Virtual Power Plant for Interoperable and Smart isLANDS

VPP4Islands

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ALPHABETICAL LISTS OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
AAI	Authentication and Authorization Infrastructure
ALWA	AlgoWatt
AMU	Aix-Marseille Université
BC2050	Blockchain2050
BornholmsVarme	Bornholms Varme A/S
BoZI	Bozcaada Belediye Baskanligi
BSP	Balancing Service Provision
BUL	Brunel University London
CIVI	CIVIESCO srl
CSIC	Consejo Superior de Investigaciones Científicas
CU	Cardiff University
DAFNI	Network of Sustainable Greek Islands
Dapp	Decentralized Application
DeFi	Decentralized Finance
DER	Distributed Energy Resources
DLT	Digital Ledger Technologies
DoS	Denial of Service
DSO	Distribution System Operator
DT	Digital Twin
EMS	Energy Management Systems
ETH	(the abbreviation of Ethereum’s cryptocurrency)
EVM	Ethereum Virtual Machine
FORM	Consell Insular de Formentera
FTK	FTK Forschungsinstitut fur Telekommunikation und Kooperation EV
GHG	Greenhouse gases
GRADO	Comune di Grado

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IDEA	Ingenieria Y Diseno Estructural Avanzado
IoT	Internet of Things
INAVITAS	INAVITAS Enerji AS
LCOE	Levelised Cost of Energy
LIS	Laboratoire Informatique des Systèmes
LTO	(the abbreviation of LTO Network's cryptocurrency)
LTO Network	Liquid Task Orchestration Network
MAD	Market Abuse Directive
MSD	Market Systems Development
MTtC	Mean Time to Confirmation
P2P	Peer-to-Peer
PoS	Proof of Stake
PoW	Proof of Work
PBFT	Practical Byzantine Fault Tolerance
PV	Photovoltaic
PVM	Protisvalor Méditerranée
RDIUP	RDI'UP
REGENERA	REGENERA LEVANTE
RES	Renewable Energy Sources
RTU	Remote Terminal Unit
SCHN	Schneider Electric
SPoF	Single Point of Failures
TROYA	TROYA CEVRE DERNEGI
TSO	Transmission System Operator
UEDAS	Uludag Electric Dagitim
UI/UX	User Interface / User Experience
VESS	Virtual Energy Storage Systems
VPP	Virtual Power Plant
VU	Virtual Units

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Executive Summary

Smart Contracts are the integral tool of Blockchain, and they compose an essential asset for those who seek to automate physical and digital procedures by adding a layer of undoubtful trust among involved participants.

Although Smart Contracts are nothing more than conditional executable code, what makes them unique, is the fact that they function in Blockchain environments, which automatically makes them immutable, thus completely unaffected by unauthorized modifications and other malicious acts. Like transactions on a blockchain, a Smart Contract can only be changed by being substituted by another one, always guided by the blockchain's consensus. Based on the above, it becomes clear why Smart Contracts have become the denominator of mutual trust when it comes to any kind of digital transactions.

The present deliverable report sheds some light on the basics of Distributed Ledger Technology (DLT) and Blockchain and introduces Smart Contracts' objective and scope into the VPP4Islands project. Since the project is young and specific details have yet to be emerged, the technical specifications of Smart Contracts are identified in terms of a roadmap to be followed. The intended development process as well as the implementation procedure are also being described as methods that will ensure the optimal deployment of Smart Contracts that will cover several core parts of the VPP4Islands spectrum.

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1. Introduction

1.1. About VPP4Islands

Under the Horizon2020 framework, the submitted proposal "VPP4Islands" was evaluated positively by the EU Commission and on October 1st, 2020 the 42 months project commenced. VPP4Islands goal is to accelerate the transition towards smart and green energy by facilitating the integration of Renewable Energy Systems (RES) in island areas. It also aims to help islands exploit energy efficiency potential and innovative storage approaches, foster the active participation of citizens and become self-sufficient in energy. All these, while reducing costs, greenhouse gas (GHG) emissions and reliance on fossil fuels to generate power. Another goal is to also create new intelligent business, growth and local skilled jobs.

For the realization of the above, VPP4Islands project proposes disruptive solutions based on Digital Twin (DT) concept, Virtual Energy Storage Systems (VESS) and Distributed Ledger Technology (DLT) to revolutionize the existing VPP and build smart energy communities.

Based on aggregation and smart management of Distributed Energy Resources (DERs), VPP4Islands will increase the flexibility and profitability of energy systems while providing novel services. VPP4Island will also enhance the Demand Response Capability of consumers by understating their behaviors and promoting self-consumption.

1.2. Distributed Ledger Technology (DLT) & Blockchain

Blockchain technology enables everyone involved in a transaction to know with certainty what happened, when it happened, and confirm other parties are seeing the same thing without the need for an intermediary providing assurance, and without a need to reconcile data afterwards.

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The terms “Blockchain” and “DLT” are often used interchangeably but to understand Blockchain, it’s important to differentiate it from Distributed Ledger Technology (DLT).

DLT is a decentralized database managed by multiple participants, across multiple nodes. In relation to Blockchain, DLT is the fundamental framework that supports it. Blockchain is a type of DLT where transactions are recorded with an immutable cryptographic signature called a hash. The transactions are then grouped in blocks and each new block includes a hash of the previous one, chaining them together, hence why distributed ledgers are often called blockchains.

1.2.1. Description

With traditional methods for recording transactions and tracking assets, participants on a network keep their own ledgers and records. Such methods can be expensive, partially because it involves intermediaries that charge fees for their services. It’s clearly inefficient due to delays in executing agreements and the duplication of effort required to maintain numerous ledgers. It’s also vulnerable because if a central system is compromised, due to fraud, cyberattack, or a simple mistake, the entire business network is affected.

The Blockchain architecture gives participants the ability to share a ledger that is updated, through peer-to-peer replication, every time a transaction occurs. Peer-to-peer replication means that each participant (node) in the network acts as both a publisher and a subscriber. Each one interacts with other nodes, by sending and receiving transactions, while the data is synchronized across the network as it is transferred.

A Blockchain network is efficient and cost-effective because it eliminates duplication of effort and reduces the need for intermediaries. It is also less vulnerable due to the fact that it uses consensus models to validate information. Transactions are secure, authenticated, verifiable and traceable, thus all blockchain-enabled procedures are characterized by ensured transparency.

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1.2.2. Functionality

Blockchain consists of three important concepts: blocks, nodes, and validators.

Blocks

Every chain consists of a sequence of blocks and each block has two basic elements: the data and the hash.

When the first block of a chain is created (Genesis Block), a cryptographic hash is generated. The data in the block is considered signed and forever tied to the hash. When a subsequent block is created, the along with its own hash, it will bear the hash of the previous block on the chain. This is how each new block is chained with the last of the chain, and this procedure goes on indefinitely, every time a new block is created.

Nodes

One of the most important concepts in Blockchain technology is decentralization. No one computer or organization can own the chain. Instead, it is a distributed ledger via the nodes connected to the chain. Nodes can be any kind of electronic device that maintains copies of the chain and keeps the network functioning.

Every node has its own copy of the chain and the network must algorithmically approve any newly mined block for the chain to be updated, trusted and verified. Since blockchains are transparent, every action in the ledger can be easily checked and viewed. Each participant is given a unique alphanumeric identification number that shows their transactions.

Validators

Blockchain has nodes that create new and attach new blocks on the chain through a process called validation or another one called mining. The consensus algorithm of the blockchain network defines which process is followed. Networks that use Proof of Work consensus (PoW) has miners, while networks that that use Proof of Stake consensus (PoS) has validators.

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In a blockchain every block has its own hash, but also references the hash of the previous block in the chain, so mining a block isn't easy, especially on large chains. Miners use special software to solve the incredibly complex math problem of finding the acceptable hash. When that happens, miners have their block added to the chain and the miners is awarded financially. Mining is a very power-consuming process, especially on big chains. Validation on the other hand, addresses this issue.

Making a change to any block earlier in the chain requires re-mining not just the block with the change, but all of the blocks that come after. This is why it's extremely difficult to manipulate blockchain technology. It is as "safety in math" since finding the acceptable hash requires an enormous amount of time and computing power.

1.2.3. Benefits

For business, Blockchain has the following specific benefits:

- **Time savings:** Transaction times for complex, multi-party interactions are slashed from days to minutes. Transaction settlement is faster, because it doesn't require verification by a central authority.
- **Cost savings:** A Blockchain network reduces expenses in several ways:
    - Less oversight is needed because the network is self-policed by network participants, all of whom are known on the network.
    - Intermediaries are reduced because participants can exchange items of value directly.
    - Duplication of effort is eliminated because all participants have access to the shared ledger.
- **Tighter security:** Blockchain's security features protect against tampering, fraud, and cybercrime. If a network is permissioned, it enables the creation of a members-only network with proof that members are who they say they are, and that goods or assets traded are exactly as represented.

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Not all Blockchains are built for business. Some are permissioned while others aren't. A permissioned network is critical for a business-oriented Blockchain, especially within a regulated industry. It offers:

- **Enhanced privacy:** Through the use of IDs and permissions, users can specify which transaction details they want other participants to be permitted to view. Permissions can be expanded for special users, such as auditors, who may need access to more transaction detail.
- **Improved auditability:** Having a shared ledger that serves as a single source of truth improves the ability to monitor and audit transactions.
- **Increased operational efficiency:** Pure digitization of assets streamlines transfer of ownership, so transactions can be conducted at a speed more in line with the pace of doing business.

1.3. Smart Contracts

A smart contract is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract. Smart Contracts allow the performance of credible transactions without third parties. They are potentially one of the most useful tools associated with Blockchain. They are self-executing programs that run on a decentralized network such as blockchain and help automation business applications.

Due to the fact that they are able to remove administrative overhead, Smart Contracts are one of most attractive features associated with Blockchain technology. While Blockchain acts as a kind of database, confirming that transactions have taken place, Smart Contracts execute pre-determined conditions. Once certain conditions of a Smart Contract are met, a variety of events may trigger: goods are dispatched, cargos arrive in a port, two parties agree to an exchange in cryptocurrency, automate the transfer of digital or fiat money, issue and send a receipt, release funds, etc.

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1.3.1. Description

As a term, “Smart Contracts” is used to describe computer code that automatically executes all or parts of an agreement and is stored on a Blockchain-based platform. The code can either be the sole manifestation of the agreement between parties or might complement a traditional text-based contract and execute certain provisions, such as transferring funds from Party A to Party B. The code itself is replicated across multiple nodes of a Blockchain and, therefore, benefits from the security, permanence, and immutability that a Blockchain offers. That replication also means that as each new block is added to the blockchain, the code is, in effect, executed. If the parties have indicated, by initiating a transaction, that certain parameters have been met, the code will execute the step triggered by those parameters. If no such transaction has been initiated, the code will not take any steps. Most Smart Contracts are written in one of the programming languages directly suited for such computer programs, such as Solidity.

1.3.2. Functionality

At present, the input parameters and the execution steps for a Smart Contract need to be specific and objective. In other words, if “x” occurs, then execute step “y.” Therefore, the actual tasks that Smart Contracts are performing are fairly rudimentary, such as automatically moving an amount of cryptocurrency from one party’s wallet to another when certain criteria are satisfied.

Before a compiled Smart Contract can be executed on certain Blockchains, an additional step is required, namely, the payment of a transaction fee for the Contract to be added to the chain and executed upon. In the case of the Ethereum Blockchain, Smart Contracts are executed on an environment called Ethereum Virtual Machine (EVM), and this payment, made through the Ether cryptocurrency (ETH), while in the case of LTO Network Blockchain, Smart Contracts are executed by paying LTO Tokens (LTO). Assets such as ETH or LTO are called “gas”. The more complex the Smart Contract (based on the transaction steps to be performed), the more gas that must be paid to execute the Smart Contract. Thus, gas currently acts as an important gate to

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prevent overly complex or numerous Smart Contracts from overwhelming the Blockchain environment.

Smart Contracts are presently best suited to execute automatically two types of "transactions" found in many contracts:

1. ensuring the payment of funds upon certain triggering events and
2. imposing financial penalties if certain objective conditions are not satisfied.

In each case, human intervention, including through a trusted escrow holder or even the judicial system, is not required once the Smart Contract has been deployed and is operational, thereby reducing the execution and enforcement costs of the contracting process.

Smart Contracts have the potential to eliminate the so-called procure-to-pay gaps. When a product arrives and is scanned at a warehouse, a Smart Contract could immediately trigger requests for the required approvals and, once obtained, immediately transfer funds from the buyer to the seller. Sellers would get paid faster and no longer need to engage in dunning, and buyers would reduce their account payable costs. This could impact working capital requirements and simplify finance operations for both parties. On the enforcement side, a Smart Contract could be programmed to shut off access to an internet-connected asset if a payment is not received. For example, access to certain content might automatically be denied if payment was not received.

1.3.3. Benefits

- **Trust**

  Smart Contracts generate absolute confidence in their execution. The transparent, autonomous, and secure nature of the agreement removes any possibility of manipulation, bias, or error. Once solemnized, the Contract is executed automatically by the network.

- **Autonomy and savings**

  Smart Contracts do not need brokers or other intermediaries to confirm the agreement, since all validations are conducted automatically via the inherit consensus mechanism; thus, they

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eliminate the risk of manipulation by third parties. Moreover, the absence of intermediary in Smart Contracts results in cost savings. Perhaps one of the most significant advantages of automated contracts is that they eliminate the need for a vast chain of middlemen. There's no need for lawyers, witnesses, banks, and other intermediaries.

- **Storage and Backup**
  All data stored on Blockchain are duplicated multiple times in a Peer-to-Peer (P2P) manner; thus, in the event that any participating node losses data, they can be restored back. These Contracts record essential details in each transaction. Therefore, anytime your details are used in a Contract, they are permanently stored for future records. In the event of data loss, these transactions are easily retrievable, by tracing back the encrypted transaction data in the Blockchain.

- **Safety and Security**
  Smart Contracts are encrypted, and cryptography keeps all the documents safe from infiltration. Automated contracts use the highest level of data encryption currently available, which is the same standard that modern crypto-currencies use. This level of protection makes them amongst the most secure items on the world wide web.

- **Speed**
  Smart Contracts automate tasks by using computer protocols, saving hours of various business processes. These contracts run on software code and live on the internet. As a result, they can execute transactions very quickly. This speed can shave hours off many traditional business processes. There is no need to process documents manually.
- **Accuracy**
  Using Smart Contracts results in the elimination of errors that occur due to manual filling of numerous forms. One of the primary requirements of a Smart Contract is to record all terms and conditions in explicit detail. This is a requirement because an omission could result in

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transaction errors. As a result, automated contracts avoid the pitfalls of manually filling out heaps of forms.

- **Efficiency**
  A natural by-product of the speed and accuracy of these contracts is the efficiency with which they operate. Higher efficiencies result in more value-generating transactions processed per unit of time.

- **Transparency**
  The terms and conditions of these Contracts are fully visible and accessible to all relevant parties. There is no way to dispute them once the Contract is established. This facilitates total transparency of the transaction to all concerned parties.

- **Clear Communication**
  The need for accuracy in detailing the contract results in everything being explicit. There can be no room for miscommunication or misinterpretation. Thus, Smart Contracts can drastically cut down on efficiency lost to gaps in communication.

- **Guaranteed Outcomes**
  Another attractive feature of these Contracts may be the potential to reduce significantly or even eliminate the need for litigation and courts. By using a self-executing contract, parties commit themselves to bind by the rules and determinations of the underlying code.

- **Paper Free**
  Businesses across the globe are becoming increasingly conscious about their impact on the environment. Smart Contracts enable the “go-green” movement because they live and breathe in the virtual world. This removes the need for vast reams of paper.

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2. Identification of Smart Contracts Requirements

The fundamental structural elements that build a Smart Contract are data and processes translated into code. For VPP4Islands project, the precise identification of data involved in Smart Contracts' realization derives from each different process that needs to be ensured through Blockchain technologies.

For this purpose, it is essential to undergo a step-by-step multi-perspective procedure in order to define the Smart Contracts' requirements, identify omissions or other possible obstacles and proceed to all precautionary actions to minimize or eliminate them if possible, before Smart Contracts are set in full operational mode.

For achieving the above, a questionnaire for the definition of Smart Contracts' requirements was distributed to the technical partners of VPP4Islands in order to pinpoint their exact needs on the project's aspects they are working on. Subsequently, their replies were combined to already defined valuable information derived from preceding WP2 tasks. Both the questionnaire itself, as well as the replies given by the technical partners, are included in Annex A.

2.1. Smart Contracts Scope & Objectives

The scope of Smart Contracts is to automate specific procedures within the VPP4Islands framework in order to facilitate cooperation between all involved stakeholders, by establishing a layer of common trust. This facilitation will be achieved by reducing the processing time of procedures, especially those that require time consuming paperwork and delays due to co-signing of documents, etc. Moreover, Smart Contract implementation will reduce operational costs, both by reducing processing times and through the elimination of intermediaries, and other excess unnecessary costs.

The objectives of Smart Contracts are oriented towards an optimal and seamless operation, by achieving high numbers of transactions per second (Tx/sec) and a short and stable Mean Time

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to Confirmation (MTtC) with minor deviations. In addition, the modularity of the system should be unaffected by the system’s size. In this context, the latter should not be in position to affect the system’s efficacy and performance in terms of scalability and efficiency, regardless of the number nodes that comprise it upon delivery or in the distant future.

2.2. Technical Requirements

2.2.1. Blockchain Protocols

A protocol is a set of rules or procedures that govern the transfer of data between two or more electronic devices and its function is to establish how the information must be structured and how each party will send and receive it in order for computers to exchange information.

A Blockchain protocol operates on top of the Internet, on a Peer-to-Peer (P2P) network of computers that all run the protocol and hold an identical copy of the ledger of transactions, enabling P2P value transactions without a middleman though machine consensus.

The Ethereum Protocol

The design objective behind Ethereum’s protocol is about creating a blockchain platform for developers to facilitate the launch of their own blockchain projects and Decentralized Applications (Dapps). Thus, a public, permissionless blockchain emerged with its underlying technology comprised by cryptographic hash function, digital signature, P2P network, private-and-public key encryption, and a Proof-of-Work consensus algorithm. Every Ethereum node has access to complete information on the blockchain. Users can conduct non-reversible transactions without the need to explicitly trust a third-party. The Ethereum blockchain gives a larger, wider horizon to the objectives that blockchain could serve.

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Ethereum 2.0 refers to Ethereum's transition from PoW consensus to PoS. Ethereum 2.0 is an upgrade to its existing blockchain. It aims to increase the speed, efficiency, and scalability of the Ethereum network, enabling it to address the bottlenecks and increase the number of transactions.

The LTO Network Protocol

LTO Network's platform has implemented the NG Protocol that was proposed to reduce the scalability issues on Bitcoin. While it was never implemented on Bitcoin, Waves NG is active on their main net since December 2017. With NG, two types of blocks are generated: the micro-block and the key block. The node that was previously elected may continue validating transactions, creating micro blocks on average every 3 seconds. When a new node is elected it creates a key block from the outstanding micro blocks. Transactions in a micro-block can be considered secure to some extent and are suitable for low-risk transactions like anchoring. The reward of the transaction fees is split between the node that forged the micro-block and the node that forged the key block in a 40%-60% split. This split must always be in favor of the key block forger. Otherwise, there would be an incentive to disregard the already forged micro-blocks and create new micro-blocks yourself.

2.2.2. Roles to coordinate

Blockchain technology is firmly established as a revolutionary new technology, not only for underpinning cryptocurrency but for its strong potential to advance procedural automation via Smart Contracts implementation. The potential applications of this technology can be found across a wide variety of sectors and industries, providing a novel way of producing coordination necessary to transact online. This renders it as one of the best available solutions able to promote further digitalization, and to effectively cope with the increasing demands for efficiency and security of online transactions.

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To make the view of coordination in blockchain-based transactions more complete, consensus protocols should be considered together with other aspects of the transaction processes that require coordination. For a transaction to take place, a contract must be signed, its conditions must subsequently be fulfilled, before the transaction is successfully executed, thus creating a situation of interdependency requiring some sort of coordinated actions. Contracts in themselves are coordination mechanisms. Blockchain technology enables the Smart Contracts to be established on a given blockchain, enabling autonomous execution of transactions whenever conditions stipulated in the contract are met. Thus, Smart Contracts effectively integrate and autonomously coordinate recognition of conditions fulfillment and contract execution aspects of transaction coordination [1].

It is apparent that through Smart Contracts, Blockchain can be modelled as an automated mechanism for online transactions by producing consensus about the information and facts included in the transaction, and subsequently to create Smart Contracts, by translating processes and procedures into executable computer code. The deployment of said Contracts ensures the distinct role of each participating stakeholder in a blockchain, by specifying permissions or setting restrictions regarding its presence and its assigned activities in the blockchain.

In the context of VPP4Islands project, consensus of involved data and stakeholders within a given procedure should be carefully designed in order to establish an environment of mutual trust that will also provide engagement incentives for both existing and new participants. The design of each individual Smart Contract will be made based on the collective results from questionnaires dispatched among WP2 partners, that deal with information and data flows as well as procedural aspects of the project. Each relevant Smart Contract will deliver optimal and automated coordination for processes and/or procedures, ensuring the validity of operations and data, while reducing procedural costs and times.

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2.2.3. Data Exchange

Blockchain technology will facilitate data exchange between modules as well as information between producers, consumers, DSOs, TSOs and other stakeholders, by providing an undisputable layer of trust and transparency.

Among others, the results of T2.4 will specify the design of standardized interfaces and data management and their optimal exchange between the different actors involved in the flexibility service provision of VPP4Islands. The above will define parts of the Blockchain communication configuration as well as the functionality of the relevant Smart Contracts. This will be further supported by the outputs of T3.1 and T3.2 that will serve as the basis for the definition of the information exchange and the interactions between all involved actors and the flexibility market.

A thorough list of data to be exchanged to serve the needs of core VPP4Islands procedures, can be found in paragraph 3.1.

2.2.4. Performance Requirements

Precise performance requirements cannot be clearly defined at this point of the project. As the overall structure of the VPP4Islands framework materializes step-by-step along with the project's progress, better and better estimates will emerge, resulting eventually in safe values that will pave the way for optimized Smart Contracts' configuration.

Overall, transactions per second (Tx/sec) should be as high as possible while the Mean Time to Confirmation (MTtC) should be as short as possible with minor deviations. This will ensure system stability and reliability towards transactions handling.

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2.3. Functional Requirements

2.3.1. Authentication and Authorization Infrastructure (AAI) Support

Authentication confirms that users are who they say they are. Authorization gives those users permission to access a resource. Organizations face the challenge of efficiently controlling user access to data and resources. For this purpose, adequate systems for reliable user identification and subsequent authorization to use data and services are established where needed. In order to encourage those interested to adopt such systems, state-of-the-art features such as Identity Management and Single Sign-on are required. Systems for implementing these features are currently being set up by many organizations and federations and they are commonly referred to as AAI – Authentication and Authorization Infrastructures.

Equipping a platform with proper means for access control is demanding, but these means are typically implemented according to a centralized approach, where a single server stores and makes available a set of identity attributes and authorization policies. Having a single root of trust is not suitable in a distributed and cooperating scenario of large-scale projects due to their multi-tenant deployment. In fact, each of the integrated systems has its own set of security policies, and the other systems need to be aware of these policies, in order to allow seamless use of the same credentials across the overall infrastructure (realizing what is known as the single-sign-on). This imposes the problem of consistent and secure data replicas within a distributed system, which can be properly approached by using the Blockchain technology. Therefore, Blockchain consists of a solid solution for distributed management of identity and authorization policies by leveraging on the distributed ledger technologies to hold a global view of the security policies within the system and integrating it in VPP4Islands.

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2.3.2. Anti-Fraud Properties

One of the many value propositions for implementing Blockchain technology is the decrease in fraud risk. The technology is anti-fraud by design - the most common theme in its application is the trust amongst all parties involved in a business transaction.

There are many factors that complicate financial transactions: the need for collateral, the time required for settlements, differences in currency denominations, third-party mediation and more. Multi-step processes, especially ones that require human interaction, are prime targets for fraudsters. With Blockchain, information can be shared in real time, and the ledger can only be updated when all parties agree. This reduces time, costs and opportunities to commit fraud, and with lessened time to completion, it is less likely a party won't be paid. In addition, Blockchain helps reduce errors, possible fraud, and transaction processing times in its short selling system for securities lending.

Identity fraud is another critical threat in the digital world, that costs billions every year. Via Blockchain, a person's or organization's digital identity and other sensitive information could be secured in a way that prevents it from being tampered with or used in an unsanctioned way. For this purpose, permissioned blockchains are utilized. These blockchains act like a private network that requires credentials in order to access the information it contains. Once identity information is placed on a permissioned Blockchain framework, authorized parties will have access to one version of the truth, and only known participants can verify transactions and ensure records are valid. The network allows individual consumers to control what information they share, while organizations can efficiently validate a customer's identity and arrange new services. By reducing redundant verification processes and the amount of paperwork needed to execute them, there would be fewer vulnerabilities for criminals to exploit.

Supply chains are complex and usually involve many different stakeholders as well as other direct and indirect participants. Therefore, a lot of holes can be found in which fraud can be committed and go undetected. Blockchain helps to reduce and even prevent fraud in a supply chain through greater transparency and improved traceability of products. It's very difficult to

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manipulate the Blockchain, which is an immutable record that can only be updated and validated through consensus among network participants. Once a product is digitized on Blockchain, it can easily be traced back to its origin because the information is on a shared distributed ledger.

2.3.3. Market Manipulation Prevention

Market manipulation is a form of market abuse, e.g., spreading false information on the market, entering both a buy and a sell order for the same security at the same price, or concealing ownership when disclosure is required by law. Market manipulation constitutes together with insider dealing what is regulated as prohibited market behavior. As the financial markets are of central importance to our economic system, finding apt regulation thereof is crucial. Market abuse is one of the greatest threats to the well-being of the financial markets. The question regarding market manipulation regulation is how to find a line between harmful trading and strategic trading.

Although market manipulation is a form of economic behavior aiming at creating false impressions as regards the value of financial instruments, it cannot be defined as every action that puts pressure on the prices of financial instruments, because that would also cover ordinary trading. Moreover, prices are also influenced and distorted by irrational market behavior due to investors' biases, overconfidence, or even fears.

As defined in Market Abuse Directive, 2003/6/EC (MAD), the term "Market Manipulation" refers to the following:

- **False or misleading transactions:** "Transactions or orders to trade, which give or are likely to give, false or misleading signals as to the supply of, demand for or price of financial instruments."
  (*MAD article 2 a. para. 1*).
- **Price positioning:** "Transactions or orders to trade which secure, by a person or persons acting in collaboration, the price of one or several financial instruments at an abnormal or artificial level."
  (*MAD article 2 a. para. 2*).

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- **Artificial transactions:** 'Transactions or orders to trade which employ fictitious devices or any other form of deception or contrivance.'
  (*MAD article 2 b*)
- **False or misleading information:** "Dissemination of information through the media /…/ which give, or are likely to give, false or misleading signals as to financial instruments, including the dissemination of rumors and false or misleading news /…/"
  (*MAD article 2 c*)

The purpose implementing Blockchain and Smart Contracts into the VPP4Islands framework is that of regulating potential market manipulations. The three basic pillars on which the philosophy of the relevant Smart Contracts will be built on, are:

1. apply regulations that secure the market functions
2. enable the enhancing of investor confidence and market efficiency
3. any prohibitions should be action-specific rather than comprehensively sorted

The principles that will underlie and support any regulation of market manipulation should be objectively beneficial for the market, so its best possible efficiency is achieved. All potentially harmful behaviors that affect the efficiency of the financial market should be carefully identified and described before being transformed into code for Smart Contracts, in order to ensure fairness and transparency between all participating stakeholders.

2.3.4. Incentives based Game Theory

Based on the regulations which will act as the base of the Smart Contracts realization, several incentives will be introduced in order to prevent market manipulation and any other predatory behavior, such as assets hoarding.

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An incentive contract should be one that minimizes the costs of compliance, minimizes the propensity to commit fraud, maximizes cash benefits to the grantee, maximizes shareholder value before compensating grantees and most accurately matches performance and reward.

For example, a first layer of implementing such incentives could be applied during the terms' negotiation phase of a contract. Incentives that apply zero-sum game principles could be the most engaging ones, since they promote win-win environments. This phase ends when all parties have mutually signed the contract.

In addition, and always in conjunction with several game theory principles, other incentives could be introduced in order to engage all involved stakeholders in participating actively. At the same time any potential fraudulent thoughts and actions would be efficiently discouraged, since that would greatly disturb the balance of earnings-losses of the perpetrator in favor of the latter.

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3. Smart Contracts Contents

3.1. Data Inputs/Outputs

VPP4Islands will be a data-rich platform, receiving data from numerous different sources in real-time. Any data required to be blockchain-secured and/or involved in any number of Smart Contracts, will be secured before leaving its corresponding source, so its intended destination will receive verifiable and trustworthy. The data will be transmitted acquired from the VPPI-Box and transmitted to reach the VPPI Platform. There, all requested data will be blockchain-secured and, from that point on the will be available by every appropriate stakeholder that has a direct need and/or use of said data.

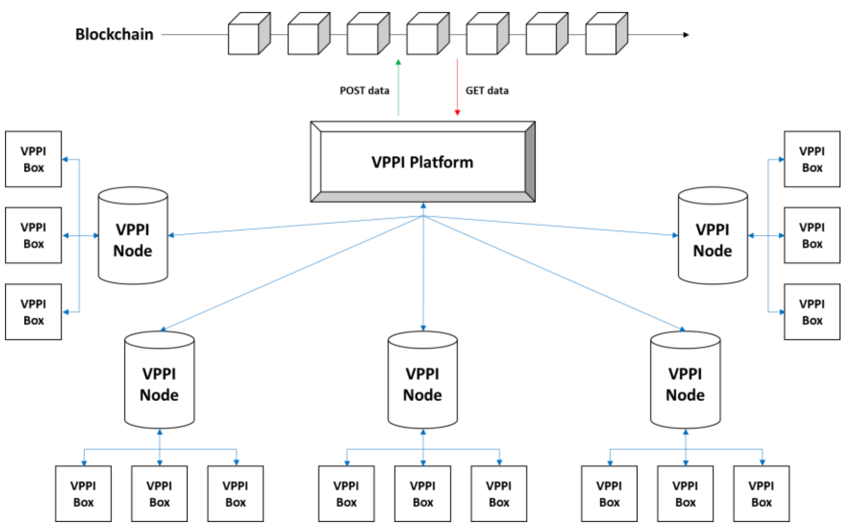

Figure 3.1: Blockchain-secured data distribution (*currently proposed, subject to change*)

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Although the list may be updated at any given time within the duration of the project, a detailed list of data that will be used for this purpose, are:

GRID

- Energy consumption
    - Commercial consumers
    - Industry consumers
    - Private consumers
    - Prosumers
- Energy production
    - Non-renewable distributed energy resources
        - Alarm fault detection
        - Alarm predictive maintenance
        - Availability
        - Degradation mechanism (variable maintenance requirements)
        - Energy generation quantity
        - Energy quantity
        - Equipment's ownership (owner/operator)
        - Fixed Maintenance requirements
        - Fuel characteristics
        - Fuel consumption
        - Generation Efficiency
        - Local fuel cost (€/L or €/kWh)
        - Power quantity
        - Supply duration
    - Prosumers
    - Renewable distributed energy resources
        - Alarm fault detection

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        - Alarm predictive maintenance
        - Availability
        - Degradation mechanism (variable maintenance requirements)
        - Energy generation quantity
        - Energy quantity
        - Environmental conditions
        - Equipment’s ownership (owner/operator)
        - Generation Efficiency
        - Levelised Cost of Electricity
        - Power quantity
        - Supply duration
        - Fixed Maintenance requirements

- Energy storage
    - Alarm fault detection
    - Alarm predictive maintenance
    - Charge duration
    - Degradation mechanism (variable maintenance requirements)
    - Discharge duration
    - Energy charge quantity
    - Energy discharge quantity
    - ESS state-of-charge
    - Energy quantity
    - Equipment’s ownership (owner/operator)
    - Fixed maintenance requirements
    - Internal Rate of Return (for equipment owner)
    - Levelised Cost of Storage
    - Power quantity
    - Round-Trip efficiency...

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- Power demand
    - Commercial consumers
    - Industry consumers
    - Private consumers
    - Prosumers
- Power quality
    - Active/reactive power
    - Congestion
    - Current
    - Frequency
    - Frequency deviations
    - Interruptions
    - Network losses
    - Voltage
    - Voltage deviations

Peer-to-peer trading

- Associated value of energy transaction
- Commission on transactions
- Energy consumption quantity
- Energy generation quantity
- Energy storage control schedule
- Energy transaction between peers
- Grid service requirements
- Local market prices
- National Market prices
- Penalties failure to deliver on agreed Smart Contract

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- Power generation quantity
- Power consumption quantity
- Smart contracts

Sea-Cable monitoring

- Alarm fault detection
- Alarm predictive maintenance
- Availability
- Degradation mechanism (variable maintenance requirements)
- Energy generation quantity
- Energy quantity
- Fixed Maintenance requirements
- Power quantity
- Supply duration

Renewable energy sales

- Bid for encrypted/verified energy transaction
- Energy quantity
- Market prices
- Power purchase Agreement characteristics
- Power quantity
- Smart export guarantee, Feed-in-Tariff, or other incentives
- Supply duration

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System status

- DER
  - CB command
  - CB status
  - Additional information
- Smart meters
  - Consumer type
  - Consumption
  - Load profile
  - Load prioritization recommendations

Weather & Climate

- Air pressure
- Cloud coverage
- Solar irradiance
- Temperature
- Wind vectors
- Wind velocity

3.2. Procedures and Processes

Apart from the required data that will be acquired either directly from their source or indirectly by another VPP4Islands system, several core processes will need to be translated into code in order to be automated in the digital world of Blockchain. Even though the list may be updated at any given time within the duration of the project, the core procedures and processes that will be used for this purpose, are:

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Balancing Service Provision (BSP)

The management of operational processes of Balancing Service Provider refers to an end-to-end solution for the entire operational process, including measurements, communication with TSO, implementation of provisions, monitoring of actions, offers on the energy market and integration with company business process. The platform's architecture is meant to make the platform scalable and modular for the management of multiple enabled Virtual Power Plants and able to follow the evolution of regulation and the market with a "cost-effective" approach oriented towards IoT. All modules of the platform are designed and developed by adopting the most stringent computer security policies, from the point of view of both the security of transmitted and stored data and the resiliency to possible cyber-attacks, such as Denial of Service (DoS). The platform is easily integrated with existing infrastructures o limit interventions in the consumption or production plants.

DER control

The objective is to manage the DER from the VPP4I-Box, based on the inputs received by the upper layers of the VPP4Islands platform. Besides, VPP4I-Box will communicate to those upper layers of the VPP4Islands platform, the status of the managed DER. The process requires a VPP4I-Box, which at least contains a Remote Terminal Unit (RTU), with interfaces with the DER (that could be wired or by communication protocols), and also with the VPP4I-Nodes, that should happen by using communication protocols. The VPP4I-Box would be able to retrieve information from the DER and communicate it to the VPP4I-Nodes, and would also able to operate the DER, based on the commands received by the VPP4I-Nodes.

DSO grid power quality

Power quality measurements from the DSO grid operations (voltage, current, frequency, active/reactive power, etc.) are monitored and recorded, and advanced algorithms determine the

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control strategy to respond to interruptions, voltage/frequency deviations, and potential congestion in the network and calculate network losses.

Energy storage system monitoring

Sensors in the Energy Storage System equipment measure and record data related to its operational parameters such as the storage state-of-charge, energy charge/discharge quantities, response times, environmental factors (temperature, wind speed, air humidity), and e.g., diagnose cell management unit microchips identify capacity retention, reversibility, electrode activity, structural changes, dendritic growth, etc. These parameters will differ based on the technology used for energy storage. Operating parameters are stored and analyzed to find anomalies or detect degradation and send an alarm when a fault is predicted or when predictive maintenance is advised.

Grid Services bidding

Forecasted demand (day-ahead, intraday, reserve market) data and market prices are used to bid into the day-ahead and intraday market to provide potential DSO services (frequency response, demand response, emerging services) services and generate revenue.

Non-renewable energy sources monitoring

Sensors in the non-renewable energy sources measure and record data related to its operational parameters such as the diesel generator's rotations per minute, fuel consumption, energy generation, etc. These parameters will differ based on the technology used for non-renewable energy generation. Operating parameters are stored and analyzed to determine efficiency for partial and dynamic load operation, find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

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Peer-to-Peer trading

From each peer in the P2P blockchain network, the energy generation/consumption quantity (in kWh or MWh), power generation/consumption quantity (in kW or MW) are monitored and recorded, and decisions for selling or purchasing energy are made based on national and local market prices and local grid service requirements. Smart contracts are established between the peers to trade, including commission fees and penalties when failed to deliver on the agreed smart contract.

Renewable energy sales

Forecasted renewable energy generation (power generation, energy generation day-ahead), market prices and power purchase agreement/levelized cost of energy data are used to determine revenue potential of renewable energy sources, as well as potential DSO services (reserve/capacity market, and other revenue streams) and make decisions to sell renewable energy to the grid or use for self-consumption.

Renewable energy sources monitoring

Sensors in the renewable energy sources measure and record data related to its operational parameters such as the wind turbine's rotations per minute, angle of attack, energy generation, etc. These parameters will differ based on the technology used for renewable energy generation. Operating parameters are stored and analyzed to find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

Sea-Cable interconnect monitoring

Sensors in the sea cable interconnect measure and record data related to its operational parameters such as the energy throughput, voltage levels, frequency, etc. (operational schedule).

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Operating parameters are stored and analyzed to find anomalies or detect degradation and send an alarm when a fault is predicted or when predictive maintenance is advised.

SMART ENERGY MANAGEMENT

According to the available data related to the market, consumers, DERs, and grid utility, the smart energy management tools will provide the optimal set points to each renewable energy installation. These set points, when accepted and executed by the DERs will generate a profit (incentive) and/or get special prices for the produced, consumed, or stored energy at a specific period of time. Each installation (DERs, Energy storage system, Controllable load, loads) will communicate its current status (production, State of charge, Consumption), according to these data. The EMS tools will make predictions, select the ancillary services to which the VPP will participate and send the set points to all installations. The EMS tools will get also some data from the market (prices), from DSO (technical specification, authorization)

SMART METERS MONITORING

Smart meters measure and record energy consumption data in industrial, commercial, and residential customers. This data is stored and analyzed to predict load profiles, evaluate energy losses and advise on load shifting.

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4. Smart Contracts Development

4.1. Blockchain Environments

4.1.1. Ethereum

Ethereum is a decentralized, permissionless, non-hierarchical, open-source Blockchain featuring Smart Contract functionality. The platform is the most actively used Blockchain and Ether (ETH) is its native cryptocurrency. The Ethereum Virtual Machine (EVM) can execute scripts and run Dapps. EVM is the runtime environment for smart contracts in Ethereum. It is a 256-bit register stack designed to run the same code exactly as intended. It is the fundamental consensus mechanism for Ethereum.

Ethereum is used for Decentralized Finance (DeFi) and has been utilized for many initial coin offerings. In late 2020, Ethereum has started implementing a series of upgrades called Ethereum 2.0, which includes a transition to from Proof of Work (PoW) consensus to Proof of Stake (PoS) and an increase in transaction throughput.

4.1.2. LTO Network

LTO Network is a hybrid blockchain designed for easy integration of business applications, aimed at breaking data silos that so many organizations face today, using Live Contracts. It has a private layer that utilizes a public Blockchain for consensus. Rather than re-introducing authorization on the network, parties reach consensus by leveraging on the public PoS Blockchain. Anchoring of the hash of private events happens on the public chain. Blocks of the public chain have a specific height, and transactions within a block are also ordered. This order

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provides a globally recognized sequence of events, which is used to reach consensus on the private chain.

4.2. Smart Contracts Architecture

As depicted in *Figure 4.1*, a typical Blockchain system generally consists of six layers, namely from bottom up, data layer, network layer, consensus layer, incentive layer, contract layer and application layer.

- **Data Layer:** This layer includes the underlying data blocks, related encrypted messages, and timestamp, etc.
- **Network Layer:** The blockchain system usually adopts the P2P protocol that is completely distributed and can tolerate a Single Point of Failures (SPoF). Blockchain network nodes have the characteristics of equality, autonomy, and distribution. All the nodes are connected in a topological structure without any centralized authoritative nodes or hierarchy.
- **Consensus Layer:** Consensus layer encapsulates various types of consensus protocols. This is due to the decentralized blockchain is jointly managed and maintained by multiple parties. Common consensus algorithms include PoW, PoS, Practical Byzantine Fault Tolerance (PBFT), etc.
- **Incentive Layer**: The consensus nodes in a decentralized system are self-interested, maximizing revenue is the fundamental goal of their participating in data verification and accounting. Therefore, incentive-compatible mechanisms should be designed, so that the individual rational behavior of the consensus nodes to maximize their own profits can be incentively aligned with the overall goal of guaranteeing the safety and effectiveness of the decentralized blockchain ecosystem.
- **Contract layer:** The Contract Layer encapsulates various types of script codes, algorithms, and sophisticated Smart Contracts, and thus is the basis for flexible programming and manipulation of blockchain systems. Most of the cryptocurrencies,

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including Bitcoin and Litecoin, use non-Turing-complete scripting language which means they have no flow control, namely, no loops or conditionals. Nowadays, more complex and flexible scripting languages for Smart Contracts have emerged, e.g., Solidity and Serpent, which enable blockchain to support a wider range of applications of finance and social systems.

- **Application Layer:** The main application in the Bitcoin system is digital currency transactions. The Ethereum platform, in addition to currency transactions, also supports Dapps. A Dapp is an application that runs on a decentralized network such as Ethereum. Ethereum's Hyperledger Fabric environment is mainly aimed at enterprise-level blockchain applications, and its Dapps can be built on SDKs using programming languages such as Go, Java, Python, and Node.js

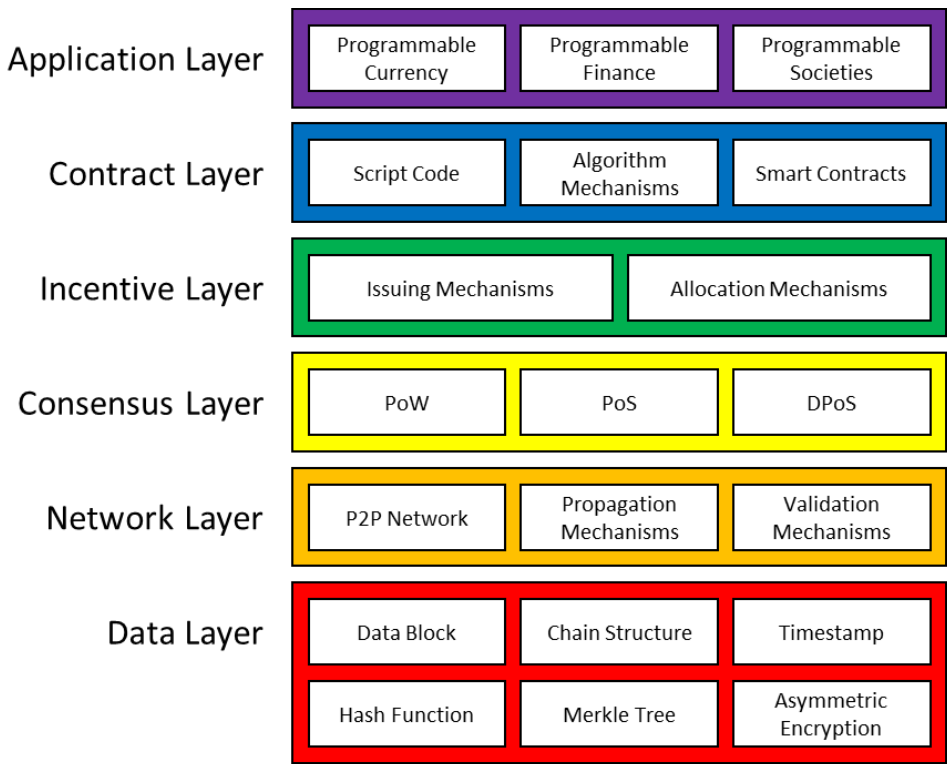

Figure 4.1: Typical Blockchain framework

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Smart Contracts are a set of Scenario-Response procedural rules and logic. In other words, they are decentralized, trusted shared codes that are deployed on blockchain. The parties signing a contract should agree on contractual details, conditions of breach of contract, liability for breach of contract and the external verification data sources (oracles), then deploy it on the blockchain in the form of smart contract thus to automate the execution of contract on behalf of the signatories. The whole process is independent of any central agencies.

The operating mechanism of smart contracts is shown in *Figure 4.2*. Normally, after the smart contracts are signed by all parties, they are attached to the blockchain in the form of program codes (e.g., a Bitcoin transaction), and are recorded in the blockchain after being propagated by the P2P network and verified by the participating nodes. Smart Contract encapsulates a number of pre-defined states and transition rules, scenarios that trigger contract execution (such as at a given time or a particular event occurs), responses in a particular scenario, etc. The blockchain monitors the real-time status of Smart Contracts and executes the contract after certain trigger conditions have been met.

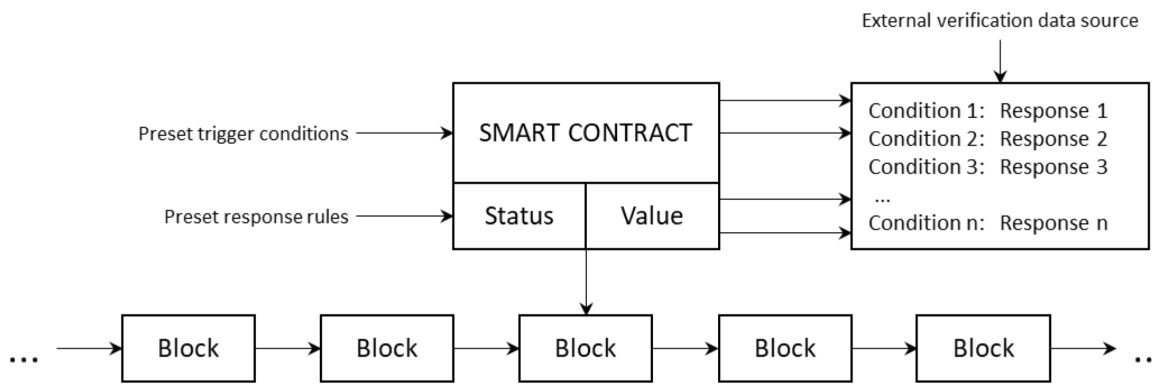

Figure 4.2: Operating mechanisms of Smart Contracts

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5. Implementing Smart Contracts in VPP4Islands

5.1. Iterative Testing

Iterative testing is a gradual optimization process based on evidence and insights gleaned from previous tests, experiments and/or user feedback on preceding implementations. It revolves around the concept of allowing a product to evolve gradually over time with small steps rather than relying on large redesigns. This has the advantage that users are often able to continue using the corresponding product with hardly noticing when changes are being evaluated.

Iterative testing is commonly practiced in a User Interface / User Experience (UI/UX) context, to ensure seamless front-end and back-end operations, but it can also be used in the context of product management. Thus, it consists of an important component of software development. For Smart Contracts, iterative testing is a valuable procedure conducted within appropriate blockchain testing environments (TestNet), in order to debug and optimize their code, before deploying them live.

5.2. Implementation Process

Implementing new software is always a challenging and its success depends heavily on planning transitions smoothly. In that matter, the complete implementation process of Smart Contracts will undergo 6 basic steps:

1. Planning

Planning is about clearly identifying which processes are going to be digitally automized and which data will be involved in each one of them. This step requires a thoughtful outlining of the

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subsequent steps, due to the high number of Smart Contracts to be developed as well as their interconnections into the system, taking into account every potential aspect of the product and any obstacles that may arise along the way.

2. Smart Contract Design

Smart Contract design refers to the transformation of each individual process or procedure into a Smart Contract. This step requires careful design in the workflow of each Smart Contract so even the first version to function as seamless as possible. This means that theoretic optimization must apply to the final product with minimum deviations.

3. Smart Contract Development

Once the design of a Smart Contract reaches an optimal theoretical level it gets to be materialized in the Blockchain world. Iterative testing in TestNet environments will be an ongoing procedure to monitor performance and ensure quality of operation from the first live version of each Smart Contract, by configuring each Smart Contract upon evidenced insights.

5. Integration

After successfully being deployed and tested in TestNet environments, Smart Contracts will be deployed into the VPP4Islands framework to serve under real operational conditions. The performance will be further evaluated by enforcing iterative testing procedures in order to further configure each Smart Contract, ultimately leading to a seamlessly operational Blockchain-based process.

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6. Conclusions

6.1. Technical Conclusions

Having Blockchain technology as a base and a clear vision of how it can contribute productively to the VVP4Islands project, what remained to be clarified was the basic principles that will govern the project's Smart Contracts. The purpose it was essential to determine the needs in terms of data transactions between stakeholders but also how these data are going to be involved in daily transactions between them. The above, should create a first guideline that will demonstrate the next and more detailed steps for the implementation of Smart Contracts.

In that matter, the assistance of all relevant partners in the Consortium was kindly requested, in order to provide the necessary information. Their contribution became a catalyst for defining the technical characteristics of the Smart Contracts. This contribution led to the definition of:

- the most suitable blockchain protocols and environments,
- the performance requirements that must be ultimately met,
- the functional requirements of the Smarts Contracts,
- a good approximate of the expected transactions data traffic,
- a good approximate of primary and secondary procedures that will be governed by Smart Contracts

From a technical point of view, the core elements of the Smart Contracts that will be developed for the realization of VPP4Islands have become more evident and the intelligence gained is expected to lead to an improved implementation process overall.

...

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6.2. General Conclusions

The conclusions of the analysis undergone in the scope of this Deliverable Report has borne valuable insights regarding the digital infrastructure that must be built to support the complex transactional nature of VPP4Islands.

Regardless of the final number or complexity of Smart Contracts that will eventually be developed for the Project, these insights have provided the necessary knowledge to ultimately create the most seamless background as possible on which all data transactional procedures will act upon.

Feedback from the Consortium's partners provided a knowledge edge and helped in the early definition of better functional and operational estimates that will contribute positively towards the development of Smart Contracts. Among others, all acquired information has given the development team a better and more realistic overview on the following Smart Contract related elements:

- the VPP4Islands system's variables
- the VPP4Islands network's infrastructure
- the stakeholders' interactions
- the scenarios that will be translated into code

All this concise knowledge has already provided a concrete base to begin with and it is expected to result in the decrease of the development times, starting with the valuable reduce in the preliminary experimental coding that occurs in the early stages of development as well as in the optimization steps that will be taken before the deployment of each Smart Contract.

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ANNEX A - QUESTIONNAIRE ON SMART CONTRACT SPECIFICATIONS

1. DISTRIBUTED QUESTIONNAIRE

Questionnaire for the definition of Smart Contracts' requirements

Survey Questions for subtask 2.5.2 participants

Introduction

VPP4ISLANDS project is one of many transnational IA projects that have been funded by EC under the H2020 framework. VPP4ISLANDS aims to facilitate and revolutionize the integration of RES in existing power distribution networks through the implementation of innovative technologies and procedures.

For this purpose, Blockchain technology will be actively and heavily participate to ensure data validity and to automate processes by incorporating smart contract mechanisms. Thus, it becomes important to gather and evaluate crucial information about the procedures that will depend on smart contracts and the data that will be ultimately involved.

The questions that follow aim to make a preliminary sweep of knowledge which will be used to enrich this very survey. Subsequently, the updated survey will be distributed among the rest partners of the Consortium with the scope to be strengthened further. All questions refer to a project procedure that your organization is involved. If you are involved in more than one procedure, then feel free to complete as many copies of this questionnaire you deem necessary. This will assist us in gaining a broader view on your needs and requirements.

Thank you in advance for providing your feedback and for the time you spent in filling this questionnaire.

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Questions

1. Please identify yourself.

Full name	
Organization	
Email	

2. What is the name of the process?

____

3. At which part of the the VPP system does this process applies to?
(*you can check with **X** more than one*)

Category	**X**	**Additional Information**
Operation Center		please define
Conventional Power Source		please define
RE Power Source		please define
Power Storage		please define
Utility Grid		please define
Consumers		please define
Cloud Services		please define
Containerized Application		please define
Electricity Market		please define
Stakeholders		please define
Stakeholder's App		please define
End-users		please define
End-user's App		please define
... (other)		please define

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4. What is the objective of the procedure?
(*you can mention inputs, outputs, results, etc.*)

____

5. Please describe the process, mentioning all critical data involved.

____

6. Fill in the following table with information of the involved data
   - *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
   - *In the **Source** column, fill the source's name, "TBD" or "unknown".*
   - *In the **API** column, fill the API's name, "TBD" or "unknown".*
   - *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

Data	Type	POST / GET	Source	API	Size/Time
name					

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.

____

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2. Partner-filled Questionnaires

2.1 AlgoWatt (ALWA)

Questions

1. Please identify yourself.

Full name	Stefano Bianchi Diego Piserà Antonio Monne Federico Nebiacolombo Raverto Ravera
Organization	algoWatt SpA
Email	stefano.bianchi@algowatt.com diego.pisera@algowatt.com antonio.monne@algowatt.com federico.nebiacolombo@algowatt.com roberto.ravera@algowatt.com

2. What is the name of the process?

Balancing Service Provision (BSP) - management of operational processes of Balancing Service Provider (field measurements, communication with TSO, modulation of loads/production, offers on MSD market, accounting).
The platforms architecture is meant to make the platform scalable and modular for the management of multiple enabled Virtual Units (in Italy for example: UVAC, UVAP, UVAN and UVAM) and able to follow the evolution of regulation and the market with a "cost effective" approach oriented towards IOT. All modules of the platform are designed and developed by adopting the most stringent computer security policies, from the point of view of both the security of transmitted and stored data and the resiliency to possible cyber-attacks (DoS).
The platform is easily integrated with existing infrastructures (load shedding remote terminal unit – see VPP4IBox by SE?) to limit interventions in the consumption or production plants.

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3. At which part of the VPP system does this process applies to?
(*you can check with **X** more than one*)

Category	**X**	**Additional Information**
Operation Center	**X**	Covering of the whole operational process for the Balancing Service Provider / Aggregator role (field measurement, communication with TSO, implementation of provisions, monitoring of actions, offers on the energy market, integration with company business processes)
Conventional Power Source	**X**	Field measurements from VPP/plants/components – with visibility of flexibility at different levels
RE Power Source	**X**	Field measurements from VPP/plants/components – with visibility of flexibility at different levels
Power Storage	**X**	Field measurements from VPP/plants/components – with visibility of flexibility at different levels
Utility Grid		please define
Consumers	**X**	Field measurements from VPP/plants/components – with visibility of flexibility at different levels
Cloud Services		please define
Containerized Application	**X**	please define
Electricity Market	**X**	Offers on the energy market
Stakeholders	**X**	Information for TSO (incl. energy market manager)/DSO, energy broker, energy market authority
Stakeholder's App		please define
End-users	**X**	Balancing Service Provider / Aggregator of prosumers
End-user's App		please define

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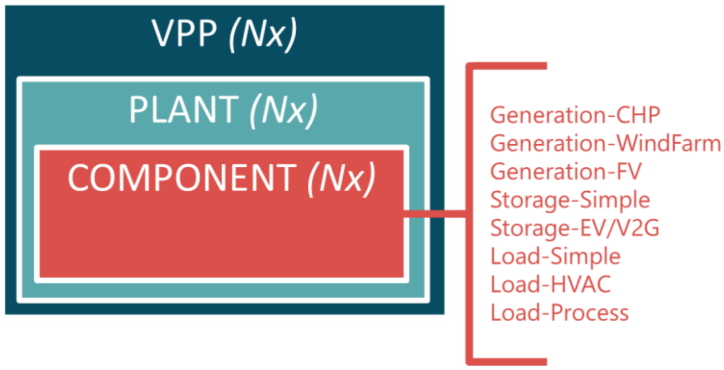
Conceptual view of managed elements and dependencies:

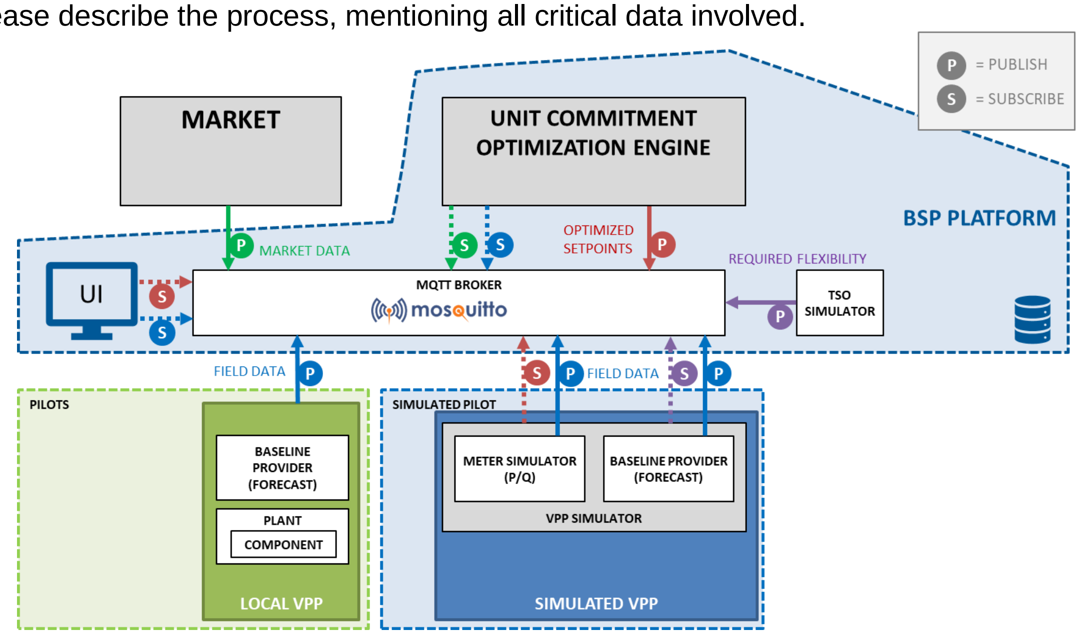


4. What is the objective of the procedure?
   (*you can mention inputs, outputs, results, etc.*)

   Provision of an end-to-end solution for the entire operational process (measurement, communication with TSO, implementation of provisions, monitoring of actions, offers on the energy market, integration with company business process).

   ____

5. Please describe the process, mentioning all critical data involved.



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6. Fill in the following table with information of the involved data
   - *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
   - *In the **Source** column, fill the source's name, "TBD" or "unknown".*
   - *In the **API** column, fill the API's name, "TBD" or "unknown".*
   - *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

Data	Type	POST / GET	Source	API	Size/Time
MARKET DATA	MQTT	GET	National System Operator es Terna for Italy	unknown	Daily
FIELD DATA (PILOTS/SIMULATED PILOTS)	MQTT	GET	VPP4BOX	unknown	Every 4sec
UNIT COMMITMENT OPT	MQTT	GET	BSP PLATFORM	unknown	One shot
UI	HTTPS	POST/GET	UI/BSP PLATFORM	unknown	One shot

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.
   Potentially YES if applied to private prosumers – could be anonymized.

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2.2 AIX-MARSEILLE UNIVERSITÉ (AMU)

Questions

1. Please identify yourself.

Full name	Seifeddine BEN ELGHALI
Organization	Aix-Marseille University
Email	seifeddine.benelghali@lis-lab.fr

2. What is the name of the process?

- Smart Energy Management
- DER Control
- Grid Services Bidding

3. At which part of the the VPP system does this process applies to?
(*you can check with **X** more than one*)

Category	**X**	**Additional Information**
Operation Center	X	The smart energy management engine needs to communicate with DSO/TSO operation centers.
Conventional Power Source	X	The smart energy management engine needs to the field measurements of DG units in order to re-schedule them according to their update condition. Note that, power sources communicate with VPPI-Box and VPPI-Node for decentralized and centralized optimization approaches, respectively.
RE Power Source	X	The smart energy management engine needs to the field measurements of renewable units in order to re-schedule them according to their update condition. Note that, RE power sources communicate with VPPI-Box and VPPI-Node for decentralized and centralized optimization approaches, respectively.
Power Storage	X	As another active resource within the smart energy management tool, energy storages communicate with VPPI-

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		Box and VPPI-Node for decentralized and centralized optimization approaches, respectively. Also, the field data is required as an input in the optimization engine.
Utility Grid	X	There are several utility grid (TSO/DSO) services that VPPI can provide and increase its revenue.
Consumers	X	The flexible consumers are considered as active participants in the VPPI smart energy management framework. The participation of flexible consumers in load curtailment programs implemented by VPPI-Node must be controlled and managed through smart meter monitoring.
Cloud Services	X	please define
Containerized Application		please define
Electricity Market	X	In the context of smart energy management, the VPPI has the opportunity of participating in different electricity markets such as day-ahead, intra-day, and real-time energy markets in order to increase its revenue and consequently the revenue of all its under contract resources such as RE/Non-RE power sources, energy storages, flexible loads, etc. To this end, market prices (Day-ahead, intraday, reserve/capacity) must be provided for the VPPI-Node to support price-based decision making.
Stakeholders		please define
Stakeholder's App		please define
End-users		please define
End-user's App		please define

4. What is the objective of the procedure?
   (*you can mention inputs, outputs, results, etc.*)

   According to the available data related to the market, consumers, DERs, and grid utility, the smart energy management tools will provide the optimal set points to each installation. These set points, when accepted and executed by the DERs will generate a profit (incentive) or\and get special prices for the produced, consumed or stored energy at a specific period of time.

5. Please describe the process, mentioning all critical data involved.

   Each installation (DERs, Energy storage system, Controllable load, loads) will communicate its current status (production, State of charge, Consumption) according to these data. The

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EMS tools will make predictions, determine the optimal strategy in the electricity market and send the set points to all installations. The EMS tools will get also some data from the market (prices), from DSO (technical specification, authorization)

6. Fill in the following table with information of the involved data
    - *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
    - *In the **Source** column, fill the source's name, "TBD" or "unknown".*
    - *In the **API** column, fill the API's name, "TBD" or "unknown".*
    - *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

Data	Type	POST / GET	Source	API	Size/Time
Market price	float	GET	Market		
weather	Float	GET	Forecasting service		
Power production	Float	GET	-PV \ Wind turbine\ Diesel generator		
Power consumption	Float	GET	- Loads\ controllable loads		
State of Charge	Float	GET	Energy storage system		
Production set point	Float	POST	- Diesel generator		
ESS set point	Float	POST	Energy storage system		
Load status	boolean	POST	controllable loads		

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.

   It mainly affects the collected Data from consumers.

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2.3 Brunel University London (BUL)

Questions

1. Please identify yourself.

Full name	Geert Jansen
Organization	Brunel University London
Email	Geert.jansen@brunel.ac.uk

2. What is the name of the process?

Financial transactions:
- Renewable energy sales to grid
- TSO and DSO services bidding
- Peer-to-peer trading

Operational data:
- Renewable energy sources monitoring
- Non-renewable energy sources monitoring
- Sea-cable interconnect monitoring
- Energy storage system monitoring
- Smart meters monitoring
- DSO grid power quality

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3. At which part of the VPP system does this process applies to?
   (*you can check with **X** more than one*)

Category	**X**	**Additional Information**
Operation Center	**X**	- VPPI-Platform (node and boxes) communicates with DSO/TSO Operation Centers.
Conventional Power Source	**X**	- Non-renewable power sources & sea-cable interconnect energy source communicates with VPPI-Box. - Depending on the deployment scenario, financial compensation will be based Levelised Cost of Energy (LCOE) of the relevant Conventional Power Source or Power Purchase Agreement via Smart Contracts.
RE Power Source	**X**	- Renewable Energy Sources communicate with VPPI-Box. Depending on the deployment scenario, financial compensation will be based Levelised Cost of Energy (LCOE) of the relevant Renewable Energy Source or Power Purchase Agreement via Smart Contracts.
Power Storage	**X**	- Energy Storage System communicate with VPPI-Box. VPPI-Box communicates with VPPI-Node's integrated Virtual Energy Storage System (VESS). - VESS can bid to electricity market via API with relevant body to earn financial compensation for service provision.
Utility Grid	**X**	- Energy services to TSO & financial compensation/smart contracts. - Energy services to DSO & financial compensation/smart contracts. - Interruptions, voltage/frequency deviations, congestion and other power quality measurements are used to determine reliability and defining services requirements. - Optional: if Internet-of-Things sensors are available in transformers/distribution system, predictive maintenance and fault prediction can be implemented.
Consumers (and prosumers) (prosumer is anyone who produces and consumes electricity)	**X**	- Smart meter measures load consumption and communicates to VPPI-Node. - Smart meter connected via API to market prices helps make decisions on whether to provide grid services, store energy, or consume produced energy themself sell, consume, or buy energy. - Smart meter can recognize prosumers behavior based on historical data and use this to predict future excess electricity

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		and provide flexibility to control the flow of electricity. - Demand Response at the consumer level allows for financial compensation for the delivered service.
Cloud Services	X	- Operational data is stored in the cloud shared Knowledge Base and accessible by all relevant stakeholders (Who can/need to access which data is to be determined in Task 8.6 Intellectual Property Rights). - Financial compensation to access the shared Knowledge Base. - Tracing transactions, commissions, and smart contracts, and strengthen trust.
Containerized Application		- TBD
Electricity Market	X	- Market prices (Day-ahead, intraday, reserve/capacity) are accessed by the VPPI-Node via API with the relevant body to support price-based decision making and bid on energy service provision.
Stakeholders	X	- VPPI-Platform shares data via the Knowledge Base - Exchanges, traders
Stakeholder's App	X	- Visual representation of the VPPI-Node activity (power demand, generation, quality, balancing, flexibility, etc.)
End-users	X	- Smart meters monitor and measure the end-user's energy consumption and predict future load profile based on historical data. - Peer-to-peer trading capabilities allow the end-users to trade energy between prosumers.
End-user's App	X	- Visual representation of the VPPI-Box activity (power demand, generation, energy savings, cost savings, carbon etc.)

4. What is the objective of the procedure?
   (*you can mention inputs, outputs, results, etc.*)

- Renewable energy sales
  - Inputs:
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MWh)
    - Supply duration (from seconds to hours)
    - Power purchase Agreement characteristics

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    - Smart export guarantee, Feed-in-tariff, or other incentives
    - Market prices
  - Outputs
    - Bid for encrypted/verified energy transaction (sales)
  - Result
    - Net revenue from sale of renewable energy

- Grid and DSO services bidding
  - Inputs:
    - Current health of grid (voltage, frequency, supply & demand)
    - Health of grid targets/nominal parameters
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MW)
    - Charge duration (from seconds to hours)
    - Discharge duration (from seconds to hours)
    - Energy Storage System State-of-Charge
    - National Market prices
    - Local market prices
  - Outputs
    - Bid for energy services (sales or purchase energy).
    - Grid service requirements identification
  - Result
    - Net revenue from service provision
    - Enhanced local grid reliability, interruption reduction, etc.

- Peer-to-peer trading
  - Inputs:
    - Energy generation quantity (in kWh or MWh)
    - Power generation quantity (in kW or MW)
    - Energy consumption quantity (in kWh or MWh)
    - Power consumption quantity (in kW or MW)
    - National Market prices
    - Local market prices
    - Grid service requirements
    - Smart contracts

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- Penalties failure to deliver on agreed smart contract
    - Commission on transactions
  - Output
    - Energy transaction between peers
    - Associated value of energy transaction
    - Energy storage control schedule
  - Result
    - Net revenue from peer-to-peer trading
    - Optimized dispatch of local energy
    - Reduced local carbon emissions
- <u>Renewable energy sources monitoring</u>
  - Inputs
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MWh)
    - Supply duration (from seconds to hours)
    - Environmental conditions
    - Degradation mechanism (variable maintenance requirements)
    - Fixed Maintenance requirements
    - Owner/operator of equipment
  - Outputs
    - Availability
    - Energy generation quantity in kWh or MWh
    - Alarm predictive maintenance (digital twin confirmed)
    - Alarm fault detection (digital twin confirmed)
    - Generation Efficiency
    - Levelised Cost of Electricity
  - Result
    - Increased resilience and reliability
    - Reduced maintenance cost

- <u>Non-renewable energy sources monitoring</u>
  - Inputs
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MWh)
    - Supply duration (from seconds to hours)
    - Degradation mechanism (variable maintenance requirements)

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- Fixed Maintenance requirements
- Fuel consumption
- Fuel characteristics
- Local fuel cost (€/L or €/kWh)
- Owner/operator of equipment

- Outputs
  - Availability
  - Energy generation quantity in kWh or MWh
  - Alarm predictive maintenance (digital twin confirmed)
  - Alarm fault detection (digital twin confirmed)
  - Generation Efficiency

- Result
  - Increased resilience and reliability
  - Reduced maintenance cost
  - Potential revenue through data sharing with TSO/DSO and stakeholders

- <u>Sea-cable interconnect monitoring</u>
  - Inputs
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MWh)
    - Supply duration (from seconds to hours)
    - Degradation mechanism (variable maintenance requirements)
    - Fixed Maintenance requirements
  - Outputs
    - Availability
    - Energy generation quantity in kWh or MWh
    - Alarm predictive maintenance (digital twin confirmed)
    - Alarm fault detection (digital twin confirmed)
  - Result
    - Increased resilience and reliability
    - Reduced maintenance cost
    - Potential revenue through data sharing with TSO/DSO and stakeholders

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- <u>Energy storage system monitoring</u>
  - Inputs
    - Energy quantity (in kWh or MWh)
    - Power quantity (in kW or MW)
    - Charge duration (from seconds to hours)
    - Discharge duration (from seconds to hours)
    - Energy Storage System State-of-Charge
    - Degradation mechanism (variable maintenance requirements)
    - Fixed Maintenance requirements
    - Owner/operator of equipment
  - Outputs
    - State of health
    - Energy charge/discharge quantity in kWh or MWh
    - Alarm predictive maintenance (digital twin controlled)
    - Alarm fault detection (digital twin controlled)
    - Round-Trip Efficiency
    - Levelised Cost of Storage
    - Internal Rate of Return (for equipment owner)
  - Result
    - Control strategy energy storage
    - Revenue from service provision

- <u>Smart meters monitoring</u>
  - Inputs
    - Consumption in kWh or MWh (historical and real-time)
    - Type of consumer (industrial, residential, commercial)
  - Outputs
    - Load prioritization recommendation
    - Load profile
  - Results
    - Customer behavior prediction model
    - Demand response capabilities

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- DSO grid power quality
    - Inputs
        - Voltage measurements
        - Current measurements
        - Frequency measurements
        - Active/reactive power
    - Outputs
        - Interruptions (quantity and location in network)
        - Voltage/frequency deviations
        - Congestion (quantity and location in network)
        - DSO network losses
    - Results
        - Services requirements
        - Reinforced system flexibility and performance objectives

---

5. Please describe the process, mentioning all critical data involved.

- Renewable energy sales

Forecasted renewable energy generation (power generation, energy generation day-ahead), market prices and power purchase agreement/levelized cost of energy data are used to determine revenue potential of renewable energy sources, as well as potential DSO services (reserve/capacity market, and other revenue streams) and make decision to sell renewable energy to the grid or use for self-consumption.

- Grid services bidding

Forecasted demand (day-ahead, intraday, reserve market) data and market prices are used to bid into the day-ahead and intraday market to provide potential DSO services (frequency response, demand response, emerging services) services and generate revenue.

- Peer-to-peer trading

From each peer in the peer-to-peer blockchain network, the energy generation/consumption quantity (in kWh or MWh), power generation/consumption quantity (in kW or MW) are monitored and recorded, and decisions for selling or purchasing energy are made based on national and local market prices and local grid service requirements. Smart contracts are

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established between the peers to trade, including commission fees and penalties when failed to deliver on the agreed smart contract.

- Renewable energy sources monitoring

Sensors in the renewable energy sources measure and record data related to its operational parameters such as the wind turbine's rotations per minute, angle of attack, energy generation, etc. These parameters will differ based on the technology used for renewable energy generation. Operating parameters are stored and analyzed to find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

- Non-renewable energy sources monitoring

Sensors in the non-renewable energy sources measure and record data related to its operational parameters such as the diesel generator's rotations per minute, fuel consumption, energy generation, etc. These parameters will differ based on the technology used for non-renewable energy generation. Operating parameters are stored and analyzed to determine efficiency for partial and dynamic load operation, find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

- Sea-cable interconnect monitoring

Sensors in the sea cable interconnect measure and record data related to its operational parameters such as the energy throughput, voltage levels, frequency, etc. (operational schedule)

Operating parameters are stored and analyzed to find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

- Energy storage system monitoring

Sensors in the energy storage system equipment measure and record data related to its operational parameters such as the storage state-of-charge, energy charge/discharge quantities, response times, environmental factors (temperature, wind speed, air humidity), and e.g. diagnose cell management unit microchips identify capacity retention, reversibility, electrode activity, structural changes, dendritic growth, etc. These parameters will differ based on the technology used for energy storage. Operating parameters are stored and analyzed to find anomalies or detect degradation and send alarm when a fault is predicted or when predictive maintenance is advised.

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- <u>Smart meters monitoring</u>

Smart meters measure and record energy consumption data in industrial, commercial, and residential customers. This data is stored and analyzed to predict load profiles, evaluate energy losses and advise on load shifting.

- <u>DSO grid power quality</u>

Power quality measurements from the DSO grid operations (voltage, current, frequency, active/reactive power etc.) are monitored and recorded, and advanced algorithms determine the control strategy to respond to interruptions, voltage/frequency deviations, and potential congestion in the network and calculate network losses.

---

6. Fill in the following table with information of the involved data
   - *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
   - *In the **Source** column, fill the source's name, "TBD" or "unknown".*
   - *In the **API** column, fill the API's name, "TBD" or "unknown".*
   - *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

To be completed when the concept is further defined.

Data	Type	POST / GET	Source	API	Size/Time
TBD	*TBD*	*TBD*	*TBD*	*TBD*	*TBD*

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.

Not to our knowledge at this stage.

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2.4 Schneider Electric (SCHN)

Questions

1. Please identify yourself.

Full name	Evgeny Prokofyev
Organization	Schneider Electric
Email	evgeny.prokofyev@se.com

2. What is the name of the process?

   Distributed Energy Resources (DER) control.

   ____

3. At which part of the the VPP system does this process applies to?
   (*you can check with **X** more than one*)

Category	X	Additional Information
Operation Center	X	Commands would be send from the SCADA to manage DER
Conventional Power Source		please define
RE Power Source	X	DER would need to be managed by the VPP4I-Box
Power Storage	X	DER would have an impact on storage
Utility Grid	X	DER would have an impact on the utility grid
Consumers	X	DER would have an impact on the power requested by the consumers from the main grid
Cloud Services	X	DER information could be made available at cloud services
Containerized Application		please define
Electricity Market	X	DER generation would have an impact on the electricity market needs
Stakeholders		please define
Stakeholder's App		please define
End-users		please define
End-user's App		please define

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4. What is the objective of the procedure?
(*you can mention inputs, outputs, results, etc.*)

The objective is to manage the DER from the VPP4I-Box, based on the inputs received by the upper layers of the VPP4Islands platform. Besides, VPP4I-Box will communicate to those upper layers of the VPP4Islands platform, the status of the managed DER.

5. Please describe the process, mentioning all critical data involved.

The process requires a VPP4I-Box, which at least contains a Remote Terminal Unit (RTU), with interfaces with the DER (that could be wired or by communication protocols), and also with the VPP4I-Nodes, that should happen by using communication protocols.

The VPP4I-Box would be able to retrieve information from the DER and communicate it to the VPP4I-Nodes, and would also able to operate the DER, based on the commands received by the VPP4I-Nodes.

6. Fill in the following table with information of the involved data

- *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
- *In the **Source** column, fill the source's name, "TBD" or "unknown".*
- *In the **API** column, fill the API's name, "TBD" or "unknown".*
- *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

Data	Type	POST / GET	Source	API	Size/Time
DER CB status	binary	GET	DER	RTU	TBD
DER CB command	binary	POST	DER	RTU	TBD
DER additional information	int/float	GET	DER	RTU	TBD

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.
The VPP4I-Box only needs to define communication interfaces with DER and VPP4I-Nodes, which are not affected by GDPR regulations, as personal data would not be required to be managed.

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2.5 Uludag Electric Dagitim (UEDAS)

Questions

1. Please identify yourself.

Full name	Mehmet KOÇ
Organization	ULUDAĞ ELEKTRİK DAĞITIM ANONİM ŞİRKETİ
Email	mkoc@uedas.com.tr

2. What is the name of the process?

WP2 Island energy services requirements and concept design

3. At which part of the the VPP system does this process applies to?
(*you can check with **X** more than one*)

Category	**X**	**Additional Information**
Operation Center		please define
Conventional Power Source		please define
RE Power Source	X	We've RES in our grid
Power Storage	X	Power storage is planned in project scope
Utility Grid	X	Electricy Distribution grid
Consumers		please define
Cloud Services		please define
Containerized Application		please define
Electricity Market		please define
Stakeholders		please define
Stakeholder's App		please define
End-users		please define
End-user's App		please define

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4. What is the objective of the procedure?
(*you can mention inputs, outputs, results, etc.*)

The fundamental purpose in the this WP is define to “Island needs and requirements”

5. Please describe the process, mentioning all critical data involved.

We will collect to some data which are energy consumption and production data between 2017-2020, wind data for 2019, wind and solar production etc. Subsequently, we will define what we need to scope of project.

6. Fill in the following table with information of the involved data
   - *In the **Post/Get** column, please write **Post** if it is about data that the procedure sends or **Get** if it is about data that the procedure requires to receive.*
   - *In the **Source** column, fill the source’s name, “TBD” or “unknown”.*
   - *In the **API** column, fill the API’s name, “TBD” or “unknown”.*
   - *In the* **Size/Time** *column, fill expected data bandwidth, as accurate as possible.*

Data	Type	POST / GET	Source	API	Size/Time
Energy Consumption	Excel	POST	TDB	unknown	130MB/Yearly
Energy Production	Excel	POST	TDB	unknown	10MB/Yearly
Wind Data	Excel	POST	TDB	unknown	15KB/Yearly

7. Are any of the aforementioned data GDPR affected? If yes, please mention which.

   No, these files don’t involve GDPR datas.

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