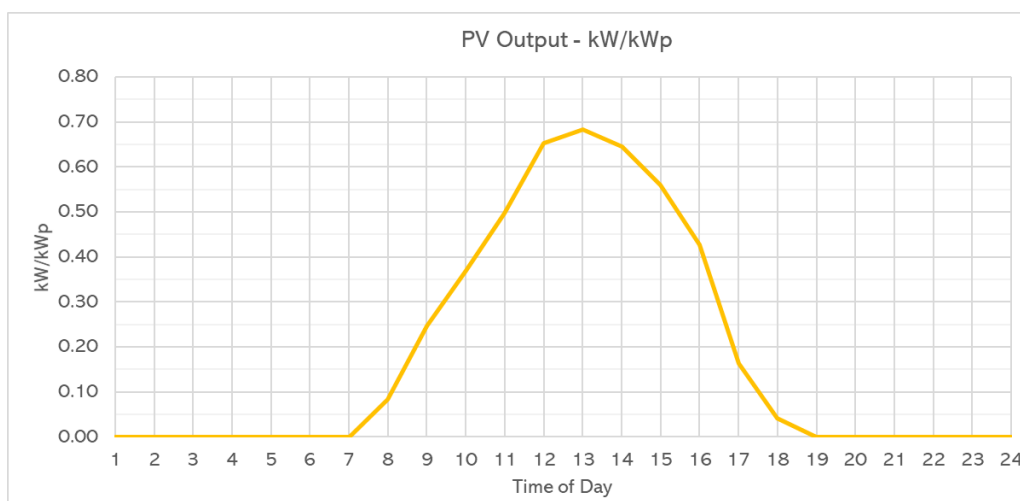


## Solar PV Station

- Photovoltaics (PV) is the conversion of light into electricity using semiconducting materials that exhibit the photovoltaic effect
- The Sunny Boy inverter is an SMA solar inverter. Sunny Boy used to convert DC from solar panels to AC. The main components of a solar inverter are an MPPT and an inverter. The former optimizes the produced energy of an array of solar panels, while the latter converts the direct current generated by it into network compatible alternating current.
- The Sunny Boy is a grid-tied inverter that can only function if it is tied to an existing grid. It needs a voltage and frequency value that it can latch itself on to debit the energy produced by solar panels. By default, the Sunny Boy will feed in the maximum possible power into the grid. In island mode like here in this demo system, the Sunny Boy reads the AC frequency to feed in only the requested output power.
- In a microgrid with solar, battery, and hydrogen, ALL energy used by loads MUST be produced by the PV. Therefore, the PV system must be sized to produce on average all the needed energy for a whole day during the sunshine hours. When sizing the energy system, we need to consider that there are efficiency losses associated with storage and conversion.
- With Enapter's smart devices, we can get all information and make it available in real time. We can read the monitoring data provided by the solar inverter's industrial communication interface. Solar irradiation, temperature and other metrics can be streamed on the Enapter application. Users can always know what the current solar irradiation is and can even create automation rules based on the value.



[graph of average irradiation over one day in Thailand]

## Microgrid, Battery Station

- A microgrid is a localized group of electricity sources – which can be a solar plant, a battery pack, wind turbines, a hydrogen system (Hydrogen generator + Fuel Cell + Hydrogen Storage), hydroelectric generator, genset – and loads (electrical equipment that needs electricity to function) that typically is disconnected from the centralized grid.
- Sunny Island is an SMA battery inverter and is a key component in the off-grid system. It utilizes DC energy from a pack of batteries to create an AC grid (the microgrid) to which one can connect other energy sources and its everyday electrical appliances. It draws DC power from batteries and converts it to AC with a given voltage and frequency at which most loads can function. When other energy sources provide more power than the loads in the grid need, it uses this energy to recharge the batteries.
- Difference between Sunny Boy and Sunny Island: The Sunny Island is a grid-creating inverter which enables multiple energy sources to feed into a microgrid. It uses batteries as its main energy source of DC current and transforms it into AC current that is readily usable by normal house appliances. The Sunny Boy is a grid-tying inverter which takes DC energy produced by solar panels, transforms it into AC, and feeds it into an existing grid. Both can work in synergy to make green microgrids possible.
- Whilst the Sunny Island creates the grid, it is not the only source of power in the grid. On the DC side of the Sunny Island, a fuel cell or any other external DC source can recharge the batteries. In order for the Sunny Island to understand that batteries are being recharged from an external source, a shunt is installed that allows the Sunny Island to measure the current being fed to the batteries. This way, it can decide if energy needs to be drawn from the AC side of the grid in order to continue charging the batteries when the external source switches off. On the AC microgrid, the Sunny Island can control the Sunny Boy solar inverter energy output, in case the energy available through the solar plant is higher than the load demand. This is done through a slight regulation of the frequency of the grid by Sunny Island, which Sunny Boy interprets as a regulation signal of its power output.
- When a load is connected to the grid, the first available source – which is the energy from the solar plant – is used. If this source is not sufficient to cover the request from the load, Sunny Island will draw energy from the batteries and convert it into AC current.

## Electrolyser / Dryer Station

- An Enapter AEM Electrolyser EL 2.0 is a modular and stackable hydrogen generator
- Each EL 2.0 yields 500 NL/hr or 0.5 Nm<sup>3</sup>/hr of hydrogen gas output at 35 bar and with a purity of 99.95%
- You need 4.8kWh to produce 1 Nm<sup>3</sup> of hydrogen gas output at 35 bar and with a purity of 99.95% with Enapter's EL 2.0. So you need 57,6 kWh to produce one kilogram of hydrogen (compressed at 35 bar and with a purity of 99.95%).
- The operative power consumption at standard conditions is 2.4 kW. The peak power consumption (max power draw at any time) is 3.0 kW and should be considered for sizing of electrical safety devices and wiring.
- Enapter's Dryer 2.0 is a hybrid temperature/pressure swing adsorption system that comprises of two cartridges filled with a highly adsorbent material.
- The dryer raises the purity of the hydrogen to >99.999%
- The EL2.0 and Dryer 2.0 are both rack-mountable in a standard 19" cabinet.
- Vent and Purge: These pipelines are needed for the correct functioning of an EL: vent pipes carry O<sub>2</sub> out of the system, purge lines are mainly used during self-cleaning procedures of the EL.

## AC Distribution Board

- The AC distribution box connects all AC systems
- Breaker guarantees over-current safety
- Differential breaker guarantees no current leakage
- Differential breaker disconnects all loads from all inputs
- Ground connection ensures exposed parts can never have a dangerous voltage
- Rule engine provides an easy way to manage different components of energy system and loads  
Lua programming language can be used to extend and configure Enapter's rule engine

## Hydrogen Fuel Cell

- A hydrogen fuel cell is a device that reacts hydrogen and oxygen to produce electricity.
- The fuel cell reaction requires high-purity hydrogen (that comes from the hydrogen tank, which in turn is filled by the electrolyser) and oxygen (which comes from the air).
- The fuel cell produces electricity (in direct current and is stored in the batteries) and water (as clean water vapour which can be released into the atmosphere).
- There are several different types of Hydrogen Fuel Cell technology. The one being shown today is based on the PEM (Proton Exchange Membrane) technology.
- The fuel cell being shown today has a flow input of 890 NL/h and an electrical output of 1,100 W (46 % efficiency).
- The number and power of fuel cells required depends on the energy generation sources, loads and devices connected to the microgrid.
- It is possible to integrate any fuel cell with our system. Just pay attention to the dimension of the rack because our modules are 19" racks.
- We can vary the input pressure to the fuel cell using a pressure regulator installed in our cabinet
- Our teams can integrate a WI-FI communication module for any kind of fuel cell

## Cabinet Station

- Purge and vent lines have to go to two different safety areas
- The vent and purge lines must not be obstructed by anything. Make sure the water in the vent line can drain and doesn't freeze
- A cabinet is not strictly required to operate the system components, it can be designed exactly to suit any particular application
- If the cabinet is enclosed and has filters, it needs forced ventilation
- Normal auxiliaries in a cabinet that house electrolysers include: breakers and power distribution, vent management system, an Enapter open source gateway and an antenna
- Necessary inputs into the electrolyser are water and electricity, into the FC hydrogen. Necessary output lines from the EL are hydrogen, purge and vent, purge from the dryer and electricity and purge from the FC
- When doing the electrical connection in a three-phase grid, we recommend to distribute multiple ELs evenly over the different phases

## Enapter Energy Management System

- Enapter's private cloud aggregates the data from connected Universal Communication Modules and Extensions and provides management, online analytics, reporting, and monitoring of energy systems.
- Enapter's Mobile application is an interface to system integrator's and end-user's connected devices such as Electrolyser, Dryer, Communication Module and Extensions.
- Enapter's mobile app allows easy and secure system setup using QR codes, management and monitoring all over the world. Mobile applications are available for Android and iOS.
- Enapter's IoT Gateway aggregates data from connected devices and stores it locally up to one year. This approach mitigates connectivity issues and minimizes the amount of traffic pushed to the Cloud. It also enables a rule-based engine to control those devices with customer-driven logic.
- Enapter's Universal Communication Module and Extensions are used to make devices smart with TLS 1.2 protected connection between different devices and the Enapter Cloud.
- Enapter's Universal Communication Module supports Modbus, CANBus, SNMP, HTTP, UDP / TCP as well as digital and analog inputs for integrated devices.
- Enapter Gateway software is based on Linux operation system and Yocto project which enables system to be open and allows devices manufacturers and system integrators to add additional devices support in easy and well-documented way using Lua scripting language.

## Enapter's Partner Program 1/2

Green hydrogen effectively decarbonizes our society in all sectors. Our vision is to make green hydrogen cheaper than fossil-fuel based energy. In order to reach this, we must focus on developing, optimizing & scaling up our production to industrial mass fabrication so we can reduce cost.

We are looking for local partners (EPC/system integrators) that share our vision and will provide solutions for all possible applications ranging from backup power, residential & commercial storage, off-grid solutions, mobility, Power-to-X, industry etc.

In order to enable our partners & us to work towards the goal of a green hydrogen economy, we devised the partner program for having a foundation for effective & trustful partnerships. Why is partner program beneficial to me? In short: Partner's enjoy discounts, periodic training, access to marketing materials & support as well many other advantages (see below).

### Roles & Types of Partner

(The partner program is still work in progress & we are looking forward to your feedback.)

Enapter commits to	
<ul style="list-style-type: none"> <li>• Manufacturing excellent AEM electrolyzers &amp; dryers</li> <li>• Developing excellent software environment</li> <li>• Promoting/marketing of electrolyzers &amp; various hydrogen use cases</li> </ul>	<ul style="list-style-type: none"> <li>• Generating leads, passing them to partners</li> <li>• Provide technical support &amp; training to partners</li> <li>• Negotiates discounts with other suppliers for partners</li> </ul>
Enapter certified partner	
Commitments	Privileges
<ul style="list-style-type: none"> <li>• Market &amp; sell Enapter's electrolyzers &amp; dryers</li> <li>• Selling our products as is/or combine them with 3rd party equipment through integration or value-added services.</li> <li>• Contributing to marketing/promoting of electrolyzers &amp; specific hydrogen use cases</li> <li>• Responding to Enapter surveys about use cases &amp; customers</li> <li>• Having at least 1 staff annually completing our training</li> <li>• Acknowledging to be independent from ENAPTER &amp; not be an agent or representative of, or in any way be entitled to act on behalf or in our name</li> </ul>	<ul style="list-style-type: none"> <li>• Use the "Enapter Certified Partner" status for public promotion &amp; marketing</li> <li>• Receive marketing material from Enapter, such as Product facts sheets, sticker packages, print templates for roll-ups, banners, posters</li> <li>• Receive preferential service &amp; technical support from Enapter</li> <li>• Group discounts through Enapter from suppliers of fuel cells, pipes, etc.</li> <li>• Buy our products at discount compared to list prices</li> </ul>
Enapter service partner	
Commitments	Privileges
<ul style="list-style-type: none"> <li>• Complete the Enapter's Service Partner Training</li> <li>• Provide service &amp; repair to customers our behalf</li> <li>• Keep at least 1 electrolyser in stock</li> </ul>	<ul style="list-style-type: none"> <li>• Use the "Enapter Service Partner" status for public promotion &amp; marketing</li> <li>• Is remunerated by Enapter when performing service requests</li> </ul>
Fulfilment partner	
<ul style="list-style-type: none"> <li>• Enapter partners are buying EXW &amp; are happy with that</li> <li>• Enapter might use fulfilment partners shipment arrangements are needed</li> </ul>	



## Enapter's Partner Program 2/2

### Territorial Exclusivity

There is no territorial/geographical exclusivity: You won't be able to market our products exclusively; we also don't ask you to only sell our products". However, we value our partner & are aware about the challenge of bringing a new product into a new market. Therefore, for 2019 & 2020 we are willing to exclusively supply product to partners for specified projects – providing that these partners do the same.

### Prices & Discounts

Prices will be communicated transparently, & we expect partners support in this & to not exceed ceiling prices. We acknowledge the value of integration partners & will support partners by communicating this value to final customers.

List Prices	New price list prices will be announced publicly in Jan 2020. Partner will be informed about the new prices as of October 2019
Partner Price:	After a first full priced electrolyser each following unit is eligible to discount
Annual Bonus:	If a partner reaches a 100,000 Euro turnover with Enapter's electrolysers in a year, a bonus will be awarded at the end of the year
Project business / large orders	Large orders (>15 units) are beneficial for Enapter and thus project business is subject to separately negotiated discounts

## Hydrogen Microgrid Economics: Learning Outcome

- Hydrogen generation and storage as part of a solar/hydrogen microgrid enables 100% renewable energy to be utilized.
- Long term, seasonal, energy storage can be achieved with Hydrogen. The only limiting factor is the capacity of your hydrogen storage.
- Capture excess renewable electricity that would have been curtailed and convert them to hydrogen.
- Solar/Hydrogen microgrid is cost competitive with diesel microgrids, even when not taking transportation of diesel fuel into account (which can be a large amount for islands/remote areas).
- A Hydrogen Microgrid allows for a truly independent off-grid experience. There is no reliance on foreign imports of diesel (Oil).
- Including hydrogen generation in a microgrid allows for more than just generating electricity, Hydrogen can be used for:
  - Heating,
  - Vehicle refueling,
  - Trade - Hydrogen is a commodity

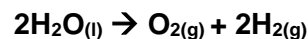
## AEM chemistry Station 1/2

### 1) Hydrogen production

Nowadays hydrogen is mainly produced from carbon and hydrocarbon-based resources. The main processes involved are steam reformation and coal gasification. Green hydrogen from renewable resources can be produced by means of water electrolysis.

### 2) Water Electrolysis

Via electrolysis, water (H<sub>2</sub>O) is split into hydrogen (H<sub>2</sub>) and oxygen (O<sub>2</sub>) according to the equation:



The process takes place via the application of a dc current to two electrodes: the anode and the cathode. The electric circuit is completed through charge carriers present in an electrolyte water solution, typically at the liquid state.

### 3) Alkaline Water Electrolysis

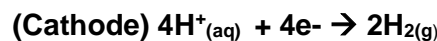
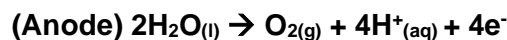
Alkaline electrolyzers use a concentrated solution of potassium hydroxide (KOH) as a charge carrier.

PROs: the use of an alkaline media allows for the use of transition metal catalysts to achieve a low temperature reaction. The technique is cheap, industrially available and based on long lifetime devices.

CONS: the use of highly corrosive and aggressive media (KOH) is requested and the achieved hydrogen purity is low. Also, the device is heavy and large.

### 4) Proton Exchange Membrane (PEM) Electrolysis

In PEM systems, an acidic solid state electrolyte membrane is employed to separate the two half reactions described by the equations:



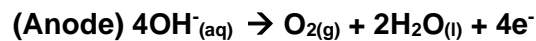
PROs: thanks to the membrane, high hydrogen pressure and purity are achieved. The employed devices are compact, allowing a simple balance of plant.

CONS: expensive materials such as Platinum, Titanium and Iridium are requested together with high purity water.

## AEM chemistry Station 2/2

### 5) Anion Exchange Membrane (AEM) Electrolysis

In AEM systems, an alkaline solid state membrane electrolyte is employed to separate the two half reactions described by the equations:



PROs: AEM technology combines the advantages of PEM and alkaline electrolysis

CONs: the state of the art still needs improvements due to the relative novelty of this technology.

### 1) Membrane Electrode Assembly (MEA)

The MEA lays at the core of both PEM and AEM electrolyzers. The MEA is usually constituted of five layers: **DM/CL/M/CL/DM** (where **DM**: diffusion media; **CL**: catalyst layer; **M**: membrane).

### 2) AEM structure

The membrane is composed of a polymer backbone to which positively charged ionic groups are attached. At a morphological level, the membrane contains ion channels which allow for water and ion transport.