Ref. Ares(2020)7986992 - 29/12/2020

Accelerating the decarbonisation of
islands' energy systems

Project No. 957669

Project acronym: ISLANDER

Project title:

Accelerating the decarbonisation of islands' energy systems

Programme: H2020-LC-SC3-2020-EC-ES-SCC
Start date of project: 01.10.2020
Duration: 48 months

Deliverable 1.1

High-level view of the overall system and components

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Due date of deliverable: M2- November 2020 **Actual submission date:** 29/12/2020

Deliverable Name	High-level view of the overall system and components
Deliverable Number	D 1.1
Work Package	WP 1
Associated Task	T1.1
Covered Period	M1-M2
Due Date	M2
Completion Date	M3
Submission Date	M3
Deliverable Lead Partner	Ayesa
Deliverable Author	Ayesa
Version	**1.3**

Dissemination Level		
PU	Public	**x**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Project funded by the European Union's
Horizon 2020 research and innovation programme

Change Control

Document History

Version	Date	Change History	Author(s)	Organisation
0.1	30/10/2020	**Table of Content**	Alicia Arce Rubio, Ángel Javier Jiménez Pérez, Emiliano Mesa Arenas	AYE
1.0	24/11/2020	**Document drafted**	Alicia Arce Rubio, Ángel Javier Jiménez Pérez, Emiliano Mesa Arenas, Carlos Martínez de Guereñu, Marta Puente, Vito Mario Fico, Olaf Look	AYE, ZIG, CEG, IDE, NBG
1.1	28/11/2020	**Document revised**	Alicia Arce Rubio, Ángel Javier Jiménez Pérez, Emiliano Mesa Arenas	AYE
1.2	14/12/2020	**Document revised & finalised**	Alicia Arce Rubio	AYE
1.3	29/12/2020	**Last version**	Alicia Arce Rubio, Ángel Javier Jiménez Pérez, Emiliano Mesa Arenas, Carlos Martínez de Guereñu, Marta Puente, Vito Mario Fico, Olaf Look	AYE, ZIG, CEG, IDE, NBG

Distribution List

Date	Issue	Group
28/11/2020	**Revision**	Coordinator AYESA, ZIG, CEG, IDE, NBG
29/12/2020	**Acceptance**	Coordinator AYESA, ZIG, CEG, IDE, NBG
29/12/2020	**Submission**	Coordinator AYESA

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Abbreviations

AEL	Alkaline Electrolyser
AFC	Referred to Hydrogen storage technology. Type of fuel cells based on Alkaline
AI	Analogue Input
ATEX	European Directives for controlling explosive atmospheres
BMS	Battery Management System
BTM	Behind The Meter
CAN	Controller Area Network. Communication protocol
CCM	Catalyst Coated Membrane
CHP	Combined Heat and Power plant
CSMS	Charging Station Management System
DBU	Deutsche Bundesstiftung Umwelt
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management System
DR	Demand Response
DSO	Distribution System Operator
EDPR	Emergency demand response program
EEG	Erneuerbare Energien Gesetz (Renewable Energies Act)
EEX	European Energy Exchange
EMG	Energy Management Gateway
EMS	Energy Management System
ESCO	Energy Service Company
ESP	Energy Service Providers
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicle
EWE	Name of the German company providing services as energy supplier
FFR	Fast Frequency Response
FTM	Front The Meter
GDE	Gas Diffusion Electrode
GSM	Global System for Mobile Communication
GWh	Gigawatts hour
HV	High Voltage
IEC	Standard
IIoT	Industrial Internet of Things
IoT	Internet of Things
KNK	Open standard for building automation
LFP	Battery technology Lithium-Iron-Phosphate
LV	Low Voltage
MCFC	Referred to Hydrogen storage technology. Type of fuel cells based on molten-carbonate
MCP	Protection and Communication Module
MEA	Membrane Electrode Assembly
MRL	Manufacturing Readiness Level
MV	Medium Voltage
NE	Netz Ebene (grid level)
NGSI	Next Generation Service Interface

PAFC	Referred to Hydrogen storage technology. Type of fuel cells based on phosphoric acid
PEM	Polymer Electrolysis Membrane
PEMFC	Referred to Hydrogen storage technology. Type of fuel cells based on Proton exchange membrane
PI-ESS	Power intensive energy storage system
PI-ESS	Power intensive energy storage system
POC	Point of connection
POD	power oscillation damping
PPA	Power Purchase Agreements
PV	Photovoltaic panel
RC	Remote Control
RESS-based system	Installation with storage and renewable energy source
RLM	Energy Tarif: Registered Performance Measurement
SA	Switch Actuator
SCADA	Supervisory Control and Data Adquisistion
SGMA	Smart Grid Model Architecture
SLP	Energy Tarif: Standard Load Profile
SOC	State of Charge
SOEC	Solid Oxide Electrolyser
SOFC	Referred to Hydrogen storage technology. Type of fuel cells based on solid oxide
SOH	State of Life
SRIA	Strategic Research and Innovation Agenda. Mentioned in the context of Hydrogen
SSH	Social Science & Humanities
STATCOM	Static Synchronous Compensator
TRL	Technology Readiness Level
TSO	Transmission System Operator
UK	United Kingdom
USEF	Universal Smart energy Framework
V1G	Unidirectional power flow
V2B	Vehicle to Building
V2G	Vehicle to Grid
VPP	Virtual Power Plant
WBG	Wide Band Gap
WLAN	Wireless Local Area Network (LAN)

1 Introduction

Islander project has as a main objective to implement several innovative actions in the field of Energy to decarbonize islands. Specifically, the demonstrator will be the Island of Borkum in Germany, but the replicability will be under the scope of the project including other European Islands in Greece, Croatia and UK. The innovative actions are mainly focused on the integration of renewables, storages, electromobility, active prosumers and district heating. To that end, different technologies will be deployed in the island and holistically design the size and the later operation in the real environment. Currently there are several pilots in Europe where different technologies are being deployed such as Insulae, React, Maesha, Ianos, Gift, Robbinson, VPP4Islands. One of the key aspects in Islander project is the holistic approach of the design of the assets and later the operational optimization in an aggregated manner with the main objective to ensure the quality of the energy grid with weak characteristics. Therefore, the project can be divided in 3 different technology aspects:

1- Optimal design
2- Deployment of hardware components
3- Advanced control and operation

This report aims to present a high-level overview of the different aspects covered in the project providing a review of the state of art and different options to be studied in the next stages of the project. The document is organized starting from the general hardware and software components to be deployed in the island of Borkum, then the several pilots to be tested in the living lab, and finally a whole overview of the main use cases to be considered within the pilots.

ISLANDER project will refine the proposed actions contained in this report and land the concept in the island of Borkum by presenting real options to be further studied in order to deploy them in a future stage of the project according to the existing possibilities.

2 Overall view

To a better comprehension about the project scope, next figure shows the Smart Grid Architecture Model (SGMA) to illustrate the main components under study. This figure is included in the Smart Grid Reference Architecture report produced by the CEN-CENELEC Smart Grid Coordination Group [14] where it is defined the architectures and a classification of protocols amongst domains and zones.

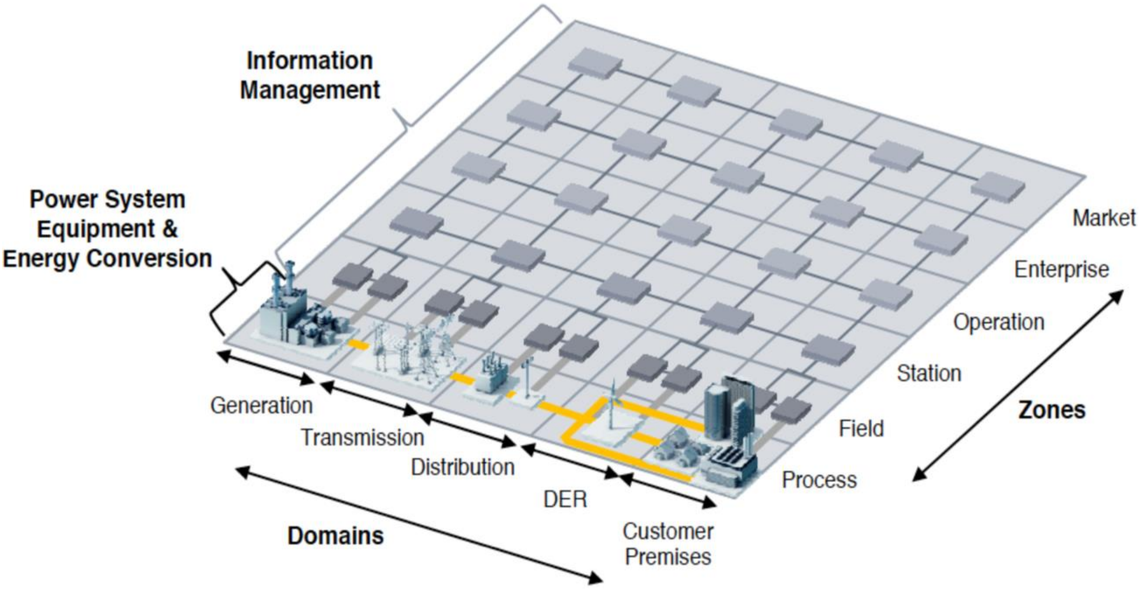


Figure 1 SGAM framework [14]

According to [14], the different domains and zones are defined as follow:

SGAM domains:

- **Bulk generation** represents the generation of electrical energy in bulk quantities by, for example, the fossil, nuclear, off-shore wind farms or large-scale solar power plants and typically connected to the transmission system.
- **Transmission** is the infrastructure and organization that transports electricity over long distances.
- **Distribution** represents the infrastructure and organization that distributes electricity to customers.
- **Distributed energy resources** (DER) are connected to the public distribution grid, applying small-scale power generation technologies (3kW-10MW) and may be directly controlled by Distribution System Operators (DSO).
- **Customer premises** (end-users of electricity and producers of electricity) include industrial, commercial and home facilities. Also, generation in form of photovoltaic, electric vehicles storage, battery, micro turbines.

SGAM zones:

- **Process** includes the physical, chemical or spatial transformation of energy and the physical equipment directly involved.
- Field includes the equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
- **Station** includes the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
- **Operation** hosts power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.

- **Enterprise** includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders …), e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement and so on.
- **Market** represents the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market and so on.

The following table contains a preliminary list of components included in the project scope, regardless of its involvement into the different use cases. The components are related to SGAM zones and domains.

Domains → Zones ↓	Generation	Transmission	Distribution	DER	Customer Premises
Market	VPP / Market	-	-	-	-
Enterprise	-	Smart IT platform	-	Cloud data provider	Web/Mobile app
Operation	-		-	-	-
Station	-	-	-	-	-
Field	-	-	-	V2G/V2B Electric storage Inverter (Charger)	Gateway/router Smart meter Datalogger V1G Smart appliances Temperature sensor
Process	-	-	Street lighting	PV	Home/Building Loads EV Seawater heat

Table 1 Zones and dominions of ISLANDER

2.1 Current status of Borkum grid

The current section is focused on providing a general understanding about the Borkum grid. Specifically, the grid structure, energy mix and stability of the energy distribution will be covered along with the energy tariffs and purchase.

2.1.1 Grid structure

The grid structure of Borkum is represented in the next figure. Three different levels are defined.

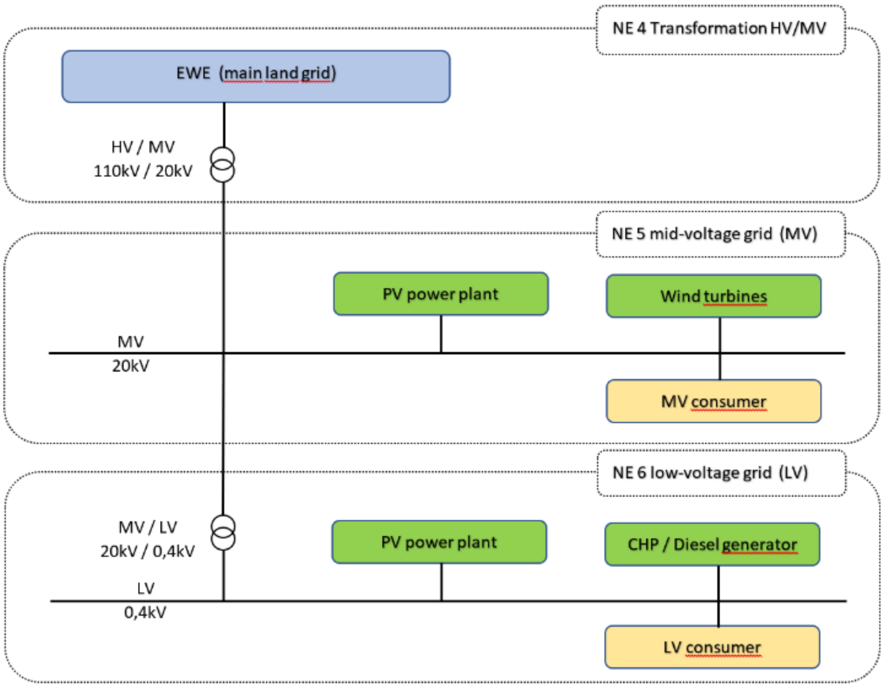


Figure 2 Grid-structure scheme

On the North Sea island of Borkum, the power supply is guaranteed by a medium-voltage grid. This medium-voltage grid is connected to the mainland in the "Reede" area by four undersea power cables about 25 km long.

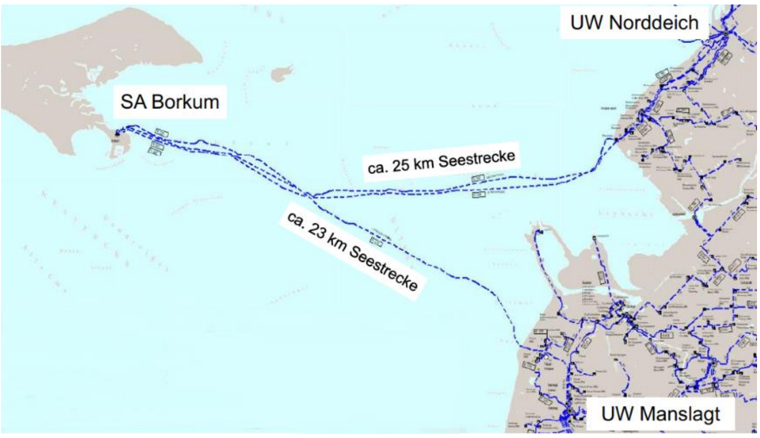


Figure 3 grid connection 20kV to the mainland

The owner of these submarine cables is the upstream energy supplier "EWE" which is also the electricity supplier of the "Stadtwerke Borkum". The transfer of the electricity energy takes place in the "Übergabestation Reede" and is transported from here over the entire 31km² island to the various users.

The medium-voltage network with a total length of 84,85 km supplies the 65 local substations with electricity. In these substations, the electricity is transformed from 20.000V to 400V and from there, it is distributed to the customers on Borkum via a 12,54 km low voltage cable grid.

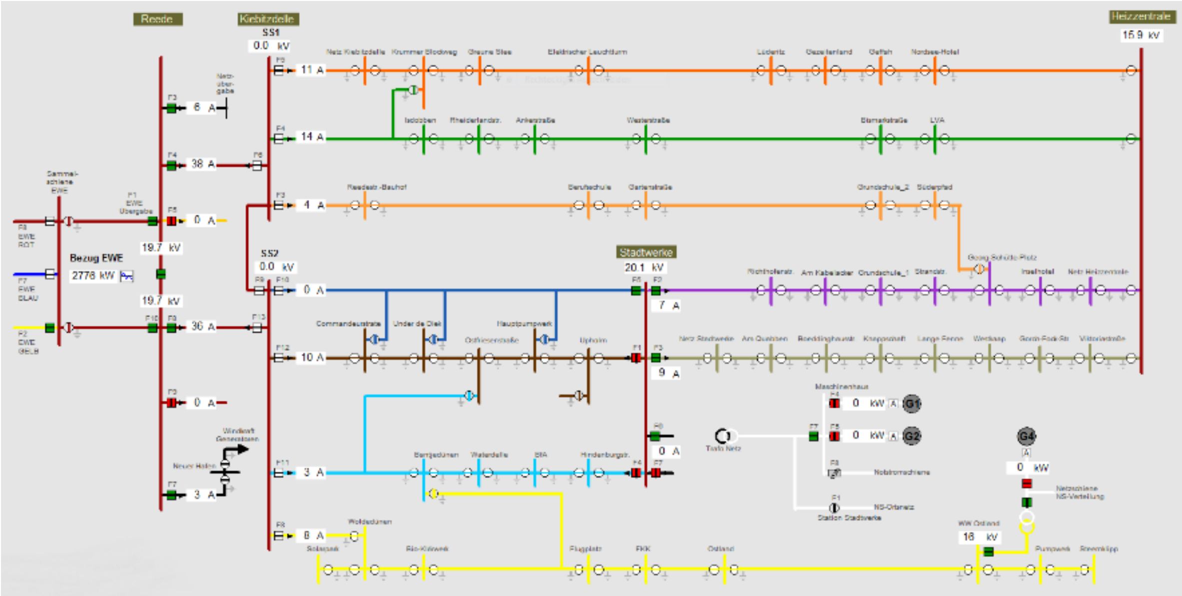


Figure 4 Medium voltage grid 20kV

The energy demand on Borkum was covered in 2019 by the following feed-ins into the island's grid:

- Upstream energy supplier "EWE" 46,11%
- Two wind turbines á 1.8MW 32,93%
- A solar park of 1.4 MWp 4,57%
- CHP 12,50%
- 160 private rooftop solar systems 3,89%

The annual energy demand (Fig. 5) of the island with its 5.200 inhabitants and about 290.000 overnight guests per year was 32.734.459 kWh in 2019.

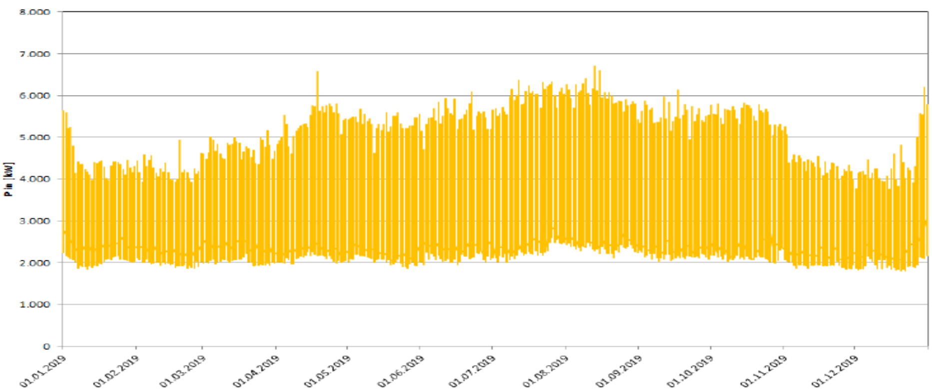


Figure 5 Annual load curve Borkum

The annual peak output (Figure 6 Grid load on peak load day) was 6,710 kW on 13.08.2019 at 11:00.

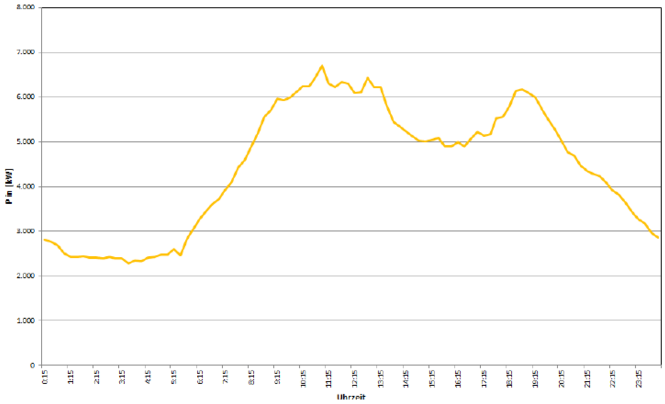


Figure 6 Grid load on peak load day

2.1.2 Energy tariffs (Stadtwerke Borkum)

There are different energy tariffs at Stadtwerke Borkum which are based on the planned annual quantity of the customer:

Standard load profile (SLP), here a standard load curve for the daily electricity consumption is assumed.

- “Grundversorgung” A tariff for customers under 2000 kWh per year.
- “StadtwerkeSpezial /BorkumWatt Comfort” Is a contract that adapts to the sales of the customer and is also interesting for commercial customers. Reason are price levels. Overall, the special customer contract is worthwhile from a consumption of approx. 2,000 kWh/a. The following price levels are available:
  - 2000 - 9999 kWh
  - 10000 - 29999 kWh
  - 30000 - 99999 kWh

  Here too, the AP becomes lower and the GP higher as consumption increases.

Registered performance measurement (RLM), In the RLM area it is so that we buy for each individual customer directly through an exchange tool. This is then also done at a low-cost time which we monitor ourselves. The advantages here are that advantageous load curves of the customers can be priced in and also receive a customer-specific purchase price.

Billing: the net price that the customer sees on the invoice is made up of many different price components. On the one hand, the pure energy price that we buy for the customer or the tranche + the electricity tax + the concession fee + all other nationwide levies. The SLP customer only sees the fully formed price. However, the invoice refers to the grid fees, the EEG levy and Co. and these are shown in a separate window. This is intended to show to what extent we can still determine the price at all and how large our share in the final price is (<40%).

Verbrauchs- und Betragsermittlung Strom

Informationen zu Ihrem Vertrag 3058505			
Der Versorgungsvertrag kann jederzeit gekündigt werden.			
Verbrauchsstelle	Wilhelm-Bakker-Str. 15 , 26757 Borkum		
Marktlokation	51150987896	**Netzbetreibercode**	9900097000008
Messlokation	DE00009726757SNSR0000000000001690		
Messstellenbetreiber	Nordseeheilbad Borkum GmbH		

Leistung							
Zählernummer /Zählwerk	**Zeitraum von**	**bis**	**Zählerstand alt**	**neu**	**Differenz**	**Faktor**	**Leistung**
	01.10.20	31.10.20					60,700 kW

Wirkarbeit							
Zählernummer /Zählwerk	**Zeitraum von**	**bis**	**Zählerstand alt**	**neu**	**Differenz**	**Faktor**	**Verbrauch**
35661449/006	01.10.20	31.10.20					14.457,200 kWh
						Gesamtverbrauch	**14.457,200 kWh**

*Ablesegrund: A = Ablesung, C = Schätzung, E = Einzug, G = Sperrung, H = Hochrechnung, P = Preisänderung (rechn. Abgr.), S = Selbstablesung, W = Wiederinbetr., Z = Zählerwechsel

Betragsermittlung							
Preisart	**Zeitraum von**	**bis**	**Abrechnungsmenge bzw. Faktor**		**Preis**	**Monate bzw. Tage**	**Betrag**
Strom Jahresleistung NSP							
Lieferung							
Arb.preis Wirk HT	01.10.20	31.10.20	14.457,200 kWh	x	5,0500 ct / kWh		730,09 €
BorkumWatt - Natur	01.10.20	31.10.20	14.457,200 kWh	x	0,2000 ct / kWh		28,91 €
BorkumWatt - Natur	01.10.20	31.10.20	0,000 kWh		0,2000 ct		0,00 €
Grundpreis	01.10.20	31.10.20			120,00 € / 12 x	1	10,00 €
Stromsteuer	01.10.20	31.10.20	14.457,200 kWh	x	2,0500 ct / kWh		296,37 €
EEG-Anteil	01.10.20	31.10.20	14.457,200 kWh	x	6,7560 ct / kWh		976,73 €
Netznutzung							
Arb.preis Netz	01.10.20	31.10.20	14.457,200 kWh	x	6,2200 ct / kWh		899,24 €
Leist.preis Netz	01.10.20	31.10.20	67,900 kW	x	33,00 € / 12 x	1	186,73 €
Konzessionsabgabe	01.10.20	31.10.20	14.457,200 kWh	x	0,1100 ct / kWh		15,90 €
KWK	01.10.20	31.10.20	14.457,200 kWh	x	0,2260 ct / kWh		32,67 €
Messbetrieb	01.10.20	31.10.20	1 St		528,40 € / 12 x	1	44,03 €
Offshore-Haftungsumlage	01.10.20	31.10.20	14.457,200 kWh	x	0,4160 ct / kWh		60,14 €
Umlage §19	01.10.20	31.10.20	14.457,200 kWh	x	0,3580 ct / kWh		51,76 €
abLa Umlage	01.10.20	31.10.20	14.457,200 kWh	x	0,0070 ct / kWh		1,01 €
					Nettosumme Strom		3.333,58 €
					Umsatzsteuer (16 %)		533,37 €
					Bruttosumme Strom		**3.866,95 €**

Figure 7 Electricity cost overview of the customer

2.1.3 Energy Purchasing (Stadtwerke Borkum)

The energy is purchased by "Stadtwerke Borkum" either at a favorable time on the EEX electricity stock exchange in Leipzig or in a so-called rolling purchase procedure in which usually 50% of the annual energy requirement is purchased.

Figure 8 Energy stock exchange

2.1.4 Stability of energy distribution

Electrical loads both generate and absorb reactive power. Since the transmitted load often varies considerably from one hour to the next, the reactive power balance in a grid varies as well. This can result in unacceptable variations in voltage, including voltage depression or even voltage collapse.

To avoid this, the upstream energy supplier "EWE" installed a so-called STATCOM system directly at the transfer point "Reede". This system uses power electronics to control the voltage stability on Borkum, especially when energy is fed in by wind and PV. This ensures a constant, good voltage stability at all times.

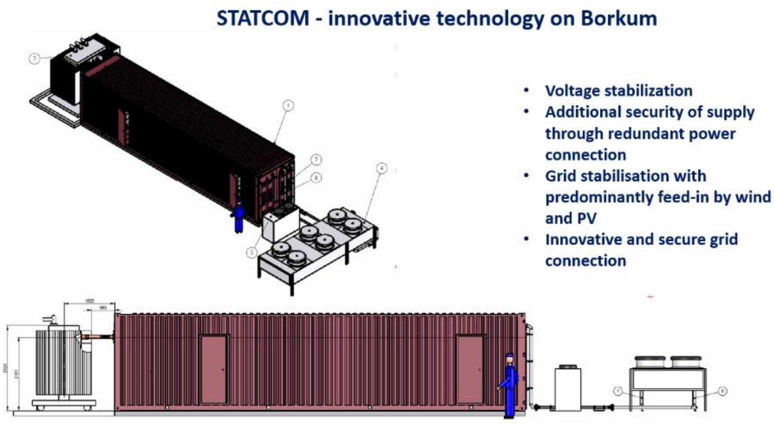
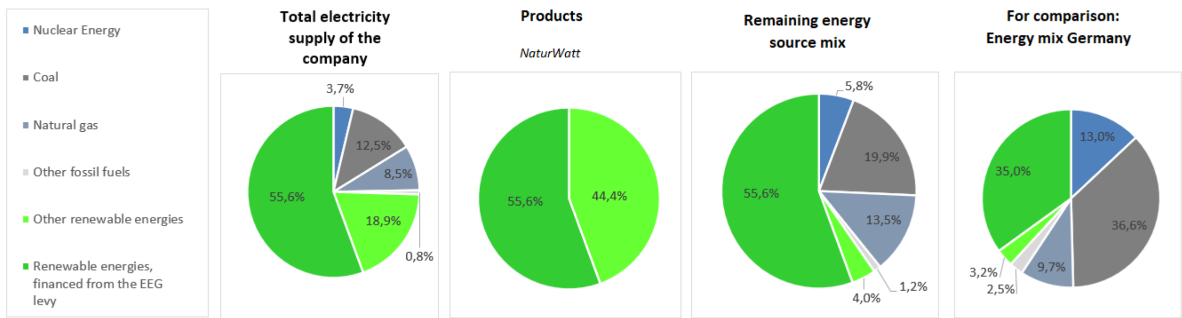


Figure 9 STATCOM

2.1.5 Energy mix on Borkum

The citizens of Borkum developed an awareness of renewable energies at a very early stage. This is based on the intention of an energy production company to build a coal-fired power station directly in front of the island on the Dutch side. With this prospect of air pollution and the resulting problems, the desire for a green electricity product on the island grew.

Therefore, the energy mix on the island is already greater than in the rest of Germany in terms of renewable energy. Currently, almost 60% of the island's energy supply is covered by renewable energies. By comparison, only about 38% of the energy in Germany as a whole is produced from renewable energies.



CO2 emission	163 g / kWh	0 g / kWh	260 g / kWh	421 g / kWh
radioactive waste	0,0001 g / kWh	0,0000 g / kWh	0,0002 g / kWh	0,0003 g / kWh

Figure 10 Energy mix Stadtwerke Borkum

2.1.6 Electromobility

As Borkum has only a limited area and therefore only a small road network. The island is an ideal environment to develop electric mobility. Therefore, there are already various applications for electric cars on Borkum.

Section 3.8 and 3.9 gathers more details about the charging stations and Electric Vehicles.

3 Power systems Equipment and energy conversion

3.1 Hydrogen production and storage

Europe is undergoing the early stages of an enormous energy transition in order to decarbonise all aspects of our daily lives in a short time. The current EU's CO_2 emission objectives include a reduction of 40% by 2030, and to successfully pursue them, energy-intensive industries shall be drastically decarbonized. It is commonly recognized that the energy transition in the EU will require hydrogen at large scale. Without it, the EU would miss its decarbonization objective. Projects as ISLANDER are crucial to develop the necessary skills and obtain data to make this transition possible.

3.1.1 Hydrogen Factsheet

Hydrogen is the lightest chemical element. It is a diatomic gas (H_2 formula), colourless, odourless and very flammable. It is the most abundant element globally, having an unlimited availability if breakdown of water is possible.

Hydrogen is an energy carrier that contains 33.33 kWh of usable energy in a 1 kg of hydrogen. Comparing this carrier with petrol and diesel, those only hold about 12 kWh/kg. Moreover, the molecular weight is 2.01 g/mol, while the molecular dimensions are between 2.4-3.1 Angstrom (1 Å = 1-10 meters). In normal conditions, hydrogen is in the gaseous phase, being the boiling point -252.8 ºC and the melting point -259.1 ºC. Between the ATEX classification, hydrogen is classified in zone 0 as hazardous location (gas/vapours), and the explosion group is IIC, being the temperature classes T1 (<450ºC).

The hydrogen density is very low (0.09 g/l in the gas phase and 70.8 g/l in the liquid phase) [5][7]. Thinking of H_2 as a fuel, the gas is around 55 times less dense than the gasoline in normal conditions. The hydrogen's gravimetric energy density is higher than other fuels' property (relation until 2.5/1), so the required fuel mass to release energy is reduced when hydrogen is the used fuel. This is a significant advantage. But due to the low density, 1 Kg of H_2 at normal conditions T and P (1 bar and 0ºC) has a volume around 11.1 m^3. This makes that the storage of the gas is a topic to be investigated at a great level of detail.

Definitively, hydrogen is considered a promising energy carrier for a sustainable future in the world. If it is produced by renewable energy much better, as will be explained in the next point about the electrolysis.

3.1.2 State of the art and future challenges

The main objective of the ISLANDER project is to obtain a significant progress towards the full decarbonization of the Borkum island foreseen by 2030, treating to completely avoid to import electricity from the mainland, as well as the consumption of electricity from Gas CHP and natural gas boilers, that produce a high percentage of carbon dioxide.

One of the key points of this process is to provide a suitable means of energy storage. Indeed, although the island has a current net negative energy balance of 17.06 GWh per year, a considerable amount of electricity (1.2 GWh per year) is also exported to the mainland. This excess is due to both the fluctuations in power production and consumption during the year. Borkum also has an additional problem, I.e., it is a tourist destination famous for its thermal areas and uncontaminated nature, fact that makes the inhabitants of the island grow five times in number during the summer period.

From this scenario, it appears clear that providing means for energy storage, above all from renewable activities is a cornerstone for a successful decarbonisation of Borkum. In this way, one of the main topics to be studied is the local generation of electricity and storage. Concretely, a hydrogen storage system coupled with renewable energy from PV. With renewable energy in excess, hydrogen can be produced and be stored at pressure. Thinking in the seasonal long-term, when there is more demand, the stored hydrogen could be used for electricity production in a fuel cell.

Today there are few technologies that could provide an effective and green way of storing energy. Figure 11 shows a summary of the most promising systems, as well as their limitations in power and discharge duration.

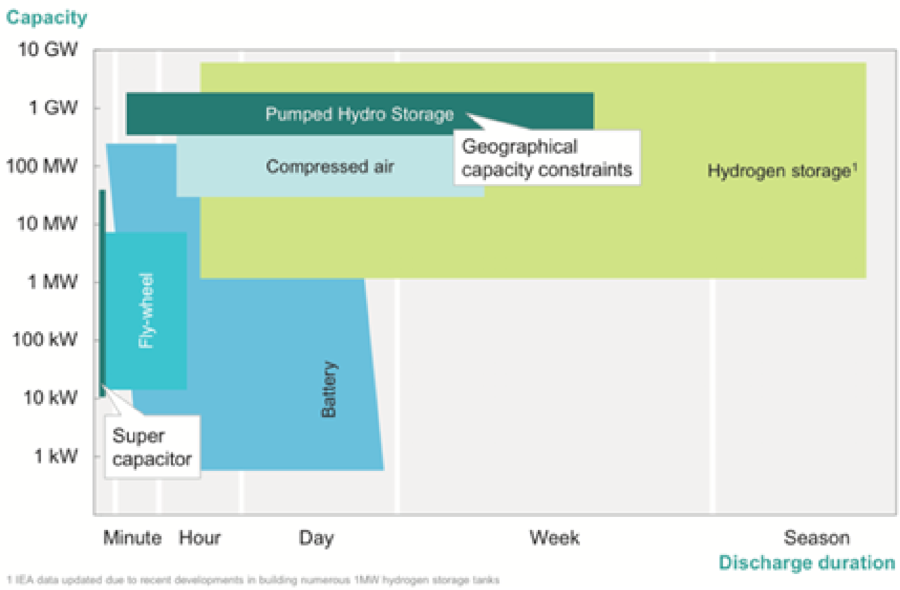


Figure 11 Capacity and discharge duration for different energy storage [3]

Battery technology has undergone a significant improvement during the last years, but still, it is not suitable for storing large amounts of electricity over time. In this framework, hydrogen plays a fundamental role, as it can be produced from (surplus) renewable energies, and unlike electricity it can also be stored in large amounts for extended periods of time.

In real life energy storage applications like as in the ISLANDER project, a storage system including both short-term and long-term energy storage is needed. The short-term storage is often based on battery packs due to its high round-trip efficiency, ability to take care of instantaneous power peaks and the convenience of charging and discharging, while hydrogen is used as a solution for the long-term (seasonal) energy storage. By combining both systems an improved storage solution is created as the technologies makes an excellent match in complementing each other [1], [2].

These points are related to one of the main challenges in the ISLANDER project, the paired storage solutions. Hydrogen production, and subsequent storage, is one of the biggest challenges today, as their development to reach a price inferior to 3€/kg [3] has been identified as the enabling point for the hydrogen-based ecosystem to compete with fossil fuels commercially.

A power-to-power system based on hydrogen as a vector, like the one to be implemented in the ISLANDER project, is mainly composed of the electrolyser, the hydrogen storage tank, the fuel cell and the buffer Li-ion battery cell. Additional components are also generally present, like the power converters and the hydrogen compressor, but they depend respectively on the grid voltage and the needed storage pressure.

In the electrolyser, the water is decomposed into oxygen and hydrogen gas using electricity. Then the hydrogen is stored in the tank at a specific pressure and special conditions. When electricity is demanded in a determinate situation or particular season of the year, the gas is released and converted by electricity into the fuel cell. This electricity is then sent to the grid for the customers' consumption. A final element as a Li-ion battery also will be installed. The battery's function will act as a buffer to stabilize voltage levels within the system and for power balancing. Other elements as inverter and power electronics will be necessary and will be specified accordingly as the project progress.

There are other techniques for mass hydrogen production. During the last decade, the most employed technique has been the reforming or gasification of fossil fuels at higher pressures and temperatures. A by-product of this process is carbon dioxide or carbon monoxide, elements very harmful to the environment. Moreover, the quality of the hydrogen is not enough for some applications. So, these reasons make electrolysis the most effective, safe and efficient technique for hydrogen generation.

An important issue is the very low volumetric energy density of the hydrogen. Under ambient conditions, a cubic metre of hydrogen provides some 3 kWh, equivalent to 0.003 kWh per litre. Compared to liquid fuels, which carry around 8.8 and 10 kWh/litre, hydrogen has a great disadvantage, which makes necessary to store it at very high pressures (more than 200 bar) in order to be competitive. Although all the technologies involved are very mature at the date, this introduces an additional complexity and danger when dealing with hydrogen-based systems.

3.1.3 General description of the system components

A general description of the components of the hydrogen storage system is presented at this point. Also, the preliminary sizing, according to the Grant Agreement for each of them is given.

3.1.3.1 Electrolyser

Electrolysis is the process where, with an electric current, substances are decomposed into simpler ones. In the water case, H_2O is split, and the elements obtained in the electrolysis are hydrogen and oxygen. The electrolyser has two electrodes, separated with an electrolyte. In the cathode (negative electrode), the current is applied, and water molecules are reduced. At the anode (positive electrode), the electrons produced by the electrochemical reactions return to the positive terminal of the DC source. Electrolysis of water is currently the best sustainable way and renewable chemical technology for hydrogen production.

It is also useful to analyse the efficiencies of the various steps in hydrogen-based power-to-power applications. An electrolyser needs around 4.2 – 6 kWh per Nm^3 of produced hydrogen, i.e., between 50–68 kWh per kilogram of produced hydrogen [4]. Having in mind that the specific energy of 1 Kg of hydrogen is 33.3 kWh, the efficiency of the equipment can vary around 60-80%. Also, if a compressor step is required, the efficiency of the equipment will be approximately 70%. Moreover, the last step in the process (fuel cell) has an efficiency that could be estimated between 60-70% [5]. The round-trip efficiency can thus be estimated between 25-40%.

The equipment where the electrolysis process is carried out is the electrolyser. Several types of electrolysers are in the market. The most common are alkaline electrolyser (AEL) and PEM (Polymer Electrolysis Membrane) electrolyser. Moreover, other types exist as Solid oxide Electrolyser (SOEC) but with some limitations due to the higher temperatures are necessary. For the ISLANDER project, a PEM electrolyser will be used, as this is a mature technology which currently offers the highest performances in terms of efficiency, maintainability and scalability. This design decision is followingly motivated by a brief overview on the available technologies.

- **Alkaline electrolyser**

As in all the types of electrolysers, two electrodes form the AEL. At the cathode, water molecules are reduced by electrons to hydrogen and negatively charged hydroxide ions. At the anode, hydroxide ions are oxidized to oxygen and water while releasing electrons. With both, an overall reaction is obtained where water molecule reacts to hydrogen and oxygen.

The reactions that take place in the electrolyser can be seen in the next equations [6]:

Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Anode: $2OH^- \rightarrow ½\ O_2 + H_2O + 2e^-$

The overall reaction: $H_2O \rightarrow H_2 + ½\ O_2$

The next image shows the principle of an alkaline electrolysis process:

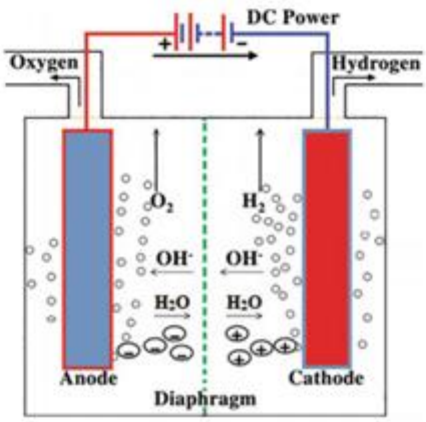


Figure 12 . Scheme of an Alkaline water electrolyser, [17]

Besides the electrodes, other components of AEL are the electrolyte, the diaphragm, and the electrolytic cells.

The electrolyte provides the necessary ions for the conduction. The most typical and effective used solution is potassium hydroxide KOH in a concentration between 25-40%. Also, solutions as NaOH or NaCl are employed. The electrolytes conductivity increases with the temperature, getting the optimum between 60-90ºC according to several studies. The next graphic presented the relation between temperature and conductivity.

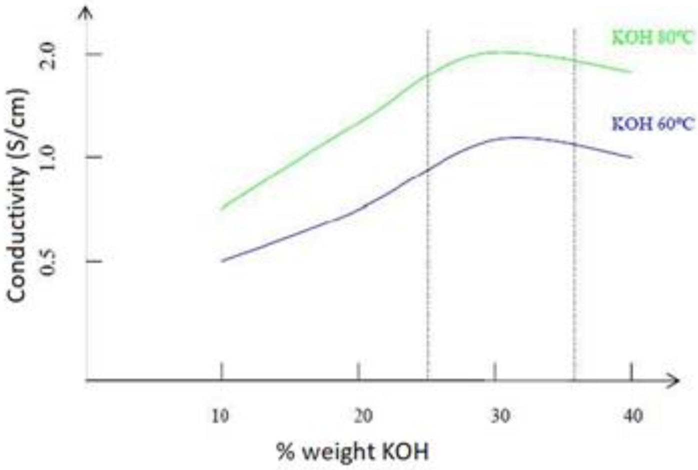


Figure 13 Relation between temperature and electrolyte concentration in the alkaline electrolyser [19]

Diaphragm or membrane separates the compartments electrodes. In this way, only it allows the passage of the ions that transmit the charge from cathode to anode. Ceramic oxides usually compose the used material in the membrane as TiO_3, $CaTiO_3$, NiO and polysulfides.

The electrolytic cells are the different elements where the electrolysis is produced. They are electrically connected to each other. In the monopolar configuration, cells are connected in parallel, while in the bipolar design, the cells are in series (anode of a cell is connected to the cathode of the next one).

- **PEM electrolyser**

Nowadays, the PEM electrolyser is considered the most promising technique for high pure efficient hydrogen production from renewable energy sources regarding sustainability and environmental impact. It emits only oxygen as a by-product without any carbon emissions. This type of electrolysers is very compact.

In PEM water electrolysis water is pumped to the anode, and water is spilt into oxygen, protons and electrons, these protons H^+ goes via proton conducting membrane to the cathode side. The electrons exit from the anode for the external power circuit providing the cell voltage for the reaction. Reactions in the process can be seen in the next equations [7]:

Anode: $H_2O \rightarrow 2H^+ + ½ O_2 + 2e^-$

Cathode: $2H+ + 2e^- \rightarrow H_2$

Overall reaction: $2H_2O \rightarrow H_2 + ½ O_2$

Main PEM electrolyser components are membrane electrode assemblies (MEAs), current collectors and separator plates. A brief description of each one is presented in the next paragraphs.

Solid perflourosulfonic membranes as Nafion or Fumapem are used as proton conductor, with thickness around 50-250 microns. Due to this technology, it is possible to operate at high densities, and the result is highly pure hydrogen production. These membranes have high efficiency and high oxidative stability, good durability, and high proton conductivity. The addition of ionomer solution with ionic transport properties in the catalytic layer promoting the proton transport from the electrode layers to the membrane, and also increasing the cell efficiency.

The separation plates and current collectors are fundamental elements in a PEM electrolyser. Between both are responsible for 50% of the total cost of the equipment. The separation plates must be a provision conduction path of pumping water and produced gases out of the electrolysis cell. Typically, titanium materials give outstanding strength and with thermal conductivity, but in the anode side, Ti could get corrosion and grows inert oxide layer, decreasing the performance of the electrolyser. To solve this issue, a coating is applied.

In a general way, PEM has some advantages compared with alkaline electrolysis. PEM electrolysers can work at higher intensities, generating purer hydrogen working at high pressure. On the other hand, it is not necessary to use corrosives electrodes, which makes it easier maintenance. Note also that PEMs have a dynamic response very fast that makes accessible the assembly to the fluctuant systems, such as renewable energies.

3.1.3.2 Hydrogen storage tank

In order for hydrogen to act as an energetic vector in power-to-power applications, it needs to be stored and then used when necessary for electricity production in the fuel cell.

More detailed information will be developed during the project execution, but mainly, hydrogen can be stored:

- In the gaseous phase in pressurized tanks.
- In the liquid phase, by using cryogenic reservoirs.
- In metallic hydrides.

Other types of hydrogen storage are glass micro-spheres, solid storage systems as carbon-based materials, but at the current state these technologies are not mature enough to be viably used in a high TRL application as the one in ISLANDER.

- **Storage at pressure**

This kind of storage is the most common method. The hydrogen is stored in the gas phase. The used tanks for this proposal are mobile or static tanks, as well as underground caves. Hydrogen for use in labs or small pilot industries is usually stored in bottles at 200 bar, while for industrial productions in horizontal tanks with a vast range of pressures.

Existing four types of vessels for hydrogen storage at high pressure [8]. The election will depend on the final application. They are classified in different types (type I, II, III, and IV). A brief description can be found in the next table:

Tank type	Description
Type I	Pressure vessel made of metal
Type II	Pressure vessel made of a thick metallic liner hoop wrapped with a fibre-resin composite
Type III	Pressure vessel made of a metallic liner fully-wrapped with a fibre-resin composite
Type IV	Pressure vessel made of polymeric liner fully-wrapped with a fibre-resin composite. The port is metallic and integrated in the structure

Table 2. Types or tanks for high pressure hydrogen storage

Due to the higher pressures of the stored, the material of the tanks is very important as appears in the previous table. The most prominent technology presents a material composed of three layers, as it is possible to see in the next figure as an example mode (Tank type III or IV). It consists of an inner layer made of a nylon-based polymer with low hydrogen permeability, an intermediate layer of epoxy resin with carbon fibre that gives the structural rigidity to the tank, and external shell manufacture of a composite material based on fiberglass to protect the tank.

These types of tanks are for significantly higher storage pressures, getting over 700 bar depending on the design. Hydrogen as industrial gas is stored in type I tanks, where the pressure is around 150-300 bar. Other types of tanks that do not appear in the previous table can also be used for the general storage gases, where the pressure is not higher. For example, to storage at 40 bar, a conventional tank is enough with, of course, an appropriate consideration during the design.

- **Cryogenic Liquid hydrogen storage**

The main issue in this method is that the hydrogen's boiling point is 20.4 K (-252.7 ºC). For to get hydrogen in a liquid phase, it is necessary to have the gas between 14 – 20 K. To be able to be stored at atmospheric pressure, these lower temperatures will be required. To get the temperature, a significant amount of energy it is necessary. This makes that the system must be not much efficient. Moreover, to maintain the low temperature inside the tank, they need to be provided with strong insulations. [8], [9]. This kind of storage is still in the testing phase for small prototypes, and in the case of the ISLANDER project is not the optimum solution.

- **Metallic hydrides**

This technology is based on the capacity of some metals as Mg, Ti, Fe, Mn, Cr or Ni to form alloys with the hydrogen. This is an attractive alternative because of its versatility and because solid compounds can store more hydrogen per unit of volume than liquid hydrogen itself, as well as increasing the safety. But it is necessary to test that the metallic hydride has some characteristics, like, for example, that the hydride must be easily formed and decomposed, so that the kinetics of the absorption and desorption is fast. Also, it should maintain optimum operating conditions for as many loading/unloading cycles as possible. Moreover, the equilibrium pressure of the decomposition temperature of the hydride should be compatible with the safety requirement of the system [10].

3.1.3.3 Fuel Cell

The fuel cell is the element where electricity is produced. In this equipment flows of fuel and an oxidizing agent are introduced, getting as result electricity and water. In the ISLANDER project, the fuel is hydrogen (produced previously in the electrolyzer), and the oxidizing agent oxygen/air. The main difference with respect to the batteries is the requirement of a continuous fuel and oxidant source.

One of the main advantages of the fuel cell is the minimum environmental impact and high efficiency. Minimal impact because, in this electricity production method, the contaminant emissions are practically non-existent. The high efficiency is because there is no thermal intermediate process in the fuel cell, so a major conversion in other machines is getting because other machines are limited by the Carnot cycle.

In all the fuel cells, three parts are presented as the most significant elements: electrodes (anode where hydrogen H_2 is reduced in protons, and anode where protons and oxygen react), electrolyte or membrane (the element that separates the gases, allowing the pass of the ions H^+), and bipolar plates (they are in charge of the separation of the cells, conduct the gases and evacuate the water).

In the actual market exist several types of fuel cells based on the different types of electrolytes used. Remark here Proton exchange membrane (PEMFC), alkaline (AFC), phosphoric acid (PAFC), molten-carbonate (MCFC) or solid oxide (SOFC), being the PEM fuel cell the most promising one. Next table shows some characteristics of each one.

	PEMFC	AFC	PAFC	MCFC	SOFFC
Electrolyte	Polymeric membrane	Alkaline solution	Phosphoric acid	Molten carbonate	Solid oxide
Operating Temp (ºC)	60 – 80	100 - 120	200 - 250	600 - 700	800 – 1000
Power range (kW)	5 – 250	5 – 150	50 – 11000	100 - 2000	100 – 250
Main advantages	-Low temp. -Fast start-up -Low maintenance	-Cathodic reaction faster	Possibility to feed impure hydrogen	Internal reforming	Internal reforming
Prominent applications	-Transport -Residential use	Space sector	Electric distributed generation and heat	Electric distributed generation and heat	Electric distributed generation and heat

Table 3. Main characteristics of the fuel cells

In general, in all the fuel cells, three parts are presented as the most significant elements: electrodes (anode where hydrogen H_2 is reduced in protons, and anode where protons and oxygen react), electrolyte or membrane (the element that separates the gases, allowing the pass of the ions H^+), and bipolar plates (they are in charge of the separation of the cells, conduct the gases and evacuate the water).

In the ISLANDER project, the fuel cell will be a PEM cell fuel. Specifically, PEM fuel cells are constituted by MEA (Membrane Electrode Assembly), the union of the proton exchange membrane with the active layer (physical support of the catalyser particles) and diffuser layer (with mission is assure homogeneous expansion of the gas in the catalyser layer); CCM (Catalyst Coated Membrane), that is the assembly of PEM and the two active layers; And GDE (Gas Diffusion Electrode) formed by active and diffuser layers.

In a PEM fuel cell, hydrogen is oxidated at the anode, and the oxygen is reduced at the cathode. Protons are transported from the anode to the cathode through the electrolyte membrane, and the electrons are carried over an external circuit load. On the cathode, oxygen reacts with protons and electrons, producing heat and forming water as a by-product. The reactions in the electrodes are:

Anode reaction: H_2 -> 2H+ + 2e^-

Cathode reaction: 2H + ½ O_2 + 2e^- -> H_20

Global reaction: H_2 + ½ O_2 -> H_20

A simplified scheme of the process is represented in Figure 14 Scheme of the operation in a fuel cell.

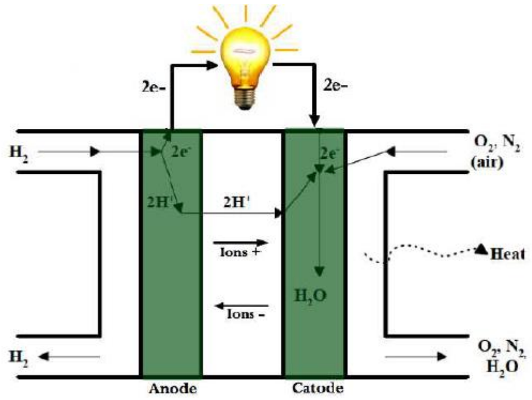


Figure 14 Scheme of the operation in a fuel cell [18]

It is possible to distinguish two PEM types depending on the operating pressure, being the first one of the next the most used. The first one (60-80ºC) is called low-temperature PEM and usually is used as electrolyte fluorinated Teflon-based material, generally called Nafion. The second one is called High-temperature PEM (110-180ºC), where it is possible to use Nafion or PBI (polybenzimidazole) doped in phosphoric acid. Note that Platinum is classically used in the catalyst for low temperature, while Platinum-Ruthenium is used in the second one.

Due to the compact design, the specific power is higher for these power sources PEM fuel cells than for all the other conventional types. It is also remarkable the fast start-up time, as well as comfortable and safe handling and maintenance.

3.1.3.4 Buffer Li-ion battery cell

At the end of the hydrogen production process (PEM fuel cell outlet) of the ISLANDER project, a Li-ion battery pack can be installed for power balancing, if needed. The objective of this battery pack is to stabilize the voltage levels within the system. In a general way, the electricity will go to the grid. Still, the possibility of storing some of the power in the battery will be possible for power balancing as it has been commented.

Another function of the battery pack is to be the basis for the short-term storage capabilities of the hydrogen system, thanks to their high round-trip efficiency, ability to take care of instantaneous power peaks and the convenience of charging and discharging. On the other hand, battery packs have a low energy density that makes the technology unsuitable for long-term usage.

3.1.3.5 *Inverter*

The final element in the hydrogen pilot plant will be a power inverter. With this power electronic device, the change of the direct current to alternating current (DC to AC conversion) will be possible. The input and output voltage, as well as the frequency, will depend on the design upstream of the pilot plant.

3.2 Seawater heat

Borkum has set itself the goal of being emission-free in 2030. This also includes that the heat demand of the island should be covered emission-free.
In order to achieve this, a much greater effort is required than just considering the electricity side, as the proportion of heat energy to electricity energy on the island is 4:1. For this reason the seawater surrounding the island has been identified as a potential renewable energy source. A first test was

carried out in 2018 as part of a project funded by the DBU (Deutsche Bundesstiftung Umwelt). This test showed the potential of the concept "Heating with the North Sea".
In this project, a new building of about 100 residential units will be supplied with heat from the North Sea and the potential of using the same system to cool the residential complex will be demonstrated.

Figure 15 Planning picture of the residential complex

For this purpose, a system is being set up in the area of the "roadstead" on Borkum which takes seawater from the harbour basin and conducts it through already existing PE pipes to the heat centre about 200m away with a system of a heat exchanger and a heat pump system.

Figure 16 PE pipes for sea water

This sea water has a fluctuating annual temperature of about 5 to 20° Celsius and also, has the problem that living organisms influence the temperature transport. In the heat station, therefore, the first step is to separate the seawater into a refrigerant and the first step of the temperature exchange. For this purpose, a heat exchanger with a following heat pump is installed in the heat centre.

From here the heat is transferred to the first stage of a heat pump which raises the temperature to a so-called cold local heating grid with a temperature of about 30° Celsius. This cold local heat is then fed through a 225m³ buffer storage tank and then through insulated district heating pipes to the transfer centre of the housing complex. Here, two separate heat pumps increase the temperature of the cold local heat (30°C) to the required heating temperature of 50°C and a hot water temperature of temporarily 70°C.

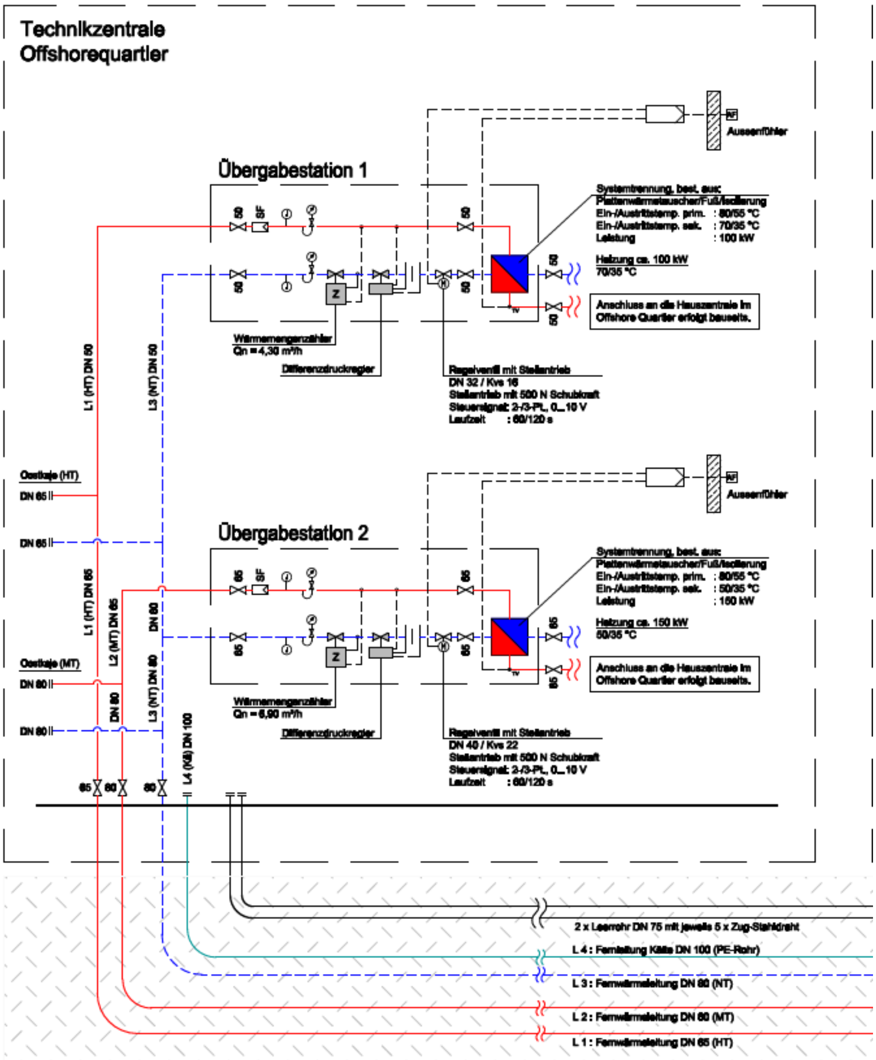


Figure 17 Technical planning residential complex

Parallel to the district heating pipes for the transmission of the cold local heating grid, cold water with the current seawater temperature can be fed to the residential complex via a separate pipe in order to ensure air conditioning of the residential complex on warmer days.

3.3 Storage Systems.

3.3.1 Households batteries

Cegasa will start from a module (eBick ULTRA 100) with a high TRL to be able to implement the new developments, in mechanics and electronics, during the 4 years of the project and carry out the necessary validations to install the batteries with total safety.

3.3.1.1 General characteristics

The eBick Ultra 170 will be the new version of Cegasa's eBick intended for residential or industrial self-consumption applications up to 50 kWh.

This battery is Cegasa's answer to installers looking for a pre-installed, self-managed battery, "Plug-and-go". Cegasa engineers have designed this energy storage system, creating a battery that is fast, intuitive and simple to install, it can also be connected to any 48 Vdc inverter in the market (SMA, Victron, Studer, Goodwe, Ingeteam, etc.), whether connected to a network or in a remote installation.

This battery is based on LFP (Iron Phosphate) chemistry which is the most suitable cell type for stationary solutions where the number of cycles or the power required is demanding. Its service life is at least 4 times higher compared to the other lithium-ion chemistry (NMC) used in EVs. In addition, it is the only completely safe chemical technology as it presents no risk of ignition or explosion, even if it is exposed to conditions outside the cell specification ranges.

Figure 18. eBick ULTRA battery

Main characteristics are:

- Cell working temperatures from -20º to 55º.
- Available as one or two modules tower.
- Easy to move from pallet to final location thanks to the optional built-in wheels.
- "Plug-and-go" installation.
- Finished in fast connectors. No need for insulated tool for installation.
- Does not require additional facilities such as spill pans or ventilation systems.
- With internal electronics (Battery Management System, BMS) offering internal battery data.
- Without maintenance.
- Autonomous equalization, without the need for intervention by the end user.

Electrical characteristics:

Nominal voltage	**48 Vdc**
Maximum voltage	53 Vdc
Minimum voltage	41 Vdc
Rated capacity	280 Ah
Stored power	13,4 kWh
Nominal discharge current	175 A
Overload current	300 A / 15 seconds
Rated charge current	100 A

Physical characteristics:

Weight	**95 kg**
Width	405 mm
Long	768 mm
High	450 mm

3.3.2 Buildings batteries

Cegasa will start from a module (eBick 180 PRO) with a high TRL to be able to implement the new developments, in mechanics and electronics, during the 4 years of the project and carry out the necessary validations to install the batteries with total safety.

3.3.2.1 General characteristics

Cegasa will use the new **eBick 57V 150Ah** module that will be developed with the aim of maximizing service continuity in the most aggressive environments and minimizing maintenance and replacement time if necessary.

This battery is based on LFP (Iron Phosphate) chemistry which is the most suitable cell type for stationary solutions where the number of cycles or the power required is demanding. Its service life is at least 4 times higher compared to the other lithium-ion chemistry (NMC) used in EVs. In addition, it is the only completely safe chemical technology as it presents no risk of ignition or explosion, even if it is exposed to conditions outside the cell specification ranges.

Figure 19 eBick module

Main characteristics are:

- Cell working temperatures from -20º to 55º
- Stackable on itself up to 4 heights.
- Pre-wired. Less installation times.
- Finished in fast connectors. No need for insulated tool for installation.
- Does not require additional facilities such as spill pans or ventilation systems.
- With internal electronics (BMS) offering internal battery data.
- Without maintenance.
- Autonomous equalization, without the need for intervention by the end user.

Electrical characteristics:

Nominal voltage	**58 Vdc**
Maximum voltage	64 Vdc
Minimum voltage	52 Vdc
Rated capacity	150 Ah
Stored power	8,7 kWh
Nominal discharge current	150 A
Overload current	300 A / 15 seconds
Rated charge current	750 A

Physical characteristics:

Weight	**100 kg**
Width	390 mm
Long	762 mm
High	470 mm

- **MCP protection module**

Each eBicks string, regardless of the number of modules it contains, includes an external protection and communications module. Called protection and communication module or MCP, it incorporates current measurements, DC Contactor and a 7" touch screen to interact with the system software, as well as the CAN or Modbus communications module for connection to the inverter.

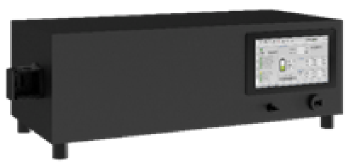


Figure 20 . MCP protection module

The MCP contains the energy management system (EMS), the card that acts as the eBick CPU. It collects data from all battery management system (BMS), manages it, acts on the protection elements and communicates with the batteries at a higher level.

The protection module incorporates a touch screen where the next data processed in the EMS are available:

- State of charge (SOC)
- State of Life (SOH)
- Current value in string
- String voltage value
- Minimum and maximum values of temperature and voltage in string and per module
- Battery status (charge, discharge, balance, standby ...)
- Alarms and flags

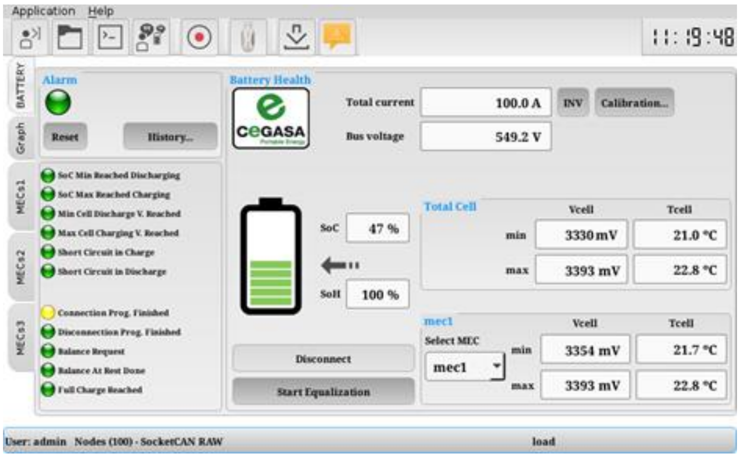


Figure 21 . MCP screen software

3.3.2.2 General characteristics of the eBick 460 Vdc storage system

The set designed for integration with the Zigor inverter whose DC bus is 460Vdc consists of 8 eBick units. Each eBick module is 58Vdc and 150Ah with which we will obtain sets of 460Vdc and 150Ah.

This layout simplifies cabling, minimizes space required, and facilitates identification of individual equipment.

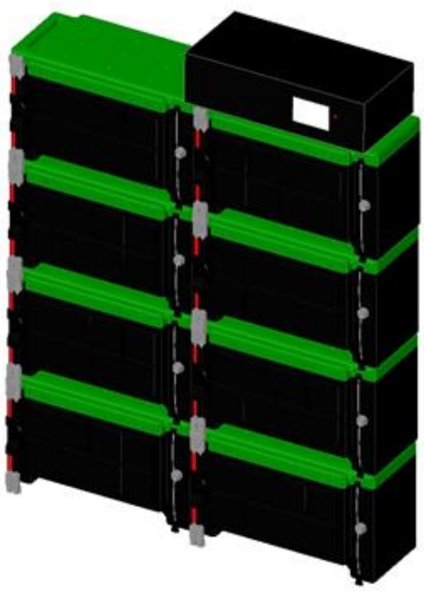


Figure 22 8 eBicks string

This distribution will set the bus voltage at a value of 460 Vdc, and will allow an easy scalability of the system, installing blocks of the same characteristics in an attached way, making increases in stored energy of 70kWh.

Electrical characteristics 8 eBicks string:

Nominal voltage	**460 Vdc**
Maximum tension	512 Vdc
Minimum tension	416 Vdc
Rated capacity	150 Ah
Stored power	70 kWh
Nominal discharge current	150 A
Overload current	300 A / 15 seconds
Rated charge current	75 A

Physical characteristics 8 eBicks string:

Weight	**800 kg**
Width	390 mm
Long	1524 mm
High	2055 mm

3.3.3 Large-scale batteries

Cegasa will start from a module (eBick 180 PRO) with a high TRL to be able to implement the new developments, in mechanics and electronics, during the 4 years of the project and carry out the necessary validations to install the batteries with total safety.

3.3.3.1 General characteristics

Cegasa will use the eBick 48 V 280Ah module for building the big size solution. This module has been designed with the aim of maximizing service continuity in the most aggressive environments and minimizing maintenance and replacement time if necessary.

This battery is based on LFP (Iron Phosphate) chemistry which is the most suitable cell type for stationary solutions where the number of cycles or the power required is demanding. Its service life is at least 4 times higher compared to the other lithium-ion chemistry (NMC) used in EVs. In addition, it is the only completely safe chemical technology as it presents no risk of ignition or explosion, even if it is exposed to conditions outside the cell specification ranges.

Figure 23 eBick module

Main characteristics are:

- Cell working temperatures from -20º to 55º**.**
- Stackable on itself up to 4 heights.
- Pre-wired. Less installation **times**.
- Finished in fast connectors. No need for insulated tool for installation.
- Does not require **additional facilities such as spill pans or ventilation systems.**
- With internal electronics (BMS) offering internal battery data**.**
- Without maintenance**.**
- Autonomous equalization, without the need for intervention by the end user**.**

Electrical characteristics:

Nominal voltage	**48 Vdc**
Maximum voltage	53 Vdc
Minimum voltage	43 Vdc
Rated capacity	280 Ah
Stored power	13,44 kWh
Nominal discharge current	280 A
Overload current	560 A / 15 seconds
Rated charge current	140 A

Physical characteristics:

Weight	**100 kg**
Width	390 mm
Long	762 mm
High	470 mm

- <u>**MCP protection module**</u>

Each eBicks string, regardless of the number of modules it contains, includes an external protection and communications module. Called protection module or MCP, it incorporates current measurements, DC Contactor and a 7" touch screen to interact with the system software, as well as the CAN or Modbus communications module for connection to the inverter.

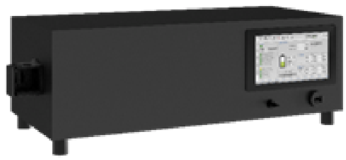


Figure 24 MCP protection module

The MCP contains the EMS, the card that acts as the eBick CPU. It collects data from all BMS, manages it, acts on the protection elements and communicates with the batteries at a higher level.

The protection module incorporates a touch screen where next data processed in the EMS are available:

- State of charge (SOC)
- State of Life (SOH)
- Current value in string
- String voltage value
- Minimum and maximum values of temperature and voltage in string and per module
- Battery status (charge, discharge, balance, standby ...)
- Alarms and flags

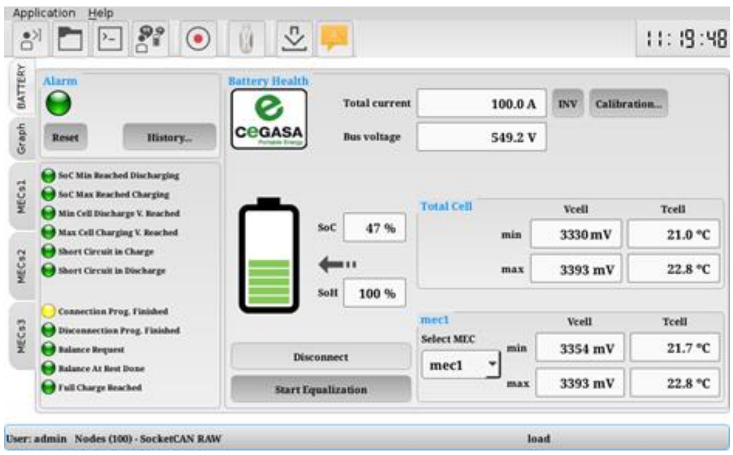


Figure 25 MCP screen software

3.3.3.2 General characteristics of the eBick 720 Vdc storage system

The set designed for integration with the Zigor inverter whose DC bus is 720Vdc consists of 15 eBick units. Each eBick module is 48Vdc and 280Ah with which we will obtain sets of 720Vdc and 280Ah.

This layout simplifies cabling, minimizes space required, and facilitates identification of individual equipment.

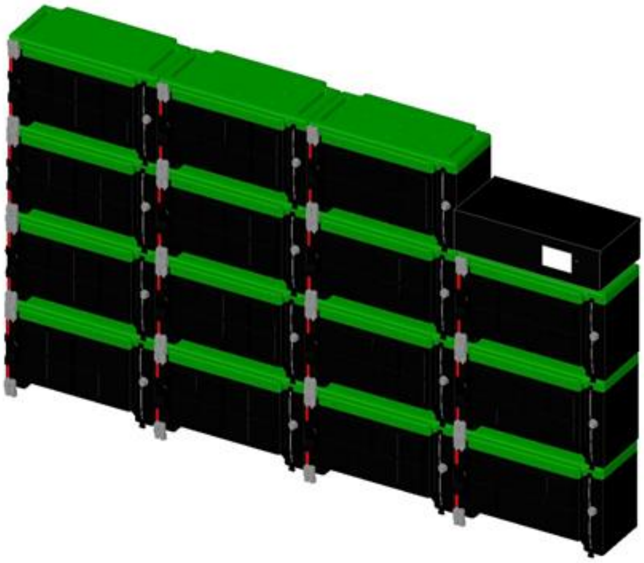


Figure 26 eBicks string

This distribution will set the bus voltage at a value of 720Vdc, and will allow an easy scalability of the system, installing blocks of the same characteristics in an attached way, making increases in stored energy of 202 kWh.

Electrical characteristics 15 eBicks string:

Nominal voltage	**720 Vdc**
Maximum tension	795 Vdc
Minimum tension	645 Vdc
Rated capacity	280 Ah
Stored power	202 kWh
Nominal discharge current	280 A
Overload current	560 A / 15 seconds
Rated charge current	140 A

3.3.3.3 eBick System 1MWh

In order to meet the power and energy specifications, it is necessary to install 5 strings of 15 eBicks that will give us a nominal discharge capacity of 1400Ah and 720Vdc and a nominal storage capacity of 1MWh.

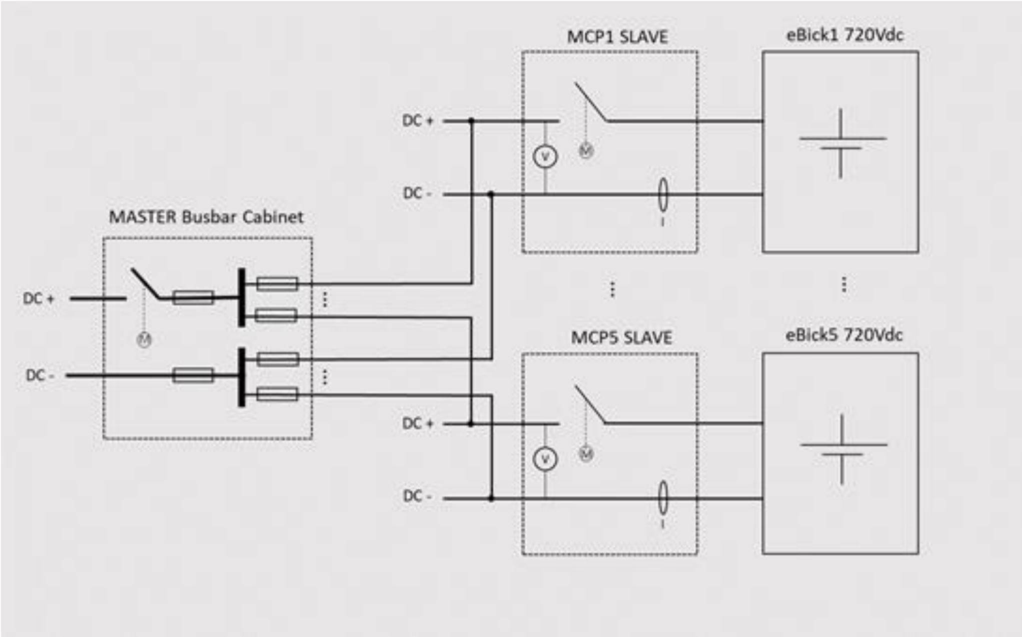


Figure 27 75 eBick string

Electrical characteristics 75 eBicks string:

Nominal voltage	**720 Vdc**
Maximum tension	795 Vdc
Minimum tension	645 Vdc
Rated capacity	1400 Ah
Stored power	1000 kWh
Nominal discharge current	1400 A
Rated charge current	2800 A

Physical characteristics 75 eBicks string:

L	**3048 mm**
W	2000 mm
H	1770 mm
Weight	75.000 Kg

3.4 Inverters

3.4.1 Household Inverters

Another key component of the PV system is the DC-AC inverter, being the most complex hardware in the system and key for a successful operation. Its primary function is to convert the DC energy from the photovoltaic panels into AC energy, including regulating output voltage and frequency and satisfying the conversion's highest efficiency. In general terms, solar inverters can be divided into three broad groups depending on the operation:

- Stand-alone inverters, used in isolated systems with or without the capacity to charge batteries but with no interaction with the grid.
- Grid-tie inverters, when the AC generated matches phase with the signal provided by the utility grid.
- Battery backup inverters, that manages the generated power to charge/discharge the batteries and expert energy to the utility grid.

Figure 28 Solar inverter for domestic applications (source: www.sma.de)

Solar inverters should be selected according to the specification and characteristics of the household solar systems. Each PV system consists schematically of a solar roof-mounted PV, with an approximate peak power of 4 kW and a Li-ion battery pack with a storage capacity of 8 kWh. The residential application implies that the design should be extremely simple but also flexible enough to provide more advanced functionalities. Moreover, the inverter will satisfy the conceivable operational conditions depending on specific site configurations such as roof orientation, tilt angle, and shading effects. Therefore, the inverter selected will be a commercial-off-the-shelf inverter that agrees with the PV system characteristics. Tentatively, the specifications will fit in the range parameters shown in Table 4. Operating parameters of a domestic solar inverter:

Input parameters	
Max. PV generator power (W)	3500-5500 Wp
Maximum input voltage	~600
Nominal input voltage (V)	360 - 710
Min. input voltage (V)	50-100
Max. input current (A)	12-18
Output parameters	
Nominal power (W)	3000 - 3700
Max. apparent power (VA)	3000 - 3700
Nominal output voltage (V)	220/230
Max. output current (A)	14-16
Power factor at rater power	1
Adjustable displacement power factor	0.8 lagging to 0.8 leading
Efficiency (%)	98-96.5

Table 4. Operating parameters of a domestic solar inverter

The electricity generated can be stored in the Li-ion battery, which is accomplished by an inverter-charger. This functionality can be provided by the inverter itself (hybrid inverter) or by coupling a separate battery-specific inverter. A set of basic charging parameters are shown in Table 5 *Representative parameters of an inverter-charger*.

Charger parameters	
Input AC voltage range (V)	170-265
Input frequency (Hz)	40-70
Maximum AC input current(A)	50-70
Maximum AC input power	11500 W
Efficiency (%)	94-96

Table 5 Representative parameters of an inverter-charger

All inverters should be CE marked and certified and in compliance with safety standards relevant to DC to AC inverter products. It will be also studied the possibility to perform grid-interactive operations (VDE-AR-N 4105, IEC 62109-1/-2, IEC 60335-1/2), prevention measures used with utility-interconnected PV systems (IEC 62116, IEC 61727) and tested under the relevant Engineering Recommendations (G83/ G59/ G98/ G99).

Conventional inverters have been designed to generate only active power, self-consumption, or even being restricted to interact with the grid (zero injection) without paying attention to the current grid's condition. This inverted-interfaced configuration impacts the power grid operation from protection, power flow, and stability perspective, specifically when PV generation is high without being consumed or stored at peak hours. Therefore, advanced features are necessary to incorporate new ancillary services to minimize and avoid these associated distortions, improving the operation stability and integration of PV into the grid. Firstly, an integrated data communication will be provided with a fully integrated datalogging, WLAN, and a range of interfaces. Connectivity to third-party components for monitoring, operation, and control will use standard protocols, such as Modbus open interfaces. The communication layer should provide a flexible system changing the control paradigm from a centralized perspective to a more dispersed and coordinated approach. Three levels of information exchange will be implemented in the inverter operating modes:

1. Autonomous operation responding to local conditions: The system is controlled under pre-set modes or schedules based on local information. Not remote interactions are required, although possible to modify operating parameters of the local control logic.
2. PV system interactions with other control systems: Focused on coordinating a group of PV systems to achieve an overall objective.
3. Broadcast/multicast communication: Consist of notification of pricing signals, emergency signals, or specific requests for operating modes changes. Usually, this notification will be provided by the utility or energy service provider and can be segmented to only specific inverters in one area.

To facilitate the development of these advanced functionalities, new standards have been developed to set an interoperability framework regarding the operativity of distributed energy resources (DER) and its interactions with the power system. Specifically, the standard IEC 61850 is emerging as the most promising communication standard for smart grids. The IEC 61850-90-7 was firstly proposed for substation automation applications and has expanded its uses to embrace many of the distributed energy resources common in smart grid applications, such as photovoltaic systems, energy storage systems, or electric vehicles where power conversions both DC-to-AC and AC-to-AC are relevant. The IEC 61850 standardizes the information models to exchange information these power converted-based systems as well as other actors in the power system with interest in voltage control, and active and reactive capabilities of the involve converted-based systems. The scope of the applications varies ranges from very small grid-connected systems such as residential applications to medium-sized (microgrids) or even large utility-managed systems. The standardized functions are listed in Table 6 Inverter capabilities listed in IEC 61850-90-7 below, grouped in nine control modes. The first seven groups are power-related capabilities expected from advanced inverters to diminish the troubles that solar generation can cause to the distribution grid.

Modes	Functions
Immediate Control	INV1: grid connect/disconnect
	INV2: adjust max. generation level up/down
	INV3: adjust power factor
	INV4: request active power
	INV5: Pricing signal (charge/disch.)
Volt-Var Management	VV1: Available Var support, no P impact
	VV2: Max. Var support based on Wmax
	VV3: Static Power Converter
	VV4: Passive Mode (No Var support)
Frequency Related	FW21: High freq. reduces P
	FW22: Limiting generation with f
Dynamic Reactive Current Support	TV31: Support during abnormally high or low voltage
Low-high voltage ride-through	"Must disconnect" (MD) "Must remain connected" (MRC)
Watt triggered	WP41: Watt power factor
	WP42: Alternative watt power factor
Volt-watt management	VW51: Volt-Watt management (generation)
	VW52: Volt-Watt management (charging)
Non-power parameters	TMP: temperature
	PS: pricing signal
Setting and Reporting	DS91: Modify DER settings (power conv.)
	DS92: Log alarms and events
	DS93: Selecting status points
	DS94: Time synchronization requirements

Table 6 Inverter capabilities listed in IEC 61850-90-7

The functionalities described by the standard IEC 61850-90-7 are focused mainly on the grid management from the distributor system operator (DSO) or aggregators interest, pursuing the objectives describe previously. While IEC 61850 ensures interoperability of control modes, communication, and data exchange, other approaches focus on standardization of the services and interaction in the smart grid. For instance, the Universal Smart Energy Framework (USEF) enables the active market participation of all players, putting the consumer at the heart of the system, and defining the market structure, the roles, and the interactions between all players. USEF focused on ensuring the required flexibility on the demand-side of the system and offering to the market in an aggregated way. Therefore, the aggregator is a key role responsible for establishing a trading flexibility mechanism, acquiring flexibility from consumers/prosumers, and offering flexible services to the rest of the market players:

- For the DSOs, alleviating the grid congestion and capacity management.
- For the ESCOs, offering a portfolio optimization, reducing energy cost with the optimal solution.
- For the TSOs, improve the system balancing of the grid.

These standardization initiatives come together and meet with the current interest in developing the so-called smart inverters. This new generation of the inverter will supply the state-of-the-art communication and interconnection standards, allowing the smooth and grid-friendly integration of renewable energy resources soon [13]. However, economic factors to be assumed for the proprietaries could be the main barrier for the widespread use of these inverters in the domestic or residential context. Therefore, from the ISLANDER scenario, the next list of possible services should be subjected to the availability of these smart functionalities in commercial inverters when the time comes:

- Identification of the optimum feed-in of reactive power
- Voltage regulation
- Frequency regulation
- Aggregated services to optimize grid performance, compensating imbalances in the network
- Dynamic feed-in control with self-consumption
- Quality control of the injected power
- Optimum performance point (stand-alone vs. aggregated services)

[STANDARDS]

VDE-AR-N 4105, Power Generating Plants Connected to the Low-voltage Grid.

IEC 62109-1:2011, Safety of power converters for use in photovoltaic power systems – Part 1: General requirements.

IEC 62109-2:2013, Safety of power converters for use in photovoltaic power systems - Part 2: Particular requirements for inverters.

IEC 62116:2014, Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures.

IEC 61727:2004, Photovoltaic (PV) systems - Characteristics of the utility interface.

Engineering Recommendation G83: Recommendations for the Connection of Type Tested Small-scale Embedded Generators (Up to 16 A per Phase) in Parallel with Low-Voltage Distribution Networks.

Engineering Recommendation G59, Recommendations for the Connection of Generating Plant to the Distribution Systems of Licensed Distribution Network Operators.

Engineering Recommendation G98: Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks.

Engineering Recommendation G99: Requirements for the connection of generation equipment in parallel with public distribution networks.

3.4.2 Buildings Inverter

The inverters to be deployed in building application will be in charge of power conversion and energy link from three different energy sources: photovoltaic (PV) panels, battery and AC grid.

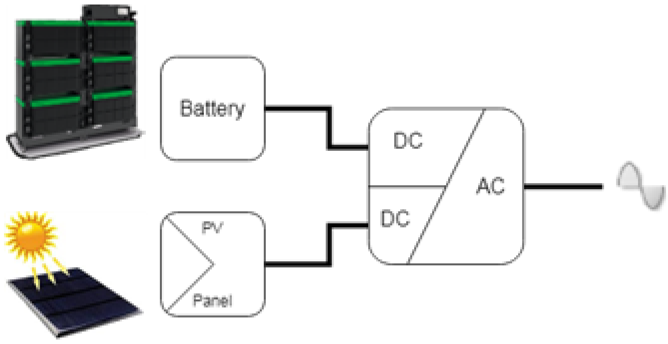


Figure 29 Building inverter scheme

The inverter is to be connected behind the meter, that is, as one of the “loads“ of the building.

The inverter is type on-grid, that is, it injects/draws current into/from the mains. Grid voltage should be always present. It is to be connected to a three-phase mains, without neutral connection. The power rating is 20kW.

There is no galvanic isolation between the three ports. In order to avoid safety issues in case of leakage current in DC ports, internal RCD circuitry is included. I will isolate both battery and PV panels from AC in case of residual current is detected.

In recent years a technology of semiconductors has been introduced in the portfolio of power devices. With the introduction of WBG (Wide Band Gap) devices such as silicon carbide (SiC) and gallium nitride (GaN) smaller and more efficient modules could be built. WBG devices allow operation at higher frequencies and temperatures than conventional silicon devices do, which results in smaller size filters and cooling systems. However, as these SiC WBG components are relatively new, they still suffer from some drawbacks. The main ones are the limited availability (high-power full SiC MOSFET modules are only available from three key manufacturers), the high cost and the uncertain reliability. Good lifetime and reliability data is still scarce and is much more available for Silicon devices.

Currently SiC technology, being relatively new, is not employed in large scale converters yet but is only found in applications with powers of up to several kW.

While SiC devices have a higher cost than their Si equivalents, all the other peripheral (e.g. filters, heatsinks, fans, cabinet …) components can be smaller due to the higher switching frequency allowing for smaller passive components. This brings the total cost down by an expected 15-20%.

SiC devices are already available from several manufacturers, mainly in discrete package, but commercial products based on that components are not available for general use. Today existing TRL 5 lab prototypes are to be matured in Borkum up to TRL7.

Expected benefits of using SiC devices in three-phase inverters are:

- Lower losses, so increased efficiency
- Lower size and weight. As switching frequency is to be higher, passive components (mainly filter inductors and capacitors) will be reduced.
- Lower audible noise, due to increase switching frequency, beyond audible frequency range.
- Lower cost. Even if SiC devices are more expensive than Si counterparts, peripheral components (passives, heatsink, case…) are reduced, so cheaper system cost is expected.

Following table resumes tentative electrical characteristics of the inverters model “HIT Gridex NG”:

HIT Gridex NG	
PV	
Independent MPPTs	2
Input Voltage range	250-500 vdc
Maximum current per MPPT	50 Amps
Maximum power per MPPT	15 kW
Battery	
Voltage range	250-600 vdc
Maximum charge/discharge current	100 Amps
Maximum charge/discharge power	20 kW
BMS connection	Modbus/CAN
AC grid	
Voltage	400 vac ±15% (3W)
Frequency	50Hz +/- 2Hz
Maximum current	40 Amps
Maximum power	20 kW
Other features	
Communication	Web server, modbus
Remote update	Yes

Table 7 tentative electrical characteristics of the inverters

The inverter will include the following functions:

- Stand-alone (self-consumption) mode. An internal meter should be connected comprising whole building consumption or just a part of it. The inverter feeds the internal (behind the meter) consumption from renewable energy (first PV, then battery) while available. Battery is charged from surplus PV power.
- Aggregated mode. Real power by the meter will track incoming setpoints from external platform.
- Primary Frequency Regulation. It would be an added value ancillary service to be monetised. It will provide (by simultaneous distributed contribution of several buildings) primary frequency regulation, according to pre-set droop curves. This service provides stability to distribution grid in the island.

To perform previously stated functions and services, the inverter should interact with other devices:

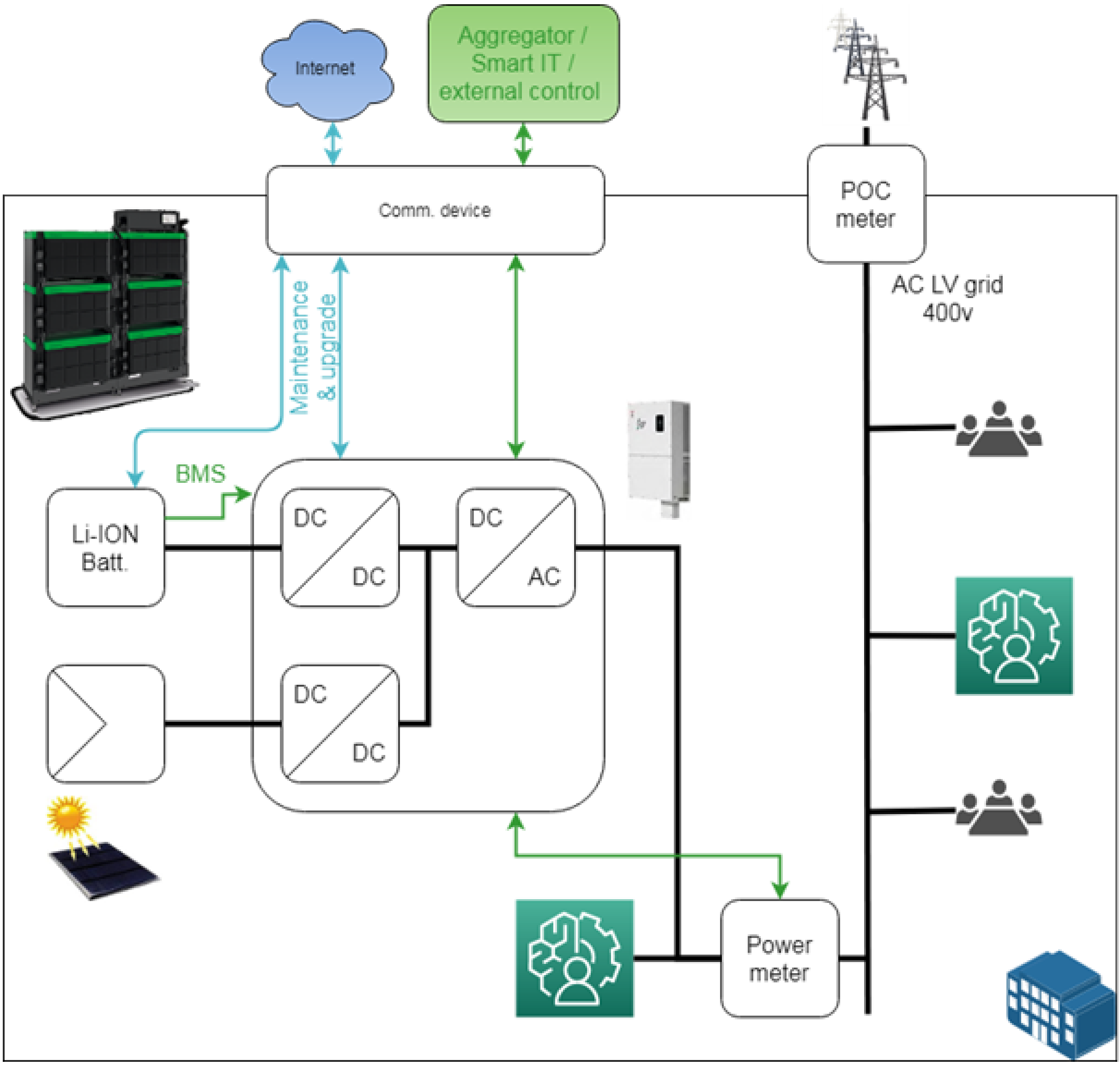


Figure 30 Interconection scheme

- Power meter. It is the device in charge of metering electrical magnitudes in the point of the installation where power is to be regulated.
- Battery. The battery BMS (Battery Management System) sends operating and limit parameters to the inverter in order to guarantee a safe and optimum performance of the accumulation system.
- Communication device. One router or similar device would provide communication of the inverter with an external controller (Smart IT platform or another aggregator). Additionally, it will provide a remote access to both battery and inverter control systems for maintenance and upgrade purposes.

3.5 Power intensive energy storage system (PI-ESS) (PI-ESS).

According to IEC 62933, a power intensive Energy Storage System (ESS) or short-duration ESS is an Energy Storage System intended for applications generally demanding in terms of step response performances and with frequent charge and discharge phase transitions or with reactive power exchange with the electric power system.

Services or applications included within this category are:

- grid frequency support / regulation
- grid voltage support
- power quality support
- reactive power flow control
- power oscillation damping (POD)
- load management (Load fluctuation reduction)
- renewable energy management (Power fluctuation reduction)

The time extent scope of that application ranges from 1 second to a few hours. To cover such wide bounds, hybridisation of several storage technologies is the right choice. In Islander two technologies are selected:

- Ultracapacitors: also known as double-layer capacitors or supercapacitors, provide high power for short duration, a few seconds. Services they can provide are mainly fast frequency response (<10 seconds) and primary frequency regulation (<1 minute). They can provide hundreds of thousands of charge/discharge cycles without noticeable degradation in performance.
- Lithium batteries: for other applications requiring time extend beyond 1 minute. Depending on the technology they can withstand around 1000 charges/discharge cycles.

In Islander the PI-ESS is to be connected in low voltage distribution grid, following next scheme:

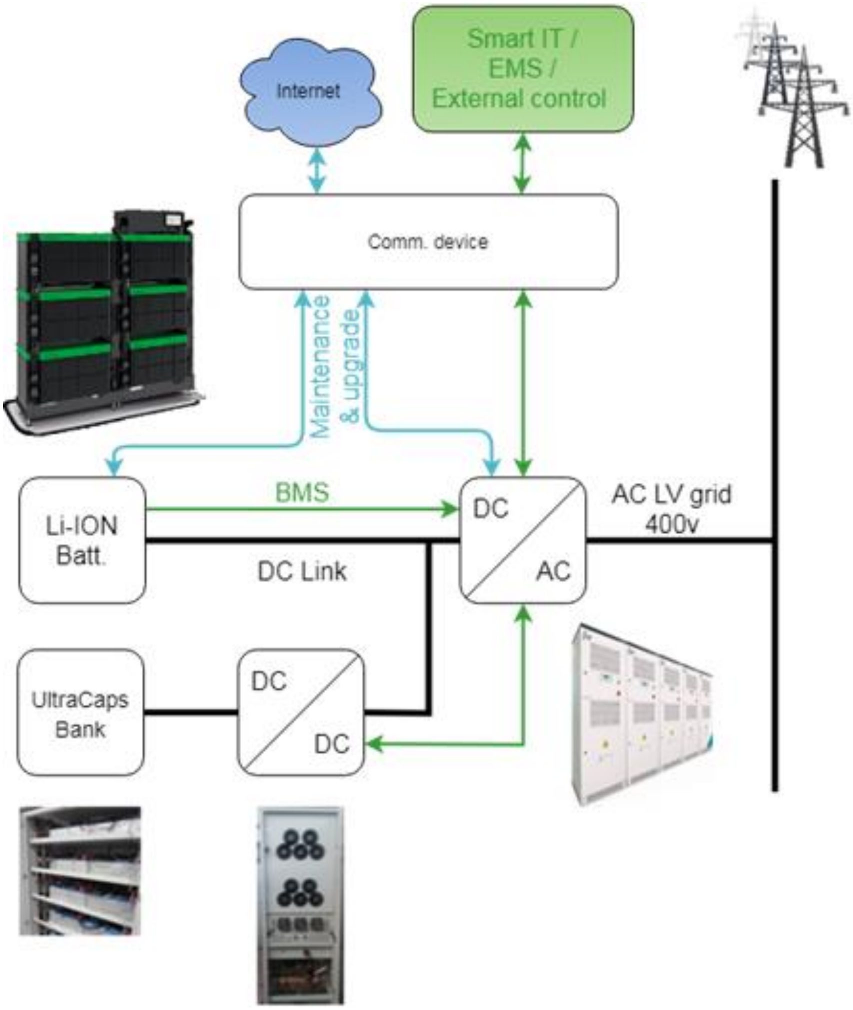


Figure 31 Interconnection scheme

Following table resumes tentative electrical characteristics of the model ESS (ZGR PCS Hyb):

ZGR PCS Hyb	
Inverter	
Voltage	400 vac ±15% (3W)
Frequency	50Hz +/- 2Hz
Maximum current	1600 Amps
Maximum power	1 MW
Battery	
Voltage range	650-850 vdc
Maximum charge/discharge current	1600 Amps
Maximum charge/discharge power	1 MW
BMS connection	Modbus/CAN
Ultracap DC/DC converter	
Voltage (ucaps side)	0-600 vdc (325v-600 full power)
Maximum charge/discharge current	3600 Amps
Maximum charge/discharge power	1 MW
Ultracaps	
Voltage	48v nominal/module
Capacity	165 F/module
Modules / string	14
Number of strings	12
Other features	
Communication	Web server, modbus
Remote update	Yes
Modular design	Yes

Table 8 Tentative electrical characteristics of the ESS

The following features will be embedded within the PI-ESS and others features will be studied according to the front-the-meter operations (see Sectionanalysis to be performed during the execution of the project:

- Virtual Inertia (ultracaps). Also known as Fast Frequency Response (FFR), the virtual inertial response of EES system is to approximate the process of inertial kinetic energy throughput of traditional generators based on the frequency change rate. The purpose is to slow down the frequency change rate of the system during sudden failures, reduce the amplitude of the transient frequency difference, increase the system damping, and enhance the system stability. Here fast activation time and ramp rate are very important. Furthermore, amount of the active power is very important (high power density). Since needed for short time (bridging up to fully primary response), energy density is not important.
- Primary Frequency Regulation (ultracaps). The primary frequency regulation of EES system means that once the frequency of the power grid deviates from the rated value, the control system automatically controls the increase or decrease of the active power of the energy storage, limits the frequency change of the power grid, and maintains the automatic control process of the grid frequency. For the first instants (a few seconds) power is taken from ultracaps. In the event of a steady condition of frequency outside deadband limits, or during the secondary frequency regulation phase, the energy stored in ultracaps will be not enough and, therefore, the battery will be used.
- Local Voltage Regulation (ultracaps/battery). A requirement for electric grid operators is to maintain voltage within specified limits. In most cases, this requires management of reactance, which is caused by grid-connected equipment that generates, transmits, or uses electricity and often has or exhibits characteristics like those of inductors and capacitors in an electric circuit.

To manage reactance at the grid level, system operators need voltage support resources to offset reactive effects so that the transmission system can be operated in a stable manner.

- EES systems used for reactive voltage support must be able to source and sink reactive power. In this mode of operation, EES systems are not required to provide real power (except conversion power losses), so the discharge duration is not relevant in this case.
- P/Q setpoint tracking (ultracaps/battery). While previous services are provided and controlled locally, other ones need an external controller or EMS (Energy Management System) commanding the ESS. For such a set of services, the ESS should follow external active and reactive power setpoints.
  Peak-shaving and load-levelling are just two of the services that will take use of setpoint tracking feature of the ESS. Both functions need an external controller/manager to perform the task.

3.6 Photovoltaic system (PV)

Solar photovoltaic system (PV system) is a fully developed technology conceived to transform solar energy into electricity. The core components of a PV system are the PV panels that absorb the solar energy and convert it into electricity, and the solar inverter, equality important to transform direct current into alternating current. Additionally, the system can be improved with an integrated storage solution to optimize and increase the flexibility of the PV systems. These systems are categorized as stand-alone or grid-connected (and even interactive) depending on the dependency on the electric power system. Since the beginning of the 90s, the price of solar panel production has dropped significatively, which is reflected in the almost exponential growth of installed PV power until nowadays.

A solar module is a group of photovoltaic cells assembled and enclosed within a material to protect it from external conditions. The solar cell is an essential component composed of a p-n semiconductor junction, where the *photovoltaic effect* occurs, which is the phenomenon to produce electricity from the sunlight. These semiconductors are sensitive and react when being hit by a photon (i.e., sunlight with sufficient power), creating a depletion region with an electric field through the migration of electrons. This phenomenon will produce a voltage difference in the semiconductor resulting in an electric current when an external circuit is formed, as shown in Figure 8. Principle operation of a solar cell Figure 8. An individual solar cell produces around 1 or 2 W of power so that several units should be connected in parallel and series, forming a larger unit (PV panel), producing a more suitable power. Additionally, PV panels are also grouped, forming arrays as shown in Figure 9, to generate more electric power.

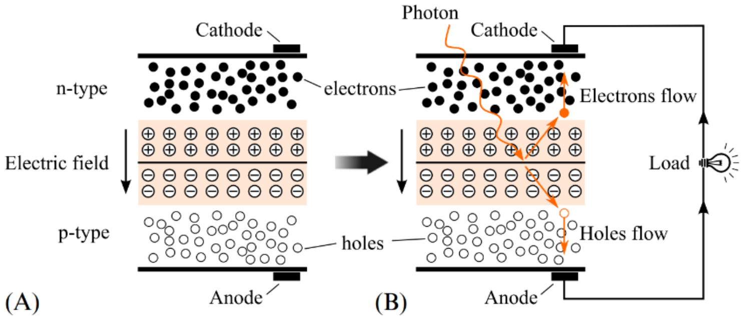
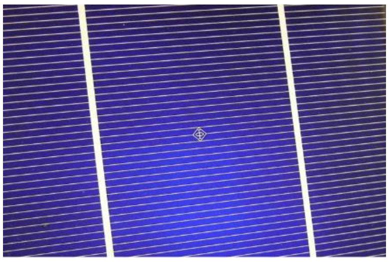


Figure 32 Principle operation of a solar cell [12]

Figure 33 Arrays of solar panels on the roof of a house (public domain)

Solar panels are manufactured using different materials and processes, but without doubt, solar cells made from crystalline silicon are the most widespread in commercial applications. There are two main configurations, depending on if the entire volume of the cell is a single crystal (monocrystalline) or formed by several crystals (polycrystalline). Both configurations differ in terms of performance, efficiency, and manufacturing costs, but without recommending one against the other since the final decision might be subject to environmental conditions. In general terms, monocrystalline cells fit better in cloudy and cold locations, while polycrystalline cells are better in hot places. Crystalline silicon has a theoretical efficiency limit of 33%, and standards solar panels range between 330-450 Wp per panel with a cost of varying between 120-180 € per panel.



(a) monocrystalline

(b) polycrystalline

Figure 34 (a) Monocrystalline solar cell (b) Polycrystalline solar cell (public domain)

New alternatives are being developed to compete with current options, achieving indeed more noteworthy efficiencies efficiencies but with drawbacks linked to higher production costs. The main developments in silicon solar cell technologies were achieved by modifying interfaces or changes in device architecture, which implies that the development in these cases is reaching a plateau. On the other hand, other technologies have made good progress in recent years, both monocrystalline configurations using gallium arsenide (GaAs), gallium indium phosphide (GaInP) or indium phosphide (GaInP) based solar cells, the rapid progress of thin-film technologies such as cadmium telluride (CdTe) copper indium gallium selenide (CIGS) solar cells and the emergence of halide perovskites as PV materials, sustainable chalcogenides, organic PVs and quantum dots technologies [11]. However, to consider these technologies as a competitive alternative, there is still a long way to run, as the efficiency should be higher and the manufacturing much lower [12, chp. 9]. Additionally, there are toxicity concerns with the widespread use of these materials, and being silicon, the second most plentiful element on the Earth's surface, making it difficult to beat. In conformity with the high TRL of the ISLANDER project, silicon-based solar panels (monocrystalline or polycrystalline) will be installed in the project.

3.7 Street lighting.

On Borkum, there are around 1100 street lighting points for lighting the streets at night. This street lighting consists of the light masts with attachment lights and a separate cable network which is only supplied with electricity at the time of lighting.

The street lighting system is controlled centrally from one point (headquarters, Stadtwerke Borkum) via a KNX system with brightness sensor and switched on at about 20 switch cabinets in the low voltage network.

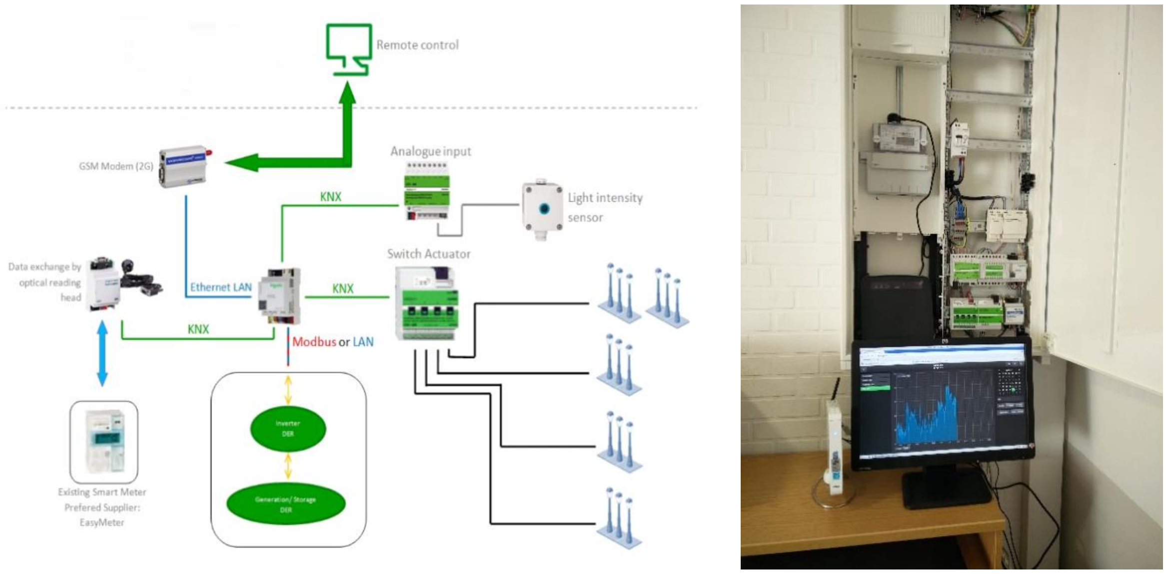


Figure 35 Control street lighting

- An Energy Management Gateway (EMG) collects data from the smart devices and uses logic function to switch and to inform the Remote Control (RC) of the owner/service provider of the street lighting.
- A KNX switch actuator with current detection (SA) is being used to switch the lights and detect faults. The actuator has hall sensors which can detect and analyse the load current of each switch channel. These analyses can be used for additional operations and functions. Detection range: 0.1 A to 16 A.
- A light intensity sensor is connected to a KNX analogue input module (AI) which is sending the data to a logic controller which monitors the thresholds and converts the control into commands to switch the street lighting on.
- Energy measurement is realized by existing Smart Meters. The optical interface is used for the data exchange with a KNX interface. This interface is connected to the EMG by KNX.

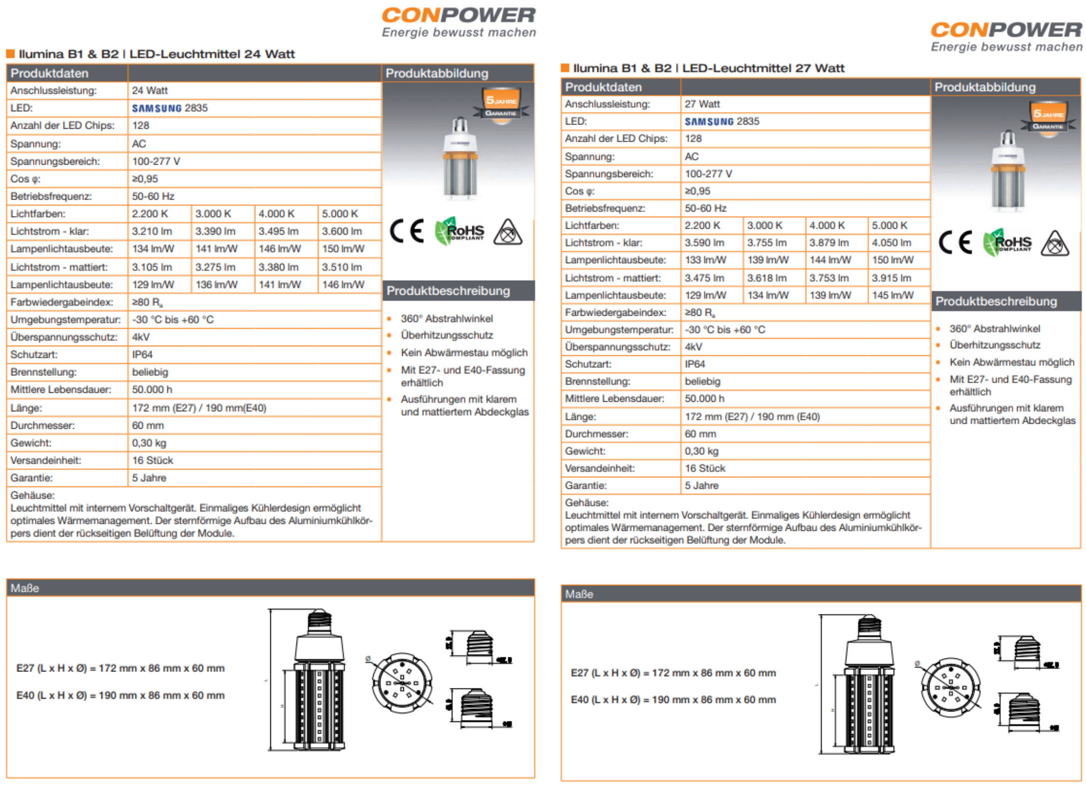
- The street lights will be separated in several sections to control every single section individually.
- Via a GSM Modem (2G) it is possible to monitor or control the control.

3.7.1 Lighting point

All street lighting points are equipped with LED technology. Depending on the type of luminaire and location, either 24 W or 27 W LED lamps with a 360° beam angle are used.

In the lamps where the light is directed downwards only, 30W LED lamps with a beam angle of 180° are used.

Figure 36 360° light point



CONPOWER
Energie bewusst machen

Ilumina B1 & B2 | LED-Leuchtmittel 24 Watt

Produktdaten				
Anschlussleistung:	24 Watt			
LED:	SAMSUNG 2835			
Anzahl der LED Chips:	128			
Spannung:	AC			
Spannungsbereich:	100-277 V			
Cos φ:	≥0,95			
Betriebsfrequenz:	50-60 Hz			
Lichtfarben:	2.200 K	3.000 K	4.000 K	5.000 K
Lichtstrom - klar:	3.210 lm	3.390 lm	3.495 lm	3.600 lm
Lampenlichtausbeute:	134 lm/W	141 lm/W	146 lm/W	150 lm/W
Lichtstrom - mattiert:	3.105 lm	3.275 lm	3.380 lm	3.510 lm
Lampenlichtausbeute:	129 lm/W	136 lm/W	141 lm/W	146 lm/W
Farbwiedergabeindex:	≥80 R_a			
Umgebungstemperatur:	-30 °C bis +60 °C			
Überspannungsschutz:	4kV			
Schutzart:	IP64			
Brennstellung:	beliebig			
Mittlere Lebensdauer:	50.000 h			
Länge:	172 mm (E27) / 190 mm(E40)			
Durchmesser:	60 mm			
Gewicht:	0,30 kg			
Versandeinheit:	16 Stück			
Garantie:	5 Jahre			

Gehäuse:
Leuchtmittel mit internem Vorschaltgerät. Einmaliges Kühlerdesign ermöglicht optimales Wärmemanagement. Der sternförmige Aufbau des Aluminiumkühlkörpers dient der rückseitigen Belüftung der Module.

Produktabbildung

Produktbeschreibung
- 360° Abstrahlwinkel
- Überhitzungsschutz
- Kein Abwärmestau möglich
- Mit E27- und E40-Fassung erhältlich
- Ausführungen mit klarem und mattiertem Abdeckglas

Maße

E27 (L x H x Ø) = 172 mm x 86 mm x 60 mm

E40 (L x H x Ø) = 190 mm x 86 mm x 60 mm

CONPOWER
Energie bewusst machen

Ilumina B1 & B2 | LED-Leuchtmittel 27 Watt

Produktdaten				
Anschlussleistung:	27 Watt			
LED:	SAMSUNG 2835			
Anzahl der LED Chips:	128			
Spannung:	AC			
Spannungsbereich:	100-277 V			
Cos φ:	≥0,95			
Betriebsfrequenz:	50-60 Hz			
Lichtfarben:	2.200 K	3.000 K	4.000 K	5.000 K
Lichtstrom - klar:	3.590 lm	3.755 lm	3.879 lm	4.050 lm
Lampenlichtausbeute:	133 lm/W	139 lm/W	144 lm/W	150 lm/W
Lichtstrom - mattiert:	3.475 lm	3.618 lm	3.753 lm	3.915 lm
Lampenlichtausbeute:	129 lm/W	134 lm/W	139 lm/W	145 lm/W
Farbwiedergabeindex:	≥80 R_a			
Umgebungstemperatur:	-30 °C bis +60 °C			
Überspannungsschutz:	4kV			
Schutzart:	IP64			
Brennstellung:	beliebig			
Mittlere Lebensdauer:	50.000 h			
Länge:	172 mm (E27) / 190 mm (E40)			
Durchmesser:	60 mm			
Gewicht:	0,30 kg			
Versandeinheit:	16 Stück			
Garantie:	5 Jahre			

Gehäuse:
Leuchtmittel mit internem Vorschaltgerät. Einmaliges Kühlerdesign ermöglicht optimales Wärmemanagement. Der sternförmige Aufbau des Aluminiumkühlkörpers dient der rückseitigen Belüftung der Module.

Produktabbildung

Produktbeschreibung
- 360° Abstrahlwinkel
- Überhitzungsschutz
- Kein Abwärmestau möglich
- Mit E27- und E40-Fassung erhältlich
- Ausführungen mit klarem und mattiertem Abdeckglas

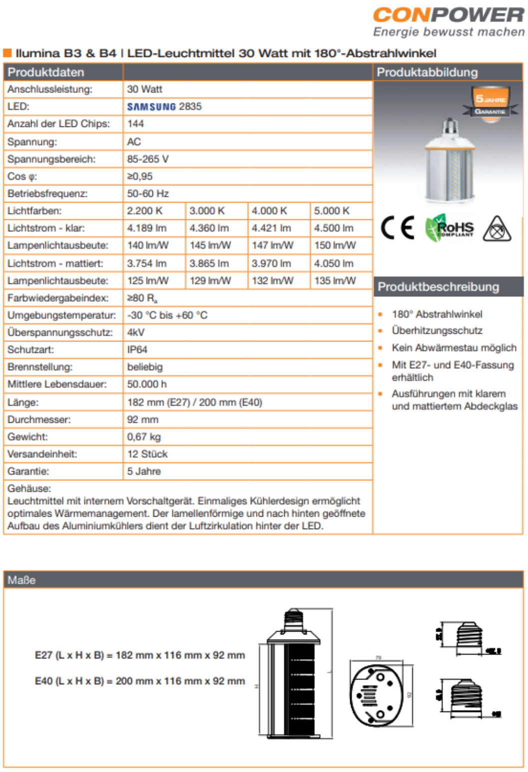
Maße

E27 (L x H x Ø) = 172 mm x 86 mm x 60 mm

E40 (L x H x Ø) = 190 mm x 86 mm x 60 mm

Figure 37 Datasheet 360° light point

Figure 38 180° light point



CONPOWER
Energie bewusst machen

Ilumina B3 & B4 | LED-Leuchtmittel 30 Watt mit 180°-Abstrahlwinkel

Produktdaten				
Anschlussleistung:	30 Watt			
LED:	SAMSUNG 2835			
Anzahl der LED Chips:	144			
Spannung:	AC			
Spannungsbereich:	85-265 V			
Cos φ:	≥0,95			
Betriebsfrequenz:	50-60 Hz			
Lichtfarben:	2.200 K	3.000 K	4.000 K	5.000 K
Lichtstrom - klar:	4.189 lm	4.360 lm	4.421 lm	4.500 lm
Lampenlichtausbeute:	140 lm/W	145 lm/W	147 lm/W	150 lm/W
Lichtstrom - mattiert:	3.754 lm	3.865 lm	3.970 lm	4.050 lm
Lampenlichtausbeute:	125 lm/W	129 lm/W	132 lm/W	135 lm/W
Farbwiedergabeindex:	≥80 R_a			
Umgebungstemperatur:	-30 °C bis +60 °C			
Überspannungsschutz:	4kV			
Schutzart:	IP64			
Brennstellung:	beliebig			
Mittlere Lebensdauer:	50.000 h			
Länge:	182 mm (E27) / 200 mm (E40)			
Durchmesser:	92 mm			
Gewicht:	0,67 kg			
Versandeinheit:	12 Stück			
Garantie:	5 Jahre			

Gehäuse:
Leuchtmittel mit internem Vorschaltgerät. Einmaliges Kühlerdesign ermöglicht optimales Wärmemanagement. Der lamellenförmige und nach hinten geöffnete Aufbau des Aluminiumkühlers dient der Luftzirkulation hinter der LED.

Produktabbildung

Produktbeschreibung

- 180° Abstrahlwinkel
- Überhitzungsschutz
- Kein Abwärmestau möglich
- Mit E27- und E40-Fassung erhältlich
- Ausführungen mit klarem und mattiertem Abdeckglas

Maße

E27 (L x H x B) = 182 mm x 116 mm x 92 mm
E40 (L x H x B) = 200 mm x 116 mm x 92 mm

Figure 39 Datasheet 180° light point

3.8 Charging station V2G.

Existing electric float has under its disposition three charging stations for the ever growing public area of electromobility at the larger car parks "Ankerstraße", "Oppermannspad" and "Am langen Wasser".

- Two charging stations V1G where the maximum charging power is 22 kW
- One charging station V1G where the maximum charging power is 80 kW, considered as quick charging station

All these private and commercial vehicles are mainly operated by company-owned charging infrastructures.

Figure 40 Charging station "Am langenWasser"

During the ISLANDER project, the consortium will study the best option to choose between the existing possibilities to include new 5 charging stations to be installed in the island of Borkum according the state of the art. Even if a tentative option is installing V2G stations, this decision will be taken once the optimization work is developed in WP1.

3.9 Electric Vehicles

The current float of vehicles used in the island of Borkum includes next assets:

- private cars
- commercial small cars and vans
- Mail delivery vehicles
- Buses for local public transport
- Vehicles of the municipal organizations
- Police vehicles
- Car-Sharing

As described in Section 3.8 , there are 3 charging stations with the declared parameters. In the next step of the project a wider knowledge will be gained about the whole existing float of vehicles to study better how to operate with them.

4 IT systems and interconnections

This section addresses a preliminary list of IT components and electric devices to which these components ought to be connected. In SGAM slang, this section is going to be focussed on the Component and Communication layers which are the lowest levels of the interoperability layers as shown in Figure 41.

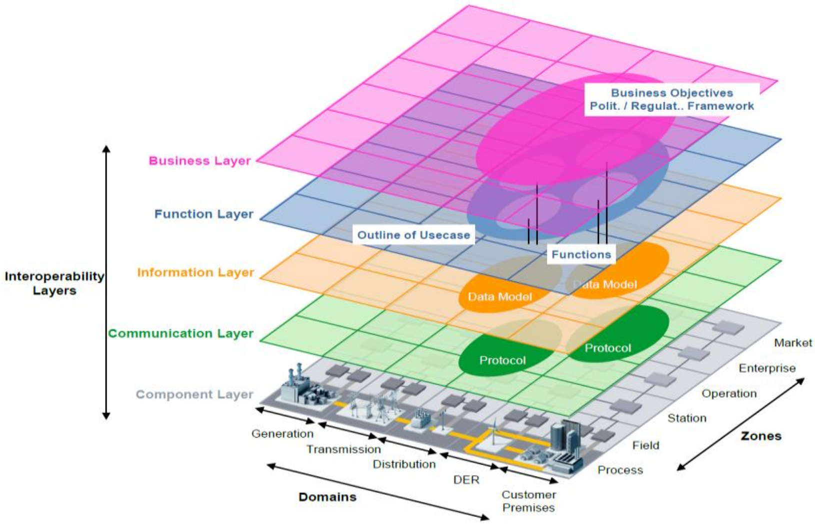


Figure 41 SGAM Interoperability Layers [14]

4.1 General overview

The IT infrastructure encompasses a wide variety of components and software systems which have to cover different aspects of the functionality and technology. After a preliminary analysis, a minimal set of IT components has been considered. These components range from software, communication devices, computer edges to electric devices which communication capabilities. The following table identifies the main IT component needs.

Functionality	Main capabilities	Location	Zone / Process
Aggregator, DERMS (smart IT platform)	• Data acquisition • Monitoring and alarms • Manual control • Smart control for energy services • Market bidding optimization • Market integration • Third party integration • Customer enrolment, dashboard	Cloud	Enterprise Operation
Market operator	• Bid offer receiving • Awarded offer notification	Third Party	Market
Cloud data provider	• 3rd Party data acquisition	Cloud	Enterprise
Web/Mobile app	• Opt-in/Opt-out • Customer dashboard	Cloud Mobile	Enterprise

	• Customer preferences		
Forecast algorithms	• Weather forecast algorithms • Price forecast • Individual load forecast algorithms • Individual generation forecast algorithms • Macroscopy load forecast algorithms • Macroscopy generation forecast algorithms	Cloud	Operation
Router	• Access point of the site private network	On site	Field
Gateway	• Single site endpoint • Field protocols integration	On site	Field
Datalogger	• Store & Forward	On site	Field
Inverter	• DC/AC transformation • PV generation • Battery charging/discharging • Load and Feed-in balancing • Control program running (self-consumption, setpoints…)	On site	Process
Electric Storage	• Battery state • Orders		
V1G station	• EV vehicle charging	On site	Process
V2B / V2G station	• EV vehicle charging/discharging • Self-consumption • Flexibility	On site	Field
Smart meters and Submeters	• Acquisition of electric measures	On site	Field
Temperature sensor	• Get temperature measures	On site	Field
Switches	• Switch on/off remotely	On site	Field
Bridges	• Field protocol translating	On site	Field

Table 9 Preliminary list of IT components

Table 10 considers power system equipment and the rest of on-site components that belong to Field zone. Notwithstanding, those electric equipment without any interconnect IT system are not included in the table, and those ones which keep some IT communication have been located as Process. The rest of IT on-site component have been located in the Field zone. Note that the smart meter is a component categorized as Field zone.

During the first months of the project a detailed requirement definition will be performed and additional components could be included to enrich the field information and cover properly different use cases. The next figure is devoted to shape a preliminary description about Communication Layer subjects as the next step in the SGAM interoperability layer.

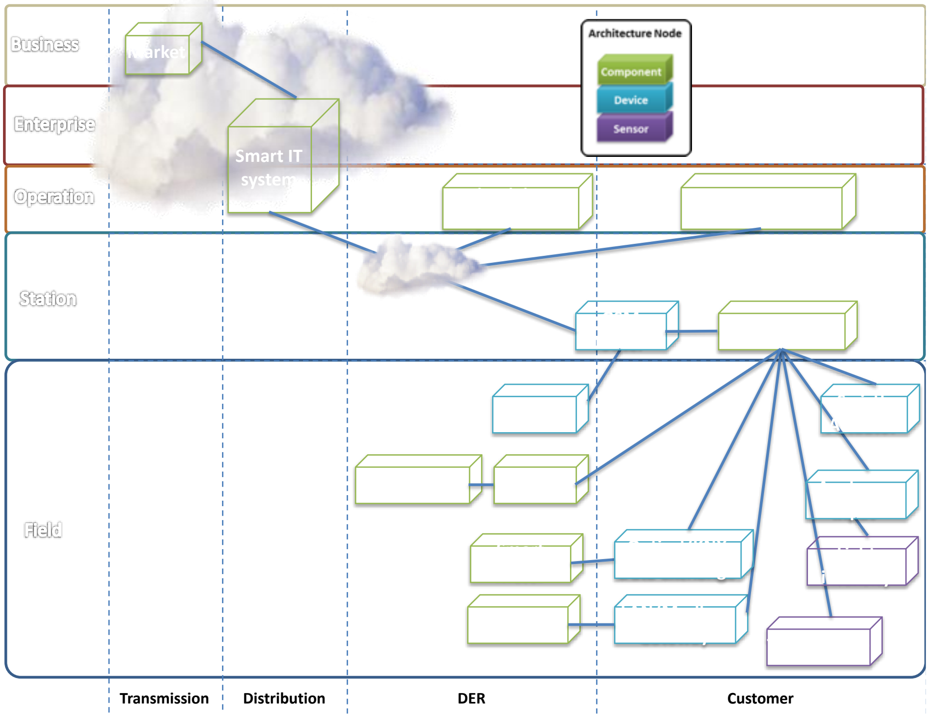


Figure 42 Component layer

4.1.1 Aggregator, DERMS (smart IT platform)

The functionalities foreseen for the smart IT Platform component are very close to those offered by the tools known by the acronym DERMS, (distributed energy resources management system). If it sees a DERM, it will match capabilities in all levels of the ISA95 pyramid, the standard for the industrial automation process. The growth of DERMS has supposed some changes in the content, and ways of integration of different ISA95 levels. Mostly, these changes have come from the irruption of the internet of things (IoT) and industrial internet of things (IIoT), supplying new devices and interconnection ways.

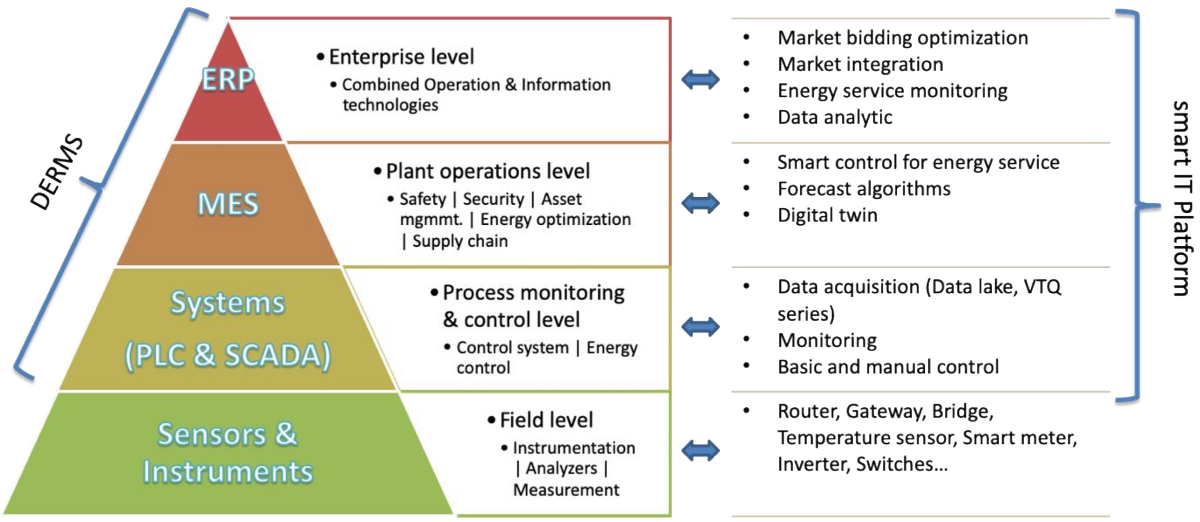


Figure 43 ISA95 & DERMS matching

Next a preliminary list of functionalities and its usage in the ISLANDER project has been enumerated:

4.1.1.1 *Data acquisition*

The data acquisition is a key piece of the platform therewith the smart IT platform counts on paramount information needed to the smart control feedback, monitoring, site performance, advanced analysis, device diagnostics. The traditional SCADA element is now replaced by a set of heterogeneous software components responsible for the storage and processing of information provided by a wide number of different sources. In fact, this information is not enclosed to field devices but also information provided by other sources such as Market prices, Weather forecasts and even results of other parts of the own smart IT platform…

4.1.1.2 *Monitoring and alarms*

The monitoring and alarms functionality range from the depict of measures registered by the Data acquisition, surveillance of thresholds, low site performance, wrong devices to the management and following-up of alarms which requires special treatment by Operators. The monitoring is not only focused on the basic information gathered from the field and process zones, but also the generated information about the commitment of Energy services. A valuable feature which will be studied in the ISLANDER project is extending the monitoring to the forecasted measures and energy service performance. In this way, the smart IT platform can anticipate anomalous situations and prevent it before it actually occurs.

4.1.1.3 *Manual control*

The operator ought to be able to fix certain circumstances detected by the Monitoring and alarms. The manual control implies sending orders to the field devices, adding new DERs, removing others, and modifying the smart control algorithm configuration involved in an energy service.

4.1.1.4 *Smart control for energy services*

Control algorithms will be key part of the IT platform to deploy and automatize energy services, in that way the platform can meet the committed services minimizing the Operator intervention. The energy operations considered in ISLANDER cover front the meter applications (FTM) and behind the meter applications (BTM) and include:

- **Optimal EV charge**. The charging algorithm considers the tariff, load and PV forecast, and the customer preferences to outreach the best cost performance at the schedule time.
- **Self-consumption**. The smart control algorithm minimizes the energy bill.
- **Demand Response**. The project will appraise what type of demand responses will be implemented and studied in the use cases. Different alternatives based on price curves, and Emergency demand response program **(EDRP)** signals could be implemented and studied.
- **Aggregated generation**. The control algorithms will calculate the dissagregated dispatches to operate as a virtual power plant.
- **Regulation and frequency operations**. The control algorithms will manage the participation of different energy assets in these services in a aggregated and disaggregated manner

4.1.1.5 *Market bidding optimization*

A set of algorithms will be focussed on the optimization of bid offers to the energy market. Likewise, the type of market will be studied in the project considering: bilateral contracts, day ahead, real time.

4.1.1.6 *Market integration*

The final recipient for the bid offers will be decided in the project. The bid offers can be directly submitted to the market operator or through a VPP, and intermediate agent.

4.1.1.7 Customer enrolment, dashboard

The site participation in the energy service could be established by the own Customers by the mean of Opt-In / Opt-out operation for certain types of energy services. The smart IT platform should support this type of operations. The Customer role could be simulated for study purposes.

4.1.2 Market operator

As already mentioned, the market operator could be TenneT TSO, or some VPP. The bid offer generated by the smart IT platform will be sent to the market operator to be selected in ISLANDER project. A viability study is needed to appraise use cases that compliances the market operator requirements as energy producer or consumer as well as the explore the other types energy transaction like the Power Purchase Agreements (PPAs).

4.1.3 Cloud data provider

The state of the art in the matter of IoT and IIoT devices has heftily evolved along the last years. Nowadays, brands which include a service in cloud to get the information generated by its own devices are easy to find. This way could take place in some use cases.

4.1.4 Web/Mobile app

The smart IT Platform will offer an user interface (UI) via Web, and also accessible via mobile phone and tablets. Although the ultimate roles will be defined along with the project,

- Market operator
- Supervisor
- Operator
- Customer
- Maintainers
- Administrator

One of the important points considered in the project is the integration of Social Science & Humanities (SSH) in all levels. This leaded the consortium to include in the scope of the project a consumers app for demand response focused to those consumers with a RESS-based system (storage + renewable). This app will be able to show the end users

- How the system is operating,
- The automatic operation mode running to maximize their cost saving
- Provide end users with best consumption profiles.

Those end users without RESS-based system will not have access to the fully operative app, but they will be provided best consumption paterns instead.

4.1.5 Forecast algorithms

A wide range of forecast algorithms will be addressed in ISLANDER project. The forecast algorithms are an important piece for the operation of the system and the control algorithms. ISLANDER project devotes a whole work package to develop the following features:

- Individual energy demand forecast models
- Individual energy supply forecast models
- Weather forecast model
- Energy price forecast model

- Macroscopic energy supply and demand forecasting models

4.1.6 Router / Gateway

The evolvement of IoT (Internet Of Things) and IIoT (Industrial Internet of Things) environments, impose a new way of device integration with the connectivity and the protocol adaption to final devices. ISLANDER project will leverage those improvements for the use case solutions. Regarding the protocol bridges and datalogger, router devices which capacity to locate software with protocol translation and Store & Forward functionalities will be considered.

4.1.7 Inverter

Although the inverter can work automatically, somehow it is able to receive orders from the smart IT platform either directly or through the IT system provided by the fabricant.

4.1.8 V1G/V2B/V2G station

ISLANDER project will study the incorporation of different EV integrations to use case. The final EV station topology will be defined in the latter stages of ISLANDER project. The Open Charge Point Protocol (OCPP) presents the following possible topologies:

- Charging Station(s) directly connected to CSMS (Charging Station Management System)
- Multiple Charging Stations connected to CSMS via Local Proxy
- Multiple Charging Stations connected to CSMS via Local Controller
- Non-OCPP Charging Stations connected to CSMS via OCPP Local Controller
- DSO control signals to CSMS
- Parallel control by CSMS and EMS

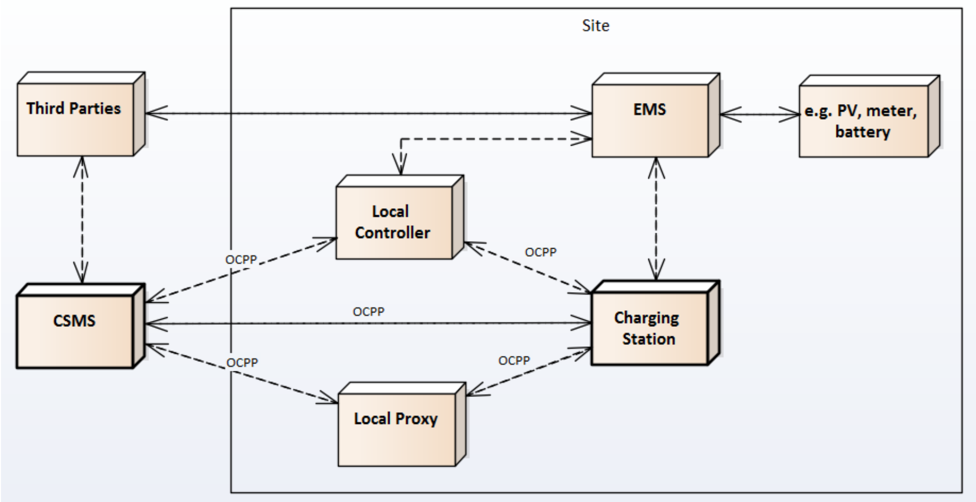


Figure 44 Possible components in a setup using OCPP [15]

4.1.9 Smart appliances

The integration of smart appliances in the mix of energy assets will allow the Smart IT platform perform more sophisticated energy operations in programs such as Demand response (DR) and behind the meter operations with better performance. For DR purposes, DR connectors will be analysed according to the TSO or DSO specifications.

4.1.10 Smart meters and submeters

Additional to the power inverters, Smart meters are needed to get measures from local installation points which are out of the power inverter range.

4.1.11 Temperature sensor

The temperature sensors will be integrated to monitor and operate the district heating system and demand response operation that include HVAC (heating, ventilation and air conditioning) devices.

4.1.12 Switches

The integration into the platform of switching actuators will be at least required to control some assets such as the street lighting.

4.1.13 Bridges

Depend on the final devices some bridges hardware could be needed to hardware adaptation in the communication.

4.2 Communication with devices

The following figure depicts a first approach for the Communication Layer. This approach has brought up

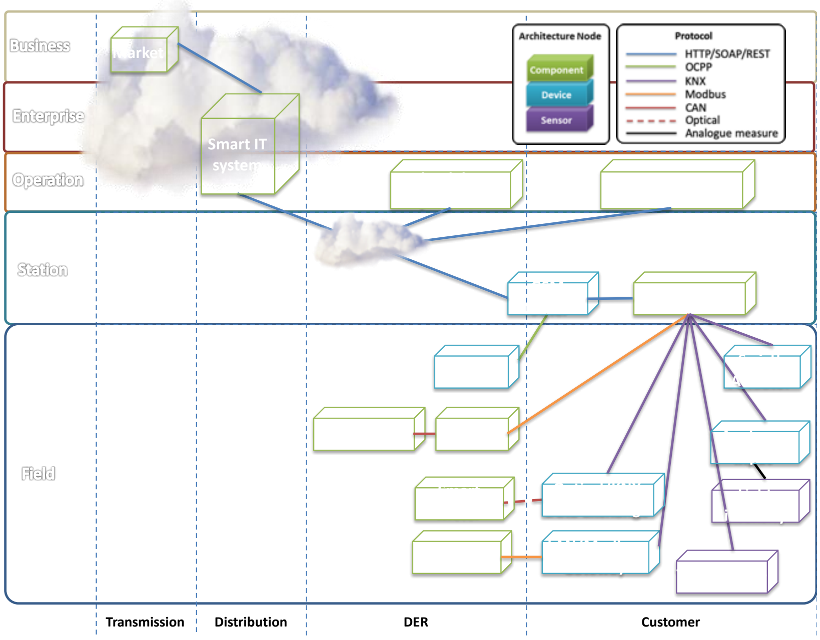


Figure 45 ISLANDER Communication Layer

The end to end communication with devices includes the following communication hops:

4.2.1 Smart IT platform (cloud) – On site hop

The smart IT platform gets information about telemetries, local alarms, and device settings; makes the data acquisition, as well as the orders sending to fix setpoints and operation modes. To that, the smart IT platform will oonsider a set of protocols adapters integrated with the data acquisition streams that eases the integration of current devices and the development of new communication protocols.

4.2.2 Device provider (cloud) – On site hop

In the case of private communications between some device provider cloud and his own devices to get telemetries and send control orders. This communication is private but not exclusive. Some devices allow to keep a private communication with its provider cloud to get telemetries and the control order sending, and also other an external communication.

4.2.3 Smart IT platform (cloud) – Device provider (cloud)

In some cases, this could be the only way to interact with certain devices. However, even if external communication with these devices were available, this way would leverage mechanisms of store and forwards, avoiding to implement that by mean of an additional device like a datalogger, and increasing the installation investment.

4.2.4 Smart IT platform (cloud) – Forecast algorithm (cloud)

Having into account the complexity and the valuable capabilities of forecast algorithms in ISLANDER project, it becomes a good decision to develop these ones in separate components and establish communication between them. The communication, in this case, will be focussed on: the historic VTQ series (Value time quality series) from the smart IT platform's data lake to the Forecast algorithms to the machine learning training; and on the result of forecast data requested by the smart IT platform. The architecture will consider enormous volume of data to transfer, sorting out, e.g. putting both components in the same cloud zones streamlining the cost and bandwidth.

4.2.5 Field hop

The integration in this hop advices catching up with the last trends in the IoT and IIoT communications, having in mind not only the functionality but also the innovation for future usages in other installations after the ISLANDER project, seizing cutting edge technologies. It is time to review the solution for the following elements, owing to these capabilities could be supplied for an only device:

- Router
- Gateway
- PLC
- Bridge
- Data loggers

4.3 Protocols

The communication protocols in microgrid environments have strongly grown in the last years. In fact, according to the CEN-CENELEC-ETSI Smart Grid Coordination Group there are more than five hundred communication protocols applicable in a microgrid. A focused approach and expertise in similar projects are advisable to deal with a project like ISLANDER. Below, the first candidates have been drawn up:

4.3.1 Energy market integration.

Having investigated several market operators such as VPP, Terna (Italy), TenneT TSO (Germany), OMIE Spain & Portugal, it is fair to say that here is not any standard for the energy bid offer sending, awarded offers notification. The protocol used is particularized for each market operator.

4.3.2 Energy service provider interoperability model.

The communication between the energy operators and the smart IT platform (DERMS) is established in the follows cases:

- **Energy dispatches**. This energy dispatches can be implicit to the awarded energy offer notifications in bilateral contracts, day ahead, and real time bids. Notwithstanding, certain services related to the frequency contingency control in ancillary services can require a direct communication between the TSO and the energy producer or load capacity provider. The energy service provider has to count on system software capable of receiving and process energy dispatches in real time ambiences.

- **Demand responses dispatches**. Regarding the DR, the major protocol reference is the standard *OpenADR*. However, there is an important discussion due to the fact that both the distribution company and the TSO responsible for the Borkum Island are not *OpenADR* compliance, whereas the most suitable standard protocol to manage all DR programs mentioned in the last section is *OpenADR*. A possible work way is splitting the *OpenADR* protocol, taking only the semantic and adapting a new interface compatible with the available one in Borkum. Taking the *OpenADR* semantic means including in the smart IT platform a protocol adapter which understands the key *OpenADR* concepts, like as EventDispatch, types of DR signals, DR Signal, Interval, Ramp-up, Ramp-down, DER target, multitarget event as well as VTN, and VEN roles with which the smart IT platform would integrate with others to delegate DR events.

4.3.3 Field

Field protocols are well known in the industry, e.g. *OPC-UA*, *Modbus TCP/RTU*, *DNP3*, *KnX*… The selection of the protocols will depend on the devices for the different use cases.

4.3.4 Data acquisition

All mentioned field protocols can be used to the telemetry ingestion; nonetheless, the IoT incursion shifts it in favour of *MQTT*, and even *AMQP* protocols for push communications and RESTFul for polling requires and control order sending.

4.3.5 V1G, V1B, and V2G

The protocol *OCPP* 2.0.1 using the *OCPP JSON* Specification by the mean of websockets will be considered to integrate these types of EV stations.

4.3.6 Standard 5G

ISLANDER project will explore the usage of the standard 5G to establish an intermedia fog layer between the smart IT platform and the field layer. This would give new possibilities to edge computing in favour of distributed control loops at condominium and neighbourhood levels, supplying better resilience, and a faster response.

4.3.7 Fiware

It is a set of open-source software components (framework) for building intelligent platforms and solutions whose aim is to create a common ecosystem in which data can be shared and to simplify the creation of new verticals through the use of common design patterns. It is treated as a de facto standard whose syntax revolves around a common language for the exchange of context information known as Next Generation Service Interface (NGSI). The adoption of Fiware technologies can accelerate the smart IT platform integration with third-party companies and the open software community.

4.3.8 Available protocols

The smart IT platform counts on following protocol adapters: OPC-UA, *OPC-UA*, *Modbus TCP/RTU*, *DNP3*, *KnX, IEC104, MQTT, AMQP (*through *RabbitMQ)*. It is remarkable the platform flexibility to add new protocols adapters, achieving an agnostic vision of final devices that allows the System to operate with devices belonging to different brands, models, datasheets, time zones and regions, in a unified way.

5 Pilots

ISLANDER project main objective is making substantial progress towards a fully decarbonised, smart geographical island which will pave the way to other Follower islands towards a zero-emissions energy system. In order to meet this main objective, all the innovation actions developed in the consortium will be implemented in a real lab in the island of Borkum as a demonstrator that can provide conclusions to keep moving forward on the renewable energy penetration into the power system.

This section aims at describing all the scenarios to be tested in the mentioned pilot of Borkum, providing a high level definition of each of them, where main components will be listed along with the number and type of users. First tentative installation schemes are provided as a first draft plan that can be modified along the lifespan of the project according to the arised needs.

5.1 Street lighting

In Borkum, the street lighting is a network independent of the main island's electrical grid. It consists of 1,100 light points accounting for about 800 hours/year of running light.

Within the ISLANDER project, this network will be provided with a major update by connecting the 1,100 lights point to the smart IT platform. This evolution will allow the street lighting network to be aggregated to the island's energy system as proposed in this project, and thus to exploit the synergies among networks.

The scenario to be tested in this pilot is still pending to be fully defined by the involved actors in a later stage of the project.

5.2 District heating

The area of "district heating from the North Sea" is described in the following overview. The main components and their subsystems are shown here.

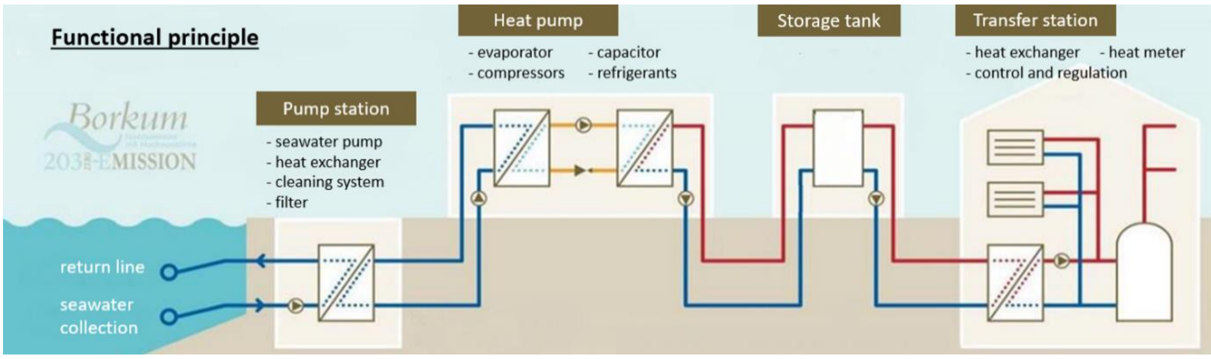


Figure 46 general principle on heat from the North Sea

A seawater pump with a capacity of 100-200m³/h is installed in the area of the pumping station. The pump transports the water through a filter and cleaning system to the heat exchanger. This heat exchanger separates the seawater from the refrigerant and transfers the water temperature to the heat pump system.

In the area of the heat pump are the evaporator, the compressor and the condenser between the pumping station and the heat storage tank. Here the seawater temperature is brought to approx. 30°C.

From here the heat is pumped to the transfer station and there it is transferred to two different heat exchangers where the local heat is increased from 30°C to 50°C for heating and temporarily 70°C for hot water.
For the heating a power of 100kW is calculated and for the hot water it will be about 150kW. This means that the whole system will be designed for about 250kW.

5.3 Buildings

Islander will include three systems installed in buildings. Each of these installations will follow the next tentative scheme:

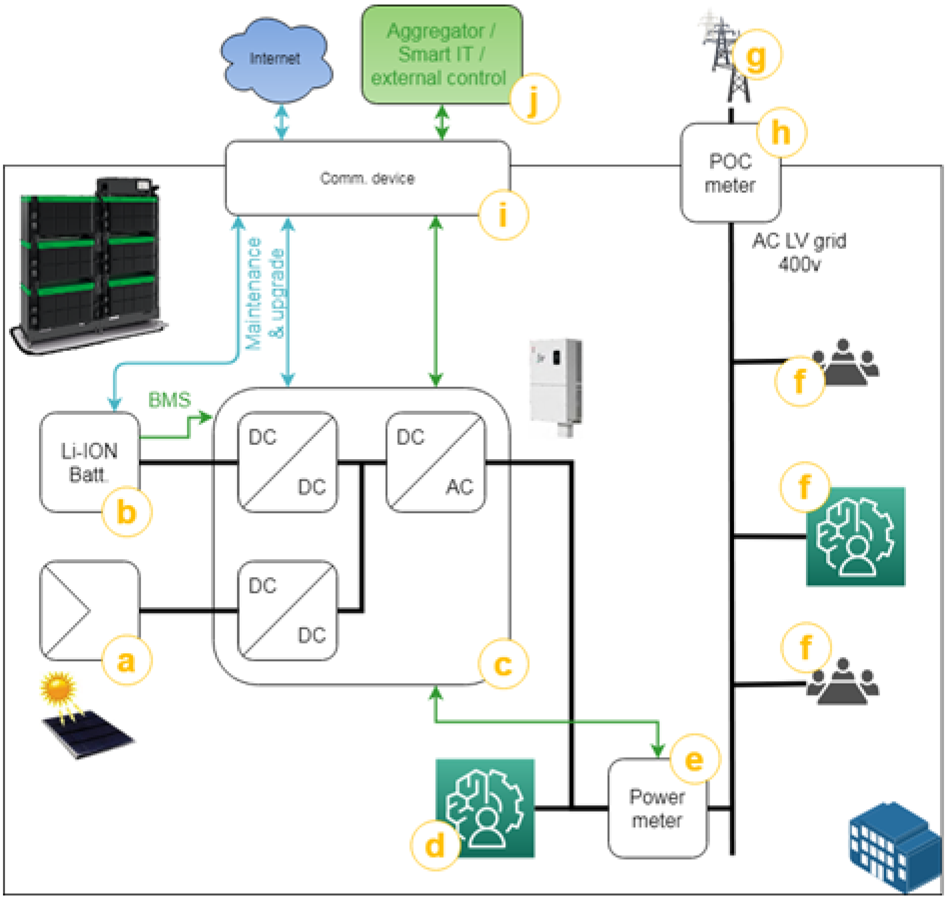


Figure 47 Interconnection scheme

a. Solar panels. They use sunlight as a source of energy and generate direct current electricity.
b. Lithium batteries. Presumably of type Lithium-Iron-Phosphate (LFP). They offer the electricity storage needed to provide all the functions required in Islander.
c. Inverter. It converts different sources of energy (PV panels, batteries and AC grid), controlling the power flow between the three components.
d. Controlled internal load. It’s one part of the building (but it could be the whole building in case power sizing is suitable); the control and regulation of its power, for self-consumption or similar purposes, is guaranteed by inverter.

e. Power meter. It measures the electrical magnitudes (basically power) to be regulated by the inverter or the aggregator/smart IT platform. It gauges the power flow from the set "inverter + controlled load" to the internal AC grid of the building. It's communicated with the inverter.
f. Out-of-the-loop loads. The additional load of the building, not being considered neither controlled in Islander.
g. Distribution grid. Low-voltage distribution grid.
h. Point of connection (POC) meter. Smart meter used for billing purposes. It measures non-controlled loads (f) and controlled power (e).
i. Communication device. One gateway or router that performs communication between internal devices (basically battery BMS and inverter) and the smart IT platform or other external controllers.
j. Smart IT. It optimizes the point of operation of the systems and sends setpoints to the inverters to function in a coordinated way.

Several use cases will be analysed in Islander project, for building pilots:

- Stand-alone (self-consumption) mode. The inverter (c) feeds the internal consumption of controlled load (d) from renewable energy (first PV (a), then the battery (b)) while available. The battery is charged from remaining PV power. The goal is that zero power is consumed from the grid while allowing exporting surplus solar power.
- Aggregated mode. Real power by the meter (e) will track incoming setpoints from the external platform.
- Primary Frequency Regulation. It would be an added value ancillary service to be monetised. It will provide (by the simultaneously distributed contribution of several buildings) primary frequency regulation, according to pre-set droop curves. This service provides stability to the distribution grid in the island. Frequency is measured locally by the inverter (c).

Building pilot	
System	
Number of installations	3
PV	
PV peak power / installation	≈20 kW
Voltage per string	<650v
Number of Strings	≤2
Battery	
Type	LFP
Energy / Capacity	≈70 kWh / 150Ah
Modules	≈8 modules (48v nominal)
BMS connection	Modbus/CAN
Inverter	
AC power	≈20 kW bidirectional
AC Voltage	400 vac (3W) / 50Hz
Other features	
Communication	Web server, modbus
Remote update	Yes

Table 10 Summary of tentative installation for building pilot

5.4 Houses

The residential photovoltaic system is a grid-connected system consists of the following elements:

a) PV arrays
b) A bi-directional inverter
c) Battery system
d) smart meter
e) system monitoring interconnected

The bi-directional inverter is conceived as an interface to act in parallel with the electric utility grid, allowing to inject the excess power to the grid when the PV generation is higher than the direct consumption and vice-versa. The system includes a Li-ion battery for energy storage.

Figure 48. Diagram of a photovoltaic system for residential application shows a tentative scheme of this scenario.

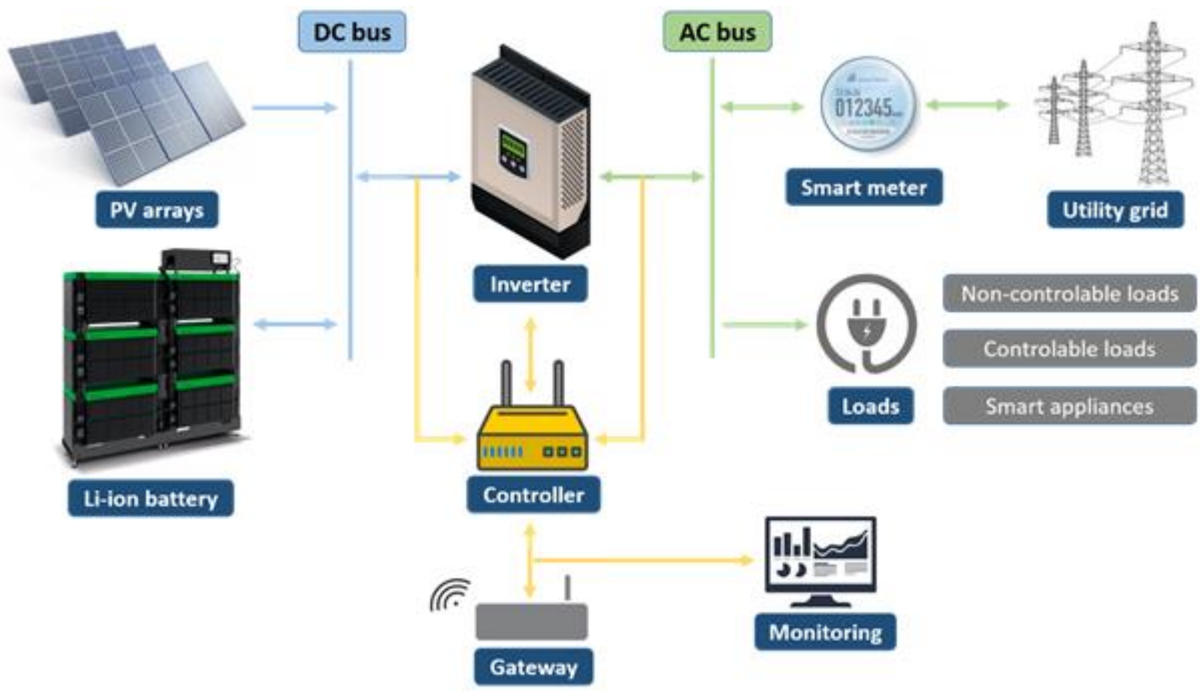


Figure 48. Diagram of a photovoltaic system for residential application

Tentatively, the dimensioning of the equipment is detailed in the next Table 5. These figures are only the first approach. They will be subjected to the building characteristics, as it will depend on the effective surface available, roof/building orientation, and shadows project by nearby elements or buildings.

Aprox. available surface (m²)	80
Aprox. installed power (kWp)	20
Battery system (kWh)	70

Table 11 Estimate sizing of the building PV systems

5.5 EV transport network

The EV transport network will be composed by 5 new charging stations that will be installed under the scope of ISLANDER, where the existing electric vehicles can connect. Furthermore, this increase in the number of charging stations will constitute an incentive for Borkum inhabitants to ease their electric transportation thanks to the improvement of the infrastructure.

Possible scenarios to be studied, according to the final decision of the new charging stations installed, will be evaluated at during the project development according to the defined state of the art regarding V1G, V2G, V2B.

5.6 Utility-scale storage

Islander will include one utility-scale ESS for power-intensive applications. It will be composed of two different technologies of storage, each of them focused on specific services:

- Ultracapacitors. High power, low energy storage. It can withstand hundreds of thousands of charge/discharge cycles; they are suitable for short-duration ancillary services such as virtual inertia or primary frequency reservation.
- Lithium batteries. They are of LFP technology for assured safety. They will be the accumulation subsystem intended for mid-duration applications, such as peak-shaving or secondary frequency response.

The power conversion system will be connected directly to the low voltage distribution grid. To be located indoor. The basic tentative scheme is:

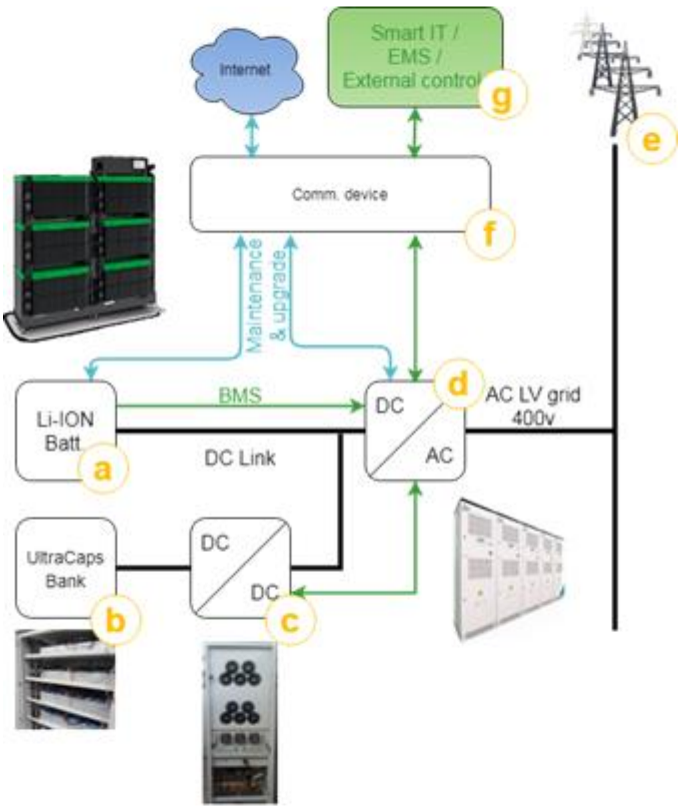


Figure 49 Interconnection scheme

The system will be composed of the following items:

a. Lithium batteries. They will be the accumulation subsystem intended for mid-duration applications, such as peak-shaving or secondary frequency response. They will be connected directly to the inverter DC-link bus. Therefore, the voltage range will be within is the inverter DC working voltage range (850-650v)
b. Ultracapacitors. They are suitable for short-duration ancillary services such as virtual inertia or primary frequency reservation. To take profit of their whole energy, the working voltage range goes from zero to nominal voltage. Because of it, an intermediate DC/DC converter is needed, with a huge voltage span in ultracapacitor side. Usually, full power is guaranteed up to half the nominal voltage, which corresponds to an energy level of 25% of nominal one.
c. DC/DC converter. It connects bi-directionally both accumulation devices. According to desired hybridisation algorithms, the converter controls the amount of power that inverter transforms from each of the accumulation technology.
d. Inverter. It performs all the required ancillary services to the utility grid, on-grid connected. All necessary power it's transferred from/to accumulation subsystems. The control board computes the energy to be assigned to each one.
e. Distribution grid. The Low Voltage distribution grid; due to the nominal power of the system (1MW), the Point of Connection should be carefully chosen. No isolation transformer is planned, so leakage current protection device should be installed.
f. Communication device. One gateway or router that perform communication between internal devices (basically battery BMS and inverter) and the smart IT platform or other external controllers (EMS).
g. Smart IT / EMS. It sends setpoints to the inverter for all the ancillary services do not controlled by the ESS itself.

Among the planned auxiliary services, we can mention the following:

- Embedded function in ESS
  - Virtual Inertia
  - Primary Frequency Regulation
  - Local Voltage Regulation
  - P/Q setpoint tracking
- Externally (EMS) controlled functions
  - Peak-shaving
  - Load-levelling
  - Secondary Frequency Regulation
  - Energy trading

Utility-Scale ESS pilot	
System	
Number of installations	1
Battery	
Type	LFP
Energy	≈1 MWh
Modules	≈75 modules (48v/280Ah nominal)
BMS connection	Modbus/CAN
Ultracapacitors	
Voltage	48v nominal/module
Capacity	165 F/module
Modules / string	14
Number of strings	12
Energy / power	≈ 27 MJ / 1MW

Estimated full power discharge time	≈ 18 s
Inverter	
AC power	≈1 MW bidirectional
AC Voltage	400 vac (3W) / 50Hz
Other features	
Communication	Web server, modbus
Remote update	Yes

Table 12 Summary of tentative installation for Utility-Scale ESS pilot

5.7 Hydrogen based seasonal storage

5.7.1 General scheme of the pilot plant

The hydrogen production process can be summarized in the next block diagram, where the raw material is filled in blue colour in grease colour the by-product or intermediate product, and in green colour the electricity to be consumed.

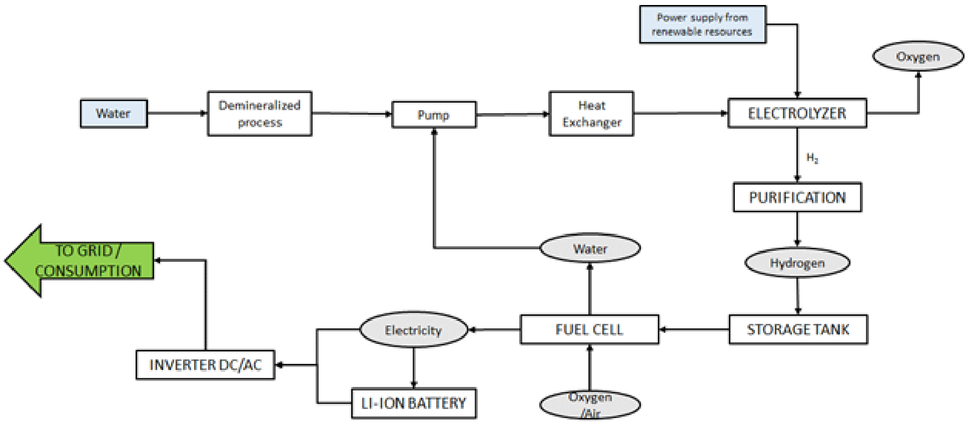


Figure 50. General scheme about the hydrogen system

As a raw material in the process, water and electricity are the main inputs in the production electricity process. It will then be possible to study the possibility of recirculating produced water in the fuel cell to the electrolyser for more hydrogen production and make the process more sustainable and efficient.

Concerning the electrolyser, the selected one is a PEM or Alkaline electrolyser with an estimated operating and outlet pressure around 30-40 bar. A possibility is that this pressure will be the same in the storage system to avoid additional equipment like a compressor and, of course, eliminate other additional power consumptions. The storage tank's capacity will be necessary to store all the hydrogen produced at the outlet pressure of the electrolyser. Another possibility is to store the hydrogen at higher pressures, i.e., between 150-300 bar, in order to drastically reduce the tank dimensions, but adding a compressor with the associated added complexity and cost.

In a first approach, the possibility of installing a relatively small electrolyser will be explored that will produce a relatively slow flow rate of hydrogen at low pressure. This will allow installing a bigger storage tank that will operate at the same low pressure as the electrolyser. Additionally, a bigger tank will maximize the amount of hydrogen for seasonal and intra-seasonal periods. On the other hand, if the storage is made at, for example, 200 bar, dimensions of the tank will be lower, but additional consumptions will be taken into account.

The equipment where the electricity will be produced is a PEM fuel cell with a polymeric membrane. Final components as a Li-ion battery pack for power balancing or inverter to convert the electricity into AC also will be installed in the system.

Special attention should be put to the hydrogen, and a specific implementation will be required due to the compound characteristics because it is the lightest element. ATEX regulations will be applied, being hydrogen is classified in zone 0 group IIC as a hazardous element. Normative SEVESO 20102/18/UE, as well as ATEX Directive 201/34/UE are mandatory and should be applied. The space for hydrogen storage must have enough ventilation to avoid problems.

5.7.2 Estimated preliminary sizing of the system's components

At this point, an initial specification of the main elements of the hydrogen system is presented. Remark that this is the first general overview of the system, and final parameters will be defined during the project's development and execution.

As it has been commented, the idea is to operate the system at the outlet pressure of the electrolyser, installing a bigger tank for seasonal hydrogen storage. The type of electrolyser will be alkaline or PEM electrolyser because they are the two most promising elements of the market. The fuel cell will be a PEM fuel cell. Concerning electrolyser and fuel cell, the possibility to install two pieces with half of the required capacity will be studied to have a more flexible process. In this way, if maintenance is required during the operation with one, the process production doesn't stop. It will be defined during the optimization process.

Electrolyser	
Hydrogen production volumetric flow (Nm^3/h)	1 – 10
Hydrogen production mass flow (Kg/day)	2.1 – 21.6
Hydrogen outlet pressure range (bar)	15 - 40
Hydrogen purity (%)	>99.99
Water consumption (L/h)	2 – 20.1
Water input pressure range (bar)	2 - 6
AC power consumption (kWh/Nm^3 H_2)	5 - 6
Power supply (kW)	6 - 53
Voltage (V AC)	400 / 480 ± 10%
Frequency (Hz)	50 / 60

Table 13 Specifications of the proposed electrolyser

H_2 storage tank	
Stored hydrogen capacity (Kg)	4 – 30
Capacity[1] (m^3)	2 - 10
Storage pressure[2] (bar)	40 - 200

Table 14 Specifications of the proposed storage tank

Fuel cell /unit	
Power output (kW)	2.5 - 10
Nominal voltage (V DC)	48
Supply voltage (V DC)	38 – 150
Nominal fuel consumption (Nl H_2 /min /kW)	11 - 145
Weight (Kg)	27 - 97

Table 15 Specifications of the proposed fuel cell

The other components necessary for the installation, as the Buffer Li-ion battery pack and the power inverter, will be selected accordingly to the chosen main components and the grid characteristics.

There are also two essential points concerning the system location, i.e.

- **Water quality:** If the quality of water is not appropriate, such its total organic carbon or conductivity, and the electrolyser does not include any water treatment system, an external demineralisation unit will be required for this proposal.
- **Water supply**: The electrolyser needs to be feed with tap water, so a connection point needs to be defined. It will be localized as close as possible to the hydrogen system. Additional elements to be considered can be a buffer water tank connected to the water grid system and a pump for feeding the electrolyser with the tank's water.
- **Connection to the grid**: The system shall be connected to the electrical grid. According to the foreseen power of the system, a connection to the low-voltage network would be enough.

This two last point shall be taken into account for the installation; thus, the final system location shall be defined as soon as possible.

[1] The tank capacity will depend on the selected operating pressure

[2] The pressure depends on the selection of Low Pressure (LP) or High Pressure (HP) storage

6 Use cases

ISLANDER project will work to develop different use cases to test in the different scenarios planned in Borkum. The main use cases are classified into the so-called behind-the-meter applications (BTM) and front-the-meter applications (FTM). The BTM applications are related to operations that occurs on the site and maily related to operations that optimize the customer energy tariffs according to their nature. The optimization will cosnider all the energy assets including the electric vehicles. The resulting BTM operations are self-consumption, arbitrage, peak limitation, optimal charging covering the stationary energy assets and electric vehicles. In some use cases it is possible to combine all/some BTM operations to optimize the customer benefits. The BTM applications will be tested in the residential, building and EV stations pilots.

The FTM applications consist on energy services that require the participation of other actors outside the site. Amongst the main FTM energy services are demand response, frecuency regulation, contingency. The terminology and rules have a strong dependency on the geographic location. Those services imply the participation in the electric market bidding process and the actuation of TSO dispatches, DR events, bilateral contract, energy service commitment and so on. The aggregation permits small sites to participate in such as FTM services since there are some limitations in the minimum volumes to participate. However, currently there are some electric markets that allows big clients such as industries to participate in such as services without the necessity to aggregate with others. The aggregation also allows the participation in some electric market bidding process in portfolio mode providing more flexibility in the operations. During the execution of Islander project, a deep dive in the main market rules will be carried out in order to define the market scenario more conviente for island conditions.

6.1 BTM operations

The BTM (Behind The Meter) operations are all energy services which occur on-site.

6.1.1 Self-consumption.

One subset of behind the meter operations are the so-called self-consumption that is the result of the optimization of the customer tariff where the energy storage is mainly used to avoid the purchase of energy. In the self-consumption scenario is possible to use the stationary battery as a main asset and combine this with electric vehicles capable to charge and discharge in the so-called vehicle-to-building (V2B) applications. The V2B capability increases the complexity of the self-consumption scenario since the electric vehicle batteries are not plugged continuosly. Therefore, the algorithms should consider in the constraints the vehicle schedule and customer habits.

The algorithms would need the following inputs to calculate the optimal operations of each energy asset: actual and forecasted PV generation, actual and forecasted load, actual and forecasted battery state, customer tariff and energy incentives and penalties.

6.1.2 Energy arbitrage

For some customers it is possible to sell and purchase energy from the grid to store in the stationary batteries (this depends on the country regulations and incentives). Thus, the asset operations would include operations that obtain profit from the difference in the energy hourly tariffs. The energy arbitrage will consider all the energy asset not only the stationary batteries but also the EV with V2B capability. In order to calculate the energy arbitrage operations is necessary the same inputs that the aforementioned for self-consumption.

6.1.3 Peak limitation

Some customers would have tariff dependent on peak values. For that reason, it would be necessary to detect such peaks and use the storage to reduce the peak consumption from the grid. The peak limitation operation will consider the stationary battery and the EV with V2B capability. The V2G capability increases the complexity of the algorithms but will increase the performance of the whole use case since the storage and peak reduction capacities increase. The algorithms will process the same inputs than the previous BTM operations.

6.1.4 Optimal EV charge.

For the case of customers with a EV charging station infrastructure, the BTM will be focused on the optimization of the charging of the electric vehicles connected to their infrastructure. To that end, it will consider the customer tariff and physical limitations of the infrastructure. The V2B capacity will increase the complexity of the operations with better expected results.

6.1.5 Power limitation.

The control algorithm watches out not exceeding a consumption limit. It deems this service as a constrain which can be applied to other services.

6.2 FTM operations

6.2.1 Aggregation

The aggregation allows to participate into energy services adding the contribution of more than one site. The aggregation supposes a new tier in the optimization algorithms and depending on the number of sites the optimization problem gets into unfeasible due to the fact that the problem belongs to NPcomplete algorithms. The aggregation implies other constraints related to the point access to the Electrical Grid that have to be considered to avoid unbalance energy zones and energy supply quality problems.

6.2.2 Energy services

Regarding FTM energy services, ISLANDER project will appraise the different alternatives and types of wholesale electric markets. The wholesale markets include different time-scales from real-time balancing markets to long-term contracts. The energy services are operations that imply delivery of electricity at some point in the future. Depending on the market or contracts different periods are established ranging from [20]:

- Long-term contracts: up to 20 years or more
- On the forward and future markets: weeks to years in advance
- On the day-ahead market: the following day
- On the intra-day market: delivery within a specified time period (for instance, an hour or a quarter)

On the balancing market: real-time balancing of supply and demand.

6.2.3 Demand Response, DR

The demand response is the energy services that control the demand in order to match the generation. This tool is essencial to some electric networks where the storage capacity is limited. Therefore, the operator has an alternative method to handle the energy deviations. The demand response should consider the dynamic of the changes in the demand and the markets impose specific roles defining demand response services with different time response and monitoring of the telemetry. There are several approaches for the demand response services such as Time-of-Use pricing (TOU), real-time pricing (RTP), variable peak pricing (VPP), critical peak pricing (CPP) and critical peak rebates (CPR).

The ISLANDER project will study these alternatives and define use cases focussed on the Demand Response implementation.

7 Deviations

Delivery of the content was expected to be submitted by 30/11/2020, but it has been finally been submitted with one month delay due to the need of launching quality and revision check at the begining the project.

8 Main conclusion

The current D1.1 provides a general understanding about the overall view of the hardware and software to be developed in the ISLANDER project by setting up the first premises and characteristics to be used as a starting point for the project development. Furthermore, there is a first tentative design about how hardware and software are jointly put together in the defined pilots and use cases.

This deliverable will be useful as a guideline for the rest of the project lifespan because general objectives were covered with specific actions to be developed by the consortium, at the same time that future actions

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