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Virtual Power Plant for Interoperable and Smart isLANDS

VPP4Islands

LC-SC3-ES-4-2020

GA 957852

Deliverable Report

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REVISION AND HISTORY CHART

Version	Date	Main Author(s)	Summary of changes
V0.1	23/08/2021	Diego Piserà	Table of Contents
V0.1.1		Diego Piserà	Market Regulation in Turkey + scenarios in Gökçeada
V0.1.2		Diego Piserà	Energy Community regulatory Framework
V0.1.3.		Diego Piserà	Scenario for testing and validate Digital Twin
V0.1.4.	24/09/2021	Seifeddine Ben El Ghali, Diego Piserà	Review of contents
V0.1.5.	24/09/2021	Diego Piserà	Reformulation of Scenarios after review
V0.2	25/10/2021	Diego Piserà, BUL review	BUL Review

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LIST OF PROJECT PARTNERS

Abbreviation	Meaning
ALWA	AlgoWatt
AMU	Aix-Marseille Université
BC2050	Blockchain2050
BORN	Bornholms Varme A/S
BoZI	Bozcaada Belediye Baskanligi
BUL	Brunel University London
CIVI	CIVIESCO srl
CSIC	Consejo Superior de Investigaciones Científicas
CU	Cardiff University
DAFNI	Network of Sustainable Greek Islands
FORM	Consell Insular de Formentera
FTK	FTK Forschungsinstitut fur Telekommunikation und Kooperation EV
GRADO	Commune di Grado
IDEA	Ingenieria Y Diseno Estructural Avanzado
INAVITAS	INAVITAS Enerji AS
LIS	Laboratoire Informatique des Systèmes
PVM	Protisvalor Méditerranée
RDIUP	RDI'UP
REGENERA	REGENERA LEVANTE
SCHN	Schneider Electric
TROYA	TROYA CEVRE DERNEGI
UEDAS	Uludag Electric Dagitim

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List of Abbreviations and Acronyms

Abbreviation	Meaning
AMI	Advanced Metering Infrastructure
BRP	Balance Responsible Party
CEC	Citizen Energy Community
CHP	Combined Heat and Power
DAM	Day Ahead Market
DER	Distributed energy resources
DF	Demand Flexibility
DLT	Digital Ledger Technologies
DSO	Distribution System Operator
DSS	Decision System Support
DT	Digital Twin
DTE	Digital Twin Environment
DTI	Digital Twin Instances
EC	Energy Community
EMD	Electricity Market Directive
EPDK	Turkish Energy Market Regulatory Authority
ESS	Energy Storage System
EV	Electric Vehicles
FoK	Fill or Kill
GHG	Greenhouse gases
GUI	Graphical User Interface
IM	Intraday Market
IoC	Immediate or Cancel
MCP	Market Clearing Price
P2P	Peer-2-peer
PV	Photovoltaic
POD	Point of Delivery
QPP	Quantity-Price Pairs
REC	Renewable Energy Community
RES	Renewable energy sources
REDII	Recast of Renewable Energy Directive
ROI	Return Of Investment
RTU	Remote Terminal Unit
SoC	State of Charge
SPT	Smart Planning Tool
SRS	Software technical Requirements Specifications
UI	User Interface
VSoC	Virtual State of Charge
VESS	Virtual energy storage systems
VPP	Virtual Power Plant
YEKDEM	Turkish Renewable Energy Resources Support Mechanism

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EXECUTIVE SUMMARY

The present report is a public deliverable (Deliverable D2.8) of the VPP4ISLANDS H2020 funded European project. The VPP4Islands project aims to facilitate the integration of renewable systems, accelerate the transition towards smart and green energy system and help islands to exploit energy efficiency potentials and innovative energy storage approaches. In particular, VPP4Islands project proposes disruptive solutions based on digital twin concept, Virtual Energy Storage Systems (VESS) and Distributed Ledger Technology (DLT) to revolutionize the existing Virtual Power Plants (VPP) and build smart Energy Communities (EC). In order to validate and evaluate the proposed solutions, two use cases in real-life with diverse assets in Gökçeada and Formentera are planned. The qualified VPP4Islands solutions will be replicated in 3 follower islands Grado, Bozcaada and Bornholm.

In this context, the objective of Deliverable D2.8 *" Scenarios for studying VPP4Islands concept "* is to define a number of representative scenarios that will be demonstrated in the real-life use case of Gökçeada and Formentera. The scenarios will be implemented in WP7 to evaluate capabilities and values of VPP4Islands solutions. The scenarios are formed considering the followings aspects of case studies:

- Characteristics and assets.
- Market structure.
- Relevant KPIs.
- Environmental constraints.

Moreover, the scenarios are design in order to provide a basis for comparing values of various configurations of energy storage systems.

The first real-life use case will take place in Gökçeada island (case study 1). The scenarios are designed to assess the flexibility and DR capability and improve the stability of the grid. The mix storage approaches will be challenged according to the requirements gathered from the Living Lab. There are four main actions related to case study 1, these are listed below:

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1. Build an energy community by integrating 100 smart meters, 10 VPP4Box and 1 VPP4INode.
2. Install a new Energy Storage System.
3. Deploy the VESS API.
4. Use the VPP4IPlatform to design the Technical Virtual Power Plant (TVPP) in the DT of the power system of the island.

These four actions are described in the detail in the three scenario design for the use case 1, in particular:

1. Scenario 1 will be to design and validate the TVPP of the power system of the island. The main role of the TVPP will be to simulate the activation of the flexibility by distributed energy resources and detect if the activation of the flexibility may arise technical problems in the distribution grid such as out-of-range voltages or over-currents.
2. Scenario 2 will be to build a renewable energy community and installed a battery energy storage system and a system composed by a resistance and a power converter able to simulate the behaviour of an HVAC system of a building. The flexibility provided by these two elements will be managed by the VESS API. In this scenario will be deploy a VPP4ISLANDS solution customized for renewable energy community, the battery energy storage system will be used to maximize the self-consumption within the renewable energy community.
3. In scenario 3 a certified energy trader, Limak Trade Energy will use the VPP4ISLANDS solution to improve the performance in the spot market of a portfolio composed of distributed energy resources and the battery energy storage system installed within the energy community. In this scenario a VPP4ISLANDS solution customized for energy traders will be deployed. The battery energy storage system will be used to maximize the profit of the portfolio of generators in the energy spot market.

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In particular, the results of scenario 2 will make possible to assess the flexibility (storage) and the demand response (HVAC system) capability to maximize the self-consumption within a renewable energy community. The results of scenario 3 will make possible to assess the flexibility (storage) capability to improve the performance of a portfolio constituted largely of plants from renewable sources in the energy spot market. Finally, scenario 1 will make possible to evaluate if the activation of flexibility and demand response in scenario 3 meet the technical constrains of the distribution grid or not.

Formentera will be used as real life use case (case study 2) to validate the technological solutions related to energy communities and Peer-to-peer energy trading. There are four main actions related to case study 2, these are listed below:

1. implement the Fuel Cell - Li-Ion/Redox-Flow Batteries:
    i. Polymer Electrolyte Membrane (PEM) Electrolyser to utilize excess electricity for hydrogen generation.
    ii. hydrogen storage system
    iii. PEM Fuel cell operated on a 100% hydrogen
    iv. Li-ion/redox flow batteries to provide fast response capabilities.
2. Create two small energy communities by installing 50 smart meters, 10 VPP4Ibox, and equip ten households (selected in the living lab) with solar panels.
3. Design test and validate the communication (latency, data format, protocol, etc.) and P2P trading engine.
4. Use the **Smart Planning Tool (SPT)** to generate a plan that allow a near independent micro grid based on installed renewable infrastructure, controllable appliances, and storage system in real time control by using the three VPP4Island modules.

These four actions are described in the detail in the three-scenario design for the use case 2, in particular:

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1. Scenario 1 will be to design and validate the digital twin of Formentera island. The Digital Twin will host the model of all the Virtual Energy Community implemented in the island.
2. Scenario 2 will be to build two renewable energy community and install a fuel cell/battery energy storage system. The flexibility provided by the fuel cell system and the energy generate by the PV plants will be used also for Peer-to-Peer energy trading. In this scenario will be deploy a VPP4ISLANDS solution customized for renewable energy community, the fuel cell-battery energy storage system will be used to maximize the self-consumption within the renewable energy community.
3. In scenario 3, we will use The Smart Planning Tool to calculate the optimal size of PV and energy storage systems to maximize the self-consumption in the energy communities.

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1. Introduction

1.1. The VPP4Islands project

The VPP4Islands project aims to facilitate the integration of renewable systems, accelerate the transition towards smart and green energy systems and help Islands to exploit energy efficiency potentials and innovative energy storage approaches, foster the active participation of citizens and become self-sufficient in energy, while reducing costs, GHG emissions and reliance on heavy fuel oil to generate power, and creating new intelligent business and local skilled jobs.

To reach these goals, VPP4Islands project will:

- Revolutionize the existing VPP by integrating many services potentially deliverable by a VPP into a single platform (i.e., the VPP4INode) that will be able to aggregate and coordinate distributed energy resources (DERs).
- Build a Digital Twin (DT) of the energy system at islands involved in the project.
- Implement the concept of Virtual Energy Storage Systems (VESS) to combine the flexibility coming from different assets such as storage and flexible loads.
- Utilise the Distributed Ledger Technology (DLT) to allow peer-2-peer (P2P) energy transaction.
- Build smart energy communities and promote self-consumption.
- Enhance the Demand Response Capability of consumers by understanding their behaviours.
- Validate and evaluate the VPP4ISolutions, with two different real-life use cases, one in Gökçeada (Turkey) and one in Formentera (Spain).
- Replicate the qualified VPP4Islands solutions in three following islands Bozcaada (Turkey), Grado (Italy) and Bornholm (Denmark).

1.2. Scenario methodology

The goal of the delivery is to design the scenarios that will be investigated in the demonstration pilots of Gokceada and Formentera. The methodology used to design the scenarios is as follows.

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First, a study was made of the national laws of interest for the implementation of the project, such as the laws governing the electricity market in Turkey or the laws on energy communities in Spain.

Secondly, a study has been carried out on the characteristics of the islands that will host the demonstration pilots and of the actors and assets that will be involved in the implementation of the project.

Finally, scenarios were described for each island to implement the functions of the VPP4ISLANDS solution. To each scenario are associated Strategic Objectives (SO) and KPIs for the evaluation of results.

The scenarios designed here are described phase by phase. The phases of realization are not intended to be realized one after the other but can be developed in parallel. Only the final phases, those of evaluation of results are intended as consecutive to the previous ones.

Each phase describes the functions that will be performed in the project by the three elements of the VPP4ISLANDS solution, namely the VPP4IBox, the VPP4INode and the VPP4IPlatform. Furthermore, it will be described through which modules the three elements will perform the described functions.

The three elements and the modules from which they are composed are described in the delivery *"D2.4 Report on the VPP4Islands concepts"*. Figure 1 shows the taxonomy of the VPP4ISLANDS solution concept. In the taxonomy it is possible to observe the modules that compose the three elements of the VPP4ISLANDS solution.

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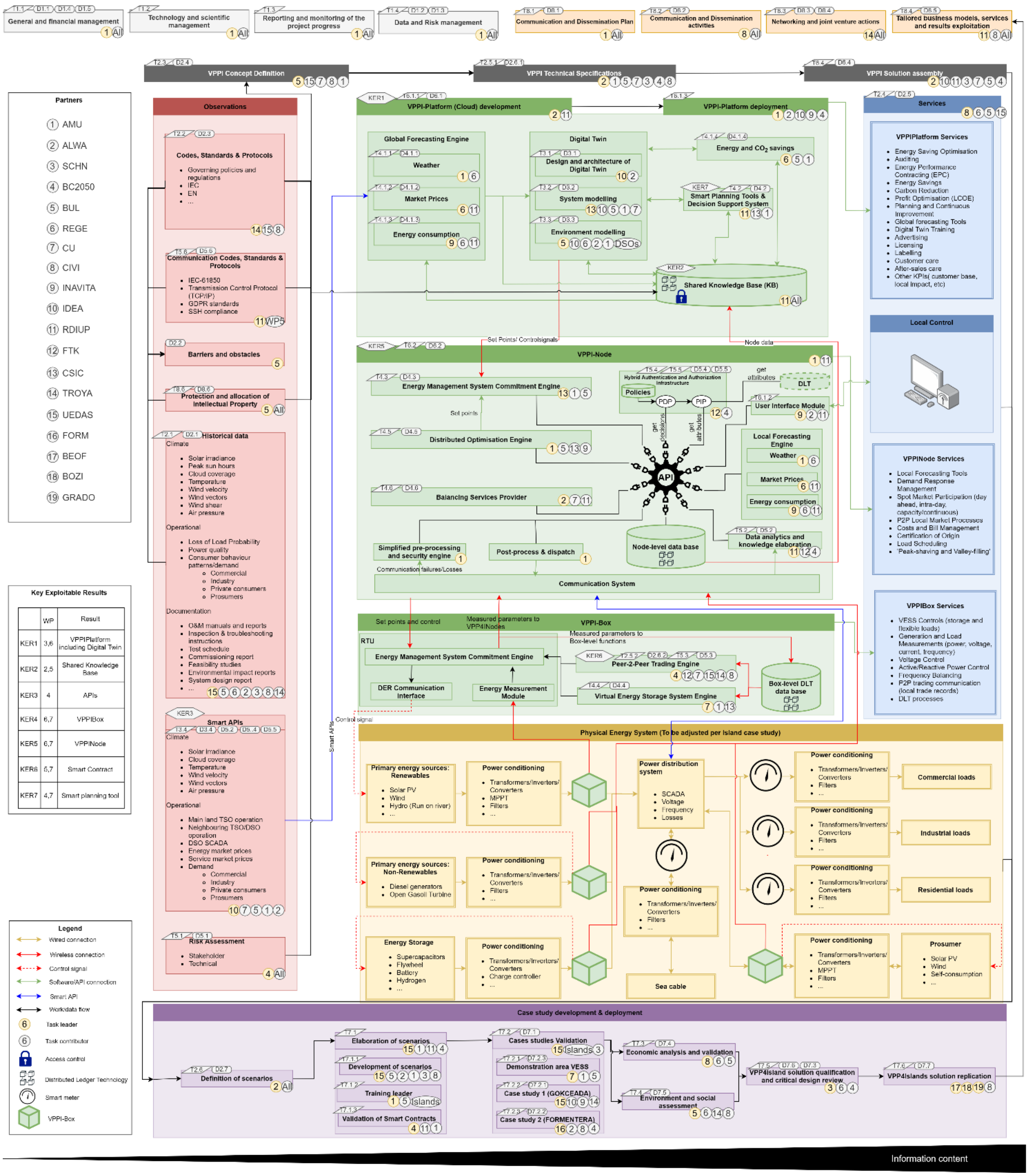

Figure 1: VPP4ISLANDS solution concept taxonomy

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1.3. Structure of Deliverable D2.8

The delivery structure is described below. Chapter 2 describes the operation of the Turkish day-ahead and intraday electricity markets. Chapter 3 describes the concept of energy community in the European regulatory framework and the legislative frameworks of Spain and Turkey. Chapter 4 describes the strategic objectives of the project and the KPIs useful for assessing the achievement of these. Chapter 5 describes the three scenarios that will be implemented on the island of Gokceada (Turkey). Chapter 6 describes the three scenarios that will be investigated on the island of Formentera (Spain). Finally, Chapter 7 describes the scenarios that will be replicated in the follower islands: Bozcaada (Turkey), Grado (Italy) and Bornholm (Denmark).

2. Electricity market regulation in Turkey

2.1. Day-ahead energy market in Turkey

The day-ahead energy trading is the trading of electricity for the following day. Day-ahead energy trades have important physical implications because of the high volumes traded.

Market participants trade on their expectations for the next day until a specific deadline every day (the gate closure). This takes place at power exchanges called Energy Exchange Istanbul (EXIST) or Enerji Piyasaları İşletme A.Ş. (EPİAŞ) by its Turkish name. Electricity can also be traded bilaterally via OTC trading (Over-the-Counter), which concerns contracts not concluded at a power exchange.

An important aspect of Day-Ahead Market (DAM) is chance of demand side to adjust its consumption based on price levels. With this, demand side has begun to actively participate to market thus has the chance of hedging itself to against fluctuating price formations. Another novelty introduced by DAM is allowing to market participants to balance their own portfolios of generators and energy consumers. This allowed participants to present more balanced structure to the market and decrease of imbalances of generation/consumption units within their respective portfolios.

The information reported here is made available by EPIAS in [1]. EPIAS also makes available a general description of the market clearing algorithm used in the DAM, [2].

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Day-ahead market: General principles

- Legal entities holding license can join Day-Ahead Market by signing Day-Ahead Market Participation Agreement which includes market participants responsibilities regarding to Day-Ahead Market.
- Day-Ahead Market transactions are performed daily on hourly basis. Each day starts from 00:00 (midnight) and ends at 00:00 (midnight) of following day and consists of hourly time periods.
- Market participants can submit their orders from next day to 5 days later.
- Prices and volumes applied for clearing of DAM at daily basis are determined for each hour.
- Advance payment notifications as results of clearing calculations for market participants based on their day-ahead balancing activities indicate payables to market operator and receivables from market operator for respective market participants and these notifications are announced in a daily basis fashion by market operator to market participants via Istanbul Clearing, Settlement and Custody Bank Inc.- Takasbank.
- At previous working day before weekend and/or official holiday, market operator performs collateral check twice a day at 11:00 and 17:00 respectively. During collateral check performed at 17:00, total collateral amount present at 11:00-collateral-check is considered.

Day-ahead market: Processes

- Day ahead market participants submit their day-ahead market orders belonging to next day every day until 11:30 am via DAM Web Application system to market operator.
- Day ahead market offers that are presented by market participants for next day are considered for determining market clearing price and market clearing volume after collateral check, based on relevant procedure, is performed and adequate collateral amount is confirmed.
- Day ahead market orders submitted to market operator are verified during 11:30 - 12:00.
- Verified orders are assessed via optimization tool during 12:00 - 13:00; market clearing price and market clearing volumes are determined for every hour of the related day.

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- Trade confirmations including sales-purchase volumes are announced to relevant market participants every day at 13:00. Market participants can object to these notifications in case of errors regarding to transactions during 13:00 - 13:30.
- Objections are evaluated during 13:00 -13:30 and relevant results are notified to market participants that made the objection. At 14:00, finalized prices and matched volumes for 24 hours of next day are announced.
- Market participants can submit their bilateral contract notifications to DAM Web Application system during 00:00 - 16:00 every day.
- Processes described above are normal processes for DAM and in case of technical problems that may arise from day ahead market system, emergency procedures are carried out by market operator.

Day-ahead market: Orders

- Participants can submit hourly and daily for a particular period of hour/hours and/or flexible orders to DAM.
- Orders are composed of volume and price information that can change for different hours.

  a. Submitted order prices have centesimal sensitivity.

  b. Orders can be made in terms of Turkish Lira (TL/MWh).

  c. Order volumes are submitted in terms of Lot as an integer number. 1 Lot is equivalent to 0,1 MWh.
- Orders can be submitted as purchase and sale instruments. Depending on the sign in front of the order volume, the order is marked either as purchase or sale order. (For instance, 100 Lot indicates a purchase order whereas -100 Lot indicates a sale order).
- Minimum and maximum price limits are determined by market operator as 0 TL and 2000 TL respectively. Depending on changing market circumstances, market operator updates minimum and maximum price limits and announces them via DAM Web Application to participants.

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- Minimum and maximum order volumes are determined by market operator as ±100.000 Lot respectively.

Day-ahead market: Bid types

In this section, we present the bid types available in the Turkish electricity day-ahead market and describe their features.

There are three different types of bids: Single (hourly), block and flexible. Each bid consists of Quantity-Price Pairs (QPPs). Each QPP represents either a supply or demand of energy. By convention, supply and demand quantities are given in negative and positive values, respectively. Let q denote the quantity and p denote the price of a QPP. In any bid, the pair (p, q) shows that the participant is willing to pay at most p per MWh to buy q units of electricity or willing to receive at least p per MWh to sell q unit of electricity. The unit of quantity is “lot” and 1 lot equals 0.1 MWh.

Day-ahead market: Single hourly orders

***Hourly bids*:** In this bid type, bidders simply specify a list of QPPs to buy or sell electricity for a single hour of the next day.

Prices in an hourly bid must be stated as an increasing sequences. Since bidders are expected to buy electricity at lower prices and sell at higher prices, corresponding quantities in the hourly bid must be a non-increasing sequence. Table 1,Table 2, and Table 3 show three different hourly bid examples.

Example 1: Table 1 shows an hourly bid of a participant, who buys 100 lot whatever the Market Clearing Price (MCP) is at that period. This kind of bids are called *price-independent bids*.

Table 1: Hourly bid of participant 1

Price (₺/MWh)	0	2000
Quantity (lot)	100	100

According to rules stated by the Turkish Energy Market Regulatory Authority (EPDK) in [3], the quantity submitted in minimum or maximum price limit might be partially accepted in case

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the MCP hits the minimum or maximum price limit, respectively (curtailment case). To illustrate, the matching quantity for the hourly bid in Table 1 can be less than 100 lot only if the corresponding MCP is 2000 ₺/MWh.

Example 2: In the second example in Table 2, there are 6 price levels in the bid. The participant is willing to buy electricity as long as the unit price is lower than 250 ₺ and sell electricity when the unit price is higher.

Table 2: Hourly bid of participant 2

Price (₺/MWh)	0	120	200	250	300	2000
Quantity (lot)	100	100	50	0	-50	-100

Example 3: The bid shown in Table 3 has 5 price levels with different supply quantities.

Table 3: Hourly bid of participant 3

Price (₺/MWh)	0	150	200	300	2000
Quantity (lot)	0	-100	-160	-200	-200

Although an hourly bid consists of a discrete set of quantity price pairs, it is in fact a piecewise linear function generated by linearly interpolating those pairs. The matching quantity of an hourly bid is the quantity corresponding to market clearing price on the piecewise linear function associated with the bid. Figure 2 shows supply curve of participant 3. In this case, if MCP is 75₺/MWh, then the matching quantity is 50 lot for this participant.

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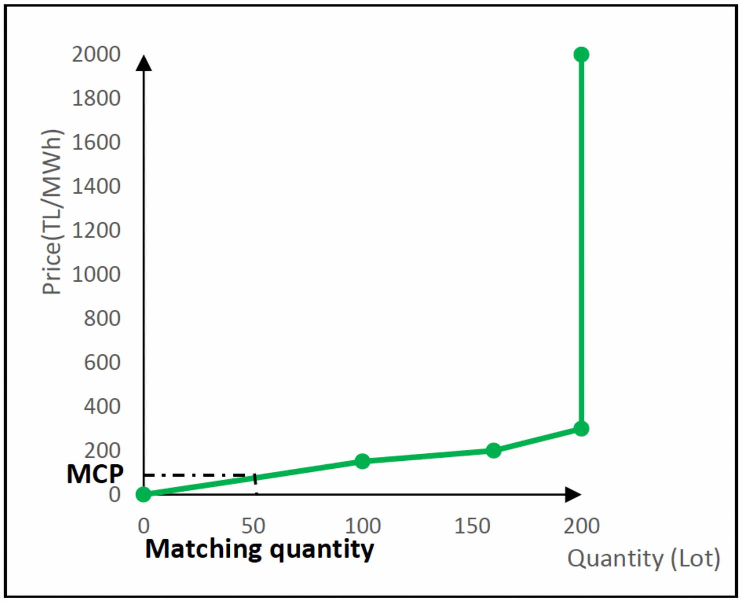

Figure 2: Piecewise linear supply curve of participant 3

The general principles of single hourly orders are listed below:

- Single hourly orders have maximum 64 steps which contain 32 purchase and 32 sales
- The prices regarding single hourly orders must be listed increasingly.
- In same price step there cannot be valid single hourly order for both purchase and sale.
- During formation of supply-demand curve, linear interpolation method is employed to interpolate values between two consecutive price/volume steps.

Day-ahead market: Block orders

Block bids: These bids are the second most commonly used type of bid in the Turkish electricity DAM. Block bids can be viewed as an indivisible set of consecutive hourly bids. However, there is only one QPP in a block bid which is constant for all the periods that the block bid spans. In this case, in addition to price and quantity, bidders also specify the number of consecutive set of hours during which they are willing to trade electricity in the next day. A block bid quantity is either totally accepted or totally rejected for all the periods it spans.

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Block bids can be linked to each other in order to depend on the acceptance of a block bid to a set of other block bids. When a block bid (child) is linked to another block bid (parent), child block bid cannot be accepted unless its parent is accepted. At most six block bids can be linked to each other in such a way that there are at most three generations and at most three children at each generation (For more information, see [4]). Linked block bids cannot form a loop, i.e., if block bid A is linked to B, then B cannot link to A. Given a supply block bid, the linked block bid cannot be a demand block bid, or vice versa. Figure 3 shows three possible linked block bid families allowed in Turkish electricity DAM.

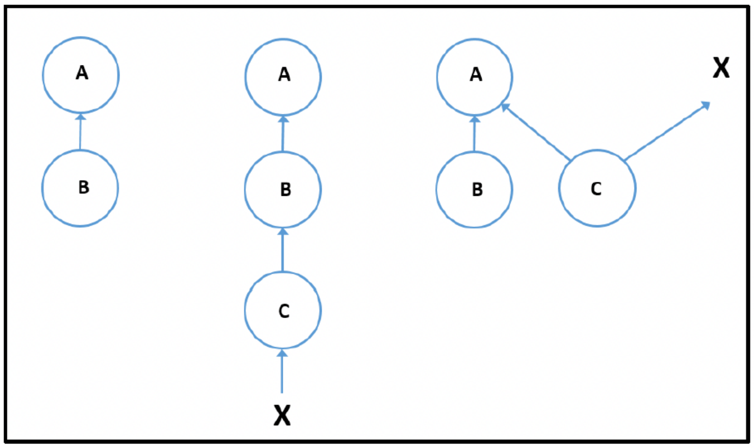

Figure 3: Set of linked block bid configurations in Turkish electricity DAM

Table 4 shows two block bids, where block bid B is the child bid of block bid A. If B is to be accepted, then A must be accepted as well.

Table 4: Linked block bid example

Block bid	Period	Price (₺)	Quantity (lot)	Link
A	1-5	150	-150	-
B	3-9	10	-100	A

The general principles of block orders are listed below:

➢ Block orders contain information regarding to price, volume and time period encompassed.

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- Block orders can encompass minimum of 3 hours and maximum of 24 hours.
- Block order hours are determined as consecutive and whole hours
- Block orders are processed as wholly-indivisible.
- Each block order can either be accepted or rejected for the time period that it encompasses.
- Participants can use existing block order name, or they can determine their own block order name.
- Daily maximum block order number that can be made is 50.
- Linked block orders can be formed by determining at most 6 block orders (purchase or sale) and given in same bidding zone. More than one linked block order can be submitted.

Day-ahead market: Flexible orders

Flexible bids: Flexible bids specify only a price and quantity information. A flexible bid can be accepted at any single hour of the day. Only supply flexible bids can be submitted in the current Turkish electricity DAM. A flexible bid is either fully accepted or completely rejected. A flexible bid is accepted if its price is less than or equal to the maximum MCP in the trading day. However, the period accepted does not have to coincide with the period of maximum MCP.

Day-ahead market: Bilateral contracts

- Bilateral contracts consist of 24-hourly data.
- Positive values are indicated in case of purchase and negative values are indicated in case of sale.
- The values given by parties are viewed reciprocally. As such, one is a purchase bid while the other one is a sale bid.
- The contract is accepted only if both parties submit same values.
- Bilateral contracts can be submitted at most 60 days earlier.

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2.2. INTRADAY ENERGY MARKET IN TURKEY

In addition to operational Day ahead, Ancillary Services and Balancing Markets, Intraday Market gives participants the opportunity to almost real-time trading and balance their portfolios in short term.

Intraday Market act as a bridge between the Day Ahead and the Balancing Markets, herewith this characteristic it will primarily contribute to the balancing and the sustainability of the Electricity Market.

As Intraday Market becomes functional, factors that result in imbalance such as utility breakdowns and fluctuations of power generation from renewables, can be eliminated; participants will be allowed to minimize or balance positive/negative imbalances that they might experience during the day.

Participants can utilize their capacities through Intraday Market trading following the closing time of the Day ahead Market and hereby an additional trading ground is established. Thus, liquidity of the market will be increased.

The information reported here is made available by EPIAS in [5].

Intraday market: General principles

- Any license holder legal entity that signs the Intraday Market Participation Agreement which comprises the participant obligations can join the Intraday Market.
- Intraday Market transactions are executed on an hourly basis every day.
- In case the new order matches with an existing offer on the order book, exchange price will be equal to the price of the existing offer.
- Settlement prices that are practiced through Intraday Market, are defined by considering all offers and trades executed in the context of Intraday Market, for each settlement period and matching.

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Intraday market: Phases

- Intraday market is a continuous market. Orders can be given until 60 minutes before the physical delivery and can be updated, cancelled, or rendered inactive.
- Intraday market trading is carried out on hourly basis. Intraday Market begins at 00:00 (midnight) and ends at 00:00 am (midnight) the following day. Intraday market orders that are made for the following day can only be given after 18:00 which is also the intraday market opening time.
- Before trading can take place, collateral requirements will be monitored twice every day at 11:30 and 17:30 before the Intraday Market opening time. Participants that are disqualified at 11:30 collateral check may fulfil their requirements until 17:00 and may continue trading once they pass the second collateral check at 17:30.
- Unlike the single session tender of the day-ahead market, intraday market orders will be interpreted instantaneously and will be matched with offers in the opposite direction.
- The status of the intraday market orders can be instantaneously monitored over the Intraday Market web application.

Intraday market: Orders

- Participants may place their orders in hourly and/or block orders for a particular time period at the Intraday Market. Orders comprise quantity and price information which may vary for different times.
  a. All prices have a precision of 2 (two) decimal points.
  b. All orders would be given in Turkish Lira (TL/MWh).
  c. Orders are placed in the form of TL/MWh.
  d. Orders are placed in Lot(s) as integer numbers. 1 Lot is equivalent to 0.1 MWh.
- Order status is classified as the following:
  a. **Active:** an order which has not been matched and is waiting on the order book.

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b. **Passive:** an order which has been de-activated and can be re-activated by the user. Orders in the Passive status cannot be traded.

c. **Cancelled:** an order which has been cancelled by the user or the market operator due to order type i.e., Immediate or Cancel (IoC), Fill or Kill (FoK), Fixed Time. Cancelled orders cannot be reactivated.

d. **Expired:** an order which has not been matched until the predefined expiration time. Expired orders will be deemed void and taken out of the list of other active orders.

e. **Matched:** an order which has been matched under given conditions.

f. **Partially Matched:** a single hourly order in which the original volume has been partially matched. Unmatched volume remains open until gate closure. When a Partially Matched order is updated, previously placed order would be cancelled and a new order would be placed. Depending on the changes made upon an order, the following conditions might emerge regarding the matter of priority:

   i. Decrease in priority:

      a. Order price changes (increase or decrease)

      b. Order volume increases

      c. Order status changed from Passive to Active

   ii. No change in priority:

      a. Order volume decreases

g. **Unmatched orders:** They can be updated, cancelled, or rendered inactive until 1 hour before the physical delivery. Participants can change volume, price, and status of the order.

- Participants will be shown the best hourly and block orders (ask & bid) pertaining to contracts on the order book. All orders related to a particular contract will be accessed from the `Order Depth` screen.
- There is no limit to the number of orders a participant can place for a trade period.

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- Minimum Ask/Bid price for the Intraday Market is set to be 0 (zero) TL.
- Orders are placed by authorized users of the participant companies on behalf of their organizations.
- Authorized users of the participant companies can place new orders, view orders that might previously be placed by different users from the same organization and update orders.
- As for the matching, latest updates on orders will be taken into consideration.

Intraday market: Hourly orders

- Hourly orders are considered to be traded as divisible orders i.e., they can be matched partially or as a whole.
- Users can select one of the following 3 order types for placing hourly orders:

  a. **Active order:** It is the default order type. Placed orders are active for matching until 60 minutes before the physical delivery. In the meantime:

     i. Unless the order matches, system would change the order status to Expired and it would be taken out of the list of other active orders.

     ii. If the order matches as a whole, system would change the order status to Matched and it would immediately be taken out of the list of other active orders.

     iii. If the order matches partially, system will change the order status to Matched and matched part would be taken out of the list of other active orders, remaining part would be kept for matching.

  b. **Immediate or Cancel (IoC):** This order type is not taken in queue for matching. If this order is placed AND is:

     i. Matched with awaiting order on the list, order status would change to Matched.

     ii. Partially matched, remaining part would be cancelled.

     iii. Not matched, order would be cancelled and would not be processed any further.

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c. **Expiration time:** If this type of order is selected, participant would need to provide active duration of order for matching. This duration can only be designated until 60 minutes before the physical delivery

d. **Fill or Kill (FoK):** This order type is not taken in queue for matching. When FoK is in place, order would not match partially. If the entire volume of the order does not match, it would be cancelled immediately and cannot be processed any further.

- Block order is in the form of PH14012018 and consists of the following:

  a. PH: Power Hour.

  b. 14: Year 2014.

  c. 01: Month 01 i.e., January.

  d. 20: Day 20.

  e. 18: Block starts time is 18:00.

Intraday market: Block orders

- Block orders are not divisible therefore they can only be traded as a whole.
- Each block order is either accepted for the total time period of contract or declined.
- Block orders will be placed for a minimum of 1 and a maximum of 24 hour(s).
- Block orders cannot include the hours of 2 different of days.
- Users can select one of the following 2 order types for placing block orders:
  - **Active order:** It is the default order type. Placed orders will wait to be matched until 60 minutes before the physical delivery. In the meantime:
    - Unless the order matches, system will change the order status to Expired and it will be taken out of the list of other active orders.
    - If the order matches, system will change the order status to Matched and it will immediately be taken out of the list of other active orders.

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- **Expiration time**: If this type of order is selected, participant will be asked to input the duration that the order will be available for matching. This duration can only be designated until 60 minutes before the physical delivery.

➢ Block order is in the form of PB14012019-04 and consists of the following:

- PB: Power Block
- 14: Year 2014
- 01: Month 01 i.e. January
- 20: Day 20
- 19: Block start time 7 pm
- 04: Duration of the order i.e. 4 hours

Intraday market: Matching general principles

➢ An order with the best available price has a priority.

➢ As for 2 orders with the same price, order with the earlier system record time, has the priority.

➢ Orders with the highest bidding price and the lowest asking price will be listed on the order book as top offers.

Intraday market: Matching Rules for Hourly Orders

When an order matches with an already existing offer, matching price will be equivalent to existing offer's price.

Hourly orders in 'buy' direction:

➢ <u>If the bid price is greater or equal to best available ask price</u>, quantities will be compared:

a. If bid quantity is equal to the best ask quantity, orders will match.

    - Transaction will be executed in line with the matching price which is equal to the existing ask price.

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- Order status will be updated as MATCHED, matched sell order will be taken out of the list of other active orders and the list of best available orders will be updated.

b. If bid quantity is greater than the best ask quantity, orders will match.

- Transaction will be executed in line with the matching price which is equal to the existing ask price.
- Buy order will be executed in the amount of ask quantity. Sell and buy order status will be updated as MATCHED and PARTIALLY MATCHED respectively and matched sell order will be taken out of the list of other active orders.
- As for the remaining bid quantity, system will look up a new possible matching; unless it can match, order will be recorded as the best available bid on the order book. Top orders list will be updated and arranged in order.

c. If bid quantity is less than the best ask quantity, orders will match.

- Transaction will be executed in line with the matching price which is equal to the existing ask price.
- Buy order will be executed in the amount of bid quantity. Buy and sell order status will be updated as MATCHED and PARTIALLY MATCHED respectively and partially matched sell order quantity will be updated and kept on the order book.

➢ <u>If bid price is less than the best ask price</u>, order will be put on the order book among best buy orders based on its price.

Hourly orders in 'sell' side:

➢ <u>If the ask price is less than or equal to the best available bid price</u> of buy order, quantities would be compared:

a. If ask quantity is equal to the best bid quantity, orders would match.

- Transaction would be executed in line with the matching price which is equal to the existing bid price.

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- Order status would be updated as MATCHED, matched buy order would be taken out of the list of other active orders and the list of best available orders would be updated.

b. If ask quantity is greater than the best bid quantity, orders would match.

- Transaction would be executed in line with the matching price which is equal to the existing bid price.
- Sell order would be executed in the amount of bid quantity. Buy and sell order status would be updated as MATCHED and PARTIALLY MATCHED respectively and matched buy order would be taken out of the list of other active orders.
- As for the remaining ask quantity, a new possible matching; would be searched and unless no match is found, the order would be recorded as the best available bid on the order book. Top orders list would be updated and arranged in order.

c. If bid quantity is less than the best ask quantity, orders would match.

- Transaction would be executed according to the matching price which is equal to the existing ask price.
- Sell order would be executed in the amount of ask quantity. Sell and buy order status will be updated as MATCHED and PARTIALLY MATCHED respectively and partially matched buy order quantity would be updated and kept on the order book.

➢ If ask price is greater than the best bid price, order would be put on the order book among best sell orders based on its price.

3. ENERGY COMMUNITY REGULATION LEGAL FRAMEWORK

3.1. INTRODUCTION

The European Union (EU) introduced new provisions on the energy market design and frameworks for new energy initiatives with the "Clean energy for all Europeans" package. Specifically, the recasts of the "directive of 11 December 2018 on the promotion of the use of energy from renewable sources" also known as Renewable Energy Directive (REDII), [6], and the

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recast of the "directive of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU" also known as Electricity Market Directive (EMD), [7], provide basic definitions and requirements for the activities of individual and collective self-consumption as well as for two types of energy communities. "Renewable Energy Communities" (defined in the REDII) and "citizen energy communities" (defined in the EMD), allow citizens to collectively organise their participation in the energy system.

These new concepts open the way for new types of energy initiatives aiming at the empowerment of smaller end-users in the energy market as well as an increased decentral renewable energy production, flexibility of the consumption, and prosumption (i.e., consumer that are also energy producer).

The main aim of this chapter is to explain the main concept and definition present on REDII and EMD related to self-consumption and energy communities and their transposition in Spain and Turkey, the two nation where are located the two leading islands involved in the VPP4ISLANDS project. This includes in particular concepts related to geographical, administrative, or system-related (e.g., electricity grid level) boundaries, specific grid tariffs for collective self-consumption and renewable energy communities, as well as questions of membership and governance in both types of energy communities.

3.2. DEFINITIONS AND CONCEPTS OF THE EU FRAMEWORK

The major concepts investigated here are four:

1. Renewables self-consumers.
2. Jointly acting renewables self-consumers also called Collective Self-Consumption (CSC).
3. Renewable Energy Community (REC).
4. Citizens Energy Community (CEC).

The definition of renewables self-consumer is reported in REDII in the Article 2, recital (14), meanwhile the definition of Jointly acting renewables self-consumer is reported in the same article, recital (15). The definitions are the followings:

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- ***'Renewables self-consumer'*** *means a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity.*
- **Jointly acting renewables self-consumers**: a group of at least two cooperating "renewables self-consumers […] who are located in the same building or multi-apartment block" or, where permitted by a member state, within other premises.

REDII Article 21 paragraph 2 details the activities that can be carried out by Renewable self-consumers and in paragraph CSCs.

Article 21 paragraph 2 is reproduced below:

Member States shall ensure that renewables self-consumers, individually or through aggregators, are entitled:

a) *to generate renewable energy, including for their own consumption, store and sell their excess production of renewable electricity, including through renewables power purchase agreements, electricity suppliers and peer-to-peer trading arrangements, without being subject:*
    i. *in relation to the electricity that they consume from or feed into the grid, to discriminatory or disproportionate procedures and charges, and to network charges that are not cost-reflective;*
    ii. *in relation to their self-generated electricity from renewable sources remaining within their premises, to discriminatory or disproportionate procedures, and to any charges or fees;*
b) *to install and operate electricity storage systems combined with installations generating renewable electricity for self-consumption without liability for any double charge, including network charges, for stored electricity remaining within their premises;*
c) *to maintain their rights and obligations as final consumers;*

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d) *to receive remuneration, including, where applicable, through support schemes, for the self-generated renewable electricity that they feed into the grid, which reflects the market value of that electricity and which may take into account its long-term value to the grid, the environment and society.*

Article 21 paragraph 4 is reproduced below:

Member States shall ensure that renewables self-consumers located in the same building, including multi-apartment blocks, are entitled to engage jointly in activities referred to in paragraph 2 and that they are permitted to arrange sharing of renewable energy that is produced on their site or sites between themselves, without prejudice to the network charges and other relevant charges, fees, levies and taxes applicable to each renewables self-consumer. Member States may differentiate between individual renewables self-consumers and jointly acting renewables self-consumers. Any such differentiation shall be proportionate and duly justified.

The Clean Energy Package (CEP) contains two definitions of energy communities: The concept of citizen energy communities (CEC), which is contained in the recast of the EMD, and renewable energy communities (REC), a concept which is contained in the REDII. The CEP frames energy communities as a non- commercial type of market actor. This is one of the major reasons why member states are required to ensure they have a level playing field to operate across the market without discrimination. This requirement is specifically embedded in both directives.

The following is a transcription of the definition of RECs contained in REDII, Article 2 recitals (16):

'renewable energy community' means a legal entity:

a) *which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity;*

b) *the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;*

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c) *the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits;*

Instead, the definition of CEC is contained in EMD Article 2 recital (11) and is set forth below:

'citizen energy community' means a legal entity that:

a) *is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;*

b) *has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and*

c) *may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders;*

A study of the differences and similarities between and CEC has been tasked within the European project COMPILE by Frieden et altera, [8]. The major differences and equalities identified in the study are shown in Table 5.

Table 5: Difference and commonalities between REC and CEC.

Major commonalities between REC and CEC:

- Require a legal entity as a community umbrella.
- Must be voluntary and open.
- Should be primarily value driven rather than focusing on financial profits.
- Require a specific governance (e.g., "effective control" by certain participants)

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Major characteristics differentiating REC and CEC are:

For citizen energy communities:

- No geographic limitation (i.e., no proximity of the “effective control” to the energy project required). Also open to cross-border participation (optionally to be allowed by member states).
- Large and medium size enterprises excluded from effective control. o Electricity only (according to the scope of the EMD).
- Technology neutral (not necessarily renewable energy).
- Major purpose of enabling frameworks: create a level playing field for the CECs as a new market actor.

For renewable energy communities:

- Proximity requirement of effective control (to be defined in national law).
- Limited membership (shareholders or members do not include large companies).
- Open to all sources of renewable energy (e.g., also heat), but renewable energy only.
- Major purpose of enabling frameworks: to promote the development and growth of RECs as a way to expand the share of renewable energy at national level.

Also, in [8], the concepts of peer-to-peer energy trading and energy shared in REDII and EMD are investigated.

A first difference between CSC, REC and CEC is about of **peer-to-peer energy trading arrangements**, in fact for renewables self-consumers, next to the sale through renewables power purchase agreements, peer-to-peer trading arrangements are stated, while Article 22 on RECs does not specifically refer to peer-to-peer trading. In COMPILE project, however, they assume that all activities referred to for renewables self-consumers equally apply to RECs and CECs as renewables self-consumption may well be carried out in the framework of an energy community. This approach is confirmed by the transposition of the REDII directive in the laws of member states: for example, in Italy CSC and REC are transposed in the same national law and have the possibility to perform the same activities (i.e., maximization of self-consumed energy) with the

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same incentive mechanisms. The definition of peer-to-peer trading in the REDII Directive, Article 2 recital (18) is given in Table 6.

Table 6: Definitions of peer-to-peer trading in REDII

'peer-to-peer trading' *of renewable energy means the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators*.

As can be seen from the definition of peer-to-peer trading admits that exchanges can only take place directly between two market participants or indirectly between two prosumers only if a third party is involved who is qualified to participate in the electricity market as an aggregator. The aggregator acts as an intermediator between final consumer or prosumer and all electricity market also in peer-to-peer trading as it does for demand response (It can be concluded by EMD Article 1 recital (39) and REDII Article 2 recital (18)).

A feature that appears in all three concepts is **"energy sharing"**, differing fundamentally from traditional supply. Even though this concept is not specifically defined, Article 16 of the recast of the EMD on CECs mentions, for instance, the need "to share electricity produced using generation assets within the citizen energy community among their members or shareholders based on market principles, for example by offsetting the energy component of members or shareholders using the generation available within the community, even over the public network, provided that both metering points belong to the community". For RECs, the REDII states that "Renewable energy communities should be able to share between themselves energy that is produced by their community-owned installations". Similarly, the REDII states for CSC that "Member States shall ensure that renewables self-consumers located in the same building, including multi-apartment blocks […] are permitted to arrange sharing of renewable energy that is produced on their site or sites between themselves".

Finally, in [8] is reported a table containing an overview of the major features, activity and actors on renewable self-consumption and energy communities, this is reported here in Figure 4.

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	REDII		EMD
Activity	RSC	REC	CEC
Production (REDII: renewables) / Generation (EMD: electricity)	✓	✓	✓
Consumption	✓	✓	✓
Storage	✓	✓	✓
Sale (RSC: excess electricity), e.g. via:	✓	✓	(✓)
- Renewables PPAs	✓	✓	(✓)
- Electricity suppliers	✓	✓	(✓)
- Peer-to-peer trading	✓	(✓)	(✓)
Sharing	✓	✓	✓
Supply		✓+	✓
Aggregation (RSC: "through aggregators")	(✓)	✓+	✓
Energy Efficiency Services			✓
EV charging services			✓
Other energy services (RED: "commercial")		✓+	✓
Shareholders or members			
Natural persons	n.a.	✓	✓
Small and Medium Enterprises (SMEs)	n.a.	✓	✓
Large enterprises	n.a.	X	✓
Local authorities incl. municipalities	n.a.	✓	✓
Effective control (RED: proximity requirement, EMD: membership in general is restricted, energy sector no primary area of economic activity)			
Natural persons	n.a.	✓	✓
Micro enterprises	n.a.	✓	✓
Small enterprises	n.a.	✓	✓
Medium enterprises	n.a.	✓	X §
Large enterprises	n.a.	X	X
Local authorities incl. municipalities	n.a.	✓	✓

+ Reference to "*the provisions relevant for such activities*"

(✓) Not explicitly stated but assumed to apply

§ However, the CEC as such can be organized as an SME (EMD, recital 44)

Figure 4: Activities and actors foreseen for renewable self-consumptions and energy communities

3.3. Self-Consumption and Energy communities in Spain

In Spain no detailed legislation on energy communities exists. The decree law 23/2020 of 23 June 2020 first introduces energy communities and aggregators, only defining their general purpose and nature (Government of Spain 2020). However, Spain has an advanced framework on self-consumption in place, allowing for the use of the public grid, which goes beyond the requirements of Article 21, REDII on CSC. This approach is explained in the following.

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The Spanish government, on April 5th, 2019, approved the ***Royal Decree 244/19*** that regulates the administrative, technical, and economic conditions of self-consumption in Spain. This Decree completes the regulatory framework on this issue, driven by Royal Decree-Law 15/2018, which repealed the so-called sun tax, and provides increased certainty and security to users. Among other measures, the Royal Decree enables individual and collective self-consumption by groups of apartment owners or in industrial estates, it reduces administrative procedures, especially in the case of small self-consumers, and establishes a simplified mechanism for compensation of energy fed into the public grid. Self-consumption previously was allowed with generation facilities located in the same dwelling only. According to the current rules, power surpluses may be shared with nearby consumers also in other buildings or fed into the grid.

Collective self-consumption using the public grid is physically and geographically limited by the following conditions:

- The participating entities must be located within the low voltage distribution grid derived from the same MV/LV substation.
- The maximum distance between the production and consumption meters is 500m.
- Participants are located in the same cadastral area.

The generation facilities are connected to the internal network of associated consumers (direct lines) or to the low voltage network. The right for feeding in electricity and receiving compensation for surpluses underlies several conditions. A general distinction is made between self-consumption with and without surpluses. The law distinguishes between:

- Modalities for self-consumption without surpluses. In these modalities, an antifouling mechanism must be installed to prevent the injection of surplus energy into the distribution network.
- Modalities of supply with self-consumption and surpluses. In these modalities, production facilities that are close to and associated with consumption facilities may, in addition to supplying energy for self-consumption, inject excess energy into the distribution networks.

For joining the surplus compensation system, the combination with other types of compensation schemes is excluded. Collective self-consumption schemes using the public grid are generally

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excluded from the compensation scheme. Non self-consumed energy would offset part of the energy that had to be purchased from the grid, at the freely agreed price with the chosen supplier or at the hourly average price of the electricity market. In any form of self-consumption, the consumer and the owner of the generating facility may be different natural or legal persons. Storage elements may be installed in all types of self-consumption.

Production facilities not exceeding 100 kW power associated with surpluses will be exempt from the obligation to register as an electricity supplier and will be subject only to technical regulations. Regulations may be developed for production facilities below 100 KW for a simplified compensation mechanism between deficits of self-consumers and surpluses from its associated production facilities. For installations above 100 kW, surplus energy is sold on the energy market. Regarding grid access, production facilities of up to 15 kW that are located on urbanized land and meeting the urban legislation requirements, will be exempt from the need for access and connection permits.

Given the expanded CSC scheme, the current Spanish framework may be interpreted as a hybrid model between collective self-consumption and renewable energy communities. Two major differences however remain; an energy community represents an organizational format that requires a legal entity underlying several governance-related rules and its potential activities go beyond self-consumption, these aspect at the moment are not contemplated in the Spanish energy framework.

One supportive factor for implementing local RES projects in Spain is an existing framework for Energy Consumption Cooperatives (Cooperativas de Consumo). These cooperatives are entities in charge of managing different activities within the local energy environment and can implement integrated RES projects. The cooperative framework is very suitable for energy communities as they work in different fields from distributed energy resources (DER) to citizen/end-user consumption with a legislation that enables and eases their operation. This cooperative framework may therefore set the ground for the organization of energy communities, shared ownership of assets and collective self-consumption, [8].

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3.4. SELF-CONSUMPTION AND ENERGY COMMUNITIES IN TURKEY

The establishment of the RES in Turkey was started with the "Regulation on Unlicensed Electricity Production in the Electricity Market" published in the Official Gazette dated 2013 and numbered 28783, and “Amending the Regulation on Unlicensed Electricity Production in the Electricity Market” published in the Official Gazette dated 2016 and numbered 29865.

This law does not provide for the form of renewable energy community but only that of energy cooperative (i.e. unlicensed electricity productor) which is described below.

Individuals and legal entities that will make unlicensed energy production are allowed to produce up to 60 times their consumption, cooperatives only allow production at the rate of the contractual power of the partners. Also, in unlicensed production of dedicated facilities, cooperatives with up to 100 members have been given the right to establish a facility of 1 MW, cooperatives with 101 to 500 members 2 MW, 501-1000 members 3 MW, and more than 1000 members have been given the right to establish a maximum facility of 5 MW.

Cooperatives are exempt from establishing companies and obtaining licenses for this purpose. Cooperatives in Turkey are commercial establishments and have a profit motive.

In order to realize a production, the partners have to start the business with a certain capital/fund. Each partner must pay a partnership fund. The equity fund is collected together with the partners. The second method of fundraising is that the cooperative members put in a certain amount of equity and use a bank or union loan for the remaining part.

Another fundraising method is to establish with the support of local governments. Local governments can become partners of these cooperatives. Of course, subscriber types must be the same as partners.

There are also institutions such as the agricultural development support institution that provides different supports to cooperatives. And cooperatives that have benefited from European Union funds do not need to wait in line for transformer connection.

The establishment of cooperatives is affiliated with the Ministry of Customs and Trade. The administrative body carries out the management of the cooperative. Renewable energy cooperatives primarily need to produce without fossil resources such as solar wind geothermal,

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biomass, waves, currents, and tides. When this article is stated in the main contract, it is not necessary to obtain a license. Cooperative members are required to combine consumption. the same port and a single meter requirement are not sought. Production facilities must be located in the distribution region where their subscriptions are located.

The first energy community in Turkey was established in 2014 and their number reached 22 as of 2018.

The procedures and principles applicable to real and legal persons, who may produce unlicensed electricity was updated in 2019. The primary purpose of the updates introduced with the new Regulation on Unlicensed Electricity Production in Electricity Market (the "**Regulation**") and the Presidential Decree Number 1044 dated 10 May 2019 (the "**Decree**"), is to bring in small-sized plants into the economy by allowing them to generate energy for mainly self-consumption purposes, without the need to obtain a license or establish a company. The new regulation is available at https://www.resmigazete.gov.tr/eskiler/2019/05/20190512-1.htm.

The essential changes introduced by the Regulation and the Decree are as follows:

- The upper capacity limit of 1 MW to be eligible to benefit from unlicensed generation has been increased to 5 MW, for facilities which become eligible to receive a calling letter after the date of 10 May 2019.
- Solar energy production facilities having a capacity below 5 MW may now only be established as a roof application.
- It is mandatory to establish the generation facilities and consumption facilities for unlicensed generation in the same distribution region. Accordingly, so long as the generation and consumption facilities are in the same distribution region, they do not need to be established in the same location.
- The installed capacity of the generation facilities cannot exceed the power limit of the relevant consumption facility set out under the connection agreement. If there is no electricity consumption in the consumption facility linked with the generation facility, no payment within the scope of the Renewable Energy Resources Support Mechanism (YEKDEM) will be made for the relevant month.

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- The hourly electricity production amount read from the meter data will be calculated as per the accounting period and then notified to the related supply company. The related supply company will calculate the payment to be made for the surplus electricity purchased and inform the market operator thereof. The companies will pay producers the calculated amount regarding the surplus from the payment made by market operators. If the producers consumed excessive electricity, then this amount will be paid to suppliers.

4. STRATEGIC OBJECTIVES AND KPIS

The strategic objectives of the project are described in the Table 7. To each strategic objective are associated KPIs by means of which it will be evaluated whether the objective has been achieved or not.

The SO from one to seven will be associated to scenarios for evaluating the results. The SO8 will be used at the end of the project, in WP8, to evaluate the effects of the project in local business.

Table 7: Strategic objective and KPI

Strategic objectives	KPI
SO1: Implement Living labs to promote renewable energy communities in islands: VPP4Islands will engage citizens, potential stakeholders, and influencers to ensure the tailored co-design of innovative market flexibility tools and services.	-Number of engaged stakeholders at least 20 -high consumer trust - At least 50 feedbacks from potential actors
SO2: Increase the exploitation and the penetration of renewable energy-based system on the Island: VPP4Islands will provide a tool to assess deeply the island capacity in terms of RES. The tool will allow to quantify the energy that can be produced from the available RES along with its implementation costs and ROI. The tool will also give	-CO2 reduction index (at least 2 Ton Co2 reduction during the experimentation) -Reduction around 40 % on Fossil fuel consumption in leading islands

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an output result including the environmental performance and monetary saving (€/kWh).	
SO3: Embracing new technologies to promote a large penetration of renewable energy sources: Mitigating the fluctuations caused by the RES and proposing advanced forecasting approaches to reduce uncertainties that will save the cost of energy and power balance, increase the quality of the supplied electricity and foster stakeholders relying on this green energy. Therefore, VPP4Islands will facilitate the integration of renewable sources by becoming more profitable and an indispensable player in the energy market.	-Forecasting accuracy (>80%) -Market price of provided energy and services
SO4: Smart combination of multiple storage strategies : VPP4Islands will promote the integration and combination of diverse storage sources (e.g., flywheel, batteries, micro CHP, hydrogen fuel cell, small hydro, etc ...) instead of one conventional ESS to act as storage with a high capacity and performance.	-Energy Return on Investment (EROI) -Storage Efficiency (> 90%)
SO5: Digitalization and ensuring the multi-dimensional flexibility and increasing the performance of the portfolio of RES: VPP4Islands will define a flexibility potential for the VPP context, which considers a set of technical flexibility characteristics, such as generation level, operating range, magnitudes of changes of its power exchanges with the grid and ramp rates to estimate the technical ability of the system to provide flexibility. A flexibility index will be calculated in a similar way as in the MAGNITUDE EU-funded project by CU and REGE; short-term and long-term. A specific module (API) will be integrated to digitize this calculation. A holistic	-Short-term flexibility index (around 15 min) -Long-term flexibility index (intra-day)

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approach to evaluate accurately the level of flexibility will be defined in four layers: load demand, energy offer, forecasting and ancillary services. The extent of flexibility will be evaluated inside the VPP, as well as multifunctional capacity.	
SO6: Enhancing the transparency and the cybersecurity of data related to the green energy: This objective aims to secure the data exchange and share information between producers, consumers, DSO/TSO, and other stakeholders in an effective and transparent way. A hybrid cybersecurity approach (AAI + DLT) will be deployed to increase data sharing and transparency. It is essential to detect, mitigate and recover from cyberattacks.	-Availability of service (99%) -Transparency
SO7: Development of an open VPP4Islands ecosystem: This project aims to facilitate the creation of flexible VPPs, unlock access to highly-valuable information related to the energy trading, empower the active participation of consumers, and facilitate the market uptake of small prosumers by reducing intermediaries and share know-how between created VPP4I-Nodes to optimize their energy management and revenues. It will be considered as VPP4Islands factory.	-Computational complexity -Number of reduced intermediaries (>2)
SO8: Development of tailored business models to support the sustainability and commercialisation VPP4Islands outputs: Market segments, target prosumers, tailored business model and exploitation strategy will be defined by automating the entire energy value chain. Market development and exploitation of VPP4Islands services will be addressed by deploying agile approaches. The project will	-Number of engaged professional end-users (>8) -Number of engaged prosumers\consumers (>100) -Number of created startups (>2)

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combine between proven strategies and novel methods to deliver optimized ancillary services while supporting the durability of the VPP. A replication study will be carried out through concrete business cases to maximise the values of the proven technologies and services.	

In addition to the strategic objectives of the project, it is useful to mention that within the VPP4IPlatform there is a module called "**Energy and CO2 savings**" which has the function to evaluate the energy performance of the demonstration sites before and after the implementation of the project. The description of the module and the KPIs it uses to evaluate energy performance in demonstration pilots is described in the Table 8.

Table 8: Energy and CO2 module description KPIs

Energy and CO2 savings	KPI
A basic software architecture will be designed and integrated, establishing the structure, identifying, and defining the process variables and establishing the operation and interaction between the different modules that will compose the software (prediction of optimum consumption curve, correction of deviations, simulation module, download of reports, etc.); as well as the main relationships between each of the modules. Identified flexibility potentials, energy demand prediction as well as the weather forecast module and market price incentives are fed into the optimisation algorithm to generate an optimised energy demand that respects the boundary conditions of the island system, suggesting new operation control strategies in order to reduce the energy costs and reduce GHG emissions. The standard method to calculate change in carbon footprint will be defined and tested with various scenarios.	KPI 1 : kWh / unit of production. KPI 2 : € / kWh, current and accumulated cost. KPI 3 : kg current and accumulated CO2. KPI 4 : percentage of self-consumption.

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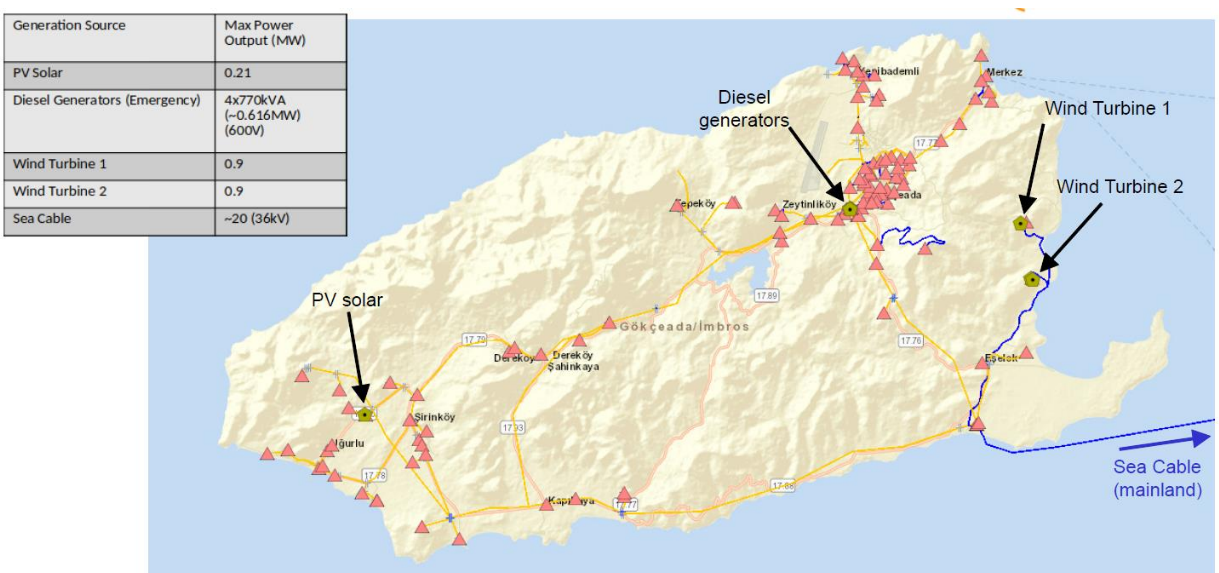
5. GÖKÇEADA REAL-LIFE USE CASE

5.1. DESCRIPTION OF THE USE CASE

Gökçeada is the largest island of Turkey and the seat of Gökçeada District of Çanakkale Province. It is located in the north-eastern of Aegean Sea, at the entrance of Saros Bay, and is the westernmost point of Turkey. Gökçeada has an area of 279 km^2 and has some wooded areas. According to the 2020 census, the island-district of Gökçeada has a population of 10,106. The main industries of Imbros are fishing and tourism.

A geographic map of Gökçeada is shown in the Figure 5; the map shows the MV/LV secondary substations of the local distribution grid (red triangle), the electrical connection to the mainland made by a submarine cable (line in blue), and the power generation plant (green pentagon). In the island are present three big-size renewable plant: two wind turbines of size 0.9 MW own by a company that has its core business in the textile sector and has decided to invest in the renewable sector, and a photovoltaic plant of size 0.21 MWp. In addition, there are five diesel generators that are operated by the DSO, UEDAS, to provide power to the island when there are in faults in the undersea cable.



Generation Source	Max Power Output (MW)
PV Solar	0.21
Diesel Generators (Emergency)	4x770kVA (~0.616MW) (600V)
Wind Turbine 1	0.9
Wind Turbine 2	0.9
Sea Cable	~20 (36kV)

Figure 5: Geographical map of Gökçeada

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The single-line diagram of the Gökçeada medium voltage network is shown in the Figure 6. The network has a tree structure and consists of 186 nodes and 188 lines. The two wind power plants are connected to node #2 and node #3 (both in green) and are located near the node #1 (in blue) where is located the primary substation 30 kV/15 kV (TUZLA primary substation). At node #1 is connected the sea cable, it connects the island to the mainland. the 0.21 MWh photovoltaic system is connected at node #150 (in yellow). While the five emergency diesel generators are connected to node #132 (in red).

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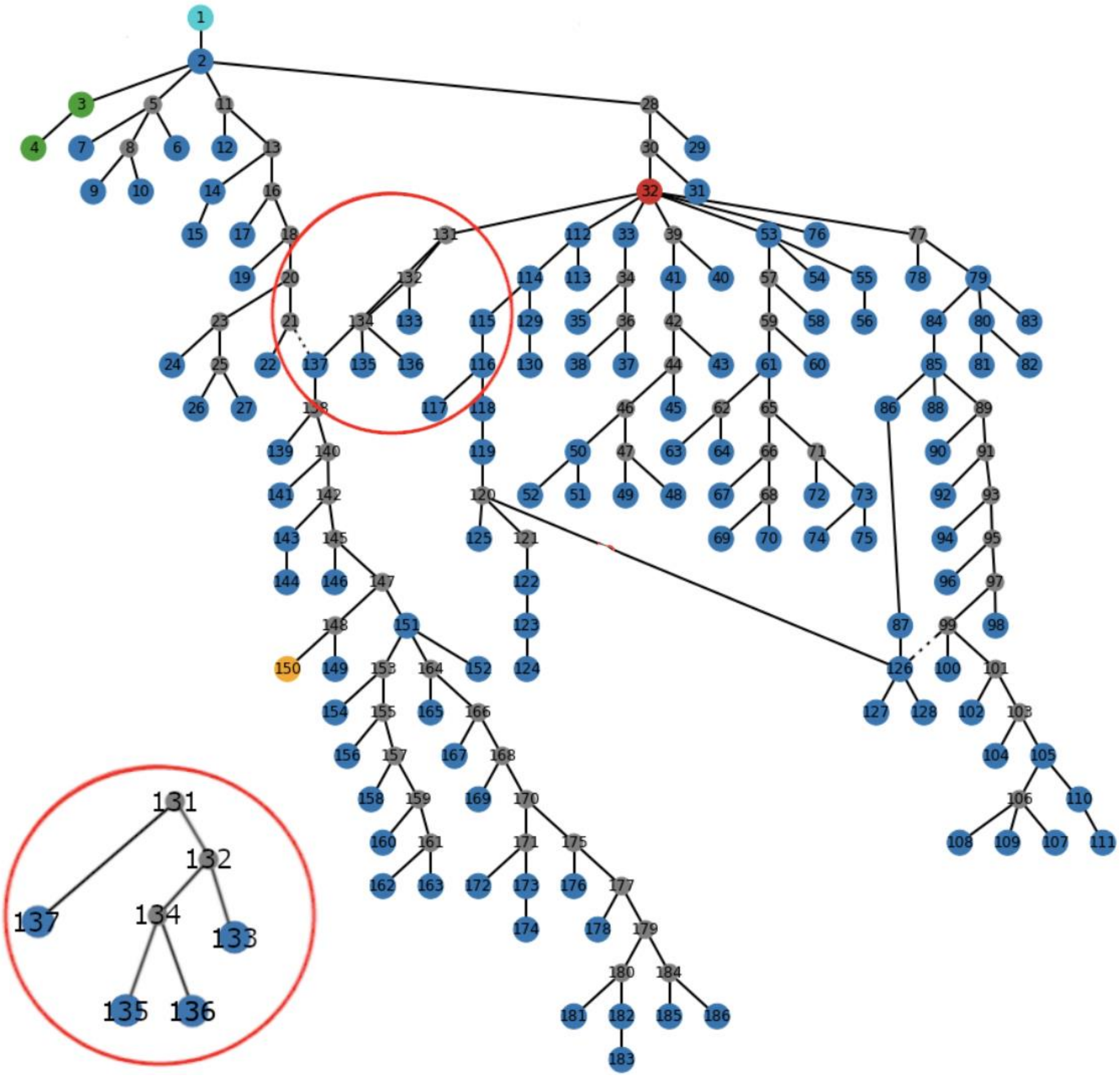

Figure 6: Single line diagram of the Gökçeada distribution network

Objectives to be achieved in the use case

Gökçeada will be used as real life use case (Case study 1) to validate the technological solutions develop within the WP3, WP4, WP5 and WP6. The validation of the solution will be carried out by the WP7, it will start in March 2023 (M30) and end in September 2023 (M36).

There are four main actions related to case study 1, these are listed below:

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5. Build an energy community by integrating 100 smart meters, 10 VPP4Box and 1 VPP4INode.
6. Install a new Energy Storage System.
7. Deploy the VESS API.
8. Use the VPP4IPlatform to design the Technical Virtual Power Plant (TVPP) in the DT of the power system of the island.

These four actions are described in the detail in the three scenario design for the use case 1, in particular:

4. In the scenario 1 will be design and validate the TVPP of the power system of the island. The main role of the TVPP will be to simulate the activation of the flexibility by disturbed energy resources and detect if the activation of the flexibility make arise technical problems in the distribution grid such as out-of-range voltages or over-currents.
5. In the scenario 2 will be built a renewable energy community and installed a battery energy storage system and a system composed by a resistance and a power converter able to simulate the behaviour of an HVAC system of a building. The flexibility provided by these two elements will be manage by the VESS API. In this scenario will be deploy a VPP4ISLANDS solution customized for renewable energy community, the battery energy storage system will be used to maximize the self-consumption within the renewable energy community.
6. In the scenario 3 a certified energy trader, Limak Trade Energy will use the VPP4ISLANDS solution to improve the performance in the spot market of a portfolio composed of distributed energy resources and the battery energy storage system installed within the energy community. In this scenario will be deploy a VPP4ISLANDS solution customized for energy traders, the battery energy storage system will be used to maximize the profit of the portfolio of generators in the energy spot market.

Scenario 2 will make possible to assess the flexibility (storage) and the demand response (HVAC system) capability to maximize the self-consumption within a renewable energy community.

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Scenario 3 will make possible to assess the flexibility (storage) capability to improve the performance of a portfolio constituted largely of plants from renewable sources in the energy spot market.

Scenario 1 will make possible to evaluate if the activation of flexibility and demand response in scenario 3 meet the technical constrains of the distribution grid or not.

Table 9: VPP4ISLANDS solution functionalities and services implemented in Gokceada

# Scenario	Functionalities	Services
1	Digital Twin of the power system of the island and simulation environment.	Real time monitoring and simulation environment.
2	Energy Community management	Self-consumption optimization. Scheduling optimization and control of energy storage system.
3	Portfolio optimization for an energy trader.	Day-ahead and intraday optimization. Scheduling optimization and control of flexible assets and energy storage system.

Actors involved in the use case

Table 10 shows the list of the actors involved in the demonstration pilots. The first column shows the univocal identification code of the actor, this is composed of the initials Ac (i.e., Actor) followed by a number (i.e., the actor's identification number). The second column shows the actor's full name. The third column indicates the role that the actor has (note that an actor can have more than one role, for example it can be both the Distribution System Operator (DSO) and the aggregator of a VPP). The fourth column indicates whether the actor is a member of the VPP4Islands project consortium. Finally, the fifth column lists all the physical assets owned by the actor.

Table 10: Actors in Gökçeada

Actors in Gökçeada

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Actor code	Actor name	Roles	Consortium member	Assets owned
Ac.1	ULUDAG ELEKTRIK DAGITIM AS (UEDAS)	DSO	Yes	As.1.1 As.1.2 As.1.3 As.1.4 As.1.5 As.1.6
Ac.2	TEİAŞ	TSO	No	
Ac.3	Wind Turbines owner	Producer	No	As.3.1 As.3.2
Ac.4	Photovoltaic (PV) plant owner	Producer	No	As.4.1
Ac.5	Private and Commercial Users	Passive Customer	No	As.5.1
Ac.6	Limak Energy Group	Energy Trader	No	As.6.1

Assets involved in the use case

Table 11 indicates the list of physical assets involved in the VPP4Island project. The first column shows the unique identification code of the asset, consisting of the asset abbreviation (i.e., As), a middle number that identifies the owner of the asset and a final number that identifies the physical asset. The second column contains the description of the physical asset.

Table 11: Assets in Gökçeada

Physical assets in Gökçeada	
Asset code	**Physical assets Description**
As.1.1	Gökçeada electrical distribution network
As.1.2	Diesel generators 4x770kVA (~616kW)
As.1.3	Lithium Battery Energy Storage System (50kW-100kWh)

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As.1.4	Sea cable (120mm2 CS, ~20MW, 50Hz AC, 36kV)
As.1.5	Emulation of the HVAC system or flexible load (~5 kW)
As.1.6	Data concentrator and Advanced Metering Infrastructure (AMI) Each secondary substation in Gökçeada is equipped with a data concentrator that can record and send all the data measured in the secondary substations (i.e., currents and voltage) and in the smart meters downstream of the secondary substations, if any.
As.3.1	Wind Turbines 1 (900kW)
As.3.2	Wind Turbines 2 (900kW)
As.4.1	PV plant (210kW)
As.5.1	94 Smart Meters already installed +100 smart meters that will be installed with the resources made available by the VPP4islands project. The smart meters will cover all customers connected downstream of three secondary substations on the island of Gökçeada.
As.6.1	Energy trade platform that allows to access to Turkish electricity market and a legal qualification to participate in the Turkish electricity market.

Table 12 shows in which asset the VPP4IBoxes will be installed in Gokceada and who will be the owner.

Table 12: VPP4IBox in Gökçeada

VPP4IBox in Gökçeada		
Code	**Owner**	**Assets monitored**
Box.1	UEDAS	As.1.3 - Lithium Battery Energy Storage System (50Kw-100kWh)
Box.2	UEDAS, the VPP4IBox will be installed in DSO side of the metering infrastructure associated to the plant.	Wind Turbines 1 (900kW)
Box.3	UEDAS, the VPP4IBox will be installed in DSO side of the metering infrastructure	Wind Turbines 2 (900kW)

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	associated to the plant.	
Box.4	UEDAS, the VPP4IBox will be installed in DSO side of the metering infrastructure associated to the plant.	PV plant (210kW)
Box.5	UEDAS	Diesel generator #1 770kVA (~616kW)
Box.6	UEDAS	Diesel generator #2 770kVA (~616kW)
Box.7	UEDAS	Diesel generator #3 770kVA (~616kW)
Box.8	UEDAS	Diesel generator #4 770kVA (~616kW)
Box.9	UEDAS	System able to emulate a heat pump (~5kW)
Box.10	Not yet defined	Not yet defined

5.2. Scenario 1: Digital Twin of Gokceada - modelling and validation

# Scenario	**Scenario 1**
Title	**Modelling and validation of the Digital Twin of Gokceada**
Short Description	The objective of this scenario is to build and validate the digital twin of the power system of Gökçeada and of the distributed energy sources and power plants connected along the power system such as photovoltaic solar panel, wind turbines, energy storage systems and flexible loads. The main aspects related to digital twin, as the data base that contain the input necessary to feed the digital twin, are here described.
Service provided	The digital twin will provide a validation tool able to analyse the effects of different control schemes/interventions/scenarios on the power grid stability. In particular will be possible analyse the impact of energy storage systems and flexible loads on the power grid.
Phases	The scenario is composed by the following phases: Phase 1: Data collection and data base construction. Phase 2: System Modelling in the Digital Twin. Phase 3: System models and Digital Twin validation

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Actors and roles	UEDAS (DSO) Digital Twin developers Owners of the distributed energy resources
Strategic objectives	**SO7: Development of an open VPP4Islands ecosystem**.
Evaluation of VPP4Islands solutions based on KPI	**SO7 KPI - Computational complexity** The Digital Twin must be able to calculate if the activation of flexibility procures any technical problem to the grid within an interval of time of 15 min. **SO7 KPI - Number of reduced intermediaries (>2)** The aggregator that operates the Commercial Virtual Power Plants (the VPP4INode) will be able to communicate his activation of flexibility to the DSO without any intermediaries.
Possible future changes	No potential future changes have been identified at this time.

Phase 1: Data collection and data base construction

I. Collecting static data of the physical assts:

   a. Collecting static input data to model the grid such as number of nodes, parameters to model transformers at nodes, lines interconnections, impedance and capacity of lines, maximal current and nominal voltage of lines.

   b. Collecting static input data to model the diesel generators such as Node of connection, Nominal power, Inertia, Primary control time scale, Inverse governor speed regulator, secondary control parameter, time scale for forcing power plant at a reference level.

   c. Collecting static input data to model the Energy Storage System that will be installed in Gokceada such as nominal power, nominal capacity, primary control time scale and time scale for forcing the storage at a reference level.

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d. The static data will be stored at **VPP4ICloud** level in the **Shared Knowledge Base (KB)**.

II. Collect historical data from renewable generation plant on Gokceada:

a. Request authorization from private owner of the two wind turbines and the photovoltaic plant to collect data on their renewable power generators.

b. Collect data from renewable generators such as power injection at the secondary substation level with a time step of 15 min. Data collection will be through **VPP4IBox**

c. The data on renewables generation will be sent from **VPP4IBox** to **VPP4INode** that will be place in Gokceada. The data will be stored within the **Node-level data base** for about three months.

d. The data will be sent from **VPP4INode** to **VPP4ICloud** on a daily basis. At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

III. Collect historical data from the Turkish electricity market:

a. The data on price of Turkish DAM and IM will be collected though the EXIST TRANSPARENCY PLATFORM (https://seffaflik.epias.com.tr/transparency/) directly via API.

b. The data on DAM and IM clear energy price will be sent to **VPP4INode** that will be place in the island. The data will be stored within the **Node-level data base** for about three months.

c. The data will be sent from **VPP4INode** to **VPP4ICloud.** At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

IV. Collect historical data from local climate:

a. Wind velocity, wind vectors and wind shear.

b. Solar irradiance.

c. Temperature.

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d. Air pressure.

e. Whenever possible cloud cover on small time scale.

f. The data on local climate will be sent to **VPP4INode** that will be place in the island. The data will be stored within the **Node-level data base** for about three months.

g. The data will be sent from **VPP4INode** to **VPP4ICloud.** At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

V. Collect data from DSO Advanced Measuring Infrastructure:

a. Request authorization from the DSO to collect data recorded in the field from measuring instruments installed on the power system.

b. Collect data on active and reactive power flowing in each secondary substation, and in the sea cable from the measuring infrastructure of the power system (dynamic input of power system model).

c. Collect data on load in each line, voltage at each bus and frequency from the measuring infrastructure of the power system (these data can be obtained as a dynamic output of power system model, in this context them will be used to validate the models implemented in the digital twin).

d. The data will be sent from the advanced measuring infrastructure of the DSO to **VPP4ICloud** and stored within the **Shared Knowledge Base** for years.

VI. Collect data from smart meters:

a. Request authorization from the customers to collect data recorded from smart meters.

b. The data coming from the smart meters are collected by the local DSO in a data concentrator. The **VPP4INode** will be able to receive data from the data concentrators. The data will be stored within the **Node-level data base** for about three months.

c. The data will be sent from **VPP4INode** to **VPP4ICloud**. At **VPP4ICloud** level the data will be stored within the **Shared Knowledge Base** for years.

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Phase 2: System Modelling in the Digital Twin

I. In the submodule of the **Digital Twin** called **System Modelling** will be implemented digital models of the followings physical assets:

   a. Gökçeada electrical distribution network (As.1.1), The digital model of the distribution network will describe the network with a depth of description that will reach the secondary substations (Medium voltage level).

   b. Diesel generators (As.1.2)

   c. PV Plant (As.4.1)

   d. Wind turbines (As.5.1, As.5.2)

   e. Energy storage system (As.1.3)

   f. Emulation of flexible load (As.1.5). The flexible load will be modelled as an electrical heating system in the context of the virtual energy community.

   g. Sea Cable (1.4)

   h. Virtual Energy Community (described in the Scenario 2)

Phase 3: System models and Digital Twin validation

I. Validation of the digital model of the electrical distribution network.

   a. Output required performance measures from the DT model such as load in each line, voltage at each bus and frequency.

   b. Compare the output from the DT model with the data coming from the measuring infrastructure of the DSO.

   c. Apply corrective actions to the DT model.

II. Validation of the digital model of the DERs involved in the project.

   a. Output required performance measures from the DT model such power generation.

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b. Compare the output from the DT model with the data coming from the measurements done by the DSO.

c. Apply corrective actions to the DT model.

5.3. Scenario 2: VPP4ISLANDS solution for renewable energy community with VESS

# Scenario	**Scenario 2**
Title	**VPP4ISLANDS solution for renewable energy community with VESS.**
Short Description	A renewable energy community will be built in Gokceada. The community will be located in a portion of the grid located downstream of a single secondary substation. UEDAS, the local DSO, will install around 100 smart meters, an ESS, and a flexible load in the energy community area. The goal of the VPP4ISLANDS solution will be to maximise the self-consumption of the renewable energy community.
Service provided	Energy community management. Maximization of self-consumption.
Phases	The scenario is composed of the following phases: Phase 1: Creation of a renewable energy community in Gokceada Phase 2: Installation of new asset in the renewable energy community area. Phase 3: Modelling the Virtual Energy Community. Phase 4: Implementation of VPP4ISLANDS solution for REC. Phase 5: Implementation of policies for authentication and authorization infrastructure. Phase 6: Validation of VPP4ISLANDS solution for renewable energy community at digital twin level. Phase 7: Implementation in the field of the solution for renewable energy community.
Actors and roles	Energy community members. Living lab.

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Strategic objectives achieved in the scenario	**SO1: Implement Living labs to promote renewable energy communities in islands.** **SO4: Smart combination of multiple storage strategies.** **SO6: Enhancing the transparency and the cybersecurity of data related to the green energy.** **SO8: Development of tailored business models to support the sustainability and commercialisation VPP4Islands outputs.**
Evaluation of the scenarios based on KPI	**SO1 KPI - Number of engaged stakeholders at least 20 (between Gokceada and Formentera)** During the Phase 1 will be engaged at least 10 stakeholders. **SO1 KPI - high consumer trust** The consumers engaged in the renewable energy community will trust the VPP4ISLANDS solution to the point of entrusting their energy consumption data. It will be explained to consumers how their data will be safeguarded from third parties. **SO1 KPI - At least 50 feedbacks from potential actors (between Gokceada and Formentera)** At least 50 feedbacks will be collected during phase 1 from end users who have a point of delivery in the pre-selected area to perform the demonstration. Feedback will be collected from both those who agree to be part of the renewal energy community and those who do not. **SO4 KPI - Energy Return on Investment (EROI)** The EROI linked to the installation of the elements that compose the VESS will be calculated. **SO4 KPI - Storage Efficiency (> 90%)** The Efficiency of the VESS (i.e., ESS+ flexible load) will be up to 90%. **SO6 KPI - Availability of service (99%)** The availability of the services delivered by the VPP4ISLANDS solution for energy community will be up to 99% **SO6 KPI -Transparency** The authentication and authorization infrastructure will be tested, and the transparency of the infrastructure will be proved.
Possible future changes	At the moment it is expected that the energy storage system can be installed in the area of the energy community. It could be installed in another node of the network, but it will be operated anyway to maximize the self-consumption of the energy community.

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Phase 1: Individuation of an area to create a renewable energy community

I. In this stage of the scenario will be **implement Living labs** to promote Renewable Energy Communities in Gokceada. VPP4Islands will engage citizens, potential stakeholders, and influencers to ensure the tailored co-design of innovative market flexibility tools and services.

II. Depending on the willingness of citizens to participate in the project and the technical constraints that arise, an area of the island will be chosen in which to implement the renewable energy community. An area here means a portion of the low-voltage grid subtended by a single secondary substation.

III. All end-users with a Point of Delivery (POD) in the chosen area will be invited to take part in the renewable energy community.

IV. All end-consumers with a POD the chosen area will be asked for permission to collect their consumption through smart meters.

Phase 2: Installations of new assets in the renewable energy community

I. All end-users owning a POD in the chosen area will be equipped with a smart meter. Even those who do not join the renewable energy community will be equipped with a smart meter by UEDAS (the DSO) as this will also be used by the DSO as a fiscal meter. Approximately **100 smart meters** will be installed.

II. **One battery energy storage system,** with a capacity of 100kWh and a maximum power of 50kW, will be installed in the chosen area. The battery energy storage system will be equipped with a **VPP4IBox** and a **smart meter**.

III. **One electrical resistance with a controllable power absorption** will be installed within the REC area. The maximum power that the resistance will be able to absorb will be

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around 5 kW. The resistor will be used to **simulate a Heating, Ventilation, and Air-Conditioning (HVAC) system of a building** (i.e., a heat pump). This element will act as a **Flexible Load (FL)** for the REC. The **electrical resistance** will be equipped with a **VPP4IBox.**

IV. The small-scale or roof-mounted photovoltaic panels will be equipped with a **smart meter**.

V. In the island will be installed a **VPP4INode.** An industrial computer that will perform the centralised operations of local renewable energy community.

Phase 3: Modelling at the DT level (Virtual Energy Community)

I. A digital model of the energy community will be implemented within the **System Modelling** submodule of the Island **Digital Twin**. The digital model will be called the Virtual Energy Community in this context.

II. The Virtual Energy Community will be composing by

  a. The digital model of the Secondary substation that feeds the area of the REC.

  b. The digital model of the smart meters connected in that area.

  c. The digital model of the battery energy storage system.

  d. The digital model of the electrical heating system.

  e. The digital model of the rooftop PV that will be installed in the area.

  f. The low voltage distribution network connecting the secondary substation to the PODs will be modelled only if scientific/technical interest is expressed by the DSO.

III. The validation on the model implemented in the digital twin will be carry out in the Scenario 1.

Phase 4: Implementation of VPP4Islands solution for Renewable Energy Community

I. Implementation of the **Communication System** between the **smart meters** and the **VPP4INode**.

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a. The **smart meters** will communicate through the power line communication technology with a data concentrator that will be installed in the secondary substation that feeds the renewable energy community area.

b. The data concentrator will aggregate and send to the **VPP4INode** the data on measurements of energy done by the smart meters. Only the data recording by the smart meters of the members of the renewable energy community will be send to the VPP4INode.

c. In the VPP4Inode, the data coming from the data concentrator will be elaborated by the **Pre-process (Data analytics and knowledge elaboration)** module. In this module the data will be unified and homogenies with the data format used in the Node-level data base **(Pre-process)**. Also, in this module a mix of advanced algorithms such as K-means and OPTICS will allow to group and classify consumer behaviours **(Data analytics and knowledge elaboration)**. These algorithms will allow to have a segmentation of the end users (for example, they will be able to understand if the POD feeds a residential house, a vacation home, or a store) and the detection of important and lasting changes in their energy consumption behaviour (e.g., new tourists, occupants leaving the house, changed work schedule).

d. After the pre-process the data will be saved in the **Node-level data base.**

e. If the renewable energy community agrees to share their data with third party entities such as other renewable energy communities, the data will also be sent from the **VPP4INode** to the **VPP4ICloud** and saved in the **Shared Knowledge Base**.

II. Implementation of the **Communication System** between the **VPP4IBoxes** and **VPP4INode**.

a. The **RTU** within the VPP4IBox will have timeseries based communication protocol such that data measurements can be collected by **Energy Measurement Module** and transferred to the VPP4INode.

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b. The RTU within the VPP4IBox will be able to receive set-points from the VPP4INode. The set-points received will be send from VPP4IBox to the power converter of the element connected to this (i.e., ESS or FL). For this aim with the VPP4Ibox will implemented a **DER Communication Interface** able to communicate with the power converters.

III. Implementation of the **Local Forecasting Engine** for renewable energy community:

a. **Forecast the energy consumption** of the renewable energy community at 1h forecasting horizon (the time horizon could be change in the future cause technical aspect yet not considered).

b. **Forecast the energy production** of the PV plants installed within the renewable energy community at 1h forecasting horizon. The production forecasting will be based on irradiance forecasting and historical data on production of PV panels.

c. The forecasting will be updated every hour.

IV. Implementation of the **Distributed Optimisation Engine** for renewable energy community:

a. Calculate the optimal scheduling of the ESS (charge and discharge) and the scheduling of the FL (consumption). The objective of the scheduling will be to maximise the self-consumed energy within the REC.

b. The scheduling will have the same time horizon of the forecast of energy production and consumption, 1h.

c. The scheduling will have the same number of time step on the data on consumption that are received from the smart meters, (e.g., if the time step of the data received from smart meters is 15 min the scheduling in a time horizon of 1h will have four time step). The scheduling will provide a set point for each time step.

d. The scheduling of the ESS and of the FL will be send to the **VPP4IBox** by the **Communication System** of the **VPP4INode**.

V. Implementation of the **Balancing Services Provider (BSP) module:**

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a. The **BSP module** will read the scheduling done by the Distributed Optimization Engine for each controllable assets within the REC (i.e., the ESS and the FL in this scenario). The scheduling will be forming the **baseline** of power injection/absorption plan of each controllable asset.

b. The **BSP module** will read the forecasting on consumption and generation within the REC.

c. The **BSP module** will read the measurements of the smart meters in line.

d. If the consumption and/or solar production will be different from the baseline the BSP module will receive the total amount of flexibility required to compensate the fluctuation from the **distributed optimisation engine**.

e. The amount of total flexibility (aggregated flexibility) required will be sent to the **VPP4IBox** of controllable asset.

f. The VESS engine within the VPP4IBox will coordinate the FL and the ESS to deliver the amount of flexibility required.

g. The BSP module will be able to quantify the amount of flexibility delivered by FL and ESS in each time step.

VI. Implementation of **Virtual Energy Storage System Engine**

a. **The VPP4IBox** will be equipped with a Raspberry Pi. The Raspberry PI will provide the computational capacity needed to implement the VESS Engine in the VPP4IBox.

b. The **VESS Engine** will provide the Smart Energy Management at VPP4IBox level. It will be able to aggregate the conventional ESS, FL and controllable generation within a geographical area (i.e., in the REC area in this case). The **VESS** will acts as a single high-capacity storage for the **Digital Twin** of the island and for the **Balancing Service Provider** module.

c. When a request of flexibility will be sent by the **BSP module,** the **VESS Engine** will be able to calculate the amount of flexibility that each element within the REC

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can provide with respect to total flexibility request by the **BSP module.** The results of this calculation will be a new set point of operation for the ESS and the FL.

d. The new set point will be sent to the **DER Communication Interface,** that will be able to transform the new set point in a control signal for the power converter that feeds the controllable element.

Phase 5: Implementation of the Policies for the Authentication and Authorization Infrastructure

In this Phase, the **policies for the authentication and authorization infrastructure** for the VPP4ISLAND solution for renewable energy community will be identified.

I. Identify subjects. Subjects are entities requesting an operation on resources such as modules in VPP4INodes or individuals.

II. Identify resources in the system. Resources are logical object or and entity (i.e., data) to be protected from unauthorized use. Moreover, in this step will be identify

   a. Under which conditions may what information be shared with which subjects

   b. Which subjects may trigger which state change?

III. Identify action applicable to different resources

IV. Describe Natural Language Policies (NPL)

V. Translate NPL is something that can be execute by the machines (Digital Policies)

Phase 6: Validation of the solution for REC at the DT level

I. The validation will be done through simulations and tests through hardware in the loop (HIL). In this test the modules of VPP4INode and VPP4IPlatform will be tested at digital twin level. The validation period will be around 1 week.

II. In this evaluation will be tested, at laboratory level, the interaction between the components of the VPP4ISLANDS solution:

   a. The connection/communication between VPP4ICloud and VPP4INode.

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b. The connection between VPP4INode and VPP4IBox.

c. The capacity of the VPP4IBox to measure energy flow and send the measurements to the VPP4INode.

d. The capacity of the VPP4IBox to send signals to the power converter that control the FL and ESS, (communication between the DER communication interface of the VPP4IBox and power converters).

e. The capacity of the VPP4INode to receive signal from the data concentrator installed at the secondary substation that feeds the renewable energy community.

III. The functionality connected to flexibility services will be tested within the Digital Twin Environment:

a. Test the accuracy of the **generation forecasting**.

b. Test the accuracy of the **consumption forecasting**.

c. Test the capacity of the **Distributed Optimisation Engine** to provide:

- a scheduling for the FL that maximise the self-consumption of the energy produced within the renewable energy community with the respect of the comfort constraints.
- A scheduling for the ESS that maximise the self-consumption of the energy produced within the renewable energy community with the respect of power and energy constraints.

d. Test the capacity of the **BSP module** to:

- Realize if any deviation from the forecasting and actual feed-in and consumption is occurring.
- Quantify the total amount of flexibility required to balance the fluctuation.
- Send the flexibility signal (total amount of flexibility) to each VPP4IBox connected to an element able to provide flexibility.

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- Quantify and record the flexibility provide by each element within the energy community.

e. Test the capability of the **VESS Engine** to:

- Receive the flexibility signal by the BSP module.
- Receive from the VPP4INode the information required to calculate the amount of flexibility each element can provide.
- Calculate the amount of flexibility each element can provide and send this value to the **DER Communication Interface.**

Phase 7: Implementation in the field

After the validation at the digital twin level will be done an implementation in the field. The objective is to increase the independency of the EC from the MV distribution grid.

I. The **Energy and CO_2 savings** module (at VPP4IPlatform level). It will be able to quantify the following KPI:

a. KPI 1: kWh / unit of production.

b. KPI 2: € / kWh, current and accumulated cost.

c. KPI 3: kg current and accumulated CO2.

d. KPI 4: percentage of self-consumption.

5.4. Scenario 3: VPP4ISLANDS solution for the spot market.

Table 13: Scenario on increasing the profit of renewable energy source in the spot market

# Scenario	Scenario 3
Title	**VPP4ISLANDS solution for the energy spot market**

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Short Description	Energy from the two wind turbines and the photovoltaic system will be aggregated and sold in the spot market by a certified energy trader. In order to maximize profit, a forecasting algorithm will be developed. The algorithm will make a first forecast of the hourly generation of renewable plants for the following 36h in order to sell the energy in the day-ahead market. The algorithm will update the generation forecasts on an hourly basis to maximize profits in the intraday market. The goal in the intraday market will be to close the gap between the energy sold in the day-ahead market and the actual amount of energy injected into the grid by the renewable plants.
Service provided by VPP4Isolution	Day-ahead and intraday bids optimization, i.e., maximizing profits from energy sales in the spot market.
Long Description	The phases of this scenario are here listed: Phase 1: Collaboration with a certified energy trader Phase 2: Installation of new assets Phase 3: Modelling of the Turkish electricity spot market at DT level Phase 4: Implementation of the VPP4ISLANDS solution for energy trader Phase 5: Implementation of the Policies for the Authentication and Authorization Infrastructure Phase 6: Validation of the VPP4ISLANDS solution for energy trader at digital twin level Phase 7: Implementation and validation in the field
Actors and roles	Wind turbines and photovoltaic owner (Producer). Limak Energy (Certified power trader or trader).
Strategic objectives	**SO3: Embracing new technologies to promote a large penetration of renewable energy sources.** **SO5: Digitalization and ensuring the multi-dimensional flexibility and increasing the performance of the portfolio of RES.** **SO6: Enhancing the transparency and the cybersecurity of data related to the green energy.**

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Evaluation of VPP4Islands solutions	**SO3 KPI - Forecasting accuracy (>80%)** The accuracy of renewable generation forecasts provided by VPP4ISLANDS solutions will be evaluated. The goal is to have forecasts with accuracy > 80% for day-ahead market participation. **SO3 KPI - Market price of provided energy and services** The plant owners currently have a bilateral contract with Limak Energy. The energy generated by the plants is paid in with a fixed price in all hours of the day, the price is set by the Turkish renewable energy laws. The revenues obtained from the sale of energy in the market will be compared with the current revenues. **SO5 KPI** - **Short-term flexibility index** The flexibility that the ESS will provide to the portfolio in the IM market will be evaluate through short-term flexibility indexes **SO5 KPI** - **Long-term flexibility index** The flexibility that the ESS will provide to the portfolio in the DAM market will be evaluate through long-term flexibility indexes **SO6 KPI - Availability of service (99%)** The availability of the services delivered by the VPP4ISLANDS solution for energy community will be up to 99% **SO6 KPI -Transparency** The authentication and authorization infrastructure will be tested, and the transparency of the infrastructure will be proved.
Possible future changes	• It is possible but not certain that new wind turbines and/or new renewable energy facilities will be installed on Gökçeada Island during the life of the project. If new facilities are installed in a timely manner, they will be considered for participation in the project. • Since the diesel generation can be used by the DSO only in emergency case (i.e., sea cable failure) is possible that the local regulator will not allow the project to use the diesel generators in the spot market during the demonstration.

Phase 1: Collaboration with a certified energy trader

In order to validate the solution with TRL 8 (TRL 8 – system complete and qualified) UEDAS will contract Limak Energy Trade, a certified energy trader in the Energy Exchange Istanbul (EXIST) or Enerji Piyasaları İşletme A.Ş. (EPİAŞ) . Limak Energy Trade is a company of the Limak group as well as UEDAS.

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The VPP4ISLANDS solution for energy trader will be use for an established **time for validation in the field** (around 1 week) by Limak Energy Trade to operate in the market.

Phase 2: Installation of new assets

In this phase will be installed in the field the following assets:

- A **VPP4IBox** at the wind turbine connected at node #3.
- A **VPP4IBox** at the wind turbine connected at node #4.
- A **VPP4IBox** at the PV plants connected at node #150.
- A **battery energy storage system** equipped with a **VPP4IBox** and a **smart meter**. Note that this battery energy storage system is the same of scenario 2.
- In the island will be installed a **VPP4INode.** An industrial computer that will perform the centralised operations for the energy trader that operate in the market the generation systems present in the island. Note that this VPP4INode is the same of scenario 2.

Phase 3: Modelling of the Turkish electricity spot market at DT level

I. The Digital twin will be configured with considered assets (Wind turbines, PV Plants, ESS, Diesel generators).

II. In this phase will be ensured that the energy trader solution can be validated within the digital twin. It means that the digital twin environment will be able to simulate of the Turkish electricity day-ahead and intraday market processes. This will be used to test the solution at Digital Twin level the VPP4ISLANDS solution for the spot market.

Phase 4: Implementation of the VPP4ISLANDS solution for energy trader

I. Implementation of the **Global forecasting engine** at the cloud level:

  - It will be able to predict the weather and market price with a prediction horizon of 37H and prediction time step of 1H. Note that since the day-ahead market close at

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11:30 a.m. of the day before of the actual feed it is mandatory have a time horizon of 37 hours, furthermore the time step must be equal to 1h cause the day-ahead market has 24 windows of 1hour.

- The forecasting will be done by machine learning algorithms, so the models used in the forecasting will be composed by hyperparameters. The **Global forecasting engine** will be able to update the hyperparameters to improve the performance of the forecasting.
- The forecasted data and training hyperparameter must be saved within the **Shared Knowledge Base.** Note that forecast of weather and upgrade of hyperparameters can be considered as a service that the VPP4IPlatform can provide to multiple VPP4INode installed in the island.
- The forecasted data and training hyperparameter must be sent to the **VPP4INode** and saved at **Node-level database.**

II. Implementation of the **Distributed Optimisation Engine** at the VPP4INode level:

- The **Distributed Optimisation Engine** will generate the optimal setpoints for buying/selling from the day-ahead market.
- In this context the scheduling of the ESS and of the diesel generators will done with the objective to maximise the profit of the portfolio in the day-ahead market. The scheduling done for the day-ahead market will be the baseline for the ESS and for the diesel generation.
- The forecasted power production of each renewable power plant done at day-ahead level will be the baseline for those elements.
- The scheduling controllable assets will be done by means of **two-level optimisation**. The first level is for DAM the second level will be for IM.

III. To participate in the intraday market, the **Local Forecasting Engine** updated with the hyperparameters received from the VPP4ICloud, will perform the prediction of energy transaction with a prediction horizon of 2h (or more up to 5) and a time step of 1h.

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IV. If any deviation, then, the **Distributed Optimisation Engine** will generate the optimal setpoints for buying/selling from the intraday market based to the results of the **Local Forecasting Engine** (second level optimisation for Intraday Market). The transaction can be accepted only if the difference is higher than 0.1MW from the day-head engagement.

V. The **Balancing System Provider module** will record the baseline at DAM level and at IM level.

VI. The **Balancing System Provider module** will record the real injection of the generators

Phase 5: Implementation of the Policies for the Authentication and Authorization Infrastructure

In this Phase, the policies for the authentication and authorization infrastructure for the VPP4ISLANDS solution for will be identified.

I. Identify subjects. Subjects are entities requesting an operation on resources such as modules in VPP4INodes or individuals.

II. Identify resources in the system. Resources are logical object or and entity (i.e., data) to be protected from unauthorized use. Moreover, in this step will be identify

   i. Under which conditions may what information be shared with which subjects

   ii. Which subjects may trigger which state change?

III. Identify action applicable to different resources

IV. Describe Natural Language Policies (NPL)

V. Translate NPL is something that can be execute by the machines (Digital Policies)

Phase 6: Validation of the VPP4ISLANDS solution for energy trader at digital twin level

- **The Local and Global Forecasting Engine** accuracy will be evaluated once the real data are available.

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- Based on DT simulation and real data, the performance of the **Distributed Optimisation Engine** will be evaluated. The evaluation will be carried out comparing the daily profit get by Limak Trade with their algorithms with the daily profit calculated at Digital Twin.
- If the daily profit achieved by Limak with their algorithms is greater than that potentially achievable with the VPP4ISLANDS solution for energy trader, the algorithms will be revised to increase their performance.

Phase 7: Implementation and validation in the field

If all tools (from Phase 6) are validated for 1 week, the field validation can be performed, and the set-points will be directly sent to Limak Energy to buy\sell energy.

The validation in the real life will during around one week.

6. Formentera real-life use case

6.1. Description of the use case

Formentera is the smallest and more southerly island of the Pityusic Islands group (comprising Ibiza and Formentera, as well as various small islets), which belongs to the Balearic Islands autonomous community (Spain). It covers an area of 83.22 square kilometres (including offshore islets) and had a population of 12,111.

Figure 7 depicts the map of Formentera and list the main generation sources connected to the distribution grid.

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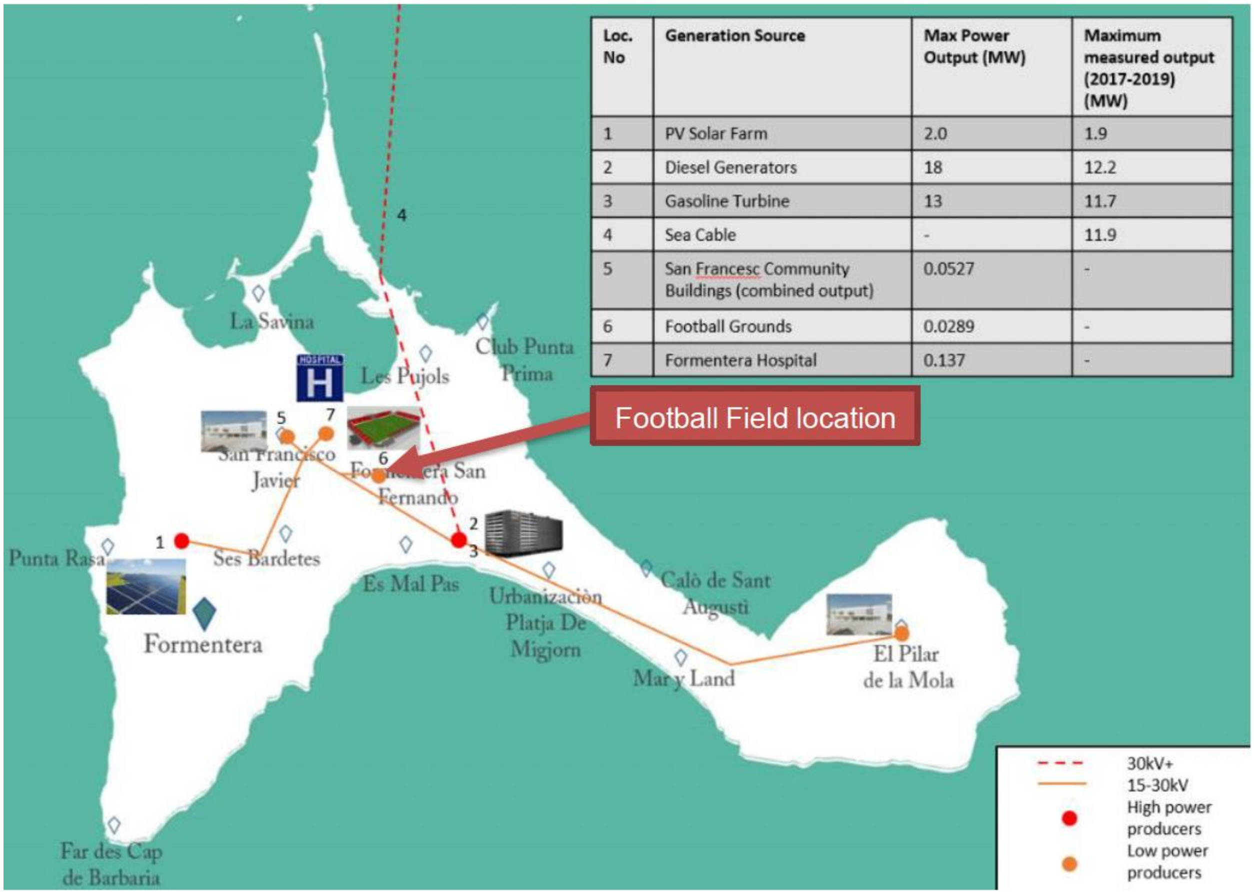

Figure 7: Geographical map of Formentera

Actors involved in the use case

Table 14 list the actor that could be involved in the creation of the energy communities.

Table 14: Actors in Formentera

Actors in Formentera				
Actor code	**Actor name**	**Roles**	**Consortium member**	**Assets owned**
Ac.1	Municipality of Formentera	Municipality	Yes	PV plant on the top of municipality building.

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Ac.2	PIME - Asociación Intersectorial de Pequeños y Medianos Empresarios de Formentera	private association	No	PV plant on the top of some building own by the association.
Ac.3	Population of Sant Francesc	citizens	No	PV plant on the top of some building own by the citizens.

Assets involved in the use case

Table 15 list some building that are potentially interested in the creation of an energy community.

Table 15: List of building that could be involved in the creation of energy communities

Location	***General Location***	***Number of panels***	***Rated power (W)***	***Installer***	***Manufacturer and model***	***Voltage at rated power (V)***	***Current at rated power (A)***
Ed. Centre Social Es Molí (RADIOILIA 107.9)	**San Francesc**	15	4800	TFV Instalaciones Frigoríficas SL	Trunsun Solar TSP-72	38.19	8.38
Antic Ed. Cultura, Educació i Patrimoni (SALA DE CULTURA)	**San Francesc**	60	15600	Insafor SL	Futura Sun SRL FU270P	31.22	8.65
Ed. Escorxador (CLOSE ITV FORMENTERA)	**San Francesc**	24	6240	Insafor SL	Futura Sun SRL	Unknown	Unknown
Col·legi de La Mola (CLOSE FAR DE LA MOLA REAL ESTATE)	**San Francesc**	8	2080	Enervega SLU	QANTUM Q.PLUS G4.3 280Wp	31.67	8.84
Col·legi Mestre Lluís Andreu (dalt)	**San Francesc**	56	14560	Enervega SLU	Canadian Solar CS6K-275P	25	9.45
Col·legi Mestre Lluís Andreu (baix)	**San Francesc**	36	9360	Enervega SLU	Canadian Solar CS6K-275P	40.5	8.45
Camp de Futbol		58	28900	Enervega SLU	Unknown	Unknown	Unknown

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Objectives to be achieved in the use case

Formentera will be used as real life use case (Case study 2) to validate the technological solutions develop within the WP3, WP4, WP5 and WP6. The validation of the solution will be carried out by the WP7, it will start in March 2023 (M30) and end in September 2023 (M36).

There are four main actions related to case study 2, these are listed below:

5. implement the Fuel Cell - Li-Ion/Redox-Flow Batteries:
    i. Polymer Electrolyte Membrane (PEM) Electrolyser to utilize excess electricity for hydrogen generation.
    ii. hydrogen storage system
    iii. PEM Fuel cell operated on a 100% hydrogen
    iv. Li-ion/redox flow batteries to provide fast response capabilities.
6. Create two small energy communities by installing 50 smart meters, 10 VPP4Ibox, and equip ten households (selected in the living lab) with solar panels.
7. Design test and validate the communication (latency, data format, protocol, etc.) and P2P trading engine.
8. Use the **Smart Planning Tool (SPT)** to generate a plan that allow a near independent micro grid based on installed renewable infrastructure, controllable appliances, and storage system in real time control by using the three VPP4Island modules.

These four actions are described in the detail in the three scenario design for the use case 2, in particular:

4. In the scenario 1 will be design and validate the digital twin of Formentera island. The Digital Twin will host the model of all the Virtual Energy Community implemented in the island.
5. In the scenario 2 will be built two renewable energy community and installed a fuel cell/battery energy storage system. The flexibility provided by the fuel cell system and the energy generate by the PV plants will be used also for Peer-to-Peer energy

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trading. In this scenario will be deploy a VPP4ISLANDS solution customized for renewable energy community, the fuel cell-battery energy storage system will be used to maximize the self-consumption within the renewable energy community.

6. In the scenario 3 we will use The Smart Planning Tool for calculate the optimal size of PV and energy storage systems to maximize the self-consumption in the energy communities.

The functionalities and the services implemented in the three scenarios are summarized in Table 16

Table 16: VPP4ISLANDS solution functionalities and services implemented in Formentera

Scenario	Functionalities	Services
1	Digital twin of the energy communities in the island.	Real time monitoring and simulation environment.
2	Energy community creation and management. Peer-to-peer energy trading.	Scheduling optimization of energy storage system for maximize the self-consumption. Peer-to-peer energy trading environment.
3	Smart Planning implementation	Calculation of the optimal size of PV and ESS to be installed in the energy communities.

6.2. Scenario 1: Digital twin of Formentera - modelling and validation

# Scenario	Scenario 1
Title	**Modelling and validation of the Digital Twin of Formentera**
Short Description	The goal of this scenario is to describe how the digital twin will be implemented. The main aspects related to digital twin as the data base that contain the input necessary to feed the digital twin and the validation of the digital models are here described.
Service provided by VPP4Isolution	The digital twin will provide a validation tool able to analyse the effects of different control schemes/interventions/scenarios on the power grid stability. In particular will be possible analyse the impact of energy storage systems and flexible loads on the power grid.

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Phases Description	The objective of this scenario is to build and validate the digital twin of the energy communities of Formentera. It will be a collection of Virtual Energy Communities. The scenario is composed by the following phases: Phase 1: Data collection and data base construction. Phase 2: System Modelling in the Digital Twin. Phase 3: System models and Digital Twin validation
Actors and roles	Municipality of Formentera Digital Twin developers Owners of the distributed energy resources within the energy communities
Strategic objectives	**SO7: Development of an open VPP4Islands ecosystem**.
Evaluation of VPP4Islands solutions based on KPI	**SO7 KPI - Computational complexity** The Virtual Energy Community (at Digital Twin level) must be able to simulate the operation of the energy community in a reasonable time to provide information to the VPP4INode **SO7 KPI - Number of reduced intermediaries (>2)** The aggregator that operates the Commercial Virtual Power Plants that manage the energy community (the VPP4INode) will be able to get and share information with others energy community aggregators through the VPP4IPlatform without intermediaries.
Possible future changes	No potential future changes have been identified at this time.

Phase 1: Data Collection and data base construction

I. Collecting static data of the physical assets:

   a. Collecting static input data to model the photovoltaic plant within the energy communities.

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b. Collecting static input data to model the Fuel Cell - Li-Ion/Redox-Flow Batteries such as nominal power, nominal capacity, primary control time scale and time scale for forcing the storage at a reference level.

c. The static data will be stored at **VPP4ICloud** level in the **Shared Knowledge Base (KB)**.

II. Collect historical data from photovoltaic :

a. Request authorization from private owner of the photovoltaic plant to collect data on their production.

b. Collect data from photovoltaic plant with a time step of 15 min. Data collection will be through **VPP4IBox** or **smart meters**.

c. The data on renewables generation will be sent from **VPP4IBox** (or **smart meters**) to **VPP4INode** that will be place in Formentera. The data will be stored within the **Node-level data base** for about three months.

d. The data will be sent from **VPP4INode** to **VPP4ICloud** on a daily basis. At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

III. Collect historical data from the Spanish electricity market:

a. The data on price of Spain DAM and IM will be collected though the EXIST TRANSPARENCY PLATFORM (https://www.omie.es/en/mercado-de-electricidad) directly via API.

b. The data on DAM and IM clear energy price will be sent to VPP4INode that will be place in the island. The data will be stored within the **Node-level data base** for about three months.

c. The data will be sent from VPP4INode to VPP4ICloud. At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

d. The data of the national market will be used to build the dynamic pricing mechanism used in the Peer-to-Peer energy trading.

IV. Collect historical data from local climate:

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a. Solar radiation.

b. Temperature.

c. Air pressure.

d. Whenever possible cloud cover on small time scale.

e. The data on local climate will be sent to **VPP4INode** that will be place in the island. The data will be stored within the **Node-level data base** for about three months.

f. The data will be sent from VPP4INode to VPP4ICloud. At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

V. Collect data from smart meters:

a. Request authorization from the customers to collect data recorded from smart meters.

b. The smart meters will be able to send the measurements to **VPP4INode**. The data will be stored within the **Node-level data base** for about three months.

c. The data will be sent from VPP4INode to VPP4ICloud. At VPP4ICloud level the data will be stored within the **Shared Knowledge Base** for years.

Phase 2: System Modelling

I. In the submodule of the **Digital Twin** called **System Modelling** will be implemented a virtual energy community representing the **energy community alpha**. The virtual energy community will contain the digital model of the following elements:

a. The 6 kW PEM (polymer electrolyte membrane) Electrolyser to utilize excess electricity for hydrogen generation.

b. The hydrogen storage system (40kWh stored energy).

c. The 6.5kW PEM Fuel cell operated on a 100% hydrogen.

d. The 50kWh Li-ion/redox flow batteries.

e. The photovoltaic plants that will be installed the area with the budget of the project.

f. The consumers.

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II. In the submodule of the **Digital Twin** called **System Modelling** will be implemented a virtual energy community representing the **energy community beta**. The virtual energy community will contain the digital model of the following elements:

a. The photovoltaic plants that will be installed the area with the budget of the project.

b. The consumers.

Phase 3: System models Validation

I. Validation of the virtual energy community that model the energy community alpha.

   a. Output required performance measures from the DT model.

   b. Compare the output from the DT model with the data coming from VPP4IBox.

   c. Apply corrective actions to the DT model.

II. Validation of the virtual energy community that model the energy community beta.

   a. Output required performance measures from the DT model.

   b. Compare the output from the DT model with the data coming from VPP4IBox.

   c. Apply corrective actions to the DT model.

6.3. Scenario 2: VPP4ISLANDS solution for renewable energy community with peer-2-peer energy trading

# Scenario	Scenario 2
Title	**VPP4ISLANDS solution for renewable energy community with peer-2-peer energy trading.**
Short Description	In Formentera will be built two energy communities. One energy community will be equipped with a Fuel cell/Lion Battery system and PV plants (energy community alpha), the other one will be equipped only with PV plants (energy community beta). The VPP4ISLANDS solution will help the energy communities to maximise the self-consumption in the energy communities. Moreover, will be implemented a Peer-to-peer energy transaction mechanism that will allow to trade energy though smart contracts.

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Service provided by VPP4Isolution	Scheduling optimization of energy storage system for maximize the self-consumption. Peer-to-peer energy trading environment.
Phases	Phase 1: Individuation of an area to create a renewable energy community Phase 2: Installations of new assets in the renewable energy community Phase 3: Modelling at the DT level (Virtual Energy Community) Phase 4: Implementation of VPP4Islands solution for Renewable Energy Community Phase 5: Smart Contract implementation Phase 6: Implementation of the Policies for the Authentication and Authorization Infrastructure Phase 7: Validation of the solution for REC at the DT level Phase 8: Implementation in the field
Actors and roles	Energy community members Municipality of Formentera
Strategic objectives	**SO1: Implement Living labs to promote renewable energy communities in islands.** **SO2: Increase the exploitation and the penetration of renewable energy-based system on the Island.** **SO4: Smart combination of multiple storage strategies.** **SO6: Enhancing the transparency and the cybersecurity of data related to the green energy.**
Evaluation of VPP4Islands solutions based on KPI	**SO1 KPI - Number of engaged stakeholders at least 20 (between Gokceada and Formentera)** During the Phase 1 will be engaged at least 10 stakeholders. **SO1 KPI - high consumer trust** The consumers engaged in the renewable energy community will trust the VPP4ISLANDS solution to the point of entrusting their energy consumption data. It will be explained to consumers how their data will be safeguarded from third parties. **SO1 KPI - At least 50 feedbacks from potential actors (between Gokceada and Formentera)** At least 50 feedbacks will be collected during phase 1 from end users who have a point of delivery in the pre-selected area to perform the

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	demonstration. Feedback will be collected from both those who agree to be part of the renewal energy community and those who do not. **SO2 KPI - CO2 reduction index (at least 2 Ton Co2 reduction during the experimentation)** The Energy and CO2 savings module will calculate the CO2 production of the areas where will be implemented the energy communities alpha and beta **SO4 KPI - Energy Return on Investment (EROI)** The EROI linked to the installation of the elements that compose the VESS will be calculated. **SO4 KPI - Storage Efficiency (> 90%)** The Efficiency of the Fuel cell/ battery system will be up to 90%. **SO6 KPI - Availability of service (99%)** The availability of the services delivered by the VPP4ISLANDS solution for energy community will be up to 99% **SO6 KPI -Transparency** The authentication and authorization infrastructure will be tested, and the transparency of the infrastructure will be proved.
Possible future changes	No potential future changes have been identified at this time.

Phase 1: Individuation of an area to create a renewable energy community

I. In this stage of the scenario will be to **implement Living labs**. The goal of the living labs will be to promote renewable energy communities in Formentera. Note that the concept of renewable energy community in Spain is transpose in national regulation by the Royal Decree 244/19 and are called self-consumption scheme. De facto the living labs will promote the Spanish self-consumption scheme. The regulation and the constrains of self-consumption scheme are described in section 3.3.

II. Choose to area to implements two small energy community in Formentera. Only one of these two energy community will be equipped with a **Fuel Cell - Li-Ion/Redox-Flow Batteries.** In

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the context of this use case, we will call the energy community with the fuel cell "*Energy Community alpha*" and the energy community without the Fuel cell "*Energy Community beta*".

III. We will make sure that in the area chosen for the alpha energy community there are the technical conditions necessary to install the fuel cell.

IV. All end-users with a Point of Delivery (POD) in the chosen areas will be invited to take part in the renewable energy community.

V. All end-consumers within the two areas will be asked for permission to collect their consumption through smart meters.

Phase 2: Installations of new assets in the renewable energy community

I. All end-users that will accept to take part will be equipped with a **smart meter**. Approximately **50 smart meters** will be installed between the two areas. Some end-users within the two energy communities will be equipped with a VPP4IBox. The end-users equipped with VPP4IBox will be able to do peer-to-peer energy transactions through smart contracts.

II. **10 households** will be equipped with small-scale or roof-mounted **photovoltaic plants**. The 10 households will be chased between the two areas. Each photovoltaic system will be equipped with a **smart meter.** Some photovoltaic plants within the two energy communities will be equipped with a VPP4IBox. The photovoltaic plants equipped with VPP4IBox will be able to do peer-to-peer energy transactions through smart contracts.

III. **Fuel Cell - Li-Ion/Redox-Flow Batteries** will be installed in the energy community alpha. The fuel cell will be composed by a PEM (polymer electrolyte membrane) Electrolyser to utilize excess electricity for hydrogen generation, a hydrogen storage system (40kWh stored energy), a PEM Fuel cell operated on a 100% hydrogen and a Li-ion/redox flow batteries to provide fast response capabilities. The Fuel Cell- Li-Ion/Redox-Flow Batteries will be equipped with a **VPP4IBox**. Demonstrators and operators will be trained on how to use, implement, and configure the Fuel cell - Li-Ion/Redox-Flow Batteries.

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IV. In the island will be installed a two **VPP4INode,** one will manage the energy community alpha and the other one the energy community beta**.** The **VPP4INode** will be an industrial computer that will perform the centralised operations of local renewable energy community.

In Figure 8 is depict a graphical representation of the energy communities alpha and beta. In can be denoted that every asset is equipped with a smart meter of with a VPP4IBox. The assets equipped with a VPP4IBox will be able to have peer-to-peer energy transaction through smart contracts.

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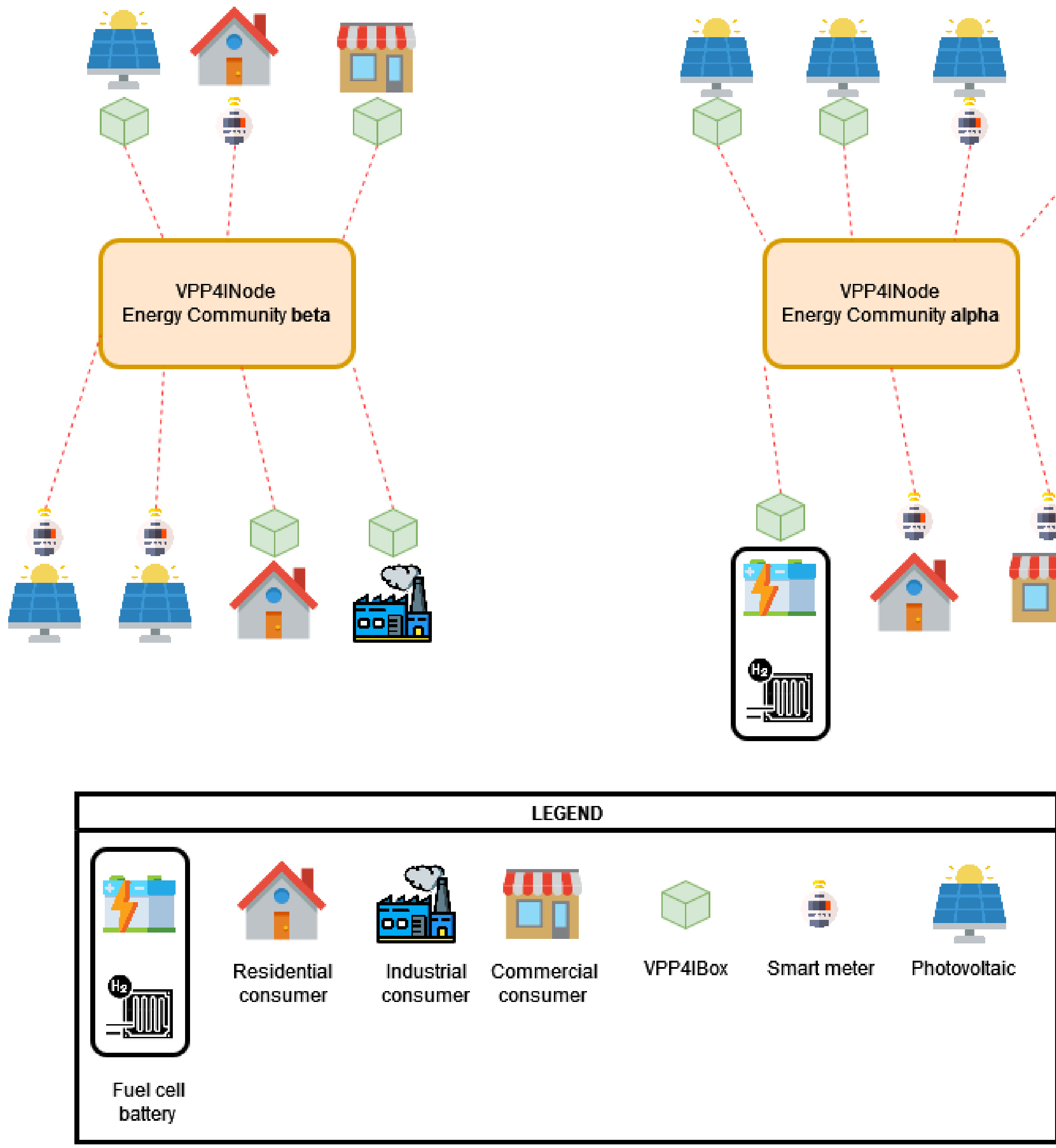

Figure 8: Graphical representation of alpha and beta energy communities

Phase 3: Modelling at the DT level (Virtual Energy Community)

I. When the two energy community will be clearly defined in term of area of implementation , the virtual energy communities will be implemented in the digital twin as described in scenario 1.

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Phase 4: Implementation of VPP4Islands solution for Renewable Energy Community

I. Implementation of the **Communication System** between the **smart meters** and the **VPP4INode**.

a. The **smart meters** will be able to send to the **VPP4INode** the data on measurements of energy.

b. In the VPP4INode, the data coming from the smart meters will be elaborated by the **Pre-process (Data analytics and knowledge elaboration)** module. In this module the data will be unified and homogenies with the data format used in the Node-level data base **(Pre-process)**. Also, in this module a mix of advanced algorithms such as K-means and OPTICS will allow to group and classify consumer behaviours **(Data analytics and knowledge elaboration)**. These algorithms will allow to have a segmentation of the end users (for example, they will be able to understand if the POD feeds a residential house, a vacation home, or a store) and the detection of important and lasting changes in their energy consumption behaviour (e.g., new tourists, occupants leaving the house, changed work schedule).

c. After the pre-process the data will be saved in the **Node-level data base.**

d. If the renewable energy community agrees to share their data with third party entities such as other renewable energy communities, the data will also be sent from the **VPP4INode** to the **VPP4ICloud** and saved in the **Shared Knowledge Base**.

II. Implementation of the **Communication System** between the **VPP4IBoxes** and **VPP4INode**.

a. The **RTU** within the VPP4IBox will have timeseries based communication protocol such that data measurements can be collected by **Energy Measurement Module** and transferred to the VPP4INode.

b. The RTU within the VPP4IBox will be able to receive set-points from the VPP4INode. The set-points received will be send from VPP4IBox to the power converter of the Fuel

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Cell. For this aim with the VPP4Ibox will implemented a **DER Communication Interface** able to communicate with the power converters.

III. Implementation of the **Local Forecasting Engine** for renewable energy community:

a. **Forecast the energy consumption** of the renewable energy community at 24h forecasting horizon.

b. **Forecast the energy production** of the PV plants installed within the renewable energy community at 24h forecasting horizon.

c. The forecasting will be updated every hour.

IV. Implementation of the **Distributed Optimisation Engine** for renewable energy community:

a. Calculate the optimal scheduling of the fuel cell (charge and discharge). <u>The objective of the scheduling will be to maximise the self-consumed energy within the renewable energy community alpha</u>.

b. The scheduling will have the same time horizon of the forecast of energy production and consumption.

c. The scheduling will have the same number of time step on the data on consumption that are received from the smart meters, (e.g., if the time step of the data received from smart meters is 15 min the scheduling in a time horizon of 1h will have four time step). The scheduling will provide a set point for each time step.

d. The scheduling of the **Fuel Cell** will be sent to the **VPP4IBox** by the **Communication System** of the **VPP4INode**.

V. Implementation of the **Balancing Services Provider (BSP) module:**

a. The **BSP module** will read the scheduling done by the Distributed Optimization Engine for each controllable assets within the REC (i.e., the Fuel cell in this scenario). The scheduling will be forming the **baseline** of power injection/absorption plan of each controllable asset (i.e., the Fuel cell in this scenario).

b. The **BSP module** will be able to read the measurements of the smart meters in line.

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c. The **BSP module** will be able to verify if the amount of flexibility delivered Fuel Cell through the smart contracts.

Phase 5: Smart Contract implementation

In this phase will be provide strategies based on smart contracts for eliminating the need for intermediaries by establishing smart contracts among VPP members and/or between the VPP, or even between members of different VPP.

In Figure 9 is shown an example of smart contract application between members of the same energy community connected . In the example three assets, a photovoltaic plant (PV) an Energy Storage System (ESS) and a flexible load, all three equipped with a VPP4IBox, participate in an auction to sell or buy electricity in a time step t.

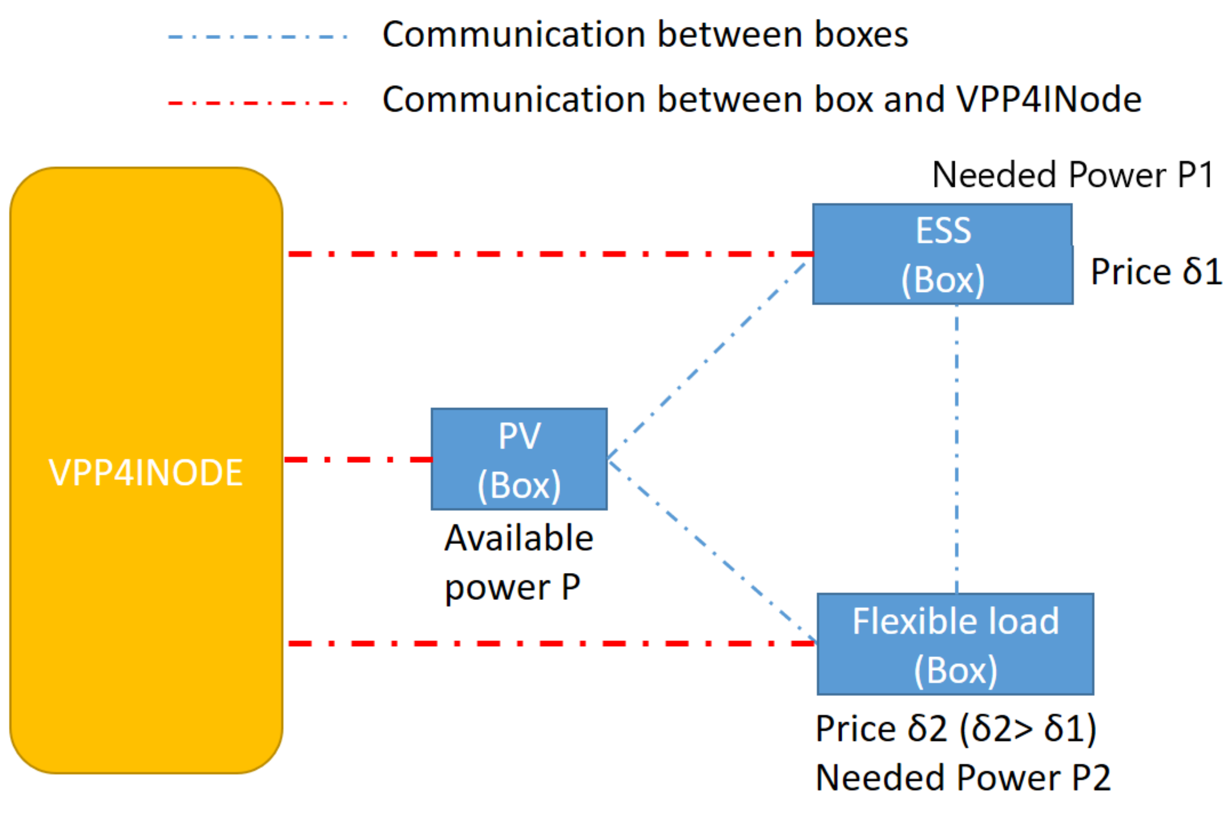

Figure 9: Example of smart contract application within an energy community

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In the example the PV place a sell order for an active power equal to P and a price equal to δ the flexible load place a buy order for an active power equal to $P2$ and a price equal to $\delta 2$, finally the ESS place a buy order for an active power equal to $P1$ and a price equal to $\delta 1$. Since

$$\delta_2 > \delta_1 > \delta$$

$$P > P2$$

$$P - P2 < P1$$

At the end of the auction the flexible load will buy an amount of power equal to $P2$ for a price equal to $\delta 2$. The ESS will buy a quantitative of power equal to $P - P2$ for a price equal to $\delta 1$. To certify the results of the auction there will be a smart contract between both the PV and the flexible load and between the PV and the ESS. The **smart contracts** will have all the information contained in the orders and auction results between the two participants that close the deal.

Following are described the order processing will be implemented for Peer-to-Peer energy trading in Formentera:

An auction mechanism, similar to that one in the example will be implemented (dynamic pricing).

I. As it can be observed in the example the auction it is done by the **VPP4IBoxes** through the **Peer-to-Peer Energy Engine.** The **VPP4IBoxes** will be able to communicate with each other and will be able to participate to auctions and place sell/buy orders. Each order will contain the information including the time period for the energy exchange, the amount of energy to be exchanged, the price of the energy to be exchanged and the details about the seller and buyer energy.

II. The smart contract will be saved in the **DLT remote Database.**

III. A mechanism for evaluate every participant will be implemented. The participants that will not deliver or consume the amount of power specified in the smart contract will be penalized by a low reputation.

IV. The **VPP4INode** through will be able to verify if the power sell with the smart contract will be produced, and if the power buy with the smart contracts will be consumed. A mechanism of settlement and penalties will be implemented.

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An example of order processing that is described in Figure 10, in particular this this the order processing using in "*Elecbay*" a Peer-to-Peer energy trading platform, .

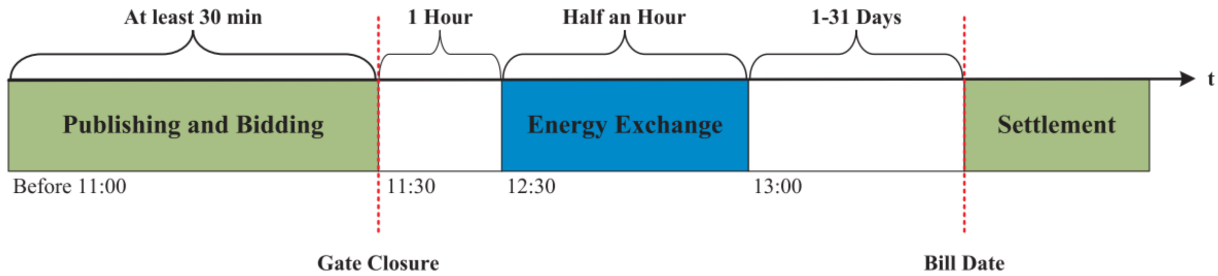

Figure 10: Example of order processing for Peer-to-Peer energy trade

Phase 6: Implementation of the Policies for the Authentication and Authorization Infrastructure

In this Phase, the **policies for the authentication and authorization infrastructure** for the VPP4ISLAND solution for energy community will be design and implemented.

I. Identify subjects. Subjects are entities requesting an operation on resources such as modules in VPP4INodes or individuals.

II. Identify resources in the system. Resources are logical object or and entity (i.e., data) to be protected from unauthorized use. Moreover, in this step will be identify

   a. Under which conditions may what information be shared with which subjects

   b. Which subjects may trigger which state change?

III. Identify action applicable to different resources

IV. Describe Natural Language Policies (NPL)

V. Translate NPL is something that can be execute by the machines (Digital Policies)

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Phase 7: Validation of the solution for REC at the DT level

I. The validation will be done through simulations and tests through hardware in the loop (HIL). In this test the modules of VPP4INode and VPP4IPlatform will be tested at digital twin level. The validation period will be around 1 week.

II. In this evaluation will be tested, at laboratory level, the interaction between the components of the VPP4ISLANDS solution:

  a. The connection/communication between VPP4ICloud and VPP4INode.

  b. The connection between VPP4INode and VPP4IBox.

  c. The capacity of the VPP4IBox to measure energy flow and send the measurements to the VPP4INode.

  d. The capacity of the VPP4IBox to send signals to the power converter that control the FL and ESS, (communication between the DER communication interface of the VPP4IBox and power converters).

  e. The capacity of the VPP4INode to receive signal from the data concentrator installed at the secondary substation that feeds the renewable energy community.

III. The functionality connected to flexibility services will be tested within the Digital Twin Environment:

  a. Test the accuracy of the **generation forecasting**.

  b. Test the accuracy of the **consumption forecasting**.

  c. Test the capacity of the **Distributed Optimisation Engine** to provide:

    i. A scheduling for the fuel cell that maximise the self-consumption of the energy produced within the renewable energy community with the respect of power and energy constraints.

  d. Test the capacity of the **BSP module** to:

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i. Realize if any deviation from the forecasting and actual feed-in and consumption was occurred during the day.

ii. Quantify and record the flexibility provide by each element within the energy community through smart contract.

IV. Validation of the **Peer-to-peer energy Engine** and **Smart contracts** for offering flexibility by VPP participants**:**

a. Auctioning of flexibility among VPP participants.

b. Application of settlement and penalties.

c. Penalization of bad actors.

Phase 8: Implementation in the field

After the validation at the digital twin level will be done an implementation in the field. The objective is to maximise the self-consumed energy through the distributed energy engine at VPP4INode level, and to maximise the profit through P2P energy trade at VPP4IBox level (i.e., al level of single component).

The validation will take place in Formentera real live use case and will have a duration of one week.

The **Energy and CO_2 savings** module (at VPP4IPlatform level) the be able to quantify the following KPI:

1. KPI 1: kWh / unit of production.
2. KPI 2: € / kWh, current and accumulated cost.
3. KPI 3: kg current and accumulated CO2,
4. KPI 4: percentage of self-consumption.

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6.4. Scenario 3: Smart planning for energy communities

# Scenario	Scenario 3
Title	**Smart planning for energy communities**
Short Description	In this phase will be use the Smart Planning Tool & Decision Support System module at VPP4ICloud level to find the optimal size of PV and ESS to be installed in the energy community alpha and beta.
Service provided by VPP4Isolution	Optimal sizing of the elements that can be installed in the energy communities. Calculation of the return of investment (ROI) for the investment done within the energy community.
Phases	Phase 1: Creation of a plan in energy communities alpha and beta Phase 2: Comparison of actual and plan performance
Actors and roles	VPP4IPlatform dev team Energy community
Strategic objectives	**SO2: Increase the exploitation and the penetration of renewable energy-based system on the Island.**
Evaluation of VPP4Islands solutions based on KPI	**SO2 KPI - Reduction around 40 % on Fossil fuel consumption in leading islands** It will be calculated how many energy communities should be built to reduce the fossil fuel consumption of the islands of the 40%. The calculation will be done base of the results get in this scenario.
Possible future changes	No potential future changes have been identified at this time.

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Phase 1: Creation of a plan in energy communities alpha and beta

In this phase will be use the **Smart Planning Tool & Decision Support System module** at **VPP4ICloud** level to find the optimal size of PV and ESS to be installed in the energy community alpha and beta.

I. Allow the **SPT & DSS module** to access the following information stored in the **Shared Knowledge base**: historical data on energy community members' consumption, historical data on photovoltaic production in the energy community area, historical data on temperature and irradiance in the energy community area.

II. Allow the **SPT & DSS module** access to use the Virtual Energy Community implemented at the Digital Twin level to perform simulations.

III. The **SPT & DSS** module will design an optimal development plan for the energy communities alpha and beta. The optimal development plant will indicate the optimal size of PV and ESS to be installed in both energy community. The optimization will be carried out while considering multi-parametric aspects as costs, environmental footprint and Return Of Investments (ROI).

Phase 2: Comparison of actual and plan performance

In this phase will be used the **Energy and CO_2 savings module** to evaluate the performance that the energy communities alpha and beta could achieve with the implementation of the optimal plan design by the **SPT & DSS module**.

For both energy communities, alpha and beta, the following steps will be followed:

II. Implement the optimal development plan in the **Virtual Energy Community at Digital** Twin level. The new PVs and ESSs that are scheduled for installation in the optimal development plan will be modelled in the **System Modelling module**.

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III. Simulation of the performance of the energy community with the new assets introduced in the development plan. The simulation will be carried out at Digital Twin level using the Virtual Energy Community.

IV. Evaluation of the performance of the energy community. The evaluation will be carried out by **Energy and CO_2 savings module** (at VPP4IPlatform level). It will be able to quantify the following KPI:

   a. KPI 1: kWh / unit of production.

   b. KPI 2: € / kWh, current and accumulated cost.

   c. KPI 3: kg current and accumulated CO2.

   d. KPI 4: percentage of self-consumption.

V. Comparison of the results obtained in scenario two during the real life implementation with the results obtained with the development plans designed in this scenario. The comparison will be done through the four calculated KPIs of the **Energy and CO_2 savings module**.

7. VPP4ISLANDS SOLUTION REPLICATION IN FOLLOWING ISLANDS

Each follower will model the Island and use the SPT to generate the sustainable plan.

7.1. BOZCAADA

Bozcaada island is small island with around 3000 inhabitants. 17 wind turbines with more 10MW of nominal capacity are installed. In addition, the island is equipped with a solar installation of 20kW and 30kW wind turbine. The electricity generated by these two systems is used to electrolyze water into hydrogen. This gas is stored compressed and used later to generate energy or as fuel in hydrogen-powered cars. Thus, Bozcaada island produce 30 times more than the whole island consumption and the excess energy is fed to the mainland through a sea-cable.

In this context Bozcaada will exploit VPP4Island platform in order to define all the needed requirements, specifications, and infrastructures of a large electric vehicles integration to reduce emissions from thermal cars while ensuring the stability of the electric grid and generate economic benefits.

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Phase 1: System Modelling in the Digital Twin

Since the DSO that operate in the island is UEDAS will be possible model the distribution electrical grid in the Digital Twin at VPP4IPlatform level. In this phase will be modelled in the Digital twin the following elements:

- Distribution network.
- Sea cable.
- #17 Wind Turbines that inject power in the grid.
- The solar installation + wind turbine + electrolyze system.

Phase 2: Collection data

In this phase will be collected the following data:

- Energy consumption in the island.
- Energy production of the wind turbines and PV plants.
- Number of vehicles circulating in the islands.

Phase 3: Creation of plan for a large penetration on electric vehicles in the island.

In the **Digital Twin** will simulate the installation of a large number of charger points for Electric Vehicles (EV).

A reinforcement plan for the power system of Bozcaada will be design at digital twin that will be able to support the integration of the new charger point. As methods of reinforcement of the electrical system will be considered both traditional methods such as the reinforcement of lines, and more innovative methods, such as the installation of energy storage systems in strategic nodes of the network.

Phase 4: Evaluate the plan at Digital Twin level.

The network reinforced with the new development plan will be tested in several states of operation. The performance that will be achieved in the network will be evaluated by the **Energy and CO_2 savings module** at VPP4IPlatform level. It will be able to quantify the following KPI:

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a. KPI 1: kWh / unit of production.

b. KPI 2: € / kWh, current and accumulated cost.

c. KPI 3: kg current and accumulated CO2.

d. KPI 4: percentage of self-consumption.

Finally, the performance of the power system before and after the development plan will be compared. The comparison will be done through the four calculated KPIs of the **Energy and CO_2 savings module**.

7.2. GRADO

Grado island is very close to mainland, and it is connected to Italy via a direct bridge. Grado accommodate a strong energy infrastructure including smart meter and advanced IoT system comparing with standard island.

Phase 1: Individuation of a potential area to build a renewable energy community and collect consumption data.

In this phase, an area will be identified in which a renewable energy community could be built within the City of Grado.

Once the area is identified, data will be collected on the electricity consumption of end users who have a POD in that area. If it is not possible to obtain the consumption data of the end users of the area will be used the consumption profiles obtained from the Gökçeada scenario.

Phase 2: Create a plan with the Smart Planning Tool.

A Virtual Energy Community will be created at the VPP4IPlatform level that will model the end users and renewable facilities installed in the area.

The smart planning tool will be able to dimension the optimal size of PV and energy storage systems to be installed in the area of the renewable energy community. The optimization will consider multiple aspects such as cost, ROI and environmental footprint.

Phase 3: Evaluate the plan at Digital Twin level.

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The performance that will be achieved in the renewable energy community after the installation of the reinforcements will be evaluated by the **Energy and CO_2 savings module** at VPP4IPlatform level. It will be able to quantify the following KPI:

a. KPI 1: kWh / unit of production.

b. KPI 2: € / kWh, current and accumulated cost.

c. KPI 3: kg current and accumulated CO2.

d. KPI 4: percentage of self-consumption.

Finally, the performance of the power system before and after the development plan will be compared. The comparison will be done through the four calculated KPIs of the **Energy and CO_2 savings module**.

7.3. Bornholm

Bornholm island has already taken many steps towards decarbonization, especially in the district heating system, where local biomass is the main fuel. About 65 % of the consumed electricity is produced on the island, with a combination of wind turbines, PV, biogass, and a woodchip fuelled CHP.

The electric connection to the mainland (sea cable to Sweden) has a limited capacity (60 MW), and the introduction of more electricity production from Wind and PV will require a VPP setup, to align the consumption better with production, especially in periods when the sea-cable will have to little capacity to export surplus production.

VPP4Islands platform will simulate the integration of the 100 MW wind turbine capacity, placed offshore along with the island energy-system, by coupling the electric system with the district heating system.

The actions of the interventions developed in the project, together with a 25 MW power-to-X capacity, and 10 MW electric boilers, at the CHP will be explored by the means of an already developed simulation model of the total energy system on the island.

Plans for the 100 MW Wind park is currently being developed by a citizen initiative, to be implemented in 2025.

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BEOF will model and generate sustainable plan for the district heating system. All plans will be initiated and assessed during the end of the project.

Figure 11: Digital Twin of Bornholm – User Interface

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Figure 12: Digital Twin of Bornholm - live data

Phase 1: System modelling in the Digital Twin

The Digital Twin of Bornholm, shown in Figure 11 and Figure 12 will be connected to the VPP4IPlatform. The Digital Twin of Bornholm contains the information about the generations of the plans the consumption of users and the price of day-ahead market.

The Boilers and the CHP will be modelled in the Digital Twin.

The 100 MW wind turbines that are planned will be modelled in the Digital Twin.

Phase 2: Optimal set point for Day-ahead market

In this phase will consider a portfolio of generation own by the citizen. The portfolio will consist of off-shore wind turbines (100MW) and heating district assets such as boilers and CHP.

The **Distributed optimisation Engine** will be able to calculate the optimal scheduling of the CHP and the boilers. The optimisation will have as objective the maximisation of the profit in the day-ahead market. A forecasting of the production of the of the wind turbines will be carried out.

Phase 3: Evaluation of the results

The performance that will be achieved in the heating district after the installation of the 100 MW wind turbines will be evaluated by the **Energy and CO_2 savings module** at VPP4IPlatform level. It will be able to quantify the following KPI:

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a. KPI 1: kWh / unit of production.

b. KPI 2: € / kWh, current and accumulated cost.

c. KPI 3: kg current and accumulated CO2.

d. KPI 4: percentage of self-consumption.

Finally, the performance of the power system before and after the installation of the wind turbines will be compared. The comparison will be done through the four calculated KPIs of the **Energy and CO_2 savings module**.

8. CONCLUSION

The objective of the D2.8 “*Scenarios for studying VPP4Islands concept”* is to design a number of representative scenarios will be demonstrated in the real-life use cases of Gokceada and Formentera.

Firstly, a study of the market structure in Turkey was done, highlighting structures and processes of the day-ahead and intraday market. Secondly, a study of the European regulation framework on energy community is reported. The study is enriched with Spanish and Turkish regulatory frameworks on energy communities and energy cooperatives.

For each of the two leading islands, Gokceada and Formentera, three scenarios were designed to investigate the functionality of the VPP4ISLANDS solution. The scenarios described take into account the electricity market structure and local regulatory frameworks.

Each scenario is broken down into multiple stages of implementation. Each implementation phase is described in detail. In the description of the phases, the functionality of the solution elements (i.e., VPP4IPlatform, VPP4INode, and VPP4IBox), and the internal modules of the elements capable of accomplishing the described functionality are emphasized. For each scenario, the strategic objectives to which they refer and the KPIs that will be used to evaluate the achievement of these are listed.

Overall, this report presents the scenario that will be implemented in VPP4ISLANDS project. The scenarios will be used by later tasks and deliverables and provide a foundation for the implementation of the technological solutions.

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