Enapter

# Make Your Microgrid Smart

## Getting Started with Microgrid Management

# Executive Summary

Microgrids have already become an integral part of the electricity landscape by providing reliable autonomy and clean energy. But they also need to become truly smart so that more people and businesses can safely embrace the technology and fully unlock its economical, ecological and societal benefits. This white paper briefly discusses how microgrid operation translates into sustainable energy management.

By way of example, we use existing energy management and green hydrogen production solutions that have worked successfully in varied geographies and contexts. Finally, the paper further outlines our vision of a grid management ecosystem which steadily adds value to all stakeholders, from equipment manufacturers and system integrators to end users and market participants.

## Contents



# 1. The Distribution Shift

For years, large centralised systems have dominated energy generation, transmission, and distribution. They continue to play a key role in supplying electricity. However, the state of energy production is becoming increasingly complicated as more and more minigrids, microgrids and even nanogrids start to energise our households and businesses.

## What's a microgrid?

Microgrids, while indeed being relatively small, actually come in a variety of sizes from a single building to sites covering extensive areas of land. It is not so much the size but the features that define a microgrid.

Microgrids are inherently decentralised although they typically also maintain interactive relationships between the central grid and the users.

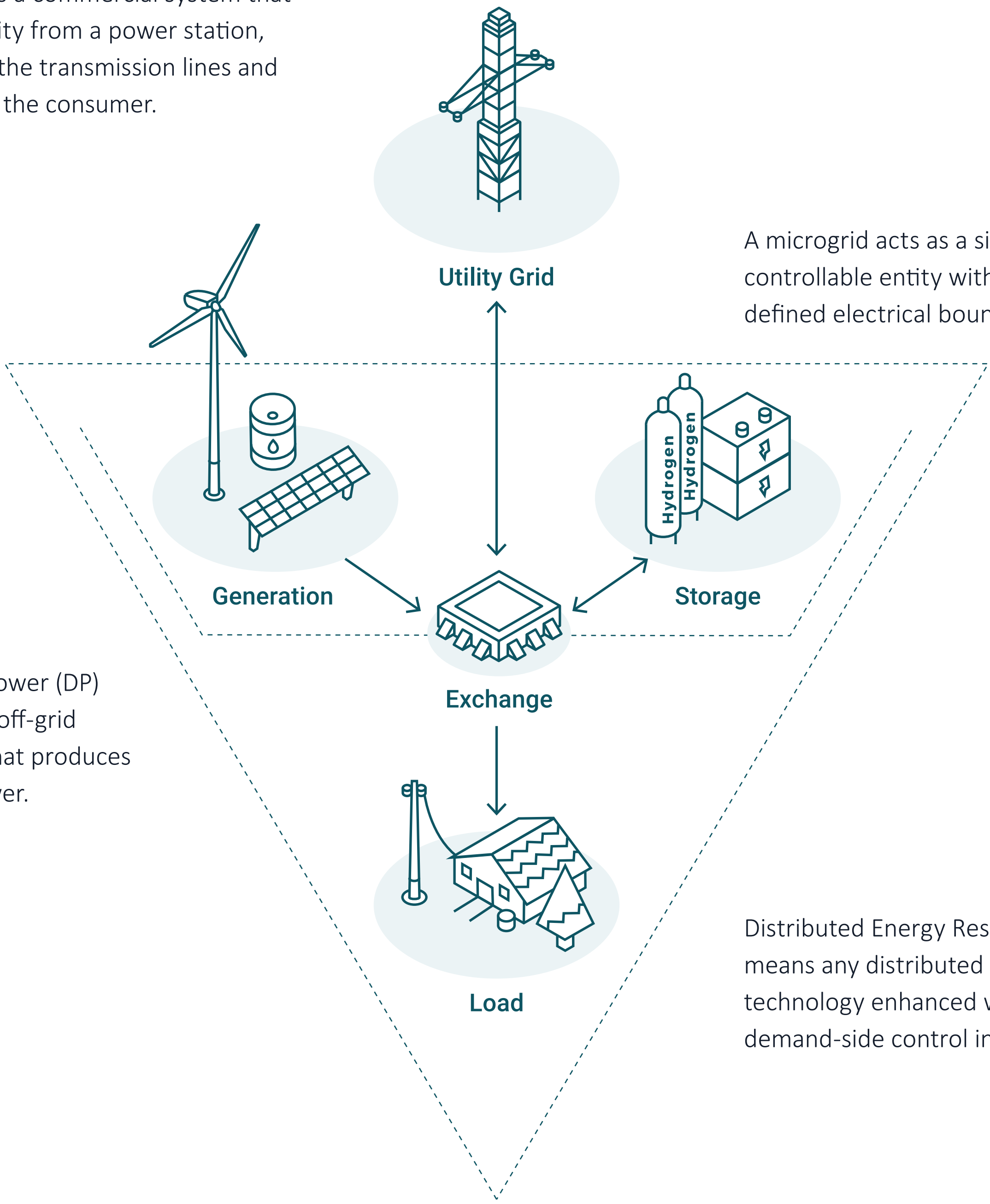
They can provide multiple economic benefits, ensuring both a reliable and affordable energy supply for off-takers and new revenue streams for microgrid stakeholders.

The U.S. Department of Energy's defines the microgrid as "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."

## What’s inside?

A typical microgrid is connected to the utility grid and further accommodates distributed generation facilities to complement centralised supply or to go completely off-grid.

A utility grid is a commercial system that takes electricity from a power station, sends it over the transmission lines and distributes to the consumer.




A microgrid acts as a single controllable entity within clearly defined electrical boundaries.

Distributed Power (DP) refers to any off-grid technology that produces or stores power.

Distributed Energy Resources (DER) means any distributed power technology enhanced with demand-side control instrumentation.

## The energy balance challenge

Microgrids face the challenge of balancing energy generation and consumption. We cannot simply produce exactly as much energy as we need at the very moment we need it.

On-site backup storage is also needed to protect against centralised power outages or local voltage drops, to deal with load fluctuations and to respond to emergencies.


**The smaller the grid, the harder it is to smooth out load fluctuations and surges, daily and seasonal changes, peaks and downtimes.**

This is where distributed power helps: We can receive electricity either from generating facilities or from storage devices, whichever are available or feasible at the moment.

Energy storages come in different types. No single solution, however, fits all applications in terms of power density, discharge rate, life-time and efficiency. Rechargeable batteries would seem be the most straightforward storage solution. But they self-discharge over time, have a limited lifespan and are difficult to recycle.


Phi Suea House, Thailand
Electrical room
Battery storage capacity: 192 kWh

Compared to batteries, supercapacitors provide much greater capacity, deliver faster charge and discharge and tolerate many more cycles. But they also are not well-suited for long-term energy storage and have technological limitations.

Recently, hybrid energy storage systems have been growing in popularity since they combine different types of storage technology into a single setup. They give flexibility to convert excess power into heat or charge various electrochemical storage units.

Microgrids have a variety of energy loads that differ in type, current and wattage, use schedules, and dispatch priority. The effective management of DERs is needed to deal with such complexity in modern microgrids, and the new generation of microgrids will require more sophisticated optimisation algorithms to achieve this.

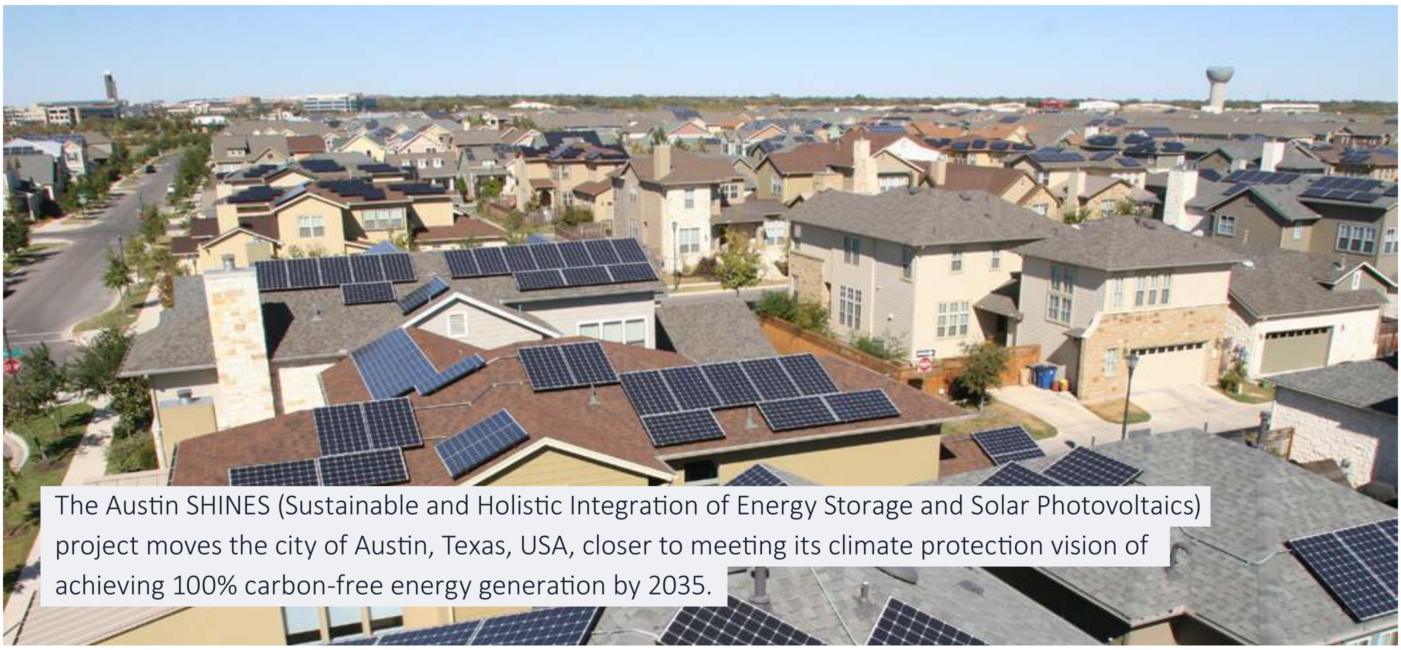
 

## Why microgrids?

Distributed resources offer a number of advantages, particularly where centralised power is not available or is in short supply. Recently, a whole new paradigm for power quality and reliability has begun to take shape.

Microgrids provide increased autonomy, flexibility, and safety, with less need for heavy infrastructure. They further democratise electricity markets and help create economic benefits for people and communities by turning them into prosumers who can trade with the grid or exchange electricity with other renewable energy producers. All of this gives microgrids a remarkable array of uses in many settings.

These range from the development sector, where decentralised microgrids offer energy access to underserved communities, to highly isolated environments such as islands or Antarctic research bases, and even public or grid-connected microgrids that are able to operate independently during emergencies or power outages.



The Austin SHINES (Sustainable and Holistic Integration of Energy Storage and Solar Photovoltaics) project moves the city of Austin, Texas, USA, closer to meeting its climate protection vision of achieving 100% carbon-free energy generation by 2035.

## 2. Clean Momentum

Distributed generation doesn't necessarily mean producing only clean energy collected from renewable resources. It may well feature conventional generators that use gasoline, diesel or natural gas.

Microgrids are well suited to accommodate both conventional and renewable energy use; in fact, they enable higher utilisation of renewable energy, with conventional generation generally compensating only where renewables cannot guarantee supply.

Most microgrids use renewable energy sources such as sunlight, wind, tides, geothermal heat or biomass, which may account for a large share of their energy balance. This is not by chance: As renewable energy generation and storage technologies mature and get cheaper they are gradually making generators that run on fossil fuels obsolete.

As "Go Green" initiatives receive greater support around the world and technical innovation brings down the costs, more and more people are getting on board with microgrids. At the end of 2018, there was 19.5 GW of planned and installed microgrid capacity around the world. By April 2020, that figure had topped 30 GW, with the microgrid count almost tripling to 6610 projects. The International Energy Agency (IEA) has projected that 30% of future electrification efforts will be supplied by microgrids.

With rising shares of renewable energy in all energy systems, the problem is no longer a shortage of clean energy but a question of storage.

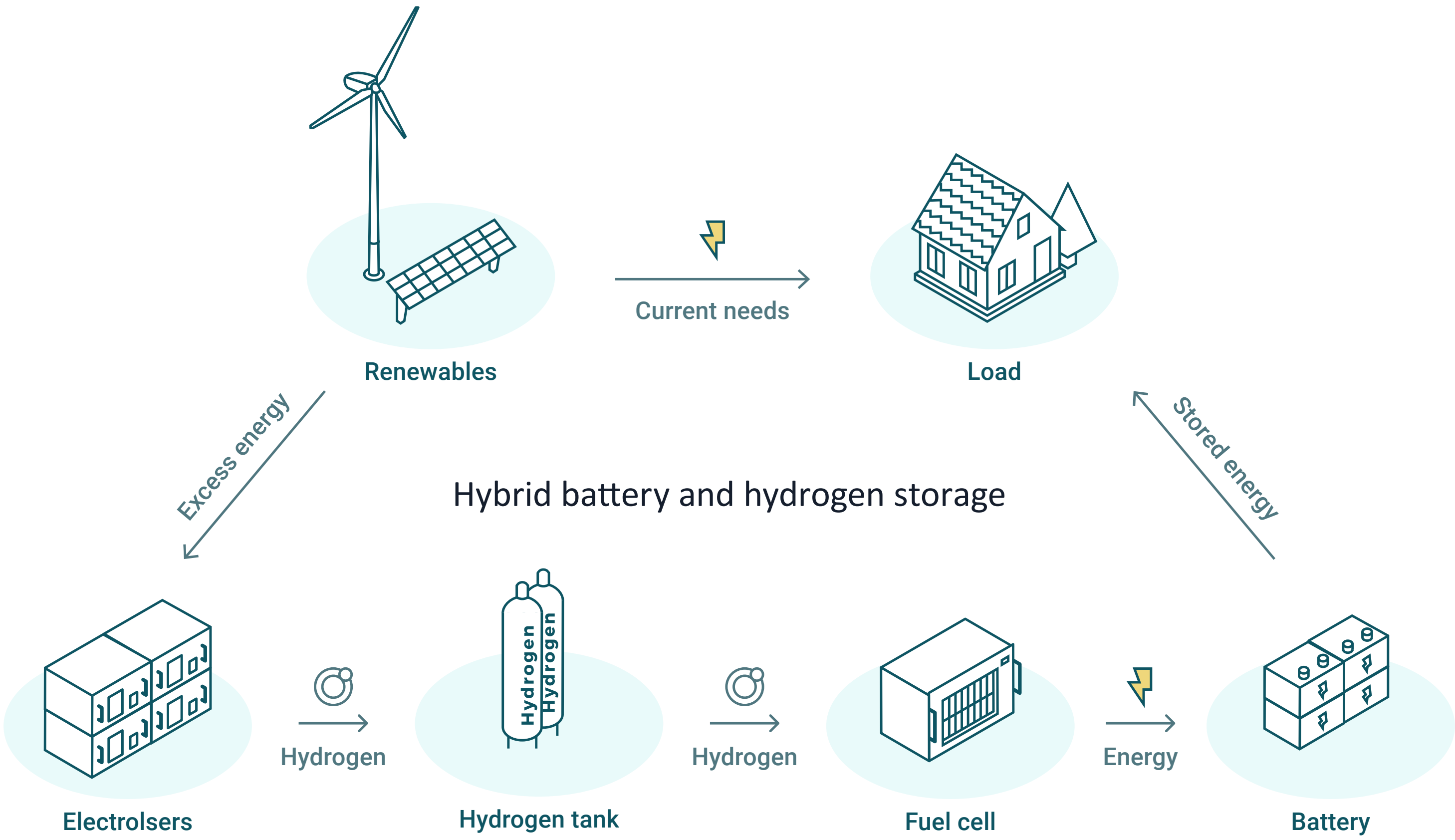
 

One clean energy source and storage medium that has recently gained a lot of momentum is green hydrogen, which provides microgrids with an emissions-free long-term energy storage solution.

Introducing hydrogen to microgrids solves the problem of seasonal or long-term storage that batteries cannot provide. It is the crucial jigsaw piece for 100% green microgrids.

Hydrogen offers high energy density, virtually unlimited shelf-life and easy commoditisation.

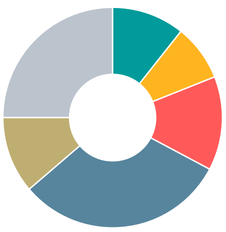
**Electrolysers** use electricity to split water into hydrogen and oxygen. The ability to take a modular approach with electrolysers makes it possible to produce hydrogen in decentralised grids with sizes ranging from residential applications to large-scale production facilities.



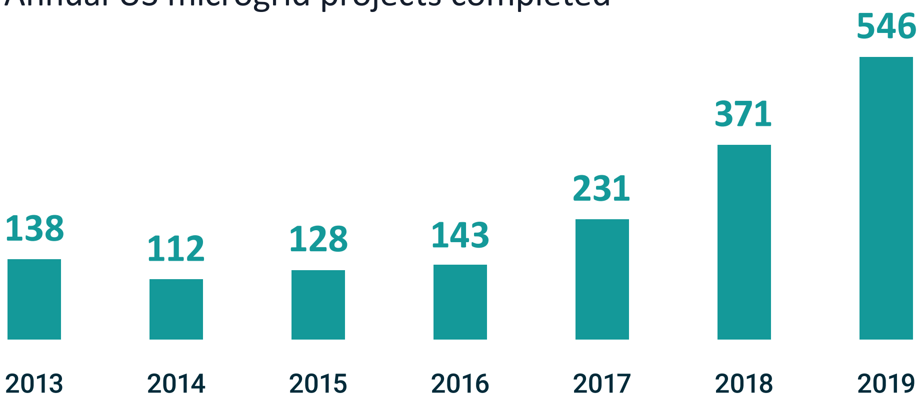
One can argue about how big the market will be and whether it's going to split into grid-tied and completely off-grid models. But microgrids have already become a part of the bigger picture, enabling many to deliver on the promise of reliable clean energy.

We still face technological challenges. Regulatory barriers and long project development cycles continue to frustrate the sector. But there's no doubt that microgrid adoption continues to grow rapidly despite this.

Projects by type:




Annual US microgrid projects completed




Source: Wood Mackenzie research, 2020

Leaving aside military installations, which account for a considerable portion of today's microgrid deployments, most projects are focused on public purpose, community services, university campuses, remote electrification and heavy commercial facilities, such as data centers. Public purpose microgrids are designed to provide energy to critical community services during an emergency. But microgrids are also increasingly used for private facilities.

## Phi Suea House – off-grid energy system

The Phi Suea House in Thailand is the world's first sustainable multi-house residence fully powered by a clean energy system based on hydrogen energy storage. The project was led by Enapter founder and Chairman Sebastian-Justus Schmidt to showcase the feasibility of combined solar and hydrogen technology.

The site in Chiang Mai features multiple buildings constructed following principles of energy-efficient design, a fully autonomous solar power system, and Enapter's own energy management solution and hydrogen production technology.

Electricity produced by the 86 kWp solar panels directly supplies Phi Suea House's daytime electricity demand.

Excess electricity then flows to its hybrid battery-hydrogen energy storage system to provide nighttime supply.

This is achieved by creating hydrogen during the day with Enapter AEM electrolysers, storing the hydrogen and using fuel cells to convert hydrogen back to electricity when it is needed at night.

Its batteries are mainly used to balance daily demand, while the hydrogen ensures the system has seasonal storage, compensating for any energy that the batteries and solar cannot supply. This microgrid setup allows Phi Suea House to reliably meet a monthly demand of approximately 6 MWh with 100% locally-produced energy – all year round.

# 3. Getting Smart

As early as 2001, Wired Magazine shared the vision of future electricity networks, which later on became known as “smart grids”. The term itself was coined in 2003, though a universally accepted definition doesn’t exist.

WIRED

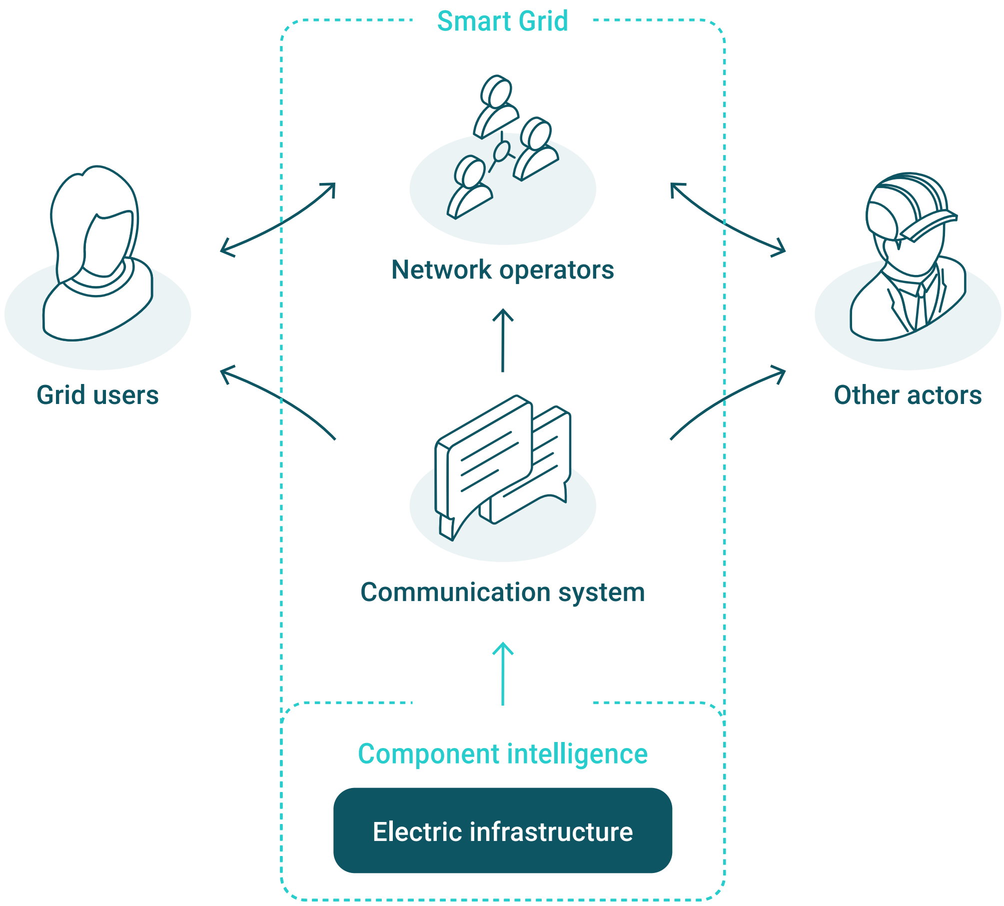
**The best minds in electricity R&D have a plan: Every node in the power network of the future will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming, and interconnected with everything else.**

In December 2008, the European Council and the European Parliament adopted and approved the EU 20-20-20 Plan, which suggested a 20% increase in energy efficiency, 20% reduction of CO2 emissions, and 20% renewables share by 2020. All of these depend on the re-configuration of the European electricity grid into a smart grid.

The document highlights that the "concept will be made possible by the participation of all smart grids actors," including:

- **Grid operators** who manage transmission and distribution networks and systems.
- **Grid users** who consume the power and can also own generating and storage facilities.
- **Other actors,** such as suppliers, metering operators, applications and services providers, aggregators, operators of power exchange platforms, energy service companies, etc.



## Smart goals

A smart microgrid employs innovative products and services together with intelligent monitoring, control, communication, and other processes in order to achieve a number of high-level goals.

While the **high-level goals** may vary from project to project, the following list gives a glimpse of what it takes to make a microgrid smart.

### Optimisation

Know customer needs, system topology and the status of every major component in real or near-real time to enable autonomous optimisation with the aim of maximising reliability, availability, efficiency and economic performance of the system.

### Adaptation

Rely as little as possible on operators, particularly in responding rapidly to changing conditions.

### Prediction

Apply operational data to equipment maintenance, identify potential problems before they occur.

### Interactivity

Provide timely and relevant information to all stakeholders, enable them to manage the system in line with their needs and competences, facilitate interaction and cooperation.

### Self-healing

Automatically repair potentially faulty equipment or remove from service, reconfigure the system to ensure reliable energy supply.

### Flexibility

Interconnect distributed power resources in a rapid and safe manner at any moment and in any location.

### Integration

Enable real-time communication and control functions within and across the entire system.

### Security

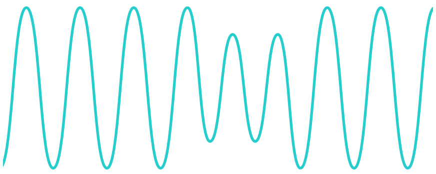
Ensure physical and cyber security of all critical assets and transactions.

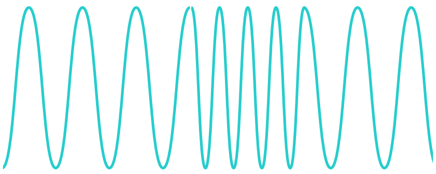
# 4. Setting Microgrid Objectives

As we move from high-level goals to operations management, we deal with performance objectives that universally apply to business and private microgrid projects, regardless of their scope and size.

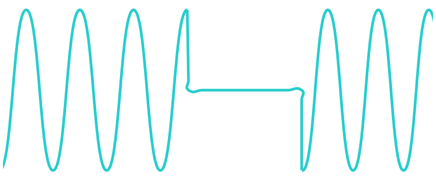
## Quality



Sags



Frequency deviations



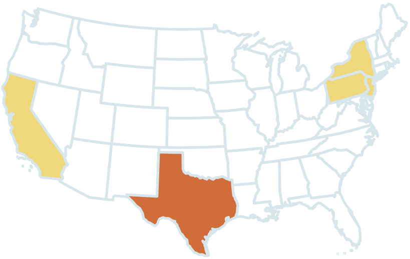
Interruptions

Above all else is electric power quality – that is, voltage, frequency, waveform, and the like properties of the supplied power. Good quality means the power is steadily supplied and is close to the rated values, which is critical for the loads to function properly. Otherwise, electrical devices may malfunction, fail or completely break down.

In developed regions we often don't even think about this. We take good quality power out of the socket for granted. This magic doesn't always work everywhere. But quality doesn't just boil down to the multimeter readings: Organisations also increasingly want to reduce reliance on fossil fuels, meet legislative and self-imposed carbon targets, and enhance their record of social responsibility.

## Speed

Speed in an electrical grid, first and foremost, translates into the time elapsed between the point when you need the power and the moment when you get it. We should also consider the time required to maintain and upgrade the equipment, as well as to increase the installed capacity.



The poweroutage.us site provides real-time data on power outages across the US. This snapshot corresponds to August 28, 2020.

For large companies, the cost of outage escalates to millions of dollars per hour. The DoE estimates that outages cost the U.S. economy about $150 billion annually. Microgrids can help mitigate this risk.

## Dependability

When speaking of energy, we usually refer to this as reliability. In fact, dependability is a broader concept, which brings together system availability, reliability and maintainability. Sometimes it's further extended to durability and safety. From an operations perspective, however, it's just as simple as:

**DEPENDABILITY = DUE TIME – ACTUAL TIME**

Put simply, when you need the power, you need it here and now. Power outage and voltage degradation can be troublesome for many remote areas. But dependability can also be a problem in developed areas, as extra power may not be available for new projects or not be sufficient to meet the ever-growing demand.

Dependability is a major driver for microgrids, especially where centralised supply is not stable.

## Flexibility

This usually means how the system adapts to changing conditions, whether internal or external. It's also important to distinguish between the flexibility of a whole operation and the flexibility of the individual resources that together make up your system.

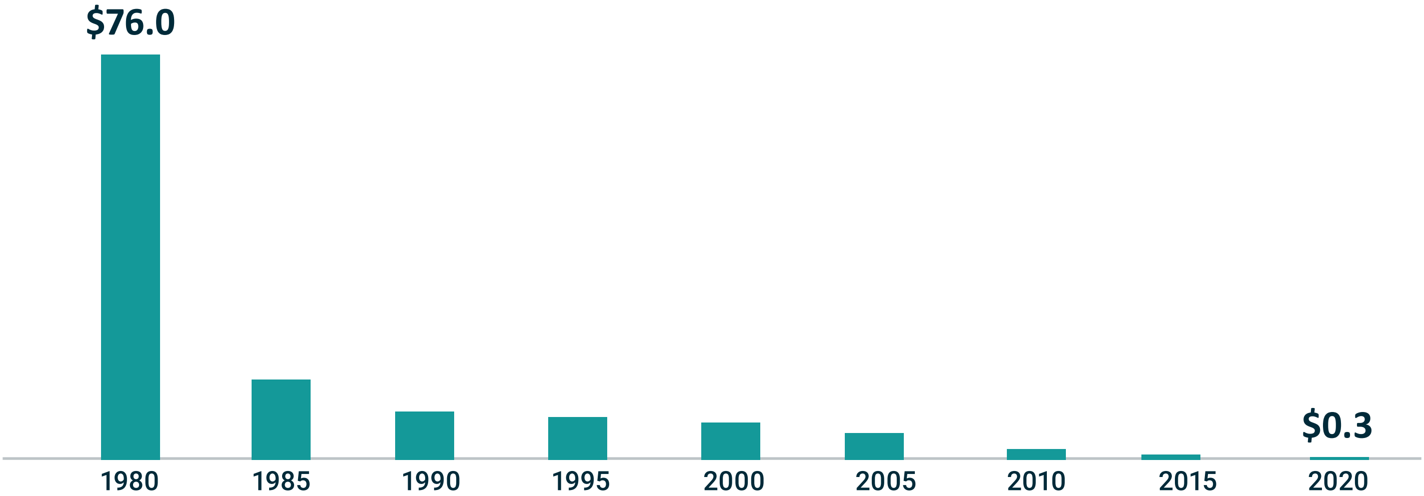
## Cost

Last but not the least, comes the cost. Too often, the whole argument is reduced to the claim that clean energy is more expensive. Quite true. It comes as no surprise that when all infrastructure is readily available, a kWh you get from the utility grid would normally be cheaper. All you need is a grid within your reach. But considerable technological progress has been made and the price gap is rapidly closing. In some cases, clean energy is already cheaper, taking into account all relevant factors.

**Levelized cost of energy (LCOE)** is a measure of the average net present cost of electricity generation for a generating facility, calculated as the ratio between all the discounted costs over the lifetime of the facility divided by a discounted value of the actually delivered energy.

We should consider costs throughout all phases of the project, the cost structure and who pays what. Many countries directly subsidise clean energy. The situation is much more complex than just a number in your utility bill. And it's changing quickly.

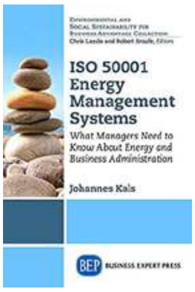
PV Cell Historical Price, $/W




Source: Bloomberg Energy Finance, pv.energytrend.com

# 5. Finding Your Strategy

Simply put, a microgrid strategy balances performance objectives against what is desired and what is possible. Our possibilities are limited by local conditions, technological environments, organisational resources and maturity, regulatory requirements, you name it.




Johannes Kals is a professor of business administration in sustainability and energy management at the University of Applied Sciences in Ludwigshafen, Germany, and the author of "ISO 50001 Energy Management Systems: What Managers Need to Know About Energy and Business Administration" (2015).

Johannes Kals suggests that any organisation may pursue one of five different energy strategies. The same holds true for private microgrid projects and the concept provides a good starting point to understand where a project stands, and where we want to go next.

- **Passive Strategy.** The organisation only deals with the most essential subjects without having systematic planning and environmental management in place.
- **Short-term profit maximisation.** The management is focused on measures that have a relatively short payback period and a high return.
- **Long-term profit maximisation.** The management embraces long-term measures that not only maximize the profit, but further help to improve an organisation's image and increase employees' motivation.
- **Realisation of all financially attractive energy measures.** The management is committed to implementing all measures that have a positive return on investment
- **Maximum strategy.** For the sake of climate protection, the organisation is ready to change even the objective of the company.

## ISO 50001 energy management

When creating an energy management strategy for microgrids, it's necessary to consider ISO 50001 – the international standard for Energy Management Systems (EMS). Its main objective is to enable organisations to follow a systematic approach in achieving continual improvement of energy performance.

**PDCA** (plan–do–check–act) is an iterative four-step management method used in business for the control and continuous improvement of processes and products.

ISO 50001 ENERGY MANAGEMENT

Based on the iterative PDCA (Plan-Do-Check-Act) management approach, ISO 50001 provides a framework that helps project planners:

- Develop a strategy for efficient use of energy.
- Fix targets and objectives to meet the strategy.
- Use data to make informed decisions.
- Measure the results.
- Review the effectiveness of the strategy.
- Continually improve energy management.

# 6. From Strategy to Sustainability

An important driver shaping the business landscape is the shift from pure energy management to strong energy awareness. This shift is causing widespread strategic change as governments, businesses and individuals around the world become increasingly concerned about questions such as:

- How much energy do we use? What do we actually use it for? Where does this energy comes from?
- What are the knock-on effects, such as environmental impacts and depletion of resources?
- What we can do to reduce or completely remove undesirable effects?
- How we can achieve sustainability?

The sustainable energy strategic approach is gaining momentum around two key elements: renewable energy and energy efficiency.

To maximise the impact of these two elements and become a real enabler of inclusive and sustainable development, microgrids need to become truly smart.

The challenge here is ensuring that your energy management system can align a workable strategy with your daily operations. In day-to-day microgrid management, you deal with distributed energy resources whose individual work needs to be intelligently streamlined and integrated to achieve high-level goals, performance objectives – and sustainability.

# 7. Turning Measurements into Information

If you can't measure it,
you can't improve it.
— Peter Drucker.

Making microgrids smart starts with data. Modern electrical components generate a great deal of measurement data that show their state and operating parameters, and are normally used for automatic control.

Measurement data provide a wealth of information for managing your microgrid at a higher level. But we face two major challenges here.

Connecting a hydrogen tank with Enapter kit.

First, we usually deal with heterogeneous complex environments. In a sense, each device speaks its own language or dialect. It's possible to get all equipment from a single supplier, ensuring that it's language compatible and having someone deal with the technical coordination. Besides creating a vendor lock-in, this may not be viable or possible with many projects. Also, for system integrators the problem is simply shifted to another level. Alternatively, we can take heterogeneity for granted. We can embrace the opportunity to streamline technical choices to local contexts, operating environments, and economic conditions.

Freedom of choice is a valued asset.
Hardware diversity is welcome.

Second, we need to homogenise and pool all of the data that come from the grid's measurement systems. For that, we need a unified communication channel. We also have to understand what each and every device is saying and translate it into a commonly understood language.

# Hierarchical control

A control system can be centralised or decentralised. With a fully centralised system, a single point of control makes decisions based on information received from all controlled units. With decentralisation, a local controller manages each unit, without knowing the situation of the others. Both approaches have their pros and cons. A compromise between the two can be achieved by means of a hierarchical control.

In the context of electrical grids, we usually consider three control levels.

Real-time

**Primary control.** Provides the first line of safety. It doesn't communicate with other devices, but features fast automatic response based on local measurements to detect unit islanding or malfunction, regulate current and voltage, and handle the output.

Seconds to minutes

**Secondary control.** Deals with short-term power management for reliable, secure and economical operation of the equipment, which is particularly challenging when operating in isolated mode with highly-variable energy sources.

Hours to days

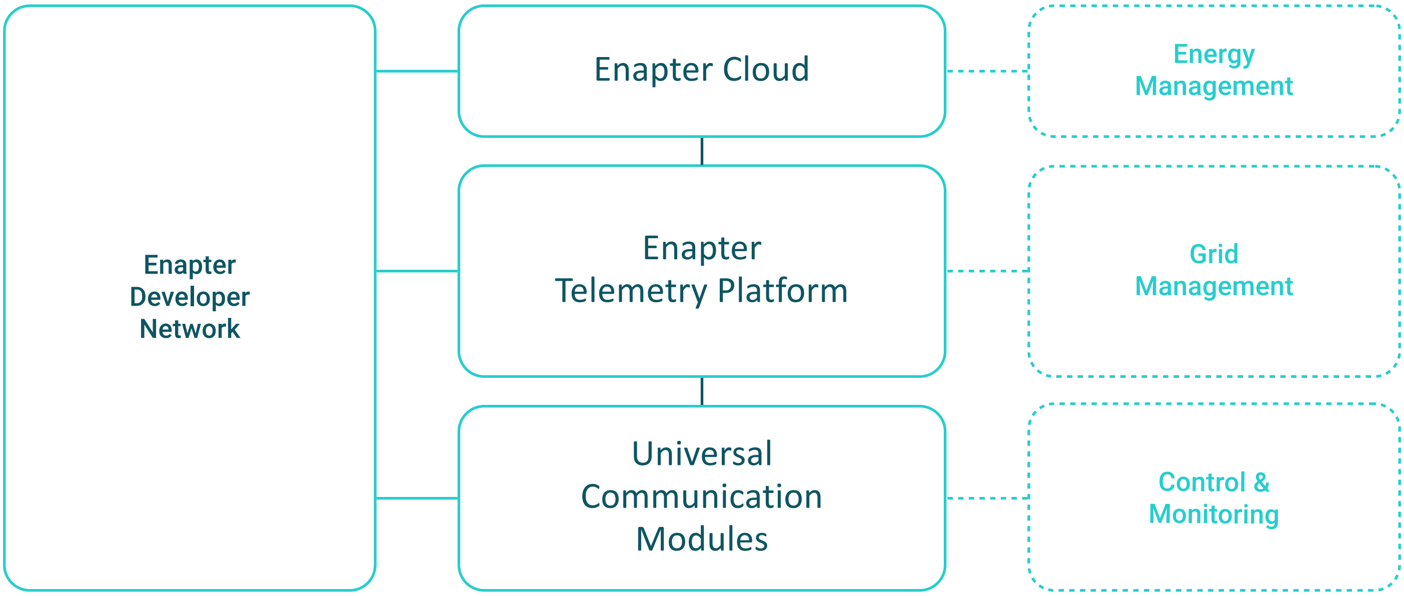
**Tertiary control.** Is about long-term energy management and system optimisation (DER prediction, CO2 emissions), as well as communication and transactions with any host grid and interacting microgrids.

# Enapter Energy Management

To learn more about the Enapter Energy Management, read our brochure.

The Enapter Energy Management toolkit offers both secondary and tertiary levels of control through a range of modular hardware and software solutions.

It helps people and businesses to plan and realise energy production, storage and consumption in microgrid projects of any size and complexity. This is achieved through the system's intelligent integration of distributed energy resources into an AI-powered management framework.

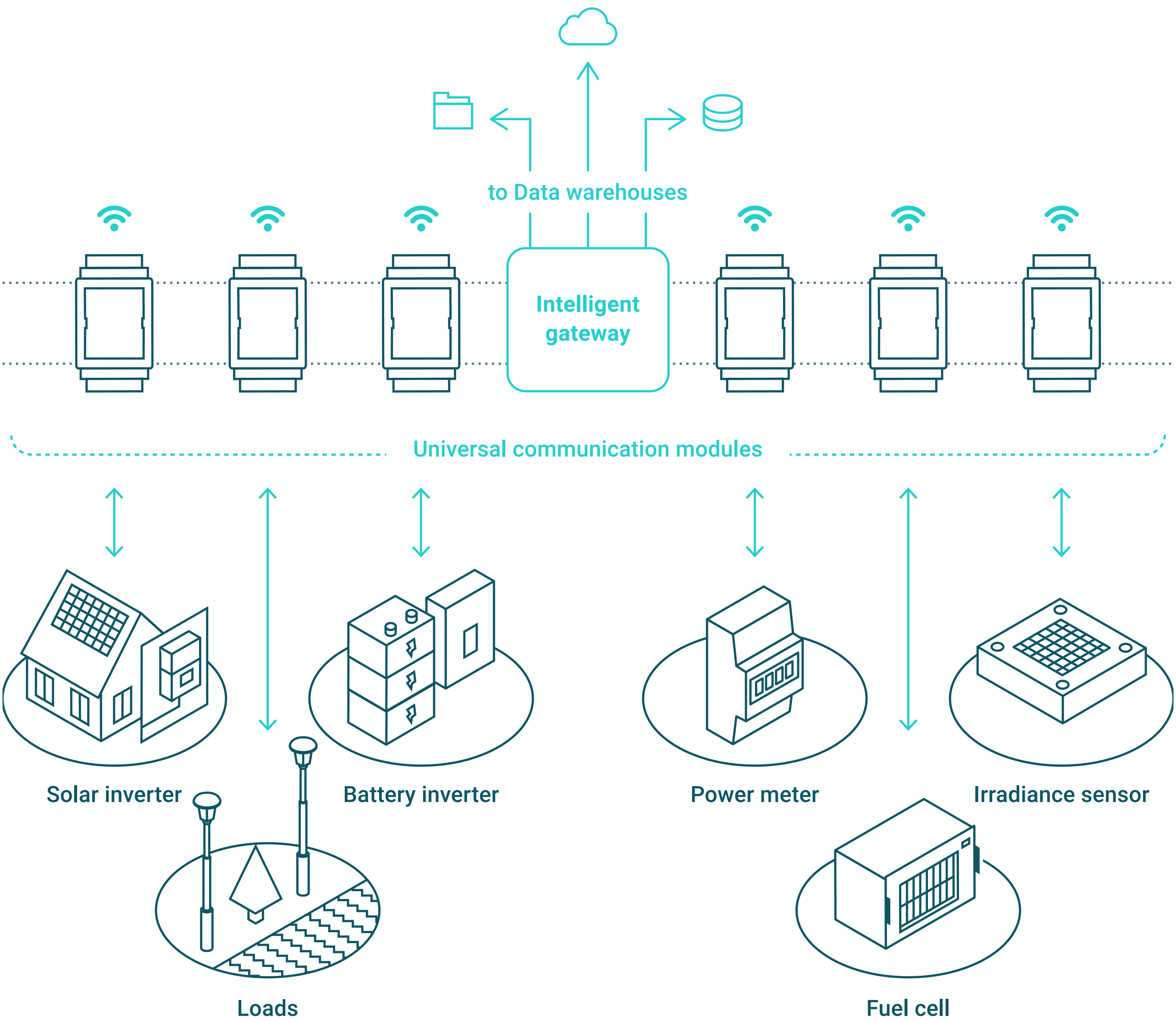



Its applications include:

- Small individual and business projects
- Residential and industrial control of hydrogen cycle
- Public and industrial projects with widely distributed energy resources
- Connected and off-grid facilities using renewable energy resources

# Enapter Telemetry Platform

This solution within Enapter's Energy Management toolkit collects telemetry data (remotely measured and transmitted data) across the distributed energy resources in a microgrid. It is a vital part of an EMS as it enables interoperability for control and management of electrical components.



# 8. From information to knowledge

Real-time telemetry data are essential for the ongoing work of microgrid equipment and operational control. As we move forward, we need historical data on hardware performance, malfunctions and failures, energy consumption, etc.

All these data should be verified, harmonised, marked up and stored in a safe way.

## Content & context

Measurement data fitted with metadata form the data content basis. To use these, we have to contextualise them. Operational context comes from both historical records and external information such as equipment specifications, environmental conditions, tariffs and prices, user preferences and even regulatory requirements.

### On premise or in cloud?

One big question here is where you want to keep your data. Clouds are great. For some projects it makes perfect sense to rely entirely on public cloud. Other projects may require different deployment scenarios or hybrid solutions, and further involve administrative work to protect and backup your data, and monitor what's going on. A robust system enables all scenarios.

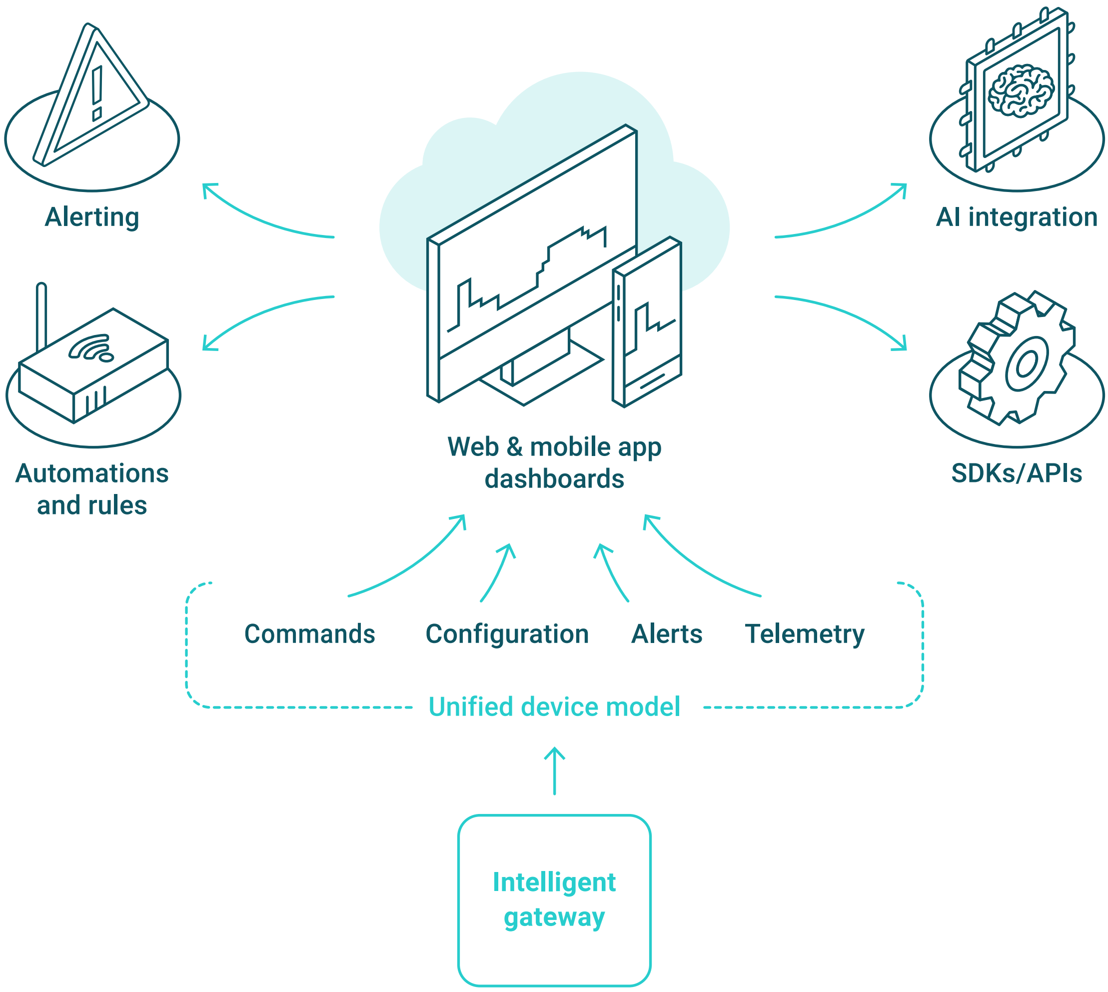
### Internet of Things

In 1982, a modified Coca-Cola vending machine became the first appliance that could report its inventory over an Internet connection. Seventeen years later, the term "Internet of things" (IoT) was coined to describe the connection of such sensing objects and devices to the internet, but it took another decade until it entered the mainstream. Now, IoT sensors in devices across microgrids allow for the real-time measurement and transmission of all the operational data we need for efficient energy management.

# Enapter Cloud

To learn more about the Enapter Cloud, read our brochure.

In response to the above challenges, the Enapter Cloud provides secure device-cloud communication, collecting performance and error data from connected devices and systems. It stores the data in a time series database, providing real-time or on-demand visualisation of collected data on customisable dashboards.



# 9. Translating Knowledge into Action

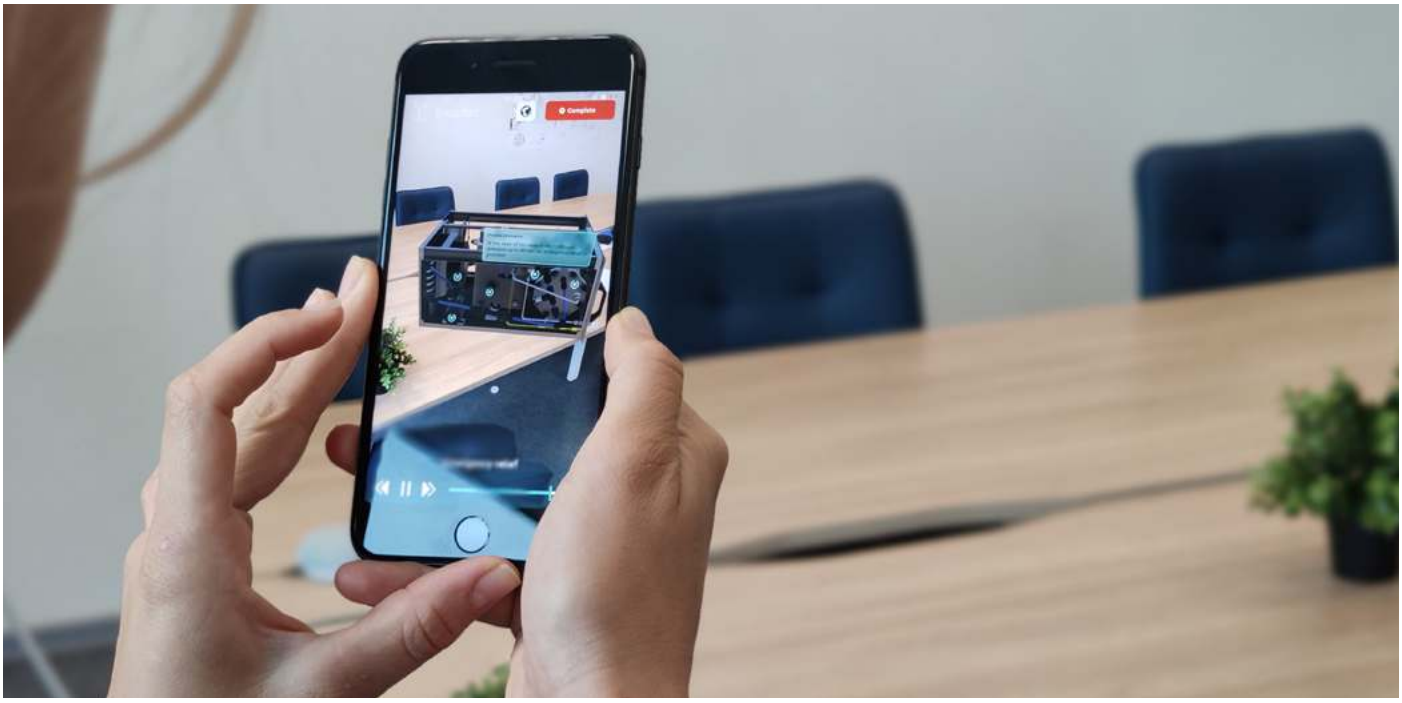
Energy management is about action. However, it's not that easy to make decisions in complicated environments like microgrids. Your system will contain multiple devices, and is affected by many internal and external factors. You often have to act quickly, and your choice may seriously affect your livelihood and business. But Machine Learning, modeling and simulation can make your job easier.

## Machine Learning

Machine Learning algorithms learn and improve from data and experience without having to be explicitly programmed. It has become an established practice to use Artificial Intelligence to support decision-making in complex environments.

However, building relevant machine learning models usually requires a great deal of data and takes a lot of computational resources, making it difficult to do on site. The best solution for microgrids is to run state-of-the-art, pre-trained models that can be customised for specific conditions and requirements. This makes your system not only reactive to what's going on but also predictive.



## Modeling & simulation

Today, software technology can offer a wide range of simulation solutions, from simple "If-Then" scenarios to sophisticated digital twins.

A digital twin is a digital replica of a living or non-living physical entity. This can be potential and actual physical assets – usually called physical twins – processes, people, places, and entire systems.

You should be able to simulate different technical and business scenarios, understand how they impact your operations, and know what consequences and risks are involved. Ideally, it also allows you to define goals and use a Problem Solver function like the one in Enapter's Energy Management toolkit. Here, the system automatically finds feasible options and suggests them along with a detailed explanation, so you can make informed decisions.

## A system to guide you

Most systems take your microgrid as a given and try to optimise a set of predefined technical objectives within the existing configuration. This is in the job description.

But what if your system could help re-configure your microgrid to match your business goals? What happens if you add a new device which takes a lot of power. How will this change your energy balance? Should you increase the capacity? By how much?

An intelligent energy management system can support you in answering these questions through your entire project lifecycle. For smaller projects, this can be practical advice on what options are available, help with making an informed decision and checks to ensure everything works just fine.

With more complicated projects, it should offer professional, step-by-step guidance, focusing especially on teamwork, benchmarking against best practices, monitoring and reporting, and ensuring compliance with standards and regulatory requirements.

It should be able to integrate with other systems that manage various resources and processes to enable consistent usability, as well as the transparent, efficient and safe operation of your microgrid.

In short, a smart energy management system is essential for microgrid management, ensuring efficient and sustainable energy, and enabling a great outcome for society, businesses and customers alike.

## Key Takeaways

1. Microgrids can offer many advantages, including distributed and clean energy.
2. Today's microgrid projects can be feasible, profitable and rewarding.
3. You should carefully consider all operational objectives and how they map to your business strategy.
4. To be viable, a microgrid should be truly smart.
5. There are technical and regulatory problems that may complicate your project but they are not going to stand in your way.
6. Making your microgrid smart starts with continually collecting telemetry data and turning operational data into useful information.
7. All of your operational data should be put into the context of all relevant information coming from external sources.
8. Your EMS should be able to advise you in a timely and actionable manner.
9. Ideally, this system should guide you through your entire project lifecycle and be able to simulate different technical and business scenarios.

# How Enapter Can Help

In 2004, an international team of engineers embarked on a R&D mission to leverage hydrogen technology for modern electrical grids. In 2017, Enapter was founded to bring this ground-breaking technology to life, emerging as one of the most innovative pioneers of green hydrogen electrolysers.

Our core strategy is a modular mass-production platform approach to bring down the equipment cost. We make our AEM electrolysers safe and easy-to-use, ensuring that this critical technology is readily available for microgrid projects of any size and complexity.

From the very beginning, we delivered all of our electrolysers with a handy control system that helps manage the entire hydrogen cycle. Over time, this evolved into a fully-fledged and independent Enapter Telemetry Platform. This forms the basis of the Enapter Energy Management toolkit, which supports a wide range of deployment scenarios and features instruments for building software applications and complex microgrid management solutions.

Contact our team to learn more about the Enapter solutions can help you solve microgrid energy storage and management problems.

We also invite you to join our partner network to together build intelligent solutions for electricity management – and to make more clean and reliable power available to people and businesses around the world.

To learn more about Enapter, visit enapter.com.