Empowering
the digitalisation of
Energy transition

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EEBUS Solutions

Exploring EEBUS Solutions – A comprehensive whitepaper on how EEBUS use cases are clustered to address specific requirements in the energy management market

By Christina Hollmann (EEBUS), Andreas Schwackenberg (EEBUS), Annike Abromeit (EEBUS)

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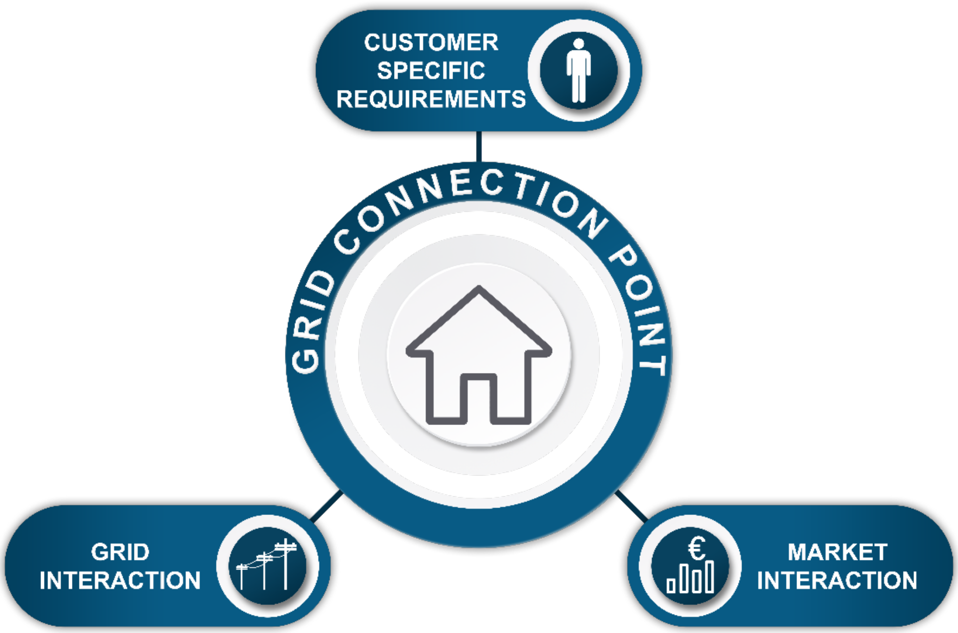
INTRODUCTION AND GOAL

The increasing electrification of the heating sector and e-mobility has significantly increased demands on the power grid. In an all-electric society, solutions are needed to maintain grid stability with as few restrictions on the customer side as possible. This can be achieved by flexible control mechanisms, originating from different actors such as market participants, grid operators or the end customer.

This whitepaper explains the solutions offered by EEBUS and their implications on different actors and device manufacturers. Ultimately, it provides device manufacturers with insights into the relevance of each solution for their business.

BACKGROUND

Three distinct actors want or need to influence power flows at the grid connection point (GCP) for different reasons:



Grid operator: The grid operator needs to protect local infrastructure and ensure local grid stability by curative intervention during acute grid congestion, e.g. limiting power consumption or feed-in power. This kind of intervention is usually regulated by law and can be found in grid connection requirements. These regulatory requirements vary by country.

Market actors: Market actors like Energy Service Providers (ESP) can save or even earn money, if device operators (customers) are willing to reduce or shift their power consumption temporally. This can be achieved through simple time-variable tariffs, giving the device operator an incentive to shift tasks with higher consumption to times with reduced cost (this usually means a lot of power is available in the grid). Likewise, incentives may encourage a device operator to feed power into the grid when power is needed.

Regardless of cost-based mechanisms, market actors may need to apply preventive measures on behalf of the grid operator to avoid potential grid congestions. These measures can include a more detailed information exchange with the device operator to improve the forecast on the grid side.

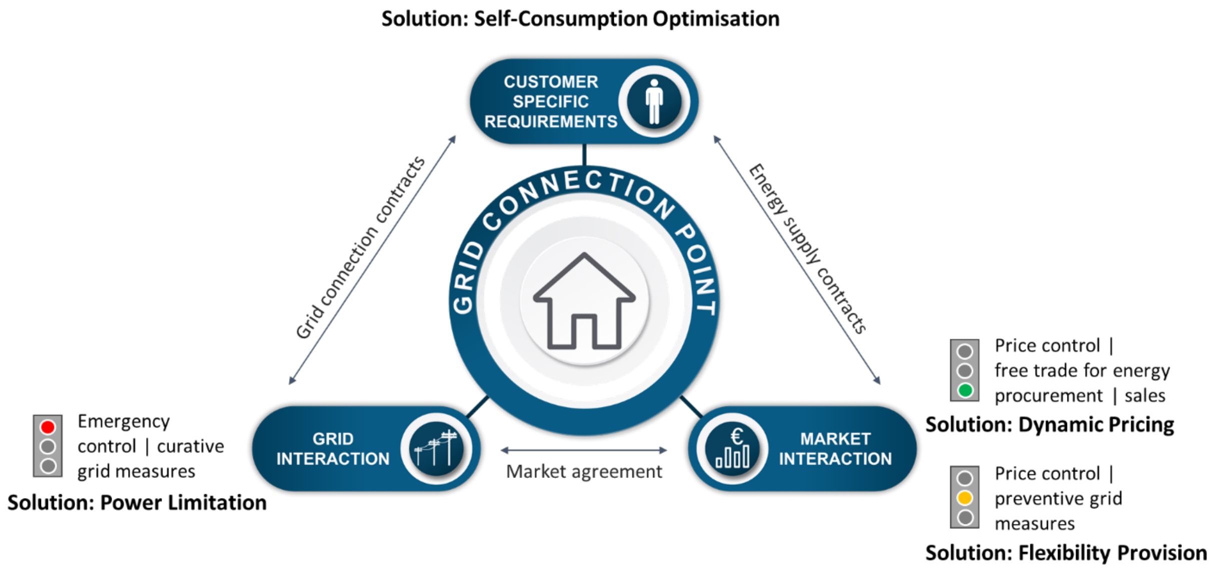
Device Operators (Customers): The device operator determines when and how much power is consumed or produced through its devices, at least as long as no curative inventions impose any limitations. Depending on its individual needs and preferences, the device operator wants to use the power in the most efficient and cost effective way.

The divergent demands of the individual actors on the same grid connection point require a coordinated, prioritised and standardised management of the various signals inside the building. An energy management system (EMS) is responsible for prioritising and coordinating these signals.

EEBUS solutions, including the use cases which are clustered there, help to solve the following challenges:

- Describing necessary information flow and behaviour of the devices which participate in the energy market. Thus, implementation of interfaces between all participating actors is enabled.
- Illustrating interconnection and complementarity of use cases, which signals are prioritised and how these signals are used. Thus, implementation of the device's internal control logic and EMS's logic* is enabled.
- Assisting in assigning technical control signals to contractual relationships among the participating actors. For a better understanding the different states are assigned to different grid states (see picture below).

*: Rules and algorithms inside the EMS are always defined by the EMS. EEBUS provides the standardised data on which the rules and algorithms are built upon.



Note: In an apartment building, there can be a separation of the customer between the grid connection taker and grid connection user. Grid connection taker is the owner of the building, who has a grid connection contract with the grid operator. The grid connection user is (e.g.) the tenant, who has a contract with the ESP.

EEBUS SOLUTIONS

This section explains the four EEBUS solutions: Power Limitation, Dynamic Pricing, Self-Consumption Optimisation and Flexibility Provision. EEBUS solutions are use case packages that address a certain problem. The solutions evolve their highest potential when they work together and complement each other.

In addition to the use cases described here, EEBUS provides further use cases that can be helpful in achieving certain goals.

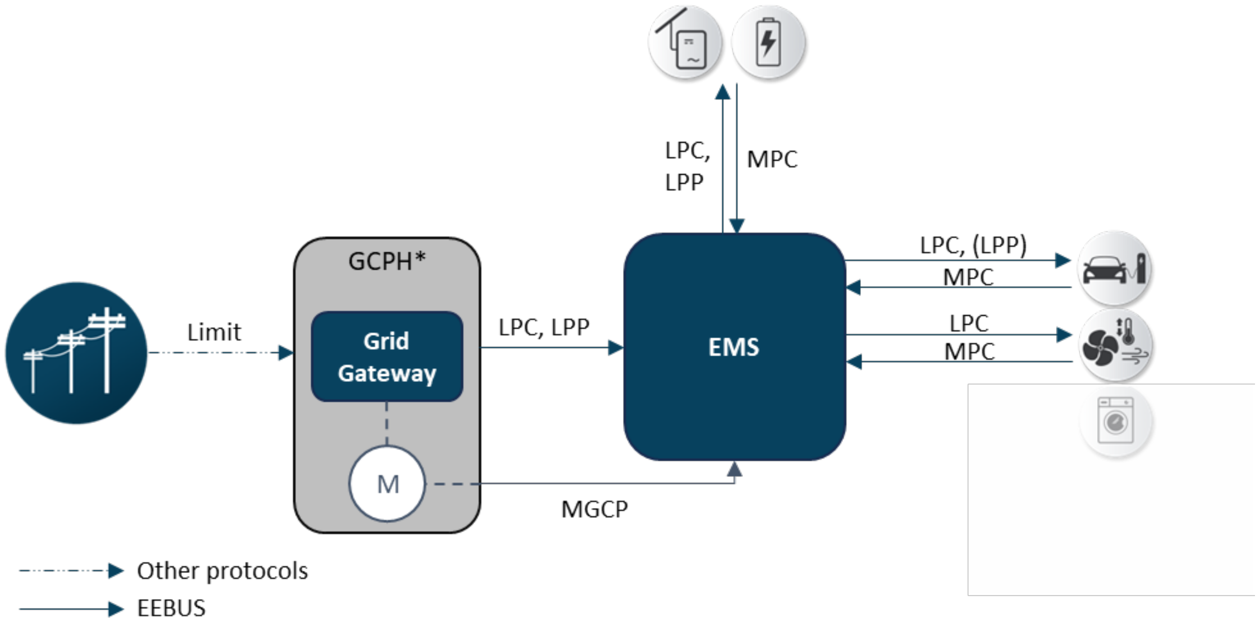
For more detailed information on how the use cases work, please download the specific use case specifications on eebus.org and read chapter 2 "High-Level description".

Power Limitation

The Power Limitation solution aims to protect local grid stability during severe instabilities.

The solution consists of four use cases:

- Limitation of Power Consumption (**LPC**)
- Limitation of Power Production (**LPP**)
- Monitoring of Grid Connection Point (**MGCP**)
- Monitoring of Power Consumption (**MPC**)



**: Grid Connection Point Hub: group of different (logical or physical) entities like smart meter gateway, grid control unit or gateway, and smart meter. The specific structure is in the responsibility of the local grid operator and the national regulatory authorities.*

Note: Simplified graphic, different infrastructure possible.

The Distribution System Operator (DSO) sends a power limit via an EMS or, in case there is no EMS installed, directly to energy-consuming devices with the use case Limitation of Power Consumption (**LPC**) to protect the local grid stability in case of acute grid overload. Excessive feed-in power can also harm the grid stability; therefore, power production limitation is also possible applying the same logic (**LPP**).

Depending on the country-specific regulatory requirements and the applied grid codes, the limit may have different aspects (for details, please read the corresponding national specifications):

- Limit for the total power at the GCP, including all devices (controllable and non-controllable)
- Limit for the total, controllable power at the GCP (single controllable device or group of devices)

The Power Limitation solution fulfils the regulatory requirements in some countries as a grid protection measure (i.a. German §14a EnWG, §9 EEG, here the limit is only related to a list of dedicated controllable devices).

The power limit always takes priority over other signals, which impact the power flow at the GCP. Rules and algorithms within the EMS or the devices must always give priority to the limit.

Power limitation as an emergency instrument ensures that the physical limits of the local grid will not be exceeded.

With the help of the use case Monitoring of Power Consumption (**MPC**), the EMS receives relevant power consumption and production values from the power-consuming or producing devices. With this data, the EMS knows what the devices consume and produce and can adjust the devices' power according to the received overall limit.

➔ relevant for limiting single devices or group of devices

The overall consumption and production data of the GCP is sent to the EMS via the use case Monitoring of Grid Connection Point (**MGCP**). This data is necessary to include consumption and production data of non-controllable devices. All this information is processed by the EMS, which adjusts the consumption or production of controllable devices via LPC and LPP accordingly.

➔ relevant for limiting the total power at the GCP

To make the overall system work, certain security and compliance measures are necessary. Therefore, the solution includes the following technical features:

- Different states of autonomous or remote activation or deactivation of limits
- Heartbeat and failsafe state to have a fallback solution in case of communication interruptions
- Acknowledgement mechanism to provide the signal that the power limit was accepted or declined in case of the obligation to provide evidence

<u>Power Limitation use case overview for each domain:</u>

Use Case / **Domain**	**Short description**	**LPC**	**LPP**	**MPC**	**MGCP**
Grid Connection Point Hub	- Sending limits and consumption/production data - Forwarding consumption/production data related to affected devices	X	X	X*	X
EMS	- Receiving limits from the grid side - Receiving consumption/production data from devices and GCP - Sending limits to devices	X	X	X	X
Inverter (PV)	- Receiving limits - Sending production data		X	X	
Inverter (Battery)	- Receiving limits - Sending consumption/production data	X	X	X	
HVAC	- Receiving limits - Sending consumption data	X		X	
EVSE	- Receiving limits - Sending consumption/(production) data	X	X**	X	

**: Only in case consumption/production data of directly connected devices need to be forwarded.*

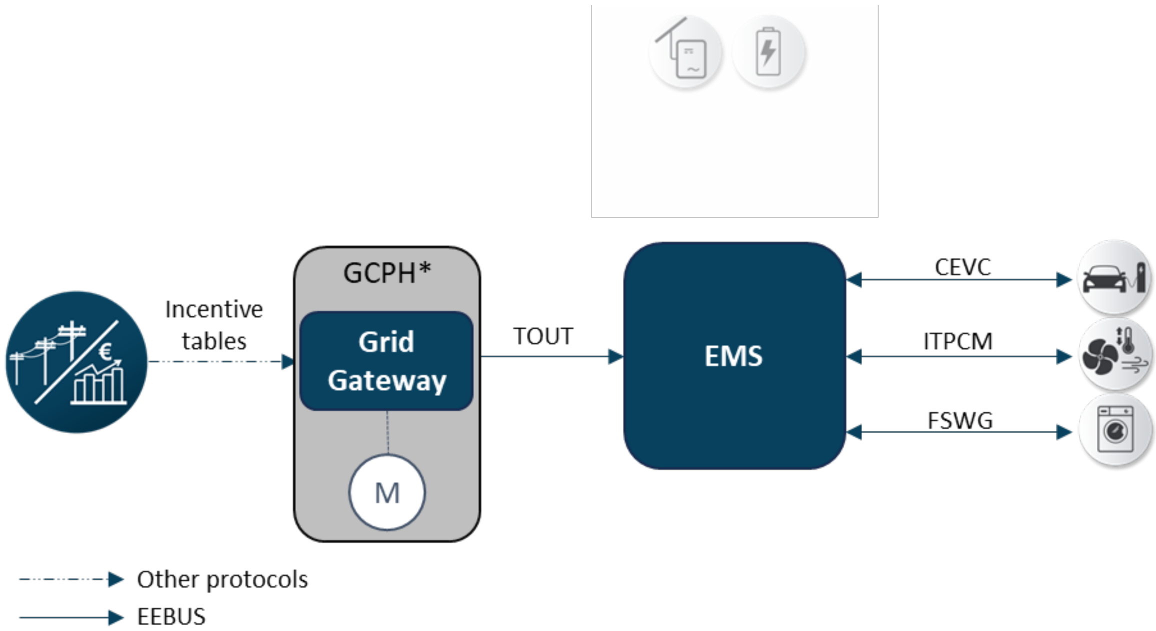
***: Only in case of bidirectional electric vehicles (EVs).*

Dynamic Pricing

The main goal of the Dynamic Pricing solution is the possibility of cost-efficient energy management through incentives. By using incentives, a device can be triggered to shift its loads to times with lower costs, thereby avoiding power over- and underload scenarios in the public electricity grid.

The solution consists of four use cases:

- Time of Use Tariff (**TOUT**)
- Coordinated EV Charging (**CEVC**)
- Incentive-Table Based Power Consumption Management (**ITPCM**)
- Flexible Start for White Goods (**FSWG**)



**: Grid Connection Point Hub: group of different (logical or physical) entities like smart meter gateway, grid control unit or gateway, and smart meter. The specific structure is in the responsibility of the local grid operator and the national regulatory authorities.*

Note: Simplified graphic, different infrastructure possible.

The DSO and ESP can offer incentives via the use case Time of Use Tariff (**TOUT**) to an EMS. This use case enables an incentive-based mechanism to shift loads not directly but based on incentives such as time-variable energy prices, CO_2 emissions, or share of renewable energy.

The incentives received by the EMS are processed and combined with the information of self-produced energy from a PV inverter. The EMS sends the calculated incentive tables via different, mostly domain-specific use cases to the device, which sends a calculated power plan (calculated estimated power consumption over hours) back to the EMS.

Charging stations receive incentive tables via the use case Coordinated EV Charging (**CEVC**) and heat pumps via Incentive-Table Based Power Consumption Management (**ITPCM**). These use cases enable a device to negotiate a power plan according to the received incentives.

Heat pumps operate frequently with higher power consumption during cold days to keep the customer's comfort in an acceptable range. A vendor's experience to control the temperature including consideration of the building's thermal inertia to shift the power consumption to some extent makes heat pumps ideal candidates for the application of use case **ITPCM**: Based upon incentives received from the EMS, the heat pump provides an updated power plan to reduce its cost while maintaining the customer's comfort. **ITPCM** even permits iterative optimisation cycles between EMS and heat pump before making the final choice.

With **CEVC**, the EMS or the EV may renegotiate the charging plan during runtime by updating the incentive table or power plan accordingly. An advanced version of the **CEVC** for bidirectional charging is being developed (**SBEVC**: Scheduled Bidirectional EV Charging).

The use cases **ITPCM** and **CEVC** enable cost-efficient operation of these devices by using their flexibilities, without direct control of the device. This considerably simplifies the development, operation and warranty of the energy management system and the devices.

White goods can be started at times of low prices by applying the use case Flexible Start for White Goods (**FSWG**). The home appliance sends a power sequence (e.g., 1kW for one hour) including a shiftable time frame to the EMS, which in turn sends back control signals to start the appliance at that time when prices are low.

<u>Dynamic Pricing use case overview for each domain:</u>

Use Case / Domain	Short description	TOUT	CEVC	ITPCM	FSWG
Grid Connection Point Hub	- Forwarding incentives	X			
EMS	- Receiving incentives - Processing incentives - Sending incentives - Receiving charging/power plans and power sequences - Sending control signals	X	X	X	X
HVAC	- Receiving incentives - Sending power plans			X	
EVSE	- Receiving incentives - Sending charging plans		X		
White Goods	- Sending power sequences - Receiving control signals				X

The use cases **ITPCM**, **CEVC**, and **FSWG** aim at cost-optimised scheduling of devices, while the use case **TOUT** reflects the procurement of energy for a GCP. This includes the possibility to express time-variable transmission fees.

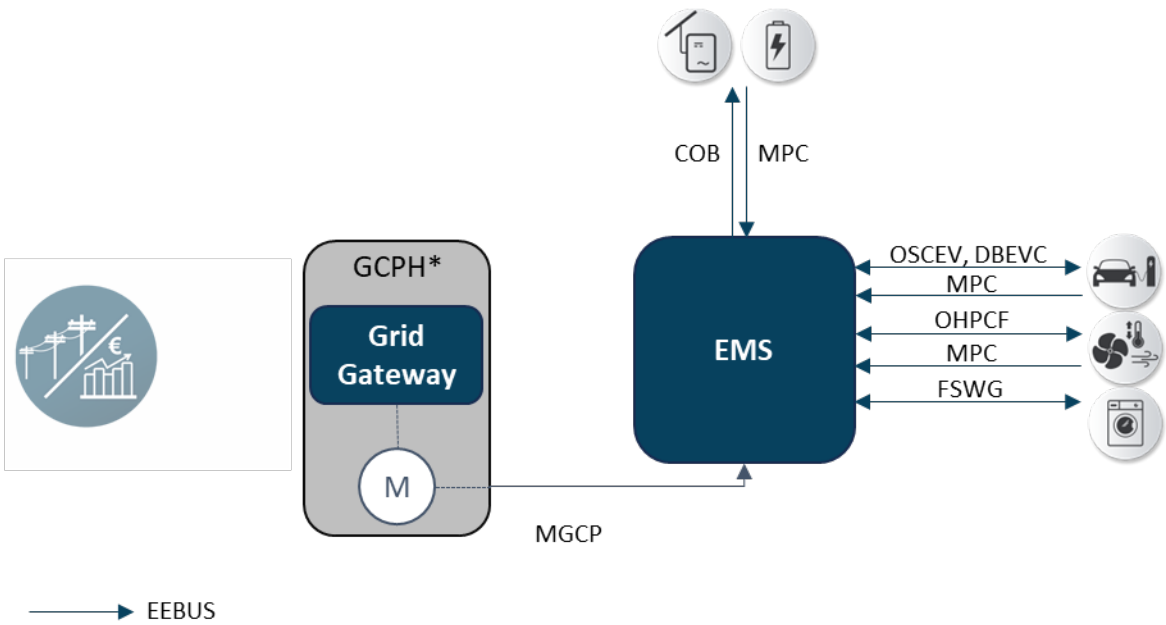
For cost optimisation, further use cases can be used for energy storage (stationary or in an EV's battery) in times of lower prices and using the stored energy in times of higher prices.

Self-Consumption Optimisation

Prosumers (consumers or producers) want to use self-produced PV power to save energy costs, to be more independent from the energy supply and to reduce their ecological footprint.

The solution consists of seven use cases:

- Monitoring of Power Consumption (**MPC**)
- Monitoring of Grid Connection Point (**MGCP**)
- Control of Battery (**COB**)
- Dynamic Bidirectional EV Charging (**DBEVC**)
- Optimization of Self-Consumption During EV Charging (**OSCEV**)
- Optimization of Self-Consumption by Heat Pump Compressor Flexibility (**OHPCF**)
- Flexible Start for White Goods (**FSWG**)



**: Grid Connection Point Hub: group of different (logical or physical) entities like smart meter gateway, grid control unit or gateway, and smart meter. The specific structure is in the responsibility of the local grid operator and the national regulatory authorities.*

Note: Simplified graphic, different infrastructure possible.

To make the whole solution Self-Consumption Optimisation work, it is necessary to obtain relevant data with the help of monitoring use cases. Via the use case **MPC**, active power and current (AC) values are sent from an inverter to the EMS. Knowing the **MPC** values from charging stations and heat pumps, the EMS can now optimise the building's overall power consumption.

Control of Battery (**COB**) enables the inverter with connected battery to receive control signals (charging/discharging). The use case **COB** has two control modes:

- Automatic control loop
- Remote control

With the automatic control loop for the point of common coupling (PCC), the inverter decides whether to charge or discharge the battery according to the power at the GCP (**MGCP**)**.** For example, with a PCC power setpoint of 0W and a measured power value of 1,500W at the GCP, the inverter would start discharging its battery with exactly 1,500W, resulting in a power value at the GCP of 0W.

With the remote control mode for power, the EMS can directly define a setpoint that controls the charge or discharge power of the battery.

For an even better optimisation, the use cases Monitoring of PV String (**MPS**) and Monitoring of Battery (**MOB**) provide the relevant PV and battery-specific direct current (DC) values and further information to the EMS. For maintenance and visualisation, the monitoring use case Monitoring of Inverter (**MOI**) provides further data.

Similar to the use case **COB**, the use case Dynamic Bidirectional EV Charging (**DBEVC**) enables an EMS for direct setpoint control of an EV's battery to optimise self-consumption. With **DBEVC**, the EV's energy demand and departure time are considered, along with further constraints.

This standardised information flow helps the EMS to obtain crucial information for self-consumption optimisation, efficiency calculations, and error detection.

Through the use case Optimization of Self-Consumption During EV Charging (**OSCEV**), the EMS sends a limit to run the charging process at low costs as PV surplus power is used. The limit does not need to be kept necessarily in case the charging process should be faster according to the consumer's demand.

With the use case Optimization of Self-Consumption by Heat Pump Compressor Flexibility (**OHPCF**)**,** heat pumps send a power sequence (e.g. 5kW, runtime unknown) to the EMS. The EMS can control (start, pause or cancel) this flexibility offered by the heat pump according to the available PV surplus power.

Less complex heating devices can use Flexible Load (**FLOA**). With this use case, the EMS can directly trigger the energy consumption of an end device via setpoint, if the device is able to consume energy.

The PV surplus power can also be used easily for white goods with **FSWG** (see solution Dynamic Pricing).

For devices that support incentive-based control (like heat pumps, EVSEs) it is recommended to use the use cases mentioned in solution Dynamic Pricing. This enables end devices to have the decision-making independence when its operation would be the best in time.

Self-Consumption Optimisation use case overview for each domain:

Use Case / Domain	Short description	MPC	MGCP	COB	DBEVC	OSCEV	OHPCF	FSWG
Grid Connection Point Hub	- Sending monitoring data		X					
EMS	- Receiving monitoring data and power sequences - Sending control signals, limits and setpoints	X	X	X	X	X	X	X
Inverter (PV)	- Sending monitoring data - Receiving control signals	X						
Inverter (Battery)	- Sending monitoring data - Receiving control signals	X	X	X				
HVAC	- Sending power sequences - Receiving control signals	X					X	
EVSE	- Receiving limits and setpoints - Sending monitoring data	X			X*	X		
White Goods	- Sending power sequences - Receiving control signals							X

**: Only in case of bidirectional EVs.*

Flexibility Provision

The Flexibility Provision solution offers use cases to benefit from energy flexibilities in households.

The participation is usually voluntary, and end customers receive remuneration for contributing. This preventive measure for grid stability aims to avoid a mandatory limitation by the solution Power Limitation.

Future scenarios may involve aggregators providing energy flexibility from numerous households in large power pools, utilising this energy as grid support for TSOs. It is also conceivable that in the future households could have to register their power requirements at the DSO and will get assigned time based power bands. Intraday trading is also envisioned as part of a flexibility provision scenario. This aspect introduces the capability for dynamic adjustments in energy trading within a day, enhancing the overall flexibility of the system.

This solution with its fundamental use cases like Power Envelope (**POEN**) and Power Demand Forecast (**PODF**) will soon be available for implementation. The solution works well together with the use case **TOUT** (prices have an influence on the forecast).

Moreover, the EEBUS roadmap 2024 includes a new use case that addresses the integration of primary balancing power for the management of frequency fluctuations.

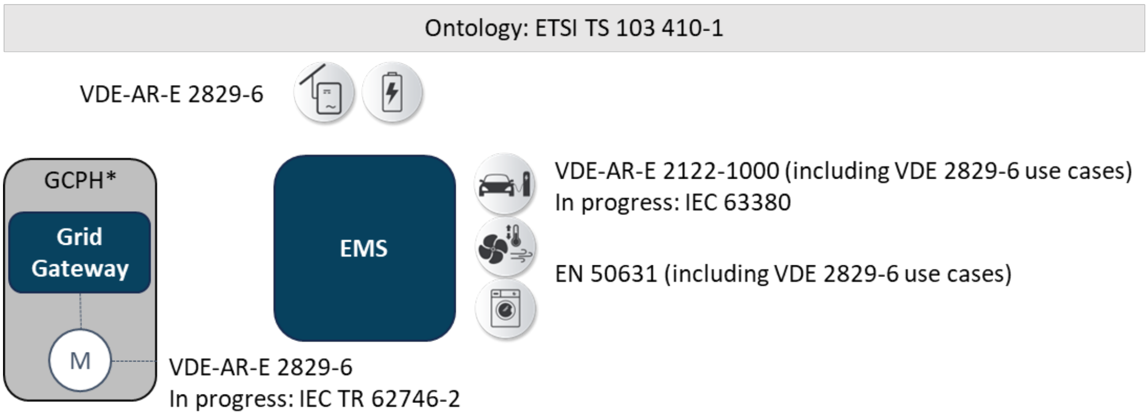
An update of this whitepaper with an additional chapter for this solution is planned for 2024.

SUMMARY

EEBUS offers the technical solution to support the digitalisation of the energy transition. The above-described EEBUS solutions cover the needs and challenges of the different actors around the grid connection point: grid stability, saving costs through self-consumption optimisation or dynamic pricing, and flexibility markets.

The use cases of the explained EEBUS solutions are nationally and internationally standardised. Here is a list of standards where EEBUS is part of:

- VDE-AR-E 2829-6 Ed.2 and VDE-AR-E 2122-1000 Ed.2
- EN 50631 Ed.2
- IEC 63380 (in progress) and IEC TR 62746-2 Ed.2 (in progress)
- SAREF4ENER ETSI TS 103 410-1 V2



These standards are valid at least on European level but also on a global scale.

The solution Power Limitation is part of all these standards which are domain-independent. Thus, EEBUS compatible devices, which support the solution Power Limitation, behave internationally in a standardised and regulatory compliant way.

All solutions have been worked out with the valuable input from our member companies and research projects for the digitalisation of the energy transition (funded by EU commission and BMWK). All relevant actors of the energy management sector have been involved like DSOs, ESPs, and device manufacturers.

EEBUS Initiative e.V. develops a communication standard for energy-relevant devices and systems with its member companies and associations. The standard covers the whole chain from grid connection point to the end device. The whole chain can be tested end-to-end and regulatory conform at the Living Lab Cologne. The Living Lab Cologne is equipped with all devices and backends necessary to test the EEBUS solutions. Device manufacturers can make an appointment to test their EEBUS implementations towards the existing infrastructure or test with other companies on a plugfest. More information about the Living Lab Cologne, please visit www.livinglabcologne.com.

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