Enapter

The Energy Management System (EMS)

Enapter's software-defined EMS allows visualization, control and management of energy systems with or without hydrogen components

The Enapter Energy Management System (EMS) is a modular hardware and software solution. It comes in the form of a toolkit and helps people and businesses to plan and realise energy production, storage and consumption for residential or industrial systems of any size and complexity. This is achieved through the system's intelligent integration of distributed energy resources into an AI-powered management framework.

Enapter's goal is to provide a modular energy management system to residential, commercial and industrial customers that integrates all different communication protocols and avoids complicated and costly integration via PLC or other limited systems. We want to simplify the setup, scalability, analysis and management of any decentralized energy systems (and the adoption of hydrogen systems in the market). To do this, we want to offer customers a solution that can integrate all energy devices that are out there in the market. Our philosophy for the EMS is to build it out as a flexible and scalable base which can be used by integrators and developers to easily expand the solution. Think of our EMS as an **operating system for any energy system** that offers core functionality to integrators, operators and developers and can easily be amended and build upon to accommodate for individual needs via open collaboration tools.

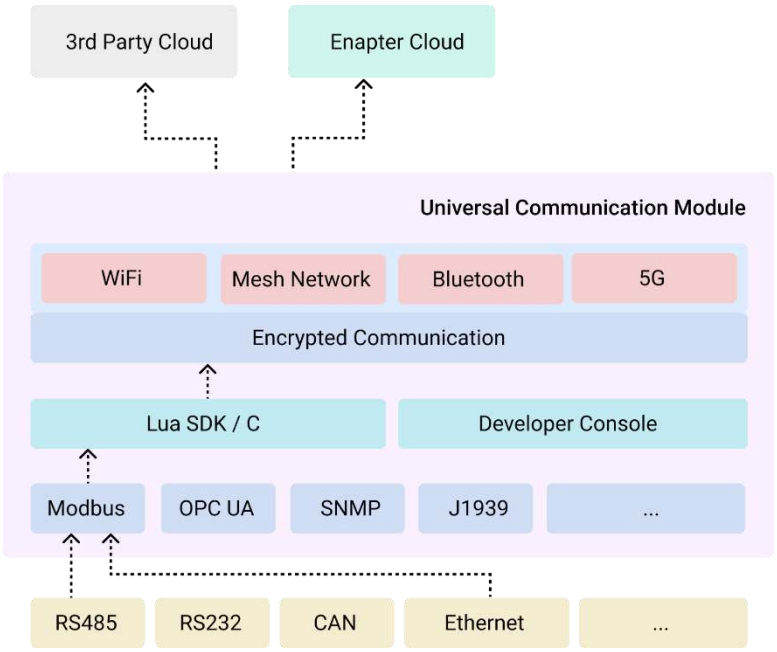
Enapters software defined energy management system can be used to

- visualize energy flows and parameters of the energy system
- configure, control and monitor devices wherever you are
- specify operating strategies (rules)
- receive automatic over-the-air (OTA) firmware updates for new protocol support and functionality improvements
- integrate any energy device, sensor, component needed using the Enapter Customization Toolkit.

Universal Communication Module

To be able to speak with all energy system components, we have developed a **Universal Communication Module** (UCM). The brain of each module is software which translates the specific energy device's protocols into a unified communication protocol. All the work needed to configure communication interfaces, which is usually performed by engineers and programmers of

complex industrial controllers, is performed by the user themselves with the help of a simple and easy to use mobile application for iOS or Android or desktop web interfaces.



A similar problem is solved by industrial PLC systems, which can be expensive and complex, and are difficult or inconvenient to operate for non-specialized engineers. Oftentimes, the hardware controllers are bulky (providing lots of inputs when only a few are being used). They are suitable for custom, complex systems and individual projects, however, not so convenient for mass, affordable and simple solutions. The Enapter hardware is compact, inexpensive, wireless and energy efficient. Modules are based on a flexible architecture, using standard components (STM32, Espressif, Broadcom, Nordic, Texas Instruments), connectors and enclosures, which ensures predictable deliveries and the ability to quickly replace vendors.

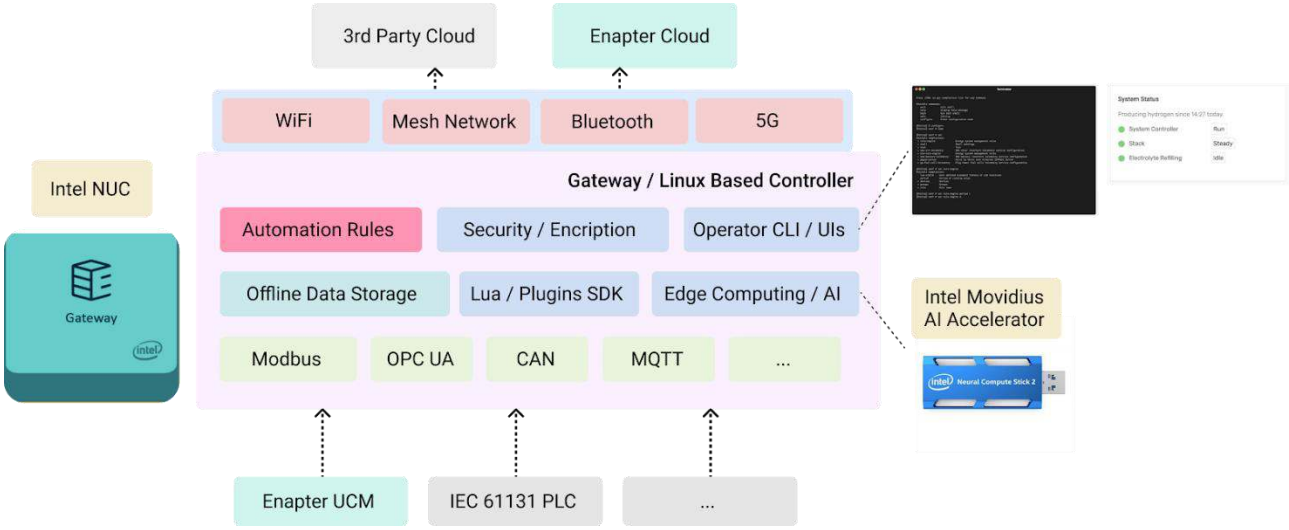
Enapter's products, i.e. the EL and the Dryer, come with built-in UCMs. Any external device (batteries, inverters, cells, pumps, sensors, etc.) can be integrated easily into the system via **UCM extensions**. Enapter supports many common industrial communication protocols for this modular extension system (i.e. HTTP, ModBus, SNMP, CAN, digital and analog sensors, etc.). In case any protocol is updated new protocols need to be supported, the device can be remotely updated with OTA (Over-the-Air) firmware updates to support this functionality without any hardware change. We currently enclose the boards in DIN-rail housings to allow using existing electrical enclosures and easy installation in accordance with existing codes. They can, however, but could be integrated in any housing.

We are creating open schematics for the UCM boards (with gerber files, BOM, placement documentation all readily available for interested developers and integrators to design and make additional UCMs). We are in the process of creating cross-platform firmware flash tools that allow to flash firmware and generate QR codes to easily commission the devices. The goal is that every device can easily be integrated into the Enapter EMS with simple toolkits provided (see below).

Rule Engine and Enapter Gateway

Fully operational energy systems require all devices to follow a central logic defined on a system controller. Usually this means custom development using PLCs, which increases cost and requires

time. However, most of the logic is common for a typical set of devices and use-cases like managing battery or hydrogen storage, load balancing, etc. Custom end-user logic can often be expressed in simple if-then rules. To control the system and allow flexible configuration of such rules, we have developed a software controller integrated with the Enapter communication modules – we call it our **Rule Engine**.



The main interface for the Rule Engine is a command line interface (CLI, available over SSH and WebRTC) with a set of high-level commands for simple and flexible system configuration, built-in documentation and convenient commands autocompletion. To speed up the setup of typical energy system control scenarios we have developed a number of rules templates – for example, algorithms for managing a hydrogen-backed energy storage with renewable energy sources, load control for the systems with a limited amount of available energy. To further simplify the deployments of small-scale standard systems we are developing mobile and web interfaces for control logic configuration. The rules allow integrators and system operators to fully control the energy system according to the individual needs.

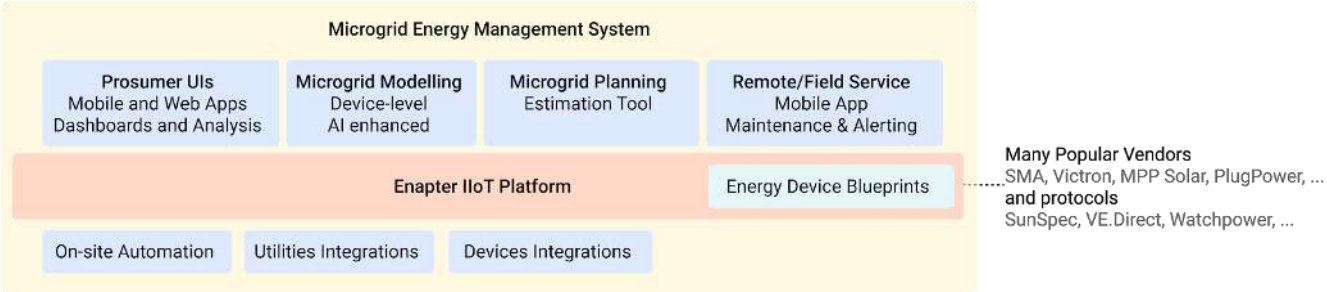
The rules work their magic on the **Enapter Gateway** which is a x86 or ARM based device (such as Intel NUC) running a customized operating system based on a Linux kernel (built with YOCTO) with OTA updates capability. The Enapter Gateway is the key energy site controller allowing to manage the energy system efficiently and easily. It collects all data from energy devices connected via UCMs. The Gateway can be organized into a reliable Master-Slave cluster where the second Gateway takes over if the first one fails. This allows for uninterruptable operation in any situation.

Enapter Cloud

The highly secure Enapter Cloud serves as a data collection, storage, processing, analysis and visualization system that provides convenient access to dashboards of energy systems and individual devices through mobile and web interfaces. It also allows for commands to be easily send to connected devices. For the tech savvy: We use a containerized (Docker) cloud-native

approach and are flexible in deployment options. Customers are free to use the Enapter cloud or deploy the solution in their cloud or on premises using Kubernetes clusters. Our philosophy: using our own infrastructure based on hardware servers is an important aspect for pricing. Having all the necessary expertise for supporting such solutions in-house, we can significantly reduce the cost of ownership for such systems to the end user – technology development is ensured by the Enapter team while integrators and partners can focus on rolling our hydrogen and energy solutions.

We use industry-standard protocols for device-cloud communication (MQTT over TLS 1.2) secured with 2 levels of X.509 certificates on the server - physically protected Enapter root CA and 3-year cycled intermediate CA used for day-to-day communication of devices to Enapter Cloud.

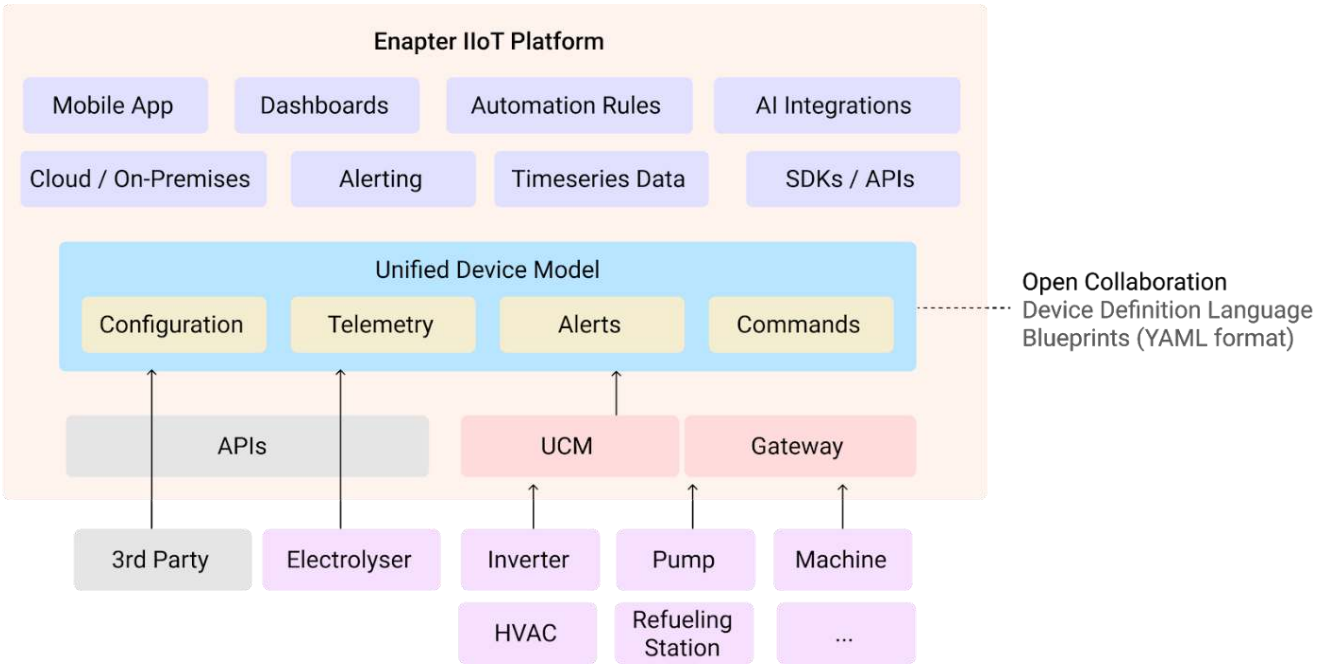


Enapter Customization Toolkits

The amount of energy devices in the market is huge and each model is unique. Two solar inverters from different vendors can have a different set of sensors, states, and supported commands. Integration of all these devices by Enapter engineers is technically possible, however providing development tools as a base for open collaboration is strategically a much more effective solution.

To ensure seamless integration of new devices by partner software integrators and third-party developers, we are developing a Unified Device Model – a system of concepts (properties, telemetry, configuration, commands, alerts) in which almost any device can be expressed. Enapter Blueprints, is YAML-based model definition language which creates a simple form for collaborative models development.

Once a developer imports a new device into the Enapter Cloud, plug-and-play support of the device is grated: telemetry and monitoring dashboards, interfaces for executing commands and easy configuring of devices. As part of the customization framework, we are preparing Lua SDKs for integrating new devices and extending functionality at all levels – communication modules, gateways and the cloud.



Using Enapter Devices without the EMS

While we believe our EMS is the best way to control and monitor Enapter's electrolysers, we are not forcing customers to use the EMS. Enapter electrolysers can be controlled via Modbus and be integrated into external PLC systems if needed.

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