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Integrated local energy systems (Energy islands)

RENergetic

Community-empowered Sustainable Multi-Vector Energy Islands

Project Nº 957845

D8.1- Description of the interim RENergetic Replicability Package and its evaluation

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Executive Summary

Energy islands as largely independent energy systems that can generate, store, and distribute renewable energy locally, are an important building block in the efforts of decarbonization of the energy system and contribute to increased energy security, reduced dependence on external energy sources and lowering overall energy costs. The RENergetic project not only aims to demonstrate solutions for various challenges that Energy Islands are confronted with, but to also provide an approach and a methodology to replicate these solutions elsewhere. Replication of energy islands is an important aspect of scaling up and spreading the benefits of decentralization of the energy system, as it allows to replicate successful energy island projects in other locations and contexts.

The RENergetic methodology for replication of energy islands has four core principles, that are: to be goal-centric, user-centric, context aware and modular in its approach.

Goal-centric replication and user-centric replication focuses on achieving specific goals and meeting the needs of the end-users respectively. Goal-centric replication involves setting specific, measurable goals for the replication process and then using key performance indicators (KPI) to track progress and evaluate the performance of the energy island. This approach allows to focus on what is important and to replicate the best practices in different locations and contexts. User-centric replication, on the other hand, involves gathering information about the users through research, user interviews, surveys, and observations. This information is then used to inform the design process, helping to ensure that the final design meets the needs of the target users. User-centric replication also involves testing and refining the design with the users, ensuring that the final design is user-friendly and efficient, and meets the user's needs.

Context-sensitive replication and modular design are used to replicate energy islands effectively. Context-sensitive replication is an approach that takes into account the specific needs and constraints of different locations when replicating energy islands. It involves gathering information about the local environment, energy needs, and available resources, and using this information to inform the design and replication process. On the other hand, modular design is an approach to designing energy islands that involves breaking down the overall system into smaller, more manageable units or modules. Each module can be designed, built, and tested independently, and then integrated into the overall system.

The RENergetic replication package executes these four core principles in the form of a Transformation Pathway, which can be understood as a plan that outlines the steps and actions required to transition to an energy island system, including the technical, economic, and social aspects of the transition. It includes identifying the current energy system, setting goals, developing a plan of action, implementing the plan, monitoring progress and adapting the plan when necessary. This approach provides a replication roadmap to an energy island system by considering all the different aspects of the transition, and by providing a plan a methodology to follow in order to achieve the desired outcome.

Combining these principles, it is possible to replicate energy islands that are tailored to the specific needs and constraints of different locations, and that are flexible, scalable, reliable and cost-effective, follow clearly defined goals that are agreed upon by the Energy Island community and all involved stakeholders and consequently have a high chance of being successfully implemented.

This deliverable D8.1 mainly outlines the methodology and replication principles developed by the RENergetic project and provides a preliminary replication package. As the project progresses all pilot action results and results of replication simulations will be implemented into the Final Replication Package, which will be documented in deliverable D8.3.

The objective of RENergetic is to demonstrate the viability of so-called ‘urban energy islands’. Energy islands seek to achieve the highest possible degree of self-sustainability with regards to the supply of its energy demand, be it electricity or heat through local renewable resources.

At the same time an urban energy island may offer ancillary services to the public grid surrounding it.

These islands place the consumer at the centre of the energy transition, giving them an active part in energy communities capable of producing their own energy, sharing the surplus with the rest of the public grid and optimizing consumption. RENergetic will demonstrate that Urban Energy Islands increase both the number of renewables in these areas and the energy efficiency of local energy systems. RENergetic will demonstrate the viability of this energy islands in three site pilots, each of them of a different nature: New Docks, a residential area in Ghent – Belgium, Warta University Campus in Poznan, Poland and San Raffaele Hospital and its investigation and research campus in Segrate-Milan, Italy. The impact of the Urban Energy Islands is assured as technical, socio-economic, and legal / regulatory aspects are considered while safeguarding economic viability.

To supplement the insights gained from these pilot site, a fourth virtual pilot is created. A simulation and hardware in the loop-based approach allows the virtual pilot to overcome barriers to realization present in the real world with respect to ensuring power quality by the energy island. Instead, the virtual pilot provides the means to evaluate the system using narrow time steps to capture the dynamic effects of the power system relevant for power quality.

RENergetic will be carried out over the stretch of 42 months involving 14 European partners: Inetum (Spain, France, and Belgium), Clean Energy Innovative Projects and Gent University (Belgium), Poznan University of Technology, Veolia and Poznan Supercomputing and Networking Center (Poland), Ospedale San Raffaele, Comune di Segrate and University of Pavia (Italy), Energy Kompass GMBH (Austria), the University of Mannheim and the University of Passau (Germany), University of Stuttgart (Germany) and Seeburg Castle University (Austria).

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Table of Acronyms and Definitions

Acronym	Definition
EI	Energy Island
RRP	RENergetic Replication Package
EV	Electric Vehicle
DR	Demand Response
HDR	Heat Demand Response
EV-DR	Electric Vehicle Demand Response
RES	Renewable Energy Source

I. INTRODUCTION

I.1. Purpose and Organization of the Document

The RENergetic project aims to build energy islands that are self-sustainable using more and more renewable energy sources and by doing so not only develop solutions that are specific to one of the three pilot sites, but that can also be easily replicated in other sites with different contexts.

This document should provide an introduction to the RENergetic replication approach and the state of its development in the project at this moment. This deliverable aims to provide the theoretic and methodological background in respect to replication efforts and concisely summarize them and provide the rationales behind the chosen approaches. It is meant to set the base for the Final Replication Package, which will be documented in deliverable 8.3 at the end of the project, containing all the practical information and lessons learned from the implementation of the demo actions.

The remaining of the document is structured as follows. Chapter II introduces the methodological framework of Energy Island replication, by providing definitions for what an EI actually is meant to be in the RENergetic project, how the SGAM framework is utilized to derive a generalized and abstract view on the specific use cases and what the four core principles of the RENergetic replication approach are.

In chapter III, the role of KPI in replication of EI is elaborated, drawing on the already available results from WP7, specifically on deliverable 7.2 for providing the list of KPI to be focused on in the RENergetic project. Chapter IV provides the main methodology of replication by introducing the concept of the Transformation Pathway as a roadmap to successful replication.

In chapter V the pilot actions are described, with their technical, social and economic interventions organized in the form of the RENergetic User Epics, which are the basis of the replication efforts. Results from the pilot work packages WP4, WP5 and WP6 as well as from WP2 (social sciences for EI) and WP3 (ICT for EI) have been included in chapter V of this deliverable.

All pilot interventions are structured around the RENergetic epics, which are the high-level requirements that describes the necessary technical, social and economic features and functionalities that need to be provided to achieve the goals of these interventions. The concept of the RENergetic epics is further described in chapter II of this document.

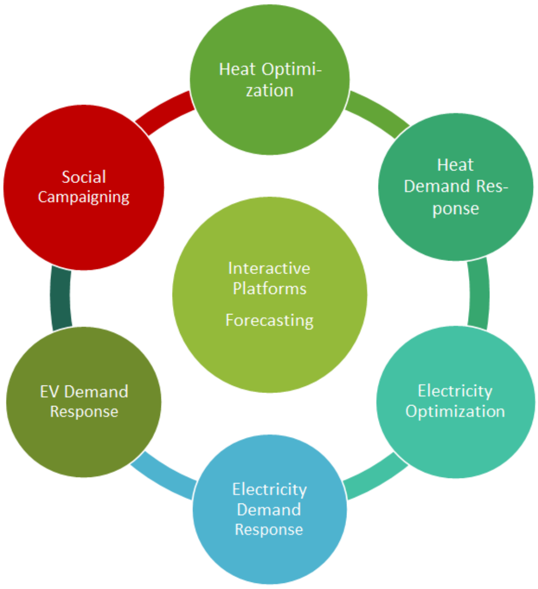


Figure 1: Schematic view of the RENergetic Epics

I.2. Scope and Audience

This deliverable is aimed at two different audience groups:

- The consortium members of the RENergetic project, specifically partners responsible for the pilots, and the development of technical, economic and social interventions and solutions for energy islands.
- Researchers of academic and industry organizations, with an interest in creating replicable design approaches, replication paradigm and methodologies or with a specific interest in implementation and acceptance of energy optimization, waste heat utilization and demand response systems.

A wider audience is invited to use the here presented document to gain an overview on replication approaches and methodologies but is not the main target of this document. The broader audience of EI communities will be specifically addressed with deliverable 8.3 that will provide the Final Replication Package that is intended to provide specific guidelines and steps to replicate the RENergetic results and findings.

II. REPLICATING ENERGY ISLANDS

II.1. Replication in the RENergetic context

Replicable results are a key goal of innovation efforts and are at the center of the RENergetic approach. In a sense, the RENergetic pilot actions are designed as the first replications of the developed solutions, following the core principle of the replication package of providing general solutions to be applied in specific contexts.

In a first step towards developing a replication methodology, at first a definition of what “replicability” does mean in the RENergetic context is needed. For this we need to define two terms that have similar but yet distinctive meanings, that is **Reproducibility** and **Replicability**.

Reproducibility in this context means, that results can be reproduced by a different team using the original team’s tools or software artifacts. Whereas Replicability means that results can be replicated by a different team using their own tools or software artifacts.

In the RENergetic project a variety of solutions will be developed and provided via the RENergetic platform. These are designed to be reproducible, that is the software developed by RENergetic is to be taken as is and utilized by other teams to reproduce the intended results.

However, these software modules need a certain **context** in order to be able to function as desired. This context, which is the sum of all technical, infrastructural, social, economic and legal frame conditions is highly specific and not easily (or even impossible to be) reproduced in another site. Following from that the frame conditions, the context in which the RENergetic modules are operable, will need to be replicated by any follower site that intends to utilize the RENergetic solutions.

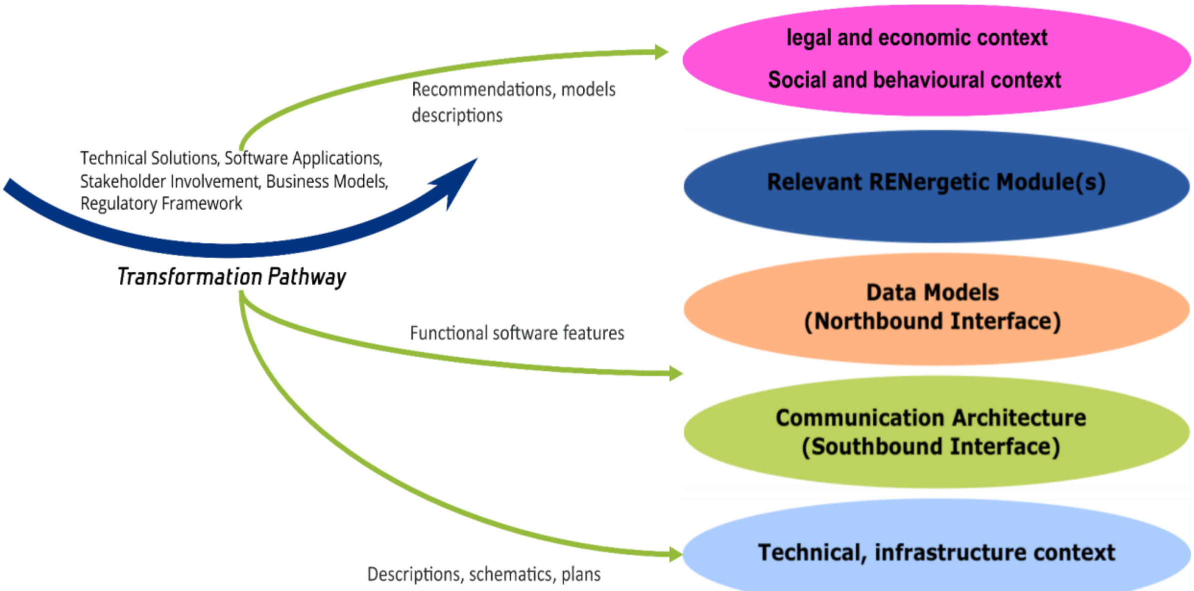


Figure 2: Schematic view of an EI replication package and the Transformation Pathway

For the replication methodology the concept of the “Transformation Pathway” has been developed, which is the sum of all interventions that are done in order to achieve the sustainability goals of a given Energy Island. It is important to note that this does not only include technical interventions, but also all social, behavioural and economic actions that are needed to accompany the base technical solutions.

As all these provided solutions need the correct technical, social, legal and economic context in order to be meaningfully deployed, the RENergetic replication package does provide a methodological toolset to replicate this needed context - infrastructure, social, legal and economic – in order to successfully replicate the results from the RENergetic pilot sites.

In order to build on already established concepts, the framework provided with the SGAM methodology was chosen as the basis for the replication methodology which makes use of all 5 layers of the SGAM model. This approach allows for a standardized comparison of different approaches, paradigms and viewpoints. The SGAM methodology is not only applied to the electric but also to the heat domain, resulting in multi-energy vector SGAM reference models of the RENergetic solutions.

II.2. Energy Island Definition

An urban energy island (EI) is a geographically delimited system that is to a considerable extent self-sufficient with regards to all present energy vectors. The differentiating factor between self-sufficiency and autarchy is the role of the energy island in the context of energy grids: if necessary, the energy island is able to draw power from or inject to the external grid as well as providing to provide ancillary grid services to the energy island and beyond. Thus, it can be an active part in a more decentralized system of small and interdependent EI that together form the mesh of the future energy system, characterized by a very high share of renewable energy sources (REN) and partially flexible energy demand. From the point of view of supply, given a pre-existing energy infrastructure, the energy island concept means to maximize local generation and optimize its distribution, from the point of view of demand it means to optimize demand across all energy vectors, adapting demand profiles as necessary, both by shifting demand temporarily and reducing it absolutely.

From an organizational and social point of view, the EI is inhabited by people living or working there, who are the end-users of energy. They are tied to the EI through their energy usage patterns and directly and indirectly by contracts. The contributions of the EI inhabitants to achieving EI objectives can be done individually, in the form of collective energy actions (i.e., “any energy action that depends on the collective involvement of energy consumers/prosumers”), and in the form of energy communities (EC), a sub-set of collective energy actions that involve continuous group interactions with or without formal underpinnings.

Energy islands are important for a number of reasons:

Energy security: By producing and consuming their own energy, energy islands can reduce their dependence on the traditional electrical grid and decrease their vulnerability to power outages caused by natural disasters or other disruptions to the grid.

Reliability: Energy islands can provide a reliable and resilient source of energy even in the face of extreme weather conditions or other challenges.

Sustainability: Energy islands promote the use of renewables which leads to a reduction in greenhouse gas emissions.

Cost-effectiveness: By producing a considerable share of their own energy, energy islands reduce their dependence on fossil fuels, thus decreasing concurring energy costs.

Economic Development: Energy islands can support economic development by providing reliable and sustainable energy to support businesses and industries and promotes investment in innovative technologies, with a focus on generating regional value chains.

Remote locations: Energy islands are an effective solution for supplying energy to remote locations where access to the traditional power grids is difficult or impossible.

Energy islands help to improve energy security and promote a sustainable, regional development while reducing dependence on fossil fuels and increasing reliability and resiliency of power supply.

Further advantages of Energy Islands also include the flexibility and inherently increased energy independence of a regional, decentralized design paradigm.

However, Energy islands also come with some disadvantages compared to the traditional, hierarchical power grid structures for energy distributions, including:

High initial cost: Setting up an energy island can have high initial investment requirements, particularly in terms of the cost of equipment and infrastructure that has to be designed and installed from scratch.

Maintenance and operation costs: Energy islands require regular maintenance and monitoring to ensure they are operating correctly. In many cases advanced automation and other digital systems are deployed, which require expert attention to ensure proper functioning throughout their lifetime.

Limited energy generation: Energy islands are typically limited in terms of the amount of energy they can produce, which can be problematic for larger communities or industrial areas.

Weather dependency: Energy islands that rely on renewable energy sources such as solar or wind power can be affected by weather conditions, which can limit the amount of energy produced.

Limited scalability: Energy islands are typically designed to serve a specific area or community, which can make it difficult to expand the system to serve a larger population.

Cybersecurity risks: As energy islands are becoming more advanced and connected, they are exposed to the same cybersecurity risks as other digital systems, which could lead to power outages, compromised privacy or other issues.

Overall, while energy islands can provide a sustainable and reliable source of energy, they also come with certain disadvantages, such as high costs, limitations on energy generation and scalability, and weather dependency. Additionally, they have specific security concerns that need to be addressed.

However, Energy islands do have the potential to play a key role in the energy transition, as they address several of the critical issues for the development of a renewables-based energy system.

- Decentralization
- Uptake of renewables utilization
- Energy independence
- Energy storage
- Energy flexibilities
- Regional economic development

EI contribute to the decentralization of the energy system and increase its reliability and resiliency. This does help to reduce the vulnerability of the energy system to disruptions and improves the ability to integrate renewable energy sources. EI also promote the use of renewable energy sources, such as solar and wind power, which is critical in order to reduce greenhouse gas emissions and combat climate change. EI also include and operate energy storage systems for multiple energy vectors (e.g., battery storage or thermal storages) which are vital to deal with the inherent volatility in energy production from renewable sources and play a key role to improve the stability of the energy system. EI can be adjusted to the specific needs of the location, including a mix of different energy sources and energy storage solutions. This can help to ensure that the energy island is tailored to the local conditions and requirements. Energy islands lend themselves to establishing regional value chains, creating incentives for the investment into local business opportunities.

By designing Energy islands around locally available energy sources, with regional value chains and local business opportunities in mind, they consequently increase independence from imported, typically fossil, energy sources and reduce economic and political dependencies.

Overall, energy islands have the potential to play a vital role in the energy transition by promoting decentralization, increased use of renewable energy, energy storage, flexibility, and supporting the economic development and independence of regional, community-based energy systems.

II.3. Energy Island Interoperability – utilizing the Smart Grid Architecture Model

The RENergetic pilot sites all have their own unique peculiarities and frame conditions, which make a direct replication of the interventions performed in the pilot actions unfeasible. As part of the replication work package, a generalized approach to Energy Islands has therefore been developed and it has been decided to use the well-established Smart Grid Architecture Model (SGAM) to provide a standardized way of documenting and describing the implementation of the demo actions.

The SGAM framework has been utilized to condense the essential parts and functions for each of the implemented user epics, in order to reduce complexity while still preserving the essential functionalities.

Deliverable D3.1 provides a short overview on how the SGAM framework has been utilized in the requirements engineering process, in the following an overview on how the SGAM is being utilized in respect to the replication methodology in the RENergetic project is given.

SGAM is a framework that describes the various components and systems that make up a smart grid, and how they interact with each other. It is designed to provide a comprehensive view of the smart grid and its functionalities, and it can be used as a guide for designing, developing and implementing smart grid systems.

The SGAM is partitioned into the physical domains of the energy conversion chain and the hierarchical zones for management of the energy processes.

Table 1 Description of the SGAM domains

Domain	Description
(Bulk) Generation	Representing generation of electrical energy in bulk quantities typically connected to the transmission system, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP).
Transmission	Representing the infrastructure which transports electricity over long distances.
Distribution	Representing the infrastructure which distributes electricity to customers.
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation and consumption technologies (typically in the range of 3 kW to 10,000 kW). These distributed electrical resources may be directly controlled by e.g. a TSO, DSO, an aggregator or Balance Responsible Party (BRP).
Customer Premises	Hosting both end users of electricity and also local producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines.

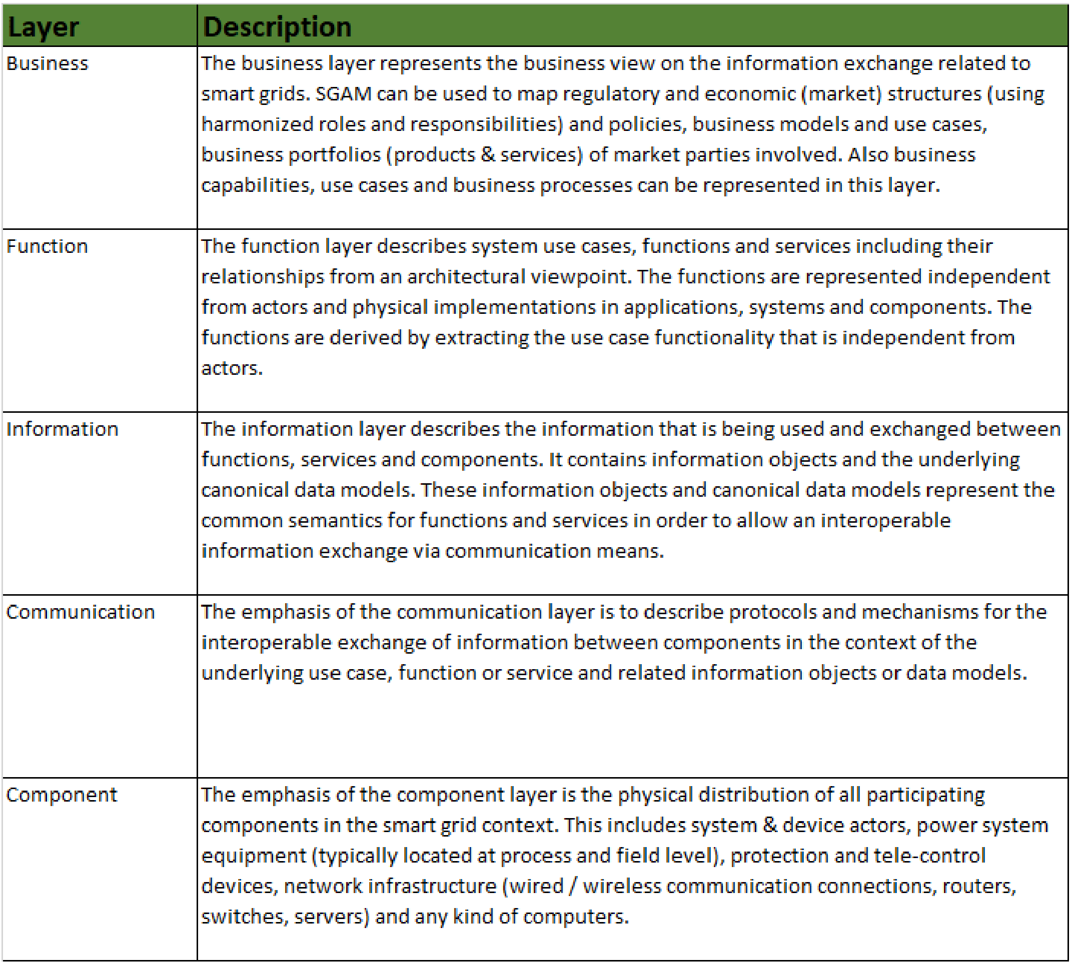
In addition to aggregation, the partitioning in zones follows the concept of functional separation. Different functions are assigned to specific zones. The SGAM zones are described below.

Table 2 Description of the SGAM zones

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind …) and the physical equipment directly involved (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads, any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
Station	Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management
Enterprise	Including commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders …), e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement.
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, retail market.

For interoperability between systems or components, the SGAM consists of five layers representing business objectives and processes, functions, information exchange and models, communication protocols and components.

Table 3 Description of the SGAM layers



Layer	Description
Business	The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures (using harmonized roles and responsibilities) and policies, business models and use cases, business portfolios (products & services) of market parties involved. Also business capabilities, use cases and business processes can be represented in this layer.
Function	The function layer describes system use cases, functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality that is independent from actors.
Information	The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.
Communication	The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.
Component	The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes system & device actors, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.

The final RENergetic Replication Package (Deliverable 8.3) will include the SGAM models of all implemented epics, as a baseline generalized SGAM representation of an Energy Island is shown below:

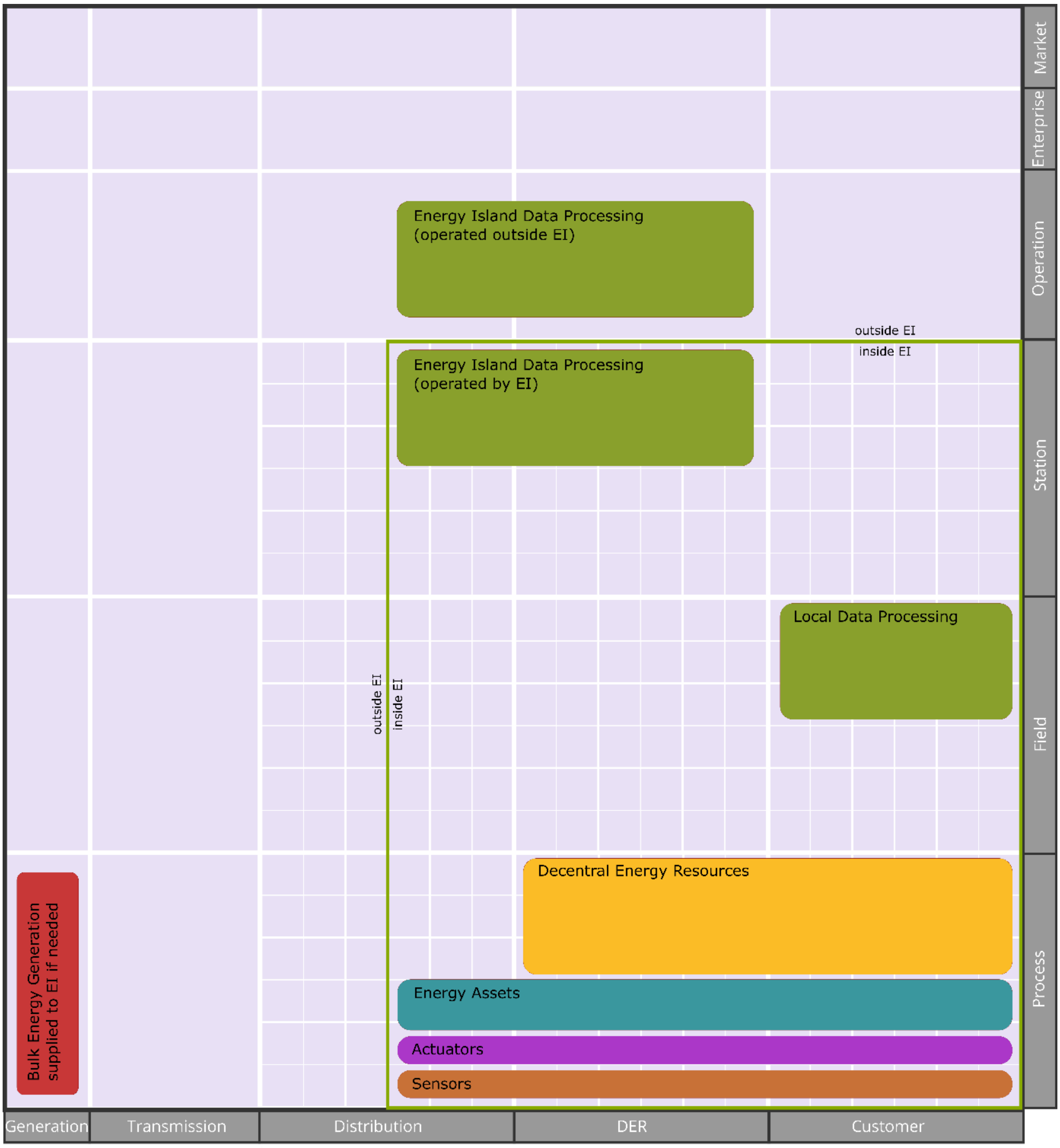


Figure 3: Component Layer of the general representation of an Energy Island

This general representation allows for a clear depiction of essential components of an Energy Island: energy assets (e.g. batteries, heat pumps, charging infrastructure, …) with the respective sensors and actuators, the decentralized RES (e.g. PV panels, wind turbines, waste heat sources, ..) and the ICT components. Within the component layer it is shown which parts reside within the EI and thus being within the responsibility of the EI community and which components are outside, being operated and maintained by third parties.

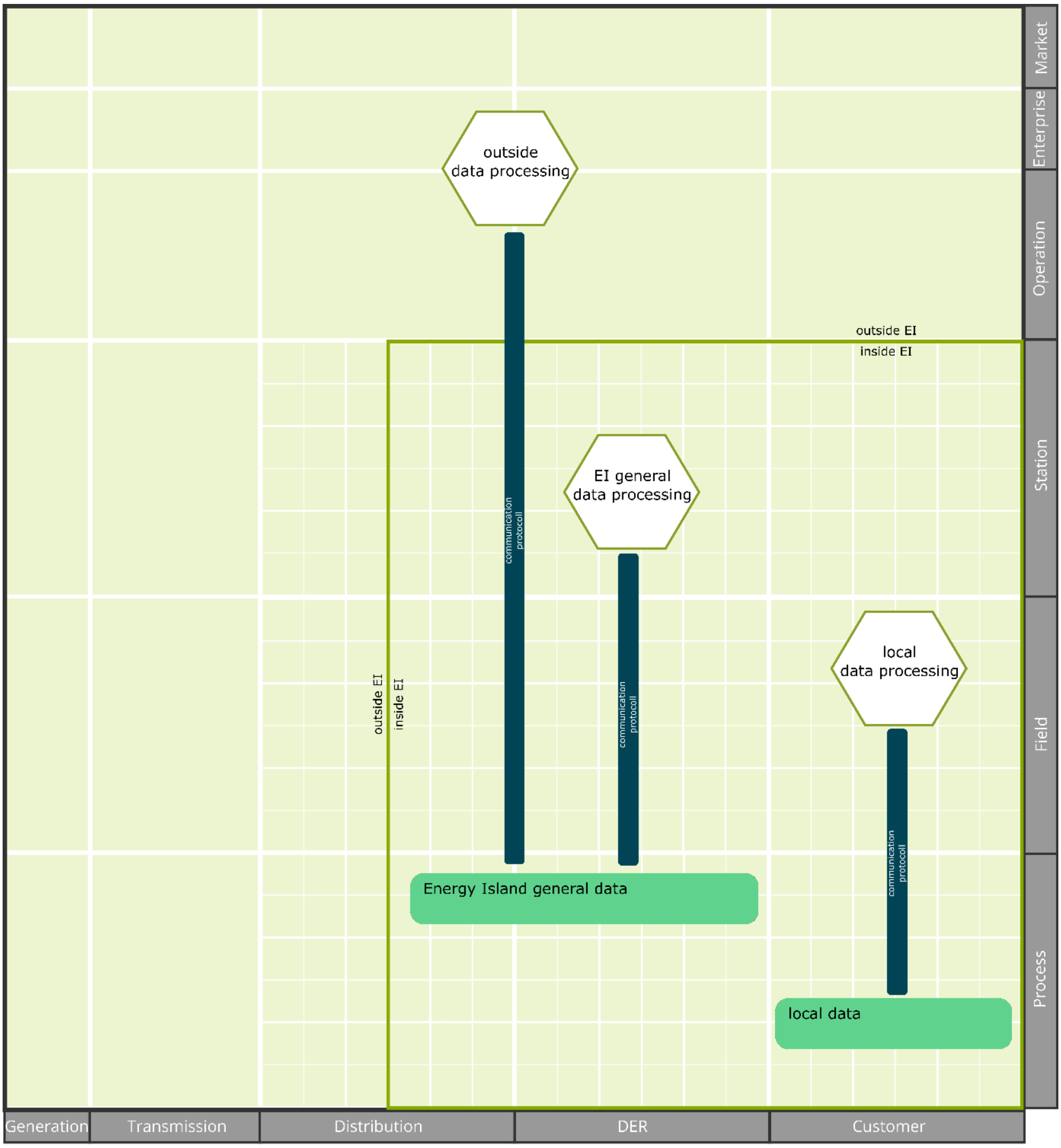


Figure 4: Communication Layer of the general representation of an Energy Island

As with the component layer, the communication layer also shows the boundaries of the EI in respect to data communication. It allows for a clear depiction of where data is generated and where it is processed and what communication protocols are used for the data transfer. This, again, is important to clearly differentiate the operational responsibilities between the EI community and outside third parties.

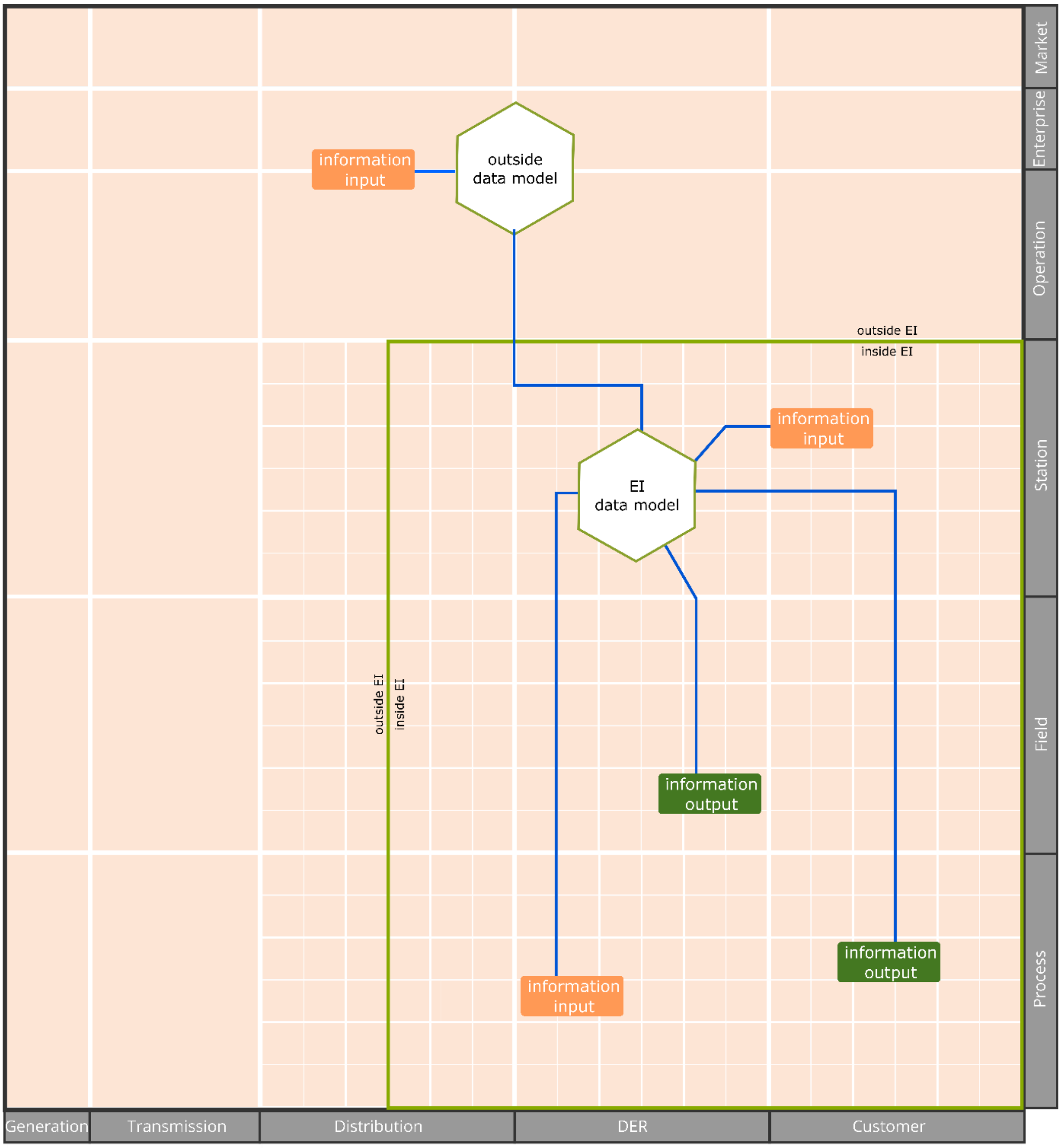


Figure 5: Information Layer of the general representation of an Energy Island

As before also the information layer gives a representation of where information inputs and outputs are generated and what kind of information is needed.

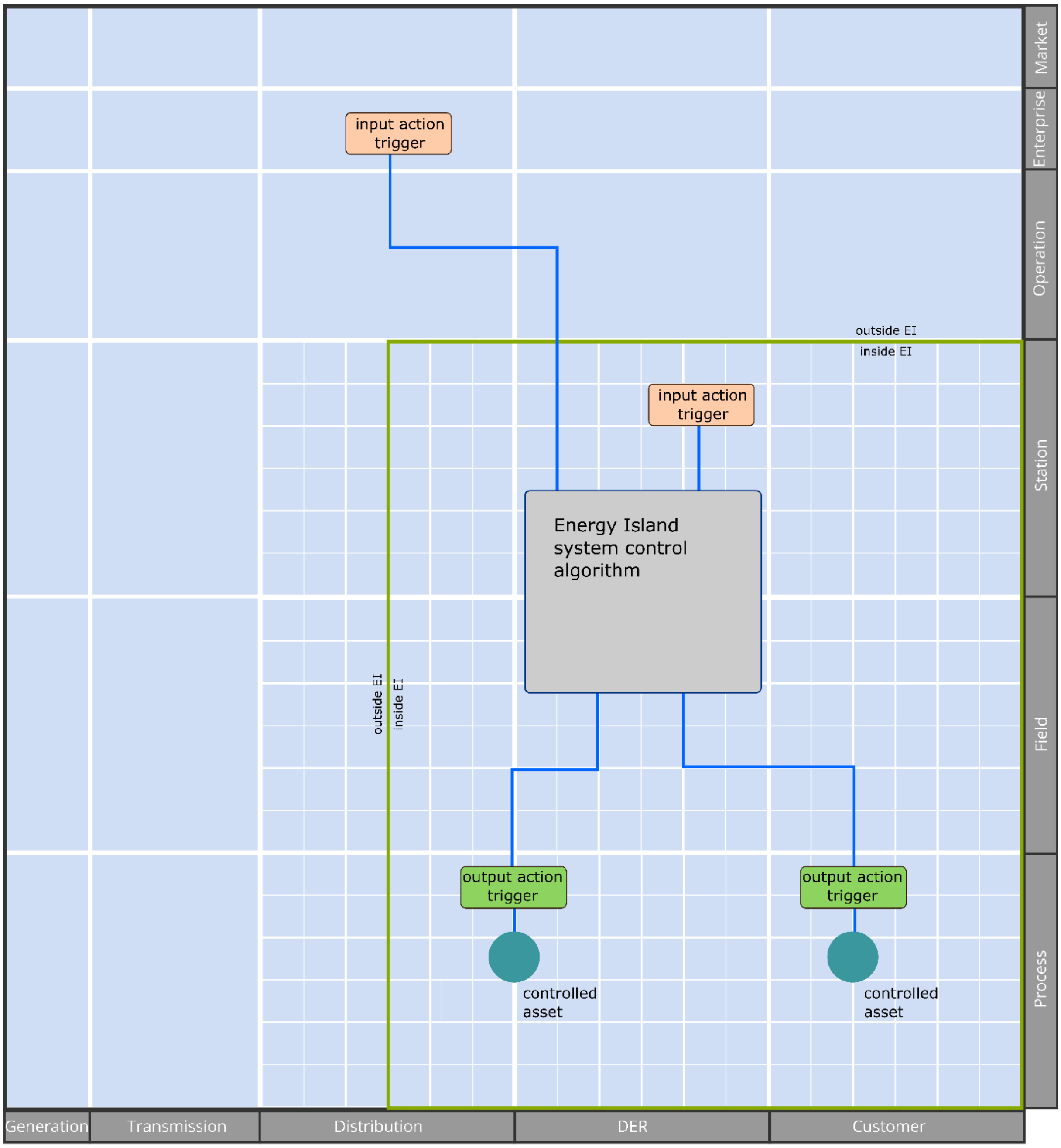


Figure 6: Function Layer of the general representation of an Energy Island

The function layer shows all the functionalities, that are implemented in the form of software control algorithms or manual interactions.

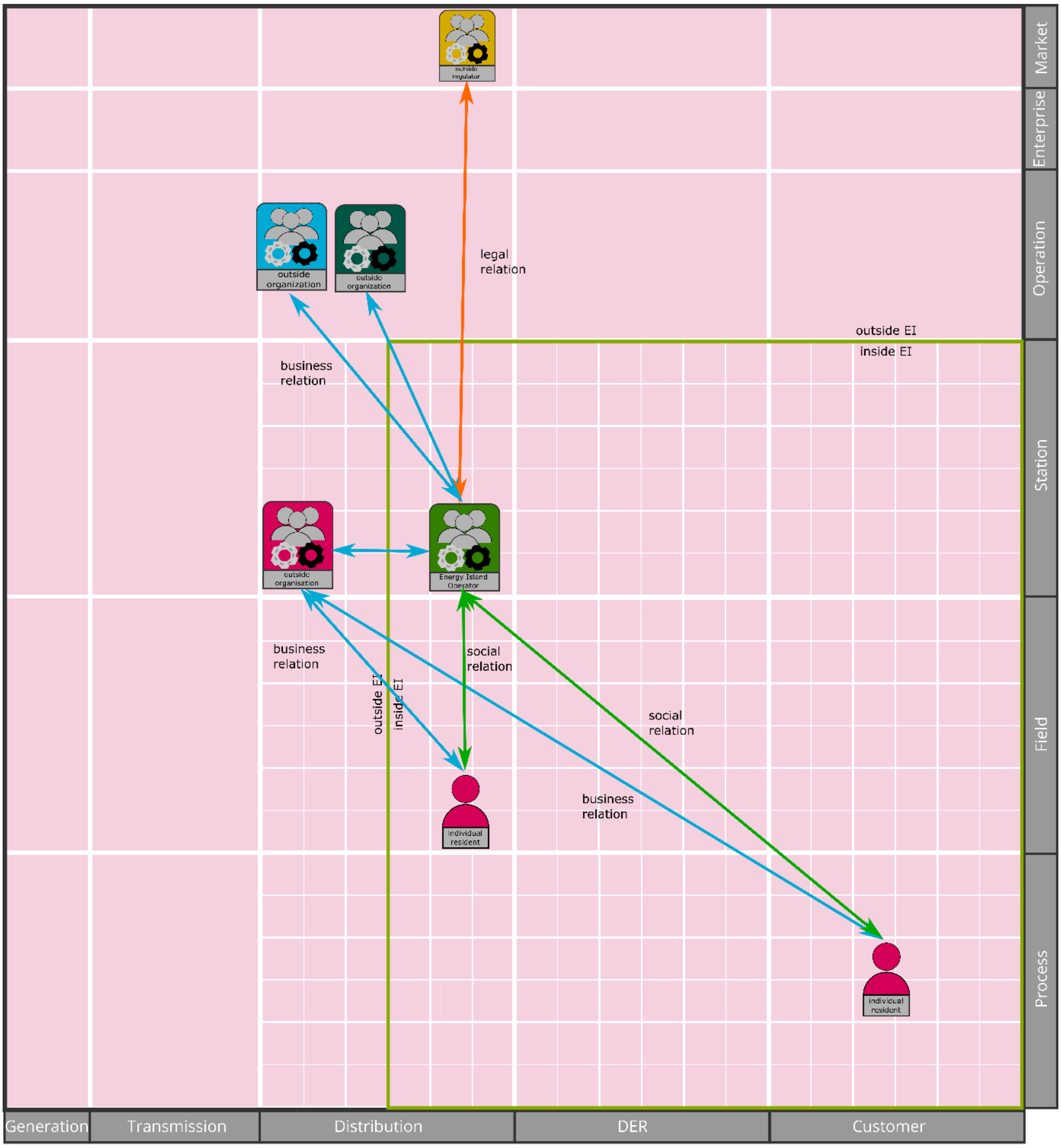


Figure 7: Communication Layer of the general representation of an Energy Island

As with the component layer, the communication layer also shows the boundaries of the EI in respect to data communication. It allows for a clear depiction of where data is generated and where it is processed and what communication protocols are used for the data transfer. This, again, is important to clearly differentiate the operational responsibilities between the EI community and outside third parties.

II.4. RENergetic Replication Package application

Replication in the context of Energy Islands can mean a range of different approaches. It can be done by using the same design and equipment between an EI and the original project. This can be done by building a new energy island in a similar location or by expanding an existing energy island to serve a larger area. There can be modular design approaches, which could involve creating prefabricated units that can be easily transported and assembled on site, or modular control software algorithms that can be deployed in a mix-and-match fashion.

Sharing knowledge and expertise about the design, construction, and operation of energy islands can help other communities or organizations to replicate the success of an existing energy island. This includes the replication of business models, provided the legal and economic frame conditions allow for it.

Overall, energy islands can be replicated by using similar design and equipment, using a modular design, sharing knowledge and expertise, scaling up and replication of business models. Each of these methods has its own advantages and disadvantages depending on the specific context, and careful consideration of the local conditions and requirements is needed when replicating an energy island.

The Final RENergetic Replication Package (RRP), which is outlined in deliverable D8.3 due at the end of the RENergetic project will combine several of the above-mentioned replication approaches and provide a clear instructive pathway for its proper application.

As such the RRP is based on the following principles:

- Goal centric
- User centric
- Context acknowledgement
- Modular Design

The following sub chapters will provide further details on these replication principles.

II.4.1. Goal centric replication

Clear and definitive goals are a great way to steer and coordinate actions towards an improved future situation. Explicitly stated and clearly communicated goals can act as beacon for an EI community if appropriately selected. Suitable goals for energy islands can vary depending on the specific context and conditions of the island, but some examples of common EI goals include:

- **Increasing the use of renewable energy**: This goal aims to increase the amount of energy generated by renewable sources, such as solar and wind power, as a percentage of total energy generated by the energy island.
- **Improving energy efficiency**: This goal aims to improve the overall energy efficiency of the energy island, including the efficiency of the energy generation and storage systems, as well as the energy consumption of buildings and other loads connected to the island.

- **Ensuring reliability**: This goal aims to ensure that the energy island is able to provide a reliable and resilient source of power, reducing dependence on the traditional electrical grid and decreasing vulnerability to power outages caused by natural disasters or other disruptions to the grid.

- **Reducing carbon emissions**: This goal aims to reduce the amount of carbon emissions associated with the energy island, including emissions from the energy generation and storage systems, as well as emissions from the energy consumption of buildings and other loads connected to the island.
- **Energy independence**: This goal aims to increase the ability of the energy island to operate independently of the traditional grid, including the percentage of energy consumed by the island that is generated on-site.
- **Energy security**: This goal aims to increase the ability of the energy island to provide a reliable and resilient source of power, reducing dependence on the traditional electrical power grid.

Economics plays a big role in the motivation and decision making of any human community, therefor it is also important to have clear economic goals in mind when setting up an energy island. Some of the common economic goals for EI include:

- **Reducing energy costs**: By generating and storing energy locally, energy islands can reduce the need to import energy and thus lower energy costs.
- **Creating jobs**: By investing in renewable energy, energy storage and other energy-related projects, energy islands can create jobs in the local community.
- **Increasing economic development**: By investing in energy infrastructure and improving energy efficiency, energy islands can help to drive economic development in the local community.
- **Creating new business opportunities**: By developing energy storage, grid management and other advanced energy technologies, energy islands can create new business opportunities for local companies.
- **Lowering the overall costs of energy**: By using a mix of energy sources, energy storage and demand side management, energy islands can help to lower the overall costs of energy to the end-user.
- **Increasing competitiveness**: By investing in energy efficiency, renewable energy, and advanced energy technologies, energy islands can help to increase the competitiveness of the local economy.
- **Attracting new investments**: By developing a reliable and sustainable energy system, energy islands can attract new investments in the local economy.

But economics and technology must not be the only subjects the matter when developing an EI. Social goals are equally important as technical or economic goals for energy islands as they have a significant impact on the acceptance and success of the project. Some reasons why social goals are important are given below:

- **Community engagement**: By involving the community in the planning and implementation of the energy island, the project can build support and buy-in from local residents. This can help to ensure that the project is accepted and supported by the community, which can increase its chances of success.
- **Social equity**: By ensuring that the benefits of the energy island are distributed fairly and equitably among all members of the community, the project can help to reduce social inequalities and promote social justice.

- **Education and awareness**: By providing education and awareness programs, the project can help to raise awareness about the benefits of renewable energy and energy efficiency and encourage individuals and communities to adopt more sustainable energy practices.
- **Health and safety**: By ensuring that the energy island is designed, built and operated in a way that protects the health and safety of the community, the project can help to improve the overall well-being of the community.
- **Cultural and environmental preservation**: By taking into account the cultural and environmental resources of the community, the project can help to preserve these resources and ensure that the community remains in harmony with its environment.
- **Public participation**: By allowing the public to participate in the decision-making process, the project can help to ensure that the project reflects the needs and aspirations of the community.
- **Transparency**: By providing regular updates and transparent information about the project, the project can help to build trust and confidence among the community.

In conclusion, setting appropriate – that is suitable, achievable and measurable – goals, that include technical, economic and social facets is a key factor in replicating (or even setting up from the ground) of an Energy Island.

II.4.2. User centric replication

Within the RENergetic project a user-centric design paradigm has been adopted and the project strives to follow these principles throughout the whole span of the project. User-centric design is an approach to designing products, services, and systems that focuses on the needs, wants, and preferences of the end-users. The aim is to create solutions that are tailored to the user's needs and that provide a positive and satisfying experience. Designing User-centric solutions involves gathering information about the users through research, such as user interviews, surveys, and observations. This information is then used to inform the design process, helping to ensure that the final design meets the needs of the target users.

User-centric design considers the user's needs throughout the entire design process and creates a user-friendly and efficient solution that meets the user's needs and goals. This approach helps to ensure that the final product is easy to use, efficient and meets the user's needs.

This use-centric approach of the RENergetic projects manifests in the **RENergetic User Epics**.

In the context of software development, an Epic is a high-level requirement or user story that describes a large and complex feature or functionality that the software is intended to provide. It is usually too large to be completed in a single sprint (a time-boxed period for completing a set of tasks) and it should be broken down into smaller, more manageable stories or tasks.

An Epic typically captures the overall goal or objective of a feature and defines the boundaries of what should be included and what should be excluded. It can be used to guide the development team in determining the scope of the feature and to help prioritize the work that needs to be done.

An Epic can also be used to help communicate the feature to stakeholders and customers, as it provides a clear and high-level overview of what the feature will do and how it will benefit the end-users.

The RENergetic project expanded on this idea of user epics that is commonly used in software development and applied it to the whole range of demo actions, that is technical, economic, and social interventions, to be implemented in the three pilot sites.

A RENergetic User Epic summarizes the high-level requirements that describes the necessary technical, social and economic features and functionalities that need to be provided to achieve the goals set forth in the respective user epic.

Defining and communicating the design requirements in the form of epics has been the chosen approach, because user epics can be utilized in the design process by providing a high-level requirement that guides the overall direction of the design and helps to ensure that the final solution meets the needs of the end-users. Ways in which epics can be utilized in a design process include:

- **Defining the scope of the design**: Epics can be used to define the boundaries of the design and to identify what should be included and what should be excluded. This helps to ensure that the design stays focused on the core functionality and does not become bogged down in unnecessary details.
- **Prioritizing design elements**: Epics can be used to prioritize the different design elements and to focus on the most important features first. This helps to ensure that the design stays on track and that the most important features are completed in a timely manner.
- **Communicating with stakeholders**: Epics can be used to communicate the overall goals and objectives of the design to stakeholders and customers. This helps to ensure that everyone is on the same page and that the design meets the needs of the end-users.
- **Guiding user research**: Epics can be used to guide user research and to identify the most important areas to focus on. This helps to ensure that the design is based on a deep understanding of the end-users and their needs.
- **Iterative design**: Epics can be used as a guide for an iterative design process, where the design is refined and improved in multiple rounds based on feedback and testing.
- **Breaking down complexity**: Epics can also be used to break down complex design problems into smaller and more manageable tasks, this helps to ensure that the design process is manageable and clear.

With these principles in mind the RENergetic User Epics have been defined as follows:

1) Heat Supply Optimization
2) Local Waste Heat Optimization
3) Heat Demand Response
4) Electric Vehicle Demand Response
5) Electricity Supply Optimization
6) Electricity Demand Response
7) Social Campaigning

As well as the two meta use-cases

1) Interactive Platform
2) Forecasting

II.4.3. Context sensitive replication

Each intervention and technological solution deployed in one of the RENergetic pilot sites is executed within this site’s specific context.

When replicating solutions from one site to another it is therefore critical to understand the specific context in which the solution has been originally deployed.

For this reason, the Final Replication Package (deliverable D8.3) will provide the SGAM framework for each of the deployed user epics as well as a set of documentation of each sites energy and ICT infrastructure to provide an understanding of the needed context for replication.

The topic of context sensitive replication will be greatly expanded upon once the pilot actions have been concluded and will be a integral part of deliverable D8.3.

II.4.4. Modular Design

In order to create a flexible, scalable, reliable, and cost-effective energy system for EI that can be adaptable to different conditions and changes a modular approach has been adopted for the software design. By breaking down the overall system into smaller, more manageable units, the system can be more easily understood, operated, maintained and scaled.

The topic of modular will be greatly expanded upon once the pilot actions have been concluded and will be an integral part of deliverable D8.3.

II.4.1. Software Design

The RENergetic software suite is being developed with the above outlined principles of replication in mind and is set up as a generally applicable tool and not as a tailor-made solution for each respective pilot.

In this sense the pilot demonstrations will be the first applied replications of the general software modules that are being developed in the RENergetic project

III. ENERGY ISLAND KPI

III.1. KPI as a mean for setting goals

Key performance indicators (KPIs) are metrics used to measure the performance of an energy island against specific goals and objectives. KPIs help to achieve goals for energy islands by providing a way to measure progress towards specific objectives and identify areas for improvement. Some examples of how KPIs can help to achieve goals for energy islands include:

Measuring **progress towards renewable energy goals**: By tracking KPIs such as renewable energy generation and carbon emissions, energy island operators can determine the effectiveness of their renewable energy strategies and identify areas for improvement.

Improving energy efficiency: By tracking KPIs such as energy efficiency and energy storage capacity, energy island operators can identify opportunities to improve the overall energy efficiency of the island, which can lead to cost savings and reduced carbon emissions.

Ensuring reliability: By tracking KPIs such as reliability and uptime, energy island operators can identify areas where the energy island is not performing as expected and take steps to improve the reliability of the island.

Identifying cost savings: By tracking KPIs such as economic performance and energy costs, energy island operators can identify areas where costs can be reduced, which can lead to cost savings and improved economic performance.

Improving energy independence: By tracking KPIs such as energy independence, energy island operators can identify areas where the island is still dependent on the traditional grid and take steps to improve energy independence.

Increasing energy security: By tracking KPIs such as energy security, energy island operators can identify areas where the island is vulnerable to power outages and take steps to increase energy security.

Increasing social cohesion and participation: By tracking social KPIs such as self-identification, acceptance and democratic participation energy island communities can identify areas where the EI might lack social acceptance and identification with the energy island project.

Within the RENergetic project a range of technical, social and economic KPI have been defined and documented in deliverable D7.2.

The selected technical KPI are:

- Self-sufficiency or autarky indicator
- Energy efficiency indicator
- Energy potency indicator
- Share of fossil fuel
- Share of Renewable Energy Sources (RES)
- CO2 intensity

The selected economic KPI are:

- Levelized cost of energy (LCOE)
- Net present value (NPV)
- Internal rate of return (IRR)
- Payback period (PP)
- Discounted payback period (DPP)
- Load purchasing from the grid.
- Energy sold to the grid.

And the selected social KPI are:

- Share of local ownership in energy infrastructure equipment
- Share of local participation in energy system related orders
- High acceptance of the community hubs
- Self-identification with community
- Social Inclusion (participants profiles e.g. social demographics)
- Energy Behaviour Intentions
- Social cohesion
- Job creation through EI
- Thermal comfort
- Attitude towards solutions
- Democratic Participation
- Behavioural intention to become active.
- Collective efficacy beliefs

The calculation, application, and interpretation of the a.m. KPI is lined out and documented in greater detail in the deliverable D7.2. Please refer to this document for a more detailed in-depth discussion of KPI within the RENergetic project. Whereas this document will focus of application of KPI for replication purposes in the next subchapter.

III.2. How to apply KPI in replication

Key performance indicators (KPI) play an important role in the replication of energy islands by providing a measurable way to track the progress of the project and evaluate its performance. Some ways in which KPI can be used in the replication of energy islands include:

- Identifying best practices
- Benchmarking
- Monitoring and controlling

KPI can help to identify best practices in energy islands by providing a measurable way to compare the performance of different energy islands and to determine which ones are performing well. However, all KPI are always context dependent and comparing figures will not necessarily yield a meaningful assessment of the performance of a given EI.

It is therefore important to contextualize the KPI measurements before they are used to identify best practices that are best suited for replication in follower sites.

In the same way Key performance indicators (KPI) can help to benchmark the performance of an energy island against industry standards or other similar projects by providing a measurable way to compare the performance of different energy islands. Benchmarking allows to evaluate the performance of an energy island against other projects, and to identify areas for improvement as long as it is properly contextualized.

Finally, KPI are also an important tool for monitoring and controlling the implementation progress when replicating energy islands. Whereas identifying best practices and benchmarking necessarily draws comparisons to other EI, monitoring and controlling is done within the context of a specific energy island. While this reduces context dependency, still the exact calculation and definition of the KPI used for monitoring needs to be carefully evaluated in order to be able to draw meaningful conclusions from the measurements.

Throughout the pilot implementations in the RENergetic, an evaluation of the KPI defined in D7.2 in respect to applicability for replication will be done and detailed in the Final Replication Package (D8.3).

IV. THE TRANSFORMATION PATHWAY

IV.1. The concept of the Transformation Pathway

A transformation pathway is a strategic plan or roadmap that outlines the steps, actions and policies needed to achieve a specific goal or outcome, in this case, in the context of energy. It defines the direction and steps needed to move from the current state to a desired future state.

Transformation pathways are used to guide the transition to a low-carbon energy system, by providing a clear vision of how to achieve a specific energy goal, such as reducing greenhouse gas emissions or increasing the use of renewable energy. They are usually long-term plans that cover multiple years, and often involve multiple sectors and stakeholders. Transformation pathways can include a wide range of actions and policies, such as increasing energy efficiency, investing in renewable energy technologies, implementing carbon pricing mechanisms, and phasing out fossil fuels. They may also include plans for research and development, public engagement, and capacity building.

The key feature of transformation pathways is that they are holistic, meaning they take into account the multiple interrelated and complex factors that influence the energy sector and the economy, including technical, economic, social, legal and political issues.

Overall, a transformation pathway is a strategic plan that outlines the steps, actions and policies needed to achieve a specific energy goal, such as reducing greenhouse gas emissions or increasing the use of renewable energy. It provides a clear vision for the transition to a low-carbon energy system and guides the actions to be taken over the long-term.

Within the RENergetic project the Transformation Pathway is the roadmap for implementation of the RENergetic solutions, which can be summarized as follows:

- Setting Goals
- Select the corresponding RENergetic User Epic
- Prepare the necessary context.
- Implement the RENergetic User Epic(s)
- Utilize KPI to monitor progress and detect deviations.
- Adapt and Iterate
- Reach the aspired goals.

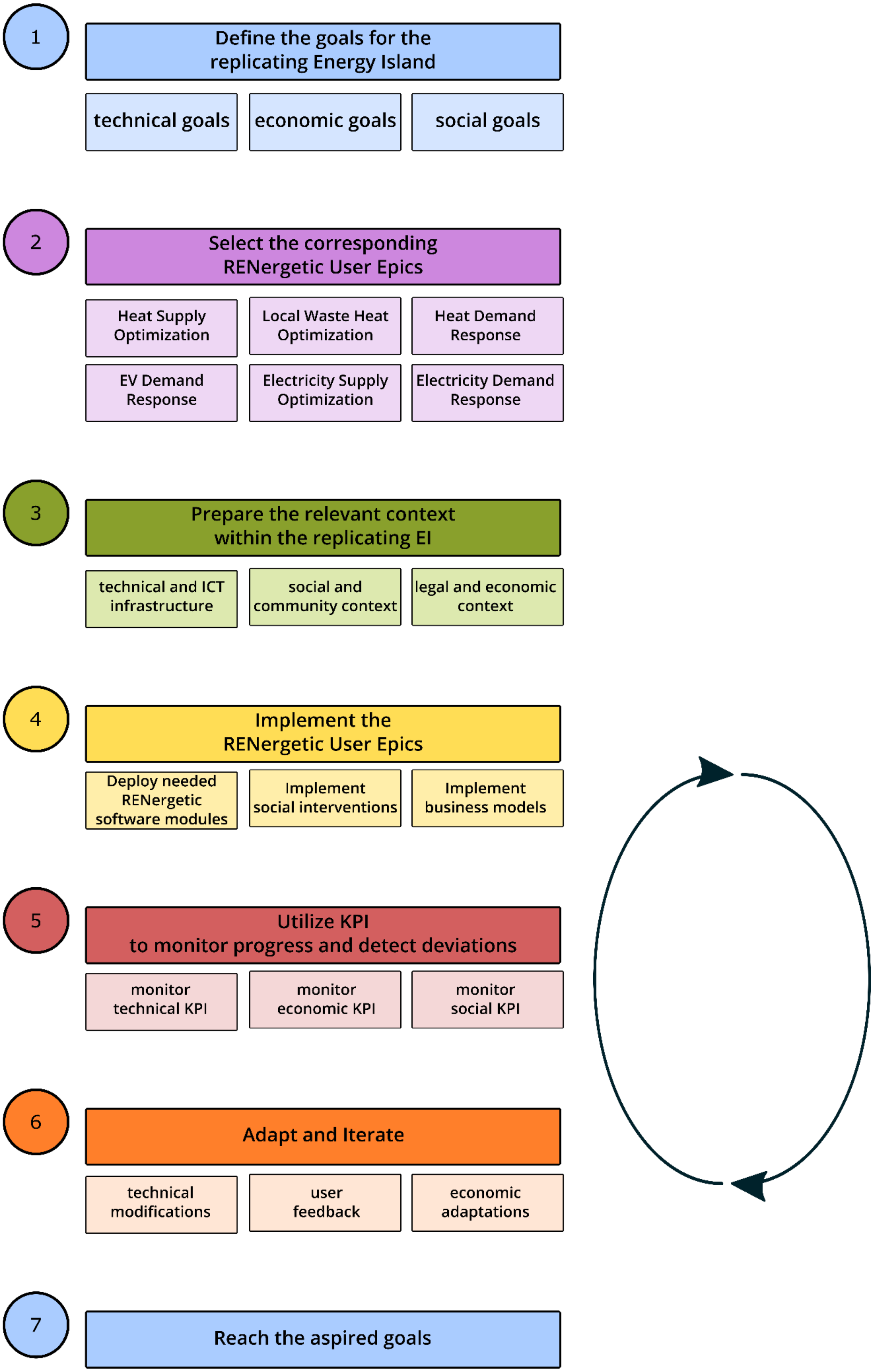


Figure 8: Schematic Overview on the RENergetic Transformation Pathway

1) Setting Goals

Setting goals is the first step of the Transformation Pathway in the process of replicating energy islands. Goals provide direction and focus for the replication process, they help to identify what is important, and they provide a way to measure progress and evaluate the performance of the energy island. Goals can be set for different aspects of the replication process, such as technical, economic, and social goals. By setting specific, measurable goals, it is possible to track progress and evaluate the performance of the energy island, and to identify areas for improvement. This helps to ensure that the replication process is aligned with the specific needs and constraints of different locations. Setting proper goals is a critical factor for successful replication.

2) Select the corresponding RENergetic User Epic

Selecting the correct user epic is the next step of the implementation of the Transformation Pathway in the process of replicating energy islands. User epics provide high-level goals and requirements that describe the needs and wants of the end-users. They are used to inform the design process and to ensure that the final implementation meets the needs of the target users. When selecting a user epic, it is important to consider the specific needs and constraints of the location and the end-users. This means gathering information about the local environment, energy needs, and available resources, and using this information to inform the implementation process. It is also important to involve the end-users in the process, by gathering their feedback. By selecting the correct user epic, it is possible to replicate energy islands that are tailored to the specific needs and preferences of different users and locations. Additionally, by involving the end-users in the process, it can help to build support and buy-in from local residents.

There are 6 user epics implemented at the pilot sites of the RENergetic project, which are summarized in the table below.

Table 4 Summary of the RENergetic User Epics

Epic	Short Description
Heat Supply Optimization	Optimization of the amount of heat that is delivered to the energy island from external sources.
Local Waste Heat Optimization	Optimization of the static configuration of settings to deliver heat to the energy island without compromising on waste heat source operation but at the same time maximizing income from selling heat.
Heat Demand Response	Demand response in heating is a change in heat energy consumption to better match demand for energy with supply of energy. This means a reaction of energy usage by end-users based on a signal: If the energy supply signals that there is a particularly high general energy consumption (i.e. a high grid load) and thus a load peak, the energy consumption should be adjusted to this lack of supply (through a reduction). Demand response in heating therefore describes a reduction of heating at peak times: It describes a (an automated) process by which, at peak times, heating is reduced by external control based on a signal about the peak to ensure sustainable energy usage. End-users should (a) decide about a certain tempaterature band, within which an optimization of heating through a demand-response system is acceptable, (b) agree to such optimization happening automatically and (c) be requested in event based cases of emergency (when the peak is threatening the supply through sustainable energy sources) to adapt their behavior accordingly and extraordinary to their temperature range.
EV Demand Response	This epic shall optimize ene charging location with multiple charge points (typically up to 22 kW), ideally with local PV and battery connected. It could be public, semi-public or private charging with different pricing and operation options. The epic implements different objectives for different stakeholders (e.g. load shifting, cost optimization, max. renewable charging). User experience is a key requirement. V2G functionality is implemented as outlook. %
Electricity Supply Optimization	The objective of this epic is threefold: (1) to balance demand and supply in the island utilizing forecasting models for both, (2) to optimize usage of available energy sources within the island (more-green-for-less-grid, prioritizing CO2 reductions, and reducing energy cost), (3) to ensure the grid stability by monitoring and controlling frequency and voltage
Electricity Demand Response	The electricity demand side shall be partially controlled through DR programs and control strategies to help supply side to smooth load peaks and insure grid reliability. Users shall also benefit by participating in the DR program, e.g. by reducing energy expenses.
Social Campaigning	The objective of Social Campaigning is to complement all technical interventions with social interventions and methods in order to achieve a high acceptancs, and thus overall success, for the respective epic implementation
Meta: Interactive Platform	The interactive platform is a meta-use case that addresses the need for representation, feedback and system analysis of all other use cases. Within this epic, it is noted (1) what data is important for an interactive platform, (2) who is interested in what data, (3) what kind of visualisations are used, (4) whether quantitative data (concrete numbers), qualitative data (feedback and recommendations) or both should be provided, and (5) how such a visualisation needs to be designed to make it both useful and vivid for the respective stakeholder groups.
Meta: Forecasting	This epic is about the different forecast user stories either in heating or electricity domains. It is about appliying 4 different models/application: Forecasting, Root-cause analysis, anomaly detection, or sensitivity analysis.

3) Prepare the necessary context

Providing the correct context is the third step of the implementation of the Transformation Pathway in the process of replicating energy islands. Context refers to the specific needs, constraints, and environment of the location where the energy island will be replicated. It includes factors such as the already available infrastructure, the local energy market, the available energy resources, the regulations and policies, as well as the cultural and social aspects of the location.

The RENergetic solutions and software models need a specific context in order to be able to be deployed to a new site. Part of providing the necessary context therefor also includes to provide the needed data, interfaces and access to controls before a solution is rolled out. The specifics of these interface requirements and needed context preparations will be detailed in the deliverable 8.3.

4) Implement the RENergetic User Epic(s)

Implementation of the RENergetic User Epics is the fourth step of the implementation of the Transformation Pathway in the process of replicating energy islands. It can be done, once the needed context is prepared and encompasses the deployment of the corresponding RENergetic software modules, accompanying social interventions and related business models.

5) Utilize KPI to monitor progress and detect deviations

Utilize KPI to monitor progress and detect deviations is the fifth step of the Transformation Pathway. Key Performance Indicators (KPI) can be used to monitor progress and detect deviations in the replication process of energy islands. KPI are specific, measurable goals that are used to track progress and evaluate the performance of the energy island. They are aligned with the specific goals and objectives of the replication process and provide a way to measure progress over time. To utilize KPI effectively, it is important to select the right KPI, set specific, measurable goals, and track progress over time. This can be done by regularly collecting data, analyzing the data, and comparing it to the goals and objectives. If a deviation is detected, it is important to investigate the cause of the deviation and make necessary adjustments to the replication process. By utilizing KPI, it is possible to track progress and detect deviations in the replication process, and to take corrective action when necessary.

6) Adapt and Iterate

As the sixth step in the Transformation Pathway, adaptation and iteration are necessary because they allow for flexibility and continuous improvement in the replication process. Replicating energy islands can be complex and challenging, and the specific needs and constraints of different locations may vary. Adaptation refers to the ability to adjust and adapt the replication process to the specific needs and constraints of different locations. This can involve making changes to the design, the technology, or the overall approach to the replication process. Iteration refers to the process of repeating some steps in the replication process, making improvements and adjustments each time, and learning from previous experiences. By adapting and iterating, it is possible to improve the results of the replication process over time, to optimize the design and technology, and to ensure that the replication process is aligned with the specific needs and constraints of different locations.

7) Reach the aspired goals

The final step in the Transformation Pathway is to reach the goals as defined in the beginning. Reaching aspired goals when replicating energy islands requires a combination of setting specific, measurable goals, utilizing key performance indicators (KPI) to monitor progress, adapting and iterating the replication process, and involving local stakeholders and community members. Involving local stakeholders and community members helps to gather feedback and preferences, build support and buy-in, and ensure that the replication process meets the needs of the target users. By following these steps, it is possible to reach the aspired goals, ensure that the replication process is aligned with the specific needs and constraints of different locations, and can increase the chances of success.

V. RENERGETIC PILOT EXAMPLES

As already mentioned above the pilot interventions in the RENergetic project are structured around the RENergetic user epics. The table below gives and overview which of the epics are being implemented in each of the pilots with some additional notes given on the implementation specifics.

Table 5 Overview on the epic implementation in the RENergetic pilots

Epic/Pilot		**Ghent**	**Poznan**	**Segrate**
Energy Reduction Campaign/Social Campaigning		**X**	**X**	**X**
	Notes	HeatDR Survey, Focus Groups, Interactive Platform	HeatDR Survey, Interactive Platform	HeatDR Survey, Focus Groups, Interactive Platform
Heat Supply Optimization				
	Notes	Optimizing Scheduling of different heat sources	Optimizing existing heat water loop	Forecasting demand and right-fit the supply accordingly
Local Waste Heat Optimization			**X**	
	Notes		Integrating Data Centre Waste Heat. Simulation tool for designing and planning of local waste heat utilization.	
Heat Demand Response		**X**	**X**	
	Notes	Manual & automated; social experiments	Manual & semi-automated; social experiments; integration with district heating network. Forecasting heat demand.	
EV Demand Response		**X**		**X**
	Notes	Manual & automated; red-light experiment		Manual & automated (with real field application in OSR parkings)

Electricity Supply Optimization			**X**	**X**
	Notes		PV generation forecasting and electricity demand. Interactive platform.	HeatDR Survey, Focus Groups, Interactive Platform; Forecasting demand and right-fit the supply accordingly
Electricity Demand Response		**X**		
	Notes	Automated: Capacity Tariff Optimization		

V.1. Ghent

The DuCoop project started in 2012, when a feasibility study was initiated by CEIP (Clean Energy Innovative Projects), which wanted to integrate decentral wastewater treatment with other sustainable technologies, like 4th generation district heating based on aquathermics (w/w heat pump) and low-temperature industrial waste heat, resource- and water recovery and smart renewable energy systems.

These concepts were integrated in ‘De Nieuwe Dokken’ site, which is considered as an important showcase on a first phase of buildings how a sustainable, liveable environment can be created in a densely populated area. The main purpose of the project is to demonstrate economically viable business models for decentral treatment of residential wastewater with integration of other sustainable technologies, like low-temperature district heating, resource- and water recovery and smart energy control systems.

At full deployment, the district will be an example of circular economy, with yearly re-use of over 30.000m³ of freshwater (>90% of the total consumption), recovery of over 750MWh of waste heat and the production of 1.500kg of phosphate- and nitrogen rich crystals (struvite), which could be used as a renewable fertilizer in a local urban agriculture project. This water treatment system will combine novel technologies like vacuum sewer systems, digestion of black water, struvite recovery, recovery of waste heat from the effluent of the water treatment plant with a heat pump and an aerobic membrane bioreactor.

The cooperation DuCoop has realized a 4th generation district heating network providing the 400 apartments in the ‘Nieuwe Dokken’ district in Ghent with central heating and sanitary hot water, supplied with sustainable waste heat that is produced from biogas and a heat pump. This will cover up to 1/3 of the district’s heat demand (1.500 MWh). The remaining heat will be provided by low-temperature (55°C) waste heat from nearby industry, which should be able to provide the peak demand of the heating system at any time. Next to this, DuCoop will develop solar PV-panels on the rooftops of the apartment buildings, offer EV-charging points for sustainable (shared) mobility and try to optimize the energy consumption through storage, information networks and data monitoring, and the use of intelligent energy management system (EMS) algorithms.

People are involved, informed and aware of the sustainable values of the project, and we are enjoying a huge degree of participation in our board meetings, information sessions, etc. Also, other stakeholders (universities, knowledge institutions, project developers, policy makers) want to come and see the project during site visits, colloquia and events.

In 2019, A first phase of buildings became realized and connected to the utility services of DuCoop. In the underground premises of the Central field all crucial sustainable systems (water treatment plant, vacuum station+ grid, district heating network & pumping station, buffers) became installed to operate the sustainability system for the whole neighbourhood.

V.1.1. Epics and their implementation in the pilot

The Ghent pilot is the most ambitious pilot site with the largest set of opportunities to pursue RENergetic objectives: it aims at a rather high level of energetic self-sufficiency, at the same time offering power services to the external power grid (via price-based DR). The reason for this is that this real estate project was developed with sustainability in mind – and a big share of inhabitants have chosen this location due to this very founding narrative. The Ghent pilot focuses on the following epics:

- Social Campaigning/Energy Reduction Campaign
- Heat Supply Optimization
- Heat Demand Response (both manual and automated)

- EV Demand Response (both manual and automated)
- Electricity Demand Response

with the help of the RENergetic approach, the pilot targets the following main technical KPIs (for the definitions, see D7.2) for the end of the project duration:

- A self-sufficiency with regards to heat of around 80%
- A self-sufficiency with regards to electricity of around 10%
- A share of sustainable sources with regards to heat of around 80%
- A share of RES with regards to electricity of around 10%

While it is difficult to attribute changes to the implementation of a specific epic, currently, data collection is being set up to enable the monitoring of the EI as a whole. In the following, the flavour of the epics' implementation and the aspired impacts are shortly described:

Social Campaigning/Energy Reduction Campaign

In the context of the energy reduction campaign epic, which is the sole epic without a computer science based technical management and optimization module, the Ghent pilot continuously engages the inhabitants of the NewDokken in order to both increase awareness of the challenges of reaching a high level of energetic self-sufficiency (e.g. understanding the issues of only temporary availability of waste heat), increase acceptance of technical measures (e.g. adapting the heat curve in case of need) and the active collaboration in cases of manual DR schemes. This is supported by understanding drivers and barriers for HeatDR through a survey.

The means applied were *interviews* at the beginning of the project. Since then, a *focus group* has been established that has started to meet on a more or less regular basis, discussing on a level playing field very concretely planned measures to increase self-sufficiency. Currently, the *public interactive platform* is being set up in order to back these discussions with almost real-time information on supply and demand structures on energy island level. This will later be amended by more information on *individual level*, specifically for participating in both heat and electricity manual demand response schemes. Finally, a *survey* was used in order to understand how to design the HeatDR schemes to boost participation and collaboration.

Heat Supply Optimization

The heat supply optimization epic, on the contrary, is a mere technical epic, where the dispatching of the heat sources available at the Ghent pilot is optimized both with regards to maximizing the share of RES and minimizing financial cost. The heat sources at Ghent that need to be managed are *air/water heat pumps, waste heat from Christeyns' production processes and later from the CHP planned by Christeyns, a biogas burner and a regular gas boiler*. The heat sources located at Christeyns are not dispatchable and the regular gas boiler is meant only as a last resort. Heat pumps are to be employed based on the current availability of EI electricity (from PV or the onsite battery), DR obligations, low prices and other electricity demand. They are therefore the connectors to the global optimizer.

Heat Demand Response

The heating challenge at Ghent consists of heating the building using a *floor heating* and heating the *hot water for the private usage* of the inhabitants. The acceptance of HeatDR for floor heating was tested in winter 2022, by asking inhabitants to agree to pre-heating their rooms via a manipulation of the thermostats as an implementation of automated DR in a step-wedge experimental design. The reason to focus on automated DR for the room heating lies in the floor heating technology: due to its high level of inertia, manipulating the room heating manually would be too much of a cognitive effort for inhabitants that would have to ponder on the delay and duration of the adaptation. The experimental results are promising, with an acceptance rate of 77% of the approached apartments. It turned out that the written communication was much less convincing than the direct personal communication to achieve agreement to the automated HeatDR scheme: almost 50% of people opted into the scheme due to personal communication. This experiment will be re-cast in winter 2023 using a higher number of apartments, an opt-out approach, and a heat-curve adaptation instead of a thermostat adaptation as the physical activation is easier for the operators.

Manual HeatDR will be implemented for the private hot water usage, based again on the availability of REN heat energy. This is planned to be tested socially and implemented technically in the winter of 2023/24.

Electric Vehicle Demand Response

With 20 private and public charging stations (CS) in the Central Field currently, 16 currently being installed in the North field and another 16 in the North field probably to come, the Ghent pilot is very interested in managing the according power flows. Also, for EV DR both options, automated and manual are being foreseen. Automated EV DR is the adaptation of the charging current in a car depending on either REN availability, price or a weighted combination of both. Constraints in the charging optimization algorithm will be mainly the due time that has to be entered by the CS user, changing a default value. However, as for the time being, the access to the CSs operational software (owned by PowerDale, not a RENergetic partner) is not possible, in a first iteration this scheme will be simulated in summer 2023. However, it is expected that access will be granted for future tests.

Manual EV DR can be either combined with Automated EV DR or implemented as a stand-alone scheme. As such, the pilot in Ghent will start with social science testing of the reaction of EV drivers to the communication of “good” and “bad” times of charging the EV from the point of REN availability: in spring 2023 a “Red-light” will be constructed at the entrance to the garage with most of the CSs that indicates this availability in a very simple way: red – “please do not charge now”; green – “this is a good time for charging” and yellow – “it is okay, to charge now or later”.

Electricity Demand Response

The electricity DR epic will be implemented in Ghent in the form of supporting inhabitants at optimizing their individual electricity demands (except EV charging, see above) against a capacity-based tariff that is being introduced currently. Through smart meters on apartment level the necessary data for managing the private demand will be made available. It is planned to implement electricity DR in the form of an automated DR using the inherent flexibilities in smart white ware as e.g., washers. For the electricity DR on island level, it is aimed at reducing the DSO capacity tariff for DuCoop. The target device in this case are the heat pumps as connectors between the heat and the electricity energy domains. The corresponding algorithms are currently being developed as part of the global optimizer; social science interventions are currently not planned.

V.1.1.a. RENergetic software modules for the pilot

Ghent pilot has already modern energy management system (EMS) that is capable of control and monitoring of the different assets in the buildings. Residents of the Ghent pilot site can monitor their energy consumption using smartphone app or screens installed in the apartments.

RENergetic system in Ghent focuses on providing new functionalities, not yet covered by the Ghent EMS, as well as on replicating the functionalities from Ghent system and making them available to use in the other energy islands. For instance, private interactive platform screens with data consumption dashboards are going to be designed in a similar way they are implemented in Ghent.

Forecasting services from RENergetic are aimed to improve control and monitoring of assets in the Ghent system. The data from Ghent pilot is sent to the RENergetic system using injection API. The result of the forecasts is shown in Grafana dashboards in RENergetic system, which can be used by the energy managers to analyse the future energy generation and consumption. The Kubeflow software manages training and inference process. The following forecasting functionalities are planned to be implemented for Ghent pilot:

- Waste heat generation forecasting,
- PV generation forecasting,
- Electricity consumption of the equipment used in the pilot cite (water treatment plant, vacuum sewer systems, elevators),
- Aggregated heat consumption of the energy island.

Output of the forecasting models are also utilized by the global multi-objective optimization algorithm. It is used for planning the energy flow between heating and electricity domain. It creates consumption and generation curves that ensure that the waste heat is utilized as much as possible and PV systems and battery storage system are used to increase the autarky of the energy island. Additional constraints, for example, terms of capacity tariff can be added to the optimization. The output of the global optimizer is available through API and is shown on the Grafana dashboards.

Public interactive dashboards screens show the current situation in the energy island – what is the share of renewable sources that are used for energy generation in electricity and heat domains. The separate screen shows what are the main consumer groups in the energy island and how much energy do they consume in each domain. The screens can be seen using the web browser and the data used for the visualizations is available through API.

Demand response for electric vehicle charging is planned to be included in the RENergetic system for the Ghent pilot. Although, due to the difficulties with controlling each charging session, the real tests in the pilot site can be replaced by simulations.

V.1.1.b. Applied business models in the pilot

The business models to be implemented in the Ghent pilot focus on mainly two topics. One is the electricity demand response to not only reduce energy costs in general but to also allow to adapt to the dynamic grid fees that are to be implemented in Belgium in the future. The other business model to be implemented revolves around the optimization of waste heat utilization in order to reduce overal heat energy cost for the pilot community. These business models will be further developed and detailed and a comprehensive summary will be given in the Final Replication package in deliverable D8.3. Applied social models in the pilot.

A rather strong community is already established within the Ghent Pilot, which is why the social models and strategies are based on this foundation. In particular, the Social Identity Model of Pro-environmental Action (SIMPEA; Fritsche et al., 2018) is employed for the development of theory-based interventions and campaigns. This model focuses on the centrality of social identity processes for pro-environmental behavior, both for public and private sphere behaviors. Here, ingroup norms, ingroup identification and collective efficacy play an important role alongside collective emotions to motivate collective actions and foster pro-environmental behavior change. Applying the SIMPEA works particularly well in contexts where inhabitants already have a concrete social group/community to fall back on, which they ideally also associate with a pro-environmental identity. In this way, strengthening identification with this group through interventions and campaigns can also lead to a strengthening of their own environmental identity. Likewise, the social norms of the group can influence not only present, but also future behavior by incorporating these norms. Collective efficacy beliefs can further be a lever to compensate for a possible lack of individual efficacy beliefs. To apply the model in a given context, interventions and campaigns are a way to translate theory-based assumptions into concrete, real-life experiments. On the one hand, this can be done by linking it to technical developments, which require user interaction anyway. Further, other measures or communication tools can also be used to strengthen the various social identity processes for pro-environmental behavior. Exemplary, established interventions especially for social norms (e.g., the communication of descriptive social norms, i.e., the behavior of others in the community) do exist.

Implementation in Ghent

Building on the already established community within Ghent, all social activities, or technical activities with a social component used a collective framing and aimed to strengthen social identity processes. This was done both e.g., through activating the collective efficacy and a shared identity with the implementation of Heat DR Trial as part of the epic Heat Demand Response, or by building up a regular focus group within the Energy Reduction Campaign/Social Campaigning. Further, trusted relationships from within the community were used to ensure credibility and a sense of belonging.

V.2. Poznan

Poznan University of Technology (PUT) together with Poznan Supercomputing and Networking Center (PSNC) create a strong academic campus and separated district for 535.000 citizens in Poznan city, western Poland. Both PUT and PSNC also own properties on Kakolewo airport located 70 km west from Poznan. Most buildings are supplied from the district heating network with heat produced from burning mainly fossil fuels (coal). RES possibilities are limited, though present.

The PUT and PSNC long-therm strategic plans (far beyond the scope of RENergetic project) include:

- Integration of local energy systems to use waste heat,
- Transfer heat from one building to another,
- Increase the share of RES (up to 1.5 MWp of solar power generation and 2 MW of ground-source heat pumps in total production) in heat (8 MW of district heat stations) and electricity (1.5 MW of power),
- Optimize energy demand using BMS and IoT technologies,
- Involving end-users in RECs.

The idea was to study and evaluate the possibility of use water circuit between PSNC and PUT campus. The loop could create the chance of transferring waste heat from PSNC to PUT and connecting PSNC to the heating network of Poznan run by Veolia company. Water-cooled chillers could have also been used to supply heat to the loop. Due to the depreciation rules and lack of funding from local sources, realisation of the construction of the prototype, as not possible within the project lifetime, was abandoned. Simulation tests will be carried out instead to confirm the validity of the assumptions and present energy reduction capabilities and replicability potential of the project.

Another idea is also to use the university buildings as a heat storage. Walls, thermal activated building structure (TABS) and atrium spaces can be useful for this. The simulation model developed in RENergetic allows the PSNC data center at PUT campus and the heating operator of Veolia to evaluate various scenarios for the reuse of waste heat. Simulation models are supported by historical data from island energy facilities and real infrastructure experiments, such as a response to thermal demand from pre-heating buildings or participation of local community users.

Due to dense urban areas, the campus could have no more than 1.5 MWp rooftop solar power plants, that is why stakeholders' future plan is to cover the total yearly energy demand by PV solar plant production located on the ground at Kakolewo Airport. PUT and PSNC investment in PV plants is divided into two phases: the first phase (2x1 MWp - tender design preparation stage) and the second phase (20 MWp in total - applying for permission stage). The second phase of the PV plant should cover current 11.000 MWh/year total electricity consumption together with additional consumption due to the implementation of ground source heat-pumps (GSHP) and new buildings to be erected. In RENergetic, technical, economic, legal and regulatory aspects of the RES integration are analyzed and evaluated.

Mobile and web applications are considered as an interface between local community users and facility managers. The applications will be dedicated for students and PUT and PSNC staff and used for Post Occupancy Evaluation. The RENergetic system will support energy managers in their decisions concerning configuration and optimization of the energy island buildings and facilities by delivering detailed monitoring, forecasts, and recommendations. The idea is also to send notifications encouraging users to specific energy savings or Demand Side Response actions (temperature increase/decrease, change ventilation rate by closing/opening window, electricity savings during consumption peaks – turning off AC or PCs, etc.). System of sensors for indoor air quality, temperature, humidity, presence should also be involved to help users to ventilate rooms right (CO2 levels). Evaluation of the impact of interactions with local community users will be done by comparing users output and real effect measured by BMS sensors.

V.2.1. Epics and their implementation in the pilot

The Poznan pilot is characterized by the neighborhood of the university (PUT) and the data center (PSNC). Contrary to the Ghent pilot DuCoop these two institutions were not originally aimed at sustainability, but mainly at offering high quality education, supported by the digital services of the data center. This mindset of local stakeholders is slowly changing with the advent of climate and energy crises. The Poznan pilot focuses on the following epics:

- Energy Reduction Campaign
- Local Waste Heat Optimization
- Heat Demand Response (both manual and semi-automated)
- Heat Supply Optimization
- Electricity Supply Optimization

While it is difficult to attribute changes to the implementation of a specific epic, currently, also in Poznan data collection is being set up to enable the monitoring of the EI as a whole. The concrete goals to be achieved in the Poznan pilot will be given as part of the deliverable D7.3

In the following, the flavour of the epics' implementation and the aspired impacts are shortly described:

Energy Reduction Campaign

The energy reduction campaign epic focuses on the inhabitants and associates of the university campus, i.e., students living in dormitories, external students and staff as well as PSNC staff. The main activity planned in Poznan except for the HeatDR acceptance survey as explained in section V.1.1. is increasing the awareness level of students and staff through displaying the information about supply and demand structure with daily actuality on screens inside corridors and making it available via websites. This objective was further supported by a one-time activity during the PMB meeting at PUT where passers-by (mostly students) were invited to participate in a visual survey game to understand the characteristics that the energy turnaround should have for PUT students and staff. With this it was originally intended to build up an EI focus group, but the effort proved to be spent in vain, as the workload of students is extremely high and their propensity of participating in such a group accordingly low: only 1 student feedbacked interest to join such a group. This is why this endeavor was abandoned.

Local Waste Heat Optimization

This epic manages the waste heat flow from PSNC data center for heating the university buildings at PUT as well as exceptionally transfer heat to the Veolia district heating network. Thus, PUT aims at increasing the campus energy self-sufficiency in terms of heat reuse instead of external heat or heat supplied via the heat pumps that still depend on electricity. The original plan in the project was to construct a physical connection (water loop circuit) between the data center PSNC and the Chemistry Faculty building at PUT. Due to financial issues (depreciation and lack of funding from local sources), this could not be realized so that this epic will be implemented via simulation using the supply data within PSCN and the heat demand data from PUT. The main features to be implemented are to forecast supplied heat via the analysis, optimization and forecasting of the PSNC data center model, to simulate the impact of workload changes on this heat supply profile and optimization of work parameters and the injection of heat into the Veolia district heating network (this is the connection with the HeatDR epic in the Poznan pilot).

Heat Demand Response

Also, in the Poznan pilot HeatDR will be implemented both in semi-automated and manual design. Here, semi-automated HeatDR is prioritized as there is a business case developing with Veolia, the district heating network operator and part of the RENergetic consortium. In order to avoid ramping up new generators thus increasing CO2 emissions, Veolia will send out heat reduction requests with a 24-hour-notice once in a while. In order to be able to keep the contract, HeatDR is carried out in the automated version; in effect, in a semi-automated way as the RENergetic system will not activate the steering points (e.g., heating curve) directly, but rather it will give out recommendations to be enacted by the PUT technical managers. The envisioned method will be to preheat buildings nightly uninhabited (as e.g., the chemistry or the architectural buildings) in order to reduce next day heat demand.

Manual HeatDR will be carried out in an experimental way in student dormitories: defining DR events either based on the HeatDR contract with Veolia or based on the REN availability to run heat pumps, PUT will send out requests to students to reduce their heating for a limited amount of time. This will take the form of a social science experiment (planned for winter 2023) asking for the best communication contents and tool in order to achieve a high level of communication. The results from the HeatDR survey will be used to design this experiment accordingly. Depending on the impact compared to the effort of implementing this DR scheme, it will be added to PUT’s RENergetic implementation.

Heat Supply Optimization

PUT currently has an existing small water loop between two buildings (Chemistry Faculty and Architecture Faculty). Due to the Covid-19 pandemic it has not yet been used. There are plans to test and optimize the operation of this installation. This installation has 450kW of power, which is nearly half the demand of the Chemistry Faculty building and more than double that of the Architecture Faculty building. These values show how much impact the proper use of this type of solution can have on increasing the autarky of the energy island.

Electricity supply optimization

Development within electricity supply optimization epic is planned as well. The electricity consumption in the energy island, especially in the data center, significantly exceeds the generation from renewable energy sources and external photovoltaic power plants, most of them are still at the planning stage and their construction is prolonged due to formal and legal issues. Thus, in this epic a significant effort will be made to forecast power/energy generation from photovoltaic energy sources as well as energy consumption within energy island. In addition, effort will be made in the development of the interactive platform where it will be possible to get information about the electricity domain. This action will increase stakeholder awareness and their access to island energy information.

V.2.1.a. RENergetic software modules for the pilot

Data from sensors and equipment installed in PSNC and PUT premises is planned to be uploaded to the RENergetic system using injection API. Public interactive dashboard screens that show the current sources of the energy and main groups of the consumers in the energy island will be available in Poznan. These screens are implemented as web pages and can be shown on the screens inside the Poznan pilot site.

The rest of the functionalities planned for the Poznan pilot focuses on providing energy managers more insights about current state of the energy island and supporting them in its further optimization. That include the forecasting models and corresponding dashboards in Grafana for the following components of the system (ML operations are supported by Kubeflow platform):

- Heat demand forecasting.
- Forecasting of the waste heat from data centre.
- PV generation forecasting.
- Electricity demand forecasting.
- Simulation of the data center waste heat re-use within the energy island (and in district heating network).

In addition to that, the web panel for energy manger is planned to be implemented in Poznan. There, the optimal parameters of the heating system can be chosen in order to react to the heat demand response messages from heat provider (Veolia). It will be based on the results of forecasting algorithms and will provide support for semi-automated heat demand response experiment.

Depending on the results of the amendment process, other dashboards for energy manger can be designed to support local waste heat optimization simulations.

V.2.1.b. Applied business models in the pilot.

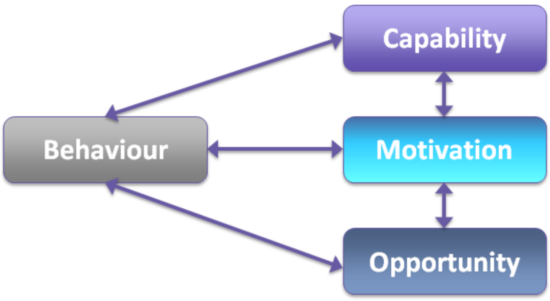
The business models to be implemented in the Poznan pilot are strongly focused on the reduction of energy costs for the heat supply and are being developed between the campus administration and the district heating supplier as the main stakeholders in this process. These business models will include (i) provision of waste heat from a data center to campus buildings and a district heating operator and (ii) on heat demand response service provided to district heating operator (or as a reaction to shortage of local waste heat).

These business models will be further developed and detailed, and a comprehensive summary will be given in the Final Replication package in deliverable D8.3.

V.2.1.c. Applied social models in the pilot

Theoretical Background

The theoretical background for the approach applied in Poznan (specifically PUT, as the potential area for the building up of a community) is the COM-B model which explains basic requirements for change and maps strategies to the different drivers. Figure xx presents the requirements, all of which must be present to some degree in order to make change happen. In essence, to make change happen, there must be the physical opportunity to implement a changing action or behaviour, e.g., the opportunity to reduce room temperature to save energy. Furthermore, people need to have the general motivation for this change (other models deal a lot deeper with the origin and drivers of motivation) and finally the mental or physical capability to do so, e.g., understand the way that a thermostat, that regulates room temperature, works. These drivers of change, however, are interdependent: if one of them is less pronounced, this can be made up by a “higher level” of another one.



Each of the identified drivers of behaviour change has to be analyzed for the specific situation, and for each of them a different set of measures can then be determined.

Implementation in Poznan

At the beginning of the project, there was no energy related community in Poznan, contrary to e.g., Gent, on which communication measures could build. In the context of the **Energy Reduction Campaign/Social Campaigning epic** RENergetic PUT team therefore tried to set up a PUT students' energy group. However, when communicating with students a high lack of interest was identified which limited the social activities that could be performed. Analyzing these challenges with the help of the COM-B model unveils that from the students point even though there is the opportunity to set up a focus group or community event in general, the high density in their schedules during the semester reduces the necessary allocation of time. Also, in general, students are capable to answer to requests from the RENergetic PUT team, the relevance for their own life for many of them was not clear, limiting their social capability to grasp this opportunity. This could have been compensated with a high level of motivation, but the communication with students showed a total lack of interest.

In order to raise interest and awareness, tackling both motivation and capability, the RENergetic team set up an information and awareness campaign as the first step:

- A gamification survey was carried through in parallel to a RENergetic PMB meeting. This "energy island game" asks participants to choose e.g., preferred partners and energy sources in a graphical way. This component will be available at the end of the project.
- Currently the public interactive platform is designed and set up at central places on the PUT campus to inform students and staff about the current energetic status of the campus. The design guidelines and mock-ups for this interactive platform will be available at the end of the project.

One focus of the PUT team is heat demand at the university, specifically the **HeatDR epic**, due to a high level of heating. To explore this option, a HeatDR experiment will be carried through at students' dormitory. One issue might be the motivation to participate, as students pay a fixed price for heating. It remains to be seen, if the information and awareness campaign will have increased motivation until then.

V.3. Segrate

The Ospedale San Raffaele OSR is a world renowned highly specialized multi-disciplinary medical center. OSR is located in the east side area of Milano and service directly the SEGRATE – MILANO – VIMODRONE area complex (North of Italy). Its service target is on treatment, clinical research and teaching activities with more than 50 clinical specialties available and with over 1340 beds, with a yearly 51,000 patient admissions, 72,000 emergency room encounters and delivery over 1.5 million outpatient medical services. Also, the Biomedical research constitutes, together with assistance and teaching, one of the pillars on which the OSR stands. With its over 1500 researchers (translational and clinical base) and more than 150 laboratories spread over an area of 130,000 m^2, the complex represents a unique model of interaction where teaching, basic research and clinical research are strictly related to each other.

Overall, the energetic system (supply/demand complex) is paramount for clinical service support and wellbeing. OSR clearly requires dedicated systems for energy supply, energy management, equipment and network installations. The energy supplies acquired from the outside are electricity and methane. Methane is used in the OSR plant of cogeneration (built in 2008) production of hot water, superheated water (steam), freezing water and electricity. The cogeneration plant supplies thermal energy to the Milano 2 area in Segrate city with a total of 11 MW of thermal power. The supply contract is flexible and allows to cover the needs of Milano 2 partially in the winter season and completely in the summer one.

The global electricity consumption and natural gas consumption can be measured directly by the delivery counters / points service providers. The quantities of the four energy carriers leaving the co-generator are measured by dedicated meters, and are distributed to individual buildings through sub-plants, electricity reaches all buildings, water (hot/cold/superheated) does not. Presently, the share of electricity supplied to each single building is not directly monitored, but it is possible to know the thermal and cooling energy supplied to the buildings attested to each substation. Cooling energy is used exclusively for air conditioning, while thermal energy is used partly for air conditioning and partly for the production of hot water and technical uses.

Some buildings have refrigeration units powered by electricity but there is no dedicated meter. It is therefore not possible to divide consumption analytically between the various buildings and services. As regards electricity consumption for which there is no partial accounting system of consumption, the breakdown may be implemented by analyzing the consumption data, the annual distribution, the breakdown of the several buildings related to the intended uses.

V.3.1. Epics and their implementation in the pilot

The Segrate Pilot,ìn in its Ospedale San Raffaele OSR part, was not only constructed without sustainability in mind; even more as a hospital, the degrees of freedom to adapt or shift energy consumption are much lower than in the other two pilots. OSR focuses on the following epics:

- Energy Reduction Campaign
- Heat Supply Optimization
- EV Demand Response
- Electricity Supply Optimization

Notably though is that 100% autarky is normally achieve as the OSR Co-Generator fulfills fully the total energy demand of the Island already.

Nevertheless, starting from the following situation at the end of the year 2024 some performance results are expected as follows:

- A CO2 Emission level of 5% reduction
- An Energy potency indicator 2% increment
- Heat Energy efficiency indicator 2% increase (via forecasting demand to right fit supply)
- Electricity Energy efficiency indicator 2% increase (via forecasting demand to right fit supply)
- Knowledge on RES vs fossil fuels increase (10% increased on knowledge levels measured by social questionnaire)
- Propensity and Social participation increase (5% increased on propensity levels measured by social questionnaire)

To what regards the Segrate (Milano 2) part of the Segrate Pilot the following indicator performances are foreseen only for partial epics application on some Milano 2 buildings:

- Share if Fossil Fuel 2% reduction (targeted Milano 2 buildings only)
- Share Renewable Energy Sources (RES) 2% increment (targeted Milano 2 buildings only)
- Knowledge on RES vs fossil fuels increase (10% increased on knowledge levels measured by social questionnaire)
- Propensity and Social participation increase (5% increased on propensity levels measured by social questionnaire)

In the following, the flavor of the epics' implementation and the aspired impacts are shortly described:

Energy Reduction Campaign

For increasing the awareness of energy issues and the RENergetic approach in the hospital, at the beginning of the project, OSR started with a set of interviews of hospital staff. It turned out that – as expected – the flexibility of personnel to perform manual changes to their energy demand due to hospital procedures is extremely low, so that OSR needs to concentrate on mere technical solutions. In order to implement these, a RENergetic focus group has been built up among technical energy managers that meets on an irregular basis discussing requirements and implementation issues for the technical solutions. In order to continuously increase awareness of EI requirements, the pilot focuses on setting up the interactive platform displaying energy demand structures (in the absence of REN on the supply side, supply will not be displayed).

The Segrate pilot also is linked to the neighbourhood "Milano II", which acts as a replicator in RENergetic. Also here, energy focus groups, with private inhabitants, but mainly with political deciders are being set up discussing ways to advance the self-sufficiency in Milano II.

Both organizations of the Segrate pilot participated in the HeatDR survey mentioned above.

As of january 2023 both OSR and Segrate have initiated dedicated workshops for "***Energy Reduction Campaign*** ".

Heat Supply Optimization

OSR has a tradition of applying data science to understand both heat and electricity demand of different building sections and rooms. The concept for decreasing local CO Emissions as one objective of RENergetic via increasing energy efficiency here is to be used as a combination of forecasting heat supply (from the local CHP plant) and forecasting heat demand on building and even on room level using AI prediction modelling. Thus, increased reliability, precision and granularity of prediction in a second step is to be turned into recommendations to OSR energy management how (when and to which degree) to reduce heat provided from the power plant to the OSR buildings. To this end, building (room) demands will be aggregated and fed back to plant management enabling the reduction of heat production at certain times and thus reducing CO2 emissions accordingly.

EV Demand Response

OSR has 5 private CS for OSR personnel and 5 public CS. Especially the private CS should be used to supply information about potential occupation for the subsequent 24 hours to the affected staff members, asking them to refrain from charging in order to reduce or avoid power peaks. Again, here the ultimate goal is not to increase REN usage but to reduce CO2 emissions due to an optimized alignment of power production and supply at the CHP. The first step is supposed to be social science experiment, however, as access to the CS has not been granted until now, it is not sure, for data privacy reasons, if this experiment can be carried through.

Also, regarding automated EV DR, again aiming at power peak management, the access to GEWISS CS service provider has been granted in 2023. Therefore, the smart scheduling algorithms will be tested via real in filed experimentations in mid-2023 onwards.

Electricity Supply Optimization

In the case of OSR, the electricity supply optimization epic is mirrored from the heat supply optimization epic and based on the same logic: using data science and AI based forecasting models the distribution of electricity on room and partially on building level is to be optimized to decrease the amount of electricity production, thus increasing energy efficiency with regards to the electricity needed to provide a specific level of energy services.

V.3.2. RENergetic software modules for the pilot

OSR pilot mainly rely on the cogeneration plant supplying both electricity and heating energy to the buildings of the hospital, without usage of renewable energy sources. Thus, only public interactive platform web page for the consumption is going to be implemented for this pilot.

Other functionalities concentrate on the energy managers in the hospital and cogeneration plant. The Grafana dashboards with the forecasts for the following parameters are planned to be implemented:

- Heat demand forecasting,
- Forecasted heat supply from co-generation plant,
- Forecasted electricity supply from co-generation plant,
- Forecasted electricity demand.

Training and inferences of the models are performed in Kubeflow software. Additionally, energy manager can receive notifications of exceeding set thresholds for the parameters, such as power or energy. The forecasted data is used as a basis for the global multi-objective optimization for balancing the energy supplied by cogeneration plant in different domains and align it with the requirements of the energy consumers in the OSR. The results of the optimization are shown in Grafana dashboards and can be used in domain specific optimization. EV charging demand response program is also planned to be implemented or simulated in the pilot, depending on the possibility for controlling charging process.

V.3.3. Applied business models in the pilot

The business models to be implemented in the Segrate pilot revolve around the optimization of the heat supply in order to lower the overall energy costs. The relevant stakeholders such as the hospital management and the energy supply company cooperate on the development of these models.

These business models will be further developed and detailed and a comprehensive summary will be given in the Final Replication package in deliverable D8.3.

V.3.4. Applied social models in the pilot

Some of the central difficulties in implementing RENergetic solutions in Segrate are, according to the social activities so far, mainly (a) a lack of technological acceptance or skepticism towards the technologies and (b) a potential lack of awareness. In order to counteract the first difficulty, particular use is made of an established psychological model for technology acceptance, the Unified Theory of Acceptance and Use of Technology (UTAUT, Venkatesh et al., 2003). Following this model, both tech-related factors such as the expected utility of technologies (performance expectancy) and ease of use (effort expectancy), but also social and contextual factors such as the expected norms in the community (social influence) or the given support infrastructure (facilitating conditions) are crucial to boost technology acceptance. The goal of applying this model within a given context is to either strengthen the perception of these factors, i.e., demonstrating the usefulness of a technology to reach sustainability goals, or to establish and develop positive influences through a supporting infrastructure or increasing awareness about acceptance within society.

Implementation in Segrate

Social influence as part of the UTAUT, but also as an important consideration within the SIMPEA (see: xx for more information) is particularly crucial when considering the second difficulty encountered within the Segrate Pilot, i.e., a lack of awareness, which was also found with regards to perceived technology acceptance of others. In the survey for Heat DR, the data demonstrated a clear gap between own acceptance and assumed acceptance of others, with the latter being significantly lower. Building on the results and applying the UTAUT model, social activities in Segrate were therefore targeted at information events and workshops for exchange and awareness.

V.4. Virtual Pilot

The virtual pilot is built as two main components: 1) A hardware in the loop platform is connecting two smart converter control boards with a power simulation operating with narrow time steps in the range of a few microseconds. The additional components included in the simulation can be varied and scaled to meet the viewpoints of several evaluation scenarios. 2) A docking module implemented as a series of virtual machines running locally at University of Passau connects the virtual pilot with the RENergetic platform.

Thus, the virtual pilot aims to evaluate the contribution an energy island can make to the power quality in relation to energy optimization across domains. Further, an exemplary implementation of the docking module shall be provided. Therefore, the virtual pilot will aid replication specifically by giving a clear example of how a future replicating site can easily connect to the RENergetic system and how use-cases that could not due to the practical constraints of the pilots can be implemented for realization in a future deployment.

V.4.1. Epics and their implementation in the pilot

The virtual pilot is primarily focused on the technical side of the electricity related epics. Evaluation of social dynamics are only relevant in so far as they impact the technical characteristics of the simulation. That means specifically no campaigning takes place at the virtual pilot, however, it may be possible to translate an increase of willingness to cooperate with DR schemes into a shifted flexibility in the pilot. Therefore, the virtual pilot is stated to focus on the following epics:

- Electricity supply optimization
- Electricity demand response (automated version)

Electricity supply optimization

Electricity supply optimization: Will be evaluated as a unit-commitment of several units (that may include PVs, CHPs, battery storage systems etc.) that also includes considerations of power quality. A selection of criteria to be investigated regarding power quality is the following:

Frequency: Frequency should be able to be maintained within a transient limit of +- 0.6 Hz and a stable lower limit of +- 0.2 Hz given a disturbance scaled to the energy island. Voltage: Voltage should be maintained within a limit of +- 10% of the nominal voltage despite unexpected events and the smart charging of electric vehicles in the grid.

These two targets will be approached by combining the cross-vector energy exchange optimization with a domain-specific optimization procedure for the electricity domain.

Electricity demand response

There are three general aspects of demand response. First, getting people to react to a certain demand response signal. Second, estimating the available demand response capabilities within an energy island at any given time. Third, calling upon the right resource for a given situation to provide their reserves. The virtual pilot will focus mainly on the latter as it will be used to evaluate the impact some behavior of the users has on an energy system.

V.4.2. Software modules for the pilot

The virtual pilot will be integrating with the RENergetic database, dashboards and optimization scheme. Thus, it will push data received from the hardware in the loop simulation to the RENergetic database and at the same time it will be able to send commands to configure parts of the real-time simulation. The relevant simulation parameters, such as voltages, frequency, power provided by various sources and the corresponding energy flows will be visualized via the dashboard platform.

V.4.3. Applied social models

This is not applicable as there is no community in the virtual pilot to be analyzed using social models.

V.4.4. Role of Business models in the pilot

While there is no actual market and business process attached to the virtual pilot, it will still consider the economic and regulatory viability of proposed control schemes. The goal is to supplement the energy-driven balancing present in the pilots and the multi-vector optimization with new aspects related to potentially providing balancing services and ancillary services to the power system.

Based on a technical evaluation of what would be possible, the expected impacts within the energy island and the power system, an analysis of legal barriers and market opportunities will be developed. The outcomes of which will be included within the deliverable D7.6 from WP 7. A selection of regulatory aspects to be investigated is the following: To enable competition of the energy islands with bigger players on the markets for balancing and ancillary services, it needs to be evaluated if the rules governing this competition are fair. Further, it may not be possible for energy islands to act on the markets directly, due to size restrictions of the participating resources, thus the actor that will ultimately represent the energy island on the market may instead be an aggregator. Finally, data protection and GDPR compliance of the control and monitoring system need to be evaluated.

Thus, the potential for future business models will be evaluated first from a technical and then from a regulatory perspective considering insights gained from the virtual pilot.

VI. REFERENCES AND INTERNET LINKS

[1] . InteGrid project, „InteGrid replication roadmap brochure“.

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