*Smart system of renewable energy storage based on **IN**tegrated E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid*

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Author:	**Schneider Electric – Per Gjerløw**

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UPC	Pau Lloret

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Table of contents

Abbreviations and Acronyms

Acronym	Description
API	Application Programming Interface
BRP	Balance Responsibility Party
CPO	Charging Point Operator
CAN	Controller Area Network
DoA	Description of Action (annex I of the Grant Agreement)
DSO	Distributed System Operator
EC	European Commission
EV	Electric vehicle
EVSE	Electric Vehicle Supply Equipment
FCR	Frequency Control Reserve
GA	Grant Agreement
HA	Home Automation
IP	Internet Protocol
PC	Project Coordinator
PCC	Project Coordination Committee
PO	Project Officer
PUC	Pilot Use Case
PV	Photovoltaic
QM	Quality Management
SS	Secondary Substation
TCC	Technical Coordination Committee
TL	Task Leader
ToC	Table of Contents
ToU	Time of Use
USB	Universal Serial Bus
V2G	Vehicle to Grid
V2H	Vehicle to Home
WiFi	Wireless Fidelity
WP	Work Package
WPL	Work Package Leader

Figures

Executive summary

This D.10.1 describes the general specifications/situation and provisions for each of the pilots in the INVADE Project.

The pilots are located in five countries: Norway, Netherlands, Bulgaria, Spain and Germany.

Each Pilot is sectioned into chapters. A general definition, large scale proposal, technical characteristics, grid topology, technical details, storage details, flexibility services, use cases for each pilot, and a list of equipment to be installed in the pilots.

For each of the pilots, there is one or several use cases to be “proved” related to what is defined in D4.

1 Introduction

1.1 Overview

The INVADE project aims to deliver a cloud-based flexibility management system integrated with electric vehicles (EVs) and batteries empowering energy storage at mobile, distributed and centralized levels to increase the share of renewables in the smart grid.

The main objectives of this deliverable are focused in complying with the technical specifications of all the pilots that will be part of the project. This includes all the main technical characteristics as topology, storage functionalities, services and equipment that will be included in each pilot.

Each pilot will be prepared for a largescale roll-out. This will be important to show efficient ways to scale-up the pilots without redesign or re-develop the basic systems in the pilots/models.

The pilots in the project are located in 5 different countries in Europe: Spain, Netherland, Bulgaria, Norway and Germany (see Figure 1.)

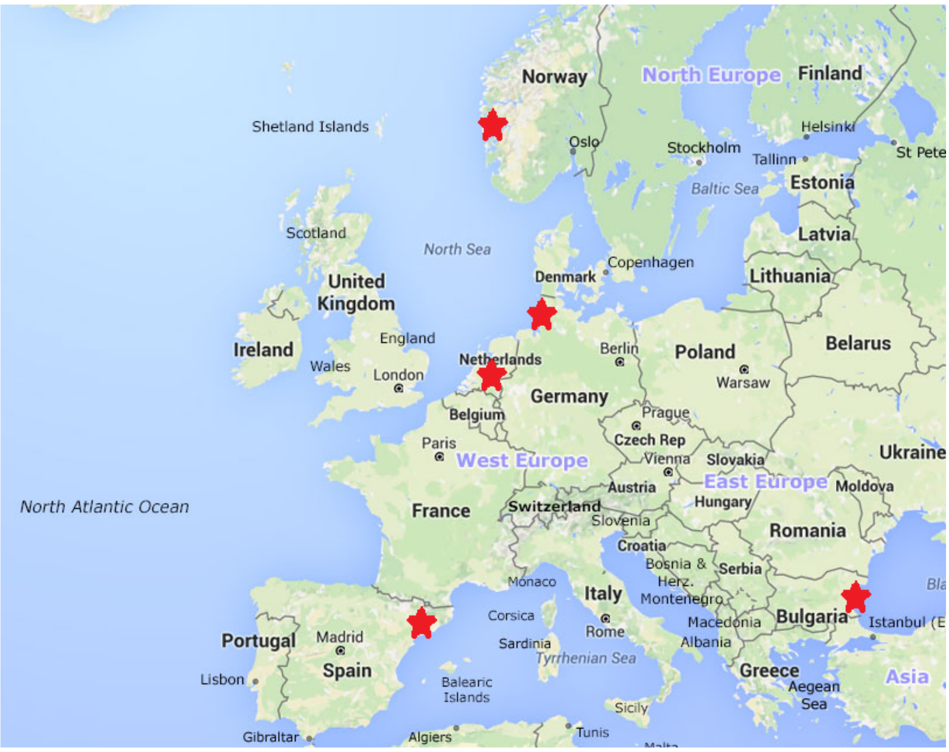

Figure 1. *Pilot Location*

The ambitions of the INVADE-project

Smart system of renewable energy storage based on **IN**tegrated E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid.

Renewable energies and EVs change the way we produce and consume electricity. It also changes the way those who manage and distribute energy have to think about the electricity system – to always provide the best possible service for their costumers, meaning managing energy consumption vs price, and different business models, but changing habits are challenging, and often takes time.

The goal of the European-funded H2020 project INVADE is to greatly speed up this process, by showing that the technologies and solutions we have today, just have to be connected in new ways to solve the challenges of tomorrow.

The WP10, where this deliverable belongs, is the work package that coordinates all the pilots. The main goals are:

- Define and implement the different pilots of the projects according to the use cases described in DoA.
- Solutions for EV, Storage and Households will be implemented and tested.

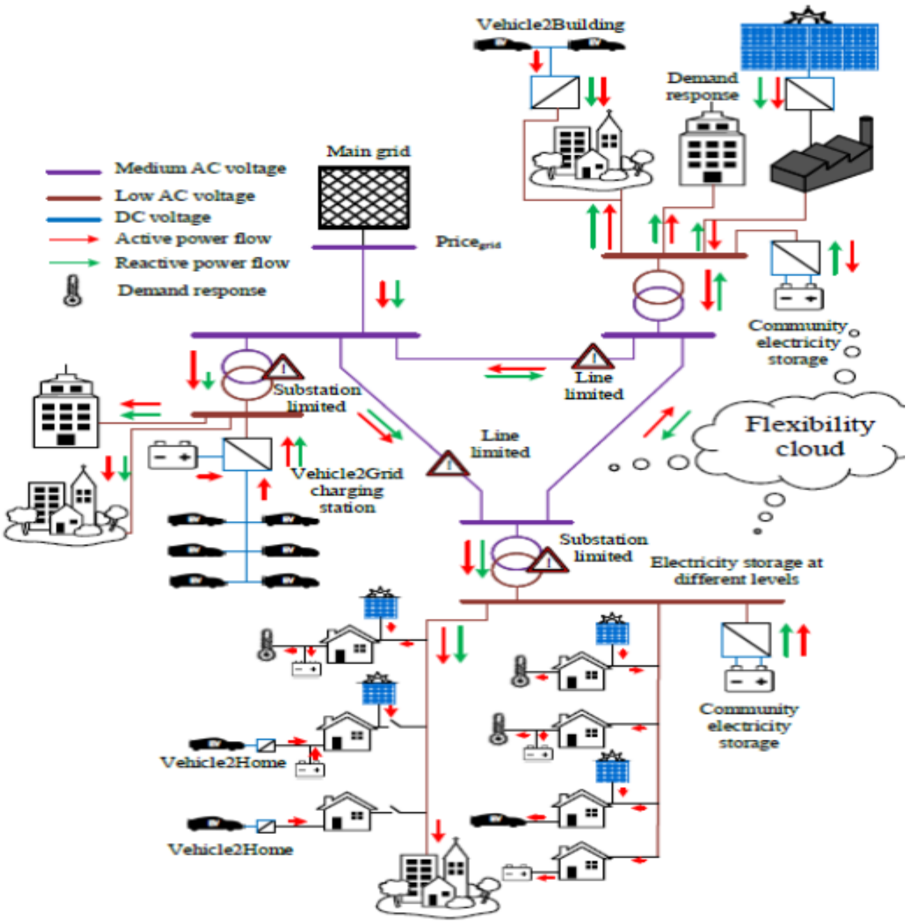

Figure 2. *General Overview INVADE*

The INVADE platform will be tested and validated by implementing several large-scale pilots in five different countries for proving relevant sustainable business models including mobile, centralised and distributed energy storage as main focus of the developments.

The pilots should easily be able to expand the number of end users, without big changes in their system. (using standardized solutions)

This deliverable will describe the main specification for each one of the pilots. This includes the specification of the general architecture, equipment and main functionalities. The report addresses each pilot specified in terms of a set of predefined use-cases. Each pilot will be designed so as to provide the best possible answers to the research questions raised in association with the use-cases defined. These research questions are derived from the overall objectives of the project. The provisions needed to test the pertinent use-cases in each pilot are important. A precise specification of these are required to assure efficient preparation and execution of the pilots. These provisions include technical, user-oriented and business-related prerequisites.

Pilot Responsible are

Norway, Lyse, www.lyse.no

Netherlands, Greenflux and Elaad. www.greenflux.nl, www.elaad.nl

Bulgaria, Albena, www.albena.bg

Germany, Badenova, www.badenova.de

Spain, EyPESA, www.estabanell.cat

1.2 Pilot Use Cases

The goal of the INVADE project is to manage the external influences on the grid and prevent that the grid will fail because of fluctuating loads and feeds. The pilots will attempt to show that EVs and batteries can play major roles to level out and effectively utilize the capacity in the infrastructure while avoiding congestions and reduced quality of supply. They are assumed to be the most flexible resources for flexibility management in the distribution grid that we currently know. In addition, EVs represents a capacity challenge itself due to increasing power demands that accumulate unfavourable peaks. Proper management of EV charging thus serves a dual purpose.

As it was defined and described in D4.1 (Overall INVADE Architecture), the INVADE platform will be tested and validated in five different countries testing / proving four pilot use cases (PUC):

1.2.1 PUC.1: Mobile energy storage using EVs for V2G, V2B and V2H operations

The use case involves mobile energy storage using EVs with focus on V2G, V2B and V2H operations along with higher renewable integration. This use case will demonstrate a link to the transport sector using renewable energy sources in each pilot site. Emphasis in PUC-1 has been placed on smart charging by means of schedules with the possibility of reverse flow. Use of more novel more experimental entities that have not reached the industry yet will be limited.

1.2.2 PUC 2: Centralised energy storage using an array of batteries at the sub-station or street level

The use case involves a centralized energy storage unit comprised of an array of smaller batteries at the substation and/or community level. This use case will demonstrate the applicability of large scale centralized storage units at the substation/street level to demand side management, power quality improvement, power peak-shaving and emergency back-up operations.

1.2.3 PUC 3: Distributed energy storage using individual batteries at the household level

The use case focus on distributed energy storage units spread across multiple households. The use case will showcase the benefits of distributing storage units across households.

There is another special case included inside PUC-3 which is one of the cases in Norway where households and smart devices will be treated.

Smart EV-charger or storage is included. INVADE Integration platform will connect remotely with these smart devices and will establish a bidirectional communication in order to collect all the electrical information and send control signal to them.

1.2.4 PUC 4: Hybrid level energy storage solutions addressing a combination of use cases 2 and 3

The use case implements a hybrid/combination of centralized and distributed energy storage units at both substation/street and household levels (a combination of use cases 2 and 3).

1.2.5 Research questions

The use cases have been designed so as to answer important research questions. These have been listed in Table 1.

Use-Case	Technical research questions to be answered	User/business related research questions to be answered
PUC-1	Can we use standard, existing protocols to ensure proper smart charging and create links to other systems like the INVADE cloud? Are there any technical hurdles to consider before we can do a large-scale roll out? What impact and benefit can smart-charging apply to increase flexibility in the grid? How can the pilots defined scale-up to encompass more end-users and other stakeholders?	Is flexibility offered in the way that this use-case prescribe a good alternative for improving the grid/infrastructure? What value can the EV driver/owner achieve in a smart charging regime and how can this value be made salient? How good is the business case and business potential for flexibility managers and other business players involved? Is the flexibility potential and concept relevant for BRPs?

	Is there a good business case for GreenFlux to continue with this and on what terms? How much energy is possible to transfer from the peak to the base? How much imbalance energy have been avoided? How can smart-charging be activated using the INVADE platform? How will V2B and V2G work?	Is it possible to save money with the facilities installed? What money did you spend for the pilot - what is the possible investment ROI-case? Can the INVADE concept yield a profit for us? Bonus question: Can this approach contribute to a "green and smart" market profile that generates incentives for the tour operators to offer “green and smart” profile? In that case - how can this added attraction value be achieved? How can hotel guests and tour operators be informed and engaged in order to acknowledge and take part in the flexibility regime established?
PUC-2	How should the storage facility be operated? What is the optimal charge/discharge pattern required to satisfy the needs of the BRP and the DSO? What is an adequate storage size for offering the flexibility needed by a DSO and a BRP? What power electronics configuration best manages the battery and its use-profile? - What efficiency improvements are possible in the distribution transformer and MV grid using flexibility? How can efficiency in the grid be improved by means of a central storage?	How can a customer save money by participating in a regime like we design here? Is it possible to save money with the facilities installed? What is the best possible investment-case? What is the ROI? Bonus question from our competitors: Can this approach contribute to a «green and smart" market profile that generates incentives from the tour-operators, for you being green and smart? In that case - how can this added attraction value be achieved?

	How can critical installations benefit from storage (securing redundancy), storage that can also be used to offer other flexibility services?	How can hotel guests and tour operators be informed and engaged in order to acknowledge and take part in the flexibility regime established? How can long-termed parked EVs and EV-users be engaged? How can the surplus produced during off-season be capitalized on together with the BRP? How can a centralized storage facilitate energy flexibility for BRPs and DSOs? How can possible/certain services in the energy sector be enhanced? What role could the Flexibility Operator play in the short term and what new business opportunities does this role offer? • in a European context • in a Spanish context, allowing the FO to come faster into play once the figure becomes legal in Spain. What would be the provisions in the longer term (and when made legal) for creating a Flexibility Operator entity, thus opening a new area to the company group within the energy sector. What new services could be offered to the DSO and BRP, two business we already operate in? What policy changes and upgrades are necessary for enhancing and leveraging flexibility?

		What are the technical and legal obstacles for a scaled-up introduction of the PUC-2 scenario?
PUC-3	How can the integrated INVADE platform best interact with an existing home energy management system? Does the equipment suit the short and long-term purpose defined? (To create new energy related services and to keep and recruit new customers in the future)? What need is there for improvement regarding hardware, software, protocols etc? How much energy is possible to transfer from the peak to the base? How much imbalance energy have been avoided?	How can a customer save money by participating in a regime like we design here? How can we create added value for our 100.000 end-customers? How should we price and sell the future product/service? What is the most suitable business model? How can all this produce an advantage into the next level of energy related services? How can we demonstrate the ability of the integrated INVADE platform to co-operate with an existing home energy management system.
PUC-4	How do the preparations for a street battery differ from a roll-out of household installation? How can the integrated INVADE platform best interact with the street battery and the household installations? What are the main differences? How do the differences in protocols affect the interactions? When comparing the street battery with the household installations of the same, overall capacity what is the most attractive/efficient alternative in terms of installation, flexibility operations and monitoring?	How do regulations favour the street battery from the household one or vice versa? To what degree did the human factor associated with the household batteries impact (positively and negatively) the INVADE operation compared to the operation of the street battery? What is the comparative cost-benefit of the street battery versus the household solution? In what way can a partnership with the household change the risk and cost of operation as well as financing of the flexibility operation?

	What is the comparative performance of the two solutions? i.e. operation, responsiveness,maintenance, degradation (specify what is relevant)	

Table 1. Research Questions

1.2.6 Use-cases versus pilots

The different pilots address different use-cases and therefore different research questions. The combinations of use-cases and pilots are highlighted in Table 2. As can be observed PUC-1 and PUC-2 will be tested in two separate pilots. The different pilots will be specified in detail in the next sections.

Pilot	PUC-1	PUC-2	PUC-3	PUC-4
Norway - Lyse	X		X	
The Netherlands – Greenflux/ElaadNL	X			
Bulgaria - Albena	X	X		
Spain - EYPESA		X		
Germany - Badenova				X

Table 2. Use Cases related to Pilots

2 Pilot Sites Specifications

2.1 Norway

2.1.1 Definition

The focus of the Norwegian pilot is to demonstrate the ability of the integrated INVADE platform to co-operate with an existing home energy management system. The technological shift in management systems, especially in the private end-user market, can be considered as a shift from centralized solutions where one actor controls every technical aspect of an installation, to an ecosystem where multiple independent or competing actors operate in the same space (e.g. a residential home). In order to ensure the commercial viability of the integrated INVADE platform, it is crucial to implement and demonstrate the ability of the platform to operate in such an ecosystem.

As part of the pilot, there will be several installations of energy centric equipment in residential homes. The equipment will be purchased by existing service providers on the general principle that the physical installations should be as close to commercial products as possible. In order to take into account, the technological advancements in the years to come, as well as shifts in regulations and incentives, some of the products (e.g. batteries) are not available or immature as a service today, so we will work with the service provider to find solutions that resemble what will be offered as a standalone commercial product in the future. The pilot equipment will, as far as possible, be purchased through Smartly AS and Lyse Energisalg AS, both fully owned by and part of the Lyse Group.

The pilot area will be in the Stavanger region where Lyse is located, and where most of the end customers lives. The Pilot participants will be families in households and Housing cooperatives and employees at Lyse.

The pilot is split into different categories in order to get as close as possible to the variety of technical energy centric equipment at households and businesses. The following categories will be tested with the Invade platform:

- Heating control 3 zones + water heater control. 10 installations in private households with existing PV systems.
    - Goal: Better utilization of self-produced energy.

    - Using optimized energy management, floor and hot water warm up when the solar system produces the maximum. This in order to better utilize self-produced energy, as well as minimize energy delivered to the electricity grid.

- Smart EV charger. 20 installations in private households.
    - Goal: EV-chargers are controlled so that the car is charged during periods of high capacity in the mains and low energy prices.
    - When using smart EV charging, the charger will be switched off when the price level is at its highest or the grid capacity are low.

- 10 kWh battery energy storage. 10 installations in private households.
    - Goal: Control energy consumption
    - The energy consumption is taken from the battery when the grid capacity is low or the energy price is high by doing peak reduction.

- 3 kWp solar plant + 10 kWh battery for energy storage. 5 installations in private households.
    - Goal: Better utilization of self-produced energy.
    - When using a battery in combination with solar production, the consumer gets better use of self-produced energy and less energy is delivered to the electricity grid.

- 3 kWp solar plant + 10 kWh battery for energy storage + Smart EV charger. 6 installations in private households.
    - Goal: Load management.
    - When using EV-charging in combination with solar power and battery, the system ensures that the electric car is charged in periods when the mains is not overloaded.

- 3 kWp solar plant + Smart EV charger + water heater control. 9 installations in private households.
    - Goal: Better utilization of self-produced energy.

    - When using EV-charging in combination with solar power and water heater control, the consumer gets better use of self-produced energy and less energy is delivered to the electricity grid.
- 7 kWp solar plant + 10 kWh battery for energy storage + 11 Smart EV charger (200 end users). Lyse Head office
    - Goal: Better utilization of self-produced energy and load management.
    - When using a EV- charging system in combination with solar power and battery, the system contributes to charging the electric cars during periods when the power grid is not overloaded. Consumers will also spend more of their own energy, and less energy will be delivered to the electricity grid.
- 50 EV chargers in Housing cooperatives. (500 end users)
    - Goal: Control energy consumption
    - The electric cars are charging during periods when the mains is not overloaded.

The total residential installations in the Norwegian pilot are as follows:

•30 PV installations

•70 Smart EV-charger installations

•30 Battery installations

•10 smart heating/boiler installations.

•Housing cooperatives, where the focus is on charging points (500 users)

In addition, a combined PV, EV-charging and battery solution that consists of 7 kWp PV, 10 kWh Battery and 11 smart EV-chargers will be included in the pilot. There are 200 active users of the system, which is located at the Lyse Headquarters.

The following input will be combined in the Norwegian pilot.

- Energy consumption from the main meter in each household.
- Energy production from PV-systems.

- Energy consumption/storage from Batteries
- Energy consumption from EV-chargers
- Energy prices: production, consumption and grid fee.
- External input, Weather data from yr.no

The output and result from the pilot:

- Optimize energy consumption based on hourly rate.
- Optimize energy consumption based on effect/power.
- Optimize utilization of self-produced energy.

2.1.2 Large Scale Proposal

The physical installations will be connected to the integrated INVADE platform via well documented APIs (Application Programming Interface). The platform will then provide the research and innovation actions outlined in the DoA, e.g. agent-based flexibility management. This is a demanding task, as it requires a well-defined relationship between the end-user, the local service provider and the integrated INVADE platform, both on a technical and a commercial level. It is an important notion that this relationship is what the Norwegian pilot will demonstrate, not that the technical equipment works and is controllable by a central agent. Therefore, the number of installations are not in the order of thousands, but significantly smaller when compared to other pilots labeled as large scale. Part of the reason for this is the level of commitment from each pilot household. We require that the pilots take an active part in the project, not just passive sharing of data. Because of this the number of installations should be regarded as large scale. One other reason for not having more pilot installations is that it is not the equipment itself that will be validated, but the technical and commercial relationship between the involved parties. Based on this notion, increasing the number of pilot installations beyond the scale listed here does not add value to the project and would be a waste of project resources.

The development of a technical and business architecture that is compatible with other platform-based ecosystems like the INVADE platform is a complex task that holds significant replication potential. Since the goal of the pilot is not testing of physical equipment but validation of a business architecture, the number of physically installed devices holds lesser importance. Such architecture is an important component in the delivery of the Norwegian pilot, but more importantly it is critical in demonstrating the commercial viability of the INVADE platform. The success of the INVADE platform after the end of the project is largely dependent on its ability to function in an ecosystem of several actors cooperating in the delivery of flexibility services. If done right, the Norwegian pilot will be ready to continue and scale as a fully commercial service after the end of the project. This will reflect very favorably on the project.

2.1.3 Technical Characteristics

2.1.3.1 Grid Topology

Topology for households will be based on Figure1 below:

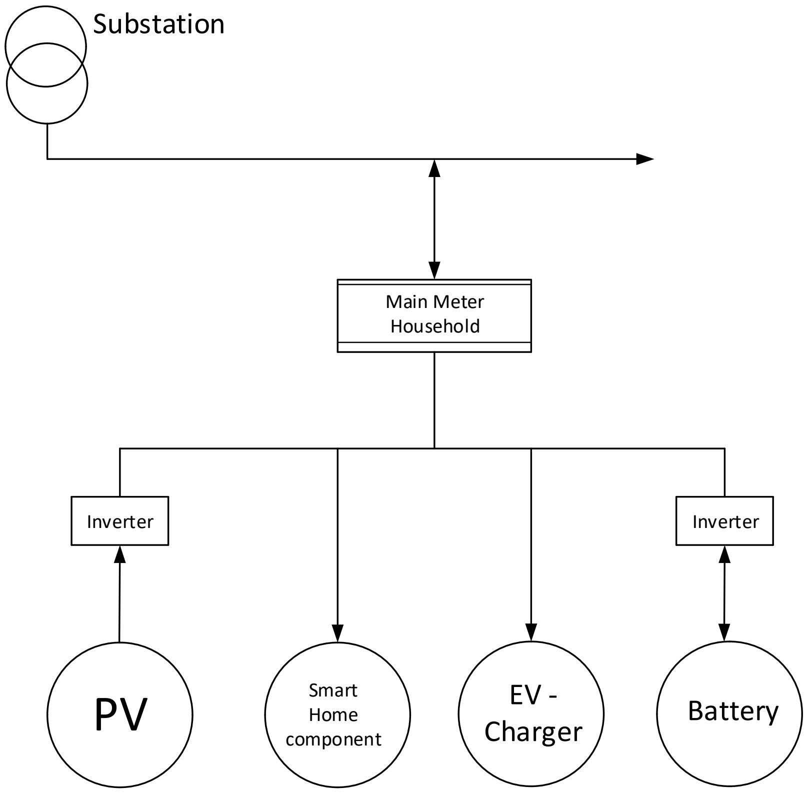

Figure 3. *Topology for households*

Topology for Lyse Headquarter will be based on Figure 2. below:

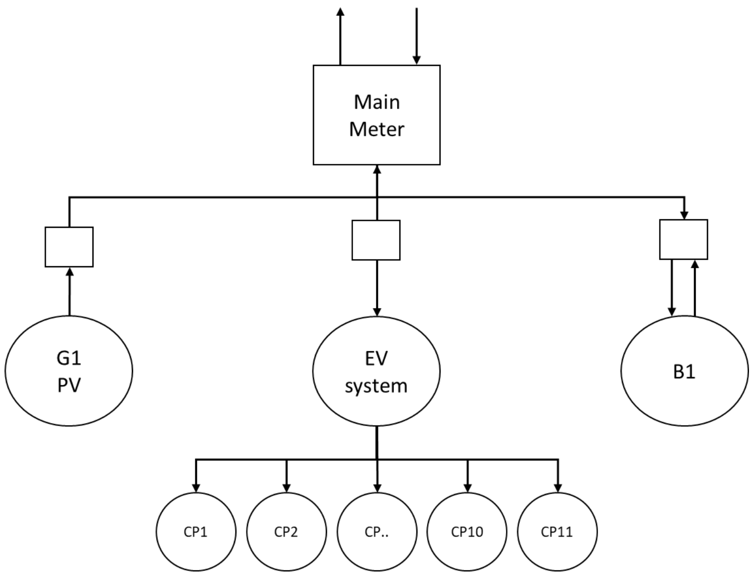

Figure 4. *Topology Lyse Headquarter*

Topology for Housing cooperatives will be based on Figure 5. Below:

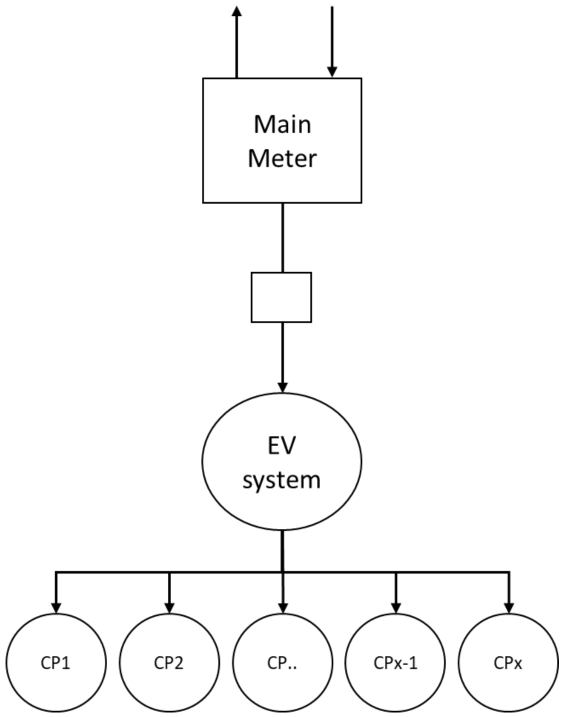

Figure 5. *Topology Housing cooperatives*

All the use cases involved in this pilot are related to devices and equipment in the home environment which have an impact on energy consumption in the home, but also the electrical grid on a substation level. The use cases will not be limited for the Norwegian market as the topology is the same for whole of Europe from a DSO perspective.

Figure 3. the DSO substation Low-Voltage network connected to the household. The households are equipped with PV, EV-chargers, Batteries and smart home equipment and will have an impact on the limited capacity on the Substation. The project will solve this problem with the INVADE flexibility platform by introducing new business models and technology related to energy services.

Figure 4. shows the topology of the pilot at the Lyse Headquarter and includes EV-chargers (11 EV-chargers), 10 kwh Fronius battery, 7kwp PV system and the main meter from the DSO. Approximately 40 percent of energy production from the PV system is sent back to the grid. The project will solve this with a combination of utilization of self-produced energy and load management provided by the Invade platform.

Figure 5. shows the topology for housing cooperatives. 40 percent of all Norwegians live in this kind of housing. Charging in housing cooperatives addresses a lot of problems to be solved when it comes to energy consumption and overload. The project will solve this problem with the Invade flexibility platform by introducing new business models and technology related to energy services.

2.1.3.2 Technical Details

A technical overview of the IT architecture for all pilot installations can be found in Figure 6 below. The general principle is that the logic and control of individual components is handled by a "Home Automation" (HA) service provider. The necessary level of interfaces is then exposed to the integrated INVADE platform via cloud-to-cloud based APIs. The INVADE platform in turn will expose supporting APIs for providing decision support and other services in order to facilitate the services described in section 2.1.2.4. The architecture will be designed in such a way that the minimal amount of access rights to the HA system that is necessary for delivering the services are given to the INVADE platform. In such a way, the HA service provider will be responsible for the customer experience and utilize the intelligence and flexibility provided by the INVADE platform to add value for its customers.

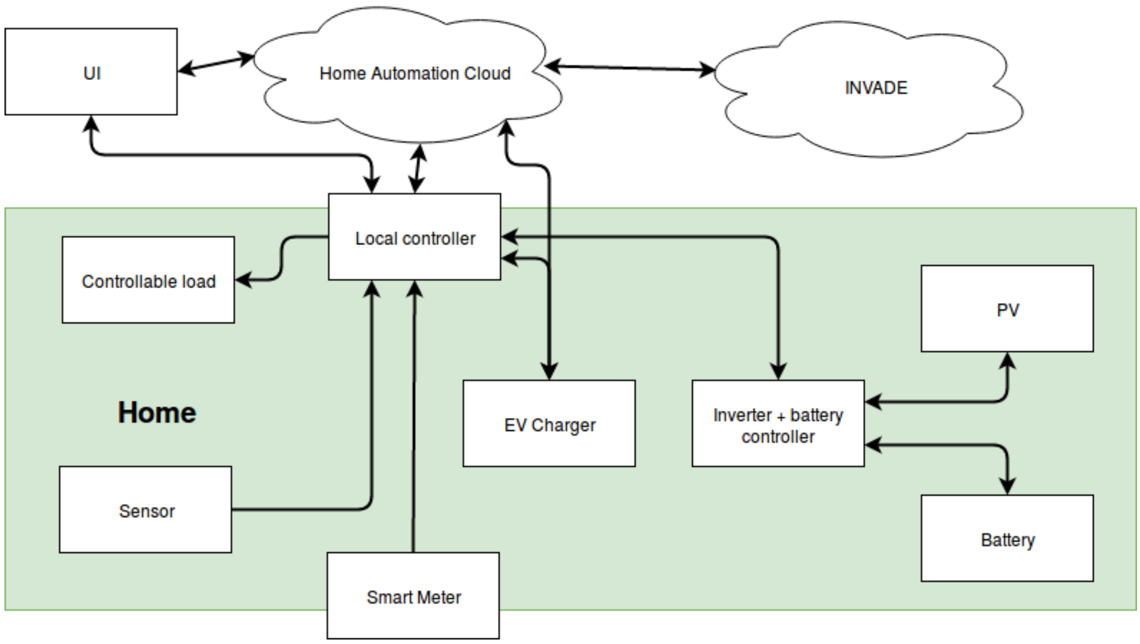

Figure 6. *Data Flow. Norwegian pilot.*

For some (IP-based) components like the EV charger, the communication may be independent of the local controller. Note that not all the components will be used in all pilot installations.

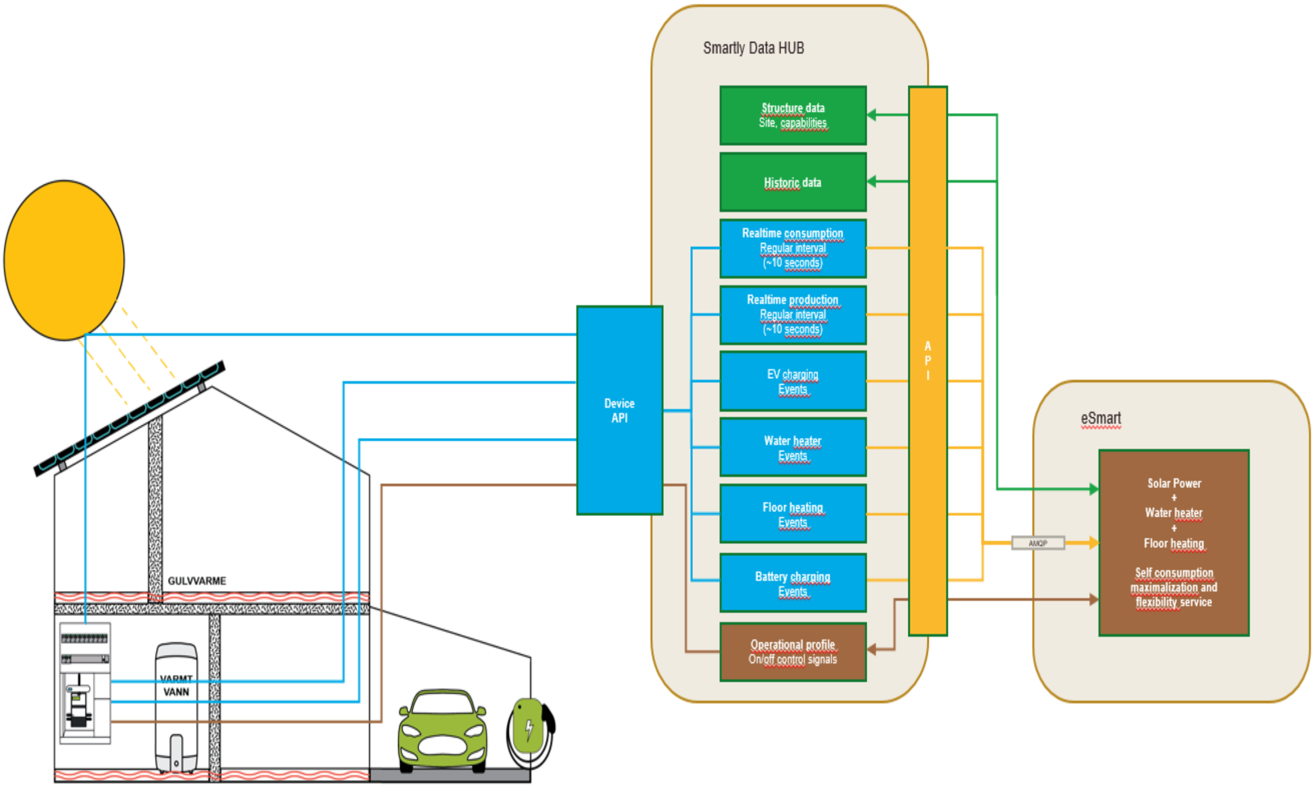

Figure 7. *Data Interfaces*

- These interfaces are separated into historical and structural data, event based data and control signals. Technical descriptions of interfaces are under construction.
- The involved device systems are part of the existing Smartly platform which includes HAN-meter data (under construction), battery cloud (under construction), solar inverter cloud, EV charging and Home automation cloud (water, heater and floor heating).

2.1.3.3 Flexibility Services

The flexibility services outlined in project deliverable D4.1, section 8.1 are relevant for the Norwegian pilot. The services that will be provided to the pilot installations are:

1. **Time of use optimization:** Load shifting from high-price to low price intervals, in order to reduce energy bill for the prosumer.
2. **kW max control:** Reducing the maximum load (peak shaving) within a predefined duration, in order to reduce the energy bill for the customer where this is applicable. If no real power-based tariffs are in place, these will be emulated to prepare for the onset of such tariffs in the Norwegian market.
3. **Self-balancing:** Maximize economic gain for self-production and storage. Typically, this will involve consuming as much of the produced energy as possible within the prosumer premise, minimizing the amount of energy that is exported to the grid.

Flexibility customer	Flexibility services INVADE	UC4: Hybrid
DSO	Congestion management	N
	Voltage / Reactive power control	N
	Controlled islanding	N
BRP	Day–ahead portfolio optimization	N
	Intraday portfolio optimization	N
	Self-balancing portfolio optimization	N
Prosumer	ToU optimization	Y
	kW_{max} control	Y
	Self-balancing	Y
	Controlled islanding	N

Table 3. Flexibility Services

2.1.3.4 Equipment

a) **Main Meter**

All pilots in Norway will use the meter data provided from the DSO. There is an ongoing process on how to integrate to get the data into the Smartly Cloud. The integration will be a cloud to cloud solution to provide the data into the INVADE platform.

Figure 9. *Main meter*

b) **EV Charger from Schneider**

The pilot in Norway will use Smart chargers from Schneider in all the pilot locations for households. Schneider is a leading technology supplier of chargers in the Nordic. The only integration with Schneider is to the Smartly cloud solution through API and use of the OCPP standard. Smartly support all chargers that uses the OCPP standard.

https://www.schneider-electric.co.uk/en/product-category/80060-electrical-car-charging/

Figure 10. *EV Charger*

c) PV panel/ inverter

Regarding PV solution for the pilot, inverters from Fronius will be used. Fronius inverters can be controlled using third-party components. The Modbus TCP and Modbus RTU open interfaces are available for this purpose. There is also possible to use digital inputs and outputs. Fronius cloud also has an API to integrate platform to platform between ecosystems.

https://www.fronius.com/en/photovoltaics

Figure 11. *Fronius PV Inverter*

d) Storage

Home batteries will be provided by Nissan/Eaton for the selected households in the Norwegian pilot. The batteries are made for residential use and meets all requirements and regulations for batteries installed in a home environment. In the project the batteries will be used in all the Flexibility services provided by the invade platform: Time of use optimization, KW max control and self-balancing.

The existing battery solution provided by Fronius in profile G will be upgraded to meet the pilot needs. In this profile the battery has been upgraded with 4 additional battery units that gives a 10 kwh 2- way storage capacity. The battery will charge and discharge in combination with solar production and EV-charging to optimize utilization of self-produced energy and load management provided by the Invade platform.

Both batteries use the same battery technology which is lithium-iron phosphate battery - guaranteeing a long service life, short charging times and a high depth of discharge which is an important recruitment for the flexibility services.

Battery

- ➔ Battery supplier for the pilot will be Eaton Electric. The battery xStorage Home solution are using Nissan`s battery technology combined with technology from Eaton Electric. The battery cells come from recycled car batteries. xStorage can be controlled using third-party components: LAN, RS-485, USB Host (with USB WIFI dongle) USB: Type B receptacle for firmware upgrade, CAN BUS: Only for battery pack - inverter internal comms, Comms Protocols HTTP REST API.

http://electricalsector.eaton.com/energystorage?wtredirect=www.eaton.com/xstorage

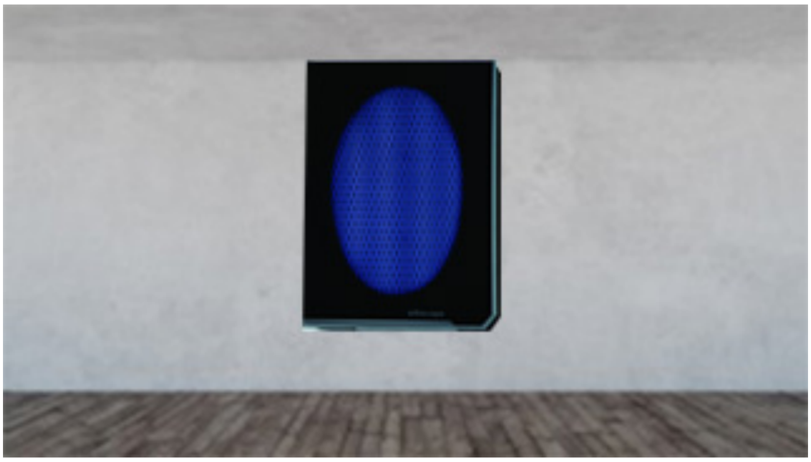

Figure 12. *Nissan/Eaton Battery*

e) Smart home components

The smart home components will be provided by Smartly AS. Smartly is a Smart home service provider. Components used in the project are water heater controllers and heating systems. The components will be controlled locally via a smart gateway, using the wireless home automation standard Z-Wave. The gateway will be managed by a cloud system. Any integrations with the INVADE platform will be on a cloud-to-cloud level. Smartly will deliver all the smart home components and a smart gateway will enable control and monitoring of different loads in the home. https://smartly.no/

Figure 13. *Home Smart Ecosystem*

f) Fronius Solar Battery (Lyse Headquarters)

The battery pack for the existing installation at Lyse Headquarters is a part of the Fronius PV system and communicate through the Fronius inverter. Fronius inverters can be controlled using third-party components. The Modbus TCP and Modbus RTU open interfaces are available for this purpose. There is also possible to use digital inputs and outputs. Fronius cloud also has an API to integrate platform to platform between ecosystems.

http://www.fronius.com/en/photovoltaics/products/all-products/storage-units/fronius-solar-battery/fronius-solar-battery-4-5

Figure 14. *Solar battery - Fronius*

g) **Zaptec Chargers (Lyse Headquarters)**

The pilot in Norway will use smart chargers from Zaptec in the existing pilot location at Lyse headquarter. Zaptec is a leading technology supplier of chargers in the Nordic and have their head office in Stavanger. The only integration with Zaptec is to the cloud solution through API. The Zaptec cloud will be integrated into the Smartly ecosystem.

http://www.zaptec.com/

Figure 15. *Zaptec charger*

h) **V2X**

Ongoing dialog with Nissan and UPC to provide us with this bidirectional charger for EV`s.

2.1.4 PUC - Use Cases

According to the type of user profiles listed below:

- Profile A: Heating control 3 zones + water heater control. 10 installations in private households with an existing PV system.
- Profile B: Smart EV charger. 20 installations in private households.
- Profile C: 10 kWh battery energy storage. 10 installations in private households.
- Profile D: 3 kWp solar plant + 10 kWh battery for energy storage. 5 installations in private households.
- Profile E: 3 kWp solar plant + 10 kWh battery for energy storage + Smart EV charger. 6 installations in private households.
- Profile F: 3 kWp solar plant + Smart EV charger + water heater control. 9 installations in private households.
- Profile G: 7 kWp solar plant + 10 kWh battery for energy storage + 11 Smart EV charger (200 end users). Lyse Head office
- Profile H: 50 EV chargers in Housing cooperatives. (500 end users)

The use cases in Stavanger will be based on the next PUCs:

Use case 1: The use case involves **mobile energy storage** using EVs with focus on V2G, V2B and V2H operations along with higher renewables integration.

- Profile B.

Use case 3: The use case focuses on **distributed energy storage** units spread across multiple households.

- Profiles A, C, D, E1, E2:

Use case 1 and 3 can also be used in combination in case E1 and E2 profiles. Case C could also simulate an EV since bidirectional cars still difficult to get hold of.

Use-Case	Technical research questions to be answered by pilot	User/Business related research questions to be answered by pilot

PUC-1 & PUC-3	How can the integrated INVADE platform best interact with an existing home energy management system? Does the equipment suit the short and long-term purpose defined? (To create new energy related services and to keep and recruit new customers in the future)? What need is there for improvement regarding hardware, software, protocols etc?	How can a customer save money by participating in a regime like we design here? How can we create added value for our 100.000 end-customers? How should we price and sell the future product/service? What is the most suitable business model? How can all this produce an advantage into the next level of energy related services? How can we demonstrate the ability of the integrated INVADE platform to co-operate with an existing home energy management system?
PUC-1	How can the test for 27 apartment buildings scale-up?	

Table 4. Research questions to be answered. Norway

Use-Case	Provisions for each use-case
PUC-1	Tested INVADE platform Sufficient access to chargers and cars that support V2G Access to the targeted charging spots and EVs

PUC-3	Tested INVADE platform Access to relevant home energy management system Access to the targeted households

Table 5. Prerequisites and necessary provisions for each case are listed in each pilots chapter

Use-Case	Potential and current impediments to be handled
PUC-1	Immature technology – specially with respect to V2G Still unclear about the availability of 2-way chargers from Nissan Understanding the relationship between the end-user, the local service provider and the integrated INVADE platform Lack of funds
PUC-2	The Norwegian pilot does not have any street batteries at this time. Focus will be place
PUC-3	Understanding the relationship between the end-user, the local service provider and the integrated INVADE platform Very rapid development in user centric energy management equipment Lack of funds to scale up quickly Sufficient activation/engagement of households

Table 6. Impediments

2.2 Netherlands

2.2.1 Definition

The pilot in The Netherlands will be focused on the impact of electric vehicle charging on the electricity network and the possibility to use as much as possible renewable energy, meanwhile keeping the energy grid in balance. This will be done as much as possible with the use of standard or de-facto standard protocols between systems.

The pilot is split in several categories or sub-pilots in order to do unique trials, experiments and create learnings on small scale as well as involving large amount of charge stations and users (EV drivers) to make impact on large scale. Following categories are foreseen:

1. Small scale home sub-pilot with several homes and known private users
    - 22 private homes with in total 25 charge points. 3 homes will have 2 charge points. Installed in different locations in The Netherlands connected to different grids
2. Large scale offices and parking lots sub-pilot, for semi private/public situations and unknown users.
    - 25 offices and parking garages with total of approximately 300 charge points, distributed across The Netherlands
3. Small scale public office sub-pilot with known users, with solutions that can finally also be used in other public situations, e.g. energy storage and Vehicle 2 Grid.
    - ElaadNL offices in Arnhem (The Netherlands) with known users (employees) and visitors
4. Large scale public sub-pilot with about thousand charge points and many unknown users. This pilot is focussed on smart charging on very large scale in the public domain.
    - Location of chargers in public domain spread across The Netherlands. Stations are already installed and in use. Users are customers from many different Mobility Service Providers. Only IDs are known.

Regarding the sub-pilots two and four, we will be able to show large scale impact of charging and also the possibility to use the results of the pilots on large-scale

2.2.2 Large Scale Proposal

As described above, the sub-pilots in The Netherlands are split in smaller sub-pilots where we can do more trials and have more interaction with the end users. Additionally, large-scale pilots that will have real impact on the grid, grid management and its flexibility. The large-scale pilots are also easiest to scale up.

A large-scale pilot has the following requirements:

- It must be able to scale up, copy and reusable for a large group of users in relative short period.
- The number of users must be large enough to come to conclusions.

This means that the tools/products/services used must be at least near to market and interaction with end users (persons) will be limited.

It is shown in the next picture is the difference between small and Large Scale proposal.

	What we do on large scale	What we do on small scale
At home	-	• 25 charge points • Smart charging (see use case) • Data analytics Responsible party: Greenflux

At the office	• 200 - 400 charge points
	• Customer experience research, including app
	• Passive user involvement (thousands)
	• Smart charging
	• Data analytics
	Responsible party: Greenflux
		• Vehicle to grid (1 EV at Elaad premises)
		• State of Charge determination (Elaad)
		    • 5 cars at Elaad
		    • Retrofit measuring device in the EV
		• Stationary battery
		• Active user involvement
		• Development DSO capacity forecasting system / flexibility signals
		• 15118 is not in scope (no cars, no chargers, no final version of the standard)
		Responsible party: ElaadNL

Public charging	• 500 – 1000 charge points • Passive user involvement (10.000+) • Smart charging (incl. use renewable energy, see use case) • Smart charging ready charge stations • Data analytics Responsible party: ElaadNL	

Table 7. Large /Small Scale EV differences

2.2.3 Technical Characteristics

2.2.3.1 Grid Topology

The main setup of all 4 sub-pilot areas is the following diagram:

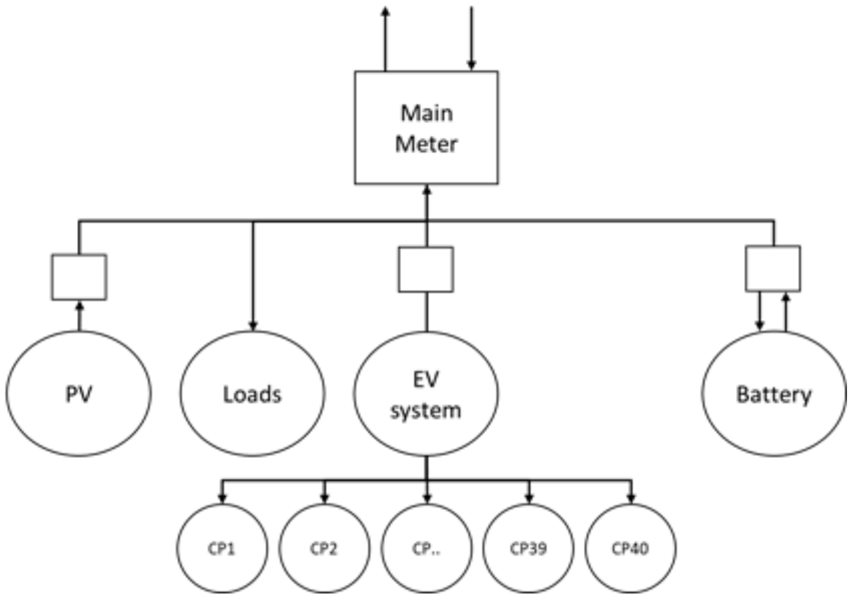

Figure 16. *EV Grid In Netherlands*

The charge points (cp 1, cp 2…) can be grouped with different power e.g. 3 groups of 250A. For pilots with the offices and parking lots this will be done that way. For the pilots at homes and in public area they will not be grouped.

2.2.3.2 Technical Details

Use of protocols

The pilots in The Netherlands will rely as much as possible on open independent protocols which can either be standards or de-facto standards. This way, the used architecture will not contain vendor lock-in situations between systems

Main used protocols are:

- Open Charge Point Protocol (OCPP): smart management of charge stations
- Open Charge Point Interface protocol (OCPI): support smart charging profiles, roaming between parties and exchange of data like charge data records, static

and dynamic charge station information and charge tariff information

- Open Smart Charging Protocol (OSCP): for communication of day ahead available energy capacity, split in short periods to support smart charging.

The INVADE pilots will result in experience of these protocols in a very flexible energy market. These experiences will be shared with the protocol responsible organisations to improve the protocols based on real world experience.

Overall Technical architecture

The diagram below shows the overall architecture for the NL pilots. The Greenflux and ElaadNL platform will work together with the eSmart platform.

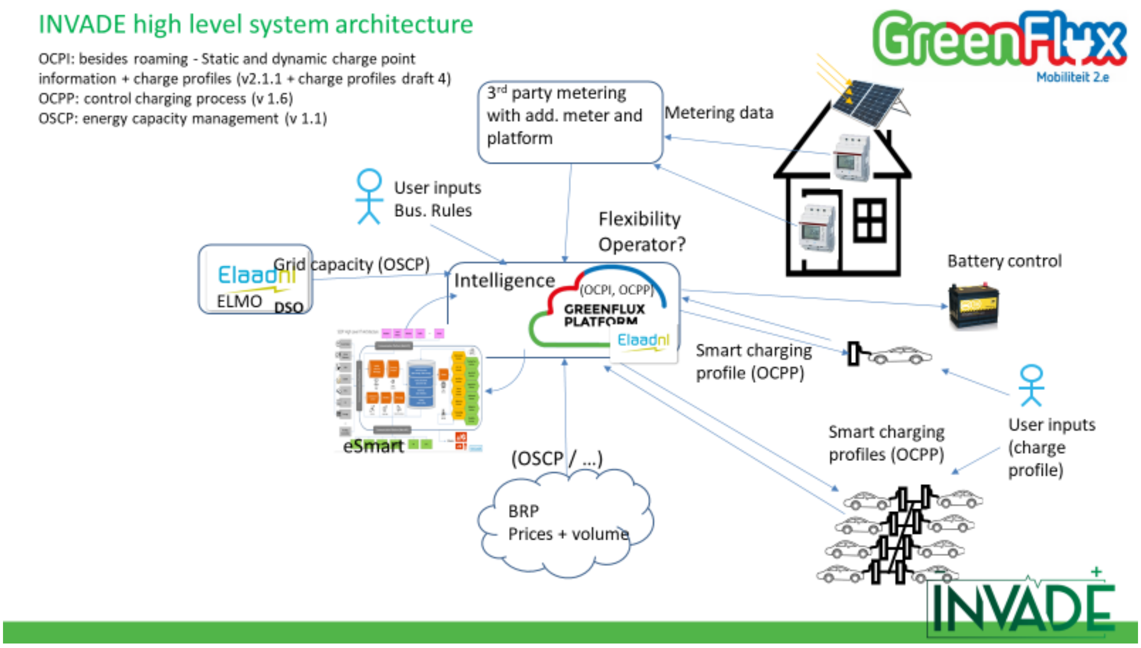

Figure 17. *Invade High Level System Architecture*

The following input will be combined in The Netherlands pilot.

- Energy usage/consumption from buildings
- Energy production from PV installations (where installed)
- Energy availability from the energy grid (day ahead)
- Energy prices
- Expected energy request for building and for charging the electric vehicles

- External input: weather information, info about events that need a lot of energy etc.
- Available energy in the local energy storage

All this information is shared with the eSmart platform and result in following output:

- Improved energy profiles: i.e. what amount of energy is available at what moment against what price
- Smart charging profiles: profiles for charging electric vehicles at certain moments, based on the improved energy profiles

As described the in previous sections, The Netherlands is split in 4 different pilots / use case to cover all possible situations, to be able to use innovative solutions on small scale and to demonstrate the use of renewable energy in a smart way on large scale. This is split in private, semi-private, semi-public and public situations.

The type of end customer for of each sub-pilot will be described below.

- **Sub Pilots**

a) Private homes, small scale

In total app. 25 households will be selected, who already have charge stations from Greenflux installed on their own premises. Each of them will have a dynamic energy contract; if not it will be offered as you can change energy contracts easily in The Netherlands. A nice to have is for this households to also have solar production. Should the solar production not be present on the same premises, then the solar production is simulated by using data from another solar roof nearby.

The energy services for this pilot are:

- Consumption and Generation
- Flexibility Management
- EV Management

Used Flexibility Services: ToU optimization and Self Balancing

Charging will be done as much as possible on the production of the own solar panels on the roof. When there is no or too little production from the solar panels (e.g. at night time), power will be drawn from the electricity grid, taking into account dynamic energy prices based on the hourly rates of the day ahead market.

We measure the real-time solar production via third party metering company which will be sent to the GreenFlux platform and (via the GreenFlux platform) to eSmart. The prices from the day ahead market via an API either directly with the Amsterdam Power eXchange (APX) or the energy supplier. This data will also be shared with eSmart. eSmart will use the incoming data to determine an optimal charge profile for the electric vehicle which will be sent to GreenFlux via OCPI. GreenFlux will then execute the charge profile in the Charge Point via OCPP.

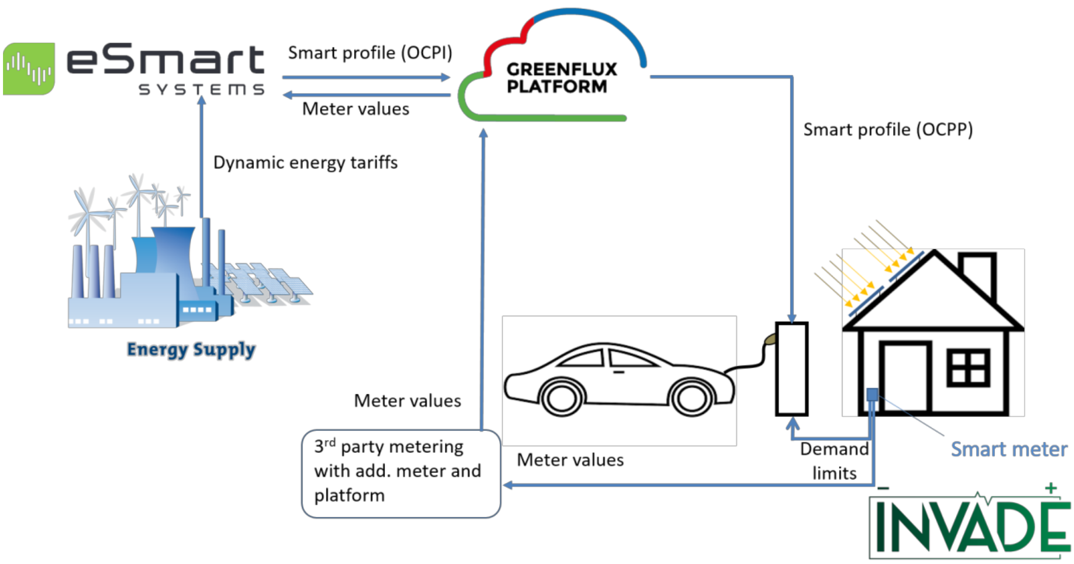

Figure 18. *eSmart System in combination with the Greenflux Platform*

Greenflux is an operator that can work with all kinds of charge stations, as long as they use the OCPP protocol. Enclosed some of the chargers that will also be used in the pilots.

b) Offices and parking lots, large-scale

In total, approximately 300 charge points will be selected at different offices and parking lots.

Charging will be done as much as possible on own solar production. If not or not enough available, power will be taken from the grid. This will de facto mean that when the sun is not shining the total capacity for the charging EVs is ‘just enough’ and charging rates (speed) are increased when the sun is shining.

eSmart will use meter values from the solar production (via 3rd party metering) and weather forecasts to predict the available renewable energy production. eSmart will combine this prediction with the available capacity in the building (fixed value, sent by GreenFlux during configuration) and thus create a capacity forecast which is sent to GreenFlux via OSCP.

In this sub-pilot, there will be multiple EV's on one grid connection. Based on the OSCP, GreenFlux will use a smart algorithm to divide the available capacity over the different EVs in an FRAND (Fair, Reasonable and Non-Discriminatory) manner. User input will be taken into account via the GreenFlux app.

The energy services for this pilot are:

- Consumptions and Generation
- Flexibility Management
- EV Management

Used Flexibility Services: Self balancing + KW Max control

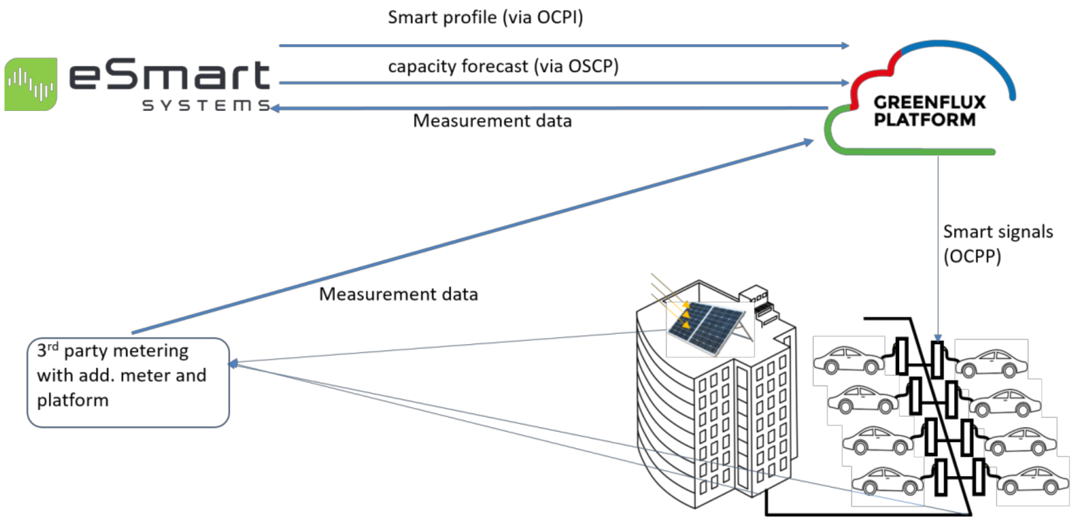

Figure 19. *Offices and parking lots, large scale*

Above figure shows the setup of the pilot in relation to the main connected systems. GreenFlux and eSmart system exchange data with meter value input. This is combined and used to manage the energy usage of the electric vehicles, based on the available energy forecast and to inform the energy companies via the eSmart about the needed energy from the vehicles.

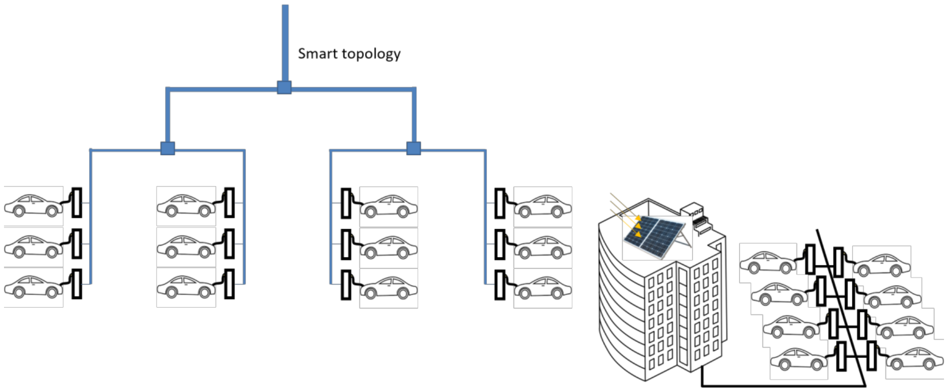

Figure 20. *Smart Topology*

Above figure shows the high-level grid topology that is used for this pilot. When more vehicles are connected then the grid connection can handle, smart charging is required. This way with even though the grid connection is limited, many vehicles can be charged.

c) Small scale office/public charging

This site will have 2 different use cases.

c.1 - Local self-balancing of charging sites

Goal

This use case describes small scale office charging in the Netherlands, with the goal of local capacity management on EVSE while gathering real-time information on the energy use of both the other EVSEs and other loads on the local site. Controlling a single site is in many ways a faster way to achieve the monitoring and control possibilities that are not yet available on the public infrastructure at large.

Specifically, this use case will develop optimal charging and discharging strategies for local storage based on external factors and predictions of renewable energy generation, electric vehicle charging, et cetera.

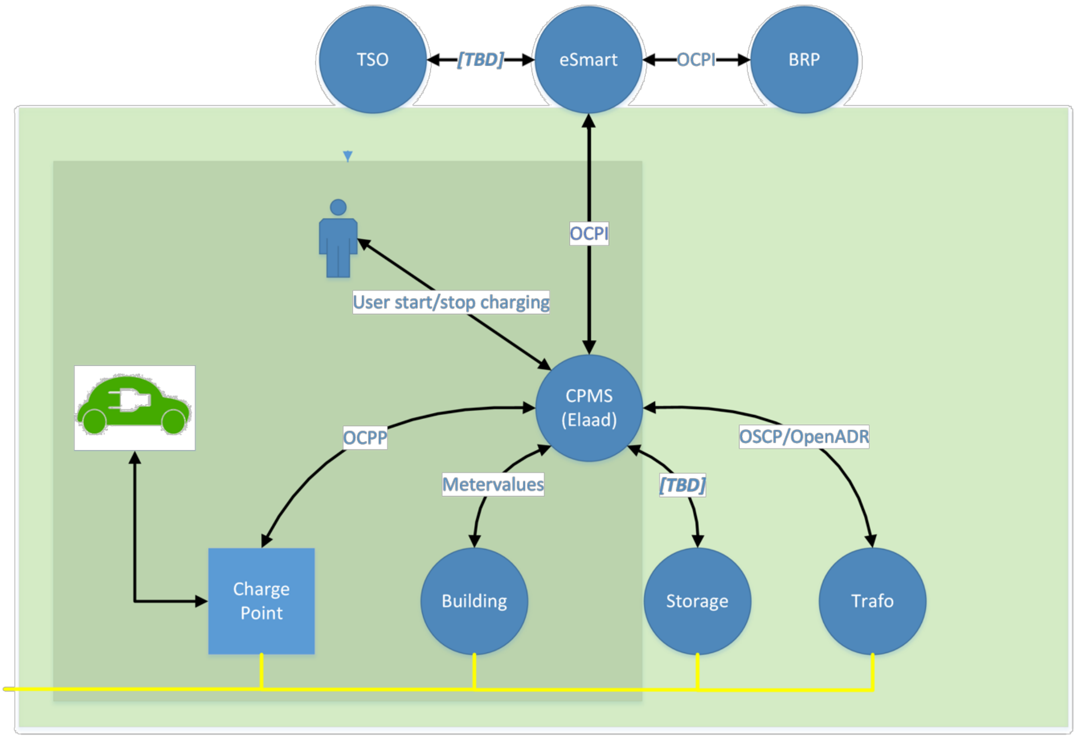

Figure 21. *Local self-balancing of charging sites*

Note1: Dark green area: local load balancing, capacity of the charge point will be adjusted to the capacity of the building by the Charge Point Management System.

Note2: The light green area: Static storage, add of a container with a transformer provides the available capacity. Storage will be used as extra buffer.

Note3: TBD in the picture means that the exact used protocol is still part of further research and will be described in next documents.

2.2.3.3 Flexibility Services

The table below shows the flexibility services that are going to be implemented in each of the Dutch pilot cases.

Flexibility customer	Flexibility services INVADE	Large scale office	Large scale public	Small scale home	Small scale public & office
DSO	Congestion management	Y	Y	Y	Y
	Voltage / Reactive power control	N	N	Y	N
	Controlled islanding	N	N	N	N

BRP	Day–ahead portfolio optimization	TBD	TBD	TBD	TBD
	Intraday portfolio optimization	TBD	TBD	TBD	TBD
	Self-balancing portfolio optimization	TBD	TBD	TBD	TBD
Prosumer	ToU optimization	Y	Y	Y	Y
	kWmax control	Y	Y	Y	Y
	Self-balancing	N	N	Y	N
	Controlled islanding	N	N	N	N

Table 8. Flexibility services to be used in the Dutch pilot (Y: yes; N: no, TBD: to be determined

2.2.3.4 Equipment

Equipment needed for the pilot in The Netherlands is:

• **Electric Vehicle charge stations**

The charge points used for this pilot come from many different manufacturers that all have very different hardware configurations. It does not add value to add all the detail specs for each model from each brand here. Having said that, they all need to do metering and for that purpose the (almost) all use the same type of meters: ABB B23, Carlo Cavazzi or Eastron.

a) **Vehicle to grid charge stations.**

The only vehicle to grid chargers available at this moment are ChaDeMo chargers used

The new generation DC-chargers for V2X will be available and tested.

b) **Smart controllers to do smart charging.**

This is very different between charge point manufacturers and even between different models from the same manufacturer. As external interface to this controller they do all speak OCPP1.6.

c) **Storage**

Below an example of the type of energy storage we are looking for. This example is from Alfen. Final details about capacity and specifications are not yet agreed.

Work package 6 is involved for the final selection and specifications.

Figure 22. *Energy storage from Alfen*

d) Electric Vehicles, at least one with V2G capabilities.

For vehicle to grid currently only one type of charger is available on the market, and that is a DC charger that uses the ChaDeMo with the car. The new generation of DC-chargers from Schneider will be available for testing in V2X for INVADE.

e) Tokens / cards to use the charge stations.

Currently the tokens/cards used to identify the user at a charging station are MiFare classic. Within the Netherlands we have roaming in place. This means that regardless of the eMobility service provider that issued the card, anyone can charge at (almost) any station, even though it is from a different charging network.

A large part of the needed equipment is already installed at the pilot locations.

There will be used many different charge stations as only existing stations are used. The following picture gives an example of the possible chargers. Maximum power per charger is 22kWh.

Figure 23. *22 Kwh Charger*

Figure 24. *Some of Greenflux operated chargers*

2.2.4 PUC - Use Cases

The NL pilots focus on use case 1 **(PUC-1**): Mobile energy storage using EVs for V2G, V2B and V2H operations

The use case involves mobile energy storage using EVs with focus on V2G, V2B and V2H operations along with higher renewables integration. The research and innovation components to be researched, developed and piloted here are: flexibility management system including demand-response schemes, integration of renewables, EV battery life-cycle analysis, energy informatics, users' practises and behaviour analysis as well as specific business models related to EV-based storage services involving individuals, communities, business establishments, energy retailers, aggregators and DSOs. This use case will demonstrate a link to the transport sector using renewable energy sources in each pilot site.

In each sub-pilot, electric vehicles are the main component as flexibility source.

The research questions that will be addressed are listed in Table 9. Prerequisites and necessary provisions for each case are listed in **¡Error! No se encuentra el origen de la referencia.**. Potential and existing hurdles that the pilot must address have been identified and listed in Table 11.

Use-Case	Technical research questions to be answered by pilot	User/Business related research questions to be answered by pilot
PUC-1	- Can existing standard protocols support smart charging and create links to other systems like the INVADE cloud? Are there any technical hurdles to take before we can do a large scale roll out?	Is flexibility a good alternative to infrastructure upgrades? What is the business potential in smart charging? What is the impact and benefit of smart charging as part of flexibility management on the grid? We expect that this pilot gives insight and proof of that. - Is there a business case for the EV driver/owner?

		Are there enough benefits for an EV driver/owner to actively implement and use Smart Charging? What is the business potential of a Flexibility Operator and a company like GreenFlux? Is there a good business case for GreenFlux to continue with this and on what terms?

Table 9. Research questions to be answered by the Dutch pilot

Use-Case	Provisions for each use-case
PUC-1	The INVADE FO cloud/ICT platform supporting the GF/Elaad business model must be completed and connected to the Greenflux management platform, Access to 22 private homes with 25 charge points Access to 25 offices and parking garages with up to 300 charge points Access to small scale and large scale public facilities, with up to 500-1000 charge points Protocols: Open Charge Point Interface protocol (OCPI), Open Smart Charging Protocol (OSCP), OCPP v 1.6 Access to local feeds i.e. PV to be dedicated charging Battery for energy storage A selection of the charging stations should be vehicle to grid.

Table 10. Prerequisites and necessary provisions for the Dutch pilot

Use-Case	Potential and current impediments to be handled

PUC-1	Lack of business case and available 'products' for V2X parts of the project. When writing the proposal, it was expected that these developments would go much faster. Getting a car to do V2G requires a protocol between charge point and car that can handle this. This would be IEC-15118. There are no production cars and very few charge points on the market that support this yet. This is all still very experimental. Extensive V2X is dependent on this development. OCPP2.0 is planned for release in April 2018. Apart from pilot implementations by the developing partners market adoption is dependent on business cases. Given the experience with previous releases of OCPP this will be very gradual and for the purpose of this project, and the large-scale element, we cannot assume 2.0 implementations are available in time. This means that we have to rely on OCPP v1.6. For V2G and V2H a lot depends on availability and affordability of vehicles and chargers that can deal with this, and that is lacking behind expectations when the project was described – so large scale on this area is impossible in this project. However, we will do some testing with V2G.

Table 11. Potential and existing impediments for the pilot

The various sub-pilots constituting Prerequisites and necessary provisions for each case are listed in Table 9.

Use-Case	Provisions for each use-case
PUC-1	The INVADE FO cloud/ICT platform supporting the GF/Elaad business model must be completed and connected to the Greenflux management platform, Access to 22 private homes with 25 charge points Access to 25 offices and parking garages with up to 300 charge points Access to small scale and large scale public facilities, with up to 500-1000 charge points

	Protocols: Open Charge Point Interface protocol (OCPI), Open Smart Charging Protocol (OSCP), OCPP v 1.6 Access to local feeds i.e. PV to be dedicated charging Battery for energy storage

Table 12. Required provisions for the pilot

2.3 Bulgaria

2.3.1 Definition

The pilot in Albena, Bulgaria, is going to demonstrate how a centralised battery storage could contribute to the overall energy efficiency of a large number of consumers, ref Figure 25. It will also address the benefits that electric vehicles can offer on its own and in combination with a centralized and stationary battery unit.

At the site of the five-star-hotel Flamingo Grand, a PV installation and a battery with inverter will be installed in order to increase the share of the renewable energy that is used.

The motivation of the project is based on the fact that a large share of renewable energy sources brings volatility into the grid energy consumption. In some cases, this volatility could lead to financial penalties by the grid operators or energy suppliers, which would cause increase instead of decrease of the energy costs. By using battery storage systems and smart charging of EVs, the consumption of energy can be controlled/balanced. Energy management approaches like peak shaving, peak shifting, valley filling, etc., may change the form of the curve of used power. Using constant residual power from the grid will lead to financial benefits for the owner and thus, make the business model of the project profitable.

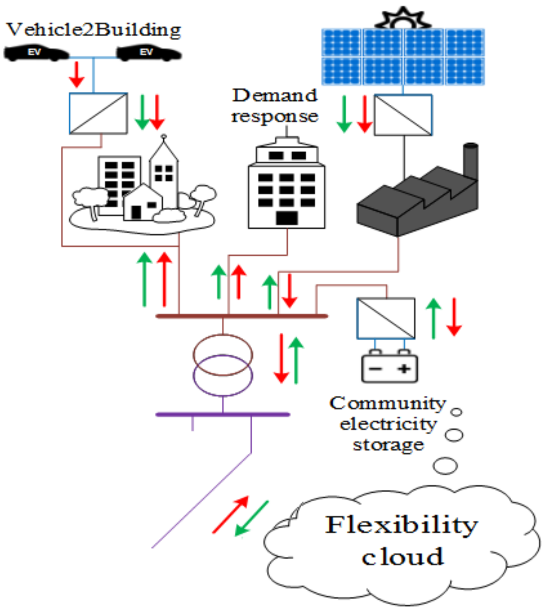

Figure 25. *The basic set up for the Bulgarian pilot (from D7.1)*

2.3.2 Large Scale Proposal

Large scale is defined as the capability of the project to attract more stakeholders. The demonstration of the potential all kinds of batteries in various energy market conditions is the goal of the pilot in Bulgaria. In Albena, most of the tourists don't use their cars for the whole duration of their stay. The batteries of their EVs can be used to create added value for the energy grid. Therefore, the pilot site will be extended by adding bidirectional charging stations for EVs. This way the pilot site in Bulgaria will demonstrate not only the advantages of the centralized energy storage, but also show how a small pool of interconnected charging stations can be created, that will represent another centralized battery storage.

The pilot site encompasses hotel facilities with 17 000 beds. At the high season (July and August) the hotels are 98% full. Depending on the economic situation in Europe facilities offered for the pilot meet around 200 000 tourists annually. They make more than 1.500.000 overnights. The number of tourists that will be impacted is highly dependable on the communication and dissemination plan of the project which also seeks to integrate such efforts into each pilot and especially in the Bulgarian pilot. The idea is to activate, raise engagement, for instance among the EV owners and create a green energy commitment that they can bring home. In addition it is an aim to leverage this to a strategic level so that tour operators acknowledge the added value of green resorts. The value of building social and environmental conscience have proven successful in other domains and the pilot will seek to cater for this too. The goal is that every single adult person (older than 14 years) in Albena gets to know what is going on in hotel Flamingo Grand and in Albena in general. Already, we have engaged ourselves with such stakeholders in order to discuss this potential.

During the winter season tourists will be absent and only a very small part of the hotels will be offering beds for guests. That suggests a greater energy surplus that can be tactically to serve the Bulgarian market at times when demands are high. Smart management of the centralized battery, to maximize payback and provide a sustainable service for a BRP is of principal interest. The INVADE platform decides if the battery should charge or discharge or just stay idle. First, it needs information about what energy consumption was forecasted for the current hour (by the BRP). Then it needs to check what was in fact consumed (information from the SCADA). Then it needs to make financial assumption based on the current imbalance prices on the energy market. In order to keep things simple, the connection to the BRP will first be made manually. I will provide them acces to send us what consumption they have forecasted. Meanwhile, we will arrange automatic information exchange. There is a risk that whey wouldn't like to share that information. The current status - they will cooperate.

2.3.3 Technical Characteristics

2.3.3.1 Grid Topology

An overview of the current electrical situation of the energy supply of the pilot site is given on Figure 26.

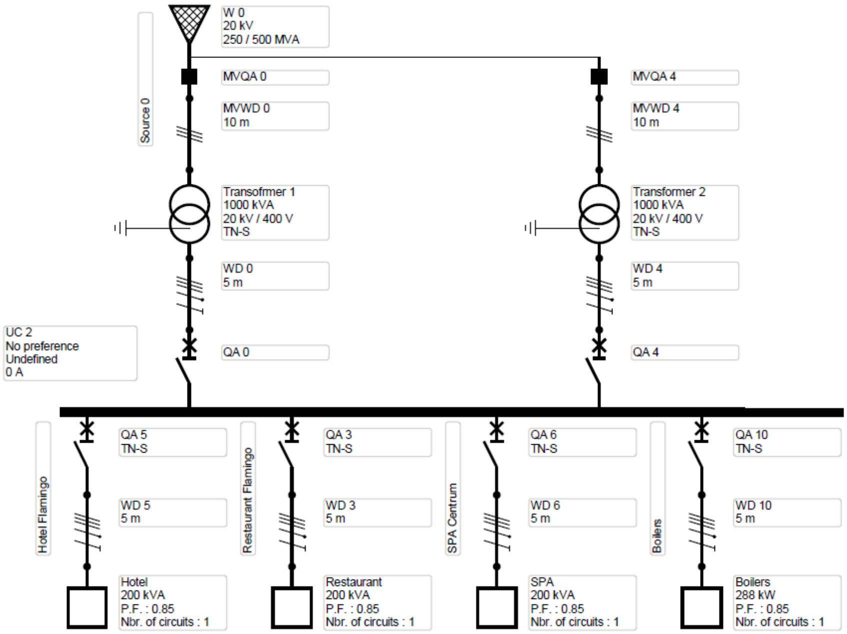

Figure 26. *Current Situation on site*

The Hotel is supplied with electrical energy directly at a transformer station 20/0,4kV, owned by Albena. Two electrical voltage transformers – one operational and one reserve, are connected to the middle voltage network, also owned by Albena. At the low voltage side, diverse consumers are connected – two hotel parts, a restaurant, a SPA centre and a boiler room.

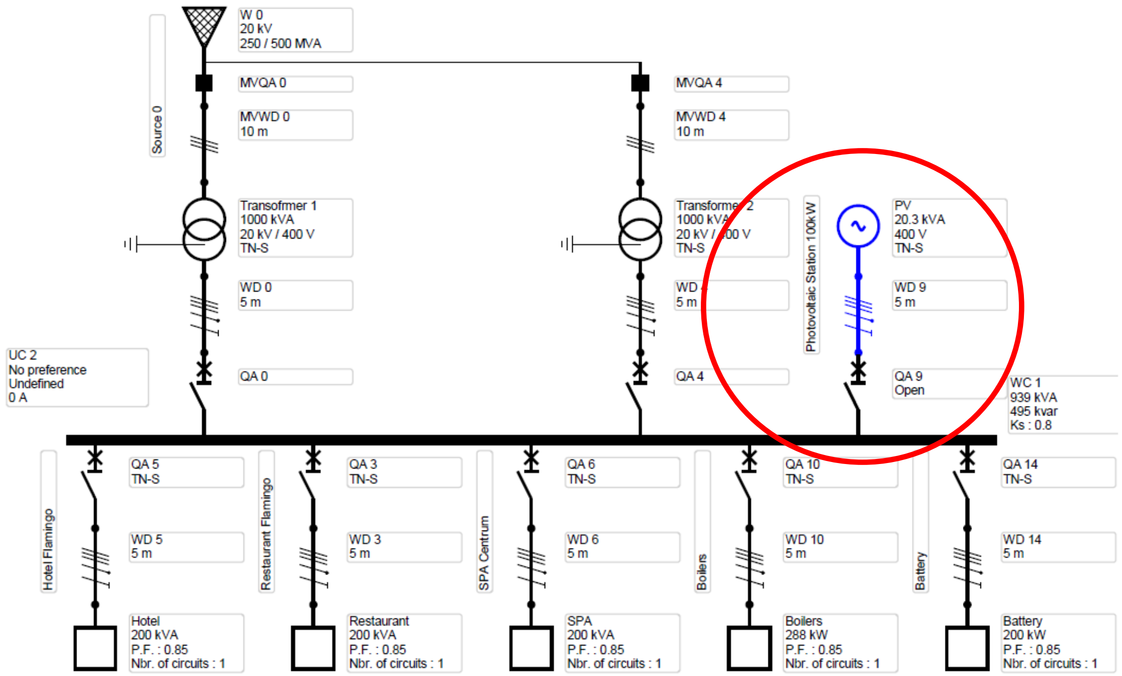

Figure 27. *A battery and a PV system will be added*

2.3.3.2 Technical Details

Within the INVADE project a Photovoltaic generator ~100kWp with the corresponding inverters will be installed, as shown in Figure 28. The PV system is intended to increase the renewable energy generation at site. The battery will have tentative capacity of 200 kWh, which will give the opportunity to apply it in the energy and flexibility management approaches defined, ref Figure 28.

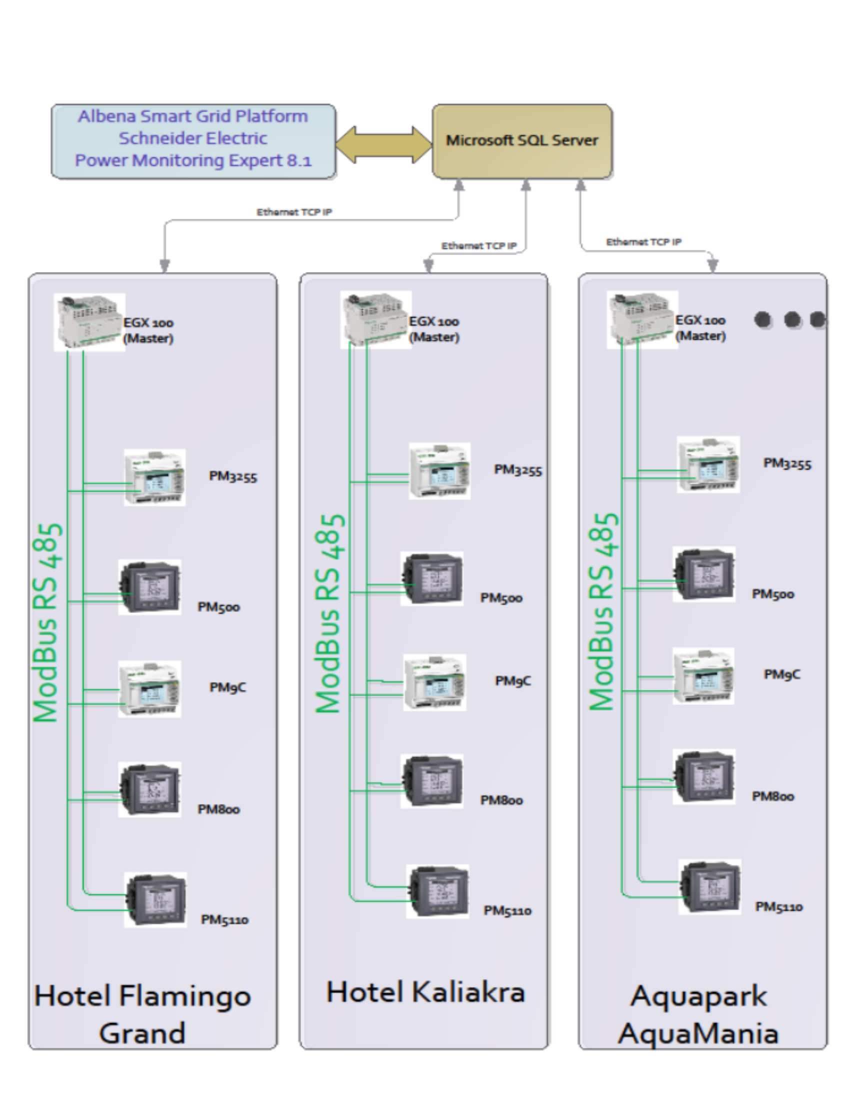

Figure 28. *Example of the communication structure in Albena*

The INVADE project architecture will be fully compatible with the already functioning energy and water SCADA StruxureWare Power Monitoring Expert in Albena – a product of Schneider Electric that is ISO50001 certified for energy management systems. Crucial part of the project is the ability of the single components to exchange information with each other. The battery and the PV inverters need to be able to communicate via Modbus in order to be able to communicate with the SCADA. Another possible way would be the use of an OPC server.

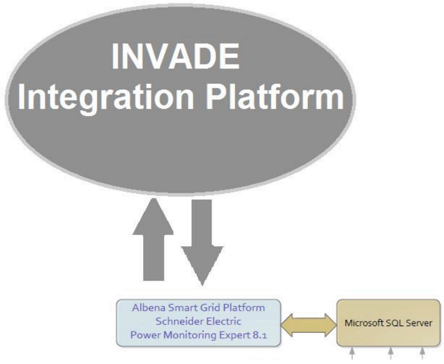

Figure 29. *Detail conection INVADE – Albenas Existing Software*

As Figure 30. implies, the power meters of the consumers communicate via ModBus RS485 with a Gateway, device that translates the signals into Ethernet TCP information that is finally stored in a SQL Database. The database contains rich information about the energy flows in the systems – for each time interval values for voltages, currents, active and reactive energy, power, frequency, etc.

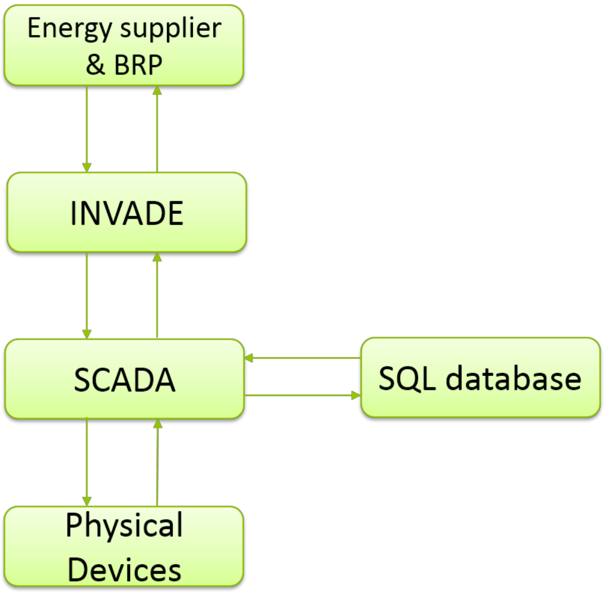

Figure 30. *Information flow between participants in the energy management system*

After the energy management data has been stored on the server it is available for analysis and for further evaluation by third party organizations. In this case this would be the INVADE platform that will provide useful energy market information. Based on that information decisions will be made in order to minimize the energy costs and offer flexibility services.

In Bulgaria in most cases the energy supplier is also the Balance Responsible Party. This means that the offered flexibility services are or could be directly related to an energy price decrease. The BRP will have the opportunity to make the battery charge or discharge based on their own calculations.

2.3.3.3 Flexibility Services

The Flexibility services that are available are all related to cooperation with the energy supplier and BRP.

Flexibility customer	Flexibility services INVADE	UC2: Centrilzed Storage
DSO	Congestion management	N
	Voltage / Reactive power control	N
	Controlled islanding	N
BRP	Day–ahead portfolio optimization	Y
	Intraday portfolio optimization	Y
	Self-balancing portfolio optimization	Y
Prosumer	ToU optimization	Y
	kW_{max} control	Y
	Self-balancing	Y
	Controlled islanding	Y

Table 13. The Flexibility services.

2.3.3.4 Equipment

Storage

The centralized energy storage will consist of modules with corresponding bidirectional power inverters. The sum of their installed energy capacity will be around 200kWh.

The equipment to be used is in negotiation phase. The system architecture will be based on the already installed SCADA system. The Battery will be driven by a battery management system that is connected to the system inverters. The system inverters that control the charging and discharging power will be managed by the SCADA system via Modbus RS-485 protocol.

On the same layer a PV system will feed in power in order to reduce the consumed power from the electrical grid. The volatility of generation will be balanced by the battery. A constant monitoring and control of the dispatched power will be done by the SCADA system.

The charging points for EVs will be also connected via Modbus RS-485 to the SCADA system. Information about the current State of Charge of the vehicles, as well as the capability to use power from it will be constantly exchanged for a constantly updated decision making.

2.3.4 PUC - Use Cases

The use cases in Bulgaria will be based on the following Use-Cases

PUC-1: The role of smart charging, V2B and EVs that are stationed at long term parking lots will be explored in tandem with the centralized battery and alone.

PUC- 2: Centralised energy storage using an array of batteries at the sub-station level that will support the Hotel/Hotels needs during the summer as well as during the winter.

The reason of these PUC´s is that the use cases of the pilot that can be implemented are based on internal energy consumption optimization.

Figure 31. shows a typical daily load profile of the hotel during the summer season. The difference in accumulated loads at low activity hours (night and early morning) compared to morning and evening is distinct. The time shift in loads can occur suddenly, depending on external factors, such a sudden rain shower. The INVADE platform should manage to predict the effect this and produce counter actions.

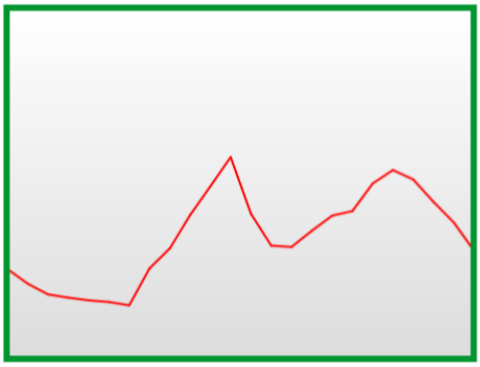

Figure 31. *A typical 24h load profile of the hotel. Early hours on the left-hand side.*

Peak power is consumed around noon at the restaurant and at evening for domestic hot water. While the noon peak is normally easily predictable, the evening peak is highly dependent on the weather. The tourists use domestic hot water when they come back to their rooms from the pools or from the beach when the sun is set. Clouds and rain usually make the tourists come back earlier which results in a shifted evening peak load. Moreover, the PV production relies entirely on the weather conditions, which makes the energy consumption from the electrical grid even more unpredictable.

The principal research questions have been listed in Table 14. .

The required provisions have been listed in Table 15. .

Potential impediments are listed in Table 16.

Use-Case	Technical research questions to be answered by pilot	User/Business related research questions to be answered by pilot
PUC-1 & PUC-2	How much energy is possible to transfer from the peak to the base? How much imbalance energy have been avoided?	Is the BRP interested in your smart energy system? Is it possible to save money with the facilities installed? What money did you spend for the pilot? Can the INVADE concept yield a profit for us? Extra - question from our competitors: Can this approach contribute to a «green and smart" market profile that generates

		incentives from the tour operators for you being green and smart? In that case - how can this added attraction value be achieved? How can hotel guests and tour operators be informed and engaged in order to acknowledge and take part in the flexibility regime established? How can we achieve the following impacts? Societal: We have 3000 employees and around 200 000 tourists (35%Germans, rising) coming to Albena each year. They will be communicated with the solutions we found or the problems we faced. How can the result of the INVADE influence them? 2. Political: As a large company we report to our ministry each year. How can INVADE influence them? 3. Financially: As a public joint share company we report success stories we create. How can the results of INVADE influence our stocks and share value?
PUC-1	How can smart charging be activated using the INVADE platform? How will V2B and V2G work?	How can long-termed parked EVs and EV-users be engaged?
PUC-2	How should the storage facility be operated?	How can the surplus produced during off-season be capitalized on together with the BRP?

Table 14. Principal research questions to be answered by the Bulgarian pilot

Use-Case	Provisions for each use-case
PUC-1	The INVADE platform connected with SCADA and tested PV panels of 100kWp installed 200kW battery installed The INVADE platform architecture must be fully compatible with the already functioning energy and water SCADA StruxureWare Power Monitoring Expert in Albena – a product of Schneider Electric that is ISO50001 certified for energy management systems. The battery and the PV inverters need to be able to communicate via Modbus in to communicate with the SCADA. The equipment to be used is in negotiation phase. Essential for the start-up of the pilot on time. The PR side of the pilot/project need enforcement Access to market i.e. intraday market based on Nord-pool is functioning since 1 week in BG. This will allow us to trade energy power flexibility.
PUC-2	To be completed

Table 15. The provisions needed for the Bulgarian pilot

Use-Case	Potential and current impediments to be handled
PUC-1 & PUC-2	The equipment required must be procured, delivered and installed on time Scalability is a matter of funding. This can be handled. Partnership with a consultant or energy trading company or acquisition of a licence are required for future capitalization Regulations are a hurdle.

	Current market power of existing players: The lack of regulation could give the DSOs possibility to block the connection of future battery generators to the distribution grid.
PUC-1	This is the V2G & V2B specific part which constitute a timewise challenge at this time

Table 16. The potential and existing impediments that the pilot must manage

2.4 Spain

2.4.1 Definition

The increasing penetration of Distributed Energy Resources (DER) together with load growth, the new requirements of decarbonization, efficiency, security and quality of power supply and the deregulation of the electricity markets have significantly changed the traditional approaches to planning, design and operation of the electrical power system. The Medium Voltage (MV) and Low Voltage (LV) levels, the distribution networks are of increasing importance. The Spanish large-scale validation area mainly involves two objectives:

1. Supply electricity to a critical building to ensure the functionalities of its important functions.

2. To install a medium scale battery in a secondary substation where its capacity can be used and shared to guarantee the previous point and to allow the possibility of production and consumption management in the validation area. This new installation will affect a group of 12 secondary substations that are interconnected.

In this sense, it is very important that this validation scenario and its technologies can interact solving congestions in the LV grid and bringing the flexibility required in the new user roles and current electrical grid challenges. To meet the above objectives, the validation area was carefully selected in EyPESA's electrical influence area, to allow the implementation and study of these upgraded grid concepts.

The validation area is in the city of Granollers, with more than 60,000 citizens at 20 km from Barcelona. EyPESA shares the distribution area in Granollers with Endesa, where EyPESA has 16,367 CUPS (Universal Code of Supply Point). The EyPESA distribution grid and secondary substations in Granollers can be seen in Figure 32. . The type of users involved are mainly residential and commercial skills.

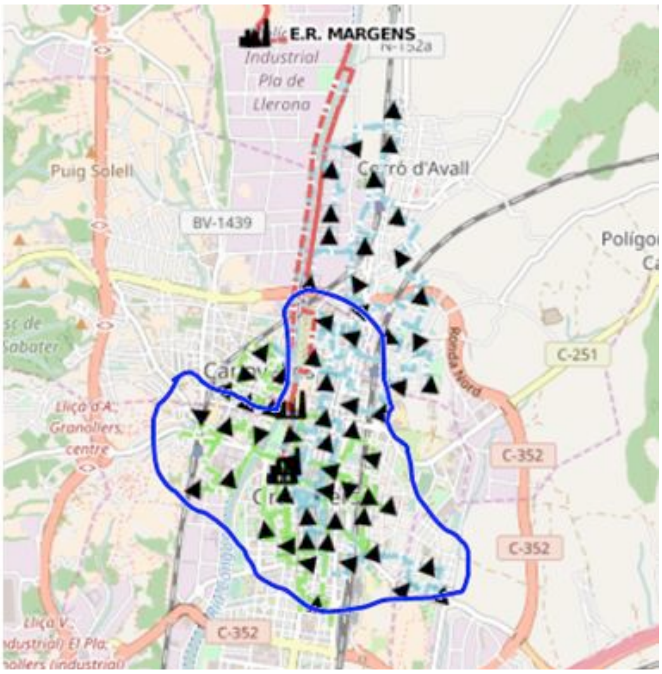

Figure 32. *Granollers EyPESA MV electrical grid*

2.4.2 Large Scale Proposal

The Spanish pilot will show how centralized storage installed at a secondary substation site can be used to provide flexibility (through the flexibility operator (FO)) to the DSO and the Balance Responsible Party (BRP) while also acting as an energy backup service to a critical site (the DSO headquarters with its control center room). A 200 kWh battery, along with a BMS and a custom developed power electronics device, will be installed inside one of the DSO's (EYPESA) secondary substations in the city of Granollers.

For the DSO, the setup will affect the grid at both the MV and LV levels, reaching 12 substations in total, with 1607 connected customers. . In the same grid area, customers will be incentivized to install distributed generation, adding to the available flexibility (at least 50% more capacity than the existing). The FO can provide flexibility to the DSO allowing more efficient grid management and minimizing the grid reinforcements needed with more distributed generation. The area covered by the pilot is connected to primary substations supplying electricity to 16,389 customers in total, and the results of the pilot can be easily extended and simulated in this part of the grid.

As for the BRP, it will be able to use the available flexibility to optimize its own portfolio. The BRP is considered such that it purchases around 4 GWh/year and supplies electricity to the retailer offering electricity to the same customers of the DSO network (1607 connected customers). Of the total energy supplied, up to 25% can come through contracts with the FO, while the rest is purchased on the Spanish electricity market. The pilot will also allow the BRP entity to be explored in a Spanish context and to assess the impact that the FO can have on the BRP's portfolio.

2.4.3 Technical Characteristics

2.4.3.1 Grid Topology

The electrical network is underground with single MV radial cables, and the validation area uses the MV topology to drive the electrical flows to the SS 535 Magatzem (orange circle in Figure 33.). It is planned to install the power electronics technology and the battery cabinet in the building of this secondary substation, connecting it to the low voltage (LV) level.

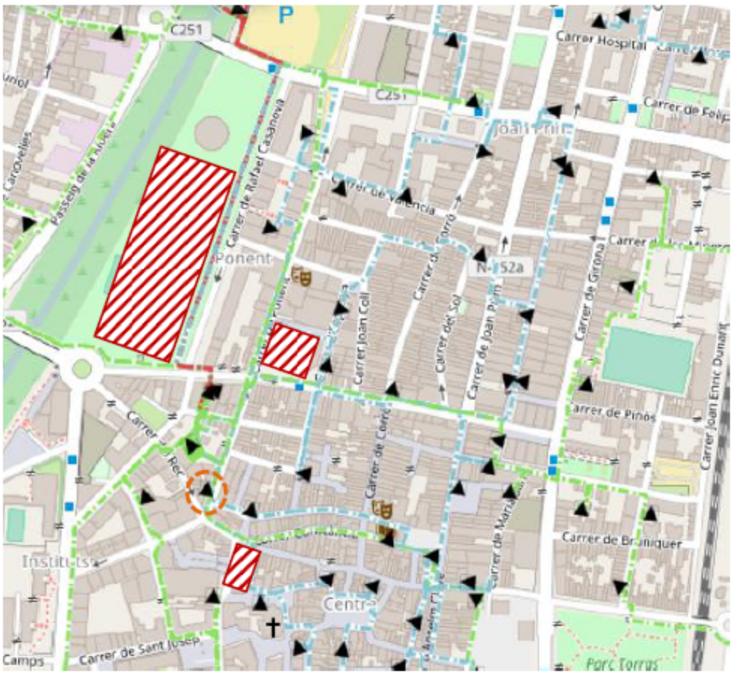

Figure 33. *Potentials surfaces to install PV in public buildings*

The Low Voltage (LV) network from Estabanell is based on the standard 3-phase with 4-wire distribution voltage, which level is 230/400V , defined in the standard IEC 60038 for underground cable distribution systems.

MV/LV distribution substations, mutually spaced at approximately 500-600 meters, are typically equipped with:

- A 3-or 4-way MV switchboard, often made up of incoming and outgoing load-break switches forming part of a ring main, and one or two MV circuit-breakers or combined fuse/ load-break switches for the transformer circuits
- One or two 1,000 kVA MV/LV transformers as a maximum power installed.
- One or two LV cabinets among four or eight LV feeders 3-phase 4-wire distribution fuse boards.

The output from a transformer is connected to the LV bus-bars via a load-break switch, or simply through isolating links.

Links are inserted in such a way that Estabanell network form radial circuits from the substation with open-ended branches Figure 34. Where a link box unites a distributor from one substation with that from a neighboring substation, the phase links are omitted or replaced by fuses, but the neutral link remains in place.

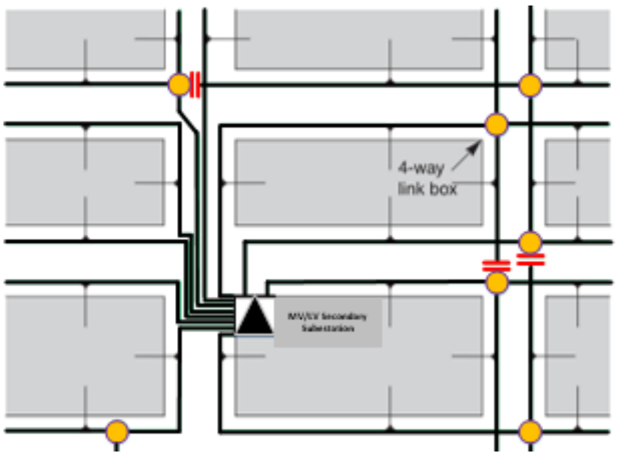

Figure 34. *LV topology network*

The Estabanell Secondary Substation involved in the project have the following performance:

SS	Contracted Power (kW)	Installed power (kVA)	LV (V)	CUPS	Houses	Buildings
535	1172,76	630	400/230	185	32	23
281	507,62	1000	400/230	180	27	32
500	891,92	630	400/230	73	24	11
930	500	800	400	1	0	1
614	957,96	630	400	58	9	11

820	375,84	630	400	44	1	6
513	731,52	400	400/230	102	19	13
299	1423,97	400	400/230	253	45	25
157	887,95	630	400/230	196	43	45
665	373,65	400	400	64	8	5
854	1.116,74	250 & 400	400&230	302	65	48
640	778,67	400	250	167	5	11

Table 17. Estabanell Secondary Substation

Each secondary substation is feeding several Universal Point of Supplier Point (CUPS). Every CUPS is composed of both a single meter in the case of households or a group of meters in the case of buildings.

Every secondary substation is constructed by medium voltage cells, with the switching system to operate at MV level the electrical grid. The transformer cell has a MV fuse as an overcurrent protection and each feeder from every secondary substation has fuses, too.

Estabanell has developed a remote management system, as a bidirectional measurement and communication system between the smart meter and the electric distributor with the maximum guarantees of integrity and security, which allows remote access to the electricity meters to read, the control of the power demanded and contracted, management of connection / disconnection of supplies, reconfiguration of the meter and other actions between the systems of the distributor and the meter. This data and order communication is done through PLC (Power Line Communications) technology using the PRIME protocol. Through the LV line of the electrical distributor, the smart meter is communicated with the concentrator located in the nearest secondary substation, and this communicates with the company's central systems by cable or 3G network. In the LV cabinet, there is a system with the data concentrator (DCU) units are collecting information from smart meters and this data is stored in the DCU, every 24 hours, the values of hourly energy are sent to the meter data collector (MDC) to start the validation process to billing process. The DCU is a device that also, it us used to be monitoring the LV bus from each secondary substation. The architecture is shown in the Figure 35.

Figure 35. *Smart Meter infrastructure*

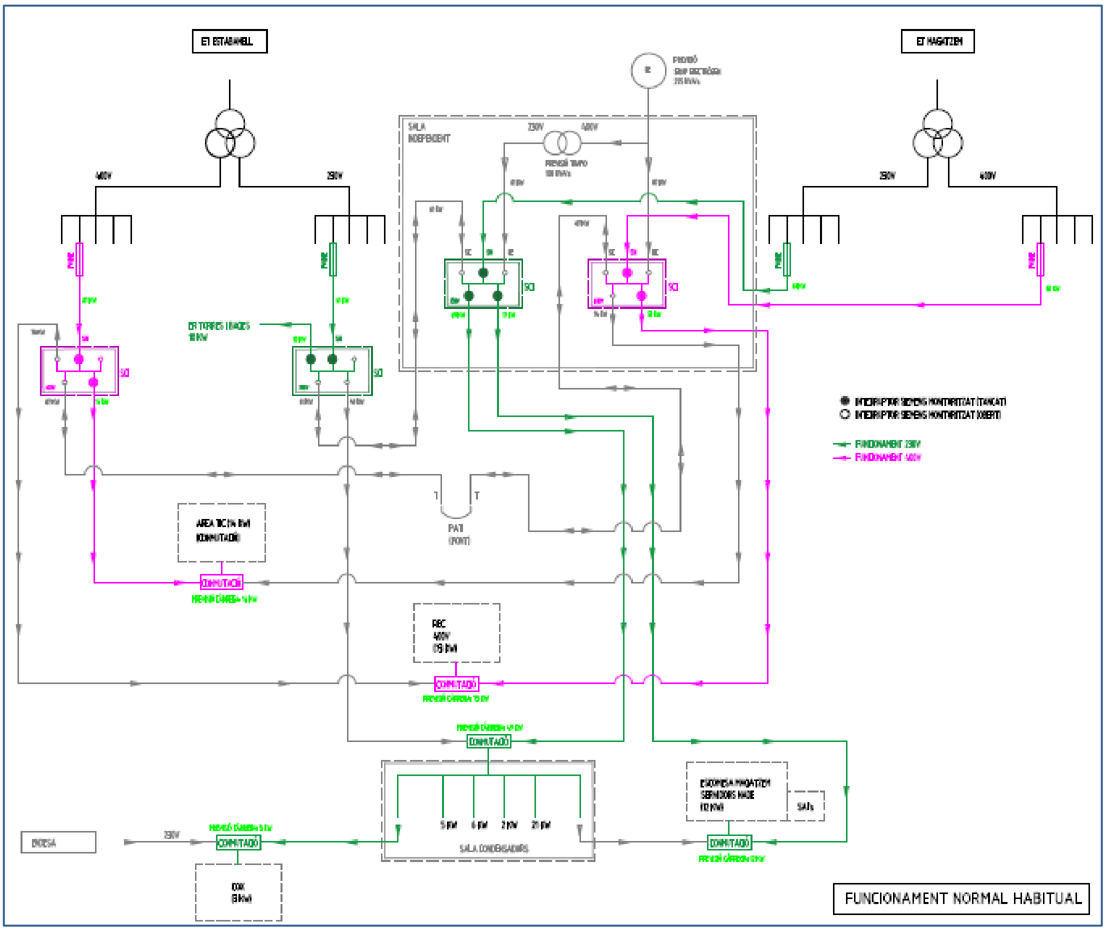

Figure 36. *Critical building main grid*

The electrical schematic for the secondary substation is shown in the Figure 36. This scheme shows the different level voltages lines concerning the feeders and gen-set switching, and how the current electrical infrastructure is connected. During the project evolution, this infrastructure will need to be updated based on the storage system and power electronics that will be introduced, and the new setup will be developed and presented.

The electrical connectivity should be as indicated in Figure 36. The block schemes explain the grid connection bus in LV 4 wires and the Vdc bus. The power electronics devices to be integrated to help ensure the objectives will need to be developed with a 100kVA power. There are several options for where the power electronics can be connected in the electrical network:

- At the low voltage bus (between the transformer and the low voltage cabinet).
- At the low voltage cabinet on the consumption side.
- In an intermediate point of the low voltage grid.

The final decision on the point of electrical connection will depend on coordination and the preference of the electrical department inside the DSO. The battery capacity is 200 kWh and the allocation expected is 100 kWh for the critical building and 100 kWh to be shared with the consumers with production capabilities.

Concerning the MV grid, Estabanell pilot area has a substation operating with the criteria n-1 elements, with fixed transformation, support of another substation through the MV network. There must be the ability to regulate the voltage automatically or remotely, either with a regulator that is built into the transformer or through an external regulator that stabilizes the voltage in the secondary busbars. The configuration of the networks will address the following characteristics:

The section of the main lines and the derivations will be uniform.
The section of the derivations will be smaller than the one of the main line or branch of greater rank. The MV network is plot in the Figure 37.

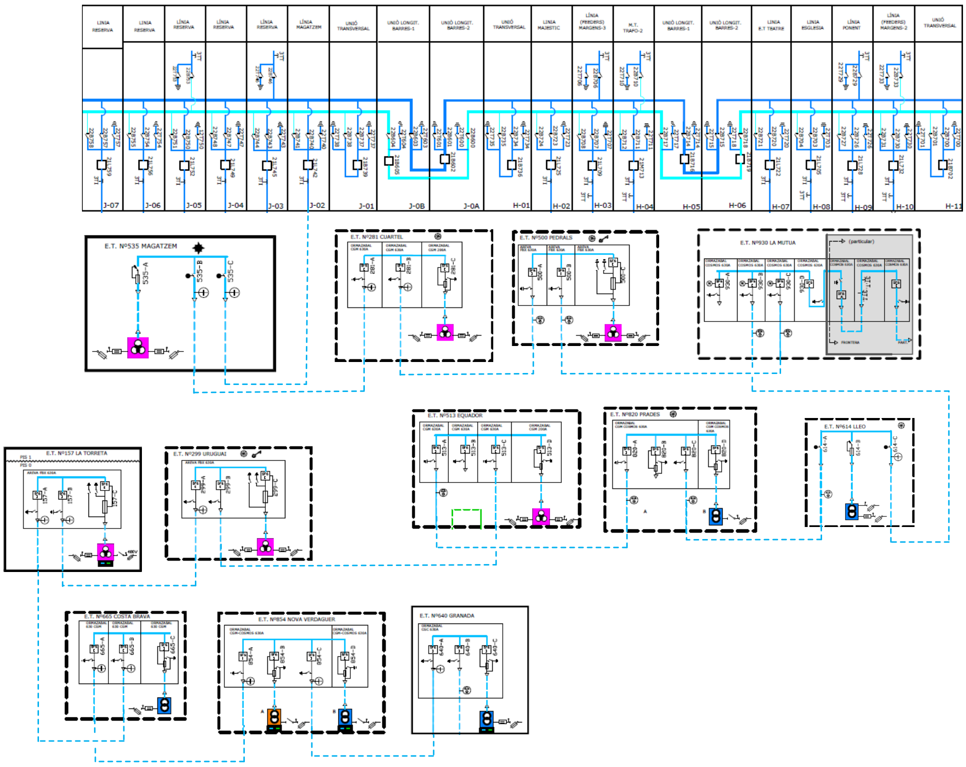

Figure 37. *MV Estabanell Pilot grid*

2.4.3.2 Technical Details

In the pilot, all telecommunication infrastructure based on Fiber optics and BPLC are available to link all kind of interconnected devices.

Every secondary substation has a metering data concentrator that includes an advanced LV supervisor and Power Line Communication (PLC) controller with network monitoring functions, in addition to remote smart meter management functions.

It implements protocols widely accepted in smart metering such as DLMS to carry readings and web services to communicate with the utility MDC (Meter Data Collecting) frontend.

The main function of Data Concentrator Unit (DCU) to poll continuously the metering devices connected to the same secondary substation where it is connected. The retrieved meter data is stored in the DCU and periodically sent them to the collecting System.

The DCU metering data concentrator implements PRIME PLC technology as an embedded PRIME base node. It ensures high power transmission without distortion and is also optimized for operation over low impedance LV grids, without affecting the line impedance.

High receiver sensitivity and efficient data transfer provide optimized communications over noisy lines. Optimal PLC network stability is a critical feature of the DCU devices. The low voltage supervision function is performed by an internal three-phase energy meter, monitoring the secondary of the distribution transformer. The DCU offers interaction with this meter, similar to the other meters in the network.

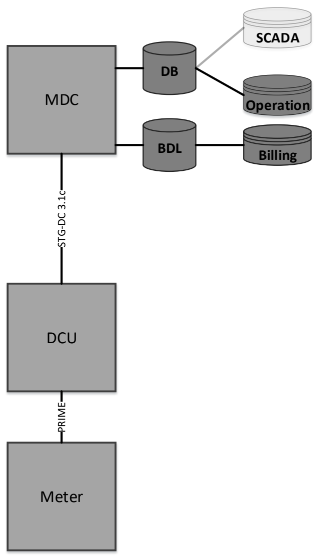

Figure 38. *Smart metering architecture*

The Remote Terminal Unit in the Pilot is not available but Estabanell has the connectivity devices defined by IEC 61850 and concerning the telecommunication links is by IEC 60870-5-104 Estabanell profile.

The architecture is based on a WAN network and it is presented in Figure 39. This infrastructure is a network designed for the interconnection of multiple RTU systems distributed throughout a broad geographical area. The RTU equipment is grouped in local networks or LANs ("Local Area Network") that in turn are interconnected by the network WAN In the local network, all the connected devices use the same configuration for the available options of the TCP / IP protocol.
The main elements between the control-centre and the RTU regarding communications point of view are:

- Control centre room (COX)
- Local Network for connection of the control centre with the WAN.
- Router that connects this local network with the WAN

Figure 39. *Estabanell Telecommunication's architecture Granollers Pilot (red circle)*

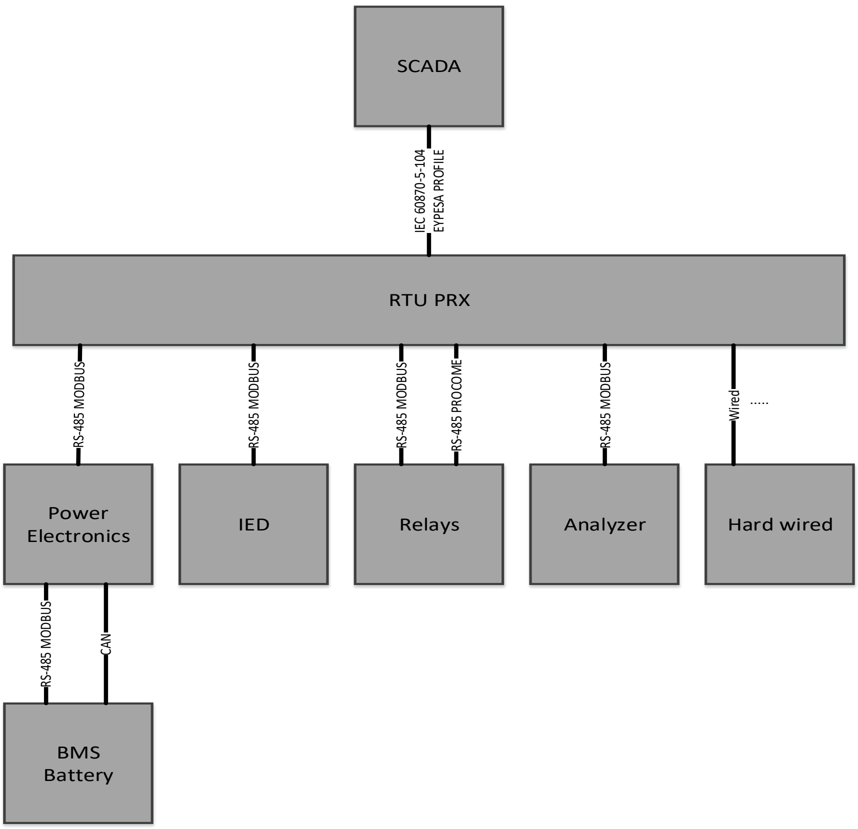

Figure 40. *Hierarchy advanced distribution automation (ADA) link in the Estabanell Pilot*

The required Remote Terminal Unit in the Pilot needs to be a robust and reliable device with two communications channels for the capture of information and performance on slave devices in PROCOME and MODBUS, and a 10/100 Base-Tx Ethernet port for connection with a Control-Centre in IEC104 .

Figure 41. *RTU standardized by ADA Estabanell Network*

All devices shall be installed in the smart grid cabinets to link with the technology needed by INVADE project. All the devices, works at 48 Vdc to ensure their operation in case of supply fault with an endurance not less than 2 hours. The Telecommunications link used is the BPLC device provided by ZIV as a base node with several ports to access.

Figure 42. *Base Telecommunications Node in Estabanell network*

2.4.3.3 <u>Flexibility Services</u>

The flexibility services that are going to be implemented in the Spanish pilot are shown in Table 18:

Flexibility customer	Flexibility services INVADE	Y/N
DSO	Congestion management	Y
	Voltage / Reactive power control	Y
	Controlled islanding	Y
BRP	Day–ahead portfolio optimization	Y
	Intraday portfolio optimization	Y
	Self-balancing portfolio optimization	Y

Table 18. Flexibility services

Estabanell will create value using a centralized battery as follows:

- Congestion management and grid operation. (DSO)
- Mercator (BRP) can also use the battery in intraday/day ahead operations.
- FO will provide services to DSO.
- Mercator will play the flexibility operator role, providing services to the DSO and the BRP.

The Flexibility Operator (FO) role (Figure 43. can cover many DSOs/companies. The FO role can look like the smartly discussion regarding the DSO that is an insecure customer regarding the willingness to pay for flexibility versus only acting as the regulators tool using tariffs. (Flexibility Operator = retailer/aggregator)

Reservation fee and activation fee coming from the BRP to the FO. DSO “red light” situation will always have priority. The FO can be passive just awaiting signals to charge/discharge from the BRP. The FO can also be active and use The Invade algorithm to know more than the other FOs. The size and the placement of the battery in the grid is then very important. Prosumer flexibility contract will not be included in the Estabanell Invade-pilot due to regulation issues and battery size.

Services to the DSO will be implemented in the pilot, whereas the services to the BRP will be simulated for the rest of the 12 secondary substation connected at MV level crating an object for each one

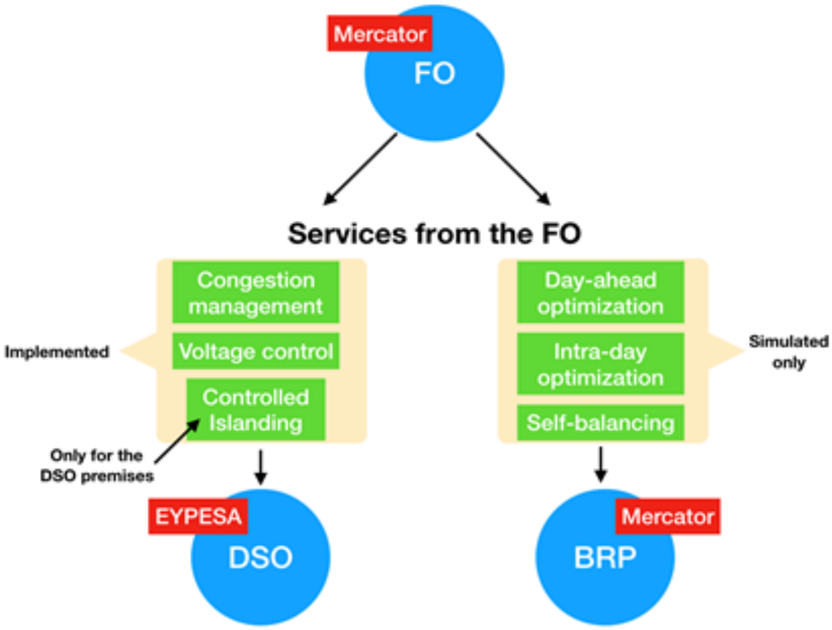

Figure 43. *Services from FO involved in Spanish INVADE Platform.*

Estabanell will provide all three services in both the DSO and BRP domain. BRPs are more competitive and willing to trade, as DSOs are more passive (receive money from the government).

The priority one in the DSO-domain is the Voltage/Reactive control service, because steep (and narrow) peaks are easy to smooth with a battery.

The priority one in the BRP-domain is more difficult to choose and will depend on the solution, but Intraday-market will probably be relevant as the prices are higher here, and this makes the FO offerings more competitive.

The flexibility service from DSO in terms to congestion management, Voltage / Reactive power control just involve the MV grid as result of the power electronics Device is connected in a LV bus of a secondary substation. The desired services are taken into account in order to improve investment in term to replace Distribution transformers and MV infrastructures lines mainly in some part of a limited section of the cable.

Regarding the Island Control Service, is just to go back after an electrical failure, where the battery will be delivering electricity to the critical Building. The system will be able to couple to recover the normal operation of the loads through its feeder.

2.4.3.4 Equipment

a) PV Panels + inverters:

PV Panels and inverters will be installed according to the agreements reached with the municipality. The number and type will be determined after the agreement is established and the locations for these installations are identified.

b) Storage

For the Spanish INVADE pilot, Estabanell will install in their secondary substation 535 Magatzem, a storage system thought the special new development power electronics such as the characteristics required shall be the Table 19.

System overview	
AC discharging power:	250 kW
AC charging power:	250 kW
Usable AC storage	212,9 kWh
Voltage min	300 Vdc
Voltage max	550 Vdc

Storage System
60 pcs per storage C&I Li-Ion Gen1 Second Life
Initial usable AC capacity of battery pack 212,895 kWh
Expected capacity loss < 4% per year (depending on use)
Maximum AC discharge/charge power of battery bank 451,4/500,2 kW
BMS communications link CAN-bus

Enviromental conditions
IP 30
0-30 ºC
Relative humidity 5-95%
2 pollution degree recommended, Pollution Degree 3 accepatable

Dimensions
W440 x D736 X H175 mm
Weight 85 kg

Set
6 pcs per storage C&I Battery Rack 42 U no doors
Rack houses up to 10 battery packs
Standard 19", 42 U form factor

Rack dimension
W600 x D1040X2022 mm

Table 19. Battery characteristics

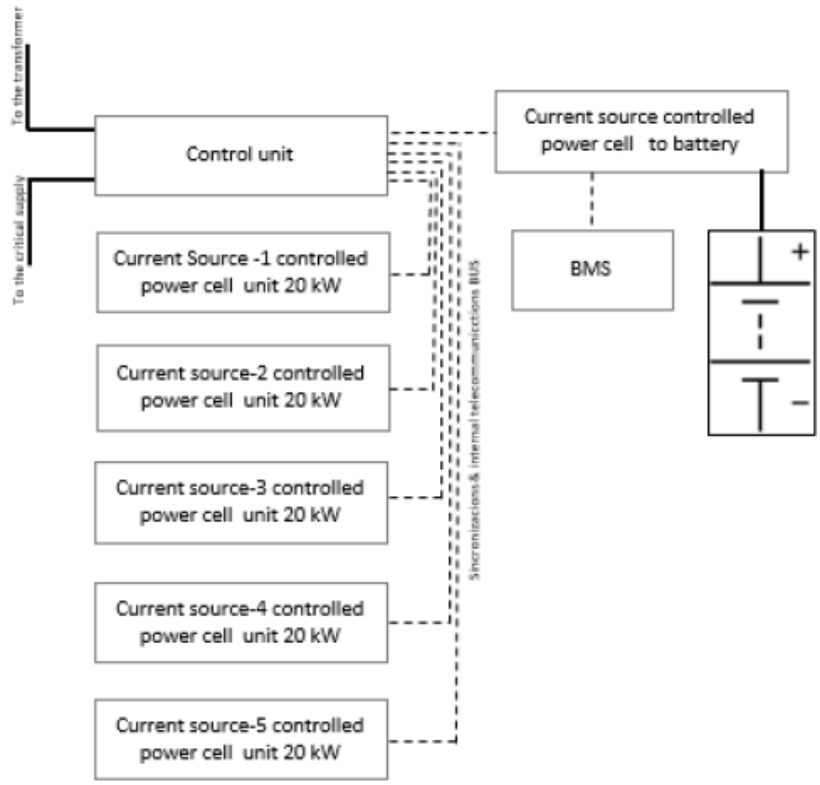

Figure 44. *Power electronic and battery link involved in the INVADE Platform.*

The battery capacity is 200 kWh and the allocation expected is 100 kWh for the critical building and 100 kWh to be shared with the consumers with production capabilities.

For those Estabanell and Nissan are working to install its product with battery cells recycled from the battery packs of its electric from LEAF car. The battery packs Figure 45. used in cars may retain up to 80% of their energy capacity even after their performance has degraded to the point where they are no longer able to meet the demands of an electric car.

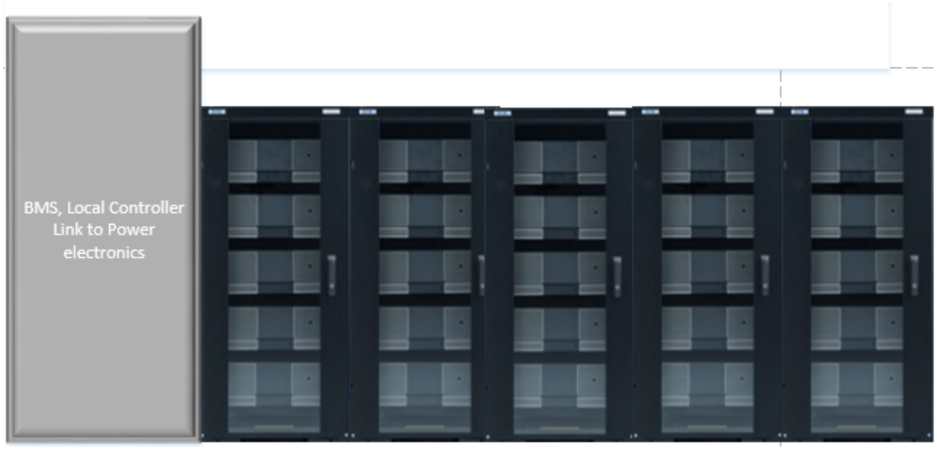

Figure 45. *Battery Nissan technology involved in the INVADE Platform.*

→Batteries:

Batteries will be installed in the secondary substation as mentioned earlier. The battery provider will be determined asap, after the ongoing discussions with three providers, Nissan, Korean provider or Saft.

c) Power electronics device:

A special power electronics device will also be installed to perform the necessary functions related to control, management, and power quality. This device will be provided by teknoCEA.

2.4.4 PUC - Use Cases

This pilot will demonstrate the pilot use case 2 (PUC-2) described as: Centralized energy storage using an array of batteries at the sub-station or street level. In the scope of this use case and the Spanish pilot, several functionalities are included:

1. Emergency backup provision (controlled islanding)

The DSO is an example of an entity with critical services needing electricity redundancy. The issue here is that redundancy depends on the HV distribution and transmission network, meaning that in the event of a blackout impacting both, all services will be down. The current alternative is to have a gen-set ready for use, which means storing fuel and an expensive investment, which is only used under extraordinary circumstances. This requires the gen-set to be up and running some hours a month, only for testing purposes. New back-up systems must be studied in order to be applied in the pilot area as storage batteries will change short-circuit values

This case consists in providing the critical service with a 2 hours' redundancy based on efficiently managed storage. The use case aims at demonstrating that a storage system shared with other users, is a safe, reliable and emission-free alternative, which will cover a gap of 2 hours without using a gen-set and thus no emissions. We consider a 2 hours' capacity using batteries to be enough to cover most of incidents. The storage system, combined with the Integrated INVADE platform and Power Electronics (Figure-37) will thus provide the network with a reliable and efficient energy backup. The solar profile over time will also be sent to the platform and the eSmart system to manage and assure the storage and supply available. The aspects applied are:

- Consumption and generation management.
- Quality of supply.

2. Demand side management

The validation pilot includes 1607 CUPS approximately which are LV and MV grid connected in the EyPESA electrical grid. The power contract that the consumers have is based on their own needs and the challenge is to achieve that some users are interested in installing PV. The aspects included in this section are:

- Consumption and generation management.
- Congestion management.

The PV installed in private or public roofs will contribute to the charging of the centralized battery in the secondary substation. The PV production that isn't consumed by the user will be driven to the battery and the surplus will be absorbed by the LV grid. All that following signals of the most efficient path taking into account dynamic energy prices based on the hourly rates of the day ahead market. The solar profile and timing should also be measured to be sent to the INVADE platform and the eSmart system. In this part of the project, EyPESA is still working with the municipality to solve the legal constraints to determine more technical details as mentioned in the previous sections. Included in this section are also the services offered to the BRP, which allow the BRP to optimize its portfolio and energy purchases as the demand changes.

3. Power quality improvement

The installed storage and power electronics in the secondary substation, in addition to assuring and managing the previous mentioned aspects (emergency back-up operations and demand side management) will be offering power quality improvements through:

- Identifying congestion points.
- Interaction through the platform with strategic devices installed in the grid (LV solid state switch gears, inverters).
- Delivering reactive and active power to grid when necessary.
- Compensating harmonic currents.
- Balancing loads.

The research questions that will be addressed, the provisions needed and current impediments related to the Spanish pilot are listed in Table 20. Table 21. and Table 22. respectively.

Use-Case	Technical research questions to be answered by pilot	User/Business related research questions to be answered by pilot
PUC-2	What is the optimal charge/discharge pattern required to satisfy the needs of the BRP and the DSO? What is an adequate storage size for offering the flexibility needed by a DSO and a BRP? What power electronics configuration best manages the battery and its end uses? Which are the efficiency improvements possible in the distribution transformer and MV grid using flexibility? How can efficiency in the grid be improved by means of a central storage?	How can a centralized storage facilitate energy flexibility for BRPs and DSOs? How can possible/certain services in the energy sector be enhanced? What role could the Flexibility Operator play in the short term and what new business opportunities does this role offer? • in a European context • in a Spanish context, allowing the FO to come faster into play once the figure becomes legal in Spain. What would be the provisions in the longer term (and when made legal) for creating a Flexibility Operator entity, thus

	How can critical facilities attractive candidates for benefiting from storage (securing redundancy), storage that can also be used to offer other flexibility services.	opening a new area to the company group within the energy sector. What new services could be offered to the DSO and BRP, two business we already operate in? What policy changes and upgrades are necessary for enhancing and leveraging flexibility? What are the technical and legal obstacles for a scaled-up introduction of the PUC-2 scenario?

Table 20. Research questions to be answered by the Spanish pilot

Use-Case	Provisions for each use-case
PUC-2	Clear framework, optimal organization and communication are all important fro a successful pilot/project A 200 kWh battery It must be possible to regulate the voltage in the MV automatically or remotely The required Remote Terminal Unit in the Pilot needs to be available, robust and reliable Equipment listed in Table 4 must be available

Table 21. Prerequisites and necessary provisions for the Spanish pilot

Use-Case	Potential and current impediments to be handled
PUC-2	Legal aspects, in Spain particularly

	National policies and regulations

Table 22. Potential and existing obstacles identified for the Spanish pilot

2.5 Germany

2.5.1 Definition

The German pilot focuses on a hybrid approach. It will create one centralised energy storage (CES) device on one hand as well as connecting distributed energy storages (DES) in private households on the other hand. The examination of new business models plays a decisive role in this context to facilitate the roll out of ideas developed in the project INVADE later on in the market.

Hybrid implementation – Centralised energy storage

The Green City Freiburg in the south-western corner of Germany has about 220.000 inhabitants. Freiburg is one of the sunniest regions in Germany, experiencing a great penetration of renewable energy sources especially photovoltaics. Further development and use of renewable energies is not limited by a lack of resources but more and more often by the lack of capacity in power lines leading to the outskirts of the city. Due to the relatively high sun radiation in the south-west compared to other regions in Germany PV systems are widely installed and used in this region and often connected to the low voltage network. Feed-in peaks during sunny days with low power consumption require already today new strategies to cope with congestion management and occurring voltage peaks.

Therefore, it suggests itself, to select an application for the centralised energy storage (CES) that deals with this problem in a rural grid area, which is operated by the local distribution system operator “bn-Netze”. bn-Netze is a subsidy of badenova. The selected spot for the CES is located at an end-feeder in the suburb “Freiburg-Opfingen”, which is a community pretty remote from the main city of Freiburg and located at the outer rim of the electricity network. Figure 46. shows the location of the CES.

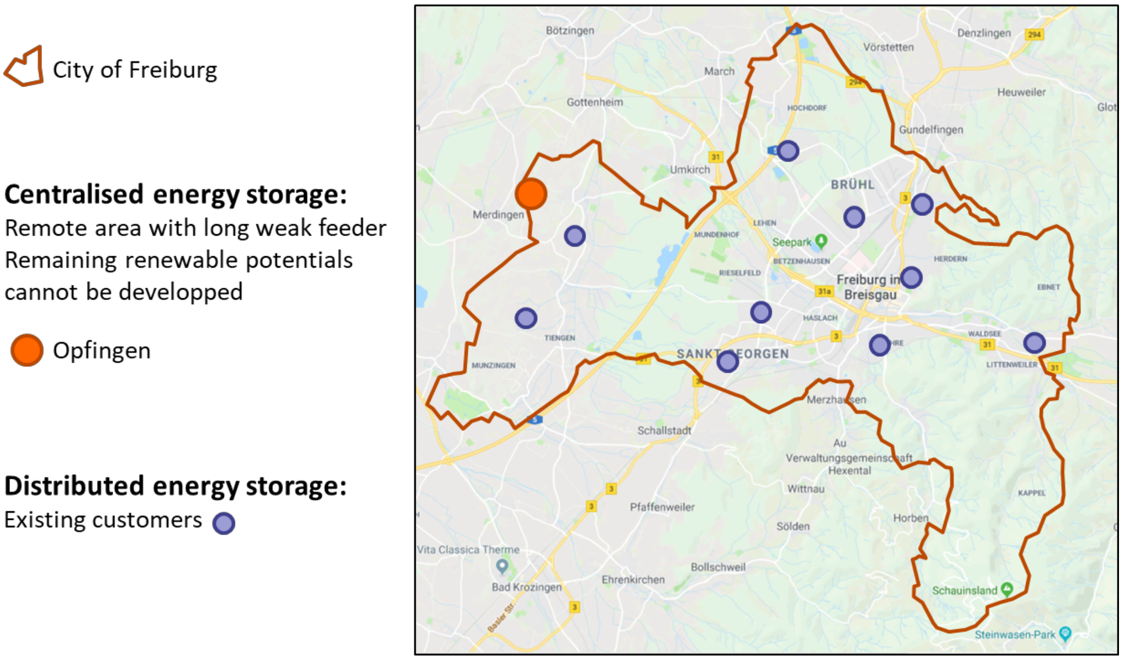

Figure 46. *Location of centralized energy storage*

Nevertheless, this region is predestined for PV-systems, because it's settled with many farm houses coming along with barns and extended roofs, perfectly suitable for the configuration with PV-modules.

In the selected case, a farmer's house is located at the end of a feeder. The property is equipped with four PV plants with a total installed power of 30.5 kW_p. All four PV plants are connected via one single grid connection point to the public low voltage grid. The location, including its surroundings as well as the chosen location for the battery, are shown in Figure 47.

The distance between the next substation and the end of the feeder is nearly 840 m. On the substation other feeders with PV generation are connected. Overall, an installed PV power of 331,8 kWp is connected to this point. On sunny days this already results in a voltage increase here. This effect is intensified towards the end of the long feeder due to the energy feed in of the PV-systems on the farmer's house. In fact, voltage limits at its grid connection point are violated by the local generation of electricity several times over the year. So, a further extension of the existing PV systems is not possible even if there is more than enough free space left on the barn's roof.

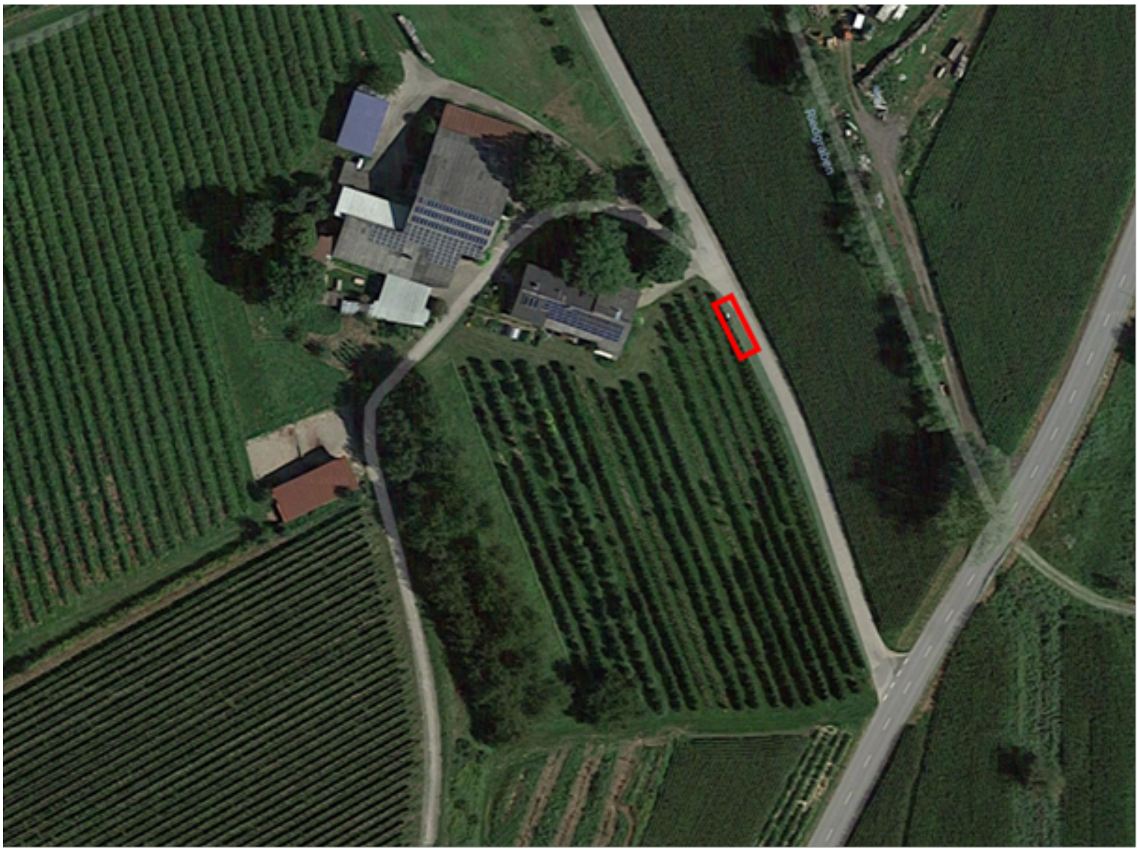

Figure 47. *Detailed test site Freiburg-Opfingen*

As shown in Figure 48. the voltage on the grid connection point of the farmer's house can rise up nearly 7.5% above the regular level on a day with maximum generation from the PV-Systems and regular load. 3% are allowed at maximum by German regulation. Due to the geographical distance of the PV installations on the roofs to the grid connection point of the farmer's house the voltage increases further along the electrical line running on the property. Thus, there are occurrences where the acceptable voltage tolerance level of 10% at the connection point of the inverters is exceeded. In such cases the inverters shut down automatically and the PV-systems are no longer able to generate electricity. In consequence, the PV-system owner loses the guaranteed feed-in tariff for the not produced energy and demands compensation for lost revenues from the grid operator. Hence, a strong interest on both sides exists, that this event is avoided in any case.

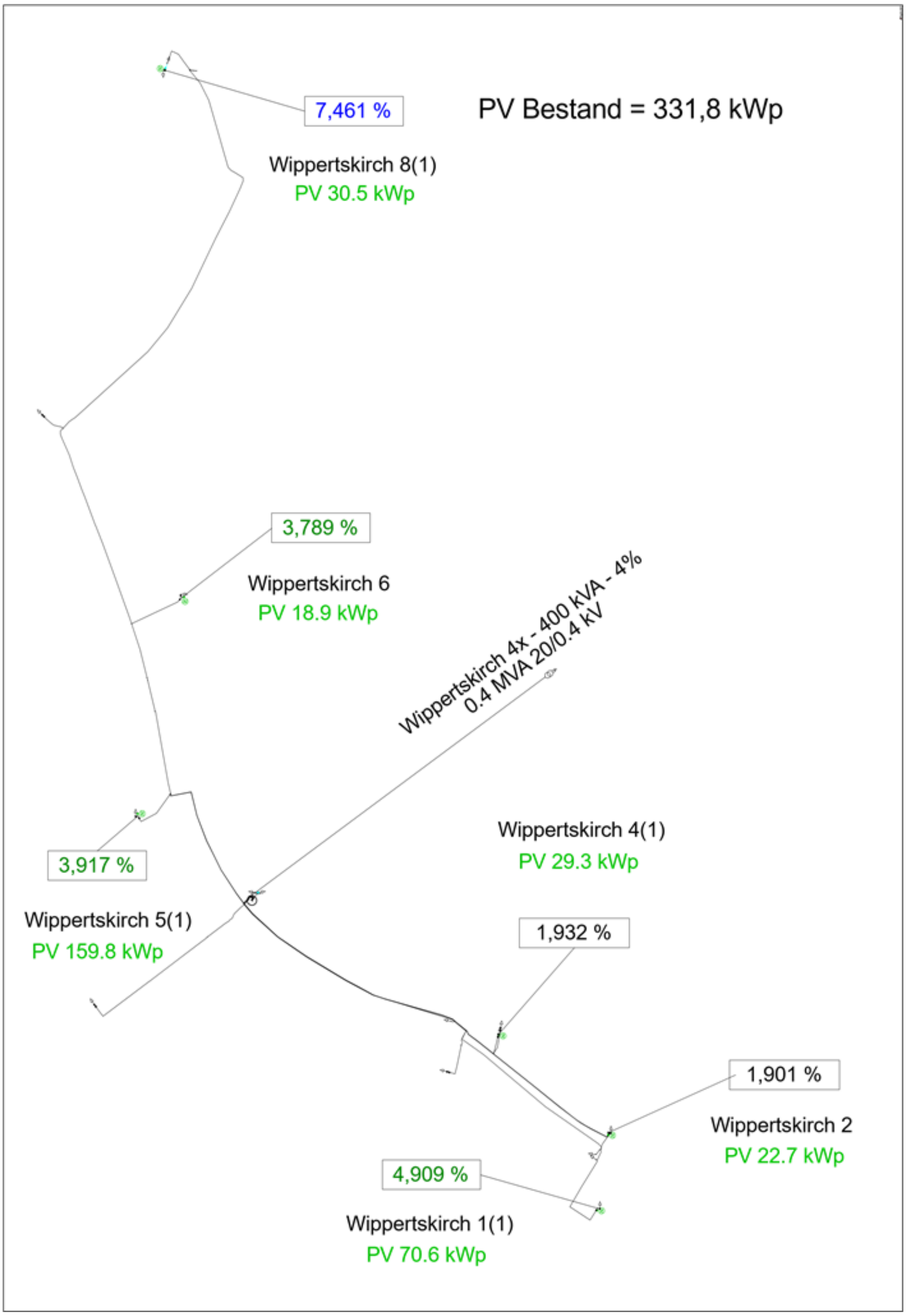

Figure 48. *Voltage increase over the long feeder during a sunny day with regular load*

By using a battery storage system, the PV plant will be able to fully feed-in into the local distribution grid even during peak production periods. The energy is foreseen not to be transported over the weak line immediately but to be stored within the battery temporarily. During night time, this energy shall be transported without causing any problems over the low stressed line. The battery will work as a grid-friendly component exclusively operated by the local DSO. In addition, it is intended that the DSO can use the CES as a supplement to the distributed storages described later on as a means of peak-shaving device for the entire grid, if the battery is not required for its initial purpose. Badenova follows here a multipurpose strategy for the CES.

This case is an excellent example of how a battery storage device can help to secure full generation of renewable energies without expensive grid enforcement. At the same time, new potentials for expanding existing PV-plants on the roofs with more panels connected to the unchanged weak feeder, can be tapped. The pilot also establishes that a battery can serve two separate use cases and value streams.

After a successful test of the CES on this location within INVADE, it is planned to transfer the know how to other spots in the electrical grid with similar problems but much more customers and PV generation. This test case builds only the first step in a row to come, to enable more PV in already existing grids without expensive grid expansion.

Hybrid pilot implementation – Distributed energy storage

The connection of distributed energy storages is the second part of the hybrid pilot implementation in Germany. Overall, in Germany there is a trend to intensify the utilization of distributed energy storage technologies. Until end of 2018, for example, badenova will have sold more than 150 PV storages to private households and there are already several hundred battery storage installations of private individuals in the entire supply area of bn-Netze provided by other service providers.

Today the costs for self-produced energy from a home solar system is about 20 ct/kWh lower than energy bought from an energy supplier. This is one reason why the number of new installed PV systems is high in Germany. Because of the significant lower price there is a strong incentive to use as much as possible of the self-produced energy. In consequence the market for private PV storages developed rapidly over the last, few years. Today, more or less all new PV systems are sold together with a PV storage as well as a home management system to maximize self-sufficiency and to minimize expensive energy supply from a utility.

The home management system takes the role of a local energy management authority at the unit level. But the overview over other households and the needs of the electrical grid are missing. INVADE can provide an additional value to take over the role of a superior management authority on a upper level. This implies taking into consideration the needs of superordinate interests and creating additional revenues by using new business models. A strong effort is set on the financial assessment of the flexibility potential as well as the scalability of the approach after closure of the project INVADE, if the business idea has passed the proof of concept.

One superior business model which will be analyzed within INVADE is preventing peak loads in the entire grid from the perspective of the DSO. DSOs in Germany pay a grid usage fee to the upstream network operator for the maximum power at the transfer points. Typically, load peaks in the grid occur in the morning, around noon or in the evening. When connected to a superior entity, DES could offer their flexibility potential to the DSO in order to avoid peaks in the grid. Keeping that in mind, the test sites intend to establish a setup where the DSO can use the flexibility potential of DES as a means of peak shaving.

The participating customers shall experience a financial benefit for their contribution to avoid peak loads for the DSO. In addition, the regulatory framework in Germany has foreseen a reduced grid usage tariff for customers with storages operated in a grid friendly manner. So both parts together mean a relevant additional benefit for each participating customer.

Within Badenova's market area ten households are to be identified and connected to the INVADE platform. The focus lays on customers already equipped with PV systems, small batteries as well as a home management system.

2.5.2 Large Scale Proposal

The hybrid pilot-implementation in Germany is split up into two different approaches as mentioned above. The following categories will be tested in the INVADE platform

- One centralised large-scale battery system installed at a weak end-feeder in the local distribution network at low voltage
    - Goal 1: Congestion management and voltage control of the local distribution grid → avoiding expensive expansion of low voltage network
    - Goal 2: Peak-shaving for the entire distribution grid
- Connecting at least ten distributed battery systems installed in private households
    - Goal: Peak-shaving for the entire distribution grid

Hybrid implementation – Centralised energy storage

Regarding the centralised battery system, it is attended to feed-in the generation peaks of the PV plants into a 120 kWh battery system. As an example, by cutting the generation peaks during the main production times between 12 a.m. and 5 p.m. on sunny days the network can be significantly relieved.

Due to the volatile PV production, the battery may not be required during all days and seasons of the year. Also, the battery might have some flexibility potential even when it is needed to ensure feeding-in of the PV plants. The DSO can harness the unused flexibility of the CES for peak-shaving purposes in the grid. By adding another use case to the CES, the battery becomes a multipurpose device and may turn out to be faster profitable.

The battery management system shall decide locally, if the battery should charge or discharge or just stay idle for the first goal of the CES – ensuring entire feeding-in of the PV plants and maintaining the voltage on an appropriate level. The INVADE platform acts as an intermediary between DSO and battery to harness the flexibility potential for peak-shaving. The capacity reserves of the CES are used additionally to the DES. The platform needs at least information about the energy consumption of the property, the electricity generation and the state of the battery to be able to implement the control algorithm.

Hybrid pilot implementation – Distributed energy storage

The pilot test site focuses on testing additional flexibility potential of households that is already optimizing their self-sufficiency with a home management system, evaluating the business idea in means of financial market potential as well as testing the technical feasibility of the setup.

Since SMA is the market leader for solar hardware in Germany, badenova seeks a strong cooperation with this company. On the other hand, SMA already provides a widely used home management system called “Sunny Home Manager”, which is capable to make forecasts of PV-generation and load consumption and to calculate on this basis an operation scheme for the local battery. This system is furthermore capable to connect devices of different manufacturers. This is an important advantage as INVADE does not have to deal with a variety of proprietary communication standards of devices on the lower house level. Instead INVADE can focus solely on connecting to the Sunny Home

Manager as the lower energy management authority and this device deals with all local devices.

Main target of the system is to maximize self-sufficiency of the customer and in the same way to minimize the energy consumption from the grid, as the tariffs for residential customers are nearly three times as high as the production costs from the own PV-system. But: The optimization algorithm in the Sunny Home Manager focuses only on the local building. A connection to a superior optimization level is not realized right now.

Prosumers increasing their self-sufficiency become highly unpredictable in terms of time and height of fed-in power and consumed power. The pilot test sites implement a test setup that still increase self-sufficiency but follow strict guidelines from the DSO.

Exactly at this point, badenova and SMA want to create an additional benefit for the DSO as well as for the private customer by connecting the households to a superior entity and making the flexibility potential accessible to the DSO. The private household still optimizes its own consumption via the local Home Manager most time of the day and can offer auxiliary services to the DSO in dedicated time slots, participating in a large-scale community. This approach seems to be technically feasible, as many battery storages on household level are dimensioned too big and still hold capacity-reserves, which are not used (Figure 49. illustrates the approach).

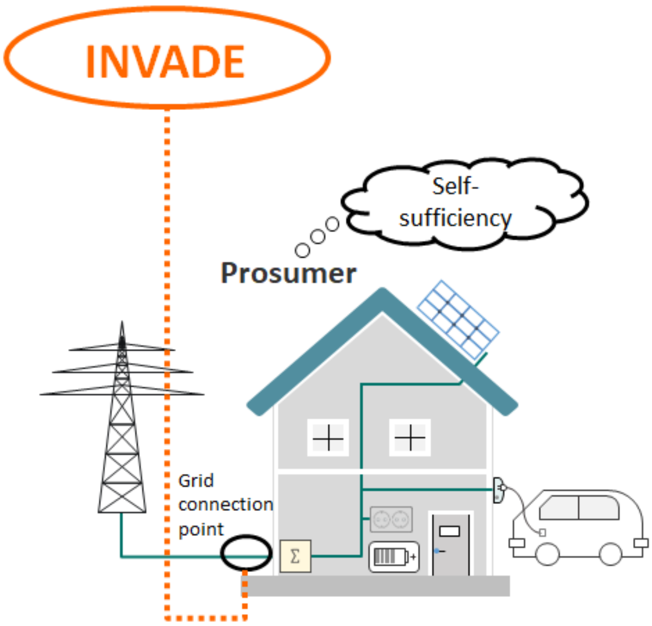

Figure 49. *Added value for private customers with home management system*

In addition to the financial benefit it is intended to provide the participating customers comfortable information services regarding the own energy system on house level as well as the requests of the DSO by visualizing data via comfortable dashboards. So the connection of energy storages in private households creates a direct experience to the participating customers. This promotes acceptance and proves the benefit of demand response in private households.

2.5.3 Technical Characteristics

2.5.3.1 Grid Topology

Hybrid implementation – Centralised energy storage

An overview of the current network situation and connection of the pilot site regarding the central energy storage (CES) is given in Figure 50.

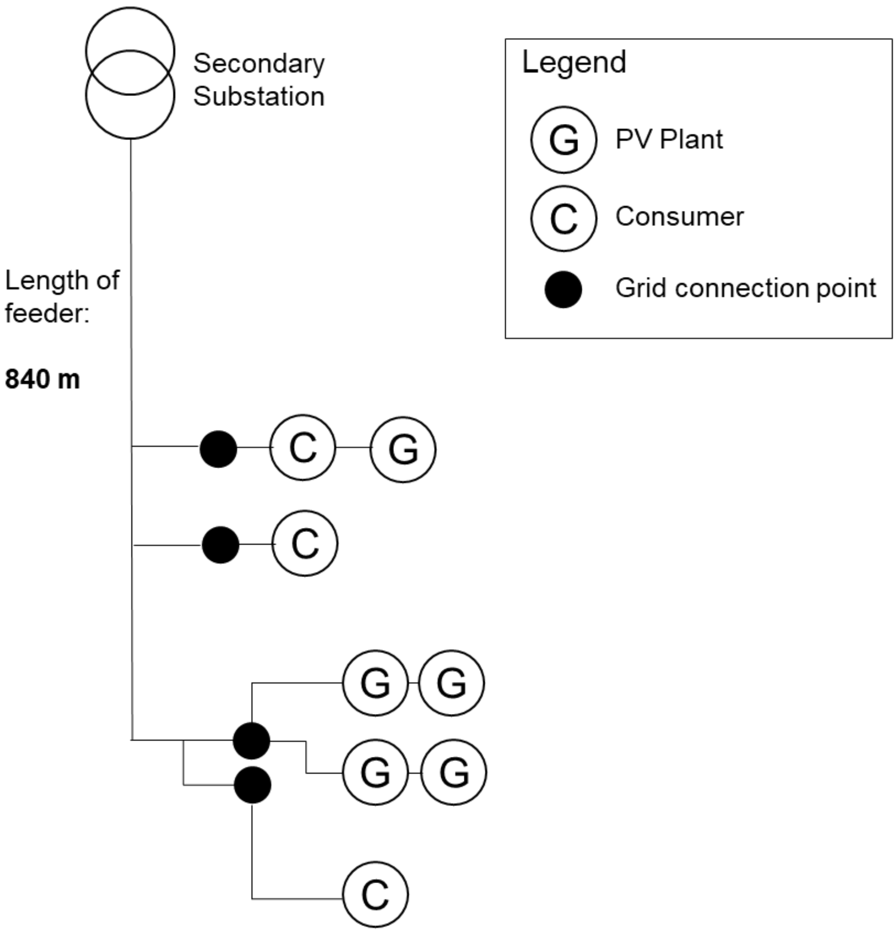

Figure 50. *Grid topology for central energy storage (CES)*

Starting from the substation, only three consumers are connected to the feeder which experiences voltage peaks and requires congestion management as wells as voltage control.

Hybrid pilot implementation – Distributed energy storage

The current setup of the distributed energy storages (DES) is built up as shown in the following Figure 51.

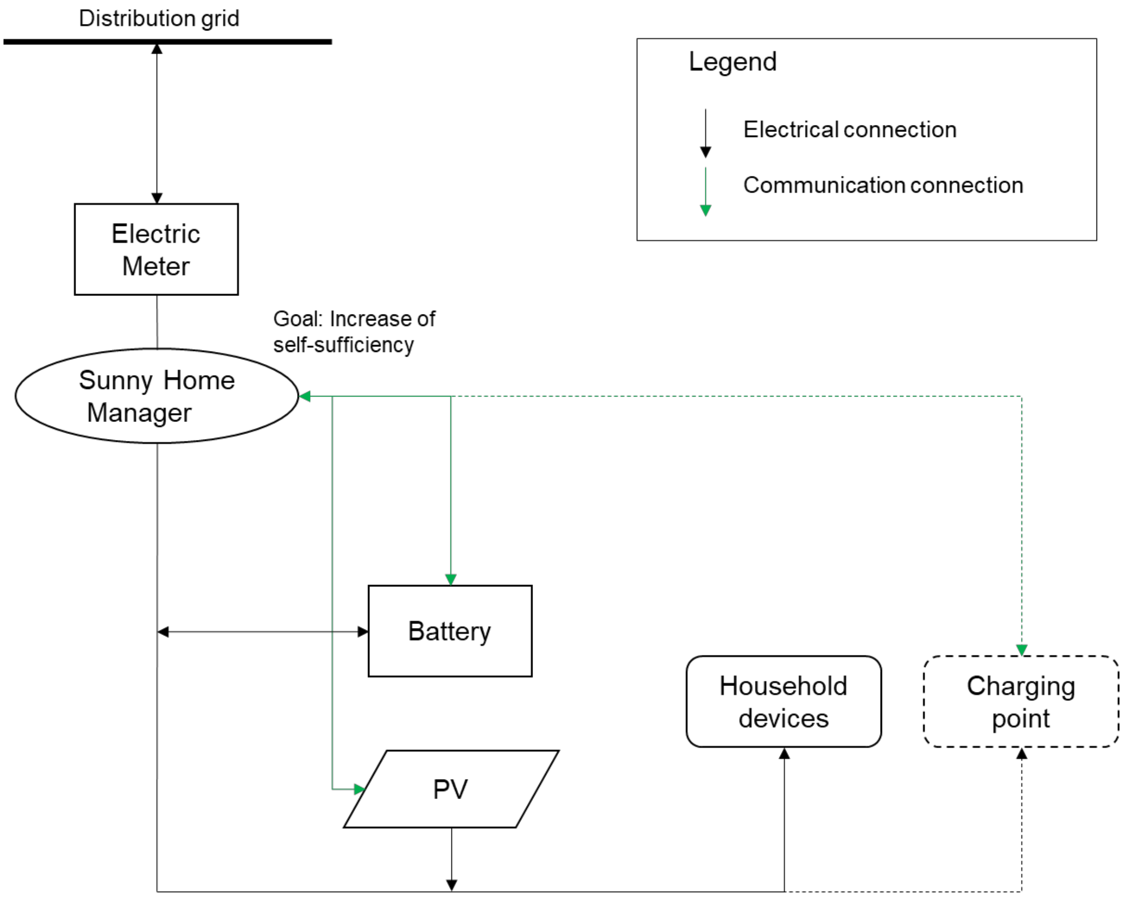

Figure 51. *Grid topology for distributed energy storage (DES)*

2.5.3.2 Technical Details

Hybrid implementation – Centralised energy storage

For the CES a redox flow battery has been chosen. It comes in a container with a bidirectional inverter with 20 kW nominal power and a capacity of 120 kWh, able to store generated electricity from the PV-system for at least five hours which is sufficient for the PUC. More technical details can be found in chapter 2.5.3.4.

It is planned to install smart meters to measure the consumption of the local farm house and the generated electricity by the PV plants separately. Unfortunately, smart meters are not available in the German market today, as the communication interfaces are not approved by the responsible governmental authority. In spite of this, badenova intends to implement first prototypes. In case these units are not available in time, flexible energy counting devices will be installed, sufficient for the purposes of the INVADE project even if not admitted as official energy meters. The telecommunication infrastructure will be based on a local DSL internet connection for the metering devices as well as GSM for the battery container. The communication interface to the INVADE platform will already be installed within the battery system. INVADE will retrieve data not only from smart meters but also from the battery management system.

Figure 52. shows the final setup of the pilot site including the communication system (green arrows).

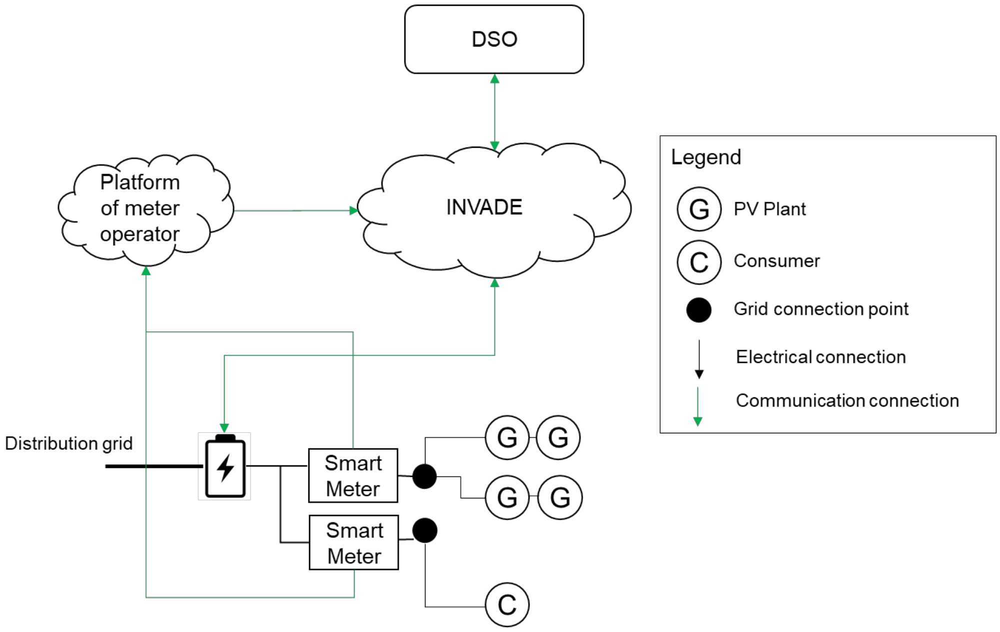

Figure 52. *Setup for the central energy storage*

<u>Hybrid implementation – Distributed energy storage</u>

So far, the Sunny Home Manager from SMA increases the self-sufficiency of the household by analysing data of the PV-inverter, purchased electricity, grid feed-in and the battery system. During the period of the project, all components and devices (battery, household devices, PV and possibly charging points) will still be controlled by the Sunny Home Manage during most of time during the day. At some points, the Sunny Home

Manager will retrieve commands from the INVADE platform via the newly installed gateway to control the energy consumption at the grid connection point as requested by the DSO. During this period, the INVADE platform overrules the home management system and keeps the power of the grid connection point to its requested value. When this period is over, the home management system takes over again and recalculates the operational scheme of all devices to return to a regular operation mode.

Following Figure 53. illustrates the setup and communication for the participating customers with DES.

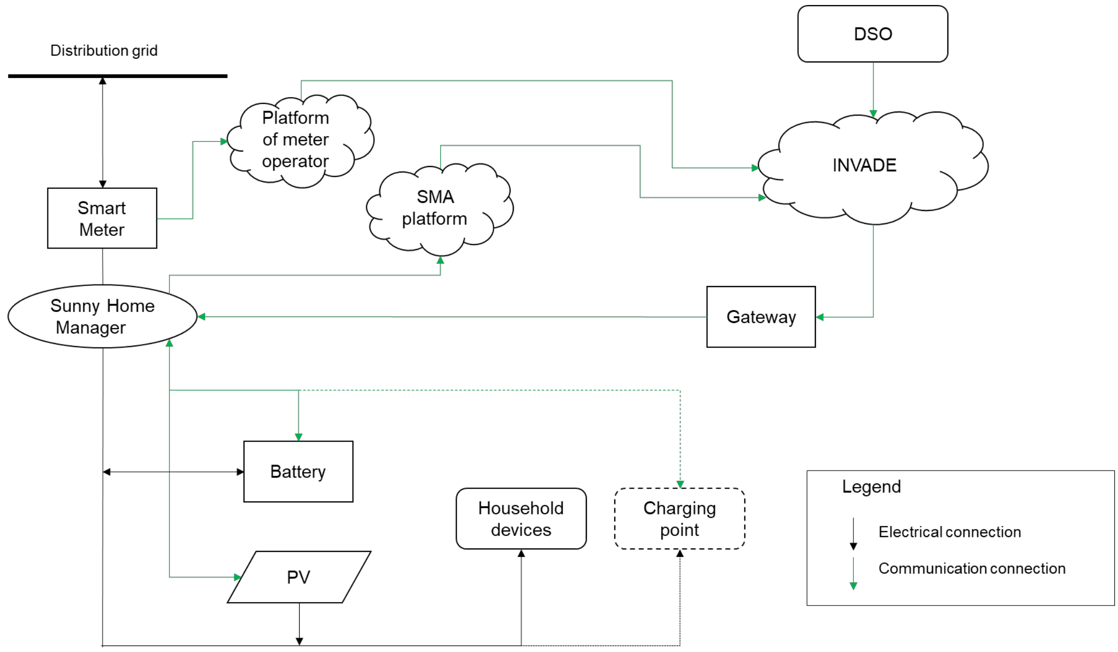

Figure 53. *Setup for customers with DES*

he detailed plan for the data flow is as follows: The DSO sends commands to the INVADE platform, if flexibility is required. Flexibility requests will always be limited to a certain time frame. The INVADE platform then enables the DSO to use the flexibility potential of the DES. INVADE directly transfers control requests to a newly developed product of SMA, a gateway, which will be installed next to the already existing Sunny Home Manager acting as the local control unit. In all participating customer households, these gateways will be installed. The gateway stands as a communication interface between the INVADE platform and the Sunny Home Manager. Control requests are sent from the INVADE platform to the gateway which transfers the commands to the Sunny Home Manager finally executing these commands. The additional control requests from the INVADE platform are expected to use the usual time slots of 15 minutes intervals for one complete day. The necessary status-information of the devices in the households (PV-systems, battery, maybe wall box for charging an e-vehicle) will be provided via the Sunny Home Manager and an already existing platform – the "SMA Sunny Portal Professional" as well as the dedicated "REST Interface". An explicit API description is available, to realize the connection between the SMA Sunny Portal Professional and the INVADE platform.

There are three separate interfaces communicating with the INVADE platform. The platform of the smart meter operator transfers data from the smart meter into the INVADE platform. The cloud platform of SMA transfers data that was initially received by the Sunny Home Manager. The platform of SMA and the meter operator solely stand as a communication interface to the INVADE platform transferring data from the battery, generation, consumption and possibly charging points. Both data streams which are retrieved by the INVADE platform are read only. Even in this case the implementation of smart meters is not for sure due to the approval issues already described in the section related to the CES. But information as PV-Generation and local load are provided by the SMA platform too so the INVADE platform will be able to request all needed information.

2.5.3.3 Flexibility Services

The flexibility services outlined in Table 23 are relevant for the German pilot. The services that will be provided to the pilot installations are the following.

Table 23. Flexibility services provided by the German pilot

Flexibility customer	Flexibility services INVADE	PUC 4
DSO	Congestion management	Y
	Voltage / Reactive power control	Y
	Controlled islanding	N
BRP	Day–ahead portfolio optimization	N
	Intraday portfolio optimization	N
	Self-balancing portfolio optimization	N
Prosumer	ToU optimization	N
	kW_{max} control	N
	Self-balancing	Y[1]
	Controlled islanding	N

[1] Prosumer self-balancing service is going to be supplied by SMA outside the scope of the INVADE project

- Congestion management: The centralised energy storage provides a dynamic solution at the specific feeder in Freiburg-Opfingen to overcome the electrical constraints enabling to operate the low voltage network within the given limits.
- Voltage control: As per VDE-AR-N 4105 voltage limits are set at ± 3 % to the initial voltage of the low voltage network. If voltage limits are violated, it may occur that connected PV plants cannot feed-in into the grid because the acceptable voltage limits at the connection points of the PV inverters are exceeded. The DSO is obliged to enable the feed-in of distributed energy resources such as PV plants. Once connected to the grid, the DSO has to enable a non-interruptible possibility to feed-in the generated electricity within the given regulatory framework.
- Prosumer self-balancing: Due to the regulatory framework a strong incentive already exists in Germany, to use as much as possible of the self-generated PV-energy within the house. The target is relatively simple: Minimize the energy provided by the utility to a minimum. This flexibility service is already provided by the Sunny Home Manager on household level too.

Unfortunately, the roll out of smart meters is far beyond schedule in Germany. Thus, Time of Use optimization is not part of regular households today and in consequence flexible tariffs are not in use on this level.

2.5.3.4 Equipment

Hybrid implementation – Centralised energy storage

A vanadium redox-flow battery is used as the centralised energy storage. The capacity of the system is 120 kWh and the usable capacity is 108 kWh. The power is limited by the stacks and the bidirectional power inverter to 20 kW.

The selected redox-flow battery from Storion Energy uses an innovative technology with very high-power densities of more than 400 mW/cm^2 giving the battery a competitive edge against other producers (Figure 54.).

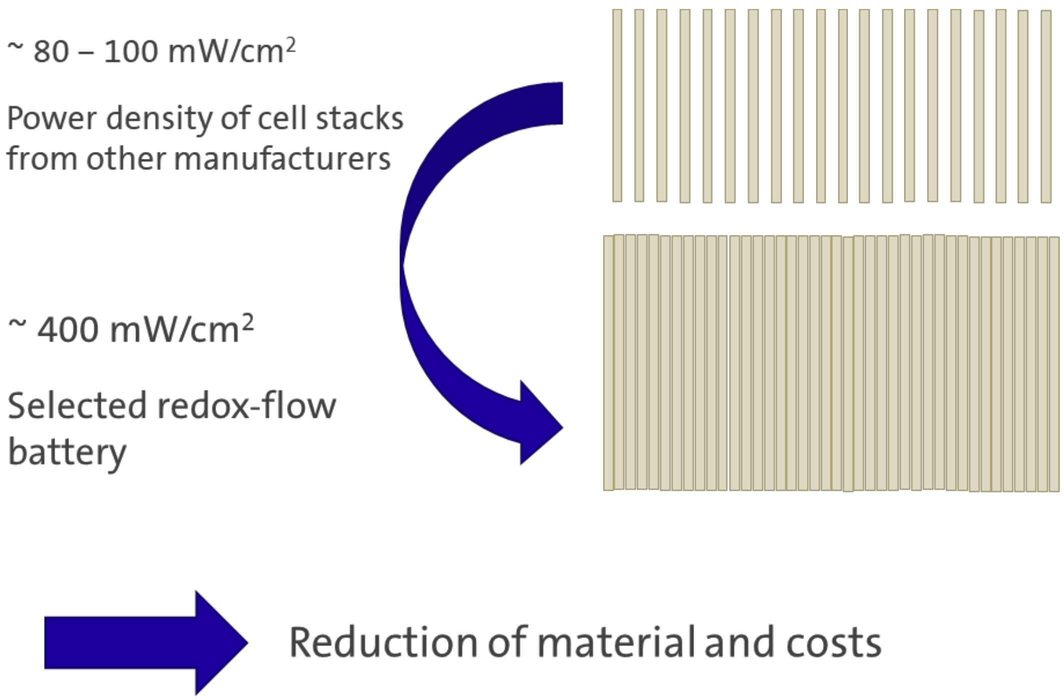

Figure 54. *Characteristics of stack*

The advantage of redox-flow batteries is that power and capacity can be scaled independently. The capacity depends on the size of the electrolyte tanks which is vanadium-based, the power depends on the stack. Further, the redox-flow battery has the ability to cycle with a depth of discharge of more than 90 % with no lifetime capacity loss, a high cycle life of up to 20,000 cycles, is fully recyclable and inherently safe. The storage system will be installed outdoors, accommodated within a container. Due to external weather influences and a certain temperature operating range of the battery system cooling or/and heating systems may be required. The container contains bidirectional power inverters from Trumpf Hüttinger, electronics assembly, a cooling and heating system and the communication interface to the INVADE platform.

The following Figure 55. gives an impression of the redox flow battery container.

Figure 55. *Redox flow battery container*

<u>Hybrid implementation – Distributed energy storage</u>

Each participating customer will be at least equipped with a smart meter (as far as available), a PV-system, a battery storage system, a Sunny Home Manager and a gateway from SMA.

a) Smart Meter

Data will be made available to the INVADE platform via a communication interface of the meter operator. If regulatory issues in Germany hinder to install smart meters, the consumption data will be retrieved from the Sunny Home Manager.

b) PV-Panel/Inverter

PV-Panels and the corresponding inverters are already installed at the selected test sites. The PV-systems are in a power range between 5 and 10 kWp.

c) Home Management System

Home management systems play a key role for the use of distributed energy storage. All pilot test sites for DES will use the Sunny Home Manager 2.0 from SMA that enables an efficient use of solar energy as well as control of battery storages, wall boxes for EV charging and household appliances (Figure 56.). In addition, the Sunny Home Manager is open for connecting devices from other manufacturers. A list of compatible devices is available. All Sunny Home Managers will be installed with the version 2.0. Eventually already installed older versions will be updated. It will yet only be the subordinate control device on house level that executes additionally requests of the superior control level made available via the gateway.

Figure 56. *Sunny Home Manager 2.0*

d) Storage

The distributed energy storage systems are already installed in each household. Each storage contains around 5-10 kWh capacity

e) Charging stations

It is planned to install in two households charging stations for EVs. They will be compatible to the Sunny Home Manager and controllable via this device.

2.5.4 PUC - Use Cases

Hybrid implementation – Centralised energy storage

PUC 4 Part 1 focuses on a CES offering services to the grid and the needs of the DSO. The storage will only be used for purposes of the DSO

1) Avoiding grid expansion by using CES
2) Using CES for congestion management and voltage control
3) Peak-shaving for the entire grid

Hybrid implementation – Distributed energy storage

PUC 4 Part 2 focuses on DES. A new concept that enables additional services of DES will be tested within the project.

Test setup: External control and management of the home management system in dedicated time slots with changing power limits at the grid connection point

Plan:

1) Control and operation of the DES follows clear guidelines of INVADE platform when flexibility is requested from the DSO
2) Idea: There is not a strict value for the charge/discharge power of the battery but a strict limit for the required power at the grid connection point of the participating households.
3) DES deals with volatility of PV-generation and consumption of the household
4) The local home management system controls and optimizes self-efficiency of the participating household when no flexibility is requested from the DSO

Advantages:

- Automatic control and management of energy flow at the grid connection point by the DES via the INVADE platform. An unpredictable customer becomes predictable. This means an important upgrade in customer quality from the perspective e.g. of the DSO
- Enables new end customer services such as variable tariffs, community tariffs, remuneration for grid stability etc. especially when smart meters will be rolled out over Germany in the future

- Creation of additional value for the participating customers, as the main target of maximising self-sufficiency is not affected in an intolerable manner by the superior level target of reducing peak load costs for the DSO

The research questions that will be addressed in the German pilot are listed in Table 24. Potential hurdles and impediments are shown in Table 25.

Table 24. Research questions to be answered by the German pilot

Use-Case	Technical research questions to be answered	User/business related research questions to be answered
PUC-4 Part 1	How should the storage facility be operated? What is the optimal charge/discharge pattern required to satisfy the needs of the DSO? What is an adequate storage size for offering the flexibility needed by a DSO? How can efficiency in the grid be improved by means of a central storage? Is CES an adequate means of flexibility to the DSO? Can CES reduce grid expansion? How much was the peak load in the grid reduced?	Is it possible to save money with the facilities installed? What is the best possible investment-case? What is the ROI? How can a centralized storage facilitate energy flexibility for DSOs? How can possible/certain services in the energy sector be enhanced? What would be the provisions in the longer term (and when made legal) for creating a Flexibility Operator entity, thus opening a new area to the company group within the energy sector. What new services could be offered to the DSO? Is the flexibility potential and concept relevant for DSOs? What policy changes and upgrades are necessary for enhancing and leveraging flexibility?

PUC 4 Part 2	How should the storage facility be operated? What is the optimal charge/discharge pattern required to satisfy the needs of the DSO? Are there any technical hurdles to consider before we can do a large scale roll out? How can the flexibility potential be used by potential flexibility operators? Does the equipment suit the purpose of the use case? How much was the peak load in the grid reduced? Is the untapped flexibility potential relevant to other market participants?	How can a customer save money by participating in a regime like we design here? What money did we spend for the pilot - what is the possible investment ROI-case? Can the INVADE concept yield a profit for us? Is the flexibility potential and concept relevant for DSOs? Is it possible to save money with the facilities installed? What is the best possible investment-case? What is the ROI? What policy changes and upgrades are necessary for enhancing and leveraging flexibility?

Table 25. Potential and existing impediments for the pilot

Use-Case	Potential and current impediments to be handled
PUC-4	Legal and regulatory aspects in Germany, especially for operation of a CES by the DSO Delivery time of the CES Communication between CES / SMA platform and the INVADE platform Customer participation for the DES case

2.6 Architecture

The Architecture for each one of the pilots will be defined in Deliverable D4.2 inside Work package 4 tasks.

3 Conclusions

This document presents the technical specifications and concept to be tested out in each of the pilots defined for INVADE. Each pilot addresses a dedicated subset of the use cases (PUCs) specified for the project. The exploration of the selected use-cases will be carried out together with an extensive and diverse number of end-users and professional business partners. Emphasis has been placed on standardisation and scalability so that the pilots can easily scale up and be replicated for the benefit of future exploitation.

The connection between the overall INVADE platform and legacy systems have been described. This should cater for the operations specified for each pilot. The technical infrastructure created in the project, including communication and control systems, will be tested to see if the objectives of each pilot and the project overall, can be met.

Each pilot has identified a set of pertinent research questions – all accommodated within the scope of the specific project ambitions specified for the project overall. Both technical, user-specific and business relevant questions have been listed. Pilot owners will be responsible for the execution of the experiments required to answer the technically oriented and business-related questions.

Each pilot will explore congruent and overlapping aspects of flexibility. Important provisions needed to launch the pilots have also been defined. These must be monitored to ensure that the pilots can be launched on time and conducted to provide deep insight in the technical matters constituting the INVADE solution and to answer or provide sufficient decision support for the business and user related issues identified.