Crash course 8: Energy Management Systems for communities

Authors: Laura Van den Berghe and Anna J. Wieczorek
Cartoons by Luc van Summeren, and **figures** by Laura Van den Berghe and Luc van Summeren
Date: 30th of June 2022

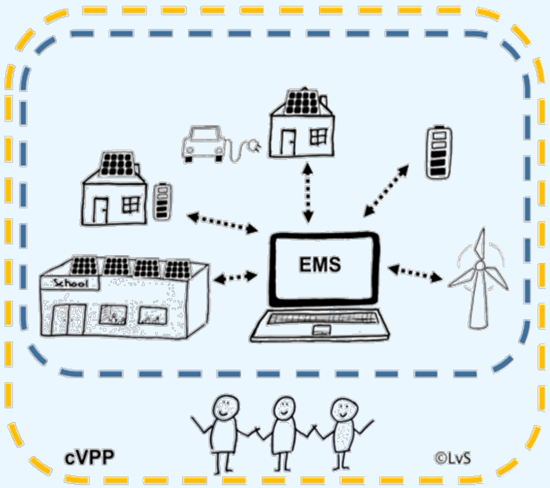
Contents

Introduction

In a community-based Virtual Power Plant (cVPP), energy communities can manage their energy production and consumption collectively and smartly, creating a win-win for both the community and its members, as well as the grid operators.

This crash course elaborates on the technological core of a cVPP: the smart Energy Management System (EMS). The EMS coordinates and schedules the operations of distributed renewable energy sources (e.g. solar panels and wind turbines) and flexible assets (e.g. batteries, electric vehicles and heat pumps) in a smart way, such that they can form one single entity together, the cVPP. Being for and by the communities, the EMS allows to fulfill the community's energy objectives and perform activities in the electricity system related not only to consumption and generation but also to managing, trading and supplying electricity.

This crash course **(1) elaborates on the technological architecture of EMS's to get a general understanding of what EMS is**, and **(2) provides tips on how to successfully implement an EMS with regards to the development of a cVPP**.



Also, take a look at the previously published crash courses to learn more about cVPP:

- Introduction to cVPP (crash course 1: What is a cVPP)
- The future energy system (crash course 2: History of the energy system & crash course 3: EU Energy policy)
- Relevant markets and market roles for energy communities and cVPP's (crash course 4: Energy flexibility, crash course 5: Energy market roles & crash course 7: Community participation in electricity markets)
- Citizen engagement in cVPP (crash course 6: Community engagement in practice)

Case studies

In this crash course, 4 energy management systems were studied as part of a community-based Virtual Power Plant:

cVPP characteristics				**EMS design**			
Community	**Country**	**IT provider**	**Users connected**	**Local hardware**	**Current functionalities, developed for the communities**	**Type of software**	**Location of main data storage and control (*)**
EnerGent	Belgium	EnergieID	+/- 16	Name: COFY-box Format: small box based on Raspberry Pi device	- Energy monitoring - Voltage control (functionality stopped) - Test to include automatic steering of assets, based on market prices and explicit remunerations	Open source	Cloud
Energie Coöperatie Loenen (ECL)	The Netherlands	ICT Group / OrangeNXT	+/- 100	Name: EARN-E Format: dongle provided by external partner	- Energy monitoring - Automatic steering of assets, based on day-ahead market prices, and individual and collective self-consumption optimization	Proprietary	Cloud
Lochem Energie	The Netherlands	HanzeNet	+/- 250	Name: HanzeBox Format: small box based on Raspberry Pi device but looking into dongle. Includes also other hardware like thermometer	- Energy monitoring - Advising best time of energy use (tests to upgrade to automatic steering of assets) - Experiments for P2P trade	Open source	Local
Tipperary Energy Agency (TEA)	Ireland	Clean Tech & Ampere Energy	+/- 4	Name: SEMS ONE Format: small box	- Energy monitoring - Automatic steering of assets, based on electricity retail prices and solar production forecasting	Proprietary	Cloud

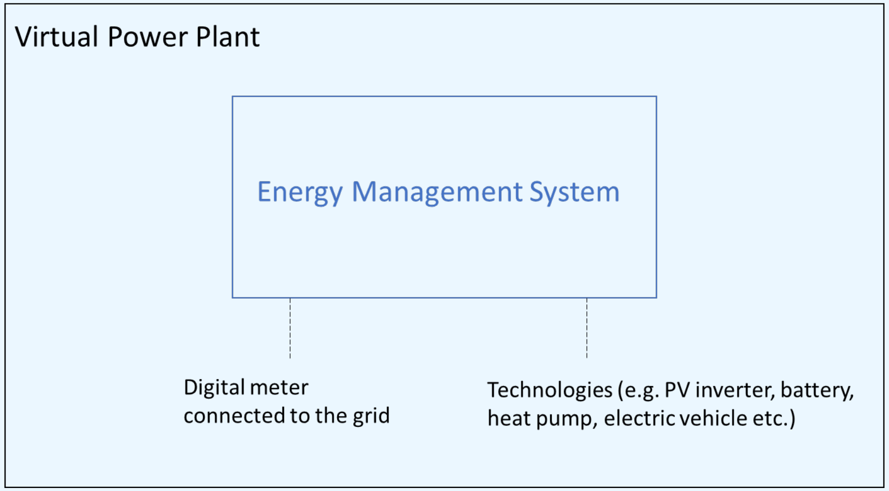
(*) All EMS's use a combination of local and cloud-based storage and control. The information in the table, however, concerns the main location for storage and control.

The architecture of energy management systems

Energy Management Systems as part of a cVPP …

An EMS allows for the management of energy production and consumption and is what makes the cVPP smart. It can be seen as the technological core of a cVPP, because it takes a central function by connecting to all kinds of technologies such as digital meters, PV inverters, batteries, heat pumps, electric vehicles etc.

Technologies in a community-based Virtual Power Plant



List of activities EMS's can support:

- Energy monitoring: understanding and knowing how much is produced and consumed to e.g. reduce standby power
- Peer-to-peer trade: energy trade between the community members
- Maximizing the individual self-consumption to e.g. reduce energy bills, avoid grid usage etc.
- Maximizing collective self-consumption to e.g. keep the energy locally in the community and support the balance of demand and supply in the grid for grid operators
- Voltage control: keeping the grid voltage stable. Read here why this could be important

To perform the required activities, EMS's have built-in **functions**:

- **Data monitoring** e.g. production data from solar PV, consumption data from heat pumps and other equipment, grid voltage data, building temperature etc.
- **Data prediction** e.g. energy production based on weather data, energy consumption based on behavioral patterns etc.
- **Optimization** of certain parameters through built-in algorithms, such as
  - Energy prices to reduce the energy bill
  - Individual self-consumption to maximize the usage of own production
  - Collective self-consumption to maximize the usage of the entire community's production in the community
  - Voltage levels to keep the grid voltage stable
  - …
- **Automatic steering** of assets as part of the optimization strategy to reach the community members' energy goals.
- …

Why could voltage control be relevant for the community?
The experiment of Energent

Recent implementation of decentral, renewable energy sources and the increased electrification of heat and mobility have expanded the electricity system and made it more complex. More complex and larger electricity flows could lead to local grid congestions. Grid operators can solve these congestions by reinforcing the grid with thicker cables. This, however, is a very costly solution, for which the whole society pays. In addition, more energy flows can result in increasing voltage levels. When these voltage levels reach a maximum value, local PV inverters are automatically switched off to relieve the grid. This means that PV owners cannot inject their produced energy into the grid anymore, lowering their financial benefits. Through smart energy management, a cVPP can avoid financial losses for solar panel owners, grid operators and the whole society. In Belgium, for example, the Energent cVPP has been developed in two streets of Ghent to accurately map the grid's voltage level and detect grid congestion. The cVPP connects 16 residential solar-battery systems, 1 large battery at a company, and 2 hybrid heat pumps with an energy management system. When sunny moments are predicted, the system will calculate the best moment when to charge the batteries or heat pumps to avoid grid congestion and prevent financial losses for individual solar panel owners.

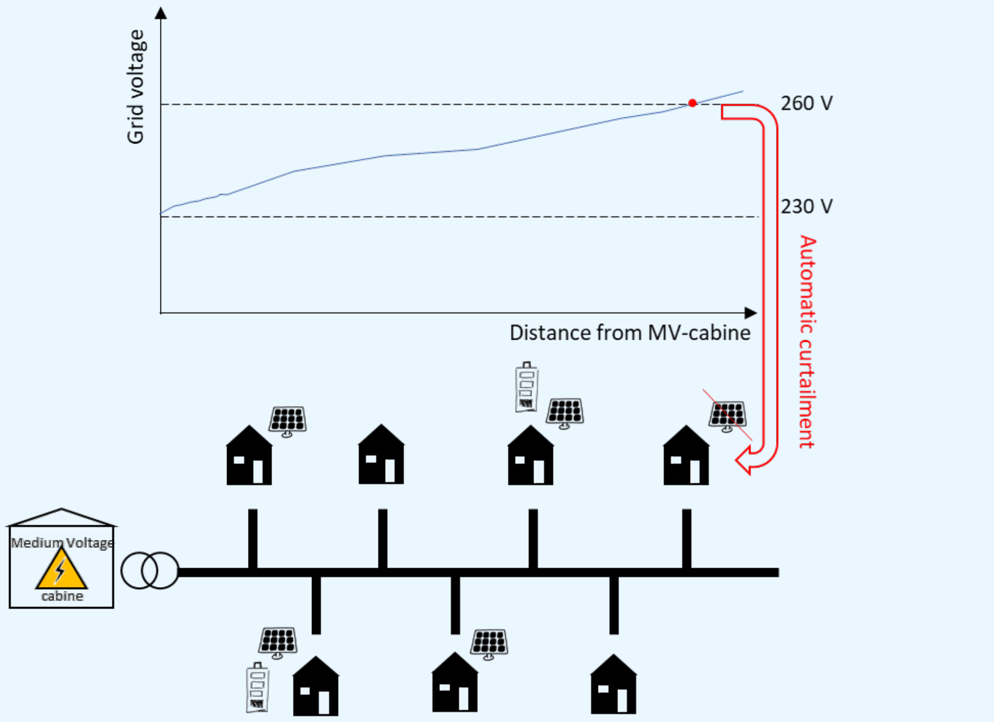
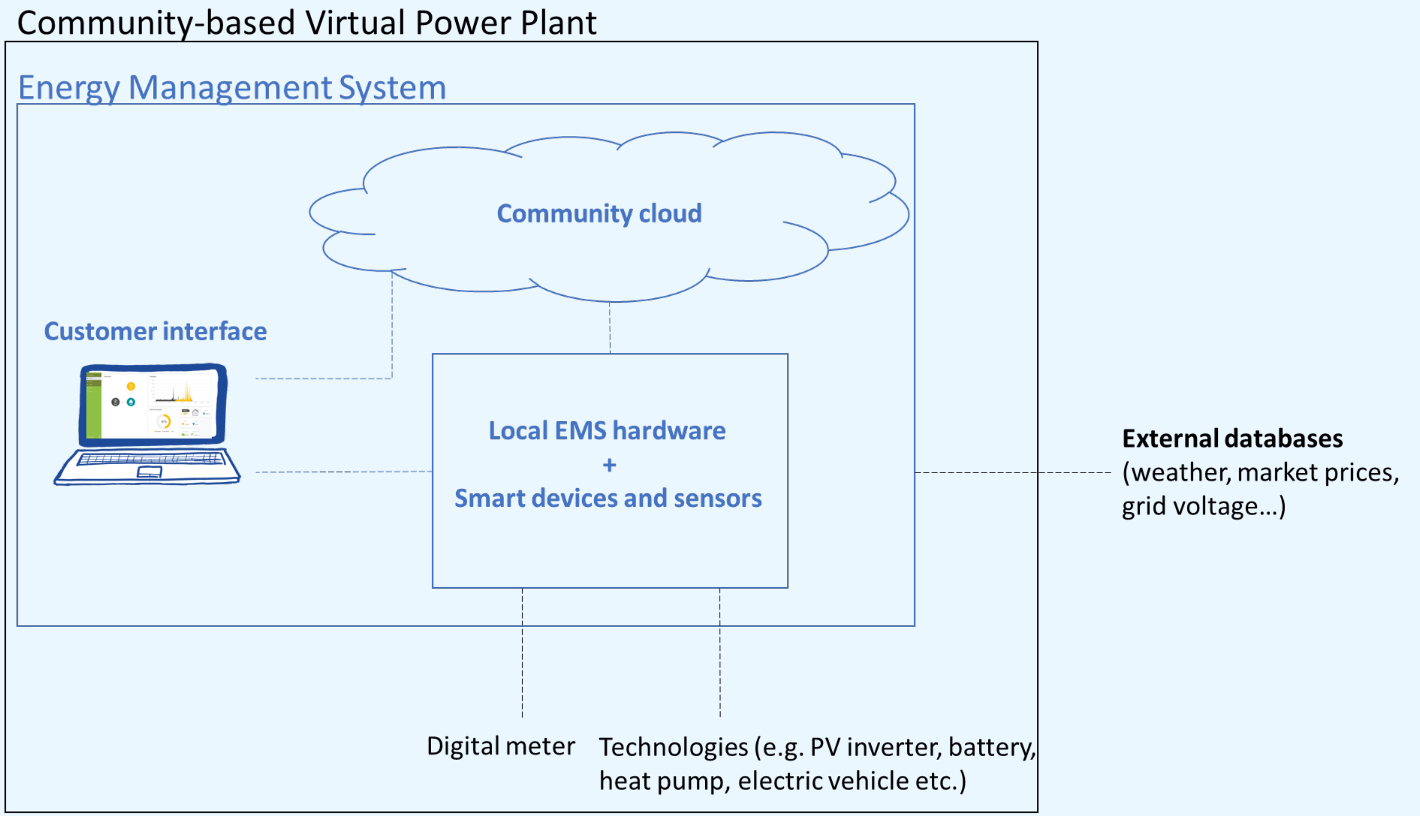


Figure by Laura Van den Berghe, adjusted from Energent

Unpacking Energy Management Systems …

Generally, an EMS consists of hardware and software components. The hardware are the physical devices of the EMS, whereas the software contains the data, algorithms and other intangible aspects with regards to the EMS operations.

The figure below shows the most important technological components of an EMS:



Individual components of the EMS:

The local hardware and the cloud
The local hardware, also often called local gateway, is the part of the EMS which is physically installed in the building. It can take either the form of a small box (e.g. COFY-box) or a USB-like gadget which is called dongle (e.g. EARN-E) (see examples). The hardware connects to the building's digital meter (which is connected to the grid) and all kinds of technologies (e.g. PV inverter, battery etc.). The cloud is a community area and provides a certain degree of centralization to the EMS.

EMS's can perform several functions (see earlier). Depending on the technical design of the EMS, these functions can be executed at the local hardware, in the community cloud or in both.

"We have developed our EMS in a modular way, which means that for each function it is decided individually how the data will be processed and stored. As such, the user has to give explicit permission to share his/her data for specific activities. This permission can be given in the application [through the interface] *by switching on and off certain functions."* HanzeNet.

Learn here more about the difference between EMS functionalities at the local (decentral) and the cloud-based (central) level.

Smart devices and sensors
HanzeNet added smart thermometers (both inside and outside) as part of the EMS hardware, to increase the EMS functionalities. Yet, all type of sensors that collect data to steer home appliances can be added, such as sensors that detect movement, light capacity, CO2 or humidity.

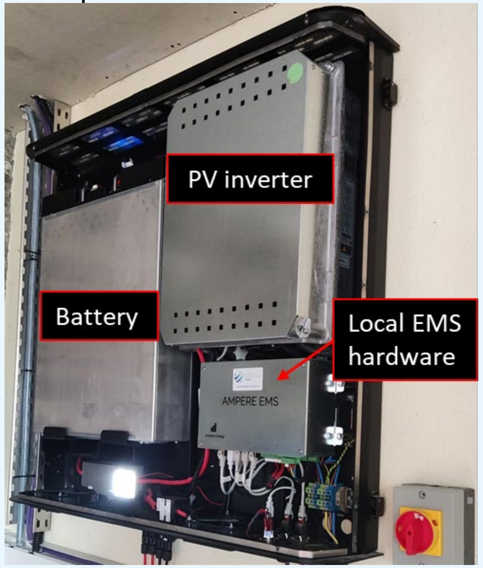
The customer interface enables the community members to access their data. Through the interface, dashboards are shown that visualize the data in a user-friendly and comprehensive way.

External connections:

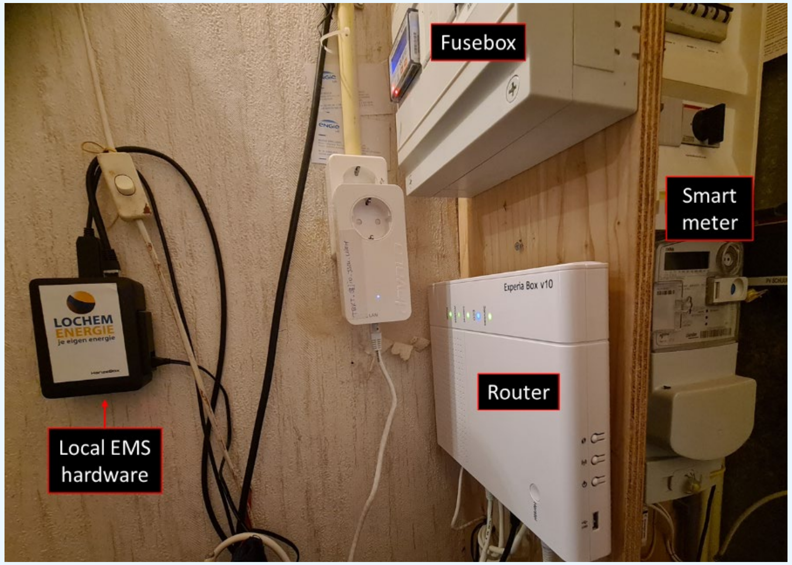
The external databases provide all kinds of input data to the EMS, such as weather conditions, market prices or grid voltage levels.

For example, the EMS in Loenen is connected to day-ahead market prices (see crash course 7 to learn more about the markets). The day-ahead market prices are hourly changing prices on the wholesale market. If people are willing to be flexible with their energy production and consumption by e.g. loading batteries or shifting consumption to times of low prices, the energy bill can be reduced; conditional to EMS's having a built-in price optimization function.

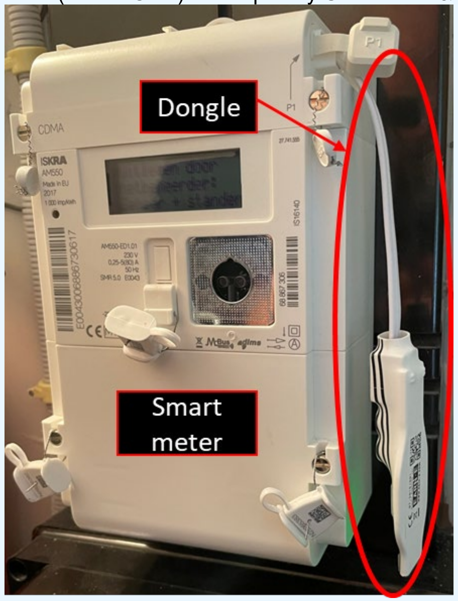
Examples



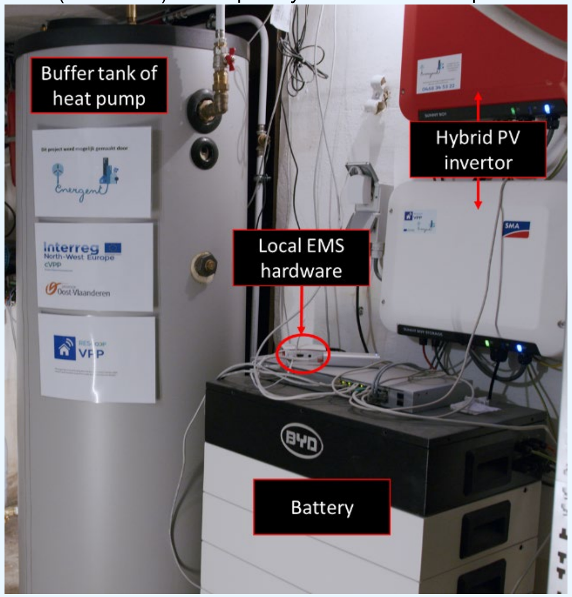
EMS (SEMS ONE) developed by Clean Tech & Ampere Energy and implemented via TEA



EMS (Hanzebox) developed by HanzeNet and implemented in the Lochem community



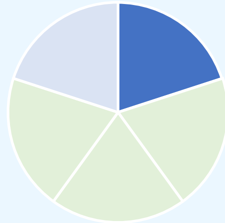
EMS developed by ICT group/OrangeNXT (based on the EARN-E dongle) and implemented in the Loenen community



EMS (COFYbox) developed by EnergieID and implemented in the Energent community

Key factors for successful EMS implementation

Implementing an EMS in a cVPP is more than just a technical process; it encompasses a social process as well because cVPP's work by and for the community by realizing the community values and expectations. Also, rather than being a one-time implementation process, EMS implementation is susceptible to fast evolving changes in the energy system and changing community. The figure below shows the key factors for successful EMS implementation. Click on the factor to learn more about it.



Community values and goals

The EMS implementation starts with an understanding of the values and goals of the community. It is important to ask the questions: **"Why do we, as a community, want an EMS and what are our members going to do with it"?**

Identifying the community values…

The values can include more than only lower electricity bills and can be identified according to the FIETS classification.

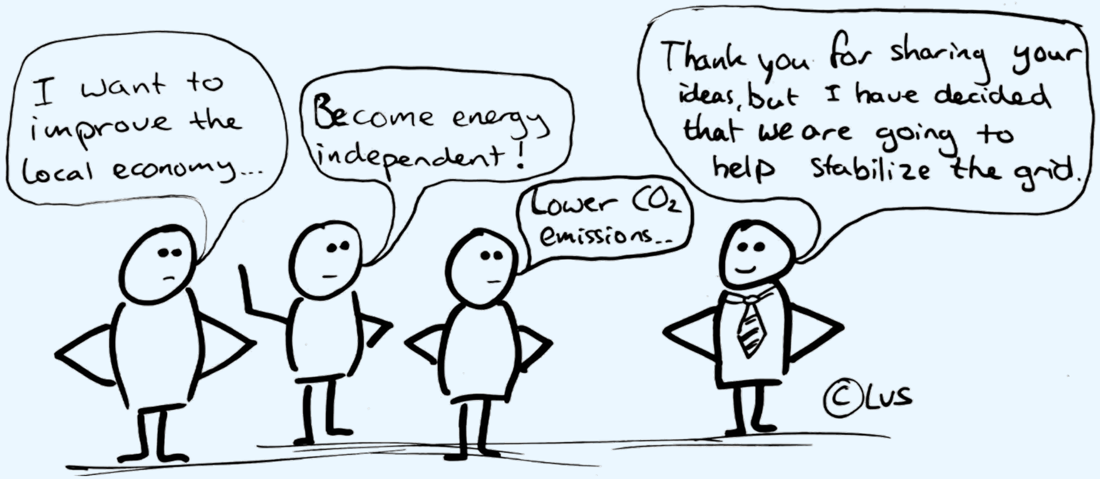
Financial: lower energy bills, additional reimbursements, lower societal costs for grid enforcements, yearly dividends for shareholders, boost to local economy, …

Institutional: Influence on sustainability and energy policies, transparent energy flows, …

Environmental: CO2 reduction, higher degree of renewables in the local neighborhood, …

Technological: Being an innovator, energy self-sufficiency, reliability of energy supply, independence from large companies, …

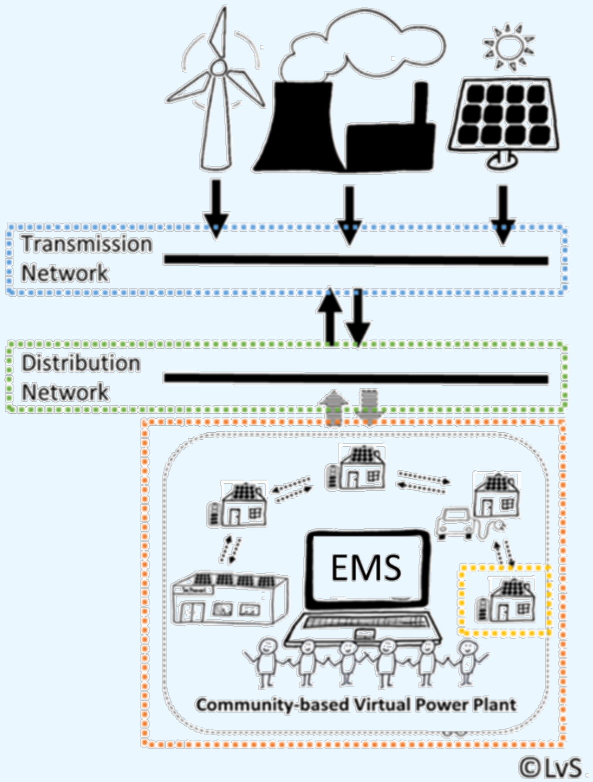
Social: High group involvement, social inclusion, increased social contacts, contact with people who have similar interests, impact on reputation, increased local employment, …



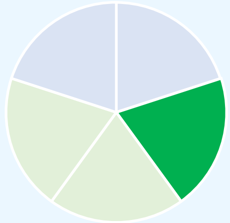
Going from community values towards goals …

The community values can be translated into **goals** by making them active, specific and achievable.

Example: Goals a cVPP can help realize at 4 levels: household, community, distribution network and transmission network (based on insights from the MoRe model):



Level	Value	Goal
Household	Lower energy bills (F)	Enable households to respond to dynamic prices to maximize household financial benefit
Community	Social inclusion (S)	Enable community members without access to renewable energy sources to use community generated renewable energy to support an inclusive energy transition
Distribution network	Lower societal costs for grid enforcements (F)	Reduce the need for the expansion of distribution network capacity for financial benefits
Transmission network	CO2 reduction (E)	Support the integration of renewable energy and appliances (e.g. electric vehicles and heat pumps) in the transmission network to support decarbonization



A profitable business case

To evaluate the business case for cVPP operations, communities have to **assess**:

- Their community values and goals in relation to possible activities
- The required resources (assets and technologies, funding, knowledge and expertise etc.)
- The potential savings and revenues and the expected costs

Useful tools for these assessments are:

- SWOT analysis
- MoRe model (p68 – 73): value-goal-activity tool

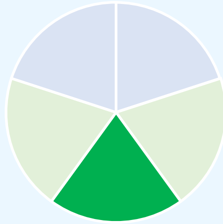
Experiences from the cVPP experiments in Loenen (NL), Lochem (NL), Gent (BE) and Tipperary (IR):

- Profits from flexibility services by households are limited by tens of euros per year. To increase the business case viability, cheap local hardware (e.g. raspberry pi) can be used, because households are not eager to install an EMS that costs hundreds of euros (Energent).
- The business case of peer-to-peer trade facilitated by an EMS highly depends on the introduction of variable distribution grid costs, as this provides incentives to use the grid at non-peak moments and to avoid grid congestions. Current distribution grid costs are too high for the business case to work (Lochem Energie).
- Try to use the EMS to optimize individual self-consumption*: "It's the idea to use as much of your own energy as possible that you produce. And the last thing to do is to export it and to give it away*" (TEA).

Below in the table - an example of how goals can be translated into activities. More examples can be found in the MoRe model.

cVPP goals and activities that provide value at the household, community, distribution and transmission network

Goals	Activities
Enable households to respond to dynamic prices to maximize household financial benefit	Use flexibility provided by storage and household appliances to change household energy demand and/or supply in response to dynamic prices (e.g. lowering energy demand when prices are high)
Enable community members without access to RES to use community generated RE to support an inclusive energy transition	Enable peer-to-peer energy trading between community members
Reduce the need for the expansion of distribution network capacity for financial benefits	Use flexibility provided by storage and household appliances to minimize the peak power usage (and peak of energy fed back to the distribution network) within households to lower the capacity tariff of households (tariff depending on size of connection with the network)
Support the integration of RE and appliances (e.g. electric vehicles and heat pumps) in the transmission network to support decarbonization	Actively collecting, aggregating and selling flexibility from RE, controllable appliances and storage (bundling this with flex from other communities, as an aggregator) (at transmission level)



The technical design

Once the community values and goals have been identified and linked to specific activities, the EMS can be designed. The technical design of the EMS, however, holds some trade-offs and should always be determined based on the community values and envisioned activities. **Four trade-offs** are discussed below.

1. **Open source versus proprietary system**

Design choice	+++	- - -
Open source: The EMS software code is made freely available to consult, modify and distribute.	Independent from third parties. Full control over EMS and data.	Very few available on the market. Consequently, systems are often less advanced, because they need to be built from scratch which is complex and time consuming.
Proprietary: The EMS software code is licensed and often not made available to consult.	Regular updates and improvements by provider for all customers. More advanced systems on the market, because of highly experienced providers.	Vendor lock-in and third party dependency; weaker negotiation position when adding new functionalities. EMS is black box, risking suboptimal correspondence with community values and needs.

2. **Simple design versus handling complexity**

Simplicity is key.

“*We try to design the EMS as simple as possible. Technicians always want to add more functionalities and intelligence, even if these don’t relate to the core activities of the cVPP, e.g. on and off switching of lights, opening and closing curtains. Keeping the EMS design simple for as long as possible is important, because complexity quickly increases and irrelevant functionalities and intelligence constrain useful capacity.*” (HanzeNet)

How to design simple energy management systems that can handle complexity? By integrating system **modularity**.

“*Modularity is the degree to which a system's components may be separated and recombined, often with the benefit of flexibility and variety in use. … Product systems are deemed "modular", for example, when they can be decomposed into a number of components that may be mixed and matched in a variety of configurations. The components are able to connect, interact, or exchange resources (such as energy or data) in some way, by adhering to a standardized interface.*" (Wikipedia)

+ Handling complexity by providing a clear structure.
+ Easy to expand with new modules and functionalities to keep up with fast evolving energy markets and needs, without having to make major costs.
+ Specialization facilitates innovation of the modules.

“*The modularity of a system can be ensured through the intelligent writing of algorithms, but also through smart integration of parameters and artificial intelligence.*” (EnergieID)

3. Centralized versus decentralized system

Decentralized systems have their EMS software running locally on the installed hardware and have a cloud-based layer sending and receiving data to and from the local level. This means that the data control and storage takes place locally.

- \+ Easily scalable
- \+ Full control by the households, at the local level, decreasing privacy related risks.
- \+ High system autonomy: everything will still work when the (internet) connection gets interrupted between the cloud and the local level
- \- Powerful hardware at the local, household level could be more expensive, but adds local flexibility

Centralized systems have a fully cloud-based EMS software. In this case, the local hardware needs less data management and storage capacity.

- \+ Lower overhead costs
- \+ Fast and efficient system updates, because can be performed at once

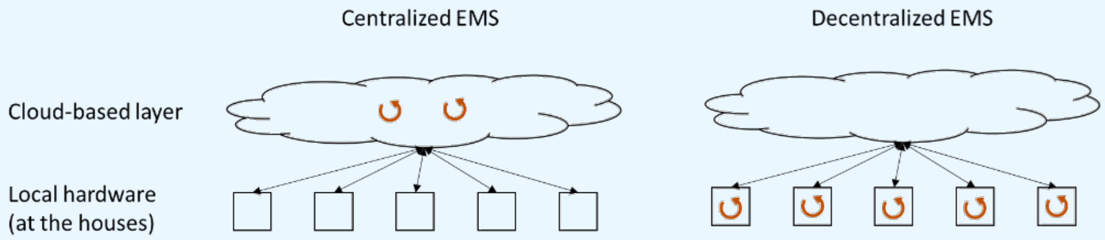
It is also possible to have a mixture of both systems, depending on the type of data.

Safeguarding privacy receives high priority of IT providers. The following measures are often taken for this:

- Specific consent from users when transferring data to the cloud and sharing data with third parties. (all)
- Standalone EMS design, meaning it doesn't need the cloud connection to function. (HanzeNet, tests at EnergieID)
- The use of anonymized data for cloud-based transactions. (ICT Group/OrangeNXT)

> The case of EnergieID
>
> "*Every user owns a private space in the community cloud. People first give consent to transport and to store data on their private storage in the cloud. All data from the local hardware, the COFY-box, is copied like a digital twin to the private cloud space. So every user has a safe space in the cloud that is secured by the community. Second, the user can decide to give consent to share the data with the community manager in the cloud, for example in the case of energy sharing or collective self-consumption optimization. The user thus explicitly consents cloud storage and the sharing of data with the community manager or other third parties.*"

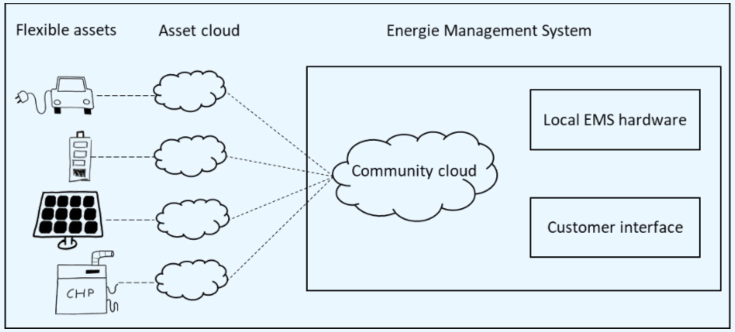
Location of EMS data control and storage:



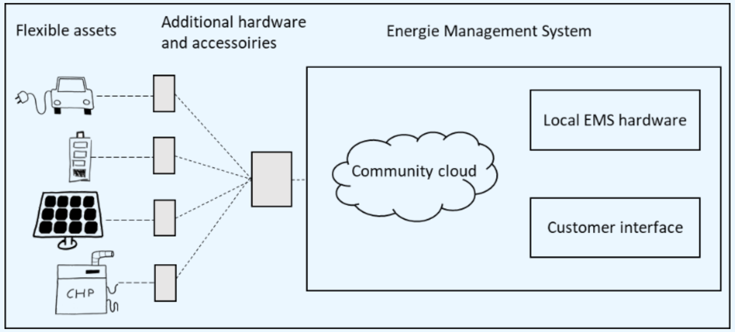
4. System communication

To steer assets and optimize energy flows, EMS's need to be connected to and communicate with local, flexible assets, such as PV invertors, heat pumps, charging stations of electric vehicles etc. This can be organized in 3 ways:

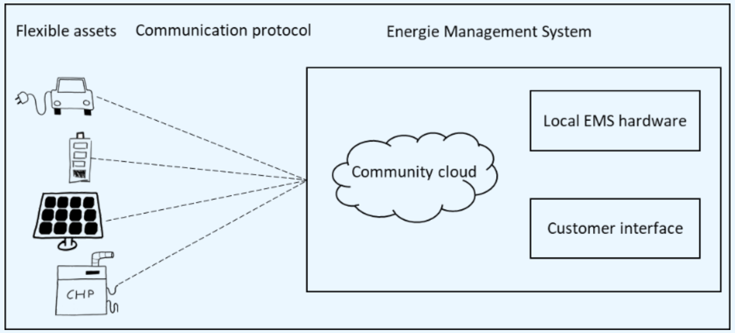
1) Through **cloud-to-cloud** connection. Most flexible assets have their own space in the cloud where they store data. The assets' cloud can be connected to the community cloud and as such share data.



2) Through **additional hardware and accessories**. Sometimes additional hardware that can measure and calculate consumption, production and voltage, is added to or built in the EMS. Often the connection to the assets is then made with other hardware 'accessories', e.g. clamps on the power cable close to the asset, current transformers. The main advantage is lower dependency from the asset providers. Energent and EnergieID, for example, experimented with the Shelly Plug in combination with power clamps in early stages of their EMS development. Read here how it works for Smappee.



3) Through **communication protocols**. In most EMS's, such additional hardware is not included and communication protocols need to be put in place to connect asset and EMS. Setting up the communication is very challenging, because of the wide range of asset types and brands. They are all configured differently and talk their own specific language, which the EMS needs to understand and interact with. Therefore, EMS software providers need to program the language skills into the EMS for each asset and brand that they want to connect to the system. The lack of standardization concerning communication between assets and the EMS forms the largest barrier. The main advantage is ease of installation and possibly lower costs.



System communication issues – A testimonial from TEA (Ireland):

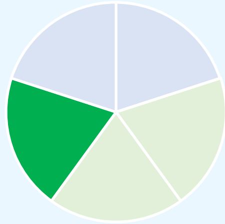
The Energy Management System could only speak to one type of inverter at the beginning. It was a Fronius inverter. So, we had a challenge in the hotel complex [where the EMS had to be implemented] because we had another type of invertor installed. … We decided to change the initial inverters to Fronius inverters. But the hotel engineer preferred their initial invertor because of higher performance and compatibility with the already installed solar PV on the roof. Hence, the EMS/VPP installation company had to do a work around and install additional hardware connected to the PV inverters in order to monitor the PV production from these inverters outputs [option 2]. *In the meantime, they are updating their software to let the EMS communicate directly with a wider range of inverters* [option 3].

Tips and tricks to avoid communication issues:

- Limit the variety of different brands by **organizing group purchases for flexible assets**, such that community members install the brands with which the EMS can communicate.

- If possible, **install hybrid invertors** from the beginning to keep options open for the future and easily connect PV to batteries.

- **Collaborate with one single entity** for EMS and asset installation. Yet, this could hold a risk of too high dependency.



Collaboration with EMS providers

A tendering process can help energy communities to set up a collaboration with EMS software providers. Consider the following steps when creating a tender:

1. **Start with an analysis of the energy-IT market providers**

Make a list of all IT providers to consider through **Google searches**, or by reaching out to your **social network**. As energy management is a very new development in the energy market, most of the IT providers are start-up companies with little track record. Moreover, because the market itself has not yet matured, there are only a few companies offering energy management IT services. Yet, this number is quickly growing.

When considering a partnership, also have a look at the company type and background as this might be important for you. Company type requirements can be:

- **Cooperative** IT provider:
  The legal status of the cooperative fits well with the community status and values. However, there exists a risk that not all knowledge is in-house yet and that multiple partners need to be involved in the collaboration to successfully develop and implement an EMS.

- **Sustainable** IT provider:
  ”*The reason why we're doing this [implementing an EMS] in the first place is to reduce CO2 and to be more sustainable and more environmentally friendly. So I think it should be one of the criteria for selecting an EMS provider.*” TEA

2. **Design the tender and send it to relevant parties**

Some tips and tricks when writing the tender:

- Provide the same information to all parties, in order to insure correct comparison between the offers
- Follow specific regulations that are in place when writing a tender. If you lack skills or information, ask the help of an external consultancy company.
- In your tender, specify the preferred goals, activities and technical design choices (only if you have specific technical requirements, otherwise keep it open for the provider to decide):
  - Be very explicit with what you want (e.g. goals and activities) and make sure this is agreed in clear and transparent contract conditions (see next page for examples)
  - Provide some open space for the IT provider to come up with innovative solutions on how certain requirements (e.g. goals and activities) can be achieved. They might think of solutions that you did not consider.

Some examples of EMS technical requirements and agreements that are important to include in the contract, as they are not automatically included and could lead to contract renegotiations at a later stage (experiences from ECL, Translyse and TEA):

- Weather prediction functionalities, because they are very important for the more advanced energy management activities.

  "*We expected, when tendering the system, that without having to explicitly state it, a weather prediction tool would have been included in the EMS, because the weather prediction influences the solar production and the energy demand* [which are used for other functionalities such as self-consumption optimization]. *… As such, we didn't specify it in the tender because for us it was very straightforward to include such an essential functionality. … Afterwards* [after renegotiation], *a solar prediction tool was then added*" (Translyse)

- Data property and the ability to use all data for analyses at individual and community level, because it might be difficult and costly to access this data for analyses when not specified.

- What is covered by support and maintenance, e.g. if the technology provider and installer has to go on site, who pays for the day for the engineer to travel (the community or is this part of the contract with the IT provider?)

3. Compare the offers through a balanced scoreboard

Tender criteria	Maximum points to be earned	Provider 1	Provider 2	…	Provider X
Price					
Quality					
Technical design					
Required activities					
Final score					

Make these criteria very specific

Allocate more points to criteria that are more important to you

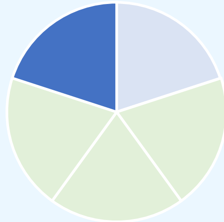
Compare different providers by giving them a score per criteria

It could happen that the requirements are too strict and that concessions have to be made towards the IT provider. Some examples of concessions are (ECL and Translyse):

- Decrease the number of assets the EMS needs to connect to
- Include shared responsibility for the realization of the asset control, e.g. by helping to negotiate with asset manufacturers
- Organize the first line help for technical malfunctions in the houses at the community level
- …

4. Final choice

Carry out a final review step including a presentation with Q&A session between all parties involved (community + potential IT provider). Document all the Q&A well and add it to the offer to avoid misunderstandings during the actual implementation.



User experiences

Most users don’t want to be bothered with the system, they just want that it works.

“The most important question is ‘why people want to use the EMS’? If their reason includes active monitoring of home appliances to save energy, then you can opt to actively send them notifications and alerts when limits have been reached. But, ideally, this is not what we want to do with the EMS. We want to create an autonomous and decentralized system, such that users are not bothered. The user could then program his preferences in advance, for example when to drink coffee such that there is electricity available around that time to make the coffee. … Ideally, the system becomes invisible for the user, but at the same time ubiquitous.” HanzeNet

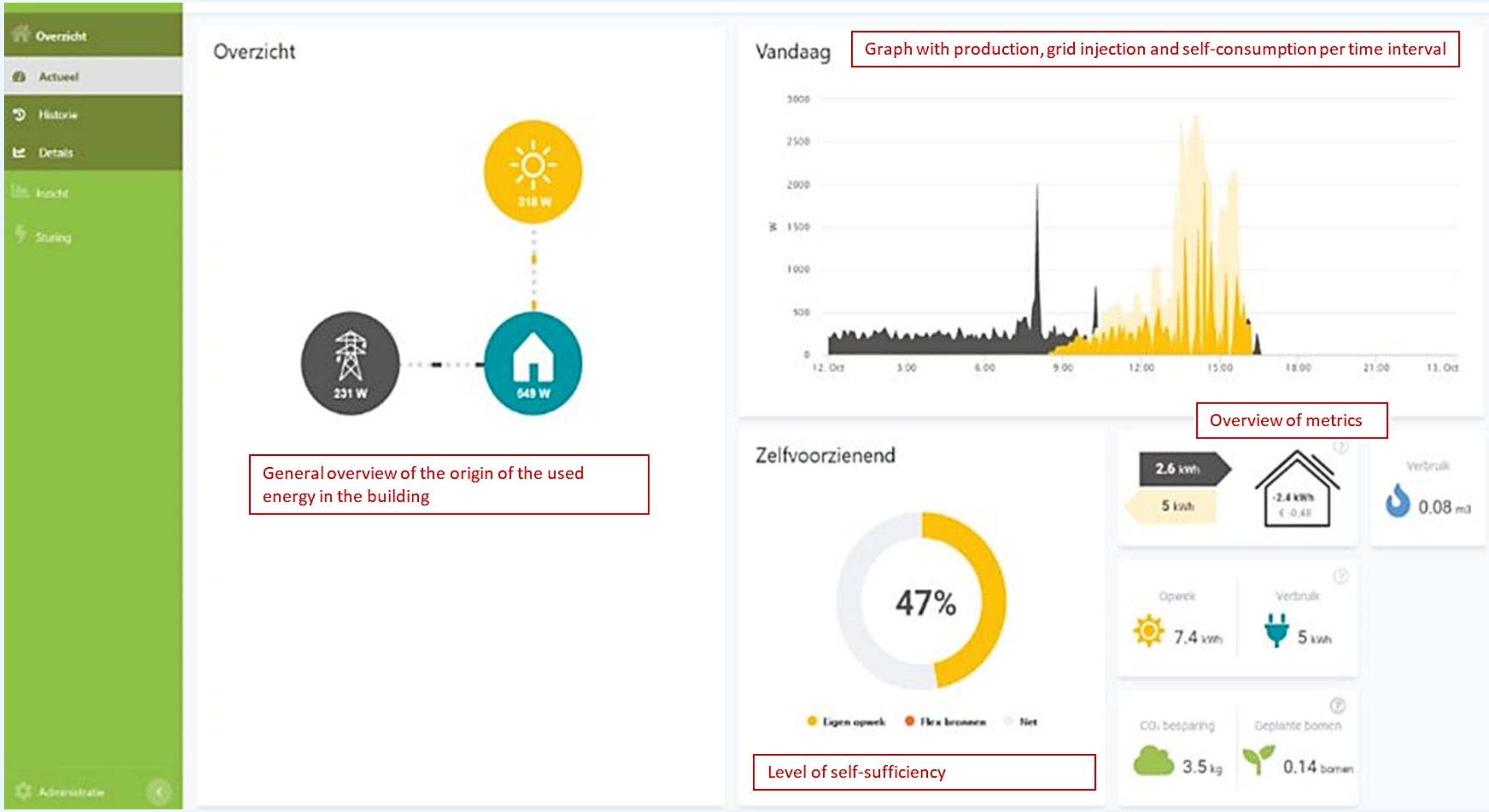
The most prominent **concerns of people** related to the EMS implementation and operations are: privacy issues, security issues (e.g. getting hacked) and complex installation.

> **Privacy and security issues** can be prevented through a well-thought out and functioning technical design, and are the responsibility of the IT-providers.
>
> Complex installation can be facilitated by the communities. People prefer the EMS to be **plug-and-play** and don’t want to be bothered with technicalities. Although EMS providers strive for plug-and-play applications, this is not always the case in practice. Here, energy communities could take an intermediary role by offering advice on what assets to buy (not all of them are interoperable) and providing installation services and technical support to people in need.

Good user experiences highly depend on the clarity and **user friendliness of the customer interface**. As people prefer to access the interface on their **phone** to get a quick overview of their energy flows and savings, it is important to develop an interface for small screens that at the same time contains a sufficient level of detail.

What information should be shown depends on the community values, goals and interests. Often the interface shows graphs and figures about production and grid injection per time interval and the level of self-sufficiency/self-consumption. More dashboards could be added however, such as specific data per technology, savings, CO_2 reduction etc. As adding more dashboards comes with a cost, it is important to distinguish between the must-have’s and the nice-to-have’s. On the next page, there is an example of a customer interface of an EMS.

Customer interface of an EMS



Dashboard of the EMS in ECL, developed by ICT Group/OrangeNXT

+ Attractive and colorful visualizations
+ Fast overview of the most important metrics
+ Community specific: the metrics ‘CO2 reduction’ and ‘number of trees saved’ were added to visualize the community members’ positive impact on the environment because of the high valuation of the value ‘sustainability’.

Acknowledgements

Special thanks go to the energy communities and software providers who were willing to participate in interviews and provided the data for this crash course. Thank you Ampere Energy, Energent, Energie Coöperatie Loenen (ECL), Energie ID, HanzeNet B.V., ICT Group / OrangeNXT B.V., Lochem Energie, Tipperary Energy Agency (TEA) and Translyse. In addition, this crash course is based on the cVPP project deliverables I1.1.2, I1.4.2, I3.1.2 and I3.4.2.

We also want to thank Anne Jonker for helping with the data collection.

References

Breukers , S., Van Summeren, L.F.M., Pernot, S.H.A., Mourik, R.M., Wieczorek, A.J. (2020) Community Energy 2.0 - A support tool for advisers and process moderators to support energy communities in developing a community – based virtual power plant. Eindhoven. Available at: https://www.dropbox.com/s/m7h1m1s3g06kyri/MoReModel-Final.pdf?dl=0