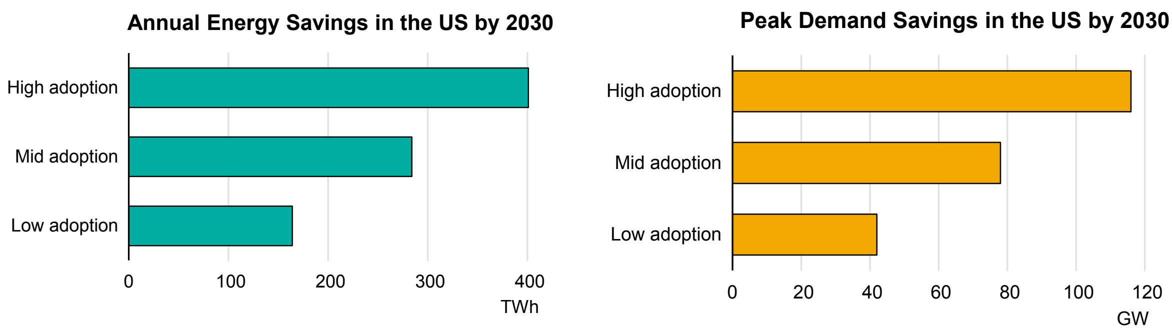
Note: GW = gigawatt.
Source: IEA (2023), Tracking Demand Response.

Estimates for the United States show that the nationwide adoption of EGIBs could lead to power system cost savings in the range of USD 100 billion to USD 200 billion over the next two decades. Power system flexibility enabled by EGIBs could lead to $CO_2$ emissions reduction of 80 million tonnes per year by 2030, which is equivalent to 6% of the United States' total power sector $CO_2$ emissions. The results of this analysis also show significant energy savings (in the range between 164 TWh and 401 TWh) and peak demand savings (42 GW to 116 GW) depending on the level of adoption of various efficient and grid-interactive solutions in buildings.

**Impacts on peak demand and energy savings in the United States by achievable level of efficient grid-interactive buildings**




IEA. CC BY 4.0.

Source: DoE (2021), A National Roadmap for Grid-Interactive Efficient Buildings.

Cost savings from demand flexibility of the United States' buildings sector are estimated at the level of USD 22 billion per year with the majority of potential savings coming from peak-load reduction and related marginal construction costs of more efficient buildings, as well as displacement of wholesale energy costs achieved through shifting flexible building loads away from peak hours.

**Strategies to enhance demand flexibility through EGIBs**

*Energy efficiency* of building envelopes and equipment helps reduce a building's energy needs, which in turn lowers the costs of using fossil fuels and lowers demand for investments into additional generation capacity.

*Load shedding* enables a temporary reduction or pause in electricity use in response to signals from the grid while maintaining required comfort levels inside the building.

*Load shifting* allows for control of the timing of electricity consumption, which can help reduce peak demand, lower energy costs for consumers as energy is often cheaper during the off-peak hours, and avoid curtailment of renewable energy.

*Modulation* helps balance power supply and demand, autonomously modulate power draw, maintain grid frequency, or control system voltage. It could reduce costs of ancillary services and improve integration of variable generation resources.

*Generation* of renewable energy on a building's site for self-consumption and dispatch to the grid lowers (or even eliminates) the need for fossil fuels to satisfy occupants' energy needs as well as large-scale electricity generation and reduces transmission and distribution (T&D) losses.

Source: Adapted from DoE (2021), National Roadmap for Grid-Interactive Efficient Buildings.

There is an increasing amount of evidence (mainly in the United States) for energy and cost savings achieved through implementation of demand flexibility strategies in EGIBs. For example, load shedding strategies that involved an automated "pre-cooling" and "demand limiting" protocol implemented in the Philadelphia United States Custom House and making use of a building's substantial thermal mass as energy storage reduced its peak demand by approximately 20% and lowered the annual electricity bill by 14% (equivalent to approximately USD 100 000 per year).

A renovation project of two public buildings in San Diego, California combined energy efficiency measures with 462 kW of solar PV systems on carports and rooftops as well as a battery energy storage system (BESS). The project achieved a 30% reduction in the total energy demand, notable peak demand reduction (average reduction of 186 kW, a maximum reduction of 582 kW), energy cost savings achieved by discharging the BESS during peak times and recharging during off-peak times (monthly on-peak demand energy cost reductions around USD 19/kW). Another building renovation project from Colorado demonstrated comparable energy cost reductions (USD 18/kW per month) through implementing energy efficiency measures, using BESS for peak-load shifting, and energy management with a control system for flattening the energy demand.

Large-scale application of EGIB measures (e.g. energy efficiency, solar PV, energy storage and load flexibility) to all public buildings owned by the General Services Administration in the United States is estimated to result in USD 70 million per year in societal value for grid users, achieving 180 gigawatt-hours per year in energy savings, reducing energy peak demand by 165 megawatts and annual energy costs by more than 20%. An assessment for a large United States retail portfolio demonstrated that an optimised bundle of EGIB measures can lead to 37% energy cost savings and reduce electricity demand by 17%, while achieving reductions in energy peak demand that varies across modelled buildings depending on the equipment and its efficiency.

Investments in grid-flexible systems for a Scottish residential block that are using electric resistance heating systems and electric water heaters have demonstrated notable benefits. The use of flexible load devices connected to the main heating systems allowed for heating demand to be adjusted and the dispatchable load to be sold back to the power markets. The flexibility triage was activated through a mechanism that interrupted electricity demands for heating by five to ten minutes and fine-tuned the system to limit the impact on occupants. The demonstration from the residential block delivered a maximum shiftable capacity of 99.6 kW, which resulted in energy shifting of around 3 600 kilowatt-hours (kWh) monthly and 100 kWh daily potential flexible demand. The flexibility resulted in the building saving around 2.7 tonnes of $CO_2$ during an 11-month period.

# Relevance of EGIBs for the ASEAN region

## About this report

In 2022, the IEA published two regional policy documents: the Roadmap for Energy-Efficient Buildings and Construction in ASEAN and the Roadmap Towards Sustainable and Energy-Efficient Space Cooling in ASEAN, commissioned by ASEAN. The roadmaps were deliverables for the project as a part of the ASEAN Plan of Action for Energy Cooperation Phase II 2021-2025, funded by the ASEAN-Australia Development Cooperation Program Phase II and supported by the ASEAN Secretariat, Energy Efficiency Sub-Sector and Conservation Network and ASEAN Centre for Energy. It aimed to help address increasing energy demand

and emissions in ASEAN and improve collaboration among stakeholders in the region. Development of the roadmaps was accompanied by capacity-building webinar series on sustainable cooling and buildings, as well as a series of stakeholder consultations.

During these stakeholder consultations a topic on synergies between energy efficiency and digitalisation in buildings emerged as a recurring area of interest for a majority of ASEAN member states. With growing electricity demand (and peak demand) in the region, along with regional and national targets for energy efficiency and renewable energy, grid-interactive buildings are seen as a follow-up work on the recently published roadmaps for buildings and construction and efficient space cooling.

For the purpose of this report, data on policy landscapes and ongoing projects related to the topic were collected for each ASEAN country through desktop research, an online survey and online interviews with experts in each of the ASEAN member states to identify existing trends and practices that can be applicable to the region's context.

Data analysis was structured around three main components:

- development of the analytical framework for enablers of efficient grid-interactive buildings in terms of technological solutions and supporting policy instruments
- analysis of the current state of play in the ASEAN buildings and electricity sectors related to energy efficiency, renewable energy, smartness and interaction with the grid
- identification of policy strategies to support the uptake of efficient, low-carbon, grid-interactive buildings in ASEAN.

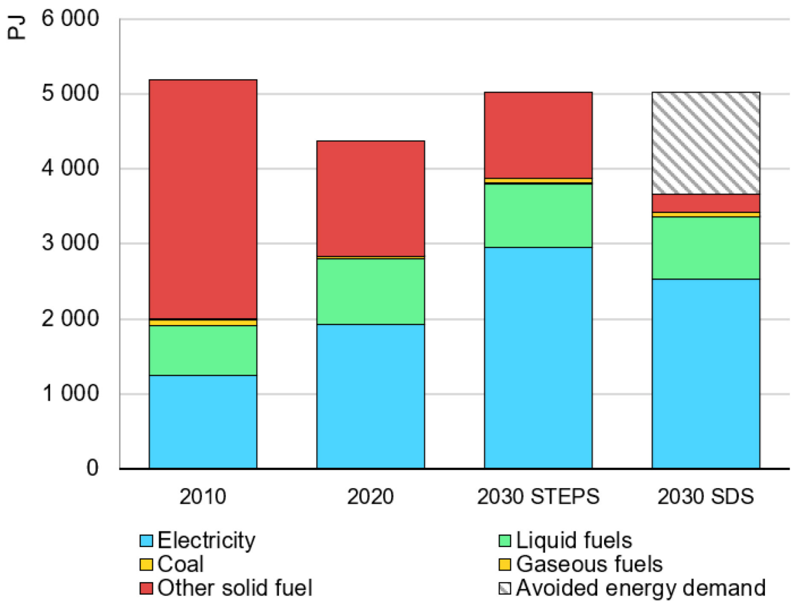
Examples of existing technology solutions and supporting policies for efficient, grid-interactive buildings in ASEAN, as well as relevant international best practices, were identified through desktop research and interviews. Selected examples were elaborated into case studies to serve as demonstrations of practical applications of solutions and their benefits.

## Energy demand in ASEAN continues to grow

By 2025, Asia will account for half of the world's electricity consumption. In the ASEAN member states, energy consumption has doubled since 2000, fuelling a regional economy that is now two and half times larger than it was in 2000 with a current population of over 660 million people. ASEAN member states include Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam.

Although the buildings sector constitutes less than a quarter of the total final energy consumption in the ASEAN region, it contributes 1.4 exajoules or 46% of the potential energy demand reduction in the Sustainable Development Scenario (SDS) spanning from 2020 to 2030. Enhanced air-conditioning efficiency can substantially contribute to lowering electricity demand, and eliminating traditional biomass for cooking could result in noteworthy advancements in overall energy demand reduction within buildings.

**Energy demand by fuel and avoided energy potential, in the ASEAN region, in the Stated Policies Scenario versus the Sustainable Development Scenario**






Notes: PJ = petajoule; STEPS = Stated Policies Scenario.
Source: IEA (2022), Energy Efficiency.

In 2022, electricity demand in the region grew by 5.5% and is expected to continue increasing by 4-6% per year until 2025. Growth in buildings electricity represents almost 50% of total electricity growth in ASEAN by 2025 from 2020. Most of that additional demand is likely to be met by fossil fuels, with renewables meeting only about a third of that demand growth.

The increase in electricity consumption can be largely attributed to rising standards of living along with the population growth and rapid urbanisation. The buildings sector has led the increase in electricity consumption, with the number of people living in cities increasing by 70% since 2000 with more than half of the region's population living in urban areas in 2020.

This growth of cities, along with increasing wealth, has led to a rapid use of air conditioners and other appliances in buildings, while the number of people with access to refrigeration has doubled since 2000. Space cooling is among the fastest growing end uses in the region given the hot and humid climate combined with rising incomes. Air-conditioner stock across ASEAN is projected to grow from nearly 50 million units in 2020 up to 300 million units in 2040. As a result, electricity use for space cooling is projected to rise from 88 TWh in 2019 to 314 TWh by 2040 – approximately equivalent to the total electricity consumption of Indonesia and Singapore combined. Almost two-thirds of this is expected to come from residential buildings. Space cooling is also estimated to account for almost 30% of peak electricity demand in the region by 2040, up from around 10% in 2017, and will require about 150 GW of additional generation capacity to meet the peak levels.

In addition to space cooling, increased access to and use of electricity and access to clean cooking are reducing the reliance on polluting fuels and raising the quality of life for many in Southeast Asia. Around 95% of households now have access to electricity and 70% use more efficient clean cooking technologies, such as liquefied petroleum gas (LPG) and improved cookstoves.

Beyond buildings, electricity use is also extending to new end-use sectors, driven by targets to halt sales of internal combustion engine vehicles in Thailand by 2035 and in Singapore by 2040, and the aim of Indonesia is to achieve 2 million electric cars on the road by 2030. Combined, these factors translate to projections of increasing electricity demand in the region but also raise questions of how the existing grid infrastructure will be able to meet these needs, particularly at peak times.

## Inefficiencies in ASEAN existing power systems create challenges for consumers

Power supply reliability, which can be defined as the ability of an electrical system to consistently provide electricity to consumers without interruptions or significant fluctuations in voltage or frequency, presents challenges for a number of ASEAN countries. Several factors have an impact on power supply reliability such as quality of the infrastructure, weather events (e.g. storms, hurricanes and extreme temperatures), reliability of T&D networks, and load management. These factors can damage power lines, transformers and other critical infrastructure, leading to prolonged outages. These outages not only disrupt daily activities but can also pose risks to vulnerable populations, such as the elderly or those with medical conditions reliant on electricity-powered devices. Additionally, extreme temperatures can increase the demand for cooling, putting additional strain on the power grid and potentially leading to brownouts or blackouts.

Data on the System Average Interruption Frequency Index (SAIFI)[2] and System Average Interruption Duration Index (SAIDI)[3] for ASEAN countries provide indications of how often and for how long an average customer experiences an interruption over the course of a year. While in a number of countries, outages do not cause long and frequent disruptions; in other cases (e.g. in Myanmar, Cambodia and Lao PDR) these issues are more prominent.

### Data on SAIFI and SAIDI in ASEAN countries in 2020

| Country | SAIFI | SAIDI |
|---|---|---|
| Brunei Darussalam | 0.3 | 0.4 |
| Cambodia | 15.4 | 20.8 |
| Indonesia | 2.2 | 2.8 |
| Lao PDR | 22.7 | 4 |
| Malaysia | 0.5 | 0.5 |
| Myanmar | 26.4 | 30.3 |
| Philippines | 2.2 | 3.6 |
| Singapore | 0.1 | 0.1 |
| Thailand | 0.7 | 0.4 |
| Viet Nam | 1.6 | 2.1 |

Notes: SAIFI is the average number of service interruptions experienced by a customer in a year. SAIDI is the average total duration of outages (in hours) experienced by a customer in a year.
Source: World Bank (2021), DataBank: Doing Business.

Moreover, the interplay between power supply issues and inefficiency can create a vicious cycle. In areas where power supply is unreliable or intermittent, end users may resort to using backup generators, further straining the energy infrastructure. These backup solutions are often less efficient and more polluting, exacerbating environmental concerns and perpetuating the cycle of inefficiency.

Another issue affecting end users is electricity theft. Illegal connections or tampering with power meters can lead to revenue losses for utilities and imbalances between power supply and demand. Electricity theft can result in inadequate power supply to legitimate users, leading to outages and voltage fluctuations. The burden of these disruptions falls on end users who suffer from unreliable power supply. In 2018, electricity theft in Indonesia cost Perusahaan Listrik Negara (PLN), Indonesia's state-owned utility, USD 72 million. In Lao PDR, such electricity theft in the first three months of 2023 cost more than USD 5 million in the capital city alone.

[2] SAIFI is the average number of service interruptions experienced by a customer in a year.
[3] SAIDI is the average total duration of outages (in hours) experienced by a customer in a year.

Power supply issues and inefficiency in the buildings sector can have profound impacts on end users. Weather events, outages, electricity theft and affordability concerns all contribute to disruptions, increased costs and compromised living conditions for end users. Strengthening the power grid's resilience through infrastructure upgrades, better monitoring tools, and advanced analytics, supported by digital solutions in combination with improving energy efficiency buildings and equipping them with solutions enabling the interactions with the grid, can reduce the frequency and duration of interruptions in power supply.

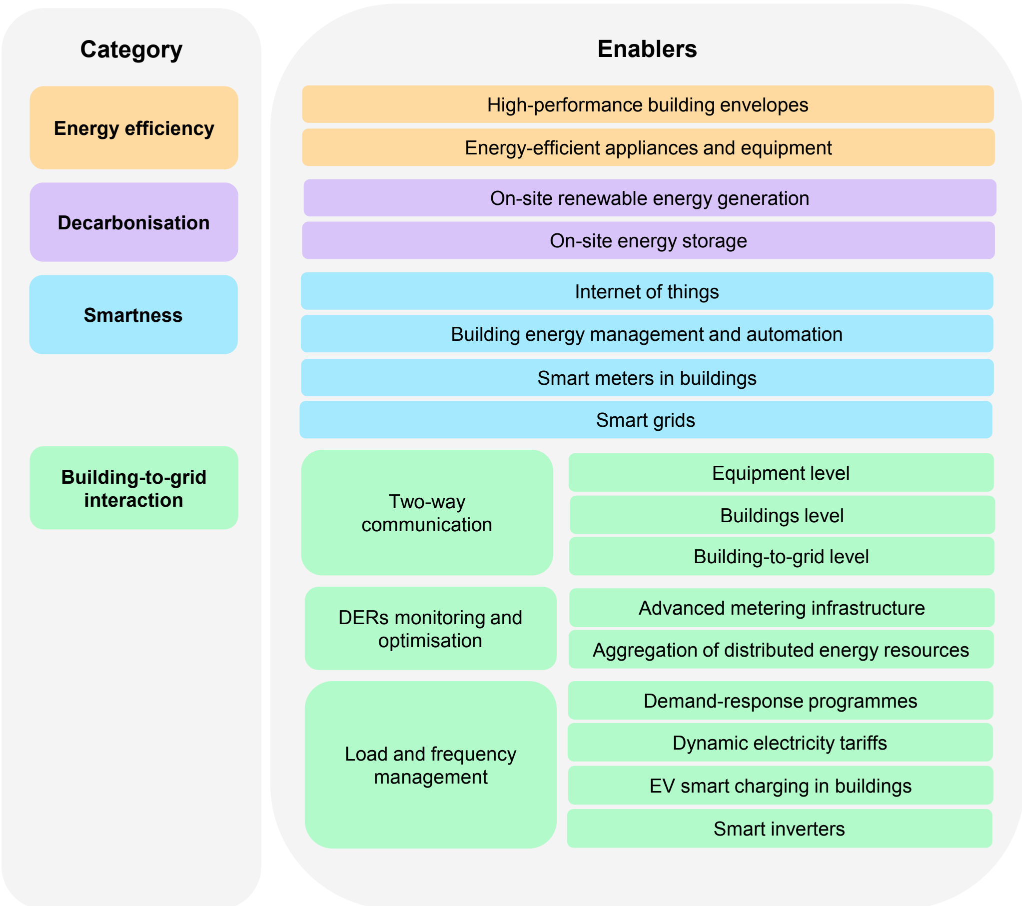
There are various ways to make buildings more efficient and grid-interactive. The next chapter presents key enablers that can be help in this process.

# Enablers for efficient grid-interactive buildings

The previous chapter demonstrated that efficient grid-interactive buildings (EGIBs) can offer a number of benefits to end users and the energy system. This chapter explores key attributes (hereafter, "enablers") that can enable a building to become efficient and grid-interactive. Such enablers should be supported by respective policies as well as adoption of technological solutions. Presence and adoption of enablers for EGIBs could be evaluated for any given country.

In this report, the enablers are placed into four main categories based on a function in the energy system that EGIBs can perform, namely: i) efficiency; ii) decarbonisation; iii) smartness; and iv) building-to-grid interaction.

**Enablers for efficient grid-interactive buildings**




IEA. CC BY 4.0.

Note: DER = distributed energy resource.

# Energy efficiency

Energy efficiency plays a crucial role in bringing global emissions towards net zero. Accelerating energy efficiency efforts beyond current policies could help avoid around one-quarter of the excess energy demand by 2030 and just over one-half of it in 2050. However, to bring the emissions from the global buildings sector towards net zero by mid-century, electrification of buildings' end uses and decarbonisation of electricity will play an important role. Fuel switching, largely from fossil fuel space heating to electric heat pumps, can shave a further one-fifth from this energy demand gap. The remainder could be avoided through behavioural changes and digitalisation of energy-related building operations, notably for space heating, space cooling and water heating. It is important to improve energy efficiency of the whole building – in this report, two separate enablers are considered: high-performance building envelopes and energy-efficient appliances, as they are typically covered by different policies.

## High-performance building envelopes

The design of the building envelope plays a crucial role in determining the energy demand for heating and cooling, as well as ensuring comfort, indoor environmental quality and safety. Additionally, the structural aspects of the building envelope have a significant impact on its embodied carbon footprint.

Improving the energy performance of building envelopes involves various measures, and building regulations (such as building energy codes) play a significant role in promoting and regulating these improvements:

- Envelope insulation: Building energy codes typically specify minimum insulation requirements for walls, roofs and floors. These codes often outline insulation material types, thicknesses and installation standards, ensuring that buildings meet a certain level of thermal resistance to reduce heat transfer and improve energy efficiency.
- Windows and glazing: Energy codes often include criteria for window performance, such as U-factor and solar heat gain coefficient. These requirements promote the use of energy-efficient windows with low-emissivity (low-E) coatings, multiple glazing layers and insulating frames to minimise heat loss or gain through windows.
- Air sealing: Building energy codes often address air leakage by setting standards for airtightness. These codes may require air barriers, proper sealing of joints and penetrations, and mandatory blower door tests to ensure buildings minimise uncontrolled air infiltration and exfiltration, reducing energy loss and improving comfort.
- Compliance and enforcement: It is important that building energy codes establish compliance and enforcement mechanisms to ensure that the energy efficiency requirements are met during the design, construction and operation phases of a

building. This can include inspections, energy performance certifications and penalties for non-compliance.

In order to align with the IEA Net Zero Emissions by 2050 (NZE) Scenario, it is essential for all countries to establish building energy codes with the vision to transition to zero-carbon-ready buildings. Additionally, the existing building floor area must be renovated to meet a zero-carbon-ready level of energy efficiency. This will require more than doubling the annual energy efficiency renovation rates globally, from the current level of less than 1% to 2.5% by 2030.

**Zero-carbon-ready buildings** are highly energy-efficient and resilient buildings that either use renewable energy directly or rely on a source of energy supply that can be fully decarbonised, such as electricity or district energy. The zero-carbon-ready concept includes both operational and embodied emissions.

Building energy codes play a vital role in driving energy efficiency improvements in buildings. They provide a framework of mandatory requirements and standards that developers, architects, builders and contractors must adhere to. By setting minimum energy performance requirements within building energy codes, these codes help raise the baseline of building energy efficiency, promote the adoption of energy-saving technologies, and contribute to overall energy conservation and sustainability goals.

It is important to note that building energy codes can vary across jurisdictions and may be influenced by local climate conditions, building types and energy policy priorities. Regular updates and revisions to the codes ensure that they keep pace with advancements in building technologies and energy efficiency practices.

As of 2022, there were 80 countries that already had fully operational building energy codes, with an additional 31 countries in emerging and developing regions actively working on developing new building codes. Among these, 69 countries have mandatory requirements in place, while 11 countries rely on performance standards such as voluntary codes, model codes or city-based standards. However, approximately 85 countries currently lack established building codes or ongoing development efforts.

The transition to net zero requires electrification of the buildings sector that presumes moving from fossil fuel-powered buildings to electric-powered buildings. End-use equipment and devices inside a building for space heating and cooling, water heating, cooking, etc., offer various flexibility opportunities through digital technologies, as described above. However, in order to realise such opportunities to a full extent, buildings themselves need to be "prepared" at the design stage or upgraded during the renovation process. To ensure that buildings can accommodate all necessary electric connections, buildings regulations need to include certain "electric-ready" requirements.

In the United States, for example, several states have made progress on such requirements. In California, 50 jurisdictions have passed policies to phase out gas appliances in new construction and 37 of them specify all-electric requirements in new residential buildings. Seattle and New Jersey also adopted plans and related regulations to electrify the majority of their buildings. Other states, such as Maine and Colorado, are accelerating electrification of space heating through accelerating the deployment of heat pump installations.

**California's 2022 Energy Code, United States**

The California 2022 Energy Code includes electric-ready requirements for newly constructed and renovated buildings starting in 2023 in compliance with the state's electrification strategy, which encourages the adoption of highly efficient electric appliances.

The mandatory requirements for electric-ready buildings envisage heat pump space heater, electric cooktop and electric clothes dryer readiness. For instance, for systems using gas or propane furnaces and cooktops to serve individual dwelling units, a dedicated 240 volt branch circuit wiring shall be installed within three feet of the furnace or the cooktop and be rated at 30 amps minimum. In addition, a space shall be reserved on the main electrical service panel to allow for the future installation of both heat pumps and electric cooktops. The main electrical service panel must also have the space for the installation of a double-pole circuit breaker for a future solar electric installation. As for electric vehicle (EV) charging stations, they have been included among the electrical loads for which minimum requirements for separation of electrical circuits to allow electrical energy monitoring are envisaged.

## Efficient appliances

Improving the energy efficiency of appliances and equipment, including heating, ventilation and air conditioning (HVAC), water heating and lighting systems, can be done through establishing efficiency standards for products through a variety of policy instruments and strategies. These approaches aim to influence manufacturers, consumers and the market as a whole to prioritise energy and resource efficiency:

- Building energy codes: Energy codes often prescribe efficiency standards for lighting and HVAC systems, promoting the use of energy-efficient fixtures, lamps and controls; establishing minimum requirements for equipment efficiency, insulation of ductwork and proper system sizing; and commissioning to improve overall system performance and reduce energy consumption.

- Mandatory minimum energy performance standards (MEPS): Governments can set legally binding minimum efficiency requirements that products must meet to be sold in the market. Products failing to meet these standards are not allowed for sale, promoting the adoption of more efficient technologies. MEPS contribute to the market transformation by gradually phasing out less efficient appliances from the market. They also help drive technological advancements by setting higher efficiency targets. Manufacturers are incentivised to develop and produce appliances that surpass the minimum requirements, leading to the introduction of more energy-efficient technologies and designs.
- Energy labels: Energy labels provide consumers with information about energy efficiency of appliances. These labels often use an energy rating system, such as star ratings, to indicate the relative efficiency of different models. Clear and standardised labels enable consumers to make informed choices and select appliances with higher energy efficiency.
- Financial incentives: Governments could provide financial incentives (tax credits, rebates, subsidies or low-interest loans) to both manufacturers and consumers for adopting more efficient products.
- Information and education campaigns: Governments launch campaigns to educate consumers about the benefits of choosing efficient products and provide tips for reducing energy consumption. This raises awareness and influences purchasing decisions.
- Research and development (R&D): Governments can allocate funds to support R&D of new technologies and product designs that improve efficiency. MEPS encourage manufacturers to invest in R&D to improve energy efficiency of their appliances. This includes innovations in components, materials and manufacturing processes that enhance efficiency without compromising performance or functionality.
- International harmonisation and co-operation: Governments can collaborate with international organisations and other countries to develop consistent efficiency standards and align policies. Harmonisation facilitates trade and encourages manufacturers to design products for global markets.

Combining these policy instruments and strategies can create a comprehensive approach to establishing efficiency standards that drive market transformation, encourage innovation and contribute to sustainable development goals. Establish mechanisms to monitor the market and gather feedback from manufacturers, consumers and other stakeholders, using this information to refine and update efficiency standards over time.

Out of these instruments, MEPS are identified as the single most cost-effective measure in driving energy efficiency improvements in appliances. By setting mandatory efficiency requirements, these standards ensure that appliances sold in the market meet a certain level of energy performance. They spur innovation; guide consumer choices; and contribute to energy savings, cost reductions and environmental benefits. Regular updates and reviews of these standards are necessary to keep pace with advancements in technology and to continuously raise the bar for energy efficiency in appliances.

More than 100 countries around the world have implemented mandatory MEPS and/or energy labels for commonly used appliances. MEPS for residential refrigeration and freezers are currently implemented in approximately 80 countries, providing coverage for around 80% of the total energy consumed worldwide in residential refrigeration. However, the application of MEPS for other appliances is more limited. For instance, washing machines are covered by MEPS in just over 50 countries, accounting for 78% of energy consumption. Similarly, televisions have MEPS in fewer than 50 countries, covering almost 75% of energy usage, while monitors have MEPS in fewer than 40 countries, accounting for 43% of energy consumption.

# Decarbonisation

Distributed variable renewable energy (VRE) technologies can help to significantly decarbonise energy used in buildings. These technologies also reduce the need for long-distance transmission lines and large-scale infrastructure investments. Solar PV systems are increasingly common in buildings around the world, promoting energy independence, reducing reliance on fossil fuels, allowing consumers to participate in utility programmes, and supporting local economic development through installation and maintenance jobs and upskilling of workers.

Buildings can also be equipped with energy storage, primarily battery systems, to help integrate VRE generation, bridging the timing differences between energy supply and demand.

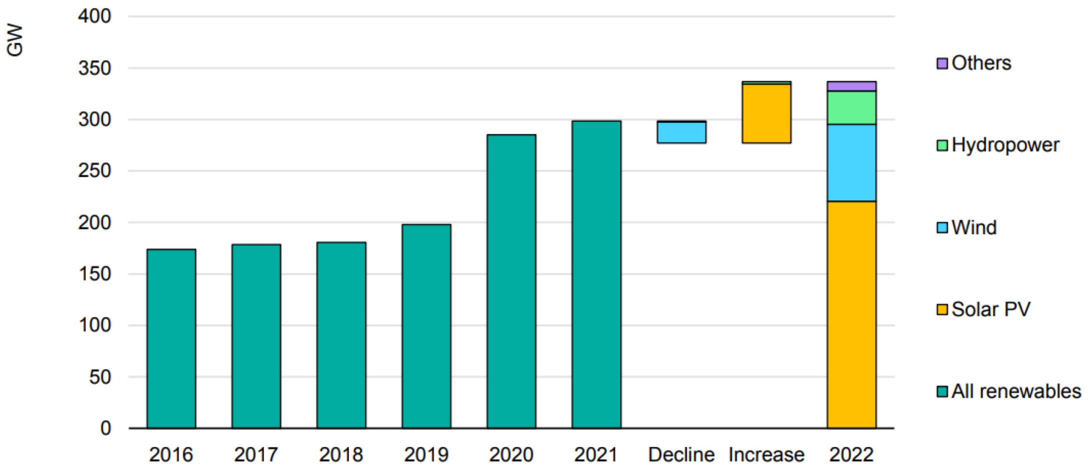
## On-site renewable energy generation

Distributed VRE technologies refer to the use of renewable energy sources, such as solar and wind power, by individual consumers or businesses on a distributed basis, rather than relying on centralised power plants. In the buildings sector, the most common VRE technologies are solar PV systems of different sizes and capacity installed on the building's site.

Distributed VRE systems are often located close to the communities they serve, and thereby can help to reduce the need for long-distance transmission lines, which are often vulnerable to weather events and other disturbances. Distributed VRE systems connected to the grid enable the possibility to feed the electricity output into storage systems or the grid when generation exceeds the needs of the local community or an individual building.

In 2022, the overall addition of renewable energy capacity globally experienced a significant increase of nearly 13%, reaching approximately 340 gigawatts (GW). Among the various renewable technologies, solar PV stood out by setting a new deployment record with an impressive net addition of nearly 220 GW, marking a 35% growth compared with 2021, with distributed applications, such as residential and commercial solar systems, accounting for almost half of global PV expansion.

**Renewable electricity net annual capacity additions, 2017-2022**






However, rapid adoption of distributed VRE technologies without proper management could put pressure on electricity grids, heighten operational intricacies and jeopardise the stability of transmission networks. The potential for reverse power flows in distribution feeders could trigger widespread disconnections during grid instability, potentially leading to blackouts.

To avert such operational challenges and related revenue losses, system operators should proactively plan, devise processes and implement tools that enable the monitoring, management and control of large-scale distributed VRE integration. Such strategies can help enhance overall system efficiency and electricity security. In Australia, for instance, the market operator implemented a digital registry to oversee distributed energy resources that improves visibility and control, providing insights into installations, and emergency disconnect mechanisms to prevent cascading blackouts. Large-scale deployment of distributed VRE technologies might also necessitate grid reinforcements and entail addressing uncertainties in net demand forecasts, thereby complicating grid planning and operation.

Policies for promoting the uptake of distributed VRE (e.g. various renumeration schemes and direct incentives for PV installation, such as tax rebates and soft loans) are an essential tool for decarbonisation of buildings and can help to improve grid resiliency and reliability taking the need for modernisation of power grids into account.

**Distributed solar PV remuneration schemes**

- *Buy-all, sell-all*: All PV generation is deemed to be sold to the utility, usually at a fixed price. The remuneration of PV electricity can be above, equal to or lower than the retail rate, while PV owners buy all electricity at the retail price to cover their demand.
- *Net metering*: PV owners can self-consume the electricity they generate, which reduces their consumption from the network. PV owners receive an energy credit for any excess generation exported to the network during a specific time period. This energy credit can be deducted from network electricity consumed on future bills at another time.
- *Real-time self-consumption models*: PV owners can generate electricity for self-consumption and sell excess to the network. While this appears similar to net metering, there are two main differences. First, energy accounting is done in real time (at hourly or less-than-hourly intervals). Second, PV owners are paid for each unit of electricity exported, rather than earning energy credits towards future bills. The price paid for exported electricity varies by jurisdiction and can be from zero to above the retail rate. In these models, remuneration rates range from wholesale to retail prices.

Source: Adapted from IEA (2019), Renewables

Such policies can also help to promote energy independence and local economic development through jobs. This is particularly true if distributed VRE systems are owned and operated by local communities or individual building owners, which can promote energy security and independence. For example, the Sosai Renewable Energies Company is a community-based renewable energy project in Nigeria that has connected over 80 households and businesses to a microgrid to support clean energy access and local industry and jobs.

A Global Environment Facility (GEF) funded project with the Indian Renewable Energy Development Agency has shown that households and businesses have increased their income and productivity through both home industry and study hours due to access to electricity generated by solar PV.

# On-site energy storage

Distributed energy storage plays a vital role for the energy system, which is integrating an increasing amount of VRE generation. Storage facilitates the integration of renewables by bridging the timing differences between energy supply and demand. This empowers residential and commercial buildings with on-site solar electricity generation to actively participate in the electricity distribution system. It empowers consumers to have control over their electricity usage, allowing them to avoid high charges during peak times or periods of increased demand. When combined with distributed generation such as rooftop solar PV, distributed energy storage can lead to energy independence for buildings. Additionally, distributed energy storage is instrumental in modernising the broader energy system by providing smart grid services. If used to increase reliance on renewables, it can yield significant climate benefits.

The most common type of storage is (usually lithium-ion) battery systems installed in buildings. Thermal energy storage, such as water tanks, passive thermal mass of the building and phase-change materials, could also be used to store renewable energy and participate in load shifting.

Currently, distributed battery storage in buildings is primarily implemented on a small scale, mainly due to high costs. However, there is a shifting trend as battery prices decrease, and utilities seek alternatives to costly infrastructure upgrades in response to growing demand.

By 2030, the costs associated with installing battery storage systems are estimated to decrease by 50% to 66%. This reduction in costs will have a transformative effect on the affordability of storage for supporting ancillary services such as frequency response or capacity reserve. These cost reductions are expected to be driven by the optimisation of manufacturing processes, improved material combinations and reduced material usage. As battery technology continues to advance, battery lifetimes and performance will improve, further contributing to the cost reduction of energy storage services.

Battery storage can participate in utility programmes in order to provide flexibility to the grid. In "bring your own device" (BYOD) initiatives, customers can register their batteries to either supply stored electricity to the grid or adjust their electricity consumption to avoid peak demand or emergency situations. They may also have the option to participate in fast-response ancillary service markets through aggregators, such as frequency regulation, voltage support or load-following reserves. The recharging of batteries can be timed to take advantage of off-peak hours, when electricity costs are low, or synchronised with periods of high renewable energy generation.

**Decentralised renewable energy generation in Ukraine**

Decentralised solutions based on renewable energy can play a key role in ensuring access to electricity, especially in times of emergency. In April 2022 the Energy Act for Ukraine Foundation was founded to supply renewable energy equipment to war-affected communities in Ukraine. The aim of the initiative is to install solar stations (PV and storage systems) in 100 schools within the next five years that could cover 30-50% of the annual electricity consumption of schools, while ensuring a backup power supply in case of outage for about three to five hours. Fifty hospitals are also expected to be equipped with solar stations within the next five years. As of February 2023, 17 installations had been completed through the collaboration of the Energy Act for Ukraine Foundation with the Polish PV distributor Menlo Electric.

# Smartness

Smart interactive technologies used in buildings, in addition to conventional energy efficiency measures, can add a time dimension to the energy efficiency of a building and make it more dynamic. Some common modern interactive technologies that can be used within a building include: smart meters, building automation systems, building load and energy management systems including smart sensors and controls for buildings equipment, and appliances that allow two-way communication between the utility or grid operator and the building.

## Internet of things

The internet of things (IoT) is a network of connected equipment, sensors and devices in buildings that communicate with one another and collect and analyse data from key building equipment such as HVAC and lighting systems, to initiate actions that would optimise energy performance of a building's operations.

Sensors and controllers can either be wired or connected wirelessly (e.g. technologies such as Zigbee, Bluetooth Low Energy) to collect actionable data from various building equipment (e.g. occupancy detections and numbers, temperature, humidity, lighting, and energy use). Integration of cloud and fog computing architectures with smart metering, sensors and controllers could enable the real-time energy management of IoT devices in buildings, optimising the performance of the system and improving the overall energy efficiency of smart building infrastructure.

Internet-connected thermostats, for example, are demonstrating an increasing adoption. In the United States and Canada they are linked to heating and cooling systems of about 30% of homes and around half of annual thermostat sales, helping to achieve up to 20% of energy savings. They allow users to remotely set their home's temperature and monitor occupancy, humidity and other parameters. Smart thermostats can also "learn" patterns of occupants' behaviour and determine an optimal energy-saving schedule automatically.

## Building energy management and automation

In order for IoT devices to communicate with one another within the building, they can be integrated using open standard or proprietary protocols into building energy management systems (BEMS), energy management systems (EMS) or building automation systems (BAS) to control and adjust parameters of the indoor environment (e.g. temperature, $CO_2$ levels, lighting) and the building's energy consumption. For residential dwellings, such systems are called home energy management systems (HEMS). A BEMS and HEMS can be defined as an integrated system of software, hardware and services that controls energy use through information and communication technology.

Automated data collection ensures a continuous flow of data from a building's equipment to a centralised database, which together with intelligent analytics provides visibility of the overall system and helps identify any issues, abnormalities or needs for adjustments to increase energy efficiency of the whole building. From the point of optimising energy use, the data analysis helps to identify operational inefficiencies, reduce energy losses in buildings, and make electricity billing more accurate.

Data analysis of energy consumption patterns and historical and real-time data across various parameters according to predefined smart rules helps to forecast a building's energy demand (and on-site electricity generation, if the building is equipped with a solar PV panel, for example) at any given time, which is particularly important for load management and demand response.

## Smart meters in buildings

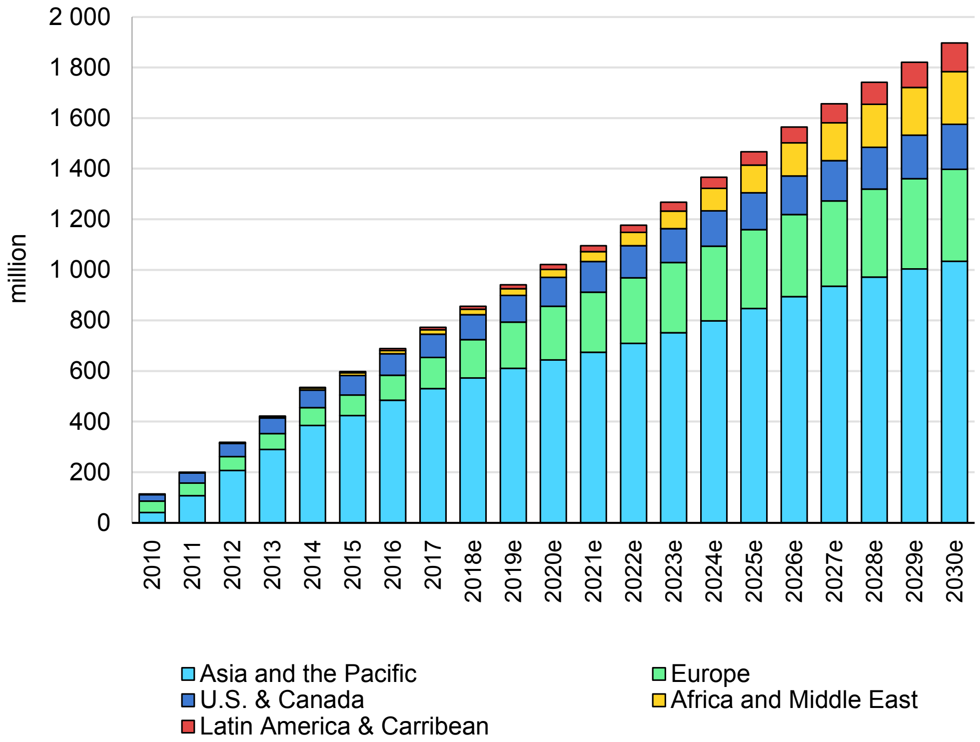
Smart meters are digital electricity meters that collect and store data on actual energy consumption in buildings on an hourly or even more detailed basis. Smart meters are crucial for increasing the visibility of behind-the-meter demand.

Smart meters are capable of remote communication and can record electricity use at a very granular level (usually every 15-30 minutes). This can enable customers to buy electricity through smart pricing mechanisms and provide incentives to purchase more energy-efficient appliances and equipment.

Access to detailed real-time data enables customers to dynamically adjust their energy consumption and achieve energy cost savings (e.g. through time-dependent automatic billing), while grid operators get an opportunity to assess the situation in the grid (e.g. supply interruptions, inefficient voltages, faulty connections) in a more efficient and accurate manner, better match electricity demand and supply at any given moment (e.g. reduce peak demand), and optimise network operations (e.g. avoid congestions). Smart meters are also indispensable for integrating distributed VRE generation, (e.g. from on-site PVs in buildings) into the main grid.

As of 2020, there were over 1 billion smart meters installed globally with more than two-thirds of them in Asia Pacific. In the United States, around four in five households already have smart meters, while in Europe they are installed in about half of the properties. By 2030, this global number is estimated to exceed 1.6 million.

**Cumulative smart meters installations by region, 2010-2030e**






Note: e = estimated.
Source: IEA analysis based on IEA (2023), Tracking Clean Energy Progress 2023 and BloombergNEF (2017).

Wide-scale utilisation of smart meters raises the question of data privacy, and customers must consent to the wireless communication of their smart meter data in accordance with the local regulations.

There is no single policy that supports smart meter roll-out – it usually requires a combination of mandates for utilities to roll out smart meters, incentives for consumers to install them, awareness-raising and consumer engagement on real-time data management, regulations on data privacy and security, etc. Most existing policies, however, are focused on rolling out smart meters and not advanced metering infrastructure (for further details see section on Advanced metering infrastructure), which limits the opportunities for interactions between buildings and the grid.

For example, the European Union (EU) set a non-binding target or an aspirational benchmark for all the member states back in 2014 to install smart meters in 80% of the buildings by 2020. As of 2021, several EU countries (e.g. Sweden, Finland and Denmark) have surpassed their requirements and progressed on to a second phase of upgrades. However, a number of countries in the region showed much slower progress or abandoned the commitment altogether.

In the United Kingdom, the government has mandated that energy suppliers offer smart meters to all households and small businesses by 2024. The government has set a target for 85% of households to have a smart meter by 2024, with the remaining 15% to be offered an alternative solution. The United States government has not mandated the installation of smart meters at the national level, but many states, for example California, have introduced regulations that require energy suppliers to offer smart meters to customers.

The Australian Energy Market Commission has put forward recommendations to achieve 100% smart meter uptake in Australia by 2030. The state of Victoria mandated smart meters in 2006 for all households and small businesses (with the installation costs applied to them) and achieved universal adoption in 2015.

The Japanese government introduced regulations that require energy suppliers to install smart meters for all households and small businesses by 2024.

The Energy Market Authority (EMA) in Singapore has mandated the installation of advanced metering for all households and businesses by 2024. The EMA has set a target of installing 1.4 million advanced meters by that time.

The Indian government introduced regulations that require energy suppliers to install smart meters for all households and businesses by 2025, aiming to reach 250 million smart meters by that time.

Countries in Latin America, such as Brazil and Mexico, are also investing in smart grid infrastructure. However, in Brazil, programmes for smart meters are voluntary with Enel establishing local production of smart meters in São Paolo and installing 300 000 of them, and Copel rolling out a large programme on deployment of smart meters and other technologies to automate its distribution networks. In Mexico, the government set a goal of installing 30 million smart meters (79% penetration) by 2025.

**The Connected (Smart) Neighborhoods, Birmingham, Alabama, United States**

The Reynolds Landing Smart Neighborhood by Alabama Power, Alabama, United States, is an initiative that is focused on enabling energy-efficient homes and systems, smart and connected devices, and a microgrid for community energy systems including solar panels, battery storage and backup gas generators.

The programme at Reynolds Landing included the construction of 62 new energy-efficient homes that included smart wall outlets such as those using standardised smart communication protocols (e.g. Z-Wave) to control appliances alongside traditional plugs. The homes include triple-pane low-E glazing, heat pump water heaters, ventilation energy recovery, variable capacity heat pumps and wall insulation. It includes a data monitoring centre, smart home control panels, and smart and energy-efficient white good appliances. In addition, the neighbourhood includes a microgrid that generates around 600 megawatt-hours (MWh) of energy a year from solar PV panels, gas generators and battery storage. Alabama Power operates the microgrid to interact with the home's hot water and heating/cooling and ventilation system to optimise the use of renewables (i.e. 330 kilowatt [kW] alternating current [AC] solar array) and battery systems (600 kilowatt-hours [kWh] of battery storage) and backup generators (400 kWh of natural gas).

The initiative between the utility and research groups analyses the value to the grid of operating microgrids with controllable loads, developing control algorithms for load shapes, evaluating the price/incentive signals within a controllable grid, and developing scalable system control architecture. Analysis from the initial demonstration shows that homes are typically 35-45% more efficient than Alabama's typical newly constructed dwellings and that demand load shifting for cooling offers energy savings for around four hours of comfort.

## Smart grids

A smart grid is an electrical network employing digital and advanced technologies for overseeing and regulating the transmission of electricity from diverse generation sources to fulfil the fluctuating electricity demands of end consumers. These intelligent grids harmonise the requirements and capacities of generators, grid operators, end consumers and participants in the electricity market. Their aim is to optimise the entire system's operation with utmost efficiency, reducing costs and environmental impacts and integrating VRE sources, while simultaneously bolstering the system's reliability, adaptability and stability.

Use of supervisory control and data acquisition (SCADA) systems within smart grids can enable the remote monitoring and control of transmission and distribution systems. SCADA systems can continuously collect data (voltage levels, current flows, equipment status and other critical parameters) providing a comprehensive view of the grid's current conditions. SCADA can also enable remote control of various grid devices, such as substations, transformers, and circuit breakers and rapidly detect abnormal conditions or faults and provide alerts to grid operators. SCADA can also integrate load-shedding and load-shifting strategies during peak demand periods and manage distributed energy resources, demand response programmes and other flexible assets. SCADA can be integrated with other advanced technologies such as advanced metering infrastructure, distributed energy resources management systems and demand response platforms to create a holistic smart grid ecosystem.

By integrating digitally enabled demand response into smart grids, the curtailment of VRE sources could be decreased by over 25% by 2030. This would enhance system efficiency, leading to lowered expenses for consumers. Moreover, improved supply and demand forecasting can bolster decarbonisation efforts, allowing for integrated energy planning and offering enhanced visibility and flexibility in electricity demand.

Governments and grid utilities can develop smart grid plans that act as a comprehensive strategy for the modernisation and transformation of a traditional electrical grid into a smarter, more efficient and technologically advanced system. This plan encompasses a wide range of initiatives, technologies and policies aimed at enhancing grid reliability, optimising energy use, integrating renewable energy sources, and enabling new services and capabilities. The primary goals of a smart grid plan usually include improving energy efficiency, reducing carbon emissions, enhancing grid resilience and accommodating the evolving electricity system's landscape.

In order to stay on the pathway towards net zero emissions by 2050, investments in smart grids need to more than double through to 2030, especially in emerging market and developing economies.

**Digital Demand-Driven Electricity Networks initiative**

Digital Demand-Driven Electricity Networks (3DEN) is an IEA initiative supported by the Italian Ministry for the Environment and Energy Security. It provides analysis and policy guidance on how digital tools can support power system decarbonisation and organises peer-to-peer knowledge exchange.

The 3DEN report Unlocking Smart Grid Opportunities in Emerging Markets and Developing Economies provides guidance for energy policy makers on possible ways to enable and drive investments in smart and resilient electricity grids and on how to create enabling environments for the effective use of digital technologies.

# Building-to-grid interactivity

Modernisation of energy efficiency in buildings can be defined as an improvement in reducing heat loss through building envelopes and increasing energy efficiency of appliances to the highest feasible levels and also making use of digital technologies that can help realise buildings' demand flexibility potential and respond to the signals from the grid. Demand flexibility can be enabled by various technologies that provide automatic control to influence and structure a customer's demand profile in a way that can provide the same or higher quality of energy services for consumers and reduce costs for both customers and the grid.

**Demonstration projects for EGIBs in Europe**

Companies across Europe are investing in energy efficiency renovations coupled with grid-interactive technologies with the aim of showcasing the benefits to utilities and consumers the potential of grid interactivity. For example, a project developed by Dcbel of a single-family home outside of Paris, France, showcased the use of a combination of energy efficiency, solar PV electricity generation, EV charging and general household electricity demand. By investing in improving the energy performance of the building through the installation of a smart gas heating and biomass pellet stove, smart lighting, and smart appliances, annual $CO_2$ emissions were reduced from 10 tonnes (t) of $CO_2$ per square metre ($m^2$) per year to 4 t $CO_2/m^2$ per year. The addition of the smart systems provide flexibility of around 11 kW of shiftable assets, which was the result of predictive scheduling and shifting to cheaper periods that also coincided with more renewables in the grid.

## Two-way communication

Building-to-grid interaction requires interoperability, meaning both sides are able to communicate with each other. There are three aspects of this interoperability:

- technical interoperability: devices are capable of both physical and digital integration and basic connectivity
- syntactic interoperability: devices use a common digital language
- semantic interoperability: devices understand specific instructions using a standardised set of recognised commands.

There are also different levels at which interoperability could be implemented within EGIBs.

**Levels of interoperability in EGIBs**

| Level | Interoperability attributes | Examples |
|---|---|---|
| Equipment | Special devices or interfaces that enable the communication and information flow, e.g. appliance controller, smart communication interface, demand response enabling device, standard socket and communication protocol to be plugged into appliances and equipment. | CTA-2045 module |
| Buildings | Building automation and communication protocols used in building energy management and automation systems to establish communication between different appliances and devices. | LonWorks, BACnet, Modbus, KNX, Zigbee |
| Building-to-grid | Communication protocols to connect various technologies between buildings and the grid, and provide automated control to manage voltage and quality fluctuations that could result from DERs. | OpenADR, IEEE 2030.5, IEC 61850, IEEE 1547-2018 |

## Equipment level

Equipment and appliances need to be capable of responding automatically to price and/or other signals by shifting or modulating electricity consumption and/or production.

To enable such communication between appliances and, for example, with the BEMS or directly with the grid, devices and equipment need to be equipped with a special device or interface that enables the communication and information flow. It is generally an appliance controller that determines the overall operation of the appliance, can send and receive information, and receives requests and triggers related responses or rejects those requests that are not applicable.

Such appliances are also smart and can be programmed to run at certain times, when electricity is cheaper, or be remotely controlled through signals from the grid or via a building (or home) EMS by automatically modifying its operation to reduce or shift demand.

For example, in the United Kingdome appliances can be equipped with a dedicated energy smart communications interface that can communicate status and forecast information concerning energy use of one piece of equipment to other devices, as well as receive energy-related information and instructions from other devices. Australia introduced an appliance interface for delivering demand response called the Demand Response Enabling Device. Air conditioners equipped with such a device allow an electricity provider to control its electricity use at various preprogrammed levels to manage users' demand in the grid during peak periods.

The CTA-2045-A module is a standard socket and communications protocol that can be plugged into direct current (DC) slots on certain appliances to enable them to communicate through the internet and connect to the grid in order to receive information (e.g. electricity price signals). There are already special certifications (e.g. EcoPort mark) for appliances that indicate that the certified appliance is equipped with a special control module that is capable of establishing network communications in line with the requirements of the CTA-2045 standard. This would align the appliance's energy consumption based on minimised electric grid costs or with times of VRE availability.

In Australia and New Zealand, for example, single-phase non-ducted air conditioners for households require energy labelling with information on demand response capability, including energy performance, input power, capacity output and variable compressor capability.

**Saver's Switch, Xcel Energy, United States**

The Saver's Switch programme by Xcel Energy in Minneapolis, United States, aims to manage peak loads during summer periods by adjusting the timing of when air conditioning systems are switched on.

The programme recruits customers with central air-conditioning systems (e.g. not mini-splits air conditioning) where the smart switch is installed at the breaker box to allow the utility to send signals to change the operation of the air conditioner. The switch cycles the air conditioning off and on at 15-20 minute intervals but allows for the system fans to stay on to circulate the air that has already been cooled. The Saver's Switch programme is typically activated during summer days between 14:00 and 19:00.

As compensation for taking part in the programme, every October the utility provides a users credit, which is equivalent to a 15% reduction on their electricity bill and varies according to the size of their air-conditioning unit. In 2020, the Saver's Switch residential cooling programme had approximately 11 500 customers participating in its demand response programme, which were estimated to have saved 3 600 MWh and avoided 5 400 kW of demand.

The Switch programme evaluation showed that participant retention was over 90% and customers were highly satisfied with the bill credits, the overall thermal comfort during the switch events, the frequency of the events and the overall programme. Customers were shown to either not notice the events or change their behaviours to pre-cool their home so that comfort would be maintained during potential events and thus embedding a behaviour to avoid energy demand during peak periods.

The Saver's Switch shows the benefit to customers signing on to allow utilities to control customer power demand to reduce grid peak load from air-conditioning units during periods where utilities might need to manage grid supply stability due to extraneous events (i.e. hot periods) and excess power generation costs (e.g. avoiding costly peak generation). The use of wireless grid communications to modify the activity of a building energy system is an example of a one-way grid to appliance interaction.

## Buildings level

At the buildings level, BEMS, HEMS and BAS (discussed in the section on Smartness above) can provide supervisory control of smart appliances, EV chargers and distributed generation. These systems can also facilitate communication among them, as well as with the grid through utilisation of building automation and communication protocols.

Building automation protocols serve as the rules and standards enabling communication among different devices in building automation systems. Typically, proprietary protocols have been utilised in these systems, even within the same company, leading to the need for gateways to convert between different protocols. However, gateway development is a complex process that requires knowledge of both protocols and introduces delays in response time. One of the biggest challenges with proprietary protocols is integrating third-party subsystems, as they lack flexibility and compatibility.

Open communication protocols, on the other hand, allow devices from different vendors to work together without the need for proprietary interfaces or gateways. The main benefit of using open protocols is the ease of expanding the system. With open protocols, there is a wider range of choices available from various vendors. However, it is important to consider certain factors when selecting a protocol, such as the number of products supporting the protocol, cost implications, adherence to regional standards and ensuring adequate security measures.

Open protocols can be categorised as wired or wireless, each with its own strengths and weaknesses. Wireless protocols are particularly suitable for existing buildings due to their easy installation, while wired protocols are preferred for new buildings where reliability and performance are critical. Additionally, wireless communication tends to be more cost-effective compared with wired communication.

A large number of proprietary protocols and a resistance of some manufacturers to accept standardised approaches makes this field very fragmented and limits interoperability among different smart technologies. However, a variety of open standard protocols (e.g. LonWorks, DeviceNet, BACnet, C-Bus, m-Bus, Modbus, KNX, some Institute of Electrical and Electronics Engineers [IEEE] standards) have been developed and are being used in different countries. The OPC Foundation has also been making efforts to encourage interoperability among major building automation standards.

Utilisation of cloud technology in BEMS and HEMS provides opportunities for demand response and property management. Machine learning and artificial intelligence are useful emerging technologies that can improve the efficiency of data management and analysis in buildings, as well as speed up operations that would otherwise be time-consuming to evaluate and decode. These technologies are particularly effective at pattern recognition in buildings operations and triggering required responses to them in an automatic manner.

BEMS and HEMS can offer benefits to the energy systems through the control of capacity and voltage, ancillary services to the grid, and integration with virtual power plants (VPPs) and other aggregators.

## Building-to-grid level

Open communication protocols can help establish interoperability, connect various technologies between buildings and the grids, and provide automated control to manage voltage and quality fluctuations that could result from DERs. OpenADR for a decentralised and demand-response-focused approach and IEEE 2030.5 for residential DER integration, direct smart inverter control, smart metering and automation of demand response are well-known international protocols that can offer such a language. Some national and subnational legislations are already adopting these protocols to facilitate building-to-grid (B2G) interactions and DER management. For example, California Rule 21 requires that generating facilities (e.g. solar panels, wind turbines, batteries) that utilise inverter-based technologies to interact with the utilities must deploy a communications protocol.

Another important tool for achieving international standards on interoperability is IEC 61850 for communication in electrical substations. This standard aims to unify communications by avoiding proprietary protocols, providing interoperability to integrate equipment from different manufacturers and providing flexibility for the standard to evolve as new use cases emerge. It is anticipated that the standard will evolve in the future to cover additional areas such as wind, solar, and hydro generation; battery storage; and EV integration.

Another standard – IEEE 1547-2018 – focuses on the interconnection of DERs, including smart inverters, and requires them to provide various types of support to the grid. This will help increase the amount of DERs that can be handled by the grid, especially as their penetration increases, while improving the stability and quality of electricity supply.

## Monitoring and optimisation of distributed energy resources

Advanced metering infrastructure (AMI) can play a key role in monitoring and managing energy usage in buildings, enabling real-time data collection and analysis, as well as demand response and outage detection. Distributed energy resource management systems (DERMS) can help monitor, co-ordinate and optimise DER operation at the distribution grid level. DERMS ensures grid reliability, efficient utilisation of DERs and integration of renewable energy resources. Aggregating DERs into VPPs further enhances their optimisation and dispatch capabilities, allowing for real-time control and optimisation of energy flows.

### Advanced metering infrastructure

AMI, similarly to smart meters, provides opportunities to monitor and manage energy usage in buildings while offering a more comprehensive system. This infrastructure includes a variety of technologies, such as communication networks and data management systems allowing for two-way communication between the smart meter and the energy provider and enabling real-time data collection, monitoring and analysis. AMI can also provide additional functionalities such as demand response, outage detection, and remote disconnection and reconnection of service.

**AMI at Brunswick Electric Membership Corporation**

Brunswick Electric Membership Corporation is located in southeastern North Carolina, United States, and serves over 90 000 meters. In order to start using AMI, the Corporation had to install new substation equipment and replace all existing meters. AMI helped to significantly improve efficiency through:

- Better monitoring: hourly data and voltage readings are used to monitor how the system is performing, which helps to identify irregularities (e.g. potentially overloaded transformers) that can be fixed before an actual failure occurs.

- More accurate payment system: PrePay Power that allows customers to pay for their power in advance or "pay-as-you-go" scheme that allows customers to track and manage their electricity consumption in real time, eliminating the need for a monthly bill and providing the opportunity to know the exact expenditure on the actual electricity used.

## Aggregation of distributed energy resources

Efficient buildings equipped with solar systems, storage and EV smart changing and enabled by digital technologies for interaction with the grid essentially become DERs that offer numerous benefits to both the grid and consumers, as discussed above. However, if they are not properly managed or integrated, they can also have negative impacts on power systems and grids:

- Introducing variability and uncertainty in power output can strain grid stability, leading to issues such as voltage fluctuations, frequency deviations and power quality problems.
- Concentrations of DERs in specific areas can result in localised grid congestion. For example, when excess renewable electricity is fed into distribution networks, it can overwhelm the capacity of local transformers and power lines.
- Individual DERs may not provide necessary grid services, such as frequency regulation or voltage support, which decreases their ability to respond to system-wide grid needs.
- The distributed nature of DERs can introduce new cybersecurity vulnerabilities to the grid, as each individual DER unit represents a potential entry point for cyberattacks, which can disrupt grid operations and compromise the security and privacy of grid data and systems.

Addressing these negative impacts requires proactive measures such as advanced grid management systems, grid codes and regulations that promote DER integration, enhanced grid infrastructure planning, and standardised communication protocols for DER devices.

DERMS can facilitate management of various DERs through the combination of a software platform and hardware devices designed to monitor, co-ordinate and optimise the operation of DERs at the level of a distribution grid. It provides comprehensive visibility and control over individual DERs and enables utilities or grid operators to manage the integration of these resources effectively. DERMS typically include functionalities such as real-time monitoring, forecasting and optimisation algorithms to manage and control DERs. Using sensor data and receiver communications, DERMS can provide real-time co-ordination of energy generation and storage across distributed, grid-connected assets.

The primary focus of DERMS is to ensure grid reliability, efficient utilisation of DERs and integration of renewable energy resources. It enables utilities to balance supply and demand, manage grid congestion, and address voltage and frequency fluctuations caused by DERs.

Digital tools can help not only manage individual DERs but also aggregate them into a single entity that can be controlled and operated as a unified system, such as a virtual power plant. The primary purpose of a VPP is to optimise the use and dispatch of these DERs. By leveraging advanced technologies and communication systems, a VPP can monitor and manage generation, consumption and storage of electricity across multiple sites. It enables real-time control and optimisation of energy flows to meet demand and supply requirements of the grid or specific market conditions.

A VPP is managed by the central information technology system that processes data such as weather forecasts, wholesale electricity prices, and overall power supply and consumption trends. This data analysis enables the optimisation of dispatchable DERs within the VPP, ensuring efficient operation based on the prevailing conditions. By aggregating multiple DERs, a VPP can create a substantial capacity comparable to that of a traditional power generator. A VPP's operator can sell electricity or ancillary services through electricity exchanges or the wholesale market, or by offering their services to system operators.

While VPPs are considered a nascent technology, they have begun to appear in countries around the world.

### Some VPP projects in the world

| Country | Developer | Key features |
| --- | --- | --- |
| Australia | Tesla | Tesla and the electricity retailer Energy Locals are developing South Australia's VPP with the purpose of reaching 50 000 solar and home battery systems. In 2020, Tesla had 1 000 Powerwall batteries online and is now rolling out phase 3 to another 3 000 houses. The project allowed consumers to save up to AUD 423 (Australian dollars) per year on electricity bill. |
| Brazil | AES Brasil | AES Brasil started developing a VPP, the first of its kind in Brazil, in 2017 in collaboration with CERTI Foundation. The second phase is expected to require an investment of USD 1.9 million. |
| China | CSG Shenzhen Power Supply | China's first VPP was launched in Shenzhen, with a capacity of 870 MW, planned to increase up to 1 GW by 2025. |

| | | |
|---|---|---|
| Japan | Tesla | As of August 2022, the project, called Miyakojima VPP, had over 300 Powerwall batteries as part of the VPP. Tesla expects to install 600 Powerwalls by the end of 2023. |
| Singapore | Energy Market Authority | In 2019, Energy Market Authority and Sembcorp, in partnership with Nanyang Technological University, started developing Singapore's first VPP. The VPP will optimise the power output of DERs located across the island and balance energy fluctuations due to solar intermittency, taking into account Singapore's power grid and market conditions through demand forecasting and optimisation algorithms. |

VPPs can offer both demand- and supply-side flexibility to the grid. Demand-side flexibility is achieved by aggregating demand-response resources and energy storage units, enabling them to respond to grid requirements. Supply-side flexibility is achieved by optimising power generation from flexible resources such as co-generation plants, biogas plants and utilising energy storage units.

**Smart campus systems, The University of Queensland, Brisbane, Australia**

Through installing a 1.1 MW/2.15 MWh battery and connecting it to the virtual power plant managed by Enel X University of Queensland's in Australia was able to offset 100% of its electricity needs with renewable energy. The university has enrolled the battery storage system in the Enel X energy management initiative that enables the battery to be used for grid optimisation. The use case for the battery was to manage the campus electricity demands alongside acting to support and reinforce the electricity grid through dispatchable load. The battery can provide around two hours of storage capacity for the entire university at full power. The university's battery system can support the grid by providing instant dispatchable load capacity if a power generation reduction or transmission failure is experienced. By doing so, the university is able to benefit from improved tariffs for on-site battery energy storage (i.e. charging during low prices and selling during high).

The investment in the VPP battery has enabled the university to save around AUD 74 000 in its first three months of operation and an expected full return on the AUD 2.1 million investment within eight years. The majority (58%) of the revenue from the battery use was from the payments made by the National Electricity Market frequency control ancillary services system, which pays for grid stability, while a further 14% came from a virtual cap that acts as an insurance for the wholesale electricity spot market volatility, and a further 28% for arbitrage.

Using the battery as part of a load management system provided a number of benefits for the university and the VPP. This included improving effective control strategies to maximise the daily arbitrage revenue related to the variability of the spot price uncertainty, and reducing the period of time the batteries were offline due to nuisance surge protections and network outages impacting the control system architecture.

The virtual power plant at the University of Queensland shows how the use of large on-site batteries to optimise the grid reliability through a combination of microgrid and virtual power plant's dispatchable load provides an opportunity for organisations, such as universities, to become "prosumers" by actively participating in the grid power market. Investing in energy efficiency investments and smart building power load management alongside on-site battery storage and virtual EMS will mean that behind-the-wire storage solutions are optimally designed for B2G interactivity.

Management and aggregation of DERs can be facilitated by means of artificial intelligence that offers the capability to constantly oversee numerous devices and promptly determine the allocation of resources in response to prevailing factors such as demand, supply, weather conditions and other dynamic variables. Artificial intelligence can also use historical data analysis and predictive modelling for real-time decision-making. This allows for generating accurate forecasts regarding the impact of these variables on the electricity system in the short, medium and long terms.

Virtual power plants can also play a vital role in peer-to-peer (P2P) solar electricity trading (hereafter P2P energy trading) by enabling the efficient and transparent exchange of renewable energy between consumers. P2P energy trading refers to the direct buying and selling of solar-generated electricity between localised energy producers (often buildings with rooftop solar PV panels) and consumers, without the involvement of traditional utility companies as intermediaries. This type of trading usually requires the use of smart meters to measure the amount of generated and consumed electricity, and a digital platform or software to connect solar panel owners with potential buyers and to track the electricity being sold, stored or bought within the network. VPPs provide such a platform with necessary infrastructure and control mechanisms, as well as enable an efficient and transparent exchange of renewable energy during the trading process among different parties.

P2P energy trading is still a relatively new concept and the potential for implementation of related projects varies depending on the region and regulatory framework. It requires supportive policies and regulations that enable the integration of DERs and the development of appropriate trading platforms. Several countries around the world are implementing related pilot projects to assess potential benefits and drawbacks.

**Some P2P energy trading projects around the world**

| Country | Project name | Key features |
|---|---|---|
| Colombia | Comunidad Solar La Estecha – El Salvador | The programme involves 24 families, 43 solar panels and 2 distributed generators, which inject nearly 3 000 kWh per month into the national grid. The distribution of benefits is expected to reduce the energy bill by 15%. |
| Germany | Landau Microgrid Project | In Landau, 20 households can trade locally generated renewable electricity on a platform via automated software agents, while data are collected through blockchain-enabled smart meters and transmitted via a mobile app. |
| India | Blockchain platform in Lucknow | The first P2P blockchain trial in India promoted by the India Smart Grid Forum (ISGF) and PowerLedger. Such technology has reduced the energy market buy price by 43% with respect to the retail tariff. |
| United Kingdom | CommUNITY | The project is based in Brixton, London, and it enables consumers to trade solar energy with each other via a mobile app. The participants reduced their energy bills by more than 20%. |
| United States | Brooklyn Microgrid | A self-contained system composed of solar panels and batteries that uses a P2P blockchain-based trading platform technology to enable participants to buy and sell energy. More than 130 buildings participated in the programme when it was launched, and the project is still expanding today. |

## Load and frequency management

Load and frequency management strategies could include demand response programmes, dynamic electricity tariffs and smart charging for EVs. Smart inverters play an important role in harnessing flexibility potential of DERs, including buildings, and optimising the operation of the electric grid. Demand response, dynamic electricity tariffs and smart charging for EVs allow consumers to voluntarily reduce their electricity demand during peak periods or shift their usage to off-peak hours, reducing strain on the grid and promoting the adoption of renewable energy. Smart charging systems for EVs enable intelligent management and optimisation of charging processes, balancing the load on the grid and maximising the use of renewable energy sources. Smart inverters support the integration of solar energy and other DERs into the grid, providing grid support functions such as voltage regulation and frequency support. These load and frequency management strategies are essential for ensuring grid stability, reducing peak demand, and promoting a more efficient and sustainable energy system.

## Demand-response programmes

Demand response enables consumers to voluntarily reduce their electricity demand when the electricity prices are high in exchange for system-wide benefits. Demand response involves shifting or shedding electricity demand to provide flexibility in wholesale and ancillary power markets, helping to balance the grid and usually reduce electricity costs, as more demand takes place during the times when electricity prices are lower. Modern data-driven demand response programmes typically use real-time validation of available demand response through two-way communication with connected electricity-consuming appliances and equipment. A user can often overwrite the demand response settings, when it is needed.

Generally, there are two main demand response mechanisms: i) implicit, or price-based programmes, which use price signals to encourage consumers to shift consumption and adapt their behaviour to save energy; and ii) explicit, or incentive-based programmes, which monetise demand response through direct payments to consumers.

**Demand-response programmes in some countries**

| Country | Standards or regulation | Description |
|---|---|---|
| Australia | AS 4755 – Demand Response Standard | Demand response capability and modes of appliances and smart devices. |
| India | Tata Power-DDL | The programme covers 55 000 residential consumers and 6 000 large commercial and industrial consumers to provide load flexibility in peak periods. The programme aims at achieving 200 MW of peak capacity reduction by 2025. |
| Japan | Post-3.11 “Demand Response” | Imposes an across-the-board 15% reduction of peak demand on large-scale consumers with contract power of 500 kW or more. |

| | | |
|---|---|---|
| South Korea | Energy Pause Programme | Residential demand response for small consumers below 70 kW. Automated demand response system interface between the smart appliance and the controlling entity. |
| Netherlands | Decree 2022 – 14201 | Producers and consumers above 60 MW must provide flexibility in highly congested areas. |
| United States | Senate Bill 49 – The Flexible Demand Appliance Standards | Mandated the California Energy Commission to adopt standards for appliances to facilitate the deployment of flexible demand technologies. |

## Dynamic electricity tariffs

Dynamic electricity tariffs (e.g. time-of-use tariffs or dynamic pricing) are a type of electricity pricing system that charges different prices for electricity depending on the time of day or day of the week. With time-of-use tariffs, electricity prices for consumers are typically higher during peak demand periods and lower during off-peak hours. This pricing structure is intended to encourage consumers to shift their electricity usage to off-peak hours, when electricity may be cheaper to produce and may come from cleaner sources, and the power grid is less stressed.

Time-of-use tariffs are becoming increasingly important as power grids modernise to incorporate more VRE and can make it difficult for grid operators to balance electricity supply and demand in real time, which can lead to power outages, blackouts and other issues.

Time-of-use tariffs can help to reduce peak demand and may also reduce overall electricity consumption. By charging higher prices during peak demand periods, consumers are incentivised to use less electricity or to shift their usage to off-peak hours, therefore reducing strain on the power grid during times of high demand, which leads to lower electricity bills for consumers.

Time-of-use tariffs are also important for promoting the adoption of EVs. With EV uptake increasing, there is a growing need for charging infrastructure that can accommodate the increased demand for electricity. Time-of-use tariffs can help to incentivise consumers to charge their EVs during off-peak hours. A study in the United Kingdom has shown that customers using hourly dynamic pricing through smart meters have shifted 28% of their demand from peak periods and on average saved around GBP 180 on their annual bills.

## EV smart charging in buildings

The EV market is experiencing rapid expansion, with sales surpassing 10 million units in 2022 globally. In 2022, electric cars accounted for 14% of all new car sales, a significant increase from approximately 9% in 2021 and less than 5% in 2020. It means that nearly one in five cars sold globally this year will be electric.

The increasing adoption of EVs in the world is also driving the demand for their charging infrastructure. Most charging demands are currently fulfilled through charging in buildings (be it at home or in non-residential buildings that serve as work or public places), making EV charging an additional energy-consuming end use in the buildings sector.

There is, however, a growing need for publicly accessible chargers to ensure the same level of convenience and accessibility as refuelling for internal combustion engine vehicles. This is particularly crucial in densely populated urban areas where access to home charging is limited, making public charging infrastructure a vital factor in facilitating the adoption of EVs. As of 2022, there were 2.7 million public charging points worldwide, with over 900 000 installations occurring in 2022 alone. This represents a 55% increase compared with the levels in 2021.

Smart charging for EVs offers intelligent management and optimisation of EV charging processes. It involves utilising advanced technologies and communication systems to co-ordinate and control the charging of EVs, taking into account factors such as electricity demand, grid capacity and user preferences.

Smart charging can balance the load on the building's electrical system by distributing and scheduling charging sessions based on available capacity. It optimises charging times to avoid overloading the grid during peak demand periods and ensures that other building operations are not disrupted. This helps prevent electricity demand spikes and reduces the need for costly infrastructure upgrades. The timing of smart charging can also be co-ordinated with the availability of VRE.

Smart charging can take advantage of time-of-use electricity pricing. By scheduling charging during off-peak hours when electricity rates are lower, EV owners can benefit from reduced charging costs.

Smart charging systems can communicate with the power grid, allowing for bidirectional flow of electricity. Such vehicle-to-grid capability can allow EVs to participate in demand response programmes where excess electricity stored in batteries can be fed back into the grid during peak demand periods or used in a building as a backup power source in the event of a power outage – in this case EVs can serve the role of distributed energy storage. A typical EV stores about 68 kWh in its battery, which means that it can power an average home in the United States for more than three days if it is not used for transportation.

**Charging Perks Pilot, Xcel Energy, United States**

The Charging Perks Pilot by Xcel Energy is a programme that is designed to better utilise the charging and capacity of EVs to optimise the use of renewable energy production and low grid demand. Xcel is looking to proactively address and manage the peak demand from EV charging and match this with renewable energy generation to make use of the EV's ability to vary its charging demands and capacity.

The programme involves working with several EV companies (BMW, Ford, General Motors, Honda and Tesla) with the intention to attract around 600 EV customers in Colorado. It will partner with the manufacturers to access the EV charging information when plugged into the grid on Level 1 and Level 2 charging stations to determine when and how much charging is needed and to match this with available renewable generation from the grid. The EV manufacturers will use the charging data along with data from the utility to create a charging schedule that ensures a customer vehicle is charged and available when needed and optimised to charge when the conditions are most suitable for using renewable energy and low demands on the grid.

The programme is focused on customers with EVs who are on both time-of-use tariffs and non-time-of-use tariffs to compare the rate designs on charging behaviour. Customers taking part in the pilot receive up to USD 300 for participating, which is equivalent to around 2 000 kWh or around 28 full charges of a 75 kWh EV battery.

Initial analysis shows that the overall cost-effectiveness of the programme is expected to be high, with the utility able to obtain information on how to scale the programme to achieve power peak kilowatt savings, improve system optimisation to address changes in peak demand timing from changes in EV charging behaviours, and evaluate benefits of automating the increase in EV charging demand during periods of wind energy curtailment.

## Smart inverters

The common interface point between the grid and energy generating and storing resources is the inverter, which converts DC voltage from renewable energy and storage systems into usable, grid-quality AC voltage.

Smart inverters are an emerging technology that can help integrate solar energy and other DERs into the electric grid. Like traditional inverters, smart inverters convert the DC output of solar panels into the AC that can be used by consumers in their homes and businesses. Smart inverters go beyond this basic function to provide grid support functions, such as voltage regulation, frequency support and ride-through capabilities.

As the number of DERs on the grid increases, the need for additional inverter functionality has grown. Additionally, existing codes and technical standards (e.g. IEEE 1547 and UL 1741) are being updated to ensure that smart inverter capabilities can be fully realised.

Fortunately, smart inverters have a variety of advanced functions that can help the grid reliably accommodate more DERs, such as rooftop solar and energy storage.

The Volt-Watt function is one of the advanced features of smart inverters that enables them to monitor the voltage within their specific area of the power grid. This monitoring capability offers significant advantages in supporting the overall grid functionality. If the voltage exceeds normal levels, the inverter can adjust the amount of power being fed from the solar array or other DERs (such as energy storage) to the grid. This adjustment helps prevent issues related to poor power quality. However, in some cases, this function can have a negative impact on individual customers since it reduces the amount of solar power being produced when activated. California, a leader in mandating the use of smart inverter functions to accommodate more DERs on the grid, stands out by requiring the implementation of the Volt-Watt function for all customers with distributed solar systems.

# Assessment of opportunities for efficient grid-interactive buildings in ASEAN

Investing in energy efficiency and digitalisation is becoming critical for managing the increase in energy demand in the Association for Southeast Asian Nations (ASEAN) region with growing pressures of population growth, urbanisation and an expanding construction sector. Early actions that prioritise the potential offered by buildings in terms of enhanced efficiency, flexible electricity demand and smart local energy storage will ensure the ASEAN electricity grid is resilient to growing demand.

By investing in energy efficiency measures, such as energy-efficient appliances, high-performance building envelopes (including passive design strategies) and materials, and intelligent building systems, buildings can reduce energy demand and add resilience to the electricity grid through greater flexibility and interactivity.

Digitalisation plays a pivotal role in optimising building performance and unlocking energy efficiency potential in the context of grid decarbonisation. Through the adoption of digital technologies such as smart meters, sensors and controllers, as well as building automation systems, and data analytics, buildings can efficiently manage their electricity consumption, respond to demand fluctuations and contribute to grid stability. These digital solutions enable real-time monitoring, analysis and control of energy usage, allowing for timely adjustments and improvements.

By embracing digitalisation and efficiency measures in buildings within ASEAN, a range of benefits can be realised including improved energy security, reduced GHG emissions, and lower operational costs for building owners and occupants. Additionally, investing in the clean energy and digital sectors can support job opportunities and help drive economic growth and technological innovation for modern electrification.

In this chapter, the framework presented in the previous chapter to introduce the enablers for building-to-grid interactivity is applied to analyse the current status of these enablers in ASEAN countries. For each enabler, several evaluation criteria were determined to capture different potential stages a country could be at for a given enabler depending on its unique context. For each country and enabler one of the four evaluation criteria is selected based on the collected data and information to assess its contribution to enabling the uptake of efficient grid-interactive buildings (EGIBs).

## Evaluation criteria for enablers for efficient grid-interactive buildings

| Category | Enablers | Evaluation criteria | | | |
|---|---|---|---|---|---|
| **Energy efficiency** | High-performing building envelopes | No mandatory or voluntary building energy codes are available | Voluntary building energy code is available | Mandatory building energy code is available for some buildings based on defined criteria | Mandatory building energy code is available for all buildings |
| | Energy-efficient appliances and equipment | No MEPS for major appliances used in buildings are available | MEPS are available for a few types of major appliances | MEPS are available for most of the types of major appliances | MEPS are available for all the types of major appliances |
| **Decarbonisation** | On-site renewable energy (RE) generation | No policies or programmes for on-site RE generation in buildings are available | Voluntary policies or programmes for on-site RE generation are available | Mandatory policies for on-site RE generation for some building types are available | Mandatory policies for on-site RE generation for all building types are available |
| | On-site energy storage | No policies or programmes for on-site energy storage in buildings are available | Voluntary policies or programmes for on-site energy storage in buildings are available | Mandatory policies for on-site energy storage for some building types are available | Mandatory policies for on-site energy storage for all building types are available |
| **Smartness** | Internet of things /smart sensors and controls | IoT /Smart sensors and controls are not used in buildings | Initial /pilot stage of IoT/Smart sensors and controls adoption in buildings | IoT/Smart sensors and controls are used in buildings often | IoT/Smart sensors and controls are very common in buildings |
| | Building energy management (BEMS) & automation systems (BAS) | BEMS or BAS are not used in buildings | Initial /pilot stage of BEMS or BAS adoption in buildings | BEMS or BAS are used in buildings often | BEMS or BAS are very common in buildings |
| | Smart meters in buildings | Smart meters are not used in buildings | Initial /pilot stage of smart meters adoption in buildings | Smart meters are used in buildings often | Smart meters are very common in buildings |
| | Smart grids | Smart grid plans are not available | High-level smart grid plans are available, but the targets and implementation are not well defined | Smart grid plans are available and set targets, but their implementation is not well defined | Comprehensive smart grid plans are available, with well-defined targets and implementation |

| Category | | Enablers | Evaluation criteria | | | |
|---|---|---|---|---|---|---|
| Building-to-grid interaction | Two-way communication | Equipment level | No policies on open communication standards for appliances are available | Voluntary policies on open communication standards for appliances are available | Mandatory policies on open communication standards for some major appliances are available | Mandatory policies on open communication standards for all major appliances are available |
| | | Buildings level | No policies on open communication standards for buildings automation (BA) | Voluntary policies on open communication standards for BA are available | Mandatory policies on open communication standards for BA are available for some building types | Mandatory policies on open communication standards for BA are available for all buildings |
| | | Building-to-grid (B2G) level | No policies on B2G interoperability are available | Voluntary policies on B2G interoperability are available | Mandatory policies on B2G interoperability are available for some building types | Mandatory policies on B2G interoperability are available for all building types |
| | DERs monitoring and optimisation | Advanced metering infrastructure (AMI) | AMI is not used | Initial/pilot stage of AMI adoption | AMI is used often | AMI is very common |
| | | Aggregation of distributed energy resources (DERs) | Aggregation of DERs is not present | Initial/pilot stage of aggregation of DERs | Aggregation of DERs is used often | Aggregation of DERs is very common |
| | Load and frequency management | Demand-response programs | DR programmes are not available | Voluntary automated DR-policies or manual DR programmes are available for certain users | Mandatory policies for automated DR are available for certain types of users | Mandatory policies for automated DR are available for all types of users |
| | | Dynamic electricity tariffs | Dynamic electricity tariffs are not available | Voluntary dynamic electricity tariffs are available for certain types of users | Mandatory dynamic electricity tariffs are available for certain types of users | Mandatory dynamic electricity tariffs are available for all types of users |
| | | EV smart charging in buildings | EV smart charging is not used in buildings | Initial/pilot stage of EV smart charging adoption in buildings | EV smart charging is used in buildings often | EV smart charging is very common in buildings |
| | | Smart inverters | Smart inverters are not used | Initial/pilot stage of smart inverters adoption | Smart inverters are used in buildings often | Smart inverters are very common |



Based on the aggregation of selected evaluation criteria across all the enablers, each country is placed in one of the three groups: Explorers, Adopters or Innovators.

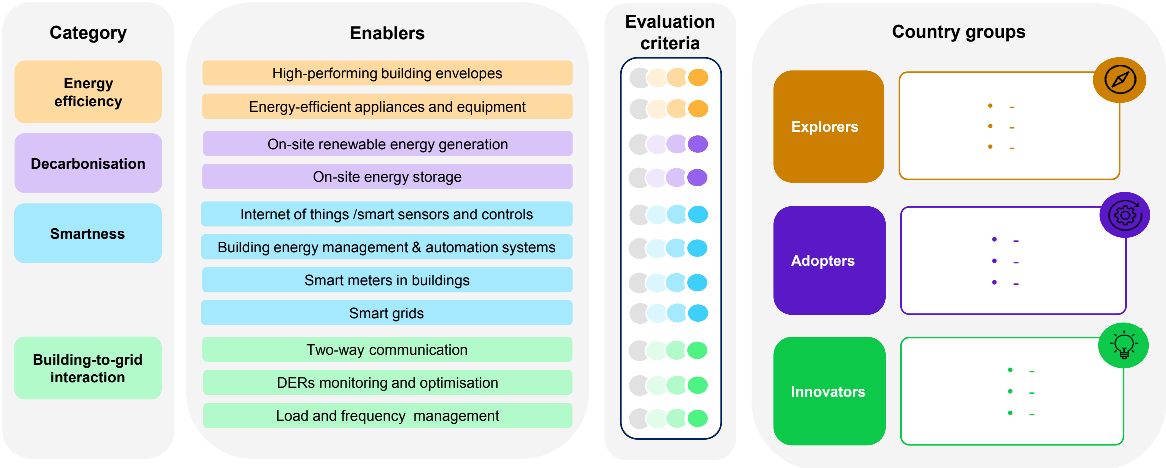
For each country, group policy-oriented recommendations are provided in the next chapter to facilitate the process of adopting practices and solutions to increase the uptake of EGIBs.

The main purpose of this analysis is to determine where each ASEAN country stands in its journey to realising the opportunities of EGIBs as well as to provide recommendations for improvement, and not for direct comparisons between the countries. The results of the assessment were discussed with experts from each country to verify the accuracy of the assessment.

Subsequent sections are structured around the enablers, and for each ASEAN country the assessment of its current status is indicated with the colour corresponding to the selected evaluation criteria based on the collected data and information.

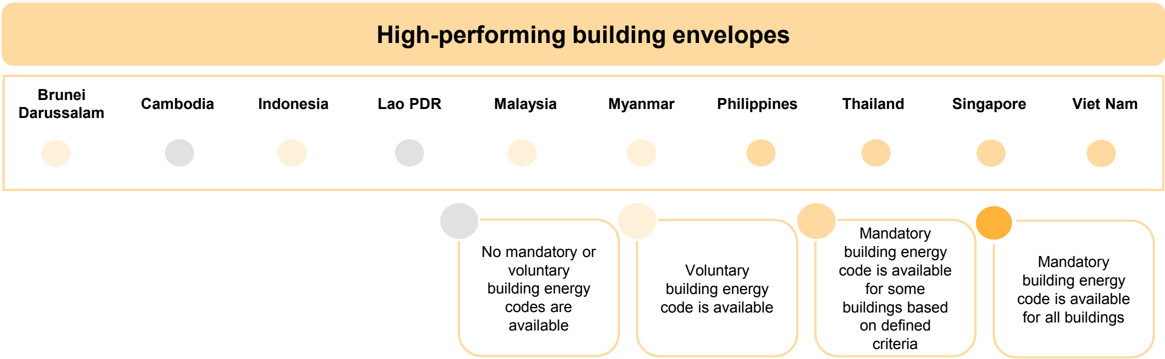
ASEAN countries are at differing levels in their status of adopting EGIBs solutions. IEA analysis shows that there are several countries that are innovating and advancing their adoption of policies and technologies to support EGIBs, along with a number of countries that have recently begun to adopt policies and demonstrate EGIB technologies, and others that continue to work on establishing a foundation for utilising EGIBs.

**Process of assessing enablers for EGIBs and forming country groups with tailored recommendations**




IEA. CC BY 4.0.

# Improving energy efficiency of buildings requires stronger enforcement of energy performance requirements



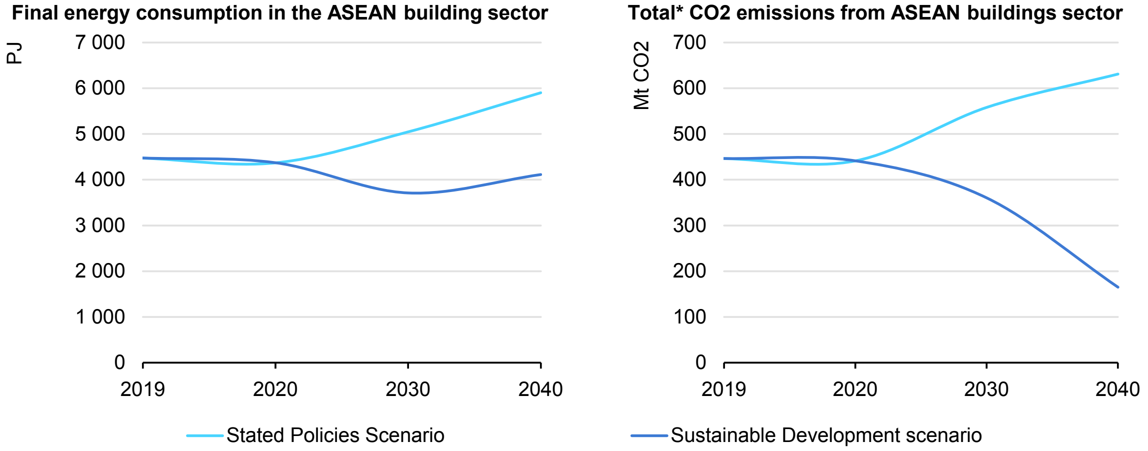



Energy efficiency in buildings in the ASEAN region is a crucial aspect of reducing energy consumption and GHG emissions. The implementation of energy efficiency measures, supported by relevant policies, can offset the projected growth in energy consumption. By improving the energy performance of building envelopes and energy efficiency of systems, increasing renewable energy use, and enhancing energy access for vulnerable households, $CO_2$ emissions from buildings can be reduced by over 60% by 2040. However, stronger enforcement of building energy codes is necessary to achieve these goals.

Under the IEA Stated Policies Scenario, both final energy consumption and $CO_2$ emissions in buildings in ASEAN will continue to grow without ambitious policy actions. However, the implementation of energy efficiency measures in all buildings supported by relevant policies throughout the region (under a Sustainable Development Scenario) will allow for offsetting most of the growth in energy consumption, while providing modern energy access for all. Improving the energy efficiency of buildings, increasing renewable energy utilisation, and phasing out the use of traditional biomass and switching to clean cooking and electricity, while enhancing the energy access of vulnerable households across the ASEAN region, can result in more than a 60% reduction in $CO_2$ emissions from buildings by 2040 from 2020 levels.

Buildings in the region account for almost a quarter of the region's total final energy consumption (TFEC) and energy-related $CO_2$ emissions. The TFEC in the buildings sector is projected to increase by approximately 45% from 29.3 million tonnes of oil equivalent (Mtoe) in 2020 to 42.5 Mtoe in 2030, and more than triple by 2050, reaching about 92 Mtoe. Thus, improving energy efficiency in buildings and appliances is an important step for ASEAN to reduce energy consumption and GHG emissions.

**Final energy consumption (left) and total $CO_2$ emissions* (right) of the ASEAN buildings sector**





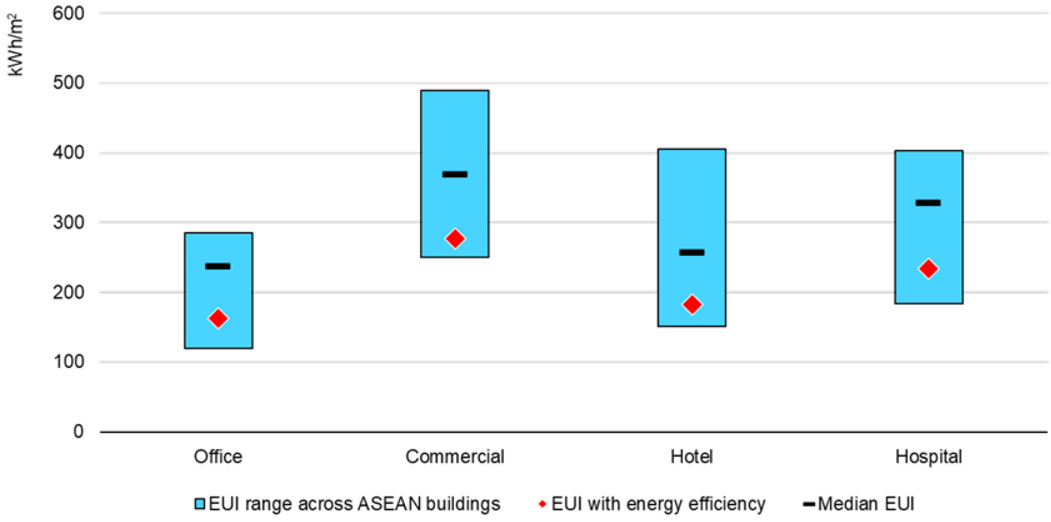

* Total $CO_2$ emissions comprise direct and indirect emissions. Direct emissions include those from coal, oil and natural gas. Indirect emissions are the emissions from power generation plants.

Notes: PJ = petajoules; Mt = million tonnes. In this figure, "buildings" energy use and emissions refer to the operational energy consumption, and do not include the construction phase or the energy and emissions associated with manufacture of materials.

Source: Adapted from IEA (2021), World Energy Outlook 2021.

Data collected for non-residential buildings in several ASEAN countries indicate that the implementation of energy efficiency measures and adherence to the certification schemes available in ASEAN, such as EDGE, Green Mark, Leadership in Energy and Environmental Design (LEED), and Green Building Index, have led to improvements in energy consumption. On average, buildings that were certified with these schemes demonstrated energy use intensities between 20-70% lower than that of a typical building of the same type. Under these certification schemes, a variety of energy efficiency measures could be implemented in buildings, such as efficient building envelopes, light-emitting diode (LED) lighting with smart controls, shading, insulation, rooftop solar panels, building automation systems, and energy management systems (EMS).

**Typical energy use intensity in ASEAN across different types of non-residential buildings**

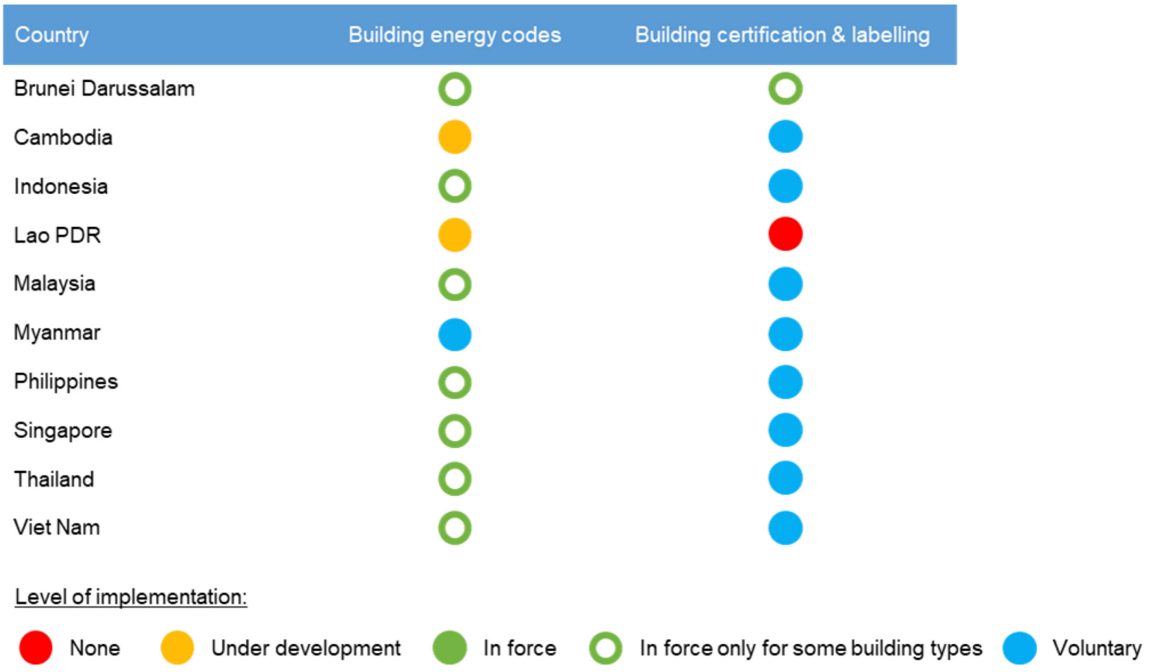





Notes: kWh = kilowatt-hours; $m^2$ = square metre; EUI = energy use intensity in kWh/$m^2$. The middle line shows the median of the non-exhaustive data set. The EUI data were collected from government databases, available publications and other secondary sources covering more than 800 buildings of four non-residential buildings types (offices, retail, hotels, hospitals) in eight ASEAN countries: 53 in Brunei Darussalam, 153 in Indonesia, 123 in Lao PDR, 21 in Malaysia, 59 in the Philippines 432 in Singapore, 76 in Thailand, 148 in Viet Nam. The diamond-shaped red marker indicates the EUI reduction after energy efficiency is implemented.

Acceleration of energy efficiency improvements in buildings in ASEAN requires comprehensive policy development and support. Mandating and enforcing building regulations with minimum energy performance requirements for buildings and other provisions for energy efficiency improvements are crucial for providing a market push towards more energy-efficient buildings. Several ASEAN member states have already adopted some form of building energy codes (BECs).

**Status of building energy codes, buildings certification and labelling in ASEAN**






Source: IEA (2022), Energy Efficiency 2022.

In Singapore, the Building and Construction Authority established a series of mandatory energy efficiency regulations for new and existing buildings through its Building Control Act (Environmental Regulations 2008). The Building and Construction Authority's regulations are mandated for new or existing buildings with a gross floor area of 5 000 m$^2$ or more. The regulations cover several energy efficiency areas, including lighting, air conditioning and building envelope design.

The Indonesian government, through the Ministry of Public Works and Housing regulation no. 21/2021, regulates the green building performance for new and existing buildings. This regulation is mandatory for buildings with a minimum of 5 000 m$^2$ of gross floor area and also sets the criteria for energy efficiency evaluation, such as building envelope, ventilation systems, air conditioning and lighting.

Thailand announced the Notification of the Ministry of Energy on Determination of Building Design Standards for Energy Conservation B.E. 2564 (2021) as the new BEC. The new notification replaced the old BEC, which was established in 2009. The new BEC is applicable to both new buildings and those undergoing major renovation, with the total gross floor area of more than 2 000 m$^2$, which can be attributed to one of the nine building types: education, office buildings, theatre, convention hall, entertainment, department store, hotels, hospitals and condominiums.

The Philippines also developed the Guidelines on Energy Conserving Design of Buildings to establish the minimum requirements for the energy-efficient design for new and retrofit buildings. These guidelines apply to two types of designated establishments: Type 1, which are buildings that consumed between 500 000 kWh and 4 million kWh of energy in the previous year, and Type 2, which are buildings that consumed more than 4 million kWh of energy annually.

Viet Nam renewed the National Technical Regulation on Energy Efficiency Buildings in 2017. The regulation provides mandatory technical standards in design for the new and retrofit building with a gross floor area of 2 500 $m^2$ or larger. The regulation applies to buildings of the following types: offices, hotels, hospitals, schools, commercial and residential.

Myanmar also revised its BEC in 2020, which replaced the previous regulation in 2016. While Myanmar's BEC contains a number of provisions for the minimum design standards that promote energy efficiency and green building criteria, it remains voluntary for implementation.

In Brunei Darussalam, the Ministry of Development, along with the Energy Department Prime Minister's office, has developed Energy Efficiency and Conservation building guidelines for non-residential buildings. The guidelines are regulatory mechanisms for buildings to establish energy efficiency and conservation standards. The building guidelines are mandatory for all government buildings and voluntary for all commercial buildings.

In Malaysia, through the Malaysian Standard 1525:2019, the government enacted a voluntary BEC for non-residential buildings. This code focuses on the architectural and passive design strategy, building envelope, efficient air conditioning and lighting, EMS, application of renewable energy in new and existing non-residential buildings, and building energy performance. For Cambodia and Lao PDR, BECs are currently still being developed.

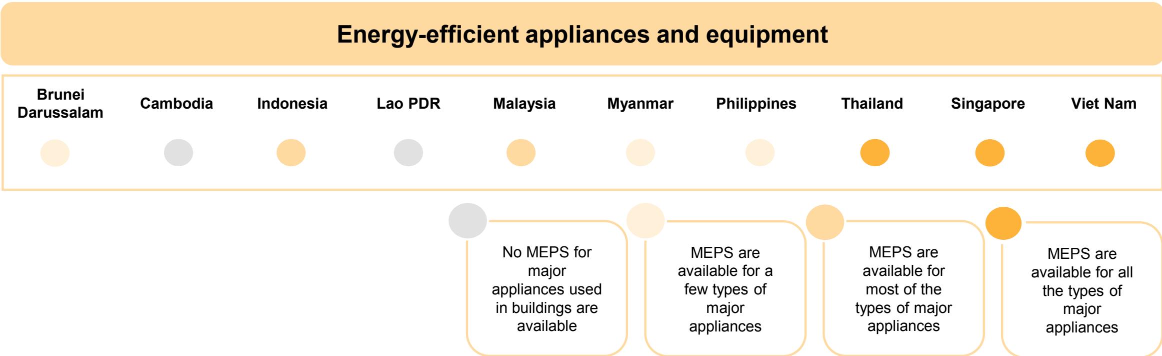
Financial mechanisms could help to encourage the achievement of higher levels of buildings energy performance going beyond the minimum requirements for energy efficiency established by the regulations, as well as promote the use of specific energy-efficient and digital solutions.

Several countries in ASEAN have implemented various financial policy instruments to support  energy efficiency and conservation projects in buildings, including:

- Thailand (e.g. Energy Efficiency Revolving Fund and Energy Service Company fund)
- Malaysia (Energy Performance Contracting Fund, Sustainability Achieved via Energy Efficiency, the Energy Audit Conditional Grant)

- Singapore (Green Mark Incentive Scheme)
- Indonesia (Viability Gap Fund and PT Sarana Multi Infrastruktur)
- the Philippines (strategic investments from the Department of Energy)
- and Viet Nam (National Technology Innovation Fund and the Viet Nam Energy Efficiency for Industrial and Enterprises).

# MEPS for appliances need to increase stringency to drive energy efficiency






Several countries in the ASEAN region have implemented energy efficiency requirements for electrical appliances, particularly focusing on air conditioners. All countries in the region now have some form of MEPS and labelling policies for air conditioners either in force or currently under development. However, the stringency of MEPS for appliances must be increased and countries must strengthen the enforcement of policies to drive further energy efficiency improvements in the region. Furthermore, rating methods and requirements for labels and standards differ across countries, which creates hurdles in creating a regional market for efficient appliances. In order to ensure MEPS across the region are coherent, ASEAN member states aim to develop a framework for harmonisation of standards and labels.

### Status of MEPS and labelling for selected appliances and equipment in ASEAN

| Country | Residential air conditioners | | Residential refrigerators | | Residential lamps | |
|---|---|---|---|---|---|---|
| | MEPS | CL | MEPS | CL | MEPS | CL |
| Brunei Darussalam | In force | Under development | None | None | None | None |
| Cambodia | Under development | Under development | Under development | Under development | None | None |
| Indonesia | In force | In force | In force | In force | In force | In force |
| Lao PDR | Under development | Under development | None | None | None | None |
| Malaysia | In force | In force | In force | In force | In force | None |
| Myanmar | Under development | Under development | None | None | None | None |
| Philippines | In force | In force | None | In force | In force | In force |
| Singapore | In force | In force | In force | In force | In force | In force |
| Thailand | In force | In force | In force | None | In force | None |
| Viet Nam | In force | In force | In force | In force | In force | None |

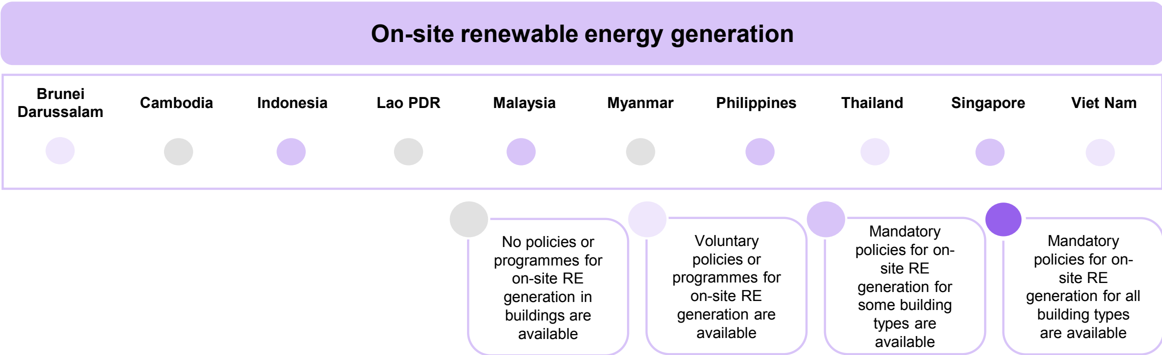
Status:
In force · Under development · None · Voluntary



Note: CL = comparative label.
Source: IEA (2022), Energy Efficiency 2022.

In 2022, Brunei Darussalam introduced efficiency standards and labelling regulations specifically targeting electrical appliances. The Indonesian government promulgated MEPS and energy labelling regulations for air conditioners, refrigerators, fans, rice cookers and LED lamps. It is projected that these MEPS can help avoid energy demand of 2 exajoules (EJ) by 2030 and 7 EJ by 2050. Furthermore, the IEA identified that all air conditioners in the Indonesian market already meet the energy efficiency requirements. Meaning the current MEPS regulation had no effect in removing low-efficiency products. It is estimated that Indonesia alone could save 225 terawatt-hours (TWh) of electricity demand growth by 2050 by implementing robust appliance efficiency standards, energy pricing reforms, and building energy codes and standards.

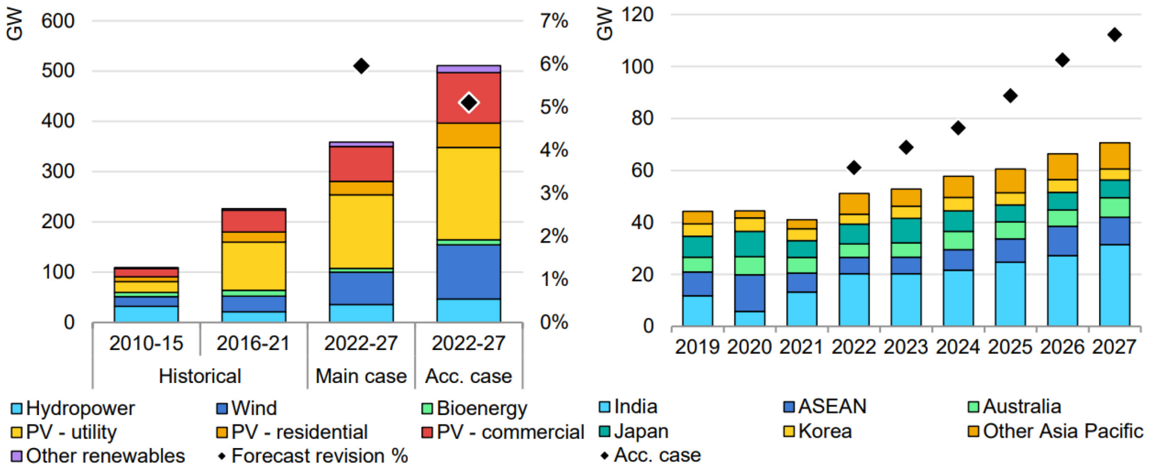
# Decentralised solar systems offer opportunities for the buildings sector's decarbonisation






In ASEAN, the share of renewable electricity in the generation mix increased from 28% to 33% between 2018 and 2020, mainly driven by the growing use of decentralised solar PV systems. This growth can be attributed to various government policies such as feed-in tariffs, net energy metering and power purchase agreements (PPAs), which incentivise the deployment of rooftop solar systems. It is expected that renewable energy capacity will increase by 51 gigawatts (GW) (+56%) during the 2022-2027 period, where solar PV will account for over half of the growth, followed by onshore wind and hydropower. However, some countries, such as Viet Nam, are considering policy changes that may hinder the growth of rooftop solar due to grid congestion. Hence, to accelerate the decarbonisation process and achieve faster deployment of renewables, it is crucial to invest in grid infrastructure, simplify permitting procedures, update national energy strategies with ambitious targets and attract international investment.

**Renewable capacity additions in Asia and the Pacific, 2010-2027 (left), and annual capacity additions by country, 2019-2027 (right)**






Notes: Acc. case = accelerated case. Other Asia Pacific excludes China.
Source: IEA (2022), Renewables 2022.

IEA analysis for an accelerated renewable deployment scenario estimates that deployment in ASEAN in the period of 2022-2027 would need to be more than 50% higher in the main case. Solar PV and wind turbines have the largest potential for power generation due to lower generation costs compared with other renewables and these technologies have become more competitive with coal-fired generation.

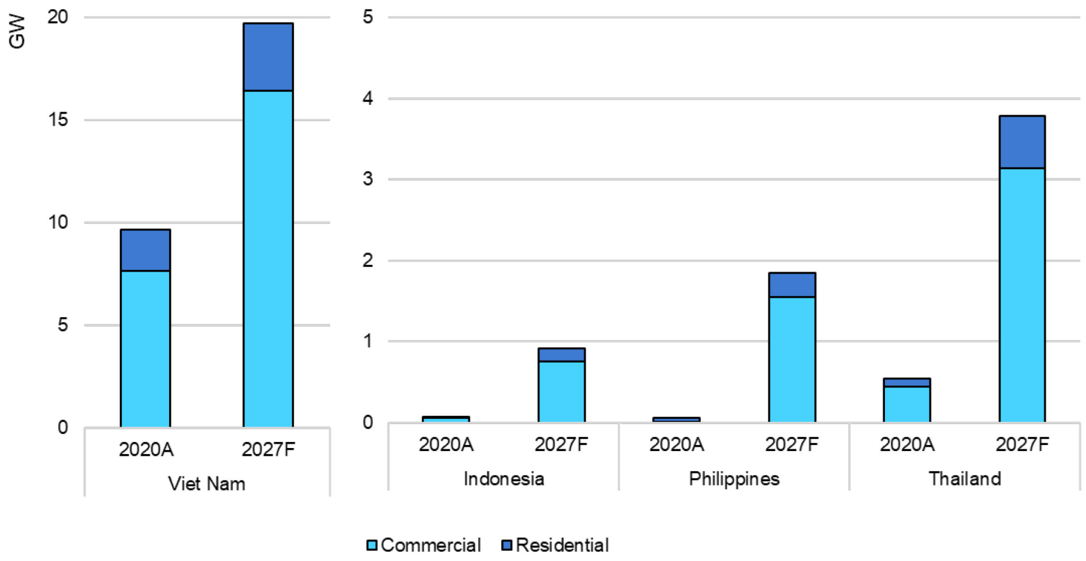
ASEAN's solar PV deployment in the commercial and residential sectors is estimated to almost triple from 2022 to 2027, led by Viet Nam but with important growth in Indonesia, the Philippines and Thailand.

In the first quarter of 2020, Viet Nam was the leader among ASEAN countries in terms of installed rooftop solar capacity, mainly driven by policies that the government previously applied, such as a feed-in-tariff scheme, net-energy metering and power purchase agreements (PPAs). At the end of 2020, the total rooftop solar capacity in commercial operations stood at 7.7 GW. However, the growth of rooftop solar will likely be hampered due to the government proposal in the upcoming Power Development Plan 8 to replace the net energy metering policy with self-consumption. Under the proposal, Viet Nam Electricity will no longer purchase generated power from rooftop solar, and the capacity will remain at the same level until 2030.

In Thailand, as of 2020, the installed solar rooftop capacity reached 3 GW, supported by a net metering scheme for residential solar PVs launched in 2019. Under this programme, the Provincial Electricity Authority purchases solar electricity generated by PV systems installed on the roofs of residential houses.

During the 2022-2023 period, the Provincial Electricity Authority set the purchase price at a fixed rate of about USD 0.063 per kWh for ten years. The Provincial Electricity Authority also determines that the total purchase target for the programme is 5 MW per year. Although the new power development plan is currently being drafted, the targets and measures for increasing renewable capacity that will be included in the plan remain uncertain.

**Installed capacity of solar PVs in commercial and residential buildings in Viet Nam (left), and Indonesia, the Philippines, Thailand (right)**






Note: A = actual; F = forecast.

Apart from government policies, Sumitomo Rubber Industries in Thailand has also taken steps towards promoting renewable energy by announcing the installation of the world's largest rooftop solar system. The system will have a capacity of 22 megawatts (MW) and is expected to generate 30 gigawatt-hours (GWh) of electricity annually, making it a significant contribution towards achieving the country's renewable energy target. The installation is scheduled to be completed in January 2025, marking a significant step towards promoting clean energy in Thailand.

In Singapore, the Building and Construction Authority and Energy Market Authority worked together to develop a one-stop guide for installing solar PV by residential dwellers and building developers. Through Green Mark 2021, Intelligence Section, the Building and Construction Authority also requires buildings to install on-site renewable energy to be certified under the Green Mark scheme. Building owners can benefit from installing solar PVs for self-consumption as well as selling the excess electricity to the grid. Energy Market

Authority offers several payment schemes for different customers, depending on their contestability and solar capacity.

The Singapore government, through the Housing & Development Board, also introduced the SolarNova auction programme to boost solar PV installations. The programme promotes and auctions aggregated solar demand by solar projects across government agencies. The SolarNova programme works by facilitating the development of solar PV systems on public sector buildings and sites, such as schools, hospitals and government agencies. The programme invites private solar companies to submit proposals for the installation and maintenance of solar PV systems on these sites. The solar companies are selected through a competitive bidding process based on their proposed pricing, technical capabilities and track record. Once selected, the solar companies will design, install, operate and maintain the solar PV systems, and sell the electricity generated to the relevant government agency or institution. Between 2015 and 2020, the auction programme awarded 296 MW of solar capacity.

Malaysia also introduced a net energy metering (NEM) programme for solar PVs in November 2016. The programme is divided into three schemes, each tailored to specific consumer categories: NEM Rakyat serves domestic consumers, NEM GoMEn caters to government agencies and NOVA (Net Offset Virtual Aggregation) targets commercial and industrial consumers. Each programme also capped the total maximum PV capacity eligible for participation during the period 2021-2023: 150 MW for NEM Rakyat, 100 MW for NEM GoMEn and 800 MW for NOVA. Within this programme, any excess electricity produced by solar PVs can be exported to the grid and counted against the next electricity bill on a one-to-one basis. Additionally, in support of the development of renewable energy in the country from May 2021, Kuala Lumpur City Hall required all future residential and commercial developments in the city to source 30% of their electricity from renewable energy. This has supported Kuala Lumpur's ambition to become carbon-neutral by 2050.

In Indonesia, the Ministry of Energy and Mineral Resources recently held a public hearing to inform the public regarding the revision of Regulation No. 26 of 2021, which governs the export of rooftop solar electricity to the grid. The revision replaces the exporting scheme with self-consumption, which means that consumers will no longer be able to export excess electricity to the grid and receive a reduction in their electricity bill. The new revision also eliminated the capacity charge for industrial players. Furthermore, through Indonesia's National Energy Plan, the country also imposes a mandatory policy for government and public buildings to use a minimum of 30% of their rooftop area for rooftop solar PV.

The Philippines also developed a net metering programme that allows end users to install up to 100 kW renewable energy sources to lower the electricity cost and sell the excess to the grid. In addition, the Philippines introduced Green Energy Option Programme, a voluntary policy to permit individuals or entities to source their electricity from renewable energy suppliers, thus lowering their emissions.

In order to accelerate solar rooftop deployment, the Philippines Department of Energy has implemented DC 2020-12-0026, which mandates that new and existing buildings meeting certain criteria must incorporate solar PV or other renewable energy sources. Specifically, buildings with electrical loads of at least 112.5 kilovolt-amperes (kVa) or a total gross floor area of 10 000 $m^2$ or more are required to source a minimum of 1% of their projected annual energy requirements from solar PV or other renewable energy sources.

### Solar rooftop supporting policies for commercial and residential consumers

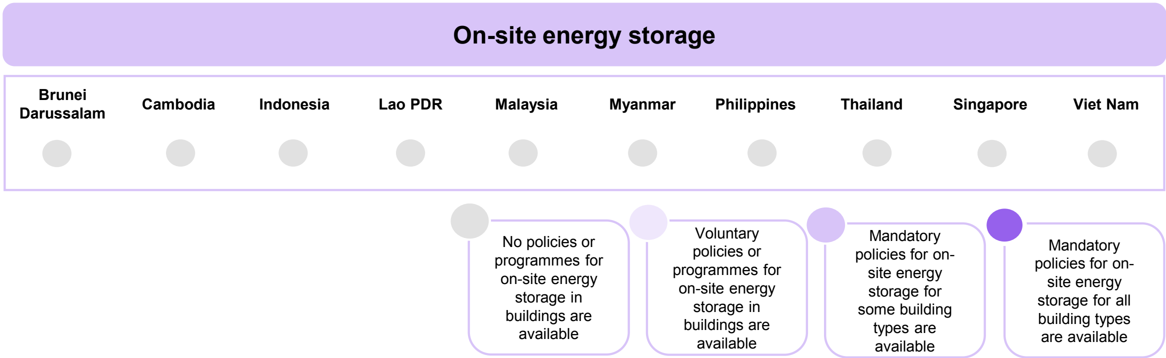
| Country | Net energy metering programme | Self-consumption |
|---|---|---|
| Brunei Darussalam | Pilot phase | Not available |
| Cambodia | Not available | Not available |
| Indonesia | Terminated | Ongoing |
| Lao PDR | Not available | Not available |
| Malaysia | Ongoing | Ongoing |
| Myanmar | Not available | Not available |
| Philippines | Ongoing | Not available |
| Singapore | Ongoing | Not available |
| Thailand | Ongoing | Not available |
| Viet Nam | Terminated | Ongoing |

Status:
Ongoing  Terminated  Pilot phase  Not available



Notes: All information collected as of July 2023. The net energy metering programme is a mechanism that allows solar panel owners to export excess electricity generated back to the grid and receive credits for the surplus of energy. Self-consumption refers to the utilisation of the solar energy generated by the rooftop PV to power the facility/property directly, reducing dependency on grid electricity and potentially leading to cost savings.

# Use of energy storage in buildings is very limited across the region





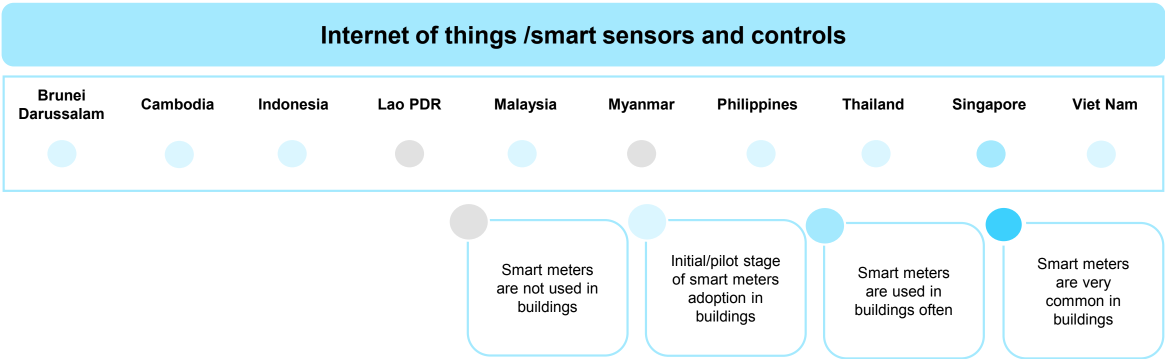

ASEAN member states have begun to address the intermittency of renewable energy through the deployment of energy storage, both on and off the grid. Currently, energy storage deployment across the region is largely centred around grid-scale projects, although there are some initiatives at the microgrid and distributed levels. In buildings, energy storage integration occurs close to the point of energy generation and consumption.

Across the region, there is a lack of policy evidence mandating the installation of energy storage. Nevertheless, there are already some energy storage solutions at the buildings level; however, the flexibility potential that storage solutions could offer through participation in demand response and other load management programmes is currently not being utilised.

In Singapore, the Energy Market Authority and Singapore Power Group plan to pilot an ice thermal energy storage in George Street to support energy demand from the Marina Bay district cooling network. The energy storage system will have a capacity up to 1 500 refrigeration tonne-hours, enabling savings of up to 2 MW, equivalent to the energy consumption of 170 four-room flats in a single day. The pilot project is anticipated to be completed in the third quarter of 2026.

In Thailand, Vistec University and Chumpoll Temple have also implemented a battery energy storage system (BESS) to enhance their renewable energy operations. They employ lithium-based batteries with capacities of 0.86 MW (Vistec University) and 5 kW (Chumpoll Temple) to ensure a consistent power supply sourced from on-site solar PV.

# Smart sensors and controls are making their way into smart buildings pilot projects

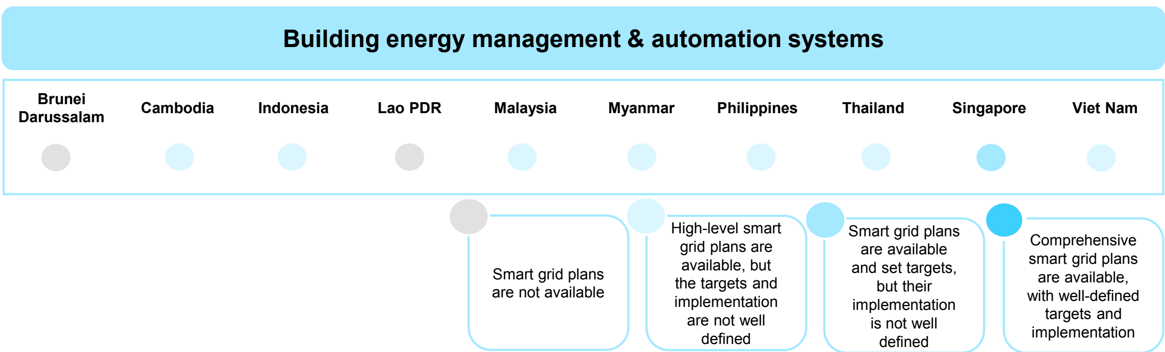





Smart solutions in buildings are being implemented in ASEAN countries at a limited scale and mainly in non-residential buildings. While there are currently no policies mandating the use of smart digital technologies in buildings, the topic has gained interest among policy makers. Various countries in the region have taken initiatives to promote building digitalisation.

Singapore through its Green Mark 2021 will encourage the use of smart building solutions, processes and controls, as well as relevant data and analytics, while a number of other countries, for example Indonesia, Malaysia, Thailand, Viet Nam, and have implemented pilot projects to test some smart solutions in real-life buildings operations.

# Energy management and automation in buildings expand potential of energy efficiency



The highlights the potential benefits of building digitalisation to enhance economic growth, energy savings and environmental sustainability. Building digitalisation, including BEMS and BAS, can enhance buildings energy efficiency and flexibility. Despite being in its infancy stage, the building digitalisation market in the region is expected to grow significantly, with an estimated compound annual growth rate of 13% over the next few years. At present, there are no policies in the ASEAN region that mandate the use of digital technologies in buildings, but the topic has gained interest among policy makers, particularly with respect to energy management.

Singapore's Code for Environmental Sustainability of Buildings included a BEMS, a standalone EMS or other similar systems to compute and display the total system energy efficiency and its component. The code is mandated for non-residential buildings with a minimum gross floor area of 5 000 $m^2$.

Singapore's newest Green Mark 2021 included integrated energy management and control systems among its assessment criteria. This criterion evaluates the presence of any mechanisms for tracking building energy use and presenting data in a relevant manner to encourage occupants and building managers to optimise building energy consumption. It covers digital tools, such as energy consumption monitoring and benchmarking systems; heating, ventilation and air conditioning (HVAC) demand controls; and lighting controls.

The Thailand 20-Year Energy Efficiency Development Plan emphasises the importance of EMS for reporting and verification on buildings. The development plan also includes a set of strategic measures to mandate buildings to follow certain rules, regulations and standards. One of the measures is to enforce the Energy Conservation Promotion Act B.E. 2535 (2021) to establish designated buildings and factories to implement an EMS and impose a penalty for those that violate the regulation. The act will be enforced for nine building types with a minimum total gross floor area of 2 000 $m^2$ or more or buildings that consume the energy of 1 million kWh per year or more.

The Indonesian Ministry of Energy and Mineral Resources and Danish Energy Agency have developed a roadmap for promoting energy efficiency and low-carbon buildings in the construction sector. The primary aim of this roadmap is to provide guidance and direction to transition towards low GHG emissions, greater energy efficiency and more environmentally friendly buildings in Indonesia. Recently, the Indonesian government promulgated Government Regulation No. 33/2023, lowering the minimum energy consumption threshold; this revision requires that all commercial and public buildings with the annual energy consumption of 500 tonnes of oil equivalent (toe) and higher (instead of from 6 000 toe) implement energy management programmes, which involve appointing energy managers and developing energy management plans. The roadmap outlines a vision for the future, with the anticipation that by 2030 a substantial number of energy managers will have received training in energy management. Furthermore, by 2050, all commercial and public buildings are expected to have operational BEMS in place, supported by dedicated energy managers.

According to an Asia-Pacific Economic Cooperation, Brunei Darussalam is considering implementing ISO 50001 standard for energy management policy as it continues to develop its national energy management policy. The government of Brunei Darussalam is encouraging building owners to install BEMS, BAS and electronic controllers to increase energy efficiency.

In Malaysia, the government developed Malaysian Standard 1525:2019, a voluntary code of practice for energy efficiency and renewable energy for non-residential buildings. The code provides a broad range of energy efficiency measures, including implementation of an EMS. The EMS covers BAS for buildings with air-conditioning systems serving an area of 4 000 $m^2$ or more.

ASEAN has developed professional training programmes and certifications for energy managers to support the implementation of BEMS, BAS and other digital technologies in buildings.  has successfully trained 343 energy managers since its inception in 2010. In 2022, a new programme, the Sustainable ASEAN Energy Management Certification Scheme, was initiated, emphasising the integration of digital technologies such as e-learning and virtual reality for practical training. Subsequently, the ASEAN-Japan Energy Efficiency Partnership Scheme 4 was introduced, aiming to improve the quality of the previous curriculum and training system. It proposes advanced practical measures for energy efficiency and enhances the implementation of related regulatory frameworks. This scheme capitalises on digital technology to augment the quality of training, thereby demonstrating the power of digital tools in driving energy efficiency.

**Nucleus Tower in Malaysia – a nexus of passive energy-efficient design and active digital technologies**

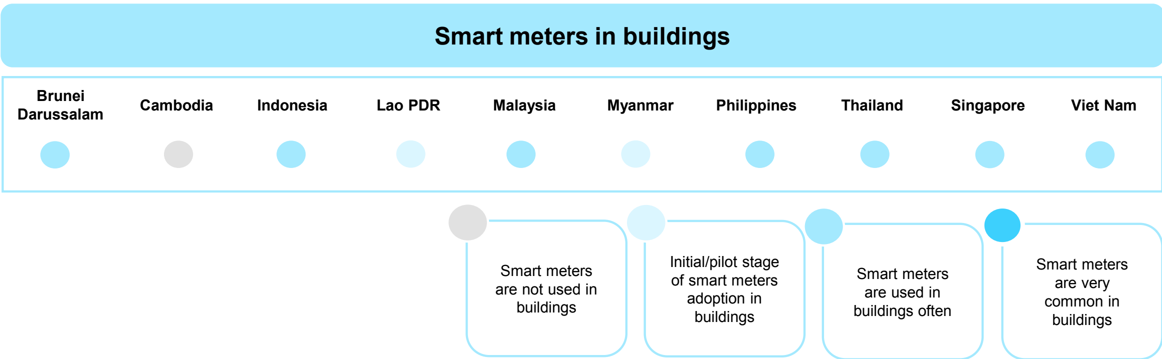
Nucleus Tower is a 24-storey office tower with a 3-storey commercial annex located in the popular Mutiara Damansara area in Malaysia. It is a green building with Green Building Index Gold Grade A certification, boasting several energy-efficient technologies. High efficiency glazing with double-glazed 12.88 millimetre glass, vertical shading and an overall thermal transfer value of 42.31 (watts per square metre) results in substantially lower building energy demand.

The building features an underfloor air-conditioning system or air distribution system for the offices to provide zonal space cooling and thus reduce the energy demand for cooling. Other energy-efficient features include lighting motion sensors, photo sensors and LED lights. During construction, the building adopted environmentally friendly processes such as the use of Mivan system formwork to reduce formwork waste, with 38% of building materials being sourced regionally. The building has been designed and constructed with storm water management and erosion and sedimentation soil prevention standards and uses 66.7 kilowatt-peak (kWp) solar panels to generate electricity.

The building also uses an integrated building management system, Smartstruxture, which allows for effective monitoring, measuring and optimisation of energy use. Smartstruxture is a building management system developed by Schneider Electric that combines environmental control, energy management and monitoring, and security management.

All of these sustainable measures have resulted in Nucleus Tower achieving a building energy intensity of 113 kWh/year/m$^2$, which is more than 50% lower in comparison to a typical office tower. This remarkable performance is due to the combination of passive design initiatives, active digital components and sustainable features that make Nucleus Tower an energy-efficient building.

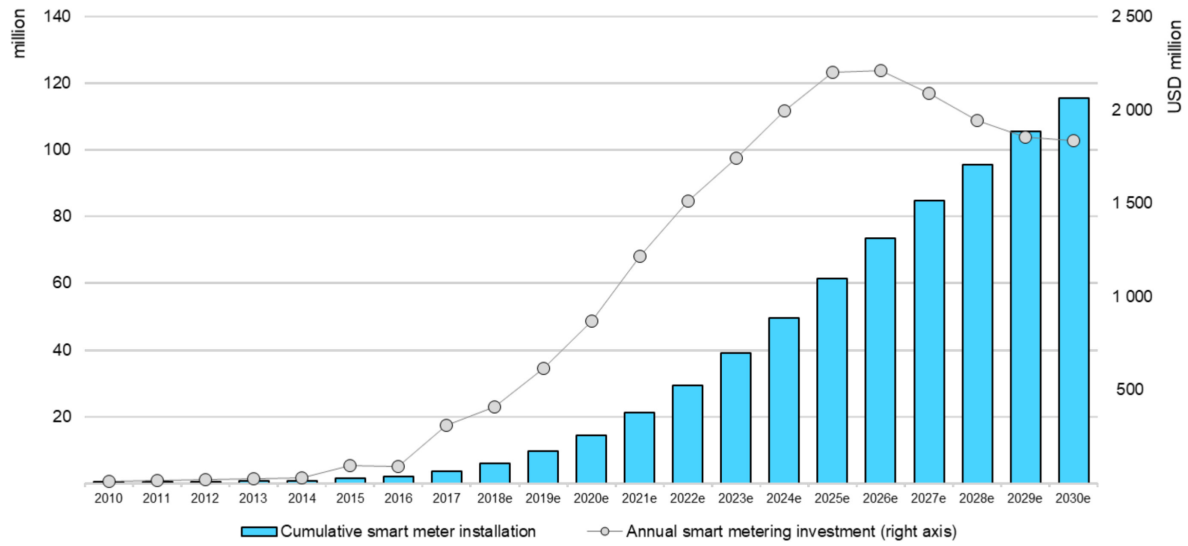
# Smart meter programmes are being rolled out across the region




IEA. CC BY 4.0.

While the number of smart meters installed across the ASEAN region is relatively low (around 30 million as of 2022), it is expected to grow rapidly. The cumulative amount of smart meter installations in the region is estimated to reach 115 million by 2030, with a compound annual growth rate of 25%. To effectively sustain the smart meter growth, the region will need an annual investment of USD 1.5 billion. The investment will play a pivotal role in supporting the deployment, maintenance and advancement of the smart meter infrastructure.

### ASEAN smart meter deployment and annual investment, 2010-2030e

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Note: e = estimated.
Source: IEA analysis based on IEA (2023), Tracking Clean Energy Progress 2023 and BloombergNEF (2017).

Each of the ASEAN member states started rolling out programmes to support the uptake of smart meters, mainly driven by the utilities, to improve data collection and billing processes. While the installation of smart meters itself does not ensure interaction between buildings and the grid, their deployment helps to create such opportunities in future, especially if smart meters are integrated into a broader framework of smart grid infrastructure and energy management systems.

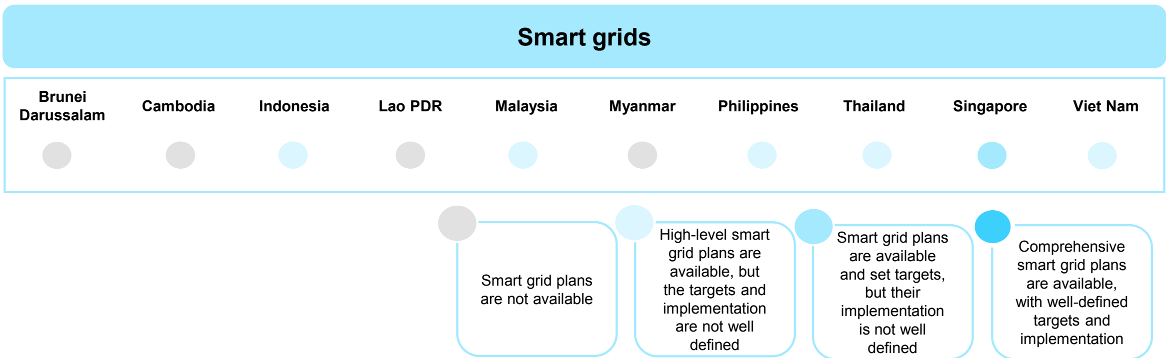
### Smart meter programmes in ASEAN

| Country | Smart meter rolling out status |
|---|---|
| Brunei Darussalam | In 2023, over 4 000 units of smart meters were installed at private residences and commercial buildings through the Unified Smart Metering System. |
| Cambodia | Cambodia is currently expanding its grid capabilities through a USD 127 million loan provided by the Asian Development Bank (ADB), including the installation of smart meters. |
| Indonesia | At the beginning of 2023, Perusahaan Listrik Negara (PLN), as the national electric utility, will start rolling out 1.2 million smart meters to customers. PLN is expecting to expand the smart meter coverage to 75 million over a ten year span. |
| Lao PDR | Electricity Du Laos, in co-operation with Huawei, is undertaking the installation of over 500 000 smart meters across four districts of Vientiane Capital. The smart meter installation programme has been ongoing since 2018, and installation has already been completed in Chanthabouly and Sisattanak districts. |

| Country | Smart meter rolling out status |
| --- | --- |
| Malaysia | Tenaga Nasional Berhad, as a national power utility, in early 2023, had met its target of installing 1.8 million smart meters in Klang Valley, Melaka. The utility plans to expand the smart meter roll-out to reach a nationwide scale of 9.1 million by 2026. |
| Myanmar | In 2019, Myanmar piloted smart meters and AMI projects in the capital of Nay Pyi Taw. |
| Philippines | The national power utility, Manila Electric Company, had already installed more than 140 000 smart meters by the first half of 2021 and is targeted to install 3.3 million smart meters by 2024. |
| Singapore | Singapore had installed more than 788 000 smart meters as of 31 March 2023 and is planning to reach 1.5 million installations by 2024. |
| Thailand | As of 2021, Thailand had rolled out 116 000 smart meters in Pattaya City. |
| Viet Nam | By 2022, over 4 million smart meters had been installed in Viet Nam. Additionally, 93% of consumers in the Central region and Central Highlands had smart meters installed. |

IEA. CC BY 4.0.

# Governments across the region are recognising the need for modernised and smarter grids

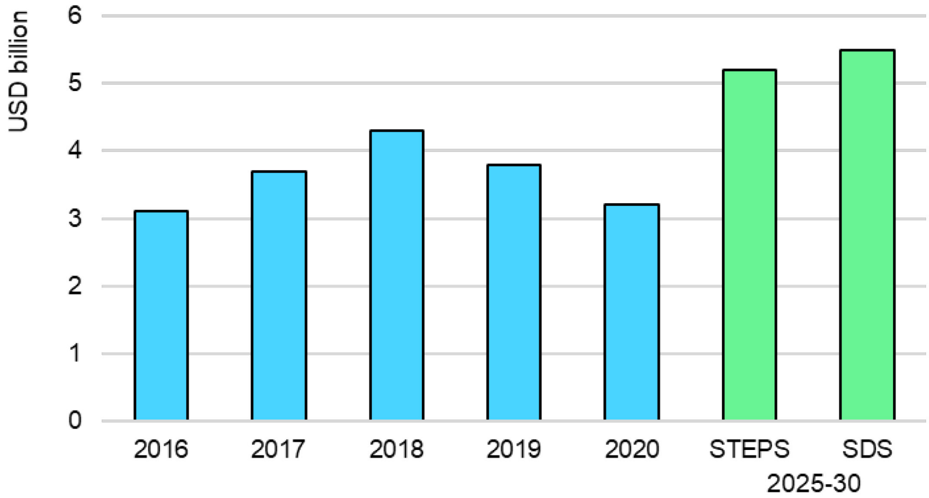



IEA. CC BY 4.0.

Today, the ASEAN power system is still dominated by generation from fossil fuels. To achieve its renewable energy target, the installed variable renewable energy (VRE) generation capacity in the ASEAN region needs to increase from 33% in 2020 to 50% by 2025. With renewable energy generation expected to increase in the following years, there is a pressing need for the grid to become more flexible and able to manage numerous points of electricity generation and consumption. IEA analysis shows that investment in transmission in ASEAN is falling short. Under the IEA Stated Policies Scenario, the average transmission investment for 2025-2030 needs to be

40% higher than the 2019 level. Additionally, in the Sustainable Development Scenario, this investment should be nearly 50% higher than the 2019 level.

**Annual transmission investment in ASEAN compared with annual average investment in IEA Stated Policies and Sustainable Development Scenarios, 2025-2030**






Notes: SDS = Sustainable Development Scenario, a trajectory consistent with Paris agreement; STEPS = Stated Policies Scenario, a trajectory consistent with current policies of governments.
Source: IEA (2020), Attracting private investment to the electricity transmission sector in Southeast Asia.

Efforts will need to be made to improve transmission infrastructure, including the expansion of high-voltage transmission lines and the development of smart grid technologies. Recognising this, many countries in ASEAN have developed smart grid plans to improve their grid capacity, while mitigating challenges posed by fluctuating availability and the distributed nature of VRE to ensure the reliability of electricity supply.

Thailand's Energy Policy and Planning Office within the Ministry of Energy published Thailand's smart grid development Master Plan (2015-2036). The master plan serves as a framework for developing a holistic smart grid policy and outlines technological development and investment direction. The preparatory phase was carried out from 2015 to 2016, followed by the short-term phase from 2017 to 2021. Currently, efforts are being made to prepare for the medium-term phase (2022 to 2031), focusing on several key areas. These include promoting real-time pricing, establishing data centres on renewable generation forecasts, and incentivising private-sector development of relevant software and hardware. A long-term planning phase will commence in 2032-2036, with greater emphasis on the investment of new technologies from the infrastructure that has already been developed.

The Indonesian national electricity utility, PLN, has a roadmap for developing the smart grid in Indonesia, divided into two distinct phases. The first phase (2021-2025) prioritises grid automation and management and the implementation of AMI. The second phase (2026-onwards) will focus on integrating DERs, energy storage systems and demand response mechanisms.

Since 2014, PLN has undertaken several pilot smart grid projects in various cities across Indonesia to test and refine smart grid technologies. In 2019, PLN installed smart load dispatching devices in Sumba to address solar energy intermittency. The dispatching device used the automated dispatch system to manage energy load and production for a hybrid solar power plant with diesel generators.

The Vietnamese government established a smart grid knowledge hub, an initiative by the Smart Grids for Renewable Energy and Energy Efficiency project, which is implemented by the Electricity Regulatory Authority of Viet Nam. The hub serves as a public platform on the topic, experience, concept sharing and official documents related to smart grid applications in the country. The hub was developed in support of Viet Nam's upcoming Power Development Plan VIII 2021-2030, which includes a smart grid plan to enhance the power quality and reliability of the power supply. A detailed strategy for the development of smart grids in Viet Nam has not yet been publicly released.

The Philippines has developed the Smart Distribution Utility Roadmap, which outlines the plan for the transition to a smart grid. The full implementation is expected by 2040. The country's plan envisions a comprehensive range of capabilities for the smart grid, such as a self-healing grid, the implementation of a competitive retail market, optimisation of energy storage systems, virtual power plants (VPPs), and smart homes and cities.

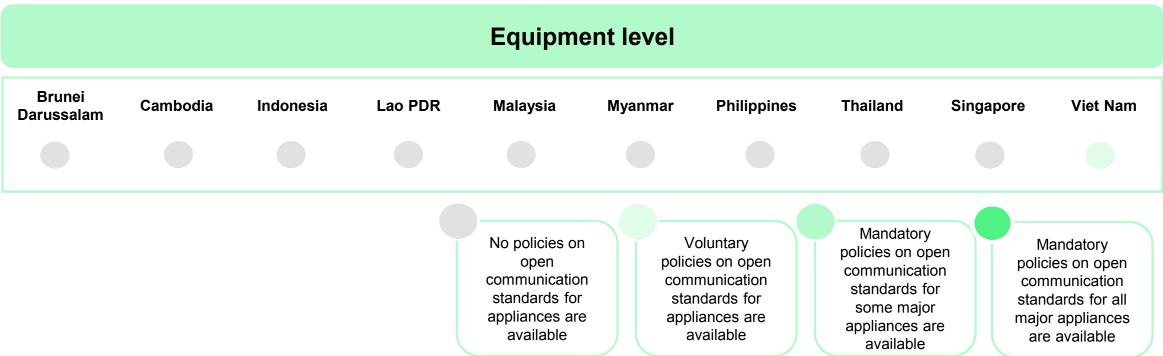
In Malaysia, since 2016, Tenaga Nasional Berhad utility has been actively working on smart grid initiatives. The primary goal of these initiatives is to create an advanced and digitally enabled national grid, aimed at optimising efficiency and enhancing reliability. The focus areas for the smart grid initiatives include automated monitoring and control, data analytics, supply reliability, integration of DERs, promoting green energy, and implementing robust cybersecurity measures. Malaysia's Sustainable Energy Development Authority has also developed the Malaysia Renewable Energy Roadmap, which identifies the smart grid as a crucial initiative to achieve the renewable energy target of 40% by 2035.

The Energy Market Authority of Singapore, in collaboration with the SP Group and the Technology Policy and Plans Office, is also developing to enhance grid resiliency (see Chapter 2). The grid digital twin serves as a virtual representation of the physical power grid assets and networks, leveraging real-time data for operation. This digital twin will consist of two essential models: the asset twin, designed to optimise the planning, operations and maintenance of grid assets, and the network twin, used to assess the effects of additional loads and DERs.

Integration of VRE can also be facilitated through cross-border interconnections across the region, while providing operational flexibility. In addition, increasing the transmission lines with multilateral trading can lower the curtailment of renewable energy and, therefore, lower operational costs for the system. In the region, member states are developing the ASEAN Power Grid to establish cross-border transmission lines that will fully interconnect the ASEAN member states.

As of 2021, significant progress has been made on interconnections. For instance, Malaysia is connected to Singapore by means of a 400 kilovolt (kV) high-voltage direct current transmission link with a capacity of 600 MW, while a 230 kV alternating current (AC) line with a capacity of 300 MW connects Thailand, Malaysia and Singapore. Another line with the same capacity and voltage connects these countries to Lao PDR. A new interconnection project involving Brunei Darussalam, Indonesia, Malaysia and the Philippines is currently in its initial phase. The project aims to utilise exclusively renewable energy sources and is expected to have a minimum capacity of 500 kV to 1 000 kV.

## Lack of interoperability standards is one of the challenges for EGIBs

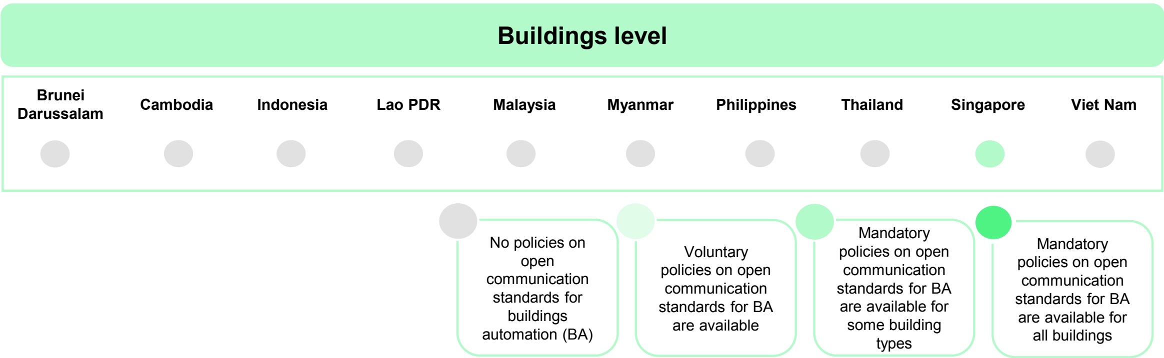





In the ASEAN region, there are currently no mandated policies, projects or programmes that utilise technologies to enable communication and information flow at the equipment level, such as CTA-2045. However, Viet Nam has adopted IEC 10192-2017:3, which outlines the features of home control system known as the home electronic system that CTA-2045 has incorporated and adapted for its own use. It is important to note that IEC 10192-2017:3 is not a standard socket like CTA-2045. Instead, it comprises a universal communication module for facilitating the exchange of energy management data between devices and EMS through the home network.

Nevertheless, several countries in the ASEAN region have implemented BACnet (building automation and control network) projects, which enable the integration of load-connected devices with the EMS. This has led to positive trends in load-connected devices, although not necessarily based on CTA-2045.

A study on smart grid interoperability standards adoption in Southeast Asia suggests that countries in the region can explore the opportunity to adopt the CTA-2045 standard. This would involve upgrading old appliances with a new universal communication module, enabling their participation in demand response programmes.






While the adoption of building automation and communication protocols (i.e. LonWorks, BACnet, Modbus, KNX, Zigbee) technologies in ASEAN buildings has gained momentum, there are no policies in place that specifically mandate their installation. Nevertheless, the increasing implementation of BACnet systems indicates a positive trend towards B2G interactivity.

In Singapore, the 2021 4th Edition of the Code for Environmental Sustainability of Buildings addressed sustainable technologies as alternative solutions aimed at reducing carbon emissions from buildings. These technologies involve the implementation of an open protocol network backbone, such as BACnet, Modbus and other similar protocols. These protocols play a crucial role in enhancing building management systems by enabling the exchange of data points and facilitating seamless communication and integration with other building systems.

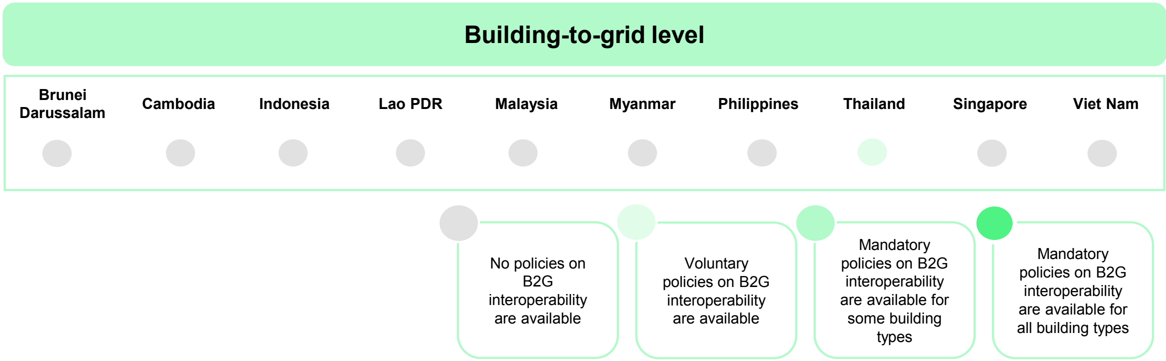
Tanjong Pagar Centre, the tallest landmark office space in Singapore, utilises ABB Cyclon, a BACnet building control technology that offers integrated control solutions for energy management applications. ABB Cyclon is employed for intelligent control of various HVAC equipment, including boilers, chillers, cooling towers, air-handling units, lighting control, variable frequency drives and metering. Moreover, the building has obtained Green Mark Platinum and LEED certifications, with an estimated energy savings of 31% compared with similarly certified and compliant buildings.

The Viettel headquarters in Hanoi, Viet Nam, implemented a BACnet system to enhance its building automation systems and integrate equipment connectivity. The BACnet system, provided by ABB, oversaw the ABB I-Bus KNX system and the HVAC ACH580 variable-speed drives. The ABB I-Bus KNX system serves as a unified bus interface system, enabling communication among various components such as lighting control, shutter control, heating, ventilation and energy management. On the other hand, ABB's ACH580 is a variable-speed drive designed for precise control of electric motors used in heating and ventilation systems. By employing the BACnet system, the Viettel headquarters can effectively manage and optimise energy use for its appliances and equipment according to the prevailing environmental conditions.

The Electricity Generating Authority of Thailand's Electrical Equipment Laboratory has been equipped with BACnet and Modbus installations by DEOS:AG, a German-based company. The project aims to control the HVAC system, which comprises three water-cooled chillers in order to optimise the supply of fresh air based on the conditions of each room. Furthermore, a Thailand-based company called Delta is actively involved in the development of BACnet products, including HVAC and lighting control solutions. These products feature fully programmable controllers along with building operations software, with the goal of enhancing building energy efficiency.

In Indonesia, PT Konimek, an Indonesian-based pharmaceutical company, installed a BACnet system in its manufacturing facility back in 2015. The BACnet system provides intelligent control for 15 air-handling units, 3 chillers, and 3 cooling towers. The purpose of implementing this system is to oversee the EMS and manage temperature, humidity and room pressure in order to ensure the quality of the clean room production area.

Alton, a Malaysia-based company, specialises in controls and automation engineering systems, as well as industrial internet of things technologies for buildings. The company offers BACnet system solutions for both commercial and industrial buildings, specifically for electrical and mechanical equipment. In 2019, Alton installed BACnet systems in the Wisma BSN building, an office building located in Kuala Lumpur. The BACnet system efficiently managed various equipment, including chillers, air-handling units, lighting control, ventilation fans, plumbing systems and fire systems.






Interoperability between buildings and the grid is currently limited in the ASEAN region. In Thailand, demand response operation has already used the interaction between machines without human interference. The Demand Response Control Centre and Load Aggregator operating mechanism uses OpenADR standards to deliver and receive any information regarding demand response events. Electricity Generating Authority of Thailand has also developed its own demand response management system based on international standard OpenADR 2.0b, which is a crucial part of the communication between the load aggregator of the Metropolitan Electricity Authority and Provincial Electricity Authority.

Several feasibility studies have also been conducted by private companies to further explore the integration of OpenADR to the electricity market. A Seoul-based company called EIPGRID is developing a benchmark for the Provincial Electricity Authority and Metropolitan Electricity Authority to work towards implementing OpenADR 2.0b communication protocols in demand response operations. The study also involves designing and developing a customised demand response-oriented electricity market with connected load devices. The project aims to deliver an OpenADR 2.0 architecture with a resource management system and operating guidelines.

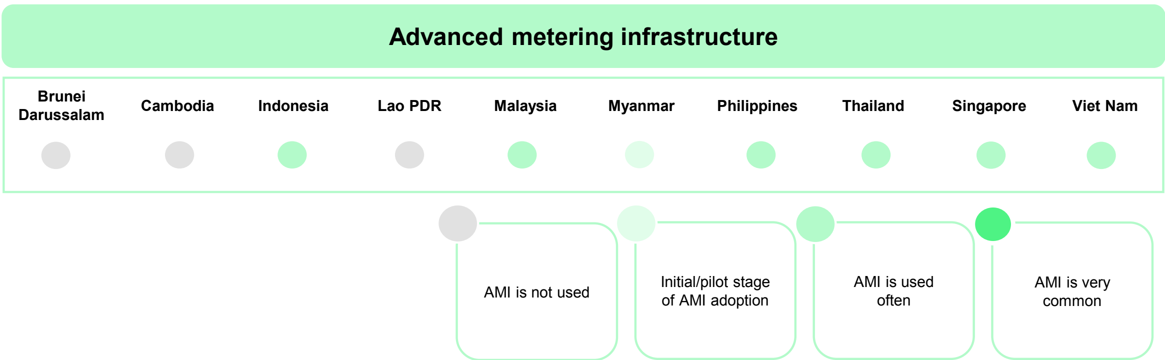
In Indonesia, there is no evidence of B2G interoperability implementation in buildings. However, the technology has been acknowledged as a potential avenue for energy efficiency development. The government Agency for the Assessment and Application of Technology, has implemented a smart EMS in the Agency's building. This system incorporates smart lighting and monitoring and information systems. In the future, the management systems aim to include air conditioners, with OpenADR serving as a communication protocol for appliances to actively contribute to energy conservation efforts.

In other countries such as Malaysia, the Philippines and Viet Nam, there was no evidence of OpenADR being used. However, a study on the adoption of smart grid interoperability standards in Southeast Asia revealed that these countries have embraced other smart interoperability standards, such as International

Electrotechnical Commission (IEC) standards and ISO. Although these standards do not directly address interoperability between B2G communication protocols, they can serve as a foundation to enhance connectivity between buildings and the grid in the future.

The study also suggests that ASEAN member states can consider adopting the OpenADR standard to automate demand response, thereby encouraging greater participation from end users. This could result in a higher level of engagement from end users in managing their energy consumption.

## Countries are tapping into the potential of advanced metering infrastructure

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As several ASEAN member states are increasing their renewable energy generation and implementing smart grid technologies and smart meters, AMI has become an essential technology for measuring, collecting, analysing and controlling energy distribution and usage.

As discussed in the previous chapter, AMI introduces automated and real-time measurement processes, enabling the continuous recording of electricity consumption with heightened frequency. Additionally, it facilitates on-demand data interactions through a centralised metering point. By offering these advanced functionalities, AMI plays a pivotal role in enhancing precision, responsiveness and efficiency of energy management.

Singapore was one of the pioneering countries in ASEAN to adopt AMI technologies through the Intelligent Energy System (IES) project. Launched in 2009, the IES aims to enhance network resiliency and interactivity through smart grid technologies. As part of the project, AMI has been implemented to enable two-way data communication between residential, commercial and industrial consumers.

In Malaysia, Tenaga Nasional Berhad utility rolled out an AMI project in 2018 to improve its grid resiliency. The project incorporated various technologies including a meter data management system and back-end information technology systems. It used radio frequency, power line communication and public cellular network technologies, involving over 340 000 electricity consumers. Sustainable Energy Development Authority also sets AMI as a strategic initiative to digitalise the power sector.

The Philippines' national electric utility, Manila Electric Company, is also transforming its network into the smart grid. This involves the  of AMI, smart devices and systems throughout the distribution network. Manila Electric Company has allocated over  in investment in this initiative and focuses on Advanced Network Automation. This initiative aims to monitor and manage network operations and address changing loads, generation and outage events. The Advanced Network Automation comprises several technologies, including those already implemented by Manila Electric Company, such as the advanced distribution management system and supervisory control and data acquisition (SCADA). Manila Electric Company plans to implement upcoming technologies to further enhance network reliability. These include advanced asset management, control centre modernisation, distributed energy resource management systems and EV management systems.

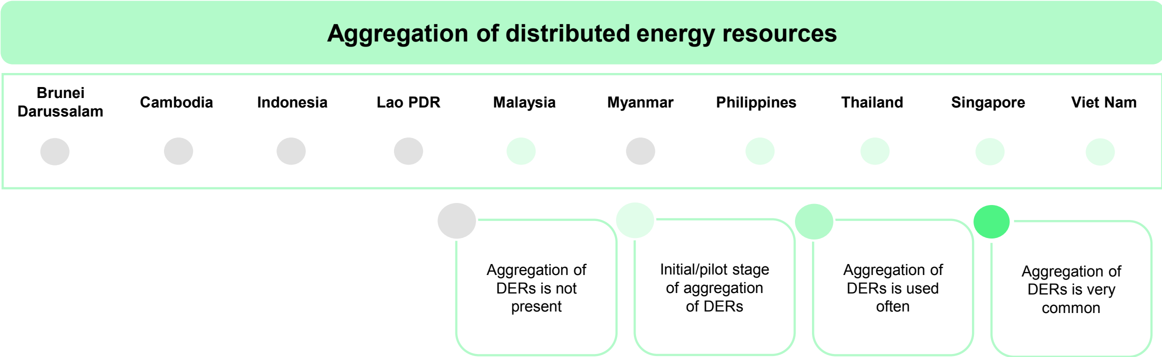
Viet Nam Electricity has implemented various AMI technologies, including automatic monitoring of substations, automatic protection for substations, remote control of 110 kV substations and automatic voltage adjustment. Additionally, most power corporations in Viet Nam have deployed grid automation applications. Currently, power corporations are investing in equipping SCADA and distribution management systems for the distribution grid.

PLN, the Indonesian national electricity utility, has developed a roadmap for the implementation of AMI and planned to begin its roll-out in mid-2023. In addition, the utility implemented several pilot projects. Between 2018 and 2019, four pilot projects were carried out to test two-way communication between smart meters and smart load dispatching devices.

Trilliant, a smart grid technology provider in Thailand, formed a partnership with Samart in 2022 to deliver AMI technologies to Provincial Electricity Authority. The implementation of AMI will enable Provincial Electricity Authority to enhance the efficiency of real-time data collection for commercial and industrial consumers. Although the specific details of the plan have not been disclosed at this time, the collaboration aims to leverage AMI to benefit Provincial Electricity Authority's operations and services.

In Myanmar, the Electricity Supply Enterprise under the Ministry of Electric Power has piloted the implementation of AMI in Nay Pyi Taw in ten townships. Among them, 50% of the households have achieved the installation as well as its control centre for billing and monitoring system. The Yangon Electricity Supply Corporation has also installed AMI in nine townships, and the next six are in the implementing stage.

# Pilot projects are demonstrating benefits of aggregating DERs

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A promising trend in the integration of DERs in the ASEAN region is the emerging deployment of peer-to-peer (P2P) energy trading and VPP projects. These innovative approaches have been implemented in several countries in the region, such as Malaysia, the Philippines, Singapore, Thailand and Viet Nam.

In Singapore, the Energy Market Authority and Sembcorp Industries partnered with Nanyang Technological University to develop Singapore's first VPP in 2019. The primary objective of the VPP is to optimise power output from various DERs, predominantly solar energy. It aggregates the energy generation data from rooftop and utility solar and uses forecasting models to predict energy demand, weather conditions, energy production and pricing forecast. By using this information, the VPP will balance the fluctuations in solar energy supply across different locations in Singapore.

In 2020, Singaporean-based company Senoko Energy together with ENGIE and Electricify, launched a P2P energy trading platform called SolarShare. The platform enables prosumers to sell excess solar energy to consumers within the same SolarShare network. Customers must install a smart meter that tracks their energy generation and consumption to participate in P2P energy trading. The smart meter sends data to the SolarShare platform, which is built on a blockchain-based system to facilitate energy transactions between buyers and sellers. In 2021, the SolarShare trading platform underwent a pilot project involving ten households in Singapore. As of now, there are no publicly available data on the amount of energy that has been traded.

In 2018, one of the largest was launched in one of the districts (T77) in Bangkok, Thailand. The project was deployed as a part of the regulatory sandbox that the government developed to demonstrate P2P energy trading with blockchain technology. Regulatory sandboxes allow companies to test their products, services, business models and delivery mechanisms with relaxed regulatory requirements.

In addition to solar PV, the T77 project also incorporated BESS to manage excess electricity supply and demand. A blockchain-based software platform was implemented to offer the solutions for tracking, tracing and trading renewable energy. The project traded solar energy across seven sites, including shopping centres, hospitals, schools and apartment buildings.

The Thailand government and Thai-based renewable energy company BCPG also developed Thai Digital Energy Development at Chiang Mai University. The project also used a blockchain platform to explore how Chiang Mai University could operate with clean energy and demonstrate renewable electricity trading and energy management solutions. The project also demonstrated how the local energy market could procure renewable energy and accelerate the deployment of rooftop solar through a market mechanism rather than through the implementation of government subsidies.

Electricity Generating Authority of Thailand also launched the National Energy Trading Platform in 2019. This platform enables households, businesses and communities with renewable energy systems to participate in the P2P energy trading by selling excess electricity back to the grid or directly to other consumers. In 2019, Electricity Generating Authority of Thailand piloted two P2P energy trading projects in the Samsen district of the Metropolitan Electricity Authority and the Provincial Electricity Authority's headquarters in Bangkhen. Both pilot projects included commercial buildings, a smart home and an EV charging station. The Metropolitan Electricity Authority project involved a 66 kW solar PV system with a 10 kW battery system, while the Provincial Electricity Authority's project used a 110 kW solar PV system without a battery system.

In Malaysia, Sustainable Energy Development Authority conducted the first P2P energy trading pilot project in 2019. This project was initiated under a regulatory sandbox framework, which provide a controlled environment for electricity prosumers to sell their excess solar PV electricity to consumers of Tenaga Nasional Berhad utility. The project aims to demonstrate the feasibility of solar energy trading in the Malaysian energy market and advance the deployment of DERs in Malaysia.

The P2P blockchain platform involved four prosumers and eight consumers, with a total installed capacity of 4 031 kWp for solar PV. Under this arrangement, the utility purchased electricity from the prosumers at a rate 10% higher than the medium voltage industrial tariff and sold it to consumers at a rate 11% cheaper than the residential tariff. During the eight-month operating period from June 2020, a total of 680 megawatt-hours (MWh) of energy was exported by the prosumers, and 470 MWh of energy was traded between participants in the P2P energy project.

The Independent Electricity Market Operator of the Philippines is currently exploring blockchain technology for P2P energy trading. This technology will be integrated in the country's Wholesale Electricity Spot Market, allowing prosumers to sell their excess electricity directly to other consumers. However, the details of the plan have not yet been made public.

Viet Nam also plans to launch its first P2P energy trading trial project. The trial project uses a blockchain platform to trade solar energy in Da Nang and Quand Nam provinces. The platform will enable prosumers to sell electricity directly to consumers. The government has not yet announced the starting date of the project.

**Virtual power plant and grid digital twin, Singapore**

The virtual power plant (VPP) in Singapore is under development by the Nanyang Technical University in partnership with the Energy Market Authority and Sembcorp Industries. The aim of the project is to develop the first VPP in Singapore that will co-ordinate and link energy resources, solar installations and energy storage systems.

The VPP uses intelligent systems to co-ordinate DERs to replicate a traditional single utility-scale power station by generating, storing, shifting, optimising, aggregating and predicting energy demand and energy supply from a range of sources, including renewables.

The VPP is an opportunity for Singapore to develop solutions that test and enable a larger mix of DERs, such as solar PV, into the grid through demand matching and storage, while protecting the power system stability. The system will include a battery storage system to balance the smart and dynamic load, and the use of installed onshore and offshore solar PV systems.

Alongside the VPP, Singapore is developing a digital twin of the national power grid that will allow the national utility to test grid interactions and evaluate energy resources and infrastructure changes. The grid digital twin provides a virtual representation of the physical grid system comprising the grid assets (e.g. substations, transformers) and network twin (e.g. grid design and operation) including over 18 000 transformers, 11 000 substations and 27 000 km of interconnection cables. The grid digital twin aims to streamline pre-testing of technology deployment and operating conditions, alongside planning and analysis, and remote testing of grid system changes in a dynamic environment.

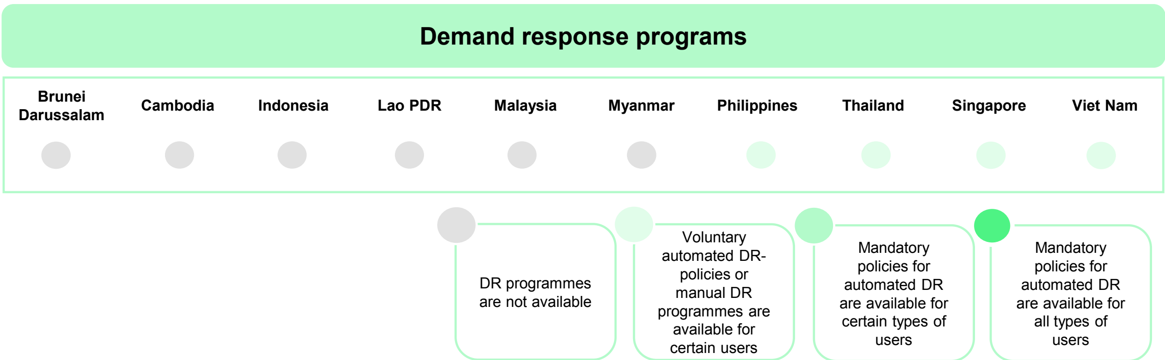
The VPP and grid digital twin systems together offer an environment to evaluate increasing interactivity of Singapore's building energy demand and test grid stability as more dynamic loads and DERs are brought online. The benefits of a grid digital twin include improved conditions for asset monitoring and asset renewals, improved network planning analysis for balancing new or peak electricity loads, and optimised investments of assets.

**Thailand's T77 Precinct, a P2P energy trading environment developed by PowerLedger and BCPG**

Thailand's Metropolitan Electricity Authority piloted a P2P energy trading environment in the T77 precinct, Bangkok, in 2018. The project used PowerLedger's energy blockchain software and Thai-based renewable energy company BCPG. The project facilitated the trade of solar power among a school, an apartment complex, a shopping centre and a hospital. PowerLedger's platform provided a transactive layer to enable P2P trading, monitor energy transactions between participants, generate an invoice to allow for settlement and summarise the trading activities of individual participants.

The P2P energy trading platform allowed the precinct to source 18% of its energy consumed from renewable sources while also reducing electricity costs for the participants and generating income for the solar owners. The T77 project has since expanded to seven buildings with a total of 1.1 MW of solar PV connected, generating an average of 2.8 MWh daily and an average of 10 MWh of energy being transacted each month. The project also installed smart meters to collect data on energy consumption patterns in households and buildings as well as a 50 kW, 200 kWh BESS aimed at balancing excess supply and demand. These smart meters measure electricity usage in real time and provide information to both consumers and developers about energy consumption patterns.

# Demand response programmes are crucial for interactions between buildings and the grid

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In the ASEAN region, demand response programmes are gaining popularity due to their potential to reduce energy consumption during peak hours and balance the electricity grid. Demand response programmes in ASEAN are typically implemented by utilities, which offer financial incentives or rebates to encourage customers to reduce their energy consumption during peak hours.

Singapore was the first country in the region that introduced an explicit demand response programme. Under this programme, the Energy Market Authority incentivises consumers to reduce their electricity demand when it is needed. Consumers can participate through demand response aggregators, which are third-party entities that typically work with electricity consumers from commercial and industrial sectors.

The aggregators typically manage consumers' electricity consumption during peak periods and participate in demand response programmes offered by Energy Market Authority. Consumers that can offer to reduce their electricity consumption by at least 0.1 MW can also participate directly in the wholesale electricity markets. The participating consumers then submit their bid demand, indicating their willingness to reduce the electricity demand at different price points. The participating consumers will receive one-third of the savings arising from the reduction in electricity prices as incentive payments. This ensures that most of the benefits are accrued to the broader consumer base while providing a fair return to participants. The incentive payment will be up to SGD 4 500 (Singapore dollars) per megawatt-hour, which is the existing ceiling for wholesale electricity prices.

Singapore also launched its Interruptible Load Scheme in 2005. This programme incentivises participating consumers to reduce their consumption during periods of high demand through their participation in the reserves market. The Interruptible Load Scheme is a voluntary programme that targets large energy users such as malls and factories, and eligible consumers must be able to reduce their electricity consumption by at least 0.1 MW.

Under the Interruptible Load Scheme, the consumers must also install a load-shedding device, known as a monitoring-recording-activation device, which can be activated remotely by the grid operator during periods of high demand. Participating consumers are informed in advance of the electricity curtailment, and the grid operator sends a signal to the load-shedding device to initiate the curtailment. The duration of curtailment typically lasts between 30 minutes and 2 hours. In exchange for participating in the scheme, the participating consumers are paid the clearing price for contingency reserves in every event where their electricity consumption is reduced. The clearing price is set through a market bidding process based on supply and demand. To participate in this programme, consumers can register through their respective electricity retailers or directly in the wholesale electricity market.

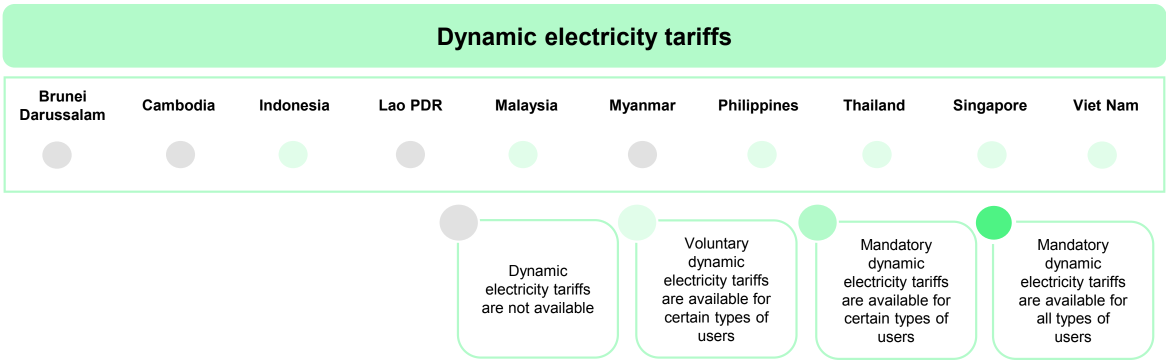
In Thailand, demand response programmes have been implemented occasionally in the past. In 2014, a demand response programme was implemented to support the maintenance of the Yetagun gas transmission system. During this implementation, the programme successfully reduced the peak demand by 70 MW out of the 200 MW target. For the period 2022-2023, Energy Policy and Planning Office and Metropolitan Electricity Authority initiated the demand response programme to test the effectiveness of reducing power system load and electricity consumption during peak periods. The programme is operational from January 2023 to December 2023 and targets commercial, industrial and residential consumers. The main objective of this demand response programme is to reduce the peak load by 19.5 MW during specific time periods, namely in the afternoon from 13:30 to 16:30 and in the evening from 19:30 to 22:30. The programme also offers financial incentives in the form of an availability and energy payment to the participating consumers.

Viet Nam is making improvements to its demand response programme to ensure balanced and reliable supply of electricity. The country has been witnessing a steep growth rate in commercial electricity demand, about 10% per year, and faces the risk of potential supply shortages in the coming years. In 2019, the government, through the Viet Nam Electricity, conducted ten demand response voluntary events, consisting of seven emergency events and three planned events. Around 1 300 consumers participated in these events, committing to reduce their electricity consumption. The total capacity reduction achieved during these events was approximately 514 MW, which accounted for about 53% of the projected demand response potential reduction. The event successfully reduced electricity by around 6 373 MWh, with an estimated saving equal to VND 24.12 billion (Vietnamese dong) (approximately USD 1 million). Looking ahead to 2023, the government has developed a demand response programme to address the challenges anticipated during the dry season, which may affect hydropower reservoirs. By mid-2023, around 6 521 consumers with an annual electricity consumption of 1 million kWh or more had registered in the programme.

In the Philippines, the Interruptible Load Programme was implemented by the Department of Energy in 2014 to manage electricity supply during peak demand periods. This programme is voluntary and targets large commercial and industrial consumers, such as shopping malls, offices and factories. The programme requires participating consumers to “de-load” during specific hours of the day when the power supply in the grid is insufficient to meet the demand, which typically occur between 9:00 and 17.00. Participants receive advance notice and “de-load” by using their own standby generators or switching to backup power sources.

The participating customers may either fully de-load by disconnecting electricity from the distribution utility or partially de-load by reducing its load from the distribution utility. To participate in the Interruptible Load Programme, the participants must be large electricity consumers with an average peak demand of at least 1 MW and have their own standby generators. Furthermore, the participant must be willing to commit to the minimum interruptible load, which represents the minimum amount of power they will commit to interrupting when requested by the distribution utility. The distribution utility will provide de-load compensation to the consumers.

# Dynamic tariff programmes reduce peak electricity demand of large consumers






In many ASEAN countries, the prevailing electricity tariff structures for building owners are primarily flat tariffs, where consumers are charged at a fixed rate. Price-based demand response programmes, such as time-of-use tariffs, on the other hand, offer an opportunity for consumers to reduce their electricity consumption during peak hours, hence saving money on electricity bills.

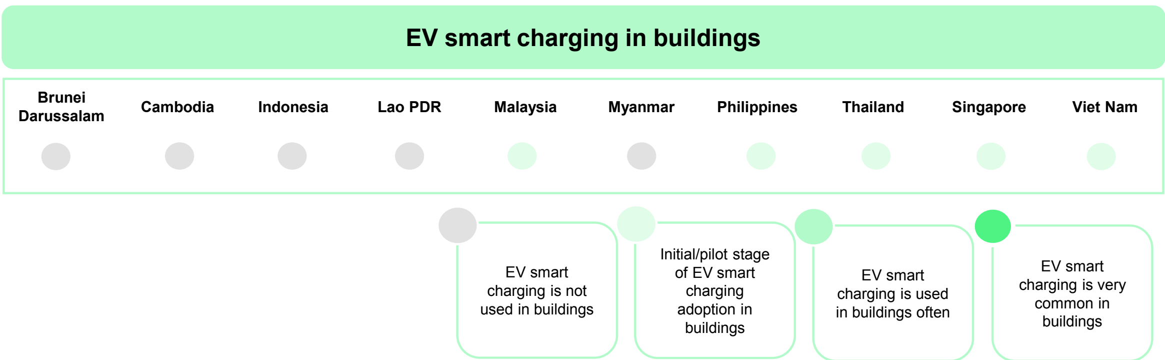
Currently, price-based demand response programmes such as time-of-use tariffs, real-time pricing and critical peak pricing are available to specific electricity consumers in the region. The table below shows the availability of price-based demand response tariffs across different types of consumers in ASEAN. Many existing time-of-use tariffs are implemented for medium to large energy consumers, such as those in the commercial and industrial sectors, while residential customers are usually subjected to a fixed tariff.

**Status of dynamic tariffs in ASEAN**

| Country | Type of tariff | Consumer eligibility |
| --- | --- | --- |
| Indonesia | Time-of-use | Businesses, industries and offices with voltage levels above 200 kVa are subject to time-of-use tariff. |
| Malaysia | Time-of-use | Time-of-use tariff is offered as optional pricing for medium- and high-voltage for commercial, industrial, agriculture and mining customers. |

| Country | Type of tariff | Consumer eligibility |
|---|---|---|
| Philippines | Time-of-use | Time-of-use tariff is offered as optional pricing for residential and commercial customers with minimum electricity consumption of 500 kWh per month. Smart meter is required for this tariff. |
| Singapore | Half-hourly prices | Consumers from residential and commercial sectors have the option to buy electricity from the Wholesale Electricity Market. Consumers pay electricity prices that vary every half hour, depending on the demand and supply. |
| Thailand | Time-of-use | Time-of-use tariff is an optional tariff for all types of customers, including residential, commercial and industrial. Smart meter is required for this tariff. |
| Viet Nam | Time-of-use | Businesses, industries and offices with voltage levels 25 kVa or above or having average electricity consumption of 2 000 kWh/month for three consecutive months are subject to time-of-use tariff. |

# Smart EV charging in buildings can help grids manage impacts of EVs' uptake






In ASEAN, it is estimated that by 2025 20% of all vehicles in the region will be electric, and by 2030 EVs are projected to make up nearly 50% of total vehicle sales. As EV adoption continues to grow, there is a pressing need to expand the charging station infrastructure. Currently, EV charging stations in the region remain limited, with member states progressing at varying paces. Moreover, it is projected that 90% of EV charging units will be installed in private settings, such as residential, commercial and industrial buildings. This widespread adoption of charging points, especially in buildings, will substantially increase the buildings' electricity consumption (more than 40% according to some estimates). These challenges also present an opportunity for EGIBs to effectively synchronise with charging stations, particularly through smart charging.

**ASEAN member states' targets for EVs and EV charging stations**

| Country | Electric vehicle target | Charging stations target |
|---|---|---|
| Indonesia | Target of 400 000 electric four-wheelers and 6 million electric two-wheelers on the road by 2025, and 5.7 million electric four-wheelers and 46.3 million electric two-wheelers by 2035. | Target of 25 000 charging stations by 2030 |
| Lao PDR | Achieve 30% of EVs in the national vehicle mix by 2030. | 500 EV charging stations by 2030. |
| Malaysia | Target of 1.5 million EVs by 2040. | Target of 125 000 charging stations by the end of 2030. |
| Philippines | The Comprehensive Roadmap for Industry of the Philippines set a target of about 1.75 million EVs (10% EV fleet*) by 2040 in the BAU Scenario, or 6.3 million EVs (50% EV fleet*) in the Philippine's Clean Energy Scenario. | Target of 41 700 charging stations by 2040 in the BAU Scenario or 147 000 by 2040 in the Philippine's Clean Energy Scenario. |
| Singapore | Under the Singapore Green Plan 2030, the Land Transport Authority aims to electrify 50% of bus and taxi fleets by 2030 and reduce peak land transport emission by 80% by 2050. | Target of 40 000 charging stations in public carparks and 20 000 in private premises by 2030. |
| Thailand | Aims to have 50% locally made vehicles to be electric by 2030, and 100% by 2050. | Target of 2 200 to 2 400 charging stations by 2025 and 12 000 by 2030. |

* EV fleet refers to the mix of all vehicles in sectors of corporate and government fleets, public transport operators, and industrial and commercial companies.

Estimates indicate that the integration of smart charging technology with buildings, particularly those equipped with time-of-use tariffs, demand charges and DERs (solar PV), has the potential to yield energy savings of up to 70% for buildings. For example, when integrated with time-of-use tariffs, the charging can be done when the grid is least constrained, usually during off-peak. This translates to cost savings on charging for EV owners, while building owners can use this strategy to create dynamic energy loads that might help buffer against potential price spikes in future electricity demand.

In ASEAN, the implementation of smart charging would not only benefit buildings but also have a significant impact on the grid system. For instance, if 10 million EVs were charged with smart charging, the peak demand would increase by only 0.5 GW, in contrast to 3 GW with unsupported charging. The integration of smart charging and buildings also expands the opportunity to provide energy services. Bidirectional charging in buildings, for instance, allows parked EVs to participate in management and/or aggregation of DERs, as well as demand response programmes.

In ASEAN, the landscape of EVs, charging points and smart charging policies varies across countries. Thailand, currently the region's leading EV market, has set a target to make 50% of their locally made vehicles electric by 2030. To accelerate the EV adoption, the Thai government has implemented a range of EV charging incentives. The government has also forged a partnership with the ADB and Energy Absolute to secure USD 48 million in green loans to fund charging infrastructure development.

At the moment, however, the smart charging infrastructure in Thailand is available only in limited locations, specifically Bangkok, Nonthaburi and Samut Prakan. These smart charging stations are part of the Metropolitan Electricity Authority's Smart Charging System project, which aims to establish grid flexibility. In line with this goal, Metropolitan Electricity Authority has also formed partnerships with Energy Absolute and JRW utility to further enhance grid flexibility through smart charging.

Indonesia also has plans to become a manufacturing hub of EVs by 2025. The country aims to export 200 000 EVs by that time – which accounts for 20% of the overall annual exports of the country. In line with this goal, the Indonesian Ministry of Energy and Mineral Resources has promulgated incentives for the development of public electric charging stations. The incentives focus on establishing the bulk tariff for charging station providers and implementing a price cap for the services they offer. The incentive also includes other benefits, such as relief on connection fees and subscription guarantees, which contribute to cost reduction.

In 2022, the country successfully added 1 415 new charging stations, surpassing the initial target of 693 by 204%. Building upon this achievement, the government has set a plan to establish an additional 1 030 charging stations by the end of 2023. Information regarding the availability of smart charging infrastructure in Indonesia is, however, not yet available.

In Singapore, a bill has been passed to ensure the widespread availability of EV chargers. Under this bill, all new buildings are required to install a minimum number of charging points, equivalent to approximately 1 for every 25 parking spaces. To further encourage the adoption of EV charging in both residential and commercial sectors, the Land Transport Authority has introduced the EV common charger grant in 2021. This grant aims to co-fund the installation costs of EV chargers. Currently, buildings account for one-third of the potential 2 000 charging points in Singapore, with a majority located in commercial settings such as malls. Through the grant programme, the government will cover 50% of the installation cost, with a maximum cap of USD 4 000 per charger. This grant will be available until December 2025, or until a total of 2 000 chargers have been co-funded.

This grant programme also offers potential co-funding for the installation of smart chargers, limited to a maximum of 1% of the total residential car park lots. The smart chargers have to comply with the Open Charge Point Protocol and are expected to fulfil multiple functions, including the ability to adjust the charging rate, monitor and record energy consumption, and transmit energy data. As of now, there is no readily available information on the exact number of smart chargers that have been installed in Singapore.

In 2023, the Malaysian government, through its Budget 2023, extended incentives for EV charging manufacturers, including a 100% tax exemption on statutory income from 2023 to 2032. These incentives also provide a 100% investment tax allowance for a duration of five years. The Budget 2023 will also allocate approximately USD 36 million for the installation of 500 new EV charging stations. In addition, the Tenaga Nasional Berhad utility, through its charger product Electron, has developed a direct current (DC) charger and will further develop smart chargers in the future.

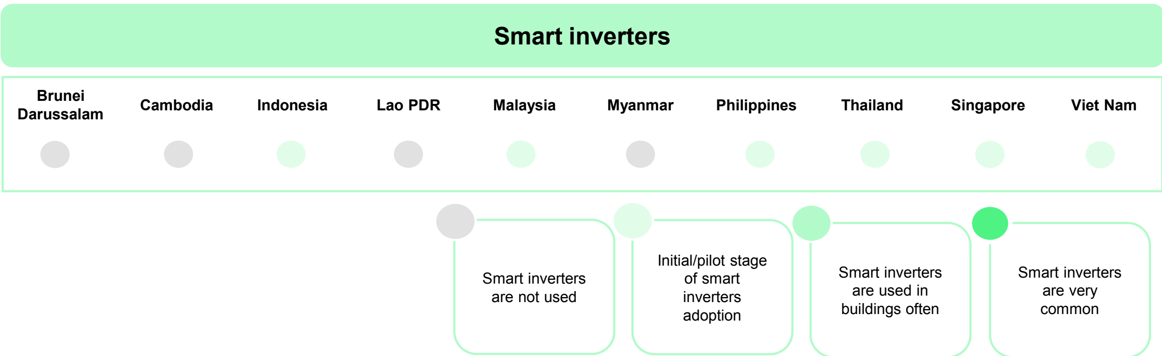
The Philippines implemented Republic Act 11697 in 2022, commonly known as the Electric Vehicle Industry Development Act, to facilitate the widespread adoption of EVs in the country. Under this law, specific provisions are in place to support EV charging infrastructure. Notably, imported charging stations are granted an exemption from payment of duties, which typically range from 10% to 30%, for a duration of eight years from 2022 to 2030.

Additionally, the Electric Vehicle Association of the Philippines in collaboration with Delta Electronics has successfully developed a smart charging solution for the country. This system combines solar power, energy storage and energy management capabilities. By leveraging these technologies, the smart charging solution provides flexibility for both EVs and grid operators. Through Delta's energy management technology, the grid operators can take advantage of peak shaving, PV self-consumption and load shifting in off-peak periods to optimise energy usage.

In Viet Nam, Vin Bus, an electric buses company, has partnered with Star Charge to develop smart charging infrastructure for their fleet. This collaboration aims to support Vin Bus' fleet of 150-200 electric buses in Hanoi, Ho Chi Minh City and Phu Quoc. The smart charging infrastructure provided by Star Charge will incorporate various intelligent features, including load management, power consumption data analysis, energy management system and energy storage capabilities to handle peak charging demands.

The increasing adoption of EVs in the ASEAN region presents a significant opportunity for the integration of EV charging infrastructure with buildings, enabling grid flexibility and energy savings. It is important to note that each ASEAN member state has set different targets for EV and charging adoption. These targets reflect their unique priorities and ambitions. By leveraging EGIBs and smart charging solutions, ASEAN countries can work towards achieving their EV targets while also enabling buildings to participate actively in the electricity grid.

# Smart inverters are showing benefits for large buildings and facilities

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With the increase of solar PV deployment in residential and commercial buildings in ASEAN, the use of inverter has become a necessity to convert DC to AC. The use of smart inverters in the region, however, is still in a nascent phase. There are several pilot projects, mainly implemented in large commercial and industrial buildings, that are benefiting from this technology, as smart inverters are programmed to respond to grid conditions in an automated manner and unlike conventional inverters that simply shut down when sensing any grid disturbance, smart inverters provide grid-supportive functionalities and effectively manage and mitigate small fluctuations in voltage or frequency.

For example, in Singapore, 20 TRIO-50 solar inverters were installed by ABB in IKEA's flagship store located in Tampines, to support the rooftop solar system capable of generating 1.3 million kWh of renewable energy annually, equivalent to powering over 280 households.

An example of such technology available in Singapore's market is the Sunny Tripower Smart Energy hybrid inverter, which combines smart technology with integrated services for storage solutions. Users can easily generate, use and store solar power, with the flexibility to expand the system by incorporating additional components such as e-mobility or heat pumps. The integrated battery-backup function ensures uninterrupted electricity supply, even during grid failures, resulting in comprehensive and self-sufficient smart energy systems with up to 100% solar energy.

In Indonesia, in Jakarta there are two examples including a hybrid PV system with an 11.68 kWp capacity and a 5.4 kWp hybrid ready system, using GoodWe ET inverters.

In Viet Nam, ABB installed a solar PV installation with a capacity of 75 kWp at its factory in BacNinh province, including three-phase solar inverters such as TRIO-27.6 and TRIO-TM-50.0, Weather Station and a smart ACB Ekip. These advanced technologies leverage the digital capabilities to ensure maximum efficiency, automation and cost-effectiveness, while also optimising space utilisation. The inverters can be remotely controlled, maintained and monitored using any web-enabled device, such as a smartphone, tablet or computer. ACB Ekip helps integrate renewable energy into the existing grid through built-in load shedding, monitoring and protection features, which optimise operations. Viet Nam also hosts a manufacturing facility for KSTAR solar inverters production.

Smart inverters were integrated into a multi-roof solar energy system (9 600 modules over 8 roofs) in Thailand implemented by Toyota using SolarEdge technology. SolarEdge includes PV modules of a total capacity of 3.4 MW connected to a power-optimising inverter system turning them into smart modules. It increases the overall efficiency, minimises power loses, allows for each module to produce solar electricity at its maximum capacity and therefore increases the amount of electricity produced by the entire system. Smart inverters and power optimisers also enable a real-time module-level monitoring of production, consumption and grid-import data, as well as accurate fault detection.

Both Malaysia and the Philippines developed guidelines on net metering, which indicates the importance of smart inverters and particular their ability for optimisation and monitoring at the system level.

# The way forward for buildings in ASEAN

Efficient grid-interactive buildings (EGIBs) in the Association of Southeast Asian Nations (ASEAN) can play a crucial role in meeting growing electricity demand while reducing GHG emissions. Governments, industry and consumers can realise the benefits from the adoption of EGIBs through greater research and development (R&D), by promoting the value of interactivity within buildings and with the electricity system at large, by engaging users to increase their awareness of potential benefits and cost savings, and through government support in development and implementation of policies, programmes and projects.

Based on the aggregation of the assessment results for each enabler presented above, each ASEAN country was placed in one of the three groups depending on where it stands in terms of the progress on enabling the adoption of efficient grid-interactive solutions in buildings.

## Assessment results for enablers of EGIBs in ASEAN countries




The assessment of EGIB status and opportunities in ASEAN has shown that interest in buildings as a source of managing energy demand through energy efficiency and promoting grid interactivity is rapidly emerging in a growing number of countries across the region, becoming an important policy area for their future buildings strategies.

The level of adoption of efficient grid-interactive solutions in buildings also may vary significantly within each group. For example, some of the countries (e.g. Singapore) within the Adopters group might be closer to moving into the Innovators category than others. It creates opportunities for countries to learn from each other through peer-to-peer exchanges. None of the countries in ASEAN were placed into the Innovators group, as policy developments and technology adoption necessary for mainstreaming efficient grid-interactive buildings are still limited. The Innovators group can serve as a vision that ASEAN countries can aspire and move towards through implementation of related action and international collaboration with other countries around the world, which have a longer track record of utilisation of efficient grid-interactive solutions and best practices in buildings (e.g. the United States, European Union).

The following recommendations highlight key actions that government, industry and consumers can take to benefit more fully from EGIBs. These recommendations are further expanded below for the groups defined in the assessment; however, the recommendations could also be seen as a potential way forward for most countries.

# Recommendations to support the uptake of efficient grid-interactive buildings

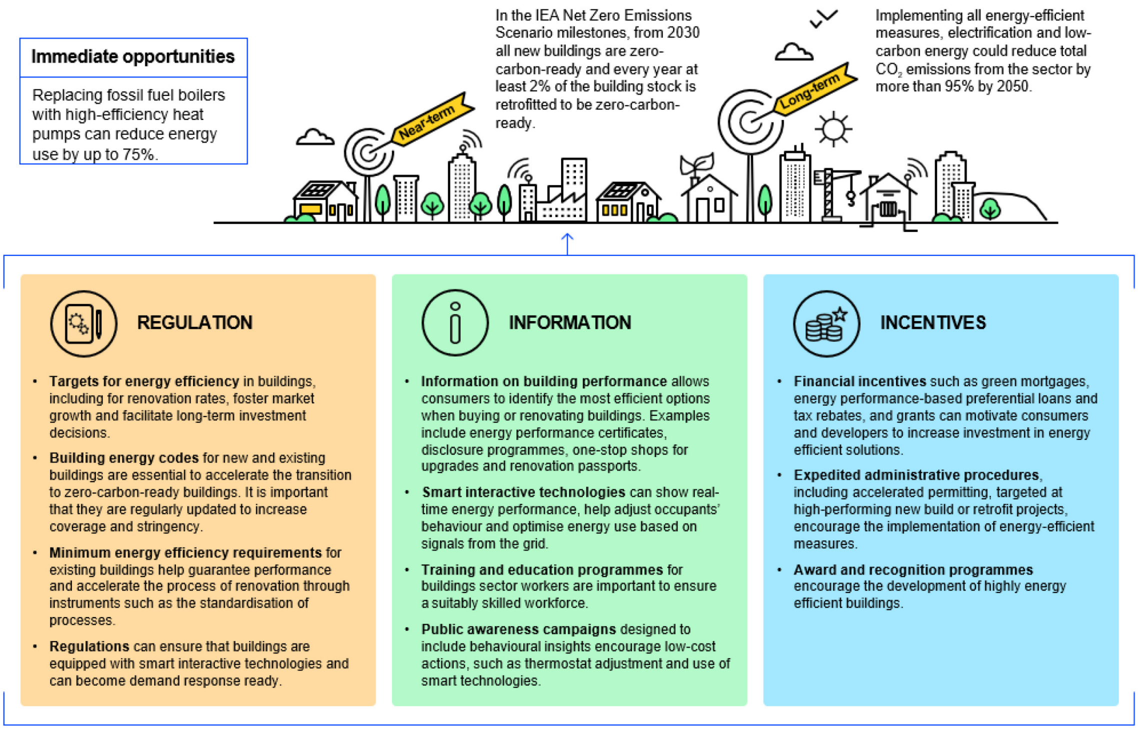
## Develop a comprehensive policy package

Implementation of energy efficiency measures, smart technologies and enabling solutions for building-to-grid interactions requires the development of a comprehensive policy package.

An effective policy package includes a combination of regulatory mechanisms, incentives and information policy instruments, supporting the transition of the buildings sector towards higher levels of buildings energy performance and contributing to enhancing flexibility of the energy system.

Establishing a foundation for the policy package could begin from setting ambitious yet achievable overarching targets for improving energy efficiency, decarbonising the buildings sector, establishing effective interactions between buildings and the grid, and communicating these targets to key stakeholder groups.

**Buildings energy efficiency policy package**






Source: IEA (2023), Energy Efficiency Policy Toolkit.

Regulations set minimum benchmarks and targets to give a signal to the market to retrofit (or in few cases, demolish) the worst performing buildings, phase out products and materials and set out a pathway for investments towards more efficient, low-carbon, smart and flexible alternatives.

Regulatory policy instruments are critical elements when developing a policy package. Building energy codes are among the "most widely recognised, scalable" and effective policy instruments for buildings. They are implemented in over 80 countries around the world. Proper tools to determine post-construction compliance will need to be deployed together with building code implementation. Such tools can also provide feedback to improve the whole construction process, taking advantage of digitalisation and controls to monitor actual buildings' performance.

Mandatory minimum energy performance standards (MEPS) and labels for key appliances and equipment used in buildings are additional fundamental policy instruments with proven effectiveness. Implemented in over 120 countries around the world, MEPS and labels "have helped more than halve the energy consumption of major appliances in countries with the longest-running programmes".

Once regulatory policies are in place, their effective implementation and enforcement could be supported by information policy instruments and incentives to ensure compliance and further progress. Building certification and labelling with ratings based on energy and carbon performance of buildings can provide clear signals for consumers and industry to encourage more informed and sustainable choices and practices.

Information tools and awareness-raising campaigns intend to help consumers and developers make informed decisions about low-carbon choices for the construction, renovation, purchase and lease of building spaces. Capacity-building programmes aim to ensure that there are sufficient skills and knowledge on various aspects of efficient grid-interactive buildings, as well as an adequate number of local, qualified experts to undertake an effective implementation of policies and to drive the necessary market transformation.

A range of financial and non-financial incentives could be linked to certification schemes to support the buildings and construction industry to adapt to the regulation at early stages of adoption and to help overcome market barriers such as upfront costs and access to capital, as well as to drive action beyond minimum standards.

Such packages could include the following elements and capitalise on the linkages between them:

- **Regulatory mandatory zero-carbon-ready requirements** for all new buildings and retrofits covering both operational and construction-phase energy intensity and emissions (e.g. through building energy codes). They would also include requirements for smart electric vehicle (EV) charging, demand management and flexibility requirements to help buildings accommodate variable renewable energy (VRE) sources and interact with the electricity system.
- **Minimum energy performance requirements** for appliances and equipment that set energy efficiency and demand response-ready requirements.
- **Certification and labelling** programmes provide identification labels to show that certification has been achieved. Such certification and labelling schemes can also include information on whether appliances and equipment are demand response-ready or if they are equipped with other smart or digital technologies that can facilitate the interaction with the grid. Applying these to new buildings and systems along with major renovations can increase consumer confidence and performance compliance.
- **Incentives** that encourage energy efficiency performance improvements and low-carbon solutions are often needed to prompt actions. Non-financial and, where appropriate, financial incentives tied to the energy and carbon performance, as well as demand response-readiness of targeted technologies and products, can boost demand for low-carbon, flexible and energy-efficient solutions.

- **Monitoring and tracking frameworks** set out the range of indicators to inform policy makers and industry of the progress, delivery and performance of sustainable and low-carbon buildings across the region.
- **Data collection** provides a means of gaining information to manage building energy use and operation, renewable energy generation, and building construction and renovation practices. These data can help to develop and regularly update baselines for tracking progress towards a net zero-carbon buildings sector and evaluate impacts of policy interventions. Robust data can also help to access project finance and develop more compelling proposals for investors. A recent tool to collect buildings data has been developed through the Building Passport, a useful way to collect data for national building stock statistics.
- **Financing and investing** conditions for sustainable low-carbon building projects (both construction and renovation) through harmonising regulations and developing quality assurance programmes are vital to addressing risk adversity and broadening investment opportunities.
- **Building capacity** among governmental officials (national, subnational and local) and industry can broaden support for low-carbon buildings. Providing accessible training on building energy performance certification, sustainable urban development and materials decarbonisation accompanied by professional accreditation (e.g. certified energy managers) is critical to moving towards a net zero-carbon buildings sector.
- **Stakeholder engagement** within policy development, communication of policy priorities, and enacting and updating policies will broaden support for efforts to deliver low-carbon buildings among national, subnational and local governments based on the principles of **multilevel governance**.

## Modernise building energy efficiency through regulation to support flexibility

Building energy codes are a key mechanism to promote energy efficiency adoption in new buildings construction, and the use of codes to include smart and interactive features will be an important approach to enabling building-to-grid interactivity. It is crucial that building energy codes include minimum requirements for various parameters, e.g. building fabric and system performance levels, as well as the whole building's performance, which is required to become more stringent over time.

For ASEAN countries that have already adopted building energy codes, in the next iteration of those codes they can include energy efficiency requirements, such as achievement of higher levels of performance of the building envelope, glazing and more efficient building services system performance requirements through reference to enhanced MEPS. For those without building codes, separate standards for new buildings can be enacted (or embedded in forthcoming codes) to set fabric performance requirements for all or most building types.

To avoid locking in the flexibility potential of buildings, it is crucial to prepare the buildings sector (especially new buildings) for potential interactions with the grid, even if it is going to take some time to modernise the electricity system. An important step in this direction is inclusion of certain requirements into the building regulations with their subsequent implementation and enforcement at the national and subnational levels. Such modernised requirements might include, but are not limited to:

- Stringent energy efficiency requirements for building envelopes and electricity-consuming systems with some level of the overall targeted building energy performance and supplemented by prescriptive compliance options. Where possible, this should be done for both new and existing buildings to ensure efficient design, maintenance, operation and renovation of buildings.
- Requirements for buildings to be equipped with smart meters, advanced controls (including demand response controls, such as demand response thermostats, demand response lighting controls, demand response heating, ventilation and air conditioning (HVAC) controls), sensors, and communication technologies.
- Requirements for buildings to be equipped with smart devices and make use of intelligent analytics to improve operation.
- Prescriptive requirements for on-site renewable energy systems.
- Grid-ready requirements for buildings (pre-wiring, space requirements for future installations of PV systems, EV charging and energy storage).
- Smart EV charging requirements.
- Requirements for thorough testing and commissioning prior to occupancy.
- Requirements for post-occupancy energy use monitoring based on the smart meter data.

In order to ensure the effective compliance with these modernised requirements and realisation of the flexibility potential buildings have to offer, it is important to assess the impact of different EGIB-related measures and their ability to provide various grid services. Some EGIB-related measures could be prioritised based on their impact and amount of effort and resources their implementation would require.

MEPS play a vital role in promoting EGIBs by setting mandatory minimum requirements for system performance which can reduce energy consumption and help reduce peak demand. MEPS can also include mechanisms that introduce controls and smart performance features, as well as demand-response-ready requirements for appliances to be equipped with devices that are communications-enabled and able to respond automatically to price and/or other signals by shifting or modulating their electricity consumption and/or production.

ASEAN countries can adopt MEPS with higher performance requirements and smart features that specifically include requirements for equipping appliances with smart controls and interoperability communication protocols.

## Support flexible decarbonisation through on-site renewables and storage

Decentralised on-site renewables (e.g. rooftop solar PV systems) provide a means for buildings to directly reduce energy demand through generation and use of that energy for building's operation. They also contribute to carbon emissions reductions and increase energy security through decentralisation of the generation. Several ASEAN governments have policies that promote renewable energy in new building construction. These policies can be adopted across the region through the use of land-use planning regulations, building energy codes, and policies for existing buildings that meet energy or power thresholds (i.e. large energy users with the energy consumption above a certain threshold). ASEAN governments and utilities can also implement measures to prioritise on-site usage to reduce curtailment and adopt measures that enable local network peer-to-peer solar electricity trading where feasible within the grid or microgrids.

On-site energy storage (thermal and electrical) is a key way to simultaneously increase the adoption of renewable energy while also reducing potential negative impacts on the grid. Sizing renewables that use battery storage designed to meet a higher base load of energy demand in buildings can result in greater energy independence of buildings and can act as reservoirs for the grid when power supply requires additional support. ASEAN countries can adopt requirements for on-site energy storage alongside renewables, which can be through installation connection permissions for renewables, building codes requirements for on-site storage, or regulations for large users requiring on-site generation and storage.

## Integrate smartness into building systems and controls

Adoption of smart systems in buildings is a way to ensure building energy service demands can be made more flexible and interactive. The "smart" elements ensure that systems are capable of being interactive and use analytics to more intuitively adapt to user and contextual factors (e.g. weather). Promoting the use of the internet of things (IoT) in building systems and the use of smart sensors and controls and their integration into building energy management systems (BEMS) will ensure that demands for cooling, lighting and ventilation are maximising user requirements and capable of being reactive to grid interactions. These systems can help users identify energy-saving opportunities and encourage behavioural changes that contribute to overall building energy efficiency. To promote wider adoption of smart systems in buildings, ASEAN governments can work with industry to adopt smart-ready standards for appliances and controls to ensure that system interoperability is not a barrier to future adoption. In addition, smart requirements for buildings can be included in building standards (e.g. MEPS) and codes for communication and power supply in buildings when issuing building permits.

Smart meters and open communication standards in buildings are a key interface for buildings that promotes interactivity with the grid. Consumers benefit from smart meters through access to their energy use information that can inform when and how energy is used, particularly when connected to smart appliances and systems, which can enable behaviour changes and choices for adopting more efficient systems. Utilities benefit from smart meters through more accurate and remote metering of usage and can help plan and better serve their customers through pricing mechanisms. ASEAN governments and utilities in the region are adopting smart meters and the continued roll-out can be further facilitated by linking the smart meter installation to programmes that incentivise adoption (e.g. time-of-use or other energy savings programmes).

## Promote technology adoption to support building-to-grid interaction

Adoption of grid-interactive technologies that are needed for establishing and ensuring an effective communication between grids and buildings should be supported by enabling policies. Technologies such as advanced metering infrastructure (AMI) that allow two-way communication from the meter point, smart inverters that allow for bidirectional flow from on-site renewable energy generation, and inclusion of smart charging for EVs in buildings electrical wiring and power connections need to be reflected into appropriate policies for their deployment. ASEAN countries can use existing mechanisms to enhance the adoption of these technologies through existing power connection standards for buildings that require AMI as part of the certification process for new or upgraded connections. For buildings that install on-site renewables, standards for commissioning as well as licences for installation and connection can require that smart inverters are used. For smart EV charging, building permissions can require that buildings adopt standards requiring smart charging to maximise power and energy supply for a greater number of EVs on-site.

Use policies and programmes that increase the value proposition of smart grids to support consumers to adopt smart technologies and utilities to promote the use of grid-interactive services. The use of demand response-readiness standards for new appliances being manufactured will ensure grid-based communications can manage energy demand from appliances. Demand response programmes that allow consumers to benefit from flexible power demands for financial or service incentives allow utilities to reduce peak power and consumers to benefit. ASEAN countries can develop policies that allow utilities to offer demand response programmes within their operating mandate to allow for consumer benefits and grid operation improvements. Regulations around MEPS can be enhanced to require manufacturers to adopt standards that allow for grid communications to transmit to building appliances, such as air-conditioning and water heating units.

Utility-based programmes and initiatives can further enable grid interactivity by providing an environment that allows for buildings to be more closely connected to the grid. This environment requires both programmes and infrastructure which ensure that, as buildings' capacity for flexibility increases through energy efficiency and smartness, the grid is able to adopt this opportunity. Utilities in ASEAN can develop programmes or allow energy service companies that aggregate flexibility in buildings to enhance the potential power and energy savings available from a larger number of buildings. Utilities can develop dynamic tariffs that allow for consumers to benefit from lower prices during off-peak periods and can enable utilities to better manage their peak power pricing to diversify the available base load. With the use of smart building systems, this power diversification can be automated to optimise energy use alongside reducing the peak electricity demand. Utilities in ASEAN can invest in creating virtual power plant (VPP) systems that can better test and manage the utility power environment, forward plan for decentralised energy generation and signal power management in smart buildings.

**Demonstrator project for EGIBs across Europe**

The Smart Readiness Indicator (SRI) is a rating tool that evaluates a building's ability to accommodate smart-ready services. The concept was introduced in the European Commission's 2018 European Energy Performance of Buildings Directive (EPBD). The concept of a smart building is related to its ability to "sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to: the operation of technical buildings systems, the external environment (including energy grids), and demands from buildings occupants." As of 2020, the SRI is established as an official EU rating system through its implementation mechanism, and as a standard.

The SRI looks across a range of energy service demand (i.e. heating, cooling, hot water, EV charging, dynamic building envelope) and determines the smart readiness of a building based on its capacity to optimise energy efficiency, adjust operations to meet occupant needs and to adapt to grid signals.

The rating system provides a score that determines a building's smart readiness using input on the three key functionalities (i.e. optimal efficiency, adaption to needs and adapting to grid) and seven impact criteria related to efficiency, maintenance, comfort, convenience, health and well-being.

A pilot phase began in 2021 to evaluate the use of the SRI among a number of member states within the European Union. Denmark is beginning a test phase of applying the standard to around 30 buildings with a variety of uses to determine the suitability of the SRI for Danish buildings, while France's Ministry for Housing and Cerema are applying the methodology on a large number of buildings in order to test and bring together the smart readiness index and energy performance certificates alongside a national testing phase.

The SRI provides an example of a regionally agreed common standard to describe any building's capacity to enable smart services. Having a standard that member states can use to evaluate buildings in their current and future smartness level means that policies can be devised to address current gaps and market limitations. The benefit of a uniform standard that is also integrated with an energy performance standard is that the smart buildings, grid interactivity and energy efficiency are aligned and self-enforcing within their criteria. For the European Union, adopting the SRI will provide a means of advancing EGIBs across the member states in the aim of achieving the EPBD and its energy and climate goals for buildings.

## Create favourable conditions and support mechanisms for EGIBs uptake

To support the above recommendations, it will be necessary for governments and industry to invest in R&D and digital systems for data to support EGIB evidence and adoption and continue to build the value propositions for grid interactivity for building owners, consumers and utilities.

ASEAN economies should prioritise funding for research in energy-efficient building systems that support flexibility, the adoption of advanced control systems for energy efficiency and energy flexibility, and the dynamics of renewable energy integration with demand and grid performance.

Data collection and analysis are essential to understand the performance of EGIBs and identify areas for improvement. Governments could establish standardised data requirements for building energy consumption and performance that can help guide where flexibility benefits are seen. These data can be used to develop benchmarks, inform policy decisions, and track progress towards efficiency and interactivity goals for buildings.

To promote the adoption of EGIBs, it is essential to demonstrate their value to both consumers and utilities. For consumers, EGIBs can offer energy cost savings, improved comfort and increased property value. Governments should develop public awareness campaigns to educate consumers about these benefits and provide incentives for adopting energy-efficient technologies.

Utilities can benefit from EGIBs through reduced peak demand, increased grid stability and lower infrastructure costs. To encourage utilities to support EGIBs, governments should establish regulatory frameworks that reward utilities for investing in demand-side management programmes, smart grids and integrating distributed energy resources (DERs).

**Actions for developing a sustainable, smart and reliable grid to support greater interactivity**

Potential and benefits of EGIBs could be realised to their full extent if their deployment is accompanied by the actions for modernisation of the electricity grids. While this area is outside of the scope of this report, the IEA report Unlocking Smart Grid Opportunities in Emerging Markets and Developing Economies offers a deep dive on the topic. The report outlines five key actions:

- Create a coherent vision and modernise planning: Governments should envision how digital grid technologies align with national priorities and update policy frameworks accordingly. Engaging stakeholders from the digital and energy sectors is crucial for success. Integrated planning that considers distributed resources and demand-side aspects must be prioritised across system operators and network companies.
- Co-ordinate implementation: Governments should ensure coherence among various departments, regulators and industry stakeholders. Aligning national innovation systems with energy policy objectives and facilitating large-scale demonstrations can validate digital solutions. Governments should also enhance data access and sharing to support digital innovation and promote socio-economic benefits.
- Facilitate rules and regulations that value digital solutions: Governments can incentivise and de-risk digitalisation investments through dedicated policies. Performance-based regulatory oversight, supply-demand balance and flexibility considerations should be integrated into regulations to promote systems efficiency.
- Integrate resiliency and security: Governments should incorporate resiliency and security into electricity policy domains, considering climate impacts and cyber resilience. Long-term planning frameworks like nationally determined contributions and light-emitting diodes (LEDs) can highlight the value of digital and physical resilience.

Strengthening ties between digital and physical infrastructure security is essential.

- Track, evaluate and disseminate progress: Governments should foster a data-driven culture and monitor digitalisation progress. Monitoring implementation, promoting information sharing and strengthening international collaboration are key. Demonstration projects can provide valuable insights and de-risk future investments, while knowledge sharing accelerates progress and standardisation.

Empowering users, installers and operators of EGIBs is essential to ensure their successful implementation. Governments should develop training programmes and certification schemes for building professionals, such as architects, engineers and facility managers, to ensure they have the necessary skills to design, construct and operate EGIBs. Governments should also promote the use of energy management systems (EMS) that allow building occupants to monitor and control their energy consumption.

Public procurement policies can play a significant role in driving market demand for EGIBs. Governments should lead by example by prioritising energy efficiency and grid interactivity in their own building projects and requiring public buildings to meet high performance standards.

Government support is crucial for fostering the widespread adoption of EGIBs. Southeast Asian governments should develop comprehensive policy frameworks that include building codes and standards, financial incentives, and public procurement policies that favour EGIBs.

## Identify actions for efficient grid-interactive buildings depending on the country context

The adoption and implementation of energy-efficient grid-interactive buildings to a large extent depend on a country's current status regarding policies and technologies related to utilising energy-efficient, smart and renewable energy solutions in buildings and establishing interactions between buildings and the grid. By assessing these factors, countries can be classified into three distinct groups: Explorers, Adopters and Innovators. Each group represents a different stage in the adoption of EGIBs, and recommendations for all three groups can be structured across four categories: Energy Efficiency, Decarbonisation, Smartness, and Building-to-Grid Interaction.

## Recommendations for Explorers

Countries falling into the Explorers category are at the initial stages of discovering and researching the potential opportunities associated with EGIBs. They are yet to implement concrete measures or policies to promote widespread adoption. For this group, the focus should be on building a foundation for EGIB adoption.

### *Energy efficiency*

Explorers are advised to develop and implement building energy codes, which will establish mandatory energy efficiency requirements for new constructions and retrofits. If not possible to introduce mandatory regulation right away, governments can consider introducing voluntary requirements first, but with a clear ambition and a timeline to make them mandatory. Additionally, introducing MEPS for household and commercial appliances can promote the adoption of energy-efficient technologies. To ensure compliance with these regulatory requirements, supporting policies such as information mechanisms and incentives should be introduced. By combining these actions, countries can foster a culture of energy efficiency, leading to reduced energy consumption and lower GHG emissions.

### *Decarbonisation*

Explorers could consider introducing voluntary requirements for the installation of on-site solar PV systems in buildings to enable the generation of renewable energy on-site. Furthermore, promoting the integration of battery storage systems to store excess solar energy enhances energy resilience and allows for better management of intermittent energy sources. By embracing these measures, countries can make significant progress in reducing their dependence on fossil fuels and advancing towards a more sustainable and low-carbon future.

### *Smartness*

Explorers could develop a smart building standard that can be voluntarily adopted by developers to encourage the integration of internet of things (IoT) solutions, smart sensors and controls in buildings, particularly in large buildings or high-energy-demand users. Implementing BEMS in these large buildings through draft regulations further enhances their smartness. Introducing regulatory requirements for smart meters could provide real-time energy data to consumers and grid operators, enabling more informed energy usage decisions. Developing a high-level plan for smart grid development sets the stage for an intelligent and interconnected energy infrastructure, allowing for better co-ordination and optimisation of energy distribution.

### *Building-to-grid interaction*

Conducting a feasibility study on open interoperability standards for two-way building-to-grid communication, based on international best practices, can pave the way for initiating the process of establishing interactions between buildings and the grid. Incorporating voluntary requirements for grid readiness in building energy codes (BECs) and MEPS can promote the adoption of grid-interactive technologies such as smart EV charging, rooftop PVs and energy storage. Developing voluntary certification and labelling for inverters, appliances and other equipment indicates their demand response capabilities, supporting efficient grid management. By conducting pilot projects and regulatory sandboxes to test grid-interactive technologies in real-life conditions, countries can gain insights and optimise the integration process. Introducing small-scale pilot programmes for demand response and voluntary options for dynamic tariffs further incentivises consumers to shift their energy usage more towards off-peak hours, contributing to grid stability and energy efficiency.

## Recommendations for Adopters

Countries in the Adopters group have identified some opportunities for EGIBs and are actively implementing pilot projects and sandboxes to test the benefits and potential of these technologies.

### *Energy efficiency*

For countries in the Adopters category, the focus in the energy efficiency category should be on transitioning from voluntary to mandatory and well-enforced measures. This includes making voluntary BECs and MEPS for appliances mandatory and expanding their scope to cover all building types, including both commercial and residential, as well as new and existing buildings. Regular updates and stricter regulations for BECs and MEPS (every three to five years) are essential to drive continuous improvement in energy efficiency. Additionally, the introduction of supporting policies, such as information mechanisms and incentives, will play a crucial role in enforcing these regulatory requirements and promoting energy-efficient practices across the country.

### *Decarbonisation*

To accelerate decarbonisation efforts, countries in the Adopters category should introduce mandatory requirements within BECs and/or standards for renewable energy generated on-site, specifying a certain proportion of energy and power demand that must be met through renewables. Similarly, the introduction of mandatory requirements for on-site battery storage with a minimum energy and power duration backup based on baseload demands will enhance energy resilience and support the integration of intermittent renewable energy sources.

### *Smartness*

For Smartness, Adopters could focus on adopting and implementing smart building standards for large buildings or high-energy-demand users, ensuring the integration of IoT solutions, smart sensors and controls. Regulations making it mandatory for these buildings to implement BEMS will further optimise energy usage and enhance building efficiency. Additionally, introducing a regulatory requirement for smart meters in all new buildings will provide real-time energy data for better energy management. Developing a detailed plan for smart grid development will set the direction for the integration of smart technologies into the national grid infrastructure.

### *Building-to-grid interaction*

Within this category, countries could focus on developing guidelines for utilising open interoperability standards for two-way building-to-grid communication based on international best practices. Within BECs, voluntary requirements for grid readiness (EV charging, rooftop PVs, energy storage) should be incorporated, with a vision to make them mandatory in the next update. Similarly, mandatory requirements for demand-response readiness in MEPS for major appliances (e.g. air conditioners) should be introduced to enable appliances to respond to grid signals. Developing certification and labelling for inverters, appliances and other equipment will help consumers identify their demand response capabilities, promoting grid-friendly choices.

Replicating and scaling up pilot projects and programmes for grid-interactive technologies (e.g. AMI, smart inverters, smart EV charging, DER aggregation, smart mini-grids) and incorporating lessons learned into regulatory updates will facilitate the widespread adoption of these technologies. The introduction of automated demand response programmes for large electricity consumers and the development of pilot projects and regulatory sandboxes for DER aggregation will further enhance grid flexibility and stability. Additionally, early adoption of dynamic electricity tariffs for large electricity consumers could incentivise electricity consumption during off-peak hours and when variable renewable energy (VRE) sources are more available, promoting demand response and grid optimisation.

## Recommendations for Innovators

Countries categorised as Innovators have been implementing various EGIB-related practices and solutions on a relatively wide scale and have integrated some of them into policy processes. Even though none of ASEAN countries were placed into this group based on the results of the current assessment, recommendations for this group provide details of the vision for the future, which ASEAN countries could move towards.

### *Energy efficiency*

For countries in the Innovators category, the focus in the energy efficiency category should be on further expanding the scope of BECs to cover all buildings, including both commercial and residential, both new and existing structures. These codes should incorporate requirements for building energy performance, ensuring that all buildings strive for optimal energy efficiency. Regular updates and stricter regulations for BECs and MEPS (every three to five years) will continue driving progress in energy efficiency. Additionally, linking supporting policies, such as information mechanisms (e.g. awards and capacity building) and incentives to higher levels of achieved building energy performance will encourage continuous improvement and recognition of energy-efficient buildings.

### *Decarbonisation*

In the decarbonisation category, countries should expand mandatory requirements within BECs and/or standards to ensure that both new and existing on-site renewable energy generation significantly contribute to meeting energy and power demand. Similarly, expanding requirements for on-site battery storage to meet a minimum energy and power duration backup based on baseload demands will enhance energy resilience and support renewable energy integration.

### *Smartness*

In the smartness category, the focus should be on adopting comprehensive smart building standards for all buildings, including IoT solutions, smart sensors and controls. Regulations making it mandatory for all non-residential buildings to implement BEMS and for residential buildings to adopt home energy management systems (HEMS) will further enhance smart building capabilities. Implementing a regulatory requirement to mandate the adoption of smart meters in all buildings will provide real-time energy data for improved energy management. Developing a comprehensive implementation plan for smart grids, supported by project development and investments, will pave the way for an intelligent and interconnected energy infrastructure.

### *Building-to-grid interaction*

Innovators would have incorporated into grid codes requirements for the implementation of AMI, smart inverters in buildings with on-site VRE generation, and open interoperability standards for two-way building-to-grid communication. Expanding demand-response readiness in MEPS for all major appliances will further enhance grid flexibility. Introducing mandatory certification and labelling for inverters, appliances and other equipment to indicate their demand-response capabilities will empower consumers to make grid-friendly choices.

Countries should also focus on further developing automated demand response programmes, specifying them in contracts with different consumers, and allowing the participation of aggregators in electricity wholesale and ancillary service markets. Introducing regulations that allow DERs to provide services to the grids will promote a more dynamic and interactive grid ecosystem. Updating electricity tariff regulations to apply mandatory dynamic tariffs to all types of consumers will incentivise electricity consumption during off-peak hours and when VRE is available, further promoting demand response and grid optimisation. By taking these measures, countries can continue to lead in the integration of grid-interactive technologies and create a more sustainable and resilient energy future.

Identifying countries as Explorers, Adopters or Innovators in the EGIB adoption journey provides valuable insights for context-tailored recommendations for targeted actions and strategies. By focusing on energy efficiency, decarbonisation, smartness and building-to-grid interaction, countries can accelerate the transition towards a more sustainable and grid-interactive built environment. These recommendations are crucial for achieving energy resilience, reducing GHG emissions and fostering the adoption of EGIBs.

## Group-specific recommendations for EGIBs based on the assessment of the current status

| | Explorers | Adopters | Innovators |
|---|---|---|---|
| **Energy efficiency** | • If BECs and MEPS for appliances have not been adopted yet, → develop and adopt them with clear and mandatory energy efficiency requirements<br>• If there are voluntary BECs and MEPS for appliances in place, → make them mandatory and well-enforced<br>• Regularly update and make more stringent BECs and MEPS for appliances (every 3-5 years)<br>• Introduce supporting policies, such as information mechanisms and incentives to support enforcement of the regulatory requirements | • In case of voluntary BECs and MEPS for appliances, → make them mandatory and well-enforced<br>• Expand the scope of BECs to include all the buildings (e.g. both commercial and residential, new and existing)<br>• Regularly update and make more stringent BECs and MEPS for appliances (every 3-5 years)<br>• Introduce supporting policies, such as information mechanisms and incentives to support enforcement of the regulatory requirements | • Expand the scope of BECs to include all the buildings (e.g. both commercial and residential, new and existing)<br>• Make sure that BECs include requirements for building energy performance<br>• Regularly update and make more stringent BECs and MEPS for appliances (every 3-5 years)<br>• Link supporting policies, such as information mechanisms (e.g. awards, capacity building) and incentives to higher levels of achieved building energy performance |
| **Decarbonisation** | • Introduce voluntary requirements for on-site renewable energy generation (typically rooftop PV) into the BECs and/or standards<br>• Include voluntary requirements into the BECs and/or standards for on-site battery storage to accompany the installation of on-site renewable energy generation to meet a minimum energy and power duration backup. | • Introduce mandatory requirements into BECs and/or standards for renewable energy produced on-site to meet a certain proportion of energy and power demand<br>• Introduce mandatory requirements into the BECs and/or standards for the on-site battery storage to meet a minimum energy and power duration backup based on baseload demands | • Expand mandatory requirements in BECs and/or standards that both new and existing on-site renewable energy generation are upgraded to meet a substantial portion of energy and power demand<br>• Expand mandatory requirements in BECs and/or standards that on-site battery storage meets a minimum energy and power duration backup based on baseload demands |
| **Smartness** | • Develop a smart building standard that can be voluntarily adopted by developers to enhance buildings' smartness through integration of IoT solutions, smart sensors and controls, starting with large buildings or high-energy-demand users<br>• Develop a draft regulation for large buildings or high-energy-demand users to implement building energy management systems<br>• Introduce a regulatory requirement for large buildings or high-energy-demand users to mandate the adoption of smart meters<br>• Develop a high-level plan for smart grids development | • Adopt requirements for implementation of IoT solutions, smart sensors and controls in accordance with the smart building standard that is mandatory for large buildings or high energy demand users<br>• Adopt the regulation that makes it mandatory for large buildings or high energy demand users to implement building energy management systems<br>• Introduce a regulatory requirement to mandate the adoption of smart meters in all new buildings<br>• Develop a detailed plan for smart grids development | • Adopt requirements for implementation of IoT solutions, smart sensors and controls in accordance with the smart building standard that is mandatory for all buildings<br>• Adopt the regulation that makes it mandatory for all non-residential residential to implement building energy management systems and for residential buildings – home energy management systems<br>• Introduce a regulatory requirement to mandate the adoption of smart meters in all buildings<br>• Develop a comprehensive implementation plan for smart grids supported by project development and investments |
| **Building-to-grid interaction** | • Conduct a feasibility study on utilisation of open interoperability standards for two-way buildings-to-grid communication considering international best practices; develop a roadmap for their utilisation in the country<br>• When developing or updating BECs consider Incorporating voluntary requirements for grid-readiness (space and wiring requirements for EV charging, rooftop PVs, energy storage)<br>• When developing or updating MEPS for selected major appliances consider incorporating voluntary requirements for demand response readiness<br>• Develop voluntary certification & labelling for inverters, appliances, other equipment to indicate their demand response capabilities<br>• Develop pilot projects, programmes and, if needed, regulatory sandboxes to test various grid-interactive technologies (e.g. AMI, smart inverters, smart EV charging, aggregation of DERs, smart mini-grids) in close-to real-life conditions<br>• Conduct a feasibility study on development of demand response and develop small-scale pilot programmes<br>• Introduce voluntary options for dynamic tariffs for some types of consumers to incentivise electricity consumption during off-peak hours | • Develop guidelines on utilisation of open interoperability standards for two-way buildings-to-grid communication considering international best practices<br>• Incorporate into BEC, voluntary (with the vision to make them mandatory in the next update) requirements for grid-readiness (space and wiring requirements for EV charging, rooftop PVs, energy storage)<br>• Incorporate into MEPS for some major appliances (e.g. air conditioners) mandatory requirements for demand response readiness<br>• Develop certification & labelling for inverters, appliances, other equipment to indicate their demand response capabilities<br>• Replicate and scale up projects and programmes for various grid-interactive technologies (e.g. AMI, smart inverters, smart EV charging, aggregation of DERs, smart mini-grids) and consider incorporating lessons learned into regulatory updates<br>• Introduce automated demand response programmes starting with large electricity consumers<br>• Develop pilot projects and regulatory sandboxes for DERs aggregation and assess services they can provide to the grids<br>• Introduce dynamic electricity tariffs starting with large electricity consumers to incentivise electricity consumption during off-peak hours and when VRE is more available | • Incorporate into the grid codes requirements for implementation of advanced metering infrastructure, utilisation of smart inverters in buildings with on-site VRE generation, utilisation of open interoperability standards for two-way buildings-to-grid communication<br>• Incorporate into BEC, requirements for grid-readiness (space and wiring requirements for EV charging, rooftop PVs, energy storage)<br>• Incorporate into MEPS for all major appliances, requirements for demand response readiness<br>• Introduce mandatory certification & labelling for inverters, appliances, other equipment to indicate their demand response capabilities<br>• Develop automated demand response programmes and specify them in the contracts with different consumers<br>• Allow participation of aggregators in electricity wholesale markets and ancillary service markets<br>• Introduce regulations allowing DERs to provide services to the grids<br>• Update electricity tariff regulations to apply mandatory dynamic tariffs to all types of consumers to incentive electricity consumption during off-peak hours and when VRE is available |

# Conclusions

The concept of efficient grid-interactive buildings (EGIBs) marks a promising and transformative path towards a sustainable energy future in the Association for Southeast Asian Nations (ASEAN) region. EGIBs are buildings that actively interact with the energy grid, optimising energy consumption, promoting renewable energy integration and supporting grid stability. By actively engaging with the electricity grid, EGIBs offer numerous benefits to the environment, grid and consumers, making them a crucial component of the transition towards a sustainable and resilient energy future.

One of the key advantages of EGIBs lies in their flexibility and the benefits this provides to the electricity grid. By dynamically adjusting their energy consumption and generation in response to grid signals, EGIBs help improve the stability of the electricity supply. This flexibility is particularly valuable in balancing the grid during peak demand periods and can significantly reduce grid congestion, mitigating the risk of blackouts or voltage fluctuations.

Moreover, EGIBs play a pivotal role in integrating distributed variable renewable energy (VRE) sources into the grid. VRE sources are subject to fluctuations due to weather conditions and different frequencies that put pressure on the grids and challenge stability of electricity supply. However, EGIBs could be equipped to optimally use and store excess renewable energy during periods of high generation, ensuring its efficient utilisation during times when VRE generation is low. This grid-interactive behaviour enables a smoother integration of VRE, reducing curtailment and maximising the utilisation of clean energy resources. This report has explored the benefits of EGIBs, drawing inspiration from international best practices and related projects and policies around the world.

To provide a comprehensive assessment of the EGIB landscape in the ASEAN region, an analytical framework was devised, encompassing key enablers for adoption of EGIBs across for main categories: energy efficiency, decarbonisation, smartness and building-to-grid interaction. This framework allows for an evaluation of each enabler, considering a four-level scale. Based on the aggregation of results across different enablers, countries in the ASEAN region were placed into one of three groups: Explorers, Adopters and Innovators, each representing different stages of EGIB adoption.

Through this assessment, Brunei Darussalam, Cambodia, Lao PDR and Myanmar were identified as Explorers, as they are in the beginning of the process of discovering and researching the opportunities for EGIBs. Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam were classified as Adopters, as they have identified some opportunities for EGIBs and are implementing pilot projects and sandboxes to test their benefits and potential, but still do not have all necessary policy instruments in place to support the mainstream adoption of EGIBs. These classifications recognise the unique national circumstances in political, economic, environmental and social spheres, and provide a basis for tailoring specific recommendations to support the uptake of EGIBs in each country.

The high-level recommendations and group-specific guidelines offered in this report provide a solid foundation for ASEAN countries to embark on a transformative journey towards EGIB adoption. Development of a comprehensive policy package, combining regulations, information instruments and incentives is key for fostering EGIB adoption, especially in a rapidly growing region, such as ASEAN, where most of the buildings are yet to be built. Within this package incorporating energy efficiency requirements, flexibility considerations and readiness features for interaction with the grid into the buildings and appliances’ regulations can help the buildings sector to leapfrog towards higher levels of energy performance and decarbonisation, as well as support modernisation of the electricity system. Policy provisions to support integration of smart sensors and controls into building systems and energy management at the building level are also crucial.

Important enablers to enhance building-to-grid interactivity, such as automated demand response programmes, aggregation of distributed energy resources and dynamic electricity tariffs are typically not present in most of ASEAN beyond some pilot projects.

Interoperability standards are crucial for establishing a two-way communication between buildings systems and the grid; however, their utilisation in ASEAN is very limited. There are currently no mandated policies, projects or programmes that utilise technologies to enable communication and information flow at the equipment level. At the building level, there are a few building projects that utilise BACnet and similar systems in several ASEAN member states. As for interoperability between buildings and the grid, the related open standards are not used in most of the ASEAN countries, except for Thailand, where OpenADR is used in demand response programmes.

The ASEAN region, comprising the ten ASEAN member states, is on the cusp of a transformative energy transition through the adoption of EGIBs. While each country faces its individual challenges and opportunities, the collective efforts towards EGIBs will accelerate the region's progress towards a sustainable and resilient future. By identifying and prioritising actions based on the recommendations and group-specific guidelines, ASEAN countries can lead the way in creating an energy-efficient and grid-interactive built environment, contributing to a cleaner and more sustainable energy landscape for generations to come.

# Annexes

## Abbreviations and acronyms

| | |
|---|---|
| 3DEN | Digital Demand-Driven Electricity Networks |
| AC | alternating current |
| ADB | Asian Development Bank |
| AMI | advanced metering infrastructure |
| ASEAN | Association of Southeast Asian Nations |
| AUD | Australian dollars |
| B2G | building-to-grid |
| BAS | building automation systems |
| BEC | building energy code |
| BEMS | building energy management systems |
| BESS | battery energy storage system |
| $CO_2$ | carbon dioxide |
| DC | direct current |
| DERMS | distributed energy resource management systems |
| DER | distributed energy resource |
| EGIB | efficient grid-interactive building |
| EMS | energy management systems |
| EPBD | Energy Performance of Buildings Directive |
| EU | European Union |
| EUI | energy use intensity |
| EV | electric vehicle |
| GEF | Global Environment Facility |
| GHG | greenhouse gas |
| HEMS | home energy management systems |
| HVAC | heating, ventilation and air conditioning |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| IES | Intelligent Energy System |
| IoT | internet of things |
| LED | light-emitting diode |
| LEED | Leadership in Energy and Environmental Design |
| low-E | low-emissivity |
| LPG | liquefied petroleum gas |
| MEPS | minimum energy performance standards |
| NZE Scenario | Net Zero Emissions by 2050 Scenario |
| P2P | peer-to-peer |
| PLN | Perusahaan Listrik Negara |
| PPA | power purchase agreement |
| PV | photovoltaic |
| R&D | research and development |
| SAIDI | System Average Interruption Duration Index |
| SAIFI | System Average Interruption Frequency Index |
| SCADA | supervisory control and data acquisition |

| | |
|---|---|
| SDS | Sustainable Development Scenario |
| SGD | Singapore dollars |
| SRI | Smart Readiness Indicator |
| STEPS | Stated Policies Scenario |
| T&D | transmission and distribution |
| TFEC | total final energy consumption |
| VND | Vietnamese dong |
| VPP | virtual power plant |
| VRE | variable renewable energy |

# Units of measure

| | |
|---|---|
| EJ | exajoule |
| GW | gigawatt |
| GWh | gigawatt-hour |
| kV | kilovolt |
| kVa | kilovolt-ampere |
| kW | kilowatt |
| kWh | kilowatt-hour |
| kWp | kilowatt-peak |
| $m^2$ | square metre |
| Mt | million tonnes |
| Mtoe | million tonnes of oil equivalent |
| MW | megawatt |
| MWh | megawatt-hours |
| PJ | petajoule |
| t | tonne |
| toe | tonne of oil equivalent |
| TWh | terawatt-hour |

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Typeset in France by IEA - October 2023
Cover design: IEA
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