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Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands

D 6.1 – Evidence base prototype for the scale up and uptake of project concepts

Lead partner: Technical University of Crete (TUC)

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Deliverable responsible	**Nikos Savvakis, Maria Aryblia, Panagiotis Dedousis, Nikos Sifakis, George Arampatzis (TUC)**		
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Document History

Version	Date	Name	Comments[2]

[1] Dissemination level: **PU** = Public, PP = Restricted to other programme participants (including the JU), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the JU)
[2] Creation, modification, final version for evaluation, revised version following evaluation, final

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Executive summary

Deliverable 6.1 aims to define the "Evidence base prototype for the scale up and uptake of project concepts" undertaken under the framework of the European H2020 project: Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands (ROBINSON).

Following the demonstration of technology solutions and practices performed in WP4, this deliverable, under the Task6.1, aims to augment the potential for creating solutions up-scale and uptake, by deploying a Web Evidence Base. Taking into consideration the assessment and evaluation of technologies undertaken into WP5, also the thorough research of available literature and the technical designs, plans and knowledge derived by the WP2-WP4, a database scheme is shaped. The Evidence Base, a flexible digital software tool prototype, encompasses data and knowledge, including multi-media content, data entry and reporting facilities. Evidence Base will serve as a powerful tool for external decision-makers and will be utilized as a basis for the development of the replication plans scheduled in Task6.2, exploiting the project results and in various dissemination activities.

The current version of D6.1 has built on thorough desk research and technologies defined in WP4 based on the energy systems components defined for the primary demo island of Eigerøy, and the follower insular territories: Crete and Western Isles. To this end, this document is considered as a living document since subsequent versions will include further information for Robinson's business planning and replication framework.

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List of abbreviations

AE : Alkaline Electrolyzer

AD-BES : Anaerobic Digestion assisted by Bio-Electrochemical unit

CAPEX : capital expenditures

CHP : Combined Heat and Power

EMS : Energy Management System

OPEX : operational expenditures

O&M : Operation & Maintenance

PEM : Polymer Electrolyte Membrane

PV : PhotoVoltaics

REST : Renewable Energy Systems & Technology UG

ROBINSON : Smart integRation Of local energy sources and innovative storage for flexiBle, secure and cost-efficIent eNergy Supply ON industrialized islands

TRL : Technological Readiness Level

WP : Work Package

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1. Introduction

Replication is a key element of the ROBINSON concept, and this is reflected in its strategy of having two follower islands (Crete and Western Isles), replicating solutions demonstrated and validated at the Eigerøy island.

The main objectives of WP6 (and especially of Task 6.4) is to produce a **Generic Replication Plan (GRP)** and guidelines for applying and upscaling ROBINSON solutions as well as specific detailed **Follower Islands Replication Plans (FIRP)**, by adapting and applying the strategy described in the DoA, Section 1.3.4.

In order to fulfil the objectives of WP6 more methodically, comprehensively and efficiently, the Project's Work Plan outlines an **interactive process** of gradual build-up and refinement of the FIRP, starting by M6 (D1.1, Islands documentation and mapping reports) and continuing to the end of the Project (M48). Thus, according to the DoA:

"a continuous feedback process with the previous technical WPs is envisaged within this task. This feedback will be facilitated and materialized by the inclusion of a devoted section regarding the replication strategy in all the technical deliverables."

An essential requirement of this process is that almost any technical deliverable produced by the Project should also include a **replication section** that will provide (or summarize from its other sections) technical information about how the solutions, methods data and knowledge developed and described in that deliverable can be applied to the replication of ROBINSON. This section will describe any specificities of the follower islands, application issues, configuration/sizing/customization parameters and options, favourable conditions and constraints, technical/organizational/ business/ regulatory requirements, things to do or avoid, recommendations and application guidelines.

Although this WP6 process focuses especially on the follower islands and their replication plans, its scope is not limited to them, but it encompasses replication in other islands (or islanded areas), in concert with networking and external stakeholders' engagement in T7.3-7.4. This will produce the outline of the GRP and guidelines.
The objective of this document is to provide instructions for composing the Replication Section for all ROBINSON's technical deliverables.

1.1 Aim of the task

Following the demonstration of all solutions (technologies and practices) performed in WP4 and their evaluation and assessment performed in WP5, this task will augment the potential for creating channels for solutions up-scale and uptake by deploying a Web Evidence Base (EB). Technical designs, plans, knowledge and data produced by WP2-4 will be analysed. An internet and literature search of available relevant information, as well as provision for future evolvements will further augment this knowledge, which will be finally converted into database schemes. A flexible digital Evidence Base, encompassing both data and knowledge of various types, including multi-media content, will be developed as a public web-based software tool prototype, including data entry and reporting facilities that will be deployed on the web. The Evidence Base will be used by external decision makers and for preparing the replication plans (T6.4), exploiting the project results (T7.2) and in various dissemination activities

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1.2 Interactions with other tasks and work packages

The interactive process for gradual development of the FIRPs and the GRP and guidelines is based on the following steps:

1. Each technical deliverable should include a replication section, as described.
2. Following deliverables should take into account results, especially the replication sections, of previous ones,
3. To facilitate this process and gradually form an outline of the replication plans, WP6 (T6.4) will issue **Interim Progress Reports on Replication** (probably after the end of each project year). These will structure and summarize the replication sections of previous deliverables and outline the progress on the flower islands replication plans.
4. Other WPs and Tasks are invited to comment on these progress reports.
5. Starting also from M13, an **Evidence Base** (**EB**) will be developed, with the purpose of convincing for ROBINSON's uptake and facilitating its replication at the follower islands and elsewhere. EB will contain selected information from deliverables and progress reports, as well as any additional information collected by WP7.
6. By M30 a **Market Analysis** report for the replication in the follower and other islands will be submitted and incorporated in the FIRPs and the GRP.
7. By M36 a **Business Planning** report for energy systems' management and the formation of energy communities will be submitted and incorporated in the FIRPs and the GRP.
8. At the project end (M48) the final replication plans and guidelines will be completed.

The term **Technical Deliverables** is used in this context to denote deliverables directly relevant to the replication of the ROBINSON concept and specifically to the development of the follower islands' replication plans. These can be categorized into four categories:

A. Deliverables that describe the selection, configuration, design, application and optimization (in setup or in operation) of ROBINSON system components (e.g. CHP, AD-BES, EMS).
B. Deliverables that describe the composition and setup of the ROBINSON system as a whole.
C. Deliverables that describe facts and details for the application of the ROBINSON system and its integration into existing energy systems and their island environments.
D. Deliverables that describe a methodology and/or provide results or information directly usable for developing the replication plans.

According to the above definition:

- **Category A** includes deliverables D2.1 (M12), D2.8[3] (M16), D2.9[3] (M16), D2.2 (M24), D2.3 (M24), D3.2 (M24), D2.7 (M29), D2.8 (M16), D2.9 (M16) and D3.3 (M29).
- **Category B** includes deliverables D1.3 (M12), D1.4 (M12), D5.1 (M12) and D3.5 (M39).
- **Category C** includes deliverables D1.2 (M12), D3.1 (M24), D4.1 (M36), D4.2 (M36) and D4.5 (M48).

[3] D2.2, D2.3 and D5.4 are interim reports summarizing preliminary results. A preliminary version of the replication section may be included in these deliverables, which can be finalized in the corresponding final reports D2.2, D2.3 and D5.5.

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- **Category D** includes deliverables D1.5 (M24), D7.5 (M24), D5.6 (M24), D5.4[3] (M29), D3.4 (M33), D5.2 (M48), D5.3 (M48), D5.5 (M48), and D5.7 (M48).

Complete lists of Technical deliverables, grouped by Work Package number, are presented in in the report "*Guidelines for composing the Replications Section*". These deliverables should include at the end (e.g. as an Appendix) a **Replication Section** (**RSc**) that will describe technically how the concepts and results described in the deliverable can be replicated. The section can contain, at a minimum, a synopsis and conclusion of information selected from other report sections, re-arranged so as to highlight key implementation/replication issues. To that, additional data, information and knowledge (collected by the respective task, but not included in the report), as well as expert advice and recommendations, may be added as seems fit in each case. Specific guidelines applying to each of the three deliverable categories, described above, are presented in the following sections.

Figure 1 summarises the expected inputs from all WPs, related to the replication plans.

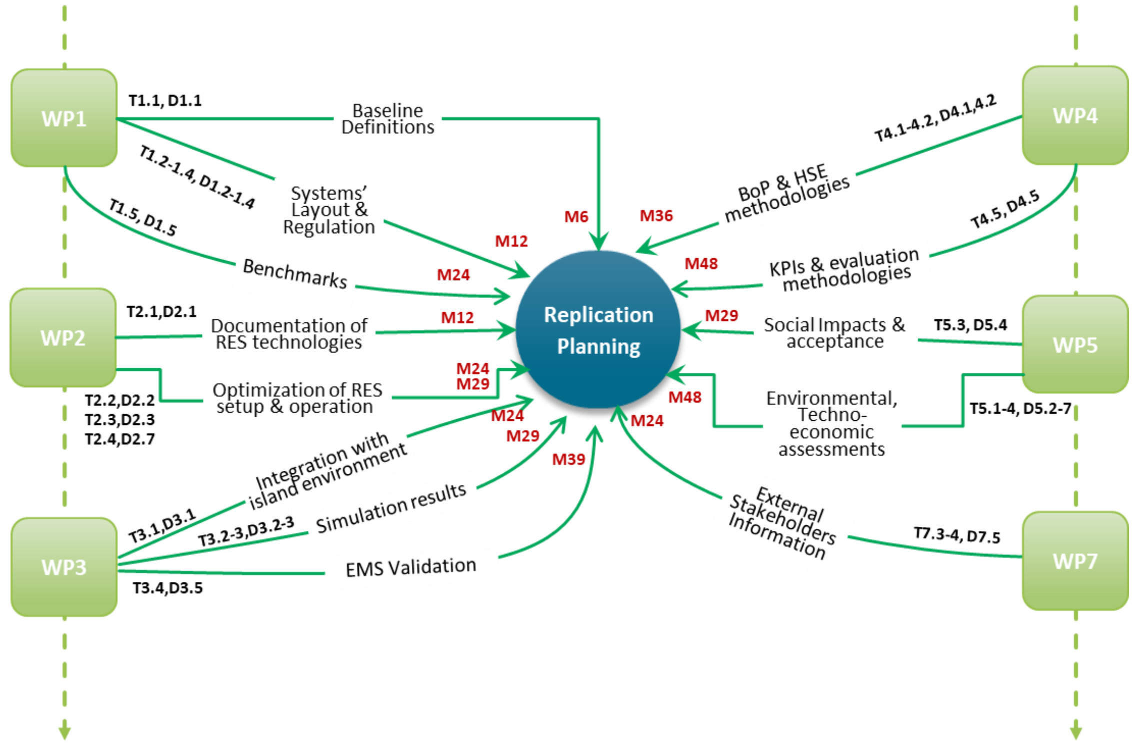

Figure 1: Inputs to replication planning from other WPs

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2. Methodological approach to define the replicability framework

2.1 Replication process in ROBINSON project

Replication is a key component in Robinson project on which a strategic approach has been developed, involving two follower islands, Crete and Western Isles, for replicating solutions demonstrated and validated at Eigerøy island. A comprehensive, holistic approach has been applied for developing a tailor-made replication plan for each of the follower islands according to configuration parameters and options, application issues, favourable conditions and constraints and various regulatory requirements (technical, organizational, etc.).

The corner stone of Robinson's replication framework is the Web Evidence Base, a replication tool which concentrates the information and knowledge reported under the Robinson's concept for uptake and facilitate the replication scheme, starting from Crete and Western Isles, and going further. Robinson's replication tool provides to end-users tailored services for ***information***, ***support*** and ***roadmap***, as depicted in Figure 2

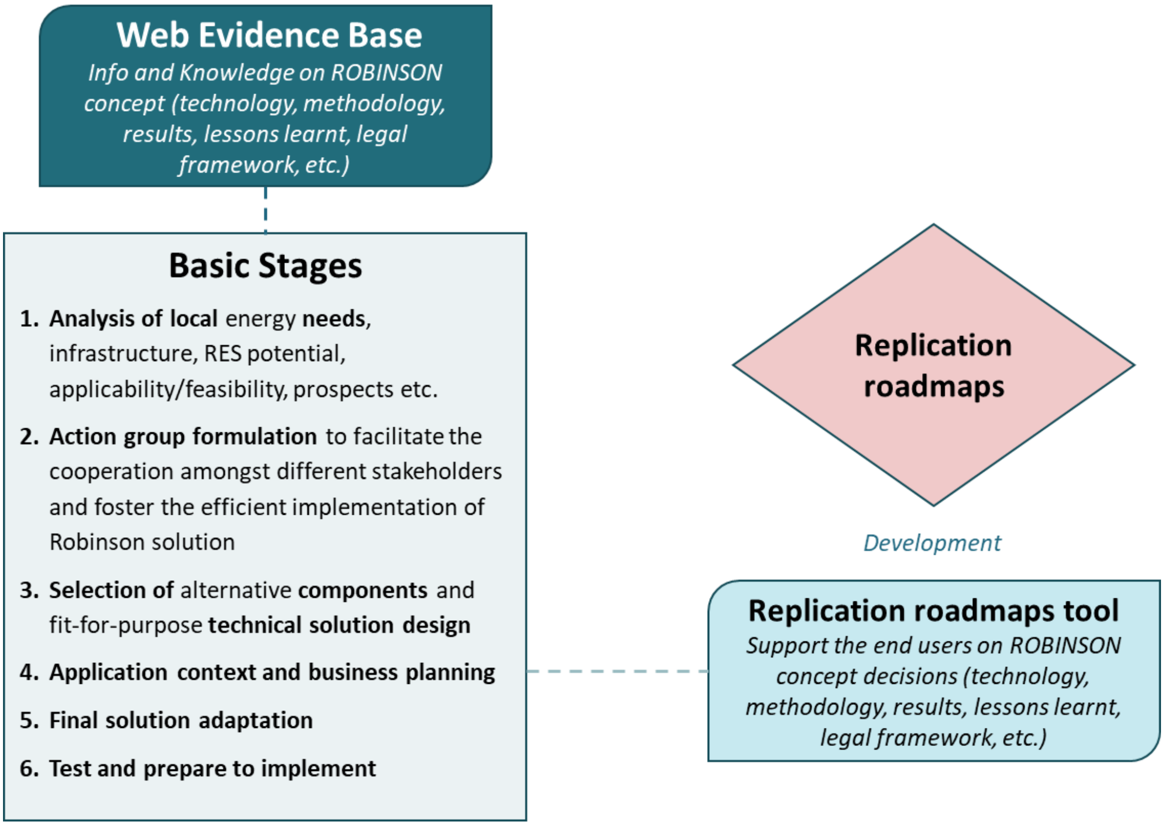

Figure 2: Replication process in ROBINSON

The Evidence Base encloses the identification of needs, risks and challenges, formulates the action group, designs a customized technical solution by selecting the suitable components, defines the application framework and a successful business plan for adapting the final solution, testing and implementation. In parallel, the end-users are being supported on concept decisions, to conclude in the roadmap part, the highest level of decision support integration by the provision of exploitable, tailor-made replication plans.

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2.2 Application levels of the Web Evidence base

Replication context within Robinson demonstrates an inclusive concept encompassing three district components: the replication of the lighthouse system in the two follower islands, the replication in other islands, areas and conditions, and the further development and upscaling of the lighthouse system beyond the project's lifetime and targets.

The replication of Eigerøy system in Crete and Western Isles, as main WP6 objective, encloses the activities of energy systems monitoring, the baseline assessment, the stakeholders' engagement and the replication plans. To replicate Robinson's approach to other islands and areas is one of the strategic objectives of the project. Expanding the development and upscaling of the lighthouse system is a supplementary objective of Robinson, delivering the validation of the demonstrate system, the recommendations of stakeholders' engagement and the development and upscaling plan.

The Web Evidence Base is the key element for achieving the project's development goals, which have been structured on the defined strategic objectives of the three replication components. The conversion of objectives to goals leads to the performance of replication roadmap tool services. The process until the development and delivery of replication tool services is shown Figure 3

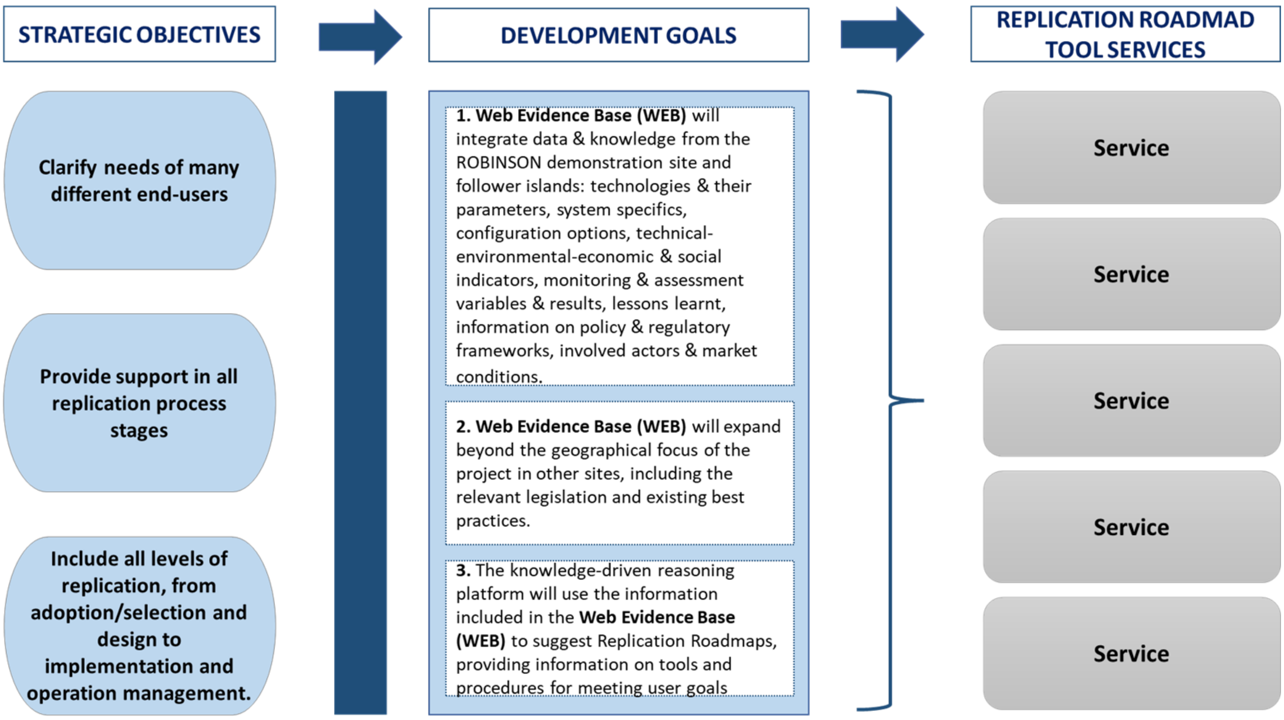

Figure 3: Converting objectives to goals to replication support services in the WP6.

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3. Web Evidence Base platform design

3.1 Overall architecture of the EB

The EB will store and manage information generated or collected by the Robinson Project. This information will be stored in the Robinson Evidence Base and utilized by the Replication Roadmap Tool. The term 'information' will be used here to describe all EB content in general, while the terms 'knowledge' & 'data' will be used to distinguish between processed & finalized information. The requirement analysis (see Chapter 3) leads to the conclusion that the EB has no independent existence, and its only purpose is to support the functionalities of the three specified Services (Information Service, Suite of Tools Service and Guidance Service) that the Robinson EB will provide to its end-users. Therefore, it seems reasonable to assume that the EB structure can follow a scheme that brings together and interconnects three simpler, more-or-less independent component sub-structures, one for each distinct Service.

Consequently, the EB can be thought of as a container of these three discreet databases, each with its own particular entities, structure and methods for CRUD (Create, Read, Update and Delete) operations. An additional fourth will form the core of DSS, sharing the other three compartments of the EB, will store and manage information that the overall system requires, in order to implement its web platform and its user and administration interfaces. For example, user instructions/help, examples of use, descriptive texts, titles & labels, images, configuration parameters, user registration & access rights data and other common & temporary files. The main structure for the EB is presented in the following conceptual diagram.

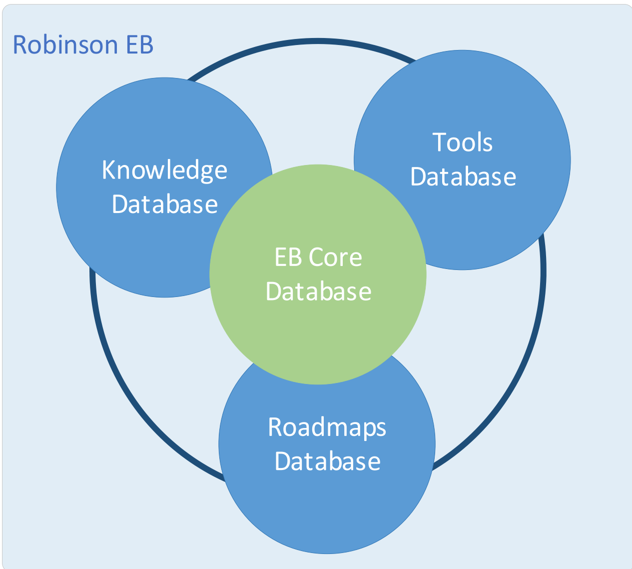

Figure 4: Conceptual diagram of the Robinson EB.

In the above diagram, the EB core database (green circle) is on top of the EB (make use of), the EB consists of three main parts (blue circles) In the following sections the entities and structure of each of the three compartments (i.e., Robinson Knowledge, Tools and Roadmaps) will be analyzed.

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3.1.1 Robinson Knowledge Compartment

This compartment contains generic data as well as exclusive Robinson knowledge, i.e. knowledge either pre-existing the Robinson Project or generated by it (through the demonstrations & assessment). It stores information regarding energy Technologies, Legal Framework and Applications of ROBINSON solutions. The actual knowledge content is stored in each knowledge item's sections. An Item may have one or more sections. This provides additional flexibility, enabling the presentation of knowledge in layers, or according to a user's level of expertise, or according to the user's access rights.

The knowledge classification scheme at that level of detail will be defined during the period of collection & compilation of knowledge, depending on the available material and periodic reviews of the respective service by users. Thus, knowledge items and their sections will not necessarily be pre-defined, but they will be freely added as soon as the information becomes available. However, even the Subject and Topics classes may be amended and redefined during the Project (or afterwards) depending on users' feedback and validation activities.

3.1.2 Robinson Tools Compartment

This part contains all information pertaining to the Robinson support Tools, i.e. information about each tool's status, availability, functionalities, installation, configuration and use. Optionally, it might contain data sets of tool input data and results (output). Naturally, since these tools support decisions on energy technologies, the information about them is organized (classified) according to their operation and usage.
the ALL/ANY/NONE/NA classes are provided).

3.1.3 Robinson Roadmaps Compartment

This part contains all information pertaining to the Robinson Roadmap Service, i.e. information about the decision support roadmaps, their contents, their application cases and the methods & mechanisms used to produce and exploit them. Roadmaps would directly support decisions on systems and are closely involved in the use of the Robinson EB, being its most fundamental service. Consequently, information about them should be organized (classified) according to the hierarchical chain of decision making (Decision Stage→User Goal→RoadMap→Step→Activity).

A (roadmap) **Step** is a discreet & coherent (i.e. almost self-contained, black-box like) part of a roadmap's procedure, that provides the first-level analysis of any roadmap (as in a flowchart). The analysis into steps is the first level of guidance that any user gets. A **Step** may consist of one or more **Activities**.

3.2 Technical Specifications of the Evidence Base Platform

The platform front-end and back-end are developed and implemented in the ASP.NET Core 3.1 using C#. The application handles the storage, management, and display functionalities for the information generated or collected by the Robinson Project. Our technical implementation builds on and expands the Piranha Content Management System (CMS) framework to create a dynamic, evidence base platform. Piranha CMS is a lightweight framework for building content-driven applications using ASP.NET MVC. This allows for cross-platform deployment and accessibility as our implementation can run on Windows, Linux, Mac OS X or even be embedded in a Xamarin App.

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The main focus of the Piranha CMS framework lies in structuring and managing content. As such, we utilize the core functionality of the Piranha CMS framework to build an evidence base platform with embedded CMS functionality. Finally, we expand the framework capabilities by implementing three core functionalities necessary for the Robinson evidence base platform, namely (i) user management, (ii) user authentication and authorization, and (iii) custom content types based on the Robinson requirements. User management allows administrators to manage resources and organize users according to their needs and roles while maintaining the security of the IT system. Authentication confirms that users are whom they say they are. The authorization permits those users to access a specific resource or content in the evident base platform. Finally, the custom content types allow for categorization and accessibility control and provide consistency across the platform. Moreover, custom content types have specific characteristics such as a template and metadata that make it possible to filter and display material based on specific search queries.

3.3 Operational Aspects of the Evidence Base Platform

3.3.1 Front-End

The home page of the Robinson EB platform front end comprises five discrete parts that can be accessed by the navigation menu (Figure 5). In addition, users can access restricted content based on their role by logging into the platform using their Robinson EB account. Figures 6, 7 and 8 demonstrate the user authentication and authorization workflow.

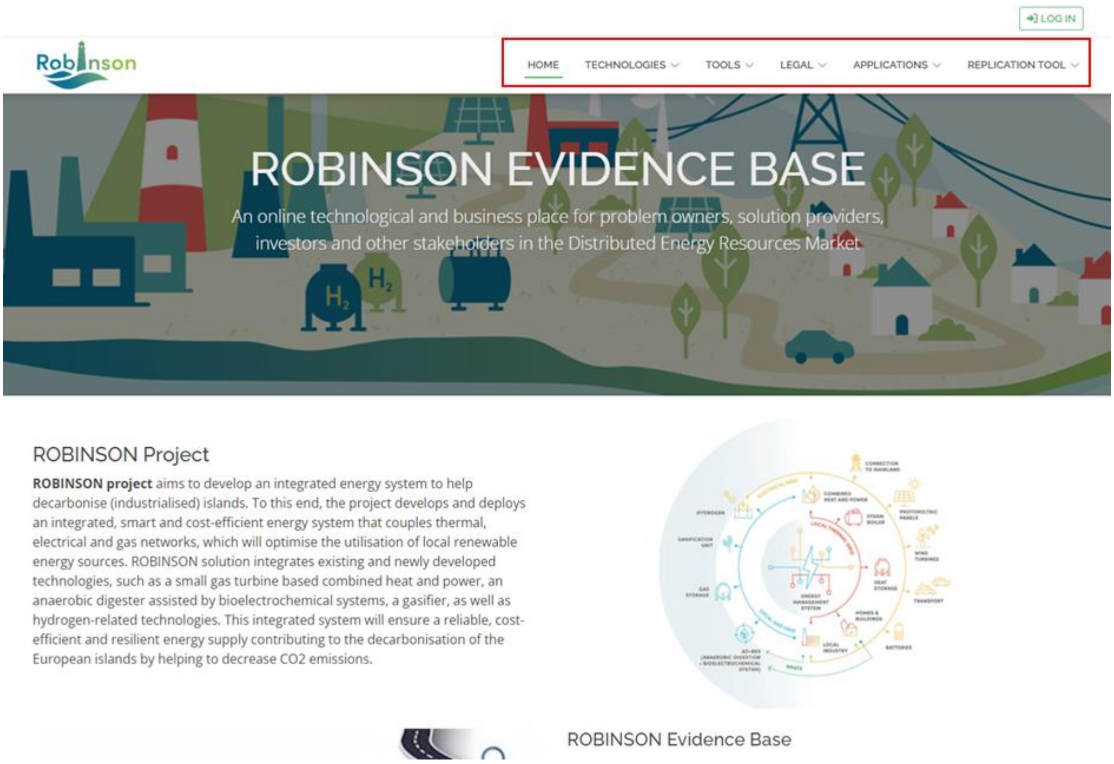

Figure 5. The Home Page of the Robinson EB platform front end. The platform's navigation menu is highlighted in red colour.

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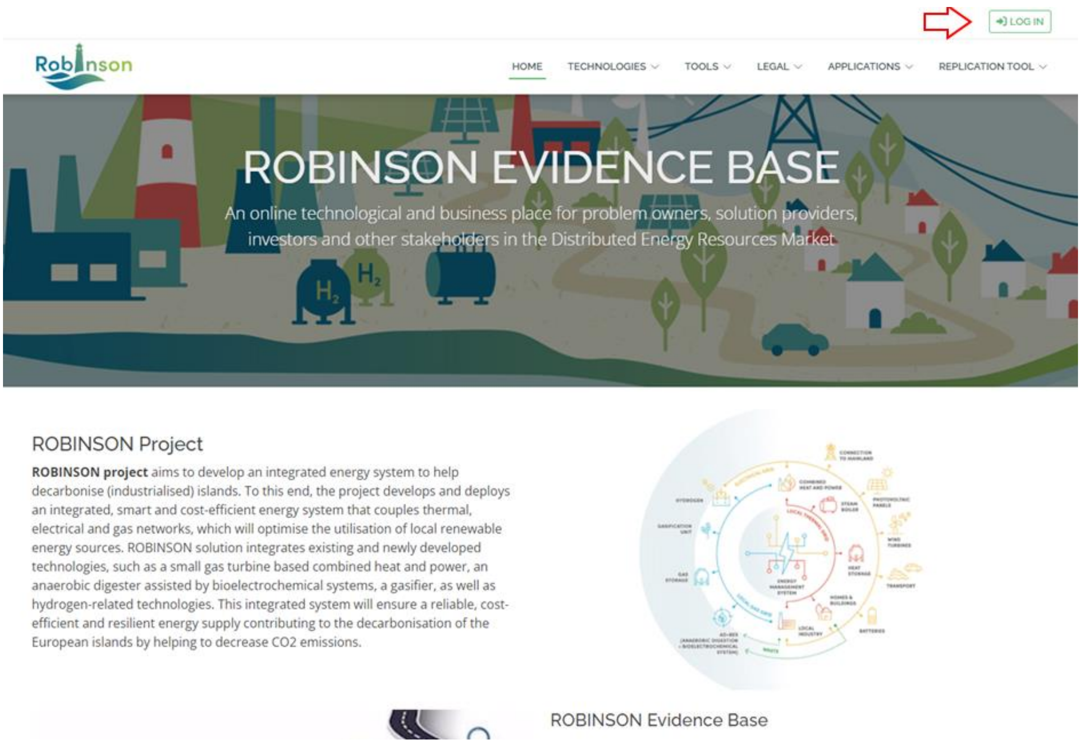

Figure 6. The first step of the authentication and authorization workflow. The platform's login button is highlighted in red colour.

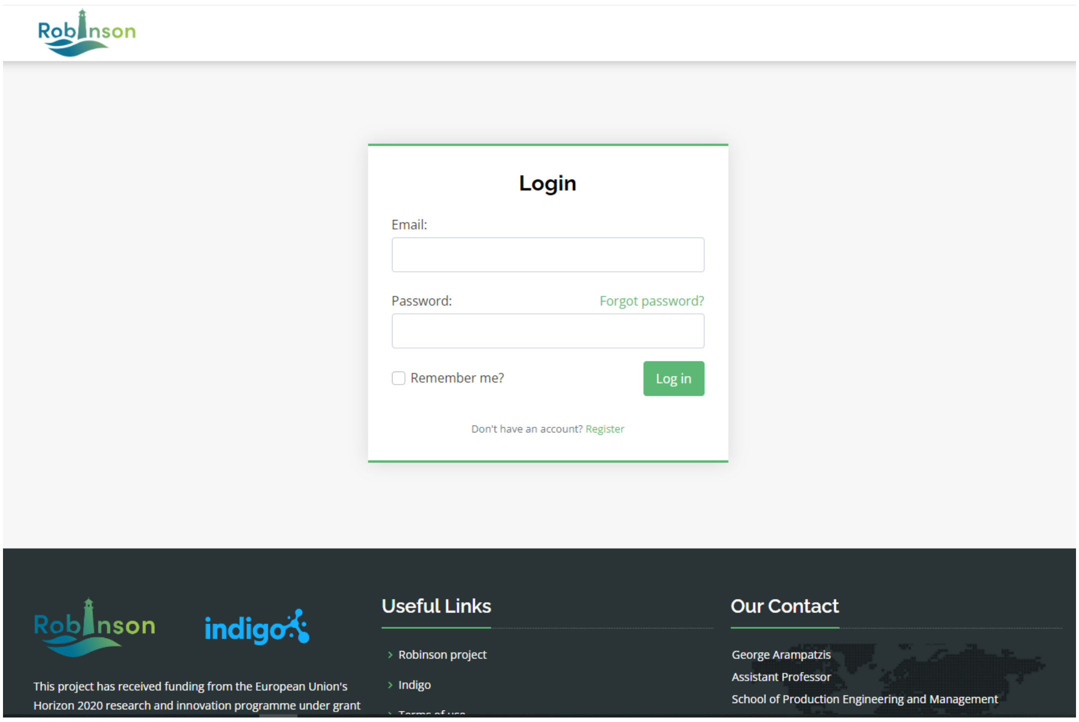

Figure 7. The second step of the authentication and authorization workflow. The platform's login page where user must enter their Robinson EB account credentials.

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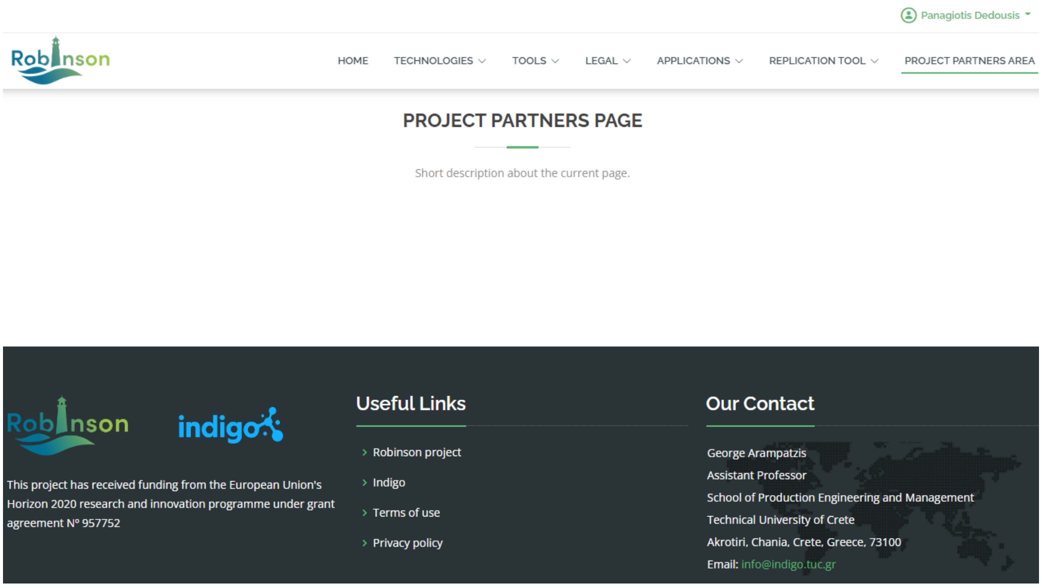

Figure 8. Restricted content page that only authorized and authenticated users can access.

3.3.2 Back-End

The home page of the Robinson EB platform back end comprises three main parts that can be accessed by the navigation menu on the left side, namely content management, user management and role management. Figure 9 illustrates the content and various categories of the Robinson evidence base, while Figure 10 illustrates the different custom content types available. Figure 11, presents the user management where administrators can manage (e.g., view, create, edit, delete) platform users, as well as assign users to specific roles. Finally, Figure 12 illustrates the platform role management page where administrators can manage (e.g., view, create, edit, delete) users' roles.

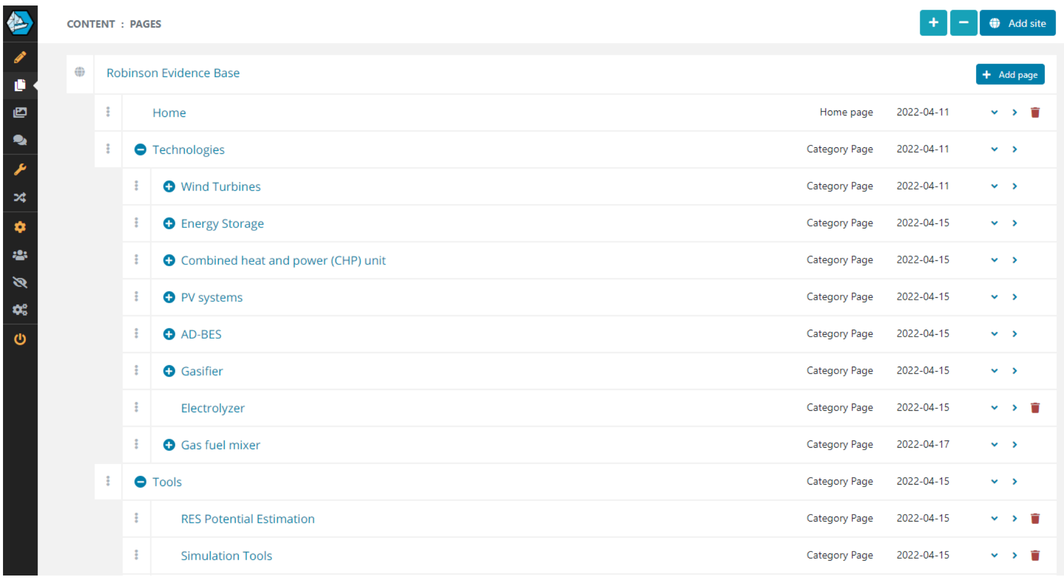

Figure 9. The Home Page of the Robinson EB platform back end. The platform's back end navigation menu is on left side of the displayed figure.

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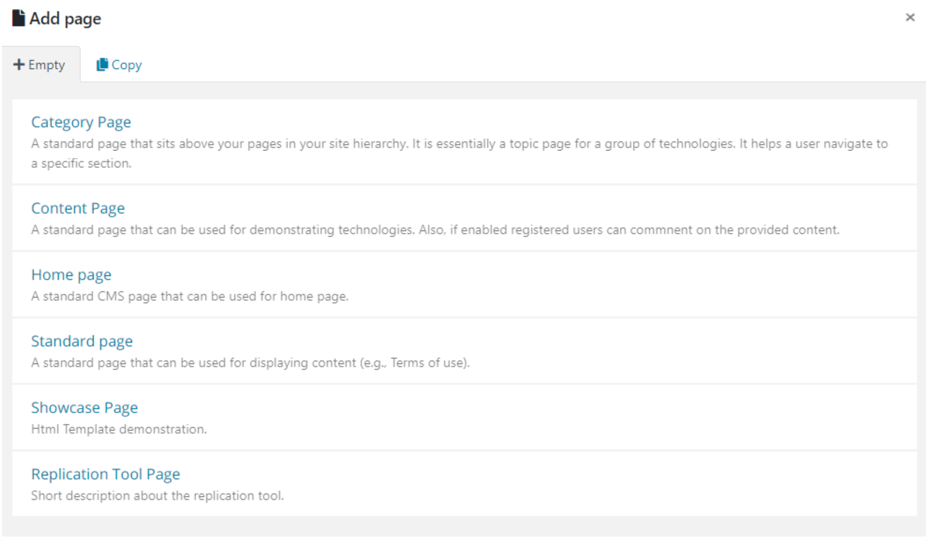

Figure 10. Available custom content types of the Robinson EB platform back end.

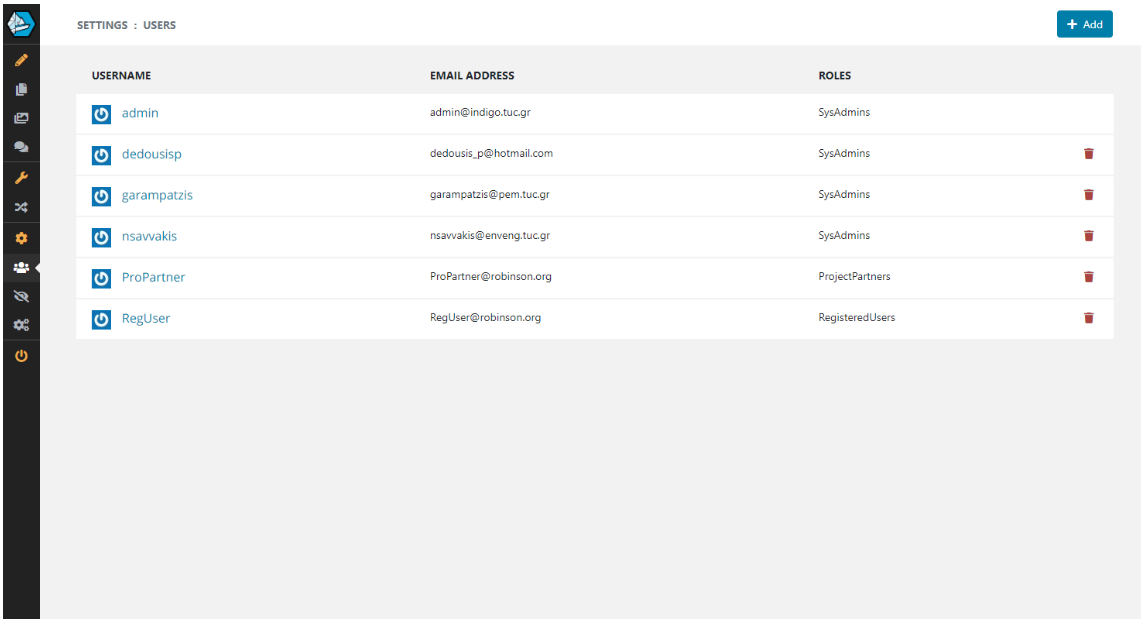

Figure 11. User management functionality in the Robinson EB platform back end.

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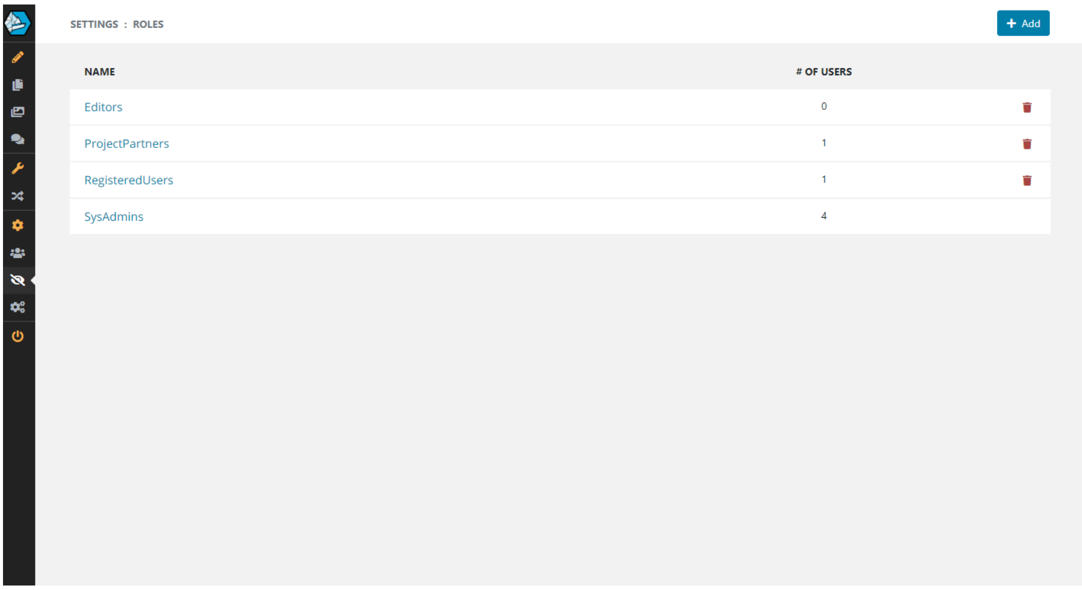

Figure 12. Role management functionality in the Robinson EB platform back end.

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4. Web Evidence structure and contents

4.1 Mapping of local needs and conditions

The energy systems of islands (either geographical or virtual) are typically sensitive to externalities; however, innovative technologies and the exploitation of renewable energy (RE) sources result in opportunities (e.g. self-sufficiency) and challenges (e.g. grid instability). In such a framework, an isolated energy system's clean transition entails a complex process that requires significant technical experience and knowledge. An essential step in this process involves exploring the island conditions to identify and analyze potential challenges, risks, opportunities, and synergies with involved actors (Hasapis et al., 2017; Rakpho & Yamaka, 2021) , bearing in mind that each island has a unique context that requires an adapted approach.

In particular, the identification procedure encloses a list of actions involving the preliminary analysis of local energy needs, the identification of the current state of local conditions and the estimation of RES potential, and the assessment of the expected impacts on society, economy and energy at the local level. Such a process will allow the determination of the interrelationships between different sectors and actors, the mapping of the sources and uses of energy in the local economy and the setting of priorities accordingly.

Robinson's Web Evidence Base is taken into account this holistic approach since the infant stage of a RES project development, starting with the energy demand and supply forecasting. Available tools can facilitate an accurate modelling and forecasting of the energy demand and supply such as the Bayesian Vector Autoregressive model – BVAR model[5], while accessible databases can provide reliable data for accurate local energy needs estimations such as Eurostat, EurObserv'ER, EU Inspire Geoportal, European Forum for Geography and Statistics, European Energy Efficiency Platform (E3P), and other.

4.1.1 Island's Energy Identity

A critical element of exploring the island's conditions is to understand its current energy system. In that sense, the collection of information related to energy production and consumption supports determining the priorities for its transition to clean energy. For this purpose, a complete analysis of the island energy system is recommended as input to develop a feasible replication plan of the ROBINSON concept. For a comprehensive description of the energy system, accurate data are crucial. In cases without accurate data, estimates can be made based on available information.

A detailed diagnosis of the location's special characteristics should be considered, along with the technical specifications of the local energy grid. Situational factors such as the size of the system, the geography and the location, affect the RES plants' synthesis and operating features, especially when investigating insular areas (Groppi et al., 2019; Katsaprakakis, 2016). Similarly, the energy storage systems present an excellent performance in insular locations, having a great potential for exploitation (Caralis et al., 2019), and acting as enablers for higher RES penetration in existing energy grids(Aragón et al., 2022). The energy system description could refer to the most recent annual and/or seasonal data. Generally, detailed, and exhaustive descriptions of the energy system are recommended to optimise the synthesis of the ROBINSON components for better impact in local environments.

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To realise the special needs and challenges of islands, the energy system description is classified according to the following energy vectors:

I. Electricity generation and consumption
II. Transport on the island
III. Transport to and from the island
IV. Heating and cooling
V. Other

To this end, Robinson's Web Evidence Base approach, has been built on a comprehensive methodology, starting from the local energy loads assessment, and the assessment of RES potential locally, at islands level, integrating data and knowledge from the demonstration site and the follower islands.

Local conditions mapping also includes the opportunities that are capable to transform the linear local economy model into a circular model, reducing simultaneously the resource depletion and the carbon emissions. Under this scope acts the exploitation of waste for energy recovery and the industrial symbiosis approaches. The solid waste-to-energy route can be assessed for defining the energy recovery potential for options such as the anaerobic digestion, landfill gat to energy, mass incineration and refuse derived fuel incineration (Kumar & Samadder, 2022), at local level, while the feasibility assessment by integrating also essential economic indicators (capital, compliance, operation cost) can indicate the full potential of each territory(Hoang et al., 2022). Following the same concept of breaking the linear relations between the consumption of resources and the produced waste in a city level, the Industrial – Urban symbiosis (I-Us) approach, uses the outputs of the industrial processes as inputs, maximizing the economic and environmental benefits in a city, focusing on recycling activities, town planning, community, and outreach (van Berkel et al., 2009). The analysis of I-Us potential in insular cities is essential for shaping the overall view of needs and conditions.

Together with the technical aspects and requirements, critical element for consideration is the insular community. The successful stakeholders' mapping facilitates the engagement of key actors into the insular project development and provides the essence of co-creation in the overall development approach. A comprehensive, balanced stakeholders' representation into the working team, also the definition of roles and the level of their involvement, will bring together essential knowledge and experience, early identification of risks and challenges, and potential solutions for being addressed, together with the assurance of increased awareness and public acceptance.

The public acceptance and willingness towards sustainable energy innovations and policies, including the installation and using of renewable energy sources, especially in close ecosystems such as the islands, is of critical importance for achieving a green energy transition. Social acceptance requires the understanding of conditions, needs and benefits of the RES involvement in an energy project, while the community's support could be ensured through the deployment of strategies and actions that aimed to attitudes and preferences, and by bringing together those solutions with the local community i.e. promoting the adoption of RES at household level; residential PV panels, etc.

On the other side of the rigorously integration of RES for achieving public acceptance, the overall capacity of installed RES in the investigated island should be addressed. The assessment of existing

RES systems, combined with the potential of RES expansion that mentioned above, exceedingly sometimes the value of 90% in islands, for making the energy transformation a feasible, success story.

4.1.2 Energy Facilities – the technological pillar

Electricity production in insular environments can be distinct depending on the type of energy supply in the network:

- An electric cable connects the island to the mainland, supplying all or part of the island's electricity.
- Part or all of the island's electricity is produced locally through proper infrastructure, solar PV, wind, etc.

The following indicators can be gathered for the entire system explanation:

- Total installed capacity per technology (whether this is an engine generator, wind, or solar energy, CHP, etc.)
- Total energy produced per technology and year
- For any technology that consumes any type of fuel (like fossil fuels, biomass, etc.) the annual fuel consumption i.e. the primary energy consumption of the electricity sector in the island.

A connected island without any auto-production receives its electricity from the national grid. In this case, electricity is analyzed from the perspective of final energy consumption - the data should represent the total electricity consumed on the island by households, industry, and agriculture. It is recommended that this data be divided into categories, e.g. residential, primary (agriculture, forestry, mining, and fishing), secondary (manufacturing), tertiary (tourism), and transport (on the island and to and from the island). Additional data points that may be interesting include the consumption recorded at the island's point of interconnection with the mainland. If there is some degree of auto-production on the island, apart from final electricity consumption, it is also necessary to consider the local electricity generation.

In addition, the accurate estimation of energy supply from RES technologies is crucial for having an efficient equilibrium. More details about methods and tools for RES potential calculation are presented in the sub-section 4.2.

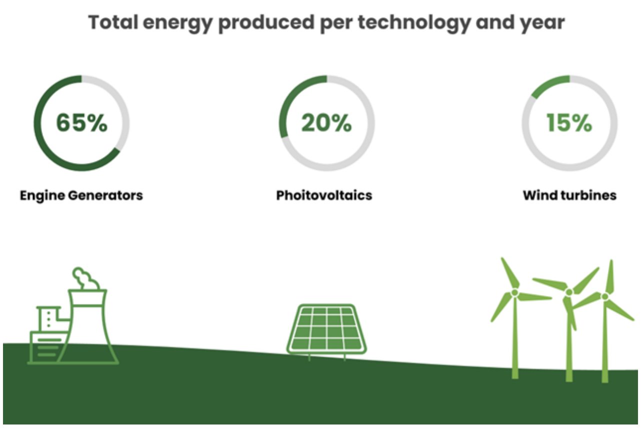

Figure 13:Indicative mapping of the energy produced per technology and year

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Heat and/or cooling may be required on the island, depending on the weather. This category should include the consumption of boilers, heat pumps, air conditioning systems, or any other heating or cooling device or technology used on the island over the last (or most recent) year. Some appliances such as A/C systems, electric boilers or heat pumps may use electricity to produce heat or cold. In this case, their consumption could either be allocated to electricity or to heating/cooling.

Possible sources for the required information are as follows:

- Electricity companies operating on the island.
- Energy cooperatives operation on the island.
- Transmission and Distribution System Operators.
- Statistics agency in the country/region, either through databases, annual reports, etc.
- Gas/fuel providers.
- Unless there is an industry or another sector on the island that requires a specific type of fuel, it could be assumed that the rest of the fuels are consumed for heating (unless there is electricity production on the island that requires a specific type of fuel).
- The **Odyssee-Mure project** provides average data on heating consumption per dwelling and per country. By estimating the island households' heating consumption with these data, we could also get an idea of the conditions on the island.

4.2 Estimation of the local RES potential

ROBINSON project intends to create and evaluate an integrated energy system targeted at industrialized islands, exploiting locally accessible energy sources, electrical and thermal networks, and contemporary storage technologies. Also, it aspires to decrease energy losses, enhance the stability and dependability of the energy system, minimize the environmental consequences, and lead to fossil-fuel savings. A macro-objective of the project is to play a fundamental role in supporting the islands' energy transition by creating a replicable solution.

One of the obstacles that hinder European islands from reducing their reliance on fossil fuels and fully using the potential of their local renewable resources, such as wind and sunlight, is the unpredictability and lack of flexibility of their energy systems. The systematic and precise assessment of renewable energy potential is crucial for the effective design of any renewable energy infrastructure (Gong et al., 2021). Due to the high dependability on RES, the accurate and reliable estimation of the local RES potential is critical for all the stages of this project.

Meteorological data are the easiest to acquire, enabling the selection of the most proper and reliable RES for each specific region/area. The relevant datasets include time series for significant parameters such as temperature, wind speed, sun hours, and others. For example, the typical seasonal profiles of solar radiation and ambient temperature for Eagerly, are demonstrated in Figure 14 and Figure 15.

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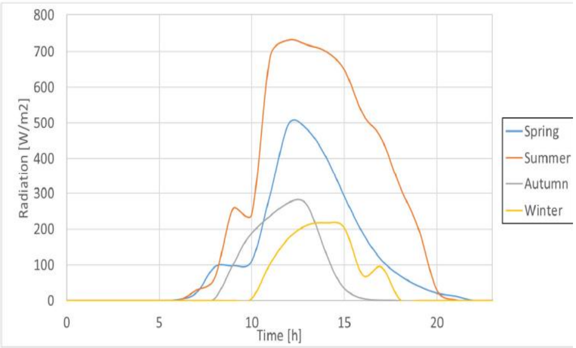

Figure 14: Typical seasonal profiles of solar radiation in Eigerøy

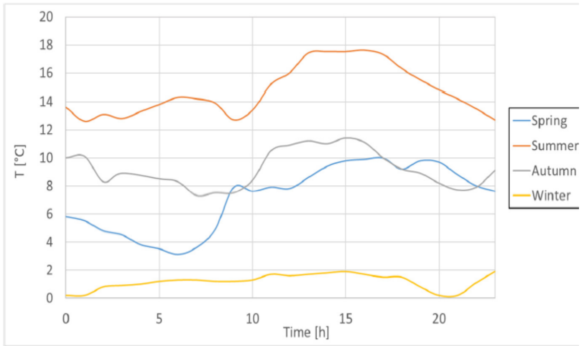

Figure 15: Typical seasonal profiles of ambient temperature in Eigerøy

The estimation of the local RES potential is of utmost importance for the project due to its direct connection to the renewable hydrogen production system, as well as the exploitation of the biomass resources in each case, enhancing the factor of satisfying the pillars of circular economy.

As it has been already mentioned, Eigerøy will be the demo island, while Crete and Stornoway will be the follower islands. Their indicative potential for the two most common RE technologies is depicted in Figure 16.

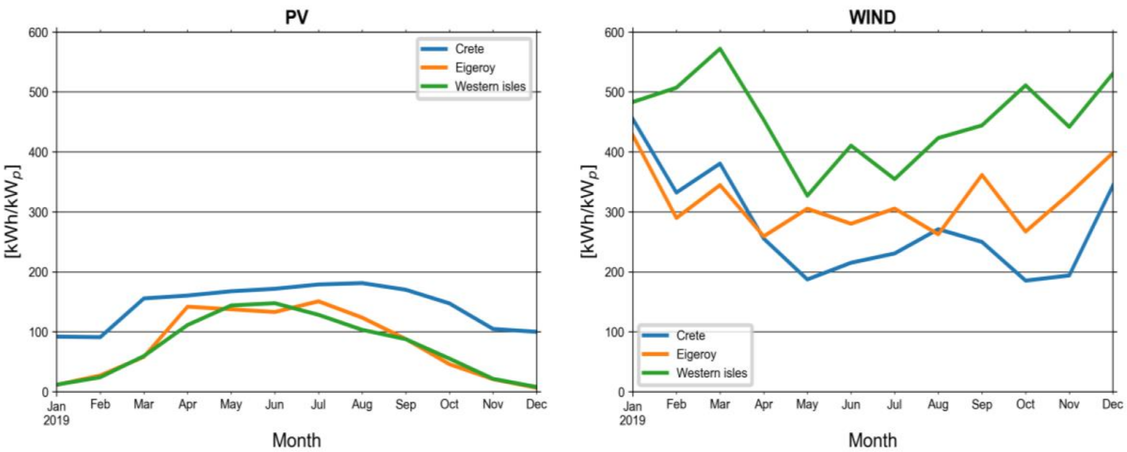

Figure 16: The left subplot shows the monthly PV electricity generation (per kWp solar panel with a tilt of 35° and solar azimuth of 180°) on Crete (blue), Eigerøy (orange) and Western Isles (green) in year 2019-2020. The right subplot shows the monthly wind electricity generation (per kWp, for a Vestas V90 2000) on Crete (blue), Eigerøy (orange) and Western isles (green) in year 2019-2020.

4.2.1 Useful tools

There are several tools for evaluating the RES potential in any desired location, such as PVGIS, IRENA Global Atlas, Pan European Thermal Atlas, NASA POWER Database, Meteonorm, etc.).

The most common tool that have been extensively used for estimating the RES potential into different regions across the globe is the GIS software (Voivontas et al., 1998; Wakeyama & Ehara, 2010, 2011). Energy potential maps are developed for each energy system category using the highest-resolution data available to give exploitable timeseries and visuals that may be used to elicit comments from

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interested parties, researchers, or engineers to support their sustainable approach (van Hoesen & Letendre, 2010), as shown in Figure 17.

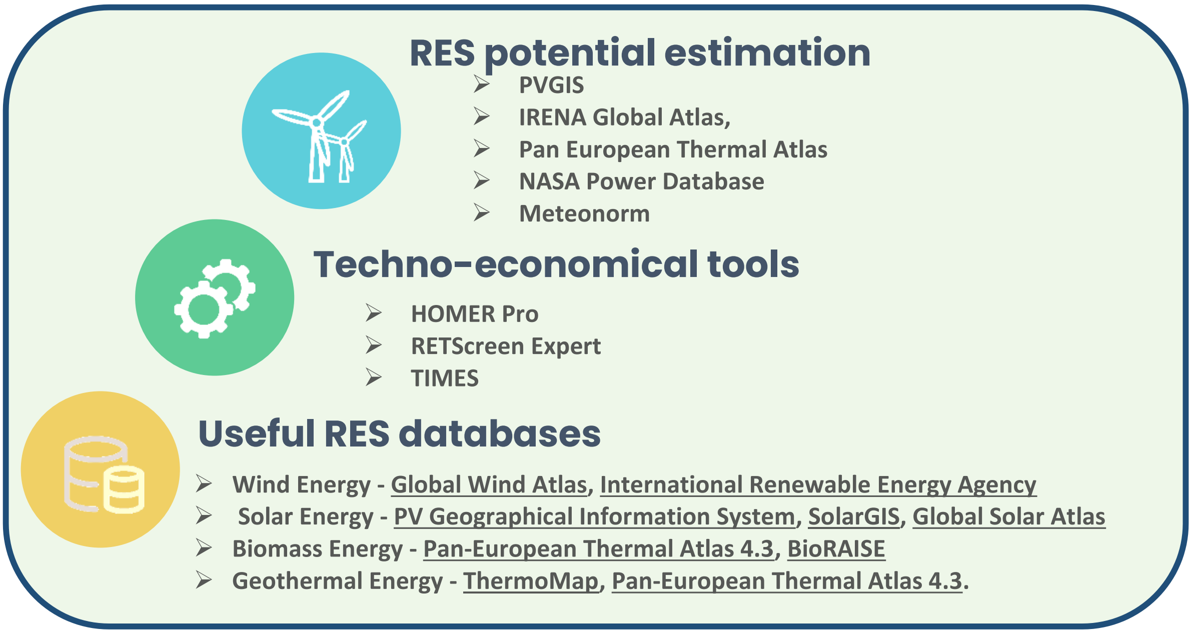

Figure 17: Common tools for estimating local RES potential

Some techno-economical optimization tools offer the capability of acquiring the required data from their databases, such as HOMER Pro, RETScreen Expert, TIMES, etc. (Aryal & Dhakal, 2022; Sifakis et al., 2021). These tools are to be exploited later in the project for the simulations and the technoeconomic analyses of the suggested systems for each case study. The databases' data will be correlated to the acquires ones to validate their reliability and accuracy (bi-direction correlation).

Besides, the second most preferred option of acquiring regional meteorological and RES potential related data are by getting in touch with the responsible authorities for each specific area, or even from open-source databases (Asakereh et al., 2022). Then, the data series are used as input to specific equations to provide the RES potential outputs (Al-Hinai & Al-Alawi, 1995; Amoatey et al., 2022; Takase et al., 2022). An example of such a database is presented in Figure 18.

During ROBINSON, at the time being, working team has acquired all the required data by cooperating with the involved stakeholders and getting in touch with the corresponding parties. All the required data have been provided by these parties in order to evaluate the current situation of each case study, while estimating each case's local RES potential.

So far, regarding the available literature on the estimation of the RES potential, and thus the modelling, and simulation of the proposed integrated energy systems, two techniques have been employed to assess the economic potential of RES. As for the first, researchers create the required, technologically feasible solutions, as shown in several previous research works (Koo et al., 2011; Østergaard & Lund, 2011). The economic or socioeconomic costs are employed only as evaluation criteria. Using the second type of methodologies, the economic potential of RES is evaluated by solving an optimization task and identifying the energy mix with the lowest cost (Schmidt et al., 2012).

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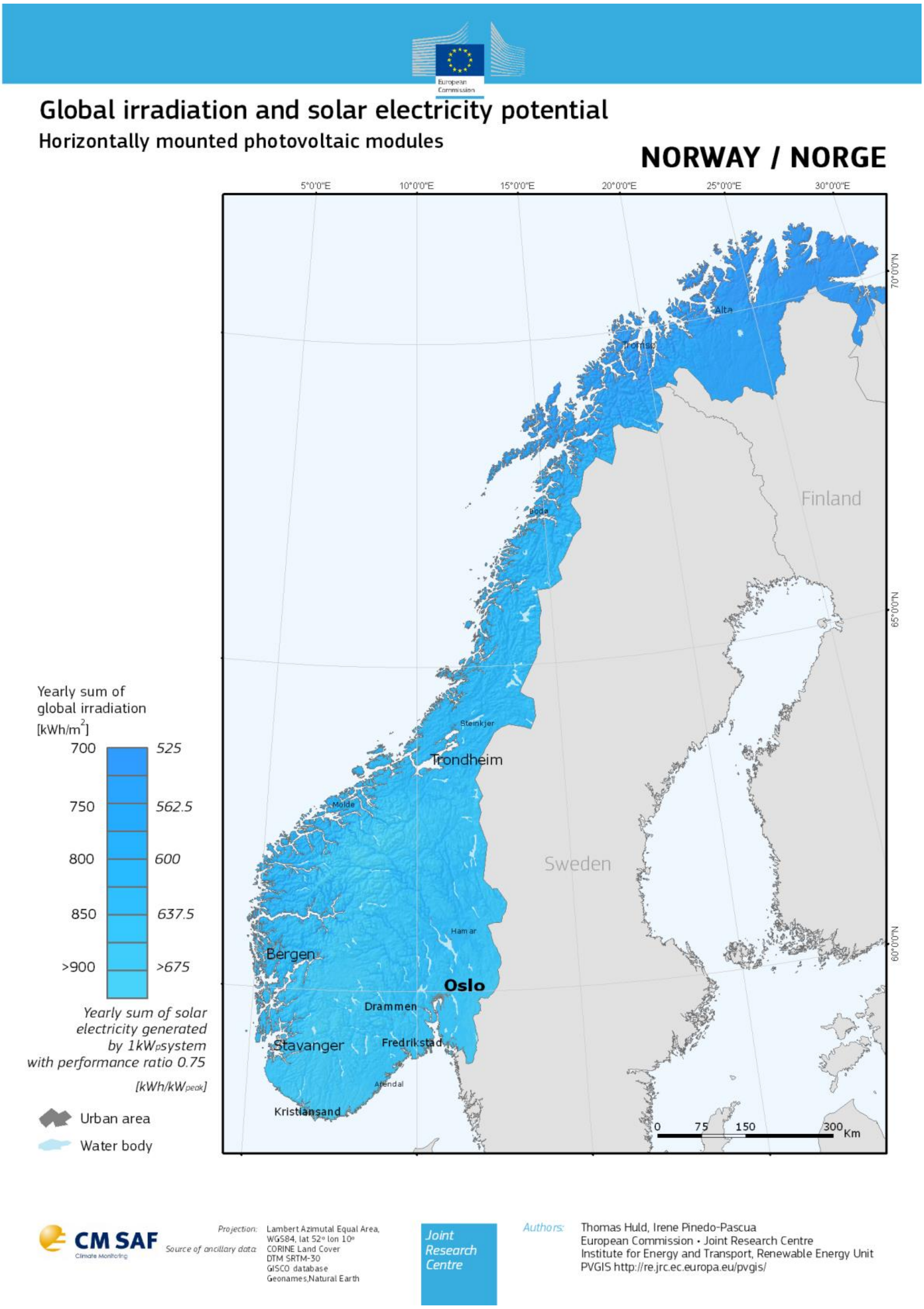

Figure 18: Example of GIS Solar Radiation Mapping

(PVGIS, 2022)

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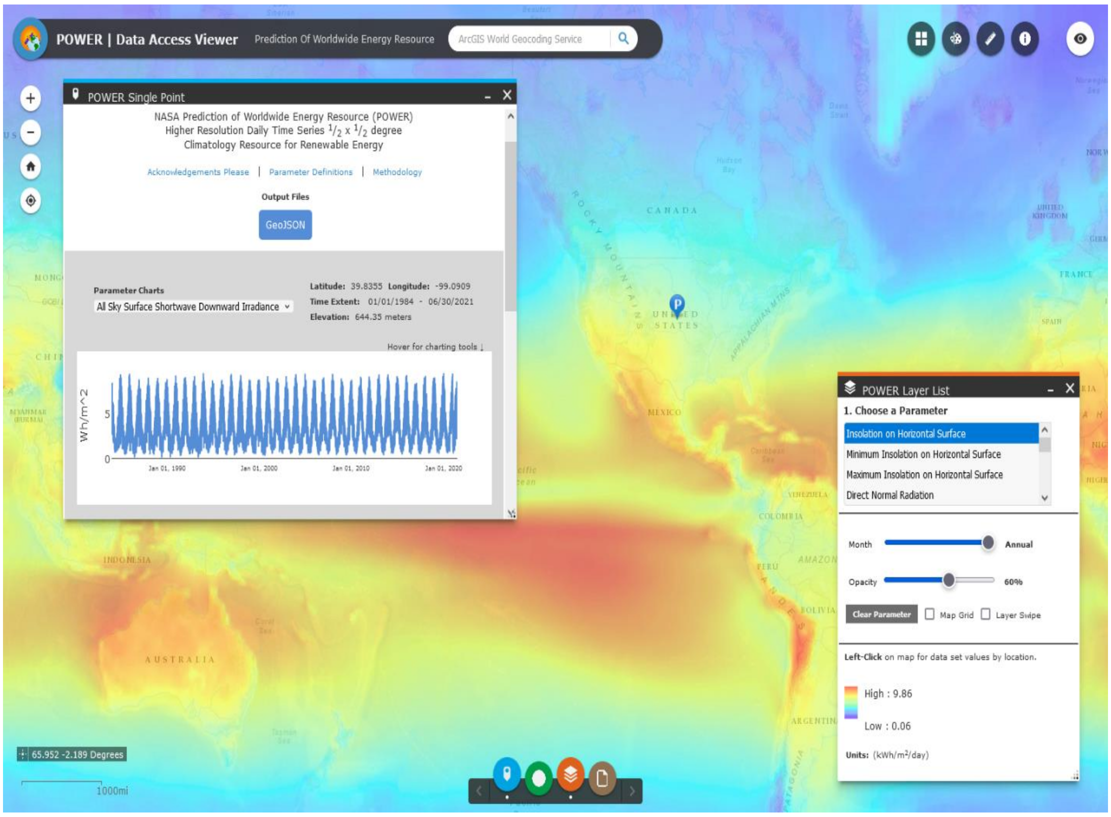

Figure 19: POWER NASA's database preview

4.2.2 Circular Economy opportunities

A highly productive, waste-free society would be undeniably beneficial. Whether a genuinely circular economy is realized, if this goal reduces waste and limits the use of scarce resources, it must be recognized as a beneficial instrument. The same applies to the concept of sustainability (Geissdoerfer et al., 2017). A circular economy is defined by two guiding principles: maximize the service offered by the materials contained in goods and minimize service loss over time (Velenturf & Purnell, 2021).

The ROBINSON project uses diverse technologies, including biomass gasification, wastewater valorisation, and heat and oxygen reuse based on the industrial symbiosis concept. The high availability of RES and the generated green hydrogen will also be examined for other uses such as ship cargo loading/unloading electrification and biogas road transport. The AD+BES allows for the conversion of liquid waste from the fish business into biomethane, which can then be utilized as fuel driven by RES excess. This novel bioenergy-based technology is another source of dispatchable energy generation and storage applications, which is especially important for islands with biological waste. A CHP unit (mixed fuel), a steam boiler, an anaerobic digestion coupled with bio-electrochemical system (AD-BES) described in Figure 20, a biomass gasifier, and a gas fuel mixer are supposed to be installed on the islands, converting island organic waste streams into biomethane. In the notion of industrial symbiosis, for example, biomass and/or waste feedstock will be utilised. Industrial symbiosis is defined as a concept that "allows entities and companies that have traditionally been separated to cooperate among themselves in the sharing of resources, contributing to the increase of sustainability with environmental, economic, and social benefits (Neves et al., 2020), and should thus result in a more circular economy. Waste heat from industrial activities will be used to replace fossil-fuel based heating

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systems at Eigerøy, and waste steams containing organic material will be used to create bio-fuel - an industrial symbiosis idea with high replicability potential on other islands.

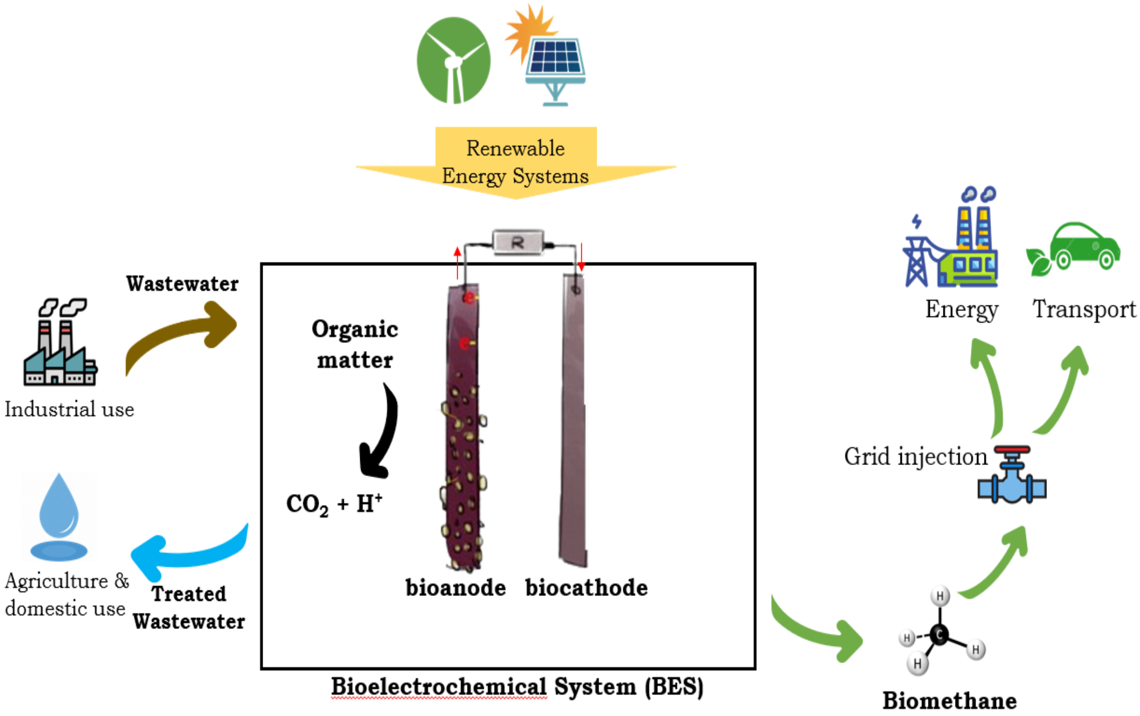

Figure 20: AD+BES Scheme

A circular bioeconomy necessitates the use of sustainable biomass to ensure that the restoration cycle is completed, and it might be continuously repeated, and that's what ROBINSON will try to promote and incorporate. Biomass is a general term applicable to all plant and animal derived materials (Sherwood, 2020). Biomass differs from other renewable energy sources since it's a substance combusted to create heat, (before it can be transformed into electrical or mechanical power) or utilized as a precursor to goods. The most common forms of biomass and their Biomass Characteristics Index (BCI) are presented in Table 1.

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Biomass types	Moisture	Moisture	Avg.	Bulk density	Bulk density	Avg. bulk	BCI
	(%, Min)	(%, Max)	(%)	(t/m³, Min)	(t/m³, Max)	(t/m³)	
Air dry wood chips	20.00	25.00	22.50	0.190	0.290	0.240	18,600
Green wood chips	40.00	50.00	45.00	0.280	0.410	0.345	18,975
Kiln dry wood chips	10.00	15.00	12.50	0.190	0.250	0.220	19,250
Empty fruit bunch	15.00	65.00	40.00	0.160	0.550	0.355	21,300
Kiln dry wood chunks	10.00	15.00	12.50	0.200	0.310	0.255	22,313
Air dry wood chunks	20.00	25.00	22.50	0.240	0.370	0.305	23,638
Green wood chunks	40.00	50.00	45.00	0.350	0.530	0.440	24,200
Mesocarp oily fiber	30.00	–	30.00	–	–	0.305	21,350
Kiln dry sawdust	10.00	15.00	12.50	0.240	0.370	0.350	30,625
Fresh fruit bunch	40.00	–	40.00	–	–	0.480	28,800
Green sawdust	40.00	50.00	45.00	0.420	0.640	0.530	29,150
Straw bales	7.00	14.00	10.50	0.200	0.500	0.350	31,325
Green roundwood	40.00	50.00	45.00	0.510	0.720	0.615	33,825
Air dry roundwood	20.00	25.00	22.50	0.350	0.530	0.440	34,100
Ash	0.00	–	0.00	–	–	0.437	43,700
Sterilized fruit	30.00	–	30.00	–	–	0.660	46,200
Fruitlets	30.00	–	30.00	–	–	0.680	47,600
Wood pellets	7.00	14.00	10.50	0.500	0.700	0.600	53,700
Press expelled cake	12.00	–	12.00	–	–	0.650	57,200
Palm nuts	12.00	–	12.00	–	–	0.653	57,464
Cracked mixture	12.00	–	12.00	–	–	0.653	57,464
Dry EFB cut fiber	10.00	–	10.00	–	–	0.710	63,900
Shell	12.00	–	12.00	–	–	0.750	66,000
Coal	6.00	10.00	8.00	0.700	0.800	0.750	69,000
Wood briquettes	7.00	14.00	10.50	0.900	1.100	1.000	89,500

Table 1: Biomass characteristics (Sims, 2013; Tang et al., 2016)

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Anaerobic digestion (AD), at its most basic, takes mixed, low-value waste streams and transforms the carbohydrate within them into methane with a theoretical maximum carbon efficiency of 50%. Several products can be converted into waste-to-use materials, thereby enhancing the circular economy concept. As a result, the goal of anaerobic digestion should be to provide value-added products generated from carefully selected feedstocks, rather than just to eliminate undesired wastes. The principal product is methane, although utilising the digestate as a fertilizer is also a crucial issue (Behera et al., 2022; Fuentes-Grünewald et al., 2021; Velvizhi et al., 2022).

Biomass gasifiers are an excellent sustainable solution towards sustainable development and circular economy as past research have shown (Ribó-Pérez et al., 2021). An HRES equipped with a biogas generator has been evaluated for two European cities in (Tiwary et al., 2019). The study proved that a biogas generator can produce more than 60% of the total energy demand for both the cases, leading to an innovative and promising system (Tiwary et al., 2019). On this context, ROBINSON is suggesting to also exploit sustainably produced heat sources, such as biomass and (renewable) hydrogen in order to produce heat. Also, it is worth mentioning that a gas storage will be installed in Eigeroy in order to store the gas and manage the amount of gas going into the gas mixer. Finally, biomass will be kept as (waste) wood chips to be used in biomass gasification. The nature and size of these storage media are currently being considered.

Concluding, all the aforementioned will move the case studies one step closer to circular economy, taking full advantage of their wastes in order to either produce heat, or energy. In this case, otherwise wasted heat will be harvested, contributing to reduced demand of primary energy and also to energy efficiency. The crucial mentality shift that occurs with a circular economy is that waste management becomes a process of returning resources to use rather than just eliminating trash, which will be also beneficial for the energy transition agenda of each island that the tool is replicated to.

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4.3 The legal and regulatory framework related to the islands' energy systems

4.3.1 EU policy (EU strategies, Green Deal, etc.)

Since ROBINSON concept is primarily held in EU, it should be in good accordance with EU legislation and strategies in order to ensure both its applicability and any funding opportunities. EU strategies are apparent and realised through various initiatives such the 'Clean Energy for Islands Initiative' (European Commission, 2022). As mentioned therein, the Paris Agreement (European Commission, 2022) acknowledges that islands are particularly vulnerable to climate change, and over-dependent on fossil fuels and energy imports. Many of Europe's 2400 islands are small isolated systems and small markets. However, these islands, where 15 million Europeans live, have the potential to be frontrunners in the clean energy transition by adopting new technologies and implementing innovative solutions. In such terms, the benefits for an island community will be multidimensional, since not only the energy self-reliance of islands is promoted and the consequent reduction of fossil fuels imports -thus reducing public expenses-, but also the implementation of tailor-made solutions will harness the available renewable energy potential more efficiently.

Additionally, EU has approved the 'Green Deal' in 2020, which is a set of policy initiatives by the European Commission aiming to make EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. The European Green Deal focuses on 3 key principles for the clean energy transition, to help reduce greenhouse gas emissions:

1. ensuring a secure and affordable EU energy supply,
2. developing a fully integrated, interconnected and digitalized EU energy market,
3. prioritizing energy efficiency, improving the energy performance of buildings and developing a power sector based largely on renewable sources.

The Commission's main objectives are:

- build interconnected energy systems and upgraded grids to support renewable energy sources
- promote innovative technologies and modern infrastructures
- boost energy efficiency and eco-design of products
- decarbonize the gas sector and promote smart integration across sectors
- empower consumers and help EU countries to tackle energy poverty
- promote EU energy standards and technologies at global level
- develop the full potential of Europe's offshore wind energy

In this context, becomes apparent that for policies and strategies to be implemented, funding opportunities shall arise. The source of these opportunities may be either EU funds under various actions and initiatives, or national funds both from the public (governmental or regional budget) or private sector (possible stakeholders, investors, etc.). Despite the origin of funding -in order to achieve it, a project shall be carefully designed in technical and financial terms, hence the need of an accurate Evidence Base for Scale up and Uptake of ROBINSON project.

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4.3.2 National framework

ROBINSON and the aforementioned policies and strategies may refer to EU under a general context, but concerning the implementation of such a project, there are differences between the EU member states' legislation that should be taken into consideration. As reported in **Deliverable 1.2**, the following is an abstract referring to regulations about: the realisation of DER systems, connection to electrical grid, connection to gas network and connection to district heating grid.

- **DER systems** consist of different energy generators/converters and storage systems that are regulated/controlled via an energy management system for a reliable, secure and cost-effective supply of the consumers, depending on the local resources. The scale of the systems depends on the local possibilities and requirements. Due to the flexible design based on the local situation, there is no one fit-for-all system. The responsibilities and framework conditions for obtaining general operating permits for systems such as those to be used in the Robison project vary greatly in some European countries and depend on the size of the respective technical systems and processes applied for. In the procedure for obtaining an operating licence, which is carried out by local administrative authorities, the effects of the proposed operation (of the subcomponents) on the (living) environment are assessed and weighed up. The applicant must provide information on: Operational safety, emissions, impact on nature (protected areas, flora/fauna) etc. There are no consistent standards for this throughout Europe. Nationally/regionally, the same value system (protection of the environment) is applied in principle, but possibly with different limit values, e.g. for distance requirements, emission limits, etc. This has a great influence on the economic viability of DER systems if, for example, the use of wind energy in the vicinity of the consumer cannot be approved. Essential here is e.g. the size and/or number of planned wind turbines. The scope of approval procedures for wind turbines depends strongly on this. In national procedures, a distinction is usually made with regard to the (maximum) height of the wind turbines, as this criterion correlates, for example, with environmental impacts such as emitted noise, shadow flicker, effects on bird migration and, in general, with acceptance by the population. In most countries, a significantly more complex procedure is required for wind turbines with a total height of 50 m above ground, with a large number of associations/persons to be involved. As a result, the open procedures may take several years and thus considerably longer than less complex procedures for other subsystems. The application for an operating permit is made by the operator. However, since a DER system can involve a large number of different technical systems, which do not have to be spatially closely connected, there is no uniform, coupled authorisation procedure. This also applies if the DER system is to be realised with different operators for individual subsystems. For a holistic view, there is therefore always the risk that individual subsystems that are essential for economic operation may not obtain an operating licence. Moreover, EU regulations 2016/631 (RfG NC 2016) apply, even if they focus more on trade issues then describing technical requirements in detail.
- Concerning the **connection to the grid**, in Europe as well as worldwide, there exists a multitude of nationally/regionally valid standards for the connection of PGM to a superordinate power grid. The rules laid out under RfG NC within the Agency for the Cooperation of Energy Regulators (ACER) Framework Guidelines on Electricity Grid Connection were aimed to meet the principles of the Third Energy Package namely to increase

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sustainability, security of supply and to elaborate the concept of a single European market for electricity. In May 2018, two years after the RfG NC had been published, European Member States have been obliged to conclude the respective national implementations of their individual grid codes. European member states in this context sublement the twenty-six European member states and following nine other European countries, which belongs to the European synchronous grid aera: Bosnia and Herzegovina, Switzerland, Montenegro, North Macedonia, Serbia, Great Britain and Northern Ireland, Iceland and Norway (relevant for the Robinson demonstrator project). The Energy Community provides documentation for technical assistance for the connection network codes implementation (Electricity Coordinating Center Ltd. 2021). In parallel the European Standard EN 50549-1/2, prepared by the European Committee for Electrotechnical Standardization (CENELEC) (CLC/TC 8X), relates to both the RfG NC and current technical market needs. Its purpose is to give detailed description of functions to be implemented in products. This European Standard is also intended to serve as a technical reference for the definition of national requirements where the RfG NC requirements allow flexible implementation (mainly for low voltage connection Typ A and B PGMs). In (CENELEC & SCHAUPP 2018) an overview about intention and scope of the EN 50549 is given.

- As for **connection to gas network**, within the Robinson demo project, the different types of gas produced are only transported in the internal network of the single consumer. There is therefore no feed-in to a regional network. Permits must be obtained from the local authorities for the construction and operation of an internal gas distribution network. Nevertheless, feeding into an existing gas distribution network is regulated differently at national/local level in the various European countries. An example of such regulations is the worksheet G2000 prepared by the DVWG (*DVWG 2017*) in Germany, or the Technical Minimum Requirements (TMA) for the injection of upgraded biogas into a local natural gas network of the operator (*NEW Netz 2019*). These guidelines are primarily concerned with the quality of the injected gas, the use of standardised components and measuring equipment, as well as the recording of the incoming/outgoing volume flows and their documentation and data exchange.
- Concerning **connection to district heating grid**, There are two types of Heat Network. The first is communal heating, in which all dwellings within a single building are supplied by a central heating system. The second is District Heating, where heat is produced from a central source and delivered through a network to multiple buildings or sites. Buildings could be residential, public or commercial use or some combination of these. In (Euroheat & Power 2016) general guidelines which contain a set of recommendations focusing on planning, installation, use and maintenance of district heating (DH) substations within district heating systems throughout Europe are given.

The following standards and EU directives are basis for these guidelines:

- Pressure Equipment Directive (97/23/EC)
- Measuring Instruments Directive (2004/22/EC)
- Energy Performance of Buildings Directive (2002/91/EC)
- Machinery Directive (2006/42/EC)
- Energy Services Directive (2006/32/EC)

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- Eco-design Directive (2005/32/EC)
- EN/CEN standards: EN 1434, CEN 311, etc.

4.3.3 Authorization procedures

A crucial part for implementing a project like ROBINSON is the authorization procedures, that are governed by the aforementioned legislative context, which as mentioned may vary from country to country. Moreover, the authoritative level that is expected to provide the essential licenses may also differ from region to region, since it could be either a municipal, a regional or a central ministry authority. Taking Greece as an example of the licensing procedures for the installation and operation of energy systems is indicative of how crucial this step may be. In Greece, while implementing an energy system, every discrete component that the system is comprised of shall follow a separate licensing process. The overarching rule for issuing such licenses includes the following successive major steps:

- A 'power production certificate' that refers to both energy and spatial space for a specific technology, according to a recent 2020 domestic law.
- The 'environmental permit' that the owner of the power production certificate is obliged to apply for within six to eighteen months, after the issuance of the power production certificate. Variations and additional demands may arise, depending on the siting of the project (e.g. within a NATURA 2000 or similar protected area).
- The 'installation license' that allows the project's owner to initialize the construction of the project. Nevertheless, issuing the installation license may also include various other permits and licenses depending on the very nature of each project. For example, a certain project may include the construction of buildings, marinas, docks, electricity networks, electromechanical facilities or other accompanying infrastructures and/or procedures like connection to the local grid, which shall be licensed according to the proper legislation.

However, there are exceptions from the obligation of issuing the 'power production certificate' to the 'Greek Regulatory Authority for Energy' for natural or legal entities that apply to:

- geothermal plants with power equal or lesser to 0.5 MW,
- biomass, biogas and biofuel plants with power equal or lesser to 1 MW
- photovoltaic or heliothermic plants with power equal or lesser to 1 MW,
- CHP plants with power equal or lesser to 1 MW,
- wind parks with power equal or lesser to 60 kW,
- small hydropower plants with power equal or lesser to 0.5 MW,
- educational/research plants with power equal or lesser to 5 MW.

Moreover, for the aforementioned cases with 'power production certificate'-exceptions, also an installation and operational license is not required. However, depending on the case, environmental permits may apply.

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Concerning the environmental permits, the 'Environmental Impact Assessments' must be issued to certain authorities depending on the unique characteristics per case, but in general, some agencies involved may be:

- municipal and regional councils/authorities,
- agencies of spatial and environmental planning of the respective ministry
- forestry and rural development agencies/ministry
- protected areas' management agencies
- ministry of maritime affairs (for offshore and coastal plants)
- regional water management agencies (for hydropower plants),
- regional/ministry agencies for antiquities, etc.

Furthermore, for an operator to deploy backup power generators a 'solemn declaration' must be issued to the license-providing authority. In this 'solemn declaration' must be included the 'Additional Connection Agreement' between the operator of the backup power generator and the respective Power Transmission/Distribution Operator per case. Once the submission of the aforementioned 'solemn declaration' to the license-providing authority takes place, the operation of the backup power generator may initiate.

It becomes apparent that implementing such a project demands accurate planning and estimation of the prerequisite procedures both from a legislative and bureaucratic aspect. Issuing the licenses shall take in mind all possible details in order for a licensing procedure to be approved and not arise delays. Bureaucracy and implications, like in any project may cause financial, operational and constructional impacts. The latter is going to be moderated by the use of the ROBINSON Replication Tool, which shall take account of as many as possible crucial characteristics that may assist or burden any further procedure, and consequently provide the decision support tool in terms of fit-to-purpose ROBINSON's replication.

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4.4 Stakeholders Engagement

Engaging stakeholders: a tangible asset

The active participation and involvement of the key actors can play a crucial role in an energy project's efficient implementation, comprehensive evaluation, and viability. This dynamic and interactive process accommodates the building of trust and confidence among the involved parties, for the development to take place considering the total of views and perspectives. This approach identifies the most suitable and advantageous solutions, encompassing a wide variety of skills, knowledge bases, expertise, experiences, and backgrounds.

This participatory approach can be extremely beneficial for the project development, enriching the knowledge and experience, maximizing therefore the possibilities for successful implementation. Moreover, the engagement of all parties and the sharing of views and perspectives, eliminates the possibilities of conflicts and arguments among the involved actors. Additionally, to this, the sense of ownership regarding the proposed solutions and actions, the process, and the objectives of the project, builds concrete foundation of cooperation among the stakeholders. Incorporating a wide variety of stakeholders, also facilitates the adaptation and replication potential of the proposed solution or system or project, with interested actors to act as multipliers disseminating the overall concept.

Robinson stakeholders' engagement process has been structured on the participatory, active approach, aiming to conclude a successful continuous participation and cooperation among the interested parties. Robinson's engagement activities have followed four specific steps to reach a prosperous outcome, aiming to develop a concrete bilateral connection between the project's developers and the key actors group.

Step 1 – Stakeholders Mapping

The identification of potential actors since the project's infant stage, is considered a strategic movement for co-creation, participatory approach, resolving of oppositions and concerns, and sufficient development. The mapping of interested parties will focus on persons that will contribute, impact and benefit the project, gaining also the corresponding benefits from their side, shaping a win-win situation.

Key element of the first step is the selection and definition of a leader stakeholder, a person that will compose technical knowledge and expertise on the field, influencing the stakeholders' group towards active participation and involvement with the project, maximizing its impact at local level.

Step 2 – Shaping the suitable stakeholders group

Finding the proper size of the stakeholders' group, selecting in parallel the key representatives, facilitates the effective management of the group and improves its effectiveness. An extended group with numerous members is difficult to build strong cooperation relations, also to be managed. The effective stakeholders' management focus on the identification of the actors with the greater influence and potential positive impact on the project, capable to cover the required technical knowledge, administrative issues and to promote sustainable solutions. When discussing about local renewable energy projects, the local stakeholders are in the frontline, followed by actors at prefecture and national level.

Step 3 – Engaging the local stakeholders

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The analysis of stakeholders' interests and motivation is a sensitive step for the development of the core team. The clear definition of roles and the level of authority, is considered crucial for an effective matching of priorities, needs and outcomes, with stakeholders' capabilities. To ensure the active participation, specific, targeted messages should be included in the invitations for participation, distinguishing each member's roles and actions. Transparent communication within the working team is also important, together with the implementation of workshops, calls and actions necessary for the project development.

Step4 – Strengthening cooperation relationships and establishment of team's viability
The engagement process is important to be developed aiming to sustain the cooperation throughout the project's lifetime and after its completion. The working team can further promote and disseminate the project's outputs and results, increasing its impact, while concrete foundations for further successful cooperation can be laid.

4.4.1 Identifying potential actors in clean islands projects

The projects include the integration of renewable energy sources at local level for establishing a secure and cost-efficient energy supply, can involve a wide range of potential interested parties. Robinson's scheme incorporates also the aspect of industrialization at insular territories, forming therefore an extended list of stakeholders and decision makers to be engaged. Table 2 below, presents the groups of actors, that could be potentially involved, categorized by his type of expertise and involvement.

Potential type of actors to be involved in a Clean Energy Islands Concept		
Actors involved for decision making	***Actors involved for technical specifications & implementation***	***Actors for dissemination, information and consent***
Local or regional authorities – municipalities	*Electricity regulators and grid operators*	*Citizens associations*
Municipal or regional companies	*RES technology suppliers*	*NGOs and other civil society representatives*
Technology providers	*Associations of RES installers*	*Industries' associations*
Institutional stakeholders (chambers, professional associations)	*RES experts, engineers*	*Media representatives*
RES experts	*Energy storage experts*	*Departments of Public Relations from the involved public authorities and other actors*
Energy storage experts	*Technology providers*	
Industrial companies of the investigated location	*Research institutes, experts in RES*	
Representatives of national administration and/or regional administration	*Industries and their technical staff*	
	Utilities including district heating companies	
	Financial partners (ESCOs, banks, private funds, other funds)	

Table 2: Type of actors to be potentially involved in clean energy islands concepts

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Robinson's approach encloses a more project-oriented presentation of stakeholders per section of involvement; in the identification section, the actors with greater influence and capacity of decision-making, are being mapped. The analysis section implies a more detailed description of the stakeholders mapped in the identification section, writing down the expectations and attitudes, their interest and willingness to cooperate. The section of action plan describes the level of involvement during the implementation, operation and after the project's lifetime.

According to the field of expertise and their level of involvement, stakeholders could play a beneficial role at multiple stages of the project's development. Combining the generic stakeholders' groups and their type of involvement as derived from the literature, with the Robinson's targeted sections, an extended list is defined. Table 3 presents this combination by delivering an upgraded list, incorporating the actor's role and impact in the development process. Moreover, Table 3 indicates the offerings gained through the stakeholder's engagement, according to their potential level of involvement.

4.4.2 Tools and methods to ensure participation

After undertaking the stakeholders mapping, the planning of an effective engagement is essential, and is based on the identification and selection of proper tools and methods. Different communication approaches can be included into the engagement planning, including involvement the types of informative participation, feedback participation, consultation, and specific involvement.

- The **informative** type includes the preparation and distribution of information material to the involved actors, including brochures, newsletters, posters, and other material including essential information about the project characteristics and objectives, and their potential role.
- The **feedback** type seeks to gain fruitful feedback from the selected stakeholders, through surveys and questionnaires, public meetings, and other available techniques for providing their perspective, opinions and knowledge.
- In **consultation** type of activities, the actors are engaged through targeted workshops, meetings, dedicated working groups, for providing their expertise.
- In **specific** type of involvement refers to specialized participatory activities such as the participation in advisory committees for planning and implementation activities.

When selecting the suitable approach of participation, the adoption of the proper communication strategy should be also considered in order to adequately inform the actors, to trigger their motivation and to keen their active involvement. Critical questions to be taken under consideration are the identification of key audience, which are the desired goals and outcomes from their involvement, are the means of communication suitable and effective, and how effectiveness could be evaluated or even being improved.

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Offerings of stakeholders' groups per type and level of involvement			
Groups of stakeholders	*Type / Level of involvement*	*Robinson Analysis Levels Attitude/Interest/Influence*	*Offerings*
Local or regional authorities – municipalities	Decision making / High	Positive/High/High	Authorization procedures, administrative decisions for implementation and operation
Municipal or regional companies	Decision making / High	Positive/High/High	Provision of knowledge, support in technical specifications and functionality issues
Technology providers and suppliers incl. RES and energy storage	Decision making, tech. specifications & implementation / High	Positive/High/High	Provision of expertise, technical and operational decisions, functionality issues
Institutional stakeholders (chambers, associations)	Decision making / Medium	Positive/Medium/High	Support in technical and operational specifications, risks and challenges, provision of expertise
RES experts, engineers	Decision making, tech. specifications & implementation/ High	Positive/High/Medium	Provision of expertise, technical and operational decisions, functionality issues, risks and challenges
Industrial companies & technical staff	Decision making / High Tech. specifications & implementation/Medium	Neutral-Positive/High/High	Provision of data and operational situation, needs, risks, opportunities, technical specifications
Representatives of national and / or regional administration	Decision making / Medium	Positive/Medium/High	Support in authorization procedures, administrative decisions
Electricity regulators and grid operators	Tech.specifications & implementation/High	Neutral-Positive/Medium/High	Authorization procedures
Research institutes, experts in RES	Tech.specifications & implementation/High	Positive/High/Medium	Research, successful implementation and operation, optimization, further opportunities
Utilities including district heating companies	Tech.specifications & implementation/Medium	Neutral-Positive/Medium/Medium	Provision of technical specifications

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Offerings of stakeholders' groups per type and level of involvement			
Groups of stakeholders	***Type / Level of involvement***	***Robinson Analysis Levels Attitude/Interest/Influence***	***Offerings***
Financial partners (ESCOs, banks, private funds, other funds)	Tech.specifications & implementation/High	Neutral-Positive/High/High	Financial support
Citizens associations	Dissemination and information/Medium	Neutral/Medium/Minor	Support project's results and outcomes
NGOs, civil society representatives	Dissemination and information/Medium	Positive/High/Medium	Support project's results and outcomes
Industries representatives	Dissemination and information/Medium	Positive/High/High	Support project's results and outcomes
Media representatives	Dissemination and information/Medium	Positive/High/High	Disseminate results and outcomes
Departments of Public Relations from the involved actors	Dissemination and information/Medium	Positive/High/High	Disseminate results and outcomes

Table 3: Mapping of potential stakeholders' groups and level of involvement

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4.5 Technical components/infrastructure selection

ROBINSON incorporates more low-carbon or renewable energy sources. In the notion of industrial symbiosis, for example, biomass and/or waste feedstock will be utilised. Industrial symbiosis is defined as a concept that allows entities and companies which have traditionally been separated to cooperate among themselves in the sharing of resources, contributing to the increase of sustainability with environmental, economic, and social benefits, and should thus result in a more circular economy. In ROBINSON, distinct (unused) waste streams are identified on geographical islands and will be used as feedstock in various waste-to-energy facilities.

ROBINSON proposes many methods to meet environmental and economic goals, which will be discussed more in this chapter. The case studies' future energy systems will incorporate renewable energy sources, namely wind and PV power, as well as sustainably produced heat sources such as biomass and (renewable) hydrogen. Furthermore, the newly proposed EMS attempts to always balance energy supply and demand while taking into account the restrictions of all system components. The ROBINSON EMS will guarantee the effective and intelligent integration of all distributed energy resources (DER), energy surpluses, and storage capabilities available on the island, while taking demand-side response, power balancing, weather forecasting, and market-related prices into account. Such an integrated system would offer a dependable, cost-effective, and resilient energy supply, so contributing to the decarbonization of European islands by phasing out fossil fuels and lowering CO_2 emissions. The software's usability and adaptability will permit replication to additional energy islands with comparable conditions, which will be assisted by active participation of local communities and other stakeholders. The EMS will be developed with the local communities for the local communities with the aim to bring relevant business opportunities, while making sure that the fragile environment of the island is preserved.

It is worth noting that ROBINSON will be applied to an industrialized region of one of the three chosen islands, allowing for the installation of an industrial microgrid in conjunction with industrial symbiosis. As a result, the notion is also relevant to distributed (multi-)energy systems. Furthermore, Eigerøy and the Western Isles now have an energy grid link to the mainland, but Crete does not. The ROBINSON idea is to create an intelligent, resilient, and adaptable energy system (Figure 1) that integrates technology from several energy vectors (electricity, heat, and gas) and is underpinned by cutting-edge digital technologies like blockchain. It will combine the island's existing energy sources with advanced and tailored technologies such as an innovative wind turbine, anaerobic digestion (AD), gas turbine-based Combined Heat and Power (CHP) units, a gasifier, and an electrolyzer, with the goal of ensuring a reliable and well-balanced coverage of RES generation and demand for electricity, process steam, and heating. Hydrogen will be produced by the electrolyzer for energy storage, which is necessary to compensate for the energy variations caused by renewable sources. To meet energy security limitations and reduce costs, the EMS will regulate the electrolyzer based on energy excess or energy storage needs, as well as the hydrogen storage level. If the stored hydrogen level has to be raised, the EMS will activate the electrolyzer. For the opposite case the device will be switched off.

A further energy recovery on the electrolysis process will be performed from a thermal standpoint. This will help to decarbonize the island's heat and power and lessen its reliance on the mainland grid. Integration of innovative energy storage in the form of renewable gases will contribute to peak shaving and balancing of the local thermal, electrical, and gas networks, while individual source/sink elements and exchange between different local prosumers and the mainland will be required for a

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stable and efficient system. Other concepts, such as waste valorization and industrial symbiosis, will add considerable value to the system's cost-efficiency and environmental impact.

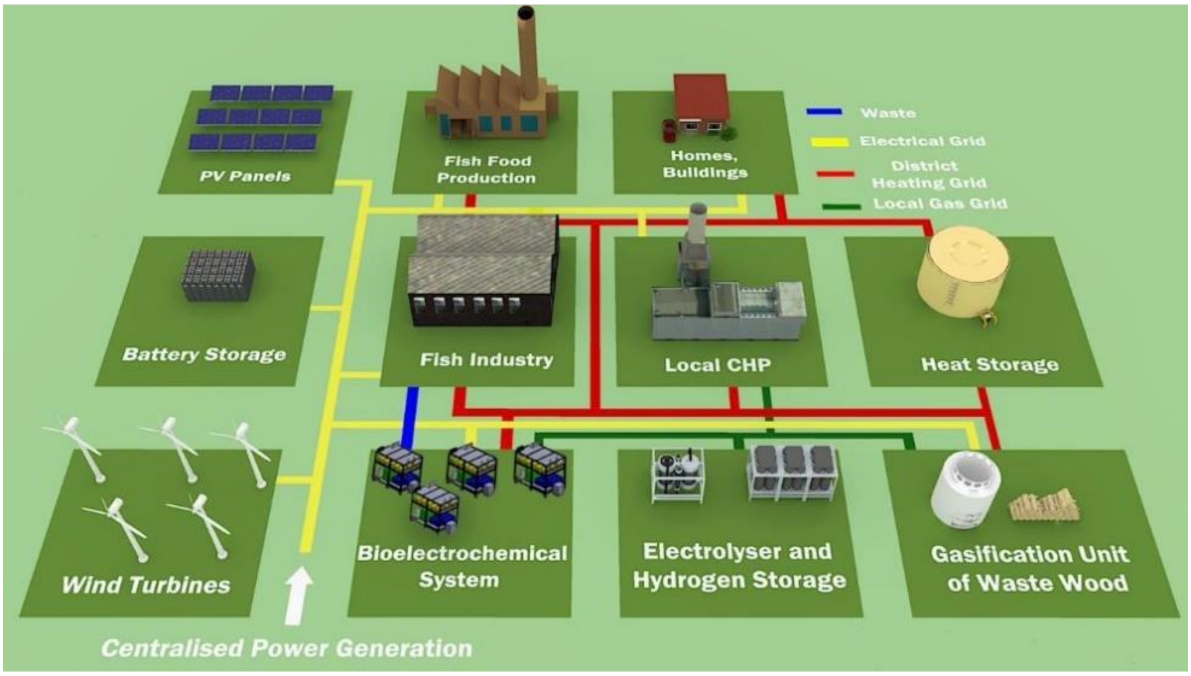

Figure 21: The integrated ROBINSON system on demo island

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Gas turbine (Aurelia)

Technical description

The innovative gas turbine Aurelia® A400 - a combined heat and power (CHP) unit - can be fueled by a mixture of biomethane, hydrogen and syngas. This CHP unit will supply dispatchable energy to the electricity grid coupled with exhaust heat recovery. The gas turbine has a maximum electrical power output, electrical efficiency and thermal efficiency are equal to 400 kW, 40% and up to 50%, respectively. It requires 28.2 m^2 (3m x 9.4m) of land and 93.1 m^3 of volume (3.3m in height). The fuels of the CHP unit are syngas (generated from the gasification of locally available waste wood), hydrogen and biomethane (from the AD-BES). A gas mixer is exploited to blend these (renewable) fuels, while the CHP gas turbine can process different fuel compositions and shares of (renewable) energy sources. The gas turbine has an initial cost of 400,000 euros, resulting in a specific investment cost (CAPEX) of 1000 euros per kW_{el}. A prominent step of the ROBINSON project is to validate this product operation under site-specific conditions (i.e. Eigerøy). The installation of the Aurelia turbine is proposed for both commercial and small industrial use.

Figure 22: Aurelia® A400 gas turbine (Aurelia, 2022)

Parameter	*Value*	*Unit*
Capacity	400	[kWe]
Electric efficiency	40.2	[%]
Thermal efficiency	Up to 50	[%]
Operation hours	8322	[hours/year]
Lifetime	20	[years]

Table 4:Technical specifications of the gas turbine (Aurelia, 2022)

Technology Flowchart

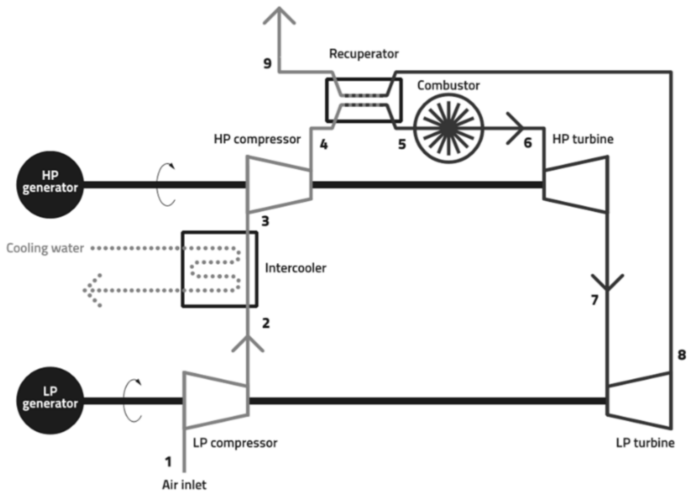

Figure 23: Aurelia turbines-process schematic

(Päivärinne, 2019)

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Technology requirements and operating conditions

The turbine is a twin-spool, intercooled and recuperated gas turbine, with both spools including a compressor, turbine, and generator. The compressor and the turbine are both of radial type. Generators are permanent magnet generators; they can operate at variable speeds, and they are directly linked to the spool without a gearbox. Due to its modular design, the combustion chamber can be properly adjusted to meet the requirements of different fuels. The turbine is designed to use all standard liquid and gaseous fuels and give options for non-standard fuels and mixtures.

The fuel supply pressure range is 7 to 8 bar (abs) and the temperature range is -10 to +80°C. Table 5 contains further operational boundary conditions. During the installation of the gas turbine, fuel composition will be within those stated in Table 6.

Item	*Value*
Mass flow rate of Air	2.16 kg/s
Air pressure after LP compressor	273 kPa (abs)
Exhaust gas temperature at full power	185 °C
Exhaust energy at full power	2.2 kg/s
Heat recovery from intercooler	278 kW
Heat recovery from exhaust gas	240 kW
Operating temperature	*-20 …. +40 °C*
Operating atmosphere	*0 – 95% RH non condensing, non corrosive*

Table 5: Operational Boundary conditions

Fuel specification	*Natural gas*	*Biogas 1/ Flare gas 1*	*Biogas 2/ Flare gas 2*	*Syngas 1*	*Syngas 2*
CH_4 [vol%]	98	75	30	65	5
H_2 [vol%]	0	2	0	28	30
CO_2 [vol%]	0	10	0	2	12
N_2 [vol%]	2	13	70	5	53
Molar mass [g/mol]	16.3	20.1	34.2	13.3	21.5
Density at 1.013 bar & 273 K [kg/m^3]	0.7	0.9	1.5	0.6	1.0
LHV [MJ/kg]	48	30	8	44	5
Fuel $q_{m,min}$ [g/s]	4	7	25	5	40
Fuel $q_{m,max}$ [g/s]	23	37	125	25	256
Max thermal power [kW]	23	37	125	25	256
Supply pressure	7-8 bars (abs)				
Supply temperature	-10…+80 °C				

Table 6: Aurelia® A400 working fuel compositions

Documentation (Links, References)

- https://aureliaturbines.com/products
- https://youtu.be/YxoNGkQCFPY
- https://circularenergy.eu/peripherals/turbines/

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Steam boiler

Technical description

ROBINSON's system includes a steam boiler; however, it will gradually be phased out and replaced with heat derived from renewable energy sources to reduce environmental impact. One of the unique features of the steam boiler - Weishaupt WKG80/3-A ZM-NR- is its multiflam® technology, which results in very low NOx emissions. Therefore, the selected gas boiler technology is ideally suited to countries with strict environmental regulations. With an operational thermal power range of 2.2 MW to 22 MW and a natural gas pressure range of 100 to 4000 mbar, this boiler is equipped with a Weishaupt burner (Type: WKG80/3-A, ZM-NR). An inverter-driven blower is fitted to the air intake duct for the burner and can successfully deliver 26,000 m^3/h of airflow while absorbing 110 kW of power and delivering a differential pressure of 95.5 mbar.

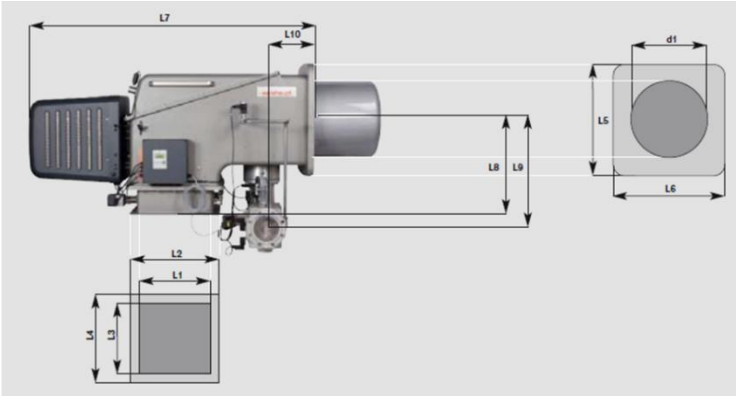

Figure 24:WK-burner from Weishaupt

(Weishaupt, 2022)

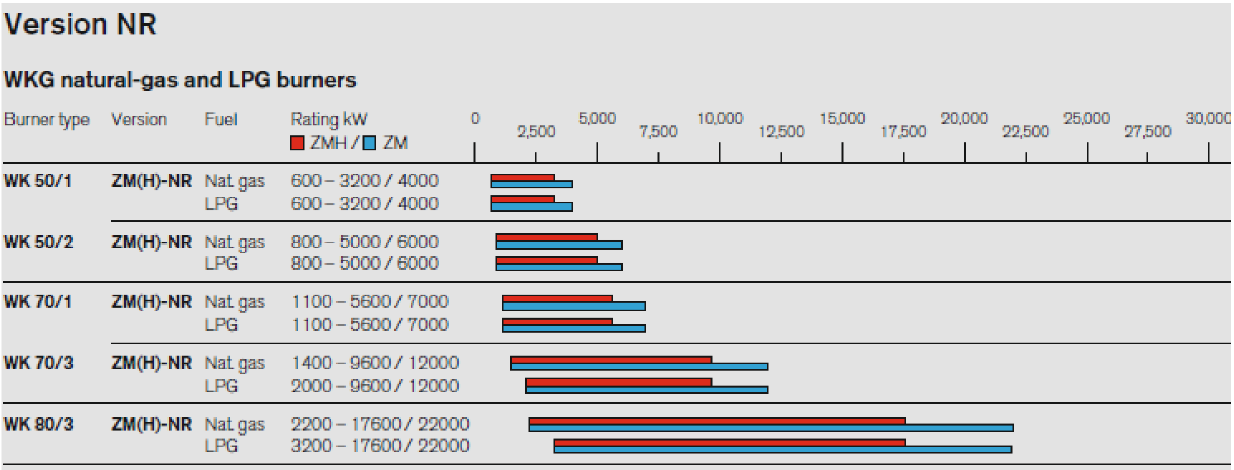

Figure 25: ZM(H)-NR Weishaupt burners

(Weishaupt, 2022)

Parameter	*Value*	*Unit*
Capacity	22,000	kWth
Efficiency	98	%
Lifetime	25	years

Table 7: Technical specifications of the steam boiler

(Weishaupt, 2022)

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Technology Flowchart

Weishaupt WK-series burners include electronic compound control and digital combustion management as standard. Modern combustion methods need accurate and repeatable dosing of fuel and combustion air.

1 Oil pump
1a External pump station with pressure maintenance
2 Oil preheater
3 Filter
4 Temperature sensor in supply
5 Temperature sensor in return
6 Low-pressure switch
7 High-pressure switch
8 Solenoid valve in supply (fitted in the direction of flow)
9 Solenoid valve in return (fitted against the direction of flow)
10 Bypass solenoid valve (normally open)
11 Solenoid valve assembly
11a Nozzle head with secondary nozzles
11b Nozzle head with primary nozzle

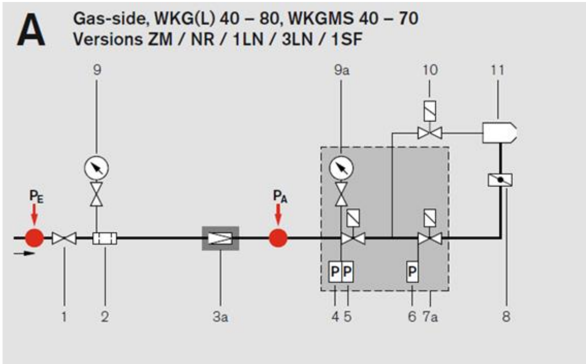

Figure 26: Weishaupt WK-series burners scheme

(Weishaupt, 2022)

Technology requirements and operating conditions

The air input temperature to the blower must be kept below 40°C. If the air inlet temperature exceeds this limit, a replacement one suitable for greater air inlet temperatures must be installed. The temperature of the input air to the burner is significantly lower. The provider suggests replacing the burner with one rated for air inlet temperatures of up to 200°C. The desired steam temperature is 180°C, and the water availability limit of Prima Protein is 30 ton/hour.

Ambient temperature during operation:	15 to +40°C
Humidity:	max. 80 % relative humidity, no condensation
Standard burner protection:	IP 54
Standards conformity: EN 267 and EN 676, Pressure Equipment Directive (97/23/EC), Gas Appliance Directive (2009/142/EC), Machinery Directive, 2006/42/EC, Electromagnetic Compatibility Directive, 2004/108/EC, Low Voltage Directive, 2006/95/EC. The burners are marked with a CE mark, CE Product ID No. and Type-test No.	

Table 8: Permissible ambient conditions for normal operation of Weishaupt WK-series burners

Documentation (Links, References)

- https://www.weishaupt-corp.com/products/burners/weishaupt-wk-series-burners-up-to-32-000-kw#tab-747-2/

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Wind Turbine

Technical description

Renewable Energy Systems & Technology UG (REST) designed the unique wind turbine, V-Twin 100 with a nominal power output of 100 kW - i.e., two turbines with 50 kW each - to optimally exploit wind as the (primary) energy source on Eigerøy. The technical specifications of the novel Wind Turbine are presented in Table 9. Figure 27 depicts an example (drawing) of the prototype wind turbine. The investment cost of the wind turbine has been approximately calculated at 150,000 euro, which makes a specific investment cost – or CAPEX – of 1500 euro/kW_p. The total lifetime of the suggested system is 20-30 years, if properly maintained (Herenčić et al., 2021).

The V-Twin 100 implementation is suggested for both commercial and small industrial applications (i.e. Eigerøy). The installation of the V-Twin 100 Wind Turbine is recommended for both commercial and small industrial applications.

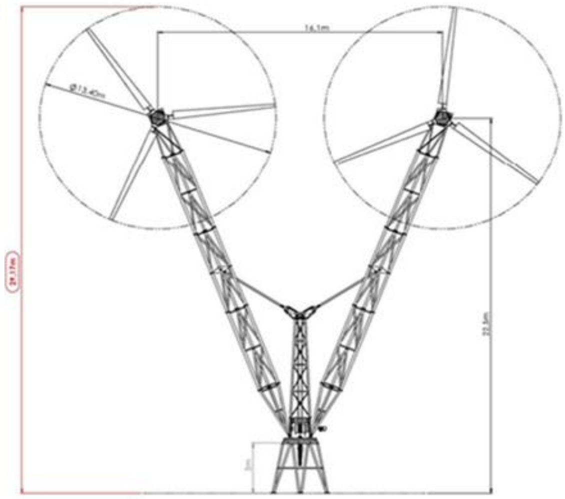

Figure 27: Sketch of the novel wind turbine developed by REST

Parameter	*Value*	*Unit*
Nominal power output	100	kW
Max net. delivered power	90	kW
Max. electrical power gradient	45	kW/s
Min. electrical power gradient	0.5	kW/s
Operation hours/capacity factor	~44 (Eigerøy)	%

Table 9: Technical specifications of the wind turbine

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Technology requirements and operating conditions

A modular method with two-blade rotors, largely made of steel, will be used to decrease the number of components as well as the required area. The absence of a gearbox in the wind turbine minimizes complexity and material consumption (without oil).

The V-Twin 100 wind turbine will be built on the island, adjacent to the Prima Protein manufacturing facility, and will be linked to the Prima Protein microgrid. It has a nominal delivery power of 100 kW and is fitted with an inverter. The wind turbine features two 13.4-meter-diameter rotors that run in tandem (50 kW each).

Figure 28 (a) presents the Wind Turbine's power curve highlighting the cut-in wind speed equal to 2.5 m/s and the cut-off wind speed which equals 19.5 m/s. Figure 28 (b) proves the almost linear dependence between the Annual Energy Yield and the average wind speed.

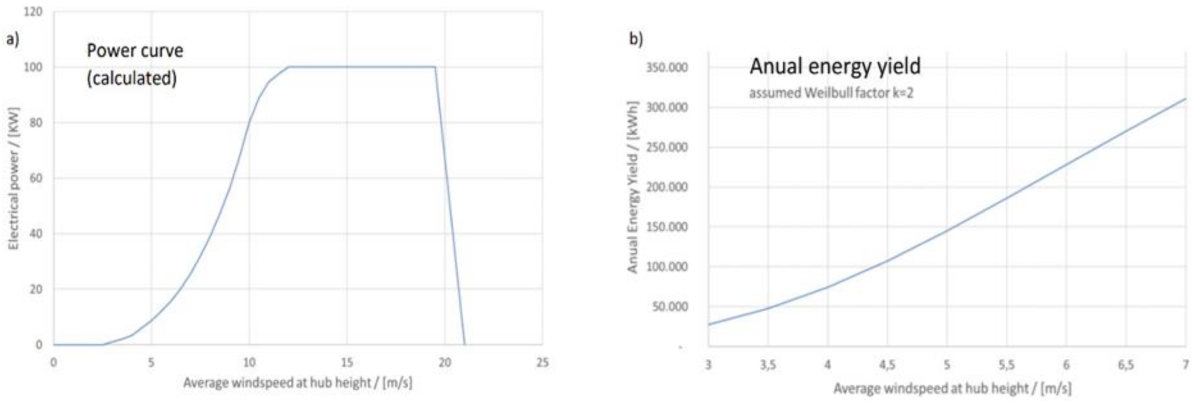

Figure 28: The calculated power output profile of the V-Twin 100 and Annual Energy Yield

Documentation (Links, References)

- **N/A**

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Electrolyzer

Technical description

Within the ROBINSON project, the electrolysis technology is applied via an Alkaline electrolyzer (AE) (or a polymer electrolyte membrane-based (PEM)). PEM electrolyzers are preferred because of their operational flexibility, which includes quick start-up and reaction times as well as relatively cheap investment costs (Bauer et. al, 2021). The technical and operational parameters of the examined PEM electrolyzers as summarized in Table 10. PEM electrolyzers have an efficiency of roughly 60%, corresponding to a specific power consumption of 56 kWh/kg hydrogen generation. Although the investment costs for this more established electrolyzer technology are much cheaper, alkaline electrolyzers offer less operating flexibility than PEM. Furthermore, AEs have a 67% efficiency, equating to a particular power consumption of 50 kWh/kg hydrogen generation (Bauer et. al, 2021). The cost data of the two types of the electrolyzers are presented into Table 11.

Main Characteristic	*H2B2 – ELN200*	*NEL – MC250*
Max nominal H_2 production [Nm^3/h]	207	246
Production range [%]	10 - 100	10 - 100
Operating pressure [barg]	15 – 40	30
H_2 Purity [%]	99.99 -> 99.999	99.95 – 99.9995
Input voltage [VAC]	3 x 400	3 x 6600 – 35000 (lower optional)
Frequency [HZ]	50 ± 5%	50
Power (BOP+Stack) [kW]	1 055.7 kW	1 250 kW
Controls system communication	Modbus TCP/IP or Profinet (RJ45 port)	-
Ambient temperature range [°C]	+5 – +45	-20 - +40
Ambient humidity [%]	0 – 95 (non-condensing)	-
Air ventilation	Available from a non-hazardous area	-
Duty cycle	24/7	
Dynamics	<1 sec start-up time from stand by	<10 sec ramp up time minimum to full load ≥15% ramp rate (% of full scale)
Cold start time [min]	<5	<5
Nitrogen for purge	For each purge, consumption is <0.2 kg at 3 barg	-
Instrumentation air system	Consumption 7 Nm^3/h at 10 barg	-

Table 10: ummary of the technical characteristics of the PEM electrolysers

The CAPEX for the PEM has an average cost of 1182€/kWe, while the CAPEX for the AE ones is 988€/kWe, on average (Herenčić et al., 2021). Their lifetimes are 60,000 and 75,000 hours, respectively. Currently, a possible supplier is being evaluated, and bids for units with a production rate

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of up to 200 kg/day or 500 kg/day are being considered (assuming full load operation of the electrolyzer).

Cost parameter	*Value (PEM)*	*Value (AE)*	*Unit*
CAPEX	385-2068 (Avg: 1182)	571-1268 (Avg: 988)	[euro/kW$_e$]
REPEX	385-2068 (Avg: 1182)	571-1268 (Avg: 988)	[euro/kW$_e$]
OPEX	19		[euro/kW$_e$]
Lifetime	60,000	75,000	[hours]

Table 11: Economic parameters of the electrolyzer

An alkaline electrolyzer from Green Hydrogen Systems (Table 12) is being assessed as an alternative installation in Denmark. Installing two A90 type electrolyzers is necessary to produce the same amount of hydrogen as the two previously stated PEM units. There is little supplier-specific information on system dynamics available. These values are simply approximations based on the Danish Energy Agency data.

Main Characteristic	*A90*
Max nominal H_2 production [Nm^3/h]	90
Production range [%]	16% – 100%
Operating pressure [barg]	35
H_2 Purity [%]	> 99.998
Input voltage [VAC]	3 x 400
Frequency [HZ]	50 ± 10%
Duty cycle	24/7
Dynamics	5 Sec from hot standby to operation (16%-100%)
Cold start time [min]	15

Table 12 Summary of technical specifications of the examined alkaline electrolyzers of Green Hydrogen Systems

Technology Flowchart

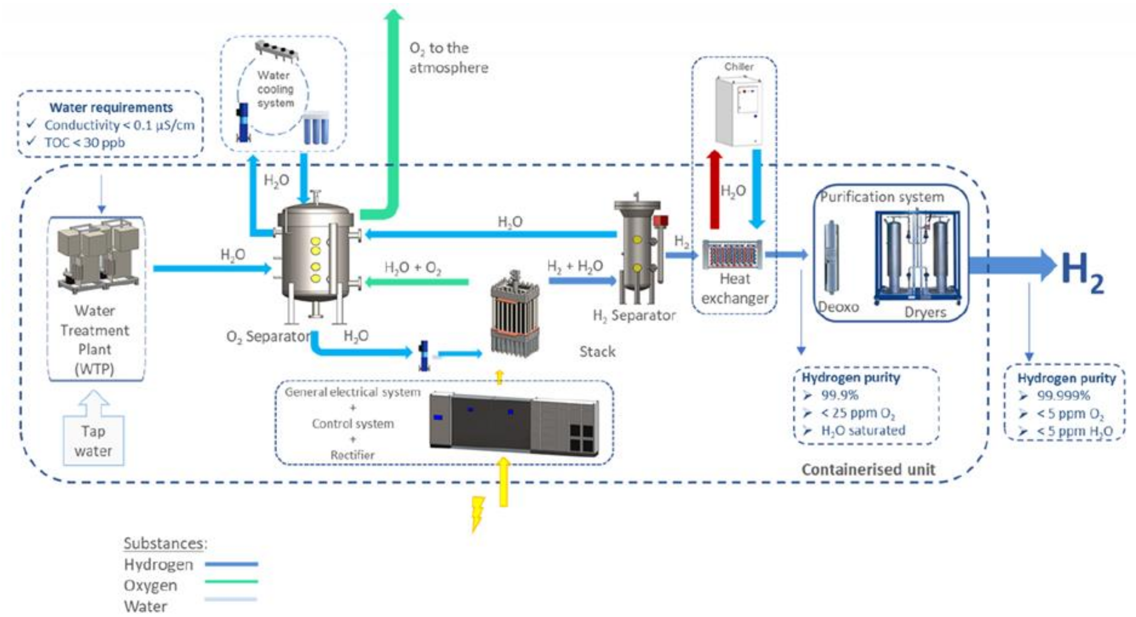

Figure 29: Schematic view of a PEM electrolyser

(H2B2,2021)

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Technology requirements and operating conditions

The operational conditions of the two PEM electrolyzers are presented into Table 13. Ambient temperature is the main parameter taken into account that the application of the MC250 is possible in freezing climates; at the same time, the ELN200 can operate only in favourable conditions.

Main Characteristic	*H2B2 – ELN200*	*NEL – MC250*
Stack consumption [kWh/Nm³ H2]	4.7	4.5
AC power consumption (BOP+Stack) [kWh/Nm³ H_2]	5.1 [kWh/Nm³ H_2]	50.4 [kWh/kg H_2]
Feedwater (might be tap water if water treatment is included) consumption [l/h]	295.7	222
Feedwater conductivity at 25 °C [uS/cm]	< 2000	-
Feedwater pressure [barg]	2 – 6	-
Ambient temperature range [°C]	+5 to 45	-20 to +40
Ambient humidity [%]	0 – 95 (non-condensing)	-
Feedwater temperature [°C]	5 – 40	5 - 40

Table 13 Summary of operational specifications of the examined alkaline of the PEM electrolyzers in evaluation

Main Characteristic	*A90*
Stack consumption [kWh/Nm3 H2]	4.33
Feedwater consumption [l/h]	81 (90 Nm³/h*0,9 L/Nm³)
Feedwater conductivity [uS/cm]	< 5
Controls system communication	Ethernet/Modbus
Ambient temperature range [°C]	+5 – +35
Ambient humidity [%]	0 – 90

Table 14: Summary of the operational specifications of the examined alkaline electrolyzers of Green Hydrogen Systems

Documentation

- https://ens.dk/sites/ens.dk/files/Analyser/technology_data_for_renewable_fuels.pdf
- https://www.h2b2.es/wp-content/uploads/2022/01/211125_H2B2-EL200N-Datasheet.pdf
- https://h2b2.es/wp-content/uploads/2021/03/H2B2-21-005-General-Intro.0.pdf

AD-BES

Technical description

In general, the AD-BES technology enables effective wastewater treatment. An anaerobic digester combined with a bio-electrochemical system (1 m^3 volume) produces biomethane with a purity of up to 95% owing to microbial conversion of the organic matter content of wastewater. The BES unit is supplied with electricity at a voltage near 1 V, to upgrade the AD unit in terms of process kinetics and CH4 content of produced biogas. The technology has several advantages, such as high process efficiency under mild operation conditions, high flexibility regarding power fluctuations and plant size, as well as offering the possibility of storing seasonal energy. Leitat develops the AD-BES unit, while Hysytech builds the AD-BES unit.

Technology Flowchart

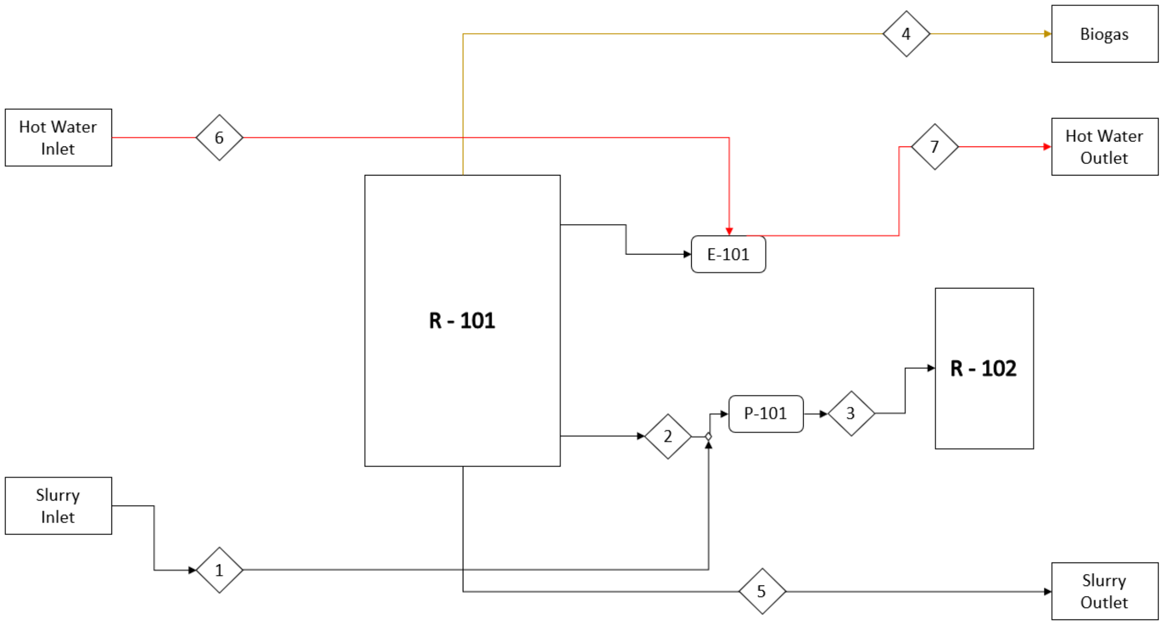

Figure 30

Technology requirements and operating conditions

Some characteristics foreseen for AD-BES units are presented in Table 6.

Parameter	*Value*
Biogas production rate	0.12 – 0.22 Nm^3/day
Delivery temperature	37 °C
Delivery pressure	0.02 bar_g
Composition of biogas (range values)	CH_4 65 mol% (min value) H_2 0 mol% H_2O 6 mol% CO_2 29 mol% H_2S 500 ppm VOC 100 ppm
Electrical power need (AC)	3.5 kW

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Parameter	*Value*
Wastewater demand	100 L/day (min value) ORL: 0.35 – 0.7 kgCOD/m^3/d (min value) 5 °C - 40 °C 2 – 8 bar_g
Compressed air	1 Nm^3/hr 6 – 8 bar_g
Flow rate of drain	Min 3 m^3/hr
Internet connection (min requirement)	1 Mbps for upload 6 Mbps for download

Table 15: Operational parameters of the AD-BES pilot plant

Documentation

- https://etn.global/wp-content/uploads/2021/06/EU-Green-week-partner-event-ROBINSON-D.-Molognoni.pdf

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Gasifier

Technical description

A Syncraft gasifier (Figure 31) is being evaluated for wood gasification, producing syngas that will be blended in the gas fuel mixer and then delivered to the CHP unit. Several procedures are used by the gasification unit to turn wood into syngas. The Syncraft gasifier is particularly versatile in terms of feedstock; any forest leftovers may be fed into the gasifier, eliminating the need of expensive feedstock such as pure wood pellets. This raw material feedstock flexibility and excellent conversion efficiency is made possible by fixed bed gasification technology. On the contrary, the gasification unit's operating flexibility is limited. As a result, slow start-up periods of roughly 20-30 minutes and cold start-up times of more than three hours are common.

Figure 31: Indicative depiction of a Syncraft gasifier

Technology Flowchart

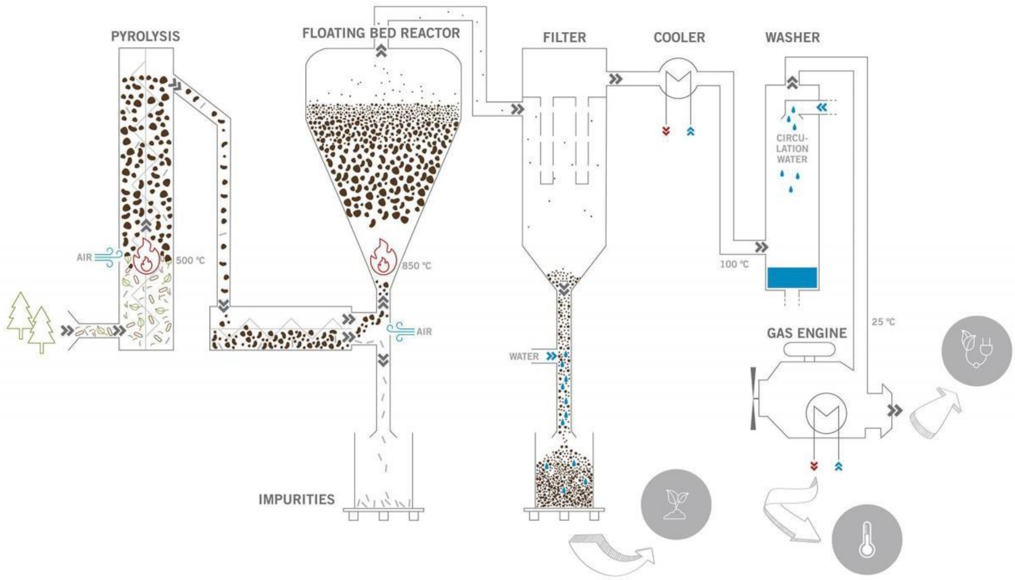

Figure 32: The gasification process of Syncraft gasifier

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Technology requirements and operating conditions

The type and size of gasifier are currently being considered. Table 16 summarizes the process and operating parameters known at the time of reporting. These are scheduled to be changed as soon as:

- Feedstock is described since it determines whether extra gas cleaning is required, which may be the case if treated waste wood is used as a feedstock.
- The provider conducts gasification testing.

The raw materials are initially transformed using a pyrolysis process, which involves heating the wood resources to 1,000 °C, resulting in the raw materials decomposing into gases and charcoal (or biochar). When applied to soils, biochar (possibly) provides for negative GHG emissions, and it might be useful to compensate for difficult to decarbonize (industrial) operations in ROBINSON (Terlouw et al., 2021).

The floating bed reactor next filters out contaminants. Furthermore, it uses gravity in the floating fixed bed reactor to select gas particles containing hydrogen, carbon monoxide, carbon dioxide, and light. Following that, the gas may be utilized to power a gas engine, which will provide heat and electricity. In addition, the gas and charcoal can be utilized as feedstock in subsequent operations. The biomass dryer, air compressor, air blower, and water pumps all require electricity (Molino et al., 2016).

Parameter	*Value*
Nominal energy input (waste wood chips)	1800 kW
Thermal power, water temp. 100°C	200 kW
Fuel demand	360 kg/hour
Max net. delivered fuel energy output (syngas)	1260 kW (788 Nm^3/hour)
Operating temperature	1000°C
Delivery temperature	30°C
Delivery pressure	150 $mbar_g$
Composition of syngas	CH_4: 3 vol%, H_2: 21 vol%, CO: 20 vol%, CO_2: 12 vol%, N_2: 44 vol%
Electrical power need	20 kW
Fresh water demand	2 – 3 m^3/day
Cooling demand (scrubber)	54 kW
Cold start up time	At least 3 hours
Hot start up	23 – 30 minutes
Operational flexibility	Low, permanent operation is standard
Interruption of feedstock flow	the syngas stored in the buffer gas tank is fed to the gas turbine and after ca. 5 min it is stopped (when the pressure is fallen below the set 120 mbar)
Service and maintenance	After 8000 hr: onsite service by SynCraft After 2000 hr: minor service by local work force

Table 16: Operational parameters of the gasification unit

Documentation

- https://en.syncraft.at/
- https://www.syncraft.at/files/pdf/Imagefolder2019-EN_FINAL.pdf

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Gas fuel mixer

Technical description

A gas mixer blends hydrogen, syngas, and biomethane produced by the electrolyzer, gasification, and AD-BES, respectively. As the gas mixes are properly blended, they are ready for use in Aurelia's innovative CHP unit (Section), where the mixtures must meet the CHP unit's gas requirements.

Figure 11 shows the tri-plot results of iso-hydrogen-concentration and iso-Wobbeinindex overwriting the source percent volumetric gas mixer inlet flow. This study enables the creation and delivery of excellent combusting fuels to CHP.

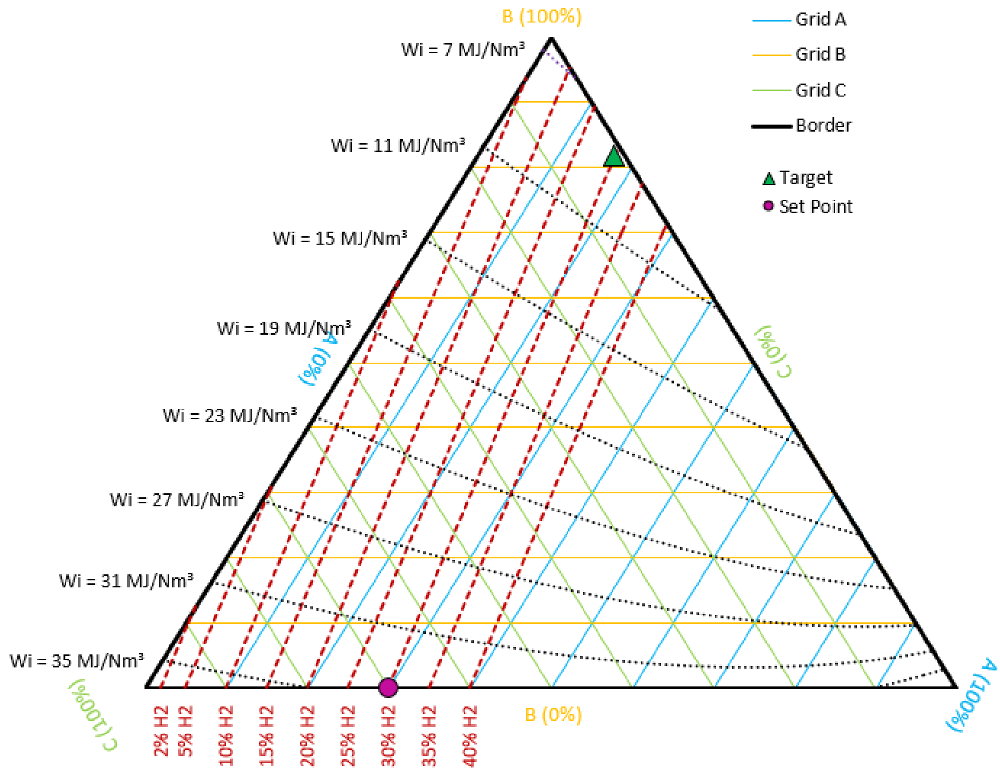

Figure 33: Fuel mixing triplot

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PV systems

Technical description

Polycrystalline silicon cells are selected for the formation of PV arrays, reflecting today's standard PV technology. The two types of PV panels have a maximum power output of 265 W_p and 270 W_p. The panels are manufactured in Germany (IBC Solar). The PV systems chosen had a module efficiency of 16.6%.

More detailed cost information must be received from the PV system provider. Furthermore, life cycle inventory might be developed if significant discrepancies between available life cycle inventory in the eco-invent database and the unique PV system under consideration are predicted. Land usage requirements of roughly 7 m^2/kW_p are derived from life cycle inventory data available in the eco-invent database. However, no new land is required if panels are put on existing building rooftops.

The CAPEX for the PV has an average cost of 1100€/kW_p. The lifetime of the examined PV is 25 to 3-years (Bauer et. al, 2021; Herenčić et al., 2021). Table 20 provides all the economic specifications of the system.

Cost parameter	*Value*	*Unit*
CAPEX	1100	[euro/kWp]
REPEX	1100	[euro/kWp]
OPEX	13-22	[euro/kWp/year]
Lifetime	25-30	[years]

Table 17 Economic parameters of the PV system. These values are based on literature.

Technology requirements and operating conditions

Eigeroy island has only 22 PV panels, generating a total peak power of 5.94 kW (270 W/panel). EMS simulations will show both the current condition and a more sustainable prime mover upgrade scenario, while scaling up the PV panel surface. IBC Solar panels have module efficiency equal to 16.6%.

Figure 7 presents the year linear power trend of the PV panels.

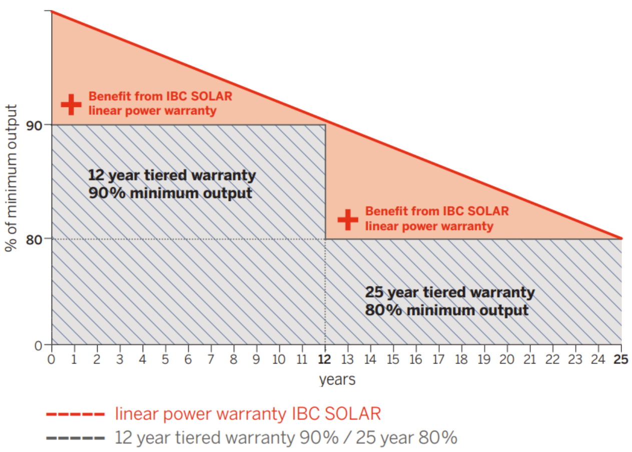

Figure 34 IBC Solar PV time efficiency

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The warranty presupposes installation un accordance with the valid installation instructions. Standard test condition: 1000 W/m^2 irradiation with a spectral distribution of AM 1.5 and cell temperature of 25 °C, 800 W/m^2 in NOCT. Information according to EN 60904-3 (STC). All values accord to the DIN EN 50380. The precise conditions and content can be taken from the respectively valid version of the product and power warranty, which you obtain from IBC Premium Partner

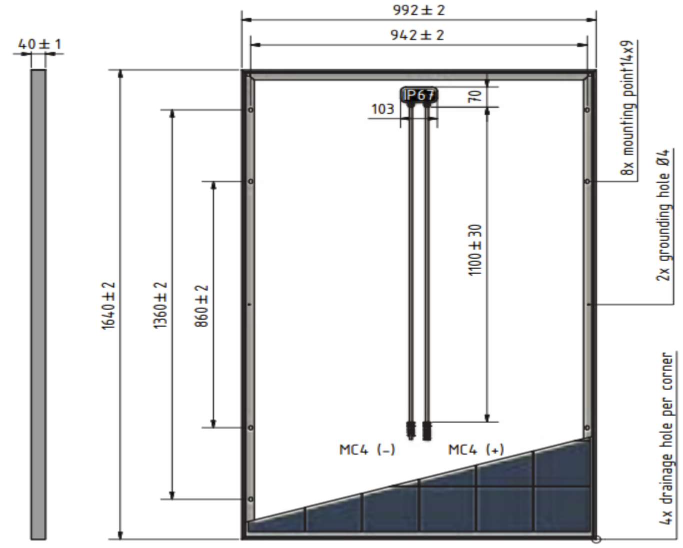

Figure 35 IBC Solar PV, geometry

The proposed PV Systems brochures are presented in Figures 17 and Figures 18.

IBC PolySol	265 CS4	270 CS4
Article number	2203800022	2203800024
Electrical data (STC):		
STC Power Pmax (Wp)	265	270
STC Nominal Voltage Umpp (V)	31.4	31.7
STC Nominal Current Impp (A)	8.44	8.50
STC Open Circuit Voltage Uoc (V)	38.6	38.9
STC Short Circuit Current Isc (A)	9,03	9.08
Module Efficiency (%)	16,3	16.6
Power Tolerance (Wp)	–0/+5	–0/+5
Electrical data (NOCT):		
800 W/m² NOCT AM 1.5 Power Pmax (Wp)	191	195
800 W/m² NOCT AM 1.5 Nominal Voltage Umpp (V)	28,0	28,1
800 W/m² NOCT AM 1.5 Open Circuit Voltage Uoc (V)	34,45	34,50
800 W/m² NOCT AM 1.5 Short Circuit Current Isc (A)	7.47	7.57
Relative Efficiency Reduction at 200 W/m² (%)	2.83	2.83
Temperature coefficient:		
NOCT (°C)	46	46
Tempcoeff Isc (%/°C)	+0.037	+0.037
Tempcoeff Voc (mV/°C)	–129	–130
Tempcoeff Pmpp (%/°C)	–0.420	–0.417

Operating conditions:	
Max. System Voltage (V)	1000
Application Class	A
Reverse Current Ir (A)	20
Current value string fuse (A)	15
Fuse protection from parallel strings	4
Mechanical properties:	
Dimensions (L × W × H in mm)	1640 × 992 × 40
Weight (kg)	19.5
Load capacity (Pa)[2]	5400
Front sheet (mm)	3.2 (low-iron photovoltaic glass and anti-reflective coating)
Frame	anodized aluminium, sturdy hollow-chamber frame
Cells	6 × 10 polycrystalline silicon cells
Connection type	MC4 (IP65)
Warranties and certification:	
Product warranty	10 years[1]
Power warranty	25 years, linear
Certification	IEC 61215, IEC 61730-1/-2 ISO 9001, ISO 14001, OHSAS 18001
Packaging information:	
Number of modules per pallet	26
Number of pallets per 40' container	28
Number of pallets per lorry	30
Dimensions incl. pallet (L × W × H in mm)	1695 × 1130 × 1150
Gross weight incl. pallet (kg)	520
Stackability per pallet	3-fold

Figure 36 IBC Solar PV, technical data

Documentation

- https://www.ibc-solar.com/

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Energy storage systems

Technical description

Storing electricity in electrochemical energy storage systems - such as batteries - is one of the popular forms of electricity storage nowadays, also on European islands. Battery technology is preferred due to its high efficiency, enhanced system stability, and low standby losses. Battery energy storage systems are, however, only preferable for short-term electricity storage due to standby losses, comparably high (and scarce) material requirements and relatively high investment costs compared to other storage mediums. In particular, lithium-ion batteries are considered to be a mainstream battery technology since they are comparably low in investment costs.

At the time of reporting, storage solutions are still being evaluated. However, the following energy carriers, on the other hand, will be storage systems:

- AD-BES raw materials will be used as feedstock for the stored systems. A further discussion and alignment with the CHP's fuel supply system are required to determine the proportions and sizes.
- Hydrogen storage will be used. A larger capacity is anticipated than what is needed by the CHP.

For the gasification unit two storage systems will be considered:

- Storage of wood chips with pre-drying using waste heat. For the time being, three chambers are planned, each with a 24h storage capacity
- The syngas will be stored in two ways. The gasifier will incorporate a buffer store to maintain the necessary backpressure. Additionally, a fuel tank will be installed as part of the CHP's fuel delivery system. Its design is linked to the gas compressor and is thus susceptible to the continuing architecture of the fuel delivery system.

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Energy Management Systems (EMS)

Technical description

As part of the ROBINSON project, different components of energy production, storage, and distribution will be integrated with existing grid connections via an intelligent Energy Management System (EMS). Inputs such as energy demands, plant status (solar and wind power, combined heat and power, etc.) and economic costs drive market functions that minimize OPEX and satisfy energy demand. Using the market function, real-time Model Predictive Control is able to obtain reference targets of prime movers. With Multi Inputs Multi Outputs MPC, imports are controlled from the mainland grid, CHP, and thermal power generators while respecting gradients and boundaries. Besides supplying electricity to Micro-Grid by burning renewable fuel, CHP also pre-heats air at the Thermal Power Generator inlet to reduce fuel consumption; besides receiving waste heat from industry. More details about the EMS are presented in the sub-section 4.6.

Technology requirements and operating conditions

The main components depend on each island's characteristics, but in order to optimise the RES in Eigerøy, the following were selected for the installation and integration:

- The already existing connection to the mainland (i.e. sea cable and associated infrastructure).
- Wind energy (and solar & batteries once available on the island) used for electricity and heating.
- Available biomass converted into additional resources: wood biomass converted by gasification into syngas, wastewater with organic agents converted into bio-methane.
- Innovative storage in the form of heat and electricity, power-to-hydrogen-to-power and heat.
- A dispatchable renewable fuel-based CHP unit contributing with electricity and heating while at the same time generating the process steam for fish food production.
- Recovery of RES surplus and industrial symbiosis

Understanding the technical features of how data from the various renewable energy plants' systems will be transported to the EMS and who will have access to the stored data is essential for developing the cybersecurity modules. We can more successfully anticipate and concentrate on the task if we are aware of these aspects in advance. Therefore, we adhere to the following criteria:

- **Entities, parts, and systems**. A list of systems, entities, or individuals with Blockchain network access and their permissions, such as write or read. We must understand the many systems that contribute data to the EMS, as well as the access controls to the information stored in the Blockchain network.
- **Unique identifiers**. To produce a digital signature, we will require a unique identification for each device and component participating in the EMS's input data. The origin of the data will therefore be confirmed.
- **Data administration**. To properly build cybersecurity procedures, it is vital to understand how data from devices and components of various renewable energy plants will be accessible or reported, as well as how external information such as electrical and thermal needs or weather conditions will be collected.

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4.6 Robinson system modelling/design

The energy system modelling process involves balancing multiple energy sectors and sources and maintaining a holistic viewpoint on the whole energy system. Overall, the energy sectors included in this category are transport, industry and heating, cooling and electricity production. The need to ensure supply security further complicates coordination between producers and consumers of different energy sources. Due to the multiplicity of involved energy sectors, the planning process needs to integrate not only a variety of technologies but also proper energy grids to address the energy system development. In this context, adopting the smart energy system approach enables the integration, combination, and optimization of different energy elements in the context of holistic energy planning. More specifically, planning procedures admit the design of alternatives, taking advantage of the ability to conduct technical analysis for a range of scenarios. As a result of this process, decision-makers gain a better understanding of alternative options and their consequences, so they can make informed decisions. Additionally, as the energy system transitions to renewable energies, which largely fluctuate in nature, it has become increasingly complicated. For managing the transition, long-term strategies and reliable energy systems modelling are required.

In consideration of this, ROBINSON will develop an Energy Management System (EMS) for isolated environments that include a model predictive control (MPC) system and fits for stabilizing the grid and ensuring energy security through well-managed energy fluxes and a balanced increase in demand and production. The ROBINSON EMS will combine the existing connection to the mainland with new installed distributed elements of the energy system to ensure a reliable and well-balanced coverage of generation and demand for electricity, and process steam and heating. Each island (lighthouse & followers) will be modelled and simulated based on the data provided for i) the component constraints and weather conditions, including actual and forecasted data, and ii) the cost data, including actual and forecasted costs the electricity cost during days and nights, the maintenance costs, etc. and iii) the power demand values. The MPC will operate in a way to minimize the system operative costs ensuring service continuity and hence energy security.

This section presents an indicative EMS layout for the ROBINSON system (figure). Energy needs, power plant synthesis (solar and wind power, CHP power, etc.) and costs are inputs in the economic model (Market Function) for limiting OPEX and satisfying energy demand. This model delivers nominal values of each mechanism to real-time Model Predictive Control. The figure shows the EMS layout of the ROBINSON concept in Eigerøy; it includes hydrogen from electrolyzers and biomethane from AD-BES with renewable syngas from the gasifier. A similar scheme could be developed for the polygeneration grid of the Western Isles and Crete, depicting different prime movers but maintaining a similar layout. Additionally, energy system simulations and transition scenarios can be executed with several different models and tools. New tools are frequently developed, making them suitable for a variety of contexts. The development of new tools is occurring in response to the increasing complexity of the renewable energy transition so that to comply with the needs of the local communities in mind.

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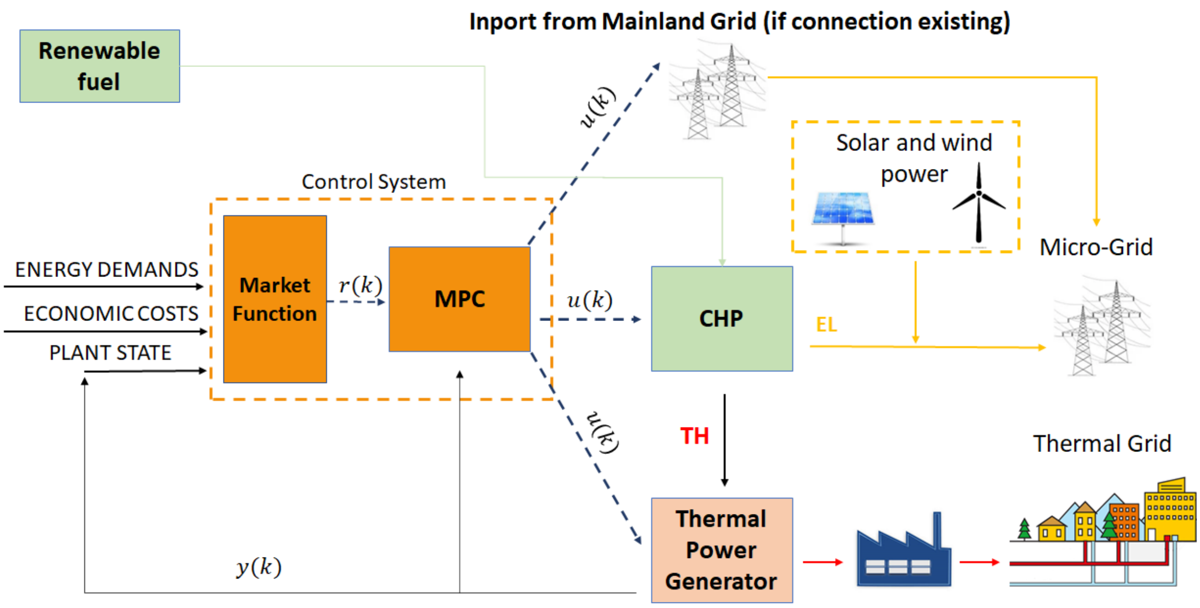

Figure 37: EMS layout in ROBINSON concept

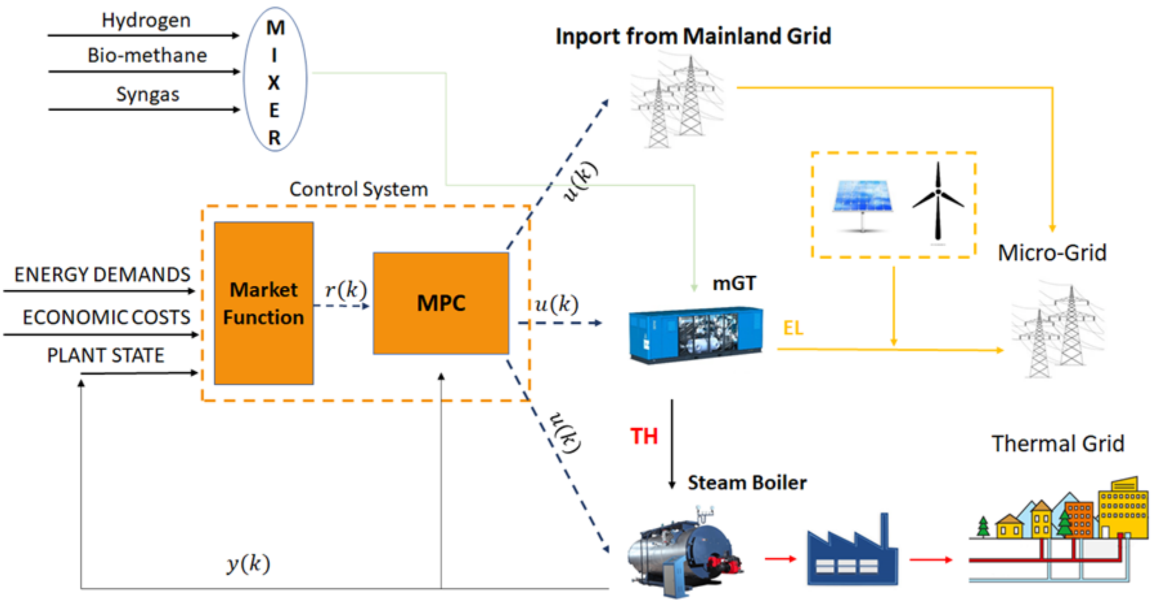

Figure 38: EMS layout in ROBINSON concept, Eigerøy

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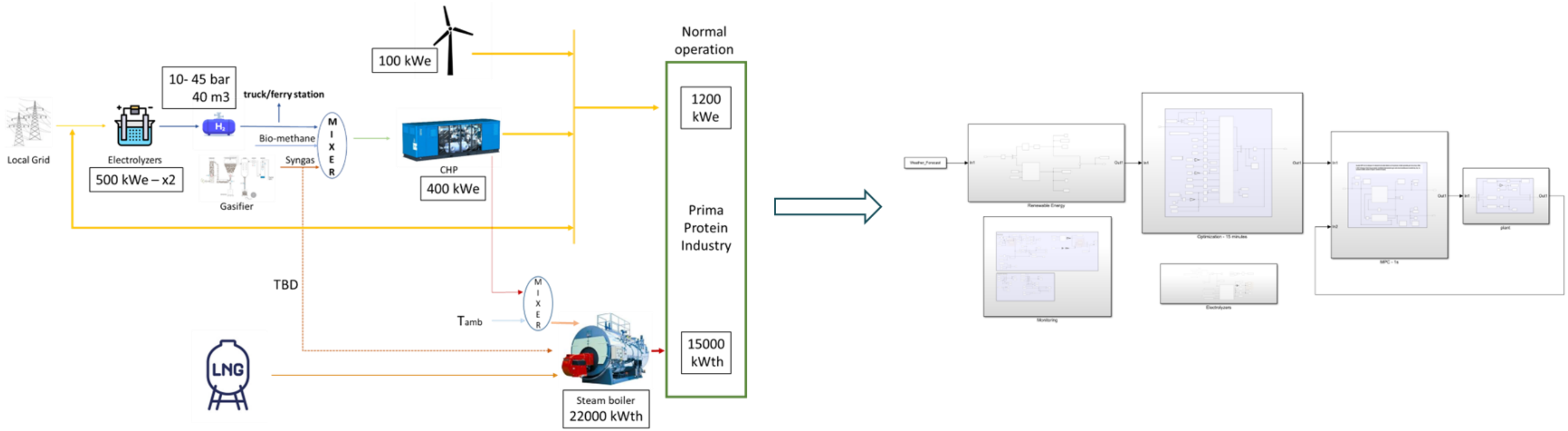

Figure 39: EMS in MATLAB Simulink environment, developed by UNIGE within WP3.

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4.6.1 Modelling and analysis of Sustainability

Apart from the energy aspects related to the ROBINSON system integration, other significant aspects essential for the implementation on the islands should be considered, such as the business models, the geographical and environmental situation, the regulatory aspects, the social acceptance and the local communities' involvement, and the system cost-competitiveness. To this end, techno-socio-economic analysis, and Life Cycle Assessment (LCA) can be considered the proper methodological tools to demonstrate the benefits of such a system installed in the island environments. Accordingly, sustainability assessment will be achieved by following specific steps to take into account economic, environmental, and social concerns:

- **Life Cycle Assessment of all considered EMS concepts**: In LCA, products, goods, and services are evaluated from a wide and comprehensive perspective to assess their environmental performance. A full life cycle can be considered, from extraction to use to end-of-life (ISO, 2006a). In addition, it provides a useful tool for making decisions on important issues arising from an assessment. Based on parameters such as waste produced, contaminants emitted, and energy/materials consumed, the ISO methodology evaluates the environmental burden of the studied process or product (ISO, 2006a); (ISO, 2006b). Obtaining and processing information about the inputs and outputs of the entire product life cycle is necessary to reach these objectives. In ROBINSON project, Life Cycle Assessment (LCA) methodology enables the quantification of different impact categories (for human health and the environment) of various integrated energy and EMS concepts. Thus, benefits and compensations will be compared with the ''AS-IS'' scenario (with fossil fuels and an extended grid connection to the mainland) and assessed regionally and globally through detailed analyses of supply chains and energy system infrastructure. The LCA will be designed in a modular way covering all system components for the different configurations by establishing new inventory data for those to allow for easy adaptation to new layouts. The state-of-the-art LCI database Eco invent will be used as a source of background inventory data. The open-source software Brightway – developed by PSI – will be used as an LCA calculation
- **A techno-economic assessment of different EMS concepts:** The techno-economic analysis is an essential part to prove the feasibility of the integration of renewable energies in standard, grid-connected environments and on both geographical and energy islands. A techno-economic review follows the same basic methodology regardless of the location, though some details of island energy systems require adjustments when simulating energy projects within those systems. As an example, limited access to a larger grid can mean that simulations must focus more heavily on things like network stability and power quality in addition to seasonality in demand (Ma et al., 2018). A techno-economic assessment will be conducted on different EMS concepts within the ROBINSON project, considering different economic scenarios. A set of economic performance indicators will be used to quantify the economic performance of different decarbonization options, including investment costs (CAPEX), operation costs (OPEX), internal rates of return, cash flow, and payback period. Life-cycle costs quantified for all EMS concepts to be used as decision criteria are expected to be the main outcome of the techno economic assessment. In literature, HOMER software has been reported as a proper tool to develop and optimize hybrid energy systems operation in islands taking into consideration specific criteria related to its economic viability

- **Reports on Socio-economics, Social impacts and acceptance:**
  Investigating social implications will be the main goal of this part, which will involve key stakeholders for each island group. A gender-balanced group is important to be established. The goal is to comprehend how advancements affect local communities and to provide people with the chance to engage with business stakeholders and local communities on a European and global scale. The participative method will guarantee that a broad spectrum of local, regional, and national stakeholders have their concerns taken into consideration. Stakeholder opinions on the benefits, viability, effects, and acceptability of the proposed renewable energy system solution will be obtained. Each island site will be assigned a specific set of societal influences, both favourable and unfavourable, e.g. Social change in communities (conflict, social class, gender), cultural and natural heritage change, demographic change (population effects, change, seasonal workers), institutional and infrastructure change, and socio-economic development (employment, labour availability, business opportunity). The development of "energy consciousness" and the primary system implications (lower energy prices, environmental effects, enhanced energy supply, greater independence, and stability) will be included in the analysis of social acceptability. Residents will be surveyed on the social impacts of energy development and integration prior to the start of participatory activities as part of baseline analysis. Quantitative and qualitative data will be integrated using a mixed approaches approach. The results of the baseline study will guide the stakeholder workshops, which will involve participation and will look at the social consequences mentioned above. For each island, a social impact management strategy will be developed to manage the effects of the energy development. This plan will be based on the findings of the social impact assessments.
- **Evaluation of the ecological effects of the ROBINSON system:** An evaluation of the ecological effects of the integrated ROBINSON system will be performed. The elements of the system will each have specific ecological effects related to the activity or technology but also, and particularly when considering developments within restricted areas such as on islands, they may have combined and cumulative effects on the ecosystem. Using a Pressure – State Change Framework such as the Driver-Pressure-State-Impact- Response (DPSIR) Framework we will identify the potential ecological effects of the Renewable Energy Systems within ROBINSON, focussing on Eigerøy but also on the follower islands. To better understand the actual ecological consequences of ROBINSON while working in the environment, as opposed to projected ones, just a few essential factors will be followed and examined further due to the possible range of ecological effects that may be uncovered. Birds will be of special relevance since they have been demonstrated in other contexts to be impacted by aspects of the ROBINSON system, like as waste management and wind turbines, as well as being crucial ecosystem components and indicators of ecosystem health. To understand the implications on the environment, it is necessary to evaluate the ecological effects of essential components of the ROBINSON system on Eigerøy. Where applicable, comparisons between pre- and post-installation will be undertaken. Results and conclusions from Eigerøy will be translated and summarised in broad terms.

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4.7 Definition of application context and adaptation aspects

4.7.1 Green energy transition in insular territories

The energy crisis facing the European territories, and globally, since the first quarter of 2022, has been underlined by the recent data; the European Power Benchmark averaged 201 €/MWh in Q1 2022, recording increase of 281% in comparison to Q1 2021(European Commission, 2022b). On the contrary to this situation, the share of renewables across the EU territories (European Commission, 2022a), reached 39%, mainly thanks to the 20% increase of onshore wind generation, 31% in solar generation and 8% in offshore wind, outrunning the fossil fuels share that reached 37%. (European Commission, 2021)

To this end, the green energy transition for the EU islands is considered extremely topical, since it can support a green, affordable, and secure energy supply for over 2.200 insular locations across the Europe. European islands host over 16 million inhabitants, but many of them welcome every year million of visitors from all over the world since their popular touristic character. Moreover, insular locations have special characteristics which considered crucial when planning for energy supply; geographic factors (climate, location, availability of resources), demographic data (size, population, density) and economic activities that forming its financial performance (European Commission, 2022a). Moreover, the connection to the mainland is considered crucial for the assessment of the transportation needs, and the energy network connectivity specifications (i.e., non-interconnected with the mainland's electricity grid). Due to those characteristics, insular territories faced significant challenges with regards the energy generation; they are typically dependent on fossil fuels for transport, heating, and industrial energy demands, which hinder their overall financial performance since the electricity generation in islands can be up to 10 times more expensive than in the mainland (European Commission, 2022c).

4.7.2 Generic Energy System planning: key points and challenges

Critical part during the investigation of the energy dynamics on a specific territory is the current energy system description. A comprehensive view of the energy production and consumption activity defines the potential room for interventions towards clean energy transition. A complete analysis of the energy system and to set a baseline for reliable evaluation, can facilitate the understanding of the needs, shaping therefore a targeted planning of the general system for efficient operation (European Commission, 2022c). The analysis requires accurate and up-to-date data for the energy breakdown concerning the:

- Electricity generation and production, with the monitoring of essential indicators such as the capacity per technology, the total energy production, the annual fuel consumption per technology, etc. The type of connection for the selected insular territory is critical for the analysis; either the island is connected to the mainland or operates through local production units.
- Transportation (inside the island and for the connection to the mainland), and the modes of transport that are available in the island, also their type of source as fuel (diesel, electricity, etc.), and the type of modes for connection of the island to the mainland (ferries, airplanes).
- Heating and cooling needs, and the type of technologies used for heating and cooling demands; boilers, heat pumps, A/C systems, etc.)

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- Industrial or entrepreneurship needs, and the type of energy used for covering the operation needs
- Other sectors (including tourism, services and other)

The acceleration and penetration of clean energy deployment market requires to address a variety of barriers: *market and social*, *information inadequacy*, *regulatory*, *financial* and *technical* barriers. Market and social barriers include the price distortion, the "hassle factor" meaning the clean energy benefits outweigh from the costs and efforts of administrative and operational tasks, and the split incentives in cases of tenants not being the RES technology owners. Limited capacity and awareness, especially of the general public hinders the customers triggering and investments in clean energy. Regulatory barriers include the complicated building permitting processes, the uncertainty of regulation and policy, and the inability of using the public grid is some countries/territories. Among the financial barriers are the low investment returns, the high upfront costs, the difficulties to access capitals, the potential of high risk, and the taxes and charges imposed by the national operational scheme. One of the most crucial categories is the technical and infrastructure barriers, referring to the constraints of network connection, the risk of curtailment occurred by the lack of flexibility and high congestion level, the low expertise at local level and the intermittency phenomena caused by the RES dependency from weather conditions (i.e. for photovoltaic panels and wind turbines), which can be managed by the energy storage systems (*CLEAN ENERGY BUSINESS MODEL MANUAL*, 2018).
Considering the design and planning of a general energy system in an insular environment, multiple challenges encounter for being addressed, such as limited fuel supplies, security, and adequacy issues, limited available space, environmental impact, and lack of economies of scale (European Commission, 2021). Depending on the type of the energy systems, fossil-fuel or RES-based, the level of challenge concerning those issues is variated.

Type of issue	Level of challenge in Fossil fuel-based systems	Level of challenge RES-based systems
Limited fuel supplies	Critical	Irrelevant - *in cases of pure RES systems*
Security	Minor – *limited variability which can be affected by external factors, flexible generators*	Critical – *need of storage to ensure adequacy at any time*
Adequacy	Minor – *for liquid fossil fuels, OPEX is more essential than CAPEX*	Critical – *variability of RES, power electronics*
Limited space	Important – *for insular ecosystems, available space is critical parameter*	Critical – *in terms of large-scale PV plants*
Lack of economies of scale	Critical – *large power plants are more efficient*	Minor – *maybe only for wind turbines*

Table 18: Level of challenge depending on the type of energy systems

When focusing on RES-based energy systems, the two fundamental aspects to ensure their reliability are the adequacy and security. Adequacy in RES is critical challenge that needs storage systems for

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ensuring, and security concerns variability issues of RES, power electronics, and other, which can be faced by dynamic management of power systems dominated by inverters.

Robinson's approach follows this integrated pathway for investigating the energy transition in the pilot use cases of Eigerøy (Norway), Crete (Greece) and Western Isles (Scotland). Starting from the definition of the background and the local needs and requirements, Robinson's approach defines thereafter the technology characteristics also in terms of cost, land requirements and life cycle inventory (i.e., material and energy flows). Moreover, the missing data or further requirements are identified per system components, involving CHP unit (mixed fuel), Steam boiler, (novel) wind turbine, electrolyzer, anaerobic digestion coupled with bio-electrochemical system (AD-BES), biomass gasifier, gas fuel mixer, photovoltaics (PV) systems and several types of energy storage mediums, such as hydrogen and battery energy storage.

4.7.3 Empowering the green energy transition and decarbonisation in islands

Considering that the insular cities are examined as bounded and isolated territories, usually segregated from the mainland and its financial, technological, energy and industrial features, with scarce resources, alternative flexible approaches have been investigated for achieving the energy saving, air-quality improvement and reuse of resources, ensuring the reliability of the energy network. To this end, the concept of industrial symbiosis has been extended investigated for islands across the Europe and beyond.

The approach of Industrial Symbiosis targets to the valorization of industrial waste, the interconnection of industries, the increased efficiency, serving therefore as an ecological mode towards economic competitiveness, sustainability, resource efficiency and security (European Commission, 2022d). The IS benefits lay therefore, mainly to the sectors of environment and economy, but also in society, by providing a positive environmental impact through recovery, reuse and recycling of waste material and sources, creating of economic value from the waste material and sources, reducing the industrial GHGs emissions and fossil fuels use, and by developing sustained businesses to augment the local growth, economy and prosperity (Martin et al., 2015; Neves et al., 2019).

Additional to this, the concept of Urban Symbiosis (UrS) encloses the circularity of cities' solid waste – outputs in the industrial processes, as inputs (Ažman Momirski et al., 2021) e.g., recycling wastewater or water from industrial processes, targeting to break the linear relations between the consumption of resources and the produced waste in a city (European Commission, 2022e). The I-US synergies can provide clean energy at city level through the contribution of the nearby Energy Industrial Parks (EIPs), improving the role of industries in local societies and communities by exploiting the incorporated renewable energy sources into EIPs facilities for producing and providing clean energy around the city, reducing the residential energy needs. Moreover, the I-US concept facilitate the local growth by creating new jobs and reducing the air-pollution related deaths and the significant financial burdens. To this end, the concept of I-US systems, can be effectively implemented and exploited as an alternative solution that will facilitate the islands' green energy transition, compiling the decarbonization of the industrial sector, energy saving and efficiency, and local growth support.

Crucial role in the energy market plays the Distributed Energy Resources, which includes generation units (fuel cells, micro-turbines, photovoltaic panels, wind turbines, biomass etc.) and energy storage

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units (batteries, etc.). DERs are considered a powerful tool for addressing environmental challenges such as the decoupling of fossil fuels use, the air-quality improvement by GHGs reduction, the higher energy efficiency, the protection of human health, and the conservation of resources and energy for alternative use, together with their capacity for meeting the rapidly growing energy demands(Ažman Momirski et al., 2021).

4.7.4 Adjustments to meet the regulatory requirements

Complying with the regulatory requirements is critical when defining the adaptation context, since energy systems' operation permits present a wide variety across Europe. The European energy policy intends to adopt measures for achieving an integrated energy market, security of energy supply and sustainable energy sector, aiming to face issues such as the high and volatile energy prices, growing global energy demand, the increasing challenges of climate change, decarbonization, challenges posed by the increasing share of renewables (European Parliament, 2022).

The EU general policy framework underlines the needs for emissions reduction, and the short- and long-term targets by 2030 and 2050 respectively, through the recent package of "European Green Deal" for transforming Europe into the first climate-neutral continent until 2050. It provides also a pathway for energy prices, targeting to affordability, and shaping an internal energy market for triggering investments in green energy, secures energy supplies and forwards climate neutrality, via the Fifth Energy Package under the European Green Deal. Additionally, the general EU framework provides the regulatory path for strengthening the external energy relations, for improving security of energy supply, and enhances the role of research, development and demonstration projects through the European Strategic Energy Technology Plan.

The planning, construction and operation of energy systems technologies integrated into DER systems must comply to a variety of aspects concerning the type and size of subsystems, the interfaces to higher-level network structures and the operator'/costumer structure.

Robinson's integrated approach has investigated the DER technical aspects that should be regulatory complied with the local/national legal terms, including the operating permit specifications and the connection of DERs with higher-level networks, together with the connection requirements per type of technology: connection to the electrical grid, connection to the gas network, connection to district heating grid. The investigation of regulatory compliance of the technical specifications for each system is critical, since major differences are identified between the EU countries and beyond, the national implementation documents include extended detailed specifications covering various features, also several countries have not undertaken yet a proper regulatory framework at national or local level.

In parallel to the "general" authorisation procedure, the granting of an authorisation for the possibly also only temporary operation of the subsystems to a grid is required by its grid operator. The rules and proofs required for the connection are determined by the respective network operator, based on national or international standards. Due to transnational character of electricity and gas grids, European Commission has requested its member states to harmonise the connection requirements for non-discriminatory and competitive access. The electricity and gas network have developed generic but concrete guidelines, also defining the regulatory framework. For electricity grids, the network code on requirements for grid connection of generator is obligated to comply with the national connection conditions of each country.

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4.7.5 Funding and Business Models

The motivation towards clean energy transition is boosted by the triggering of investments, aiming to provide a positive impact in society, environment, and economy. The adoption of suitable business models is able to financially support a project, effectively, by generating financial returns.

Multiple factors should be taken into consideration when deciding of the most appropriate business model selection. Local conditions, financial situation, regulatory and institutional framework, and the support mechanisms of each territory are among the most critical. When designing and planning the project, its scale, potential risks, and barriers, expected revenues and social benefits are included in the list for sufficient business model definition and adoption.

Ownership (assets owned by user) and Service Models (customer acquires the energy produced by a company/entity/body that owns the system) are types of business models adopted in cases of RES energy systems, depending on the ownership of assets from Public-Private Partnerships or Cooperative schemes, and the availability of upfront capital of feed-in-tariffs.

Several types of Business Models are available for investigation in the clean energy projects, as presented in Table 19Table 19: Business Models for investigation in the clean energy projects(*CLEAN ENERGY BUSINESS MODEL MANUAL*, 2018).

Clean Energy Business Models	
Type of BM	**Description**
Self-consumption	Self-generation of clean energy, city/industry/municipality as the owner of the energy plant
Power Purchase Agreement (PPA) ○ **On-site private wire PPA** ○ **Direct off-site PPA** ○ **Sleeved PPA** ○ **Synthetic (Virtual) PPA** ○ **Aggregated PPA** ○ **Wholesale PPA** ○ **Mini-utility PPA**	Customer can negotiate a direct power purchase agreement with renewable energy generators. The customer does not owe the power plant, but he purchases the clean energy. Many different types of PPA models are available.
Public-Private Partnership (PPP)	PPP involves a contract between a public-sector authority and a private party for a clean energy project. The private partner provides the financial support, undertakes the installation activities, the technical operation and maintenance actions and costs and upon completion of the project.
Energy Services Company (ESCO)	ESCOs deliver a variety of energy services such as heating and cooling, energy efficiency upgrade or other, to a customer's premises or facility. ESCOs manage the level of financial risk through providing performance standards e.g. pre-determined energy savings.
Leasing model	The investor/owner of the clean energy installation leases the system to the occupant or owner of the site, who operates the system and either self-consumes the energy or exports it back to the grid via an export price or net metering mechanism.

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Clean Energy Business Models	
Type of BM	**Description**
Community energy	In the community model, the main target is the community ownership, leadership and benefits, meaning that the ownership and ventures are shared by the community, crowd-funded projects and community ownership models such as co-operatives, social enterprises.
Virtual power plant (VPP)	A virtual power plant (VPP) is a software platform that remotely controls a network of medium and small-scale generator units such as solar, micro combined heat and power plant (CHP), wind, biogas, small hydro, storage systems connected to flexible consumers that have the capacity to increase or decrease their demand. A city can apply this type of BM with households and businesses to become part as flexible customers.
Municipal aggregation	In this model, a municipality, city, or a group of municipalities can form an entity to procure electricity in bulk to meet the aggregated energy demand of interested residents and businesses.
Reverse Auction	In this type of BM, the roles of seller and buyer are reversed so the sellers bid in the auction procedure. Some reverse auction cases include a city that announced a call for tender for clean energy projects with specified technology and capacity as necessary requirement for the seller to join the auction process. Another case is the city/municipality to request for buying a clean energy product or service or technology, and the seller to bid for providing it.

Table 19: Business Models for investigation in the clean energy projects

Ensuring the funds to support a clean energy process is a critical step to deal with since the launch of the project's vision and concept. The funding opportunities for a clean energy project includes 4 key-types of financing (SP Energy Networks, 2022):

- The Grand Funding, referring to amounts that awarded with no obligation to be repaid, often being used to facilitate the planning and development phases of a project.
- The Dept Finance, referring usually to loans, the most common type of dept financing, generally used to fund the development and construction phases of a project.
- Equity Finance, the process of raising capital through the sale of shares, mainly by bilateral agreements with the investors for sharing the profits and involve them in the decision-making processes since the project's initiation.
- Financial Incentives & Subsidies, which are usually available to renewable energy projects in operation phase and are capable to provide a guaranteed revenue stream over a set period.

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4.8 Test and implementation

The main components of implementation procedures are described in this stage since they might vary from one nation to another and even within regions in terms of the processes, licences, and supporting documentation that must be submitted and authorised prior to the actual investment. The viability factors of the planned RES project in insular areas should also be considered, including the definition of materials, components, and manufacturers; an early estimation of investment costs; procurement processes; etc. As a result, the readiness and validity of the planning process in earlier phases have a direct bearing on the implementation phase's success.

Primary objective of ROBINSON is to deploy the newly developed energy tool/system on a demonstration site and optimise it for use in numerous other scenarios that are comparable to this one; the system will be tested in Eigerøy, Norway. Two islands will serve as follower islands, and by communicating with more than 5,000 contacts, at least ten (10) more islands will be made aware of the results. To evaluate the findings and guarantee the dependability, the demo system will be integrated into Stornoway, Scotland, and Crete, Greece, with a minimum of 1,000 hours of operation. Specific interventions must be implemented in the Eigerøy initially, followed by the Western Islands and Crete, in order to achieve the aims associated with the ROBINSON project. Table 1 provides all the basic information about the islands.

- **Eigerøy island** is a small island in Norway that is interconnected to the mainland by an undersea cable. The required energy is generated mainly from hydropower (89,2 %), with 8,6 % onshore wind power with and 2,2 % thermal power. One of the unique features of Eigeroy is that new industries will be created on the island in the next years, particularly near the Kaupanes harbor region.
- **Western Isles** are located in Scotland, being interconnected to the mainland by an active current (AC) cable from a modular integrated transportable substation (MITS) substation at Fort Augustus. The ROBINSON project will be implemented on a site at Creed Waste Management Facility on the outskirts of **Stornoway**. The Outer Hebrides have a lot of renewable energy resources, including wind, wave, and tidal energy which have been scarcly exploited till the time being.
- **Crete** is an island in Greece that is interconnected with the continental Greece by an undersea cable. Apart from the electricity grid, no additional energy networks, such as natural gas networks or decentralized CHP plants, are currently installed in Crete. Crete is heavily based on imported fossil fuels to cover its energy consumption. Particularly regarding electricity, Crete is depended on 78 % on heavy fuel and diesel oil, consumed in three centralised thermal power plants, located at the western, central, and eastern part of the island. In Crete, the integrated ROBINSON solution will be implemented in the Kissamos area of Chania, focusing on the rusk bakery industry "the Manna", with 931 MWh annual electricity consumption and 398 tn/y annual diesel oil consumption.

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Name	Eigerøy	Western Isles	Crete
Country	Norway	Scotland	Greece
Location	South west coast of Norway 58°26’37,608”N 5°57’11,581”Ø	A chain of islands off the west coast of Scotland	Approximately 160 km south of the Greek mainland
Size	20 km^2	3,059 km^2	8,336 km^2
Population	About 2.500 within about 800 households	More than 26.000 within about 12.500 households	About 635.000 in about 214.150 households
Climate	Influenced by the coast with relatively high temperatures in winter and low temperatures in summer, wind speeds are high	The climate is mild and oceanic. High wind speed.	The climate is mainly Mediterranean

Table 20: Basic information of the involved islands

4.8.1 Eigerøy

Eigerøy is selected as the demo site for the ROBINSON project due to its high RES potential and the urgent need of implementing green energy generation technologies, SEMS and circular economy incentive into the current energy system. The majority of the system's parts will be installed at the Prima Protein production plant which currently consumes the most fossil fuels in Eigerøy. The installation of the gasification unit, the CHP unit (mixed fuel), the electrolyser, and the AD-BES are all possible as shown in Figure 40. Additionally, wood will be stored in the harbour, around 100 metres from the wood gasification facility, reducing transportation distances and guaranteeing short-distance gas connections. The electrolyser and potential hydrogen storage can be constructed next to the gasification unit. The CHP unit may be installed in the steam boiler hall since it is small enough to fit in a typical ship container.

Electric connections to the grid are provided by the community's power grid operator, Dalane Energi. A special wind turbine will also be put in place close to the harbour. The unique wind turbine's proposed location is shown in Figure 41. On appropriate rooftops of commercial and residential structures, with an estimated area of 28,000 m^2, PV systems may potentially be installed.

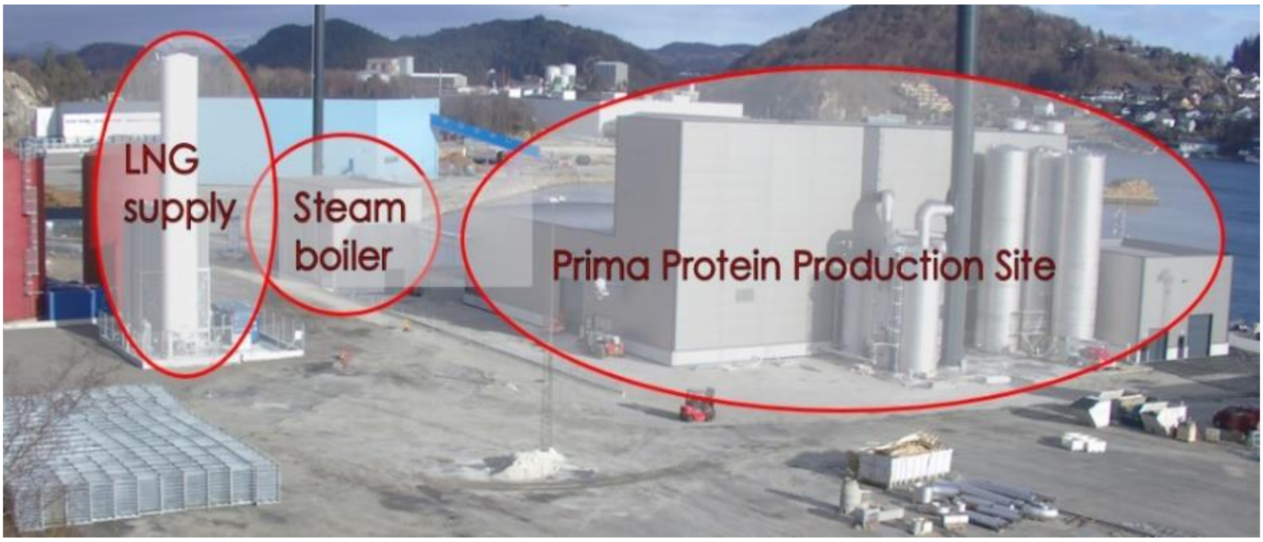

Figure 40: Production site of Prima Protein nowadays, demonstrating available space for novel system components. Figure is reproduced from the ROBINSON proposal

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Figure 41 Proposed location of the novel wind turbine on Eigerøy, indicated with the red colored circle.

The AD-BES reactor at Eigeroy will use the Prima Protein organic matter content in liquid waste to make Biogas. Prima Protein employs steam (180°C) in the manufacturing process, and the ROBINSON system incorporates thermal waste recovery for the manufacture of heating fluids, resulting in productivity benefits.

Table 7 shows the costs for the different feedstock and energy carriers, for Eigerøy.

Cost parameter	Value	Unit
Waste Wood	0 – 10	€/t
White Wood	20	€/t
Lower heating value	3.50	kWh/kg
LNG Cost (2020)	43.19	€/MWh
CO_2 tax (2020)	14.35	€/MWh
Electricity Nordpool (av. 2020)	33	€/MWh

Table 21 Feedstock and energy carrier prices in Eigerøy

4.8.2 Follower islands

Proving the replicability of the ROBINSON EMS and of the concepts demonstrated on Eigerøy is one of the cornerstones of the project. The Follower Islands will not only "follow" the project activities but will have an active role in selecting the best scenario corresponding to their needs, so that the consortium can validate the EMS with their own data on lab-level. They will be able to select different modules, including those technologies and concepts developed in the project if applicable, and integrate them in the EMS – therefore proving its replication. The results of these activities will be described in the Replication plans. The following figures (Figure 42, Figure 43) provide a preliminary illustration of the concepts that could be developed.

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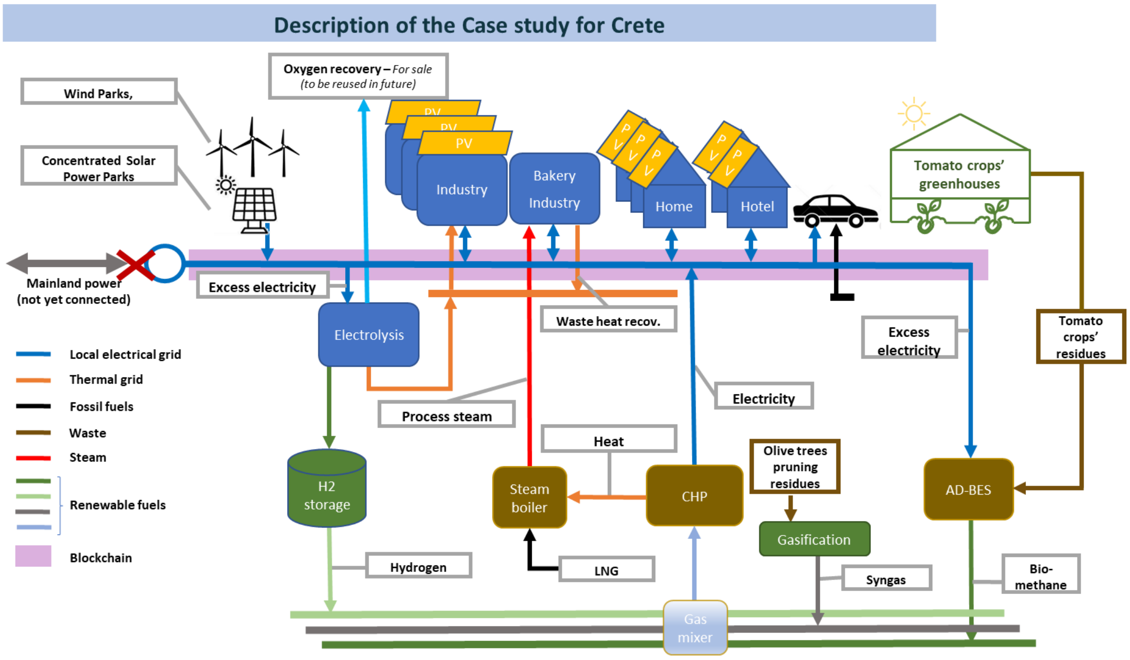

Figure 42: Theoretical replication of ROBINSON system on Crete.

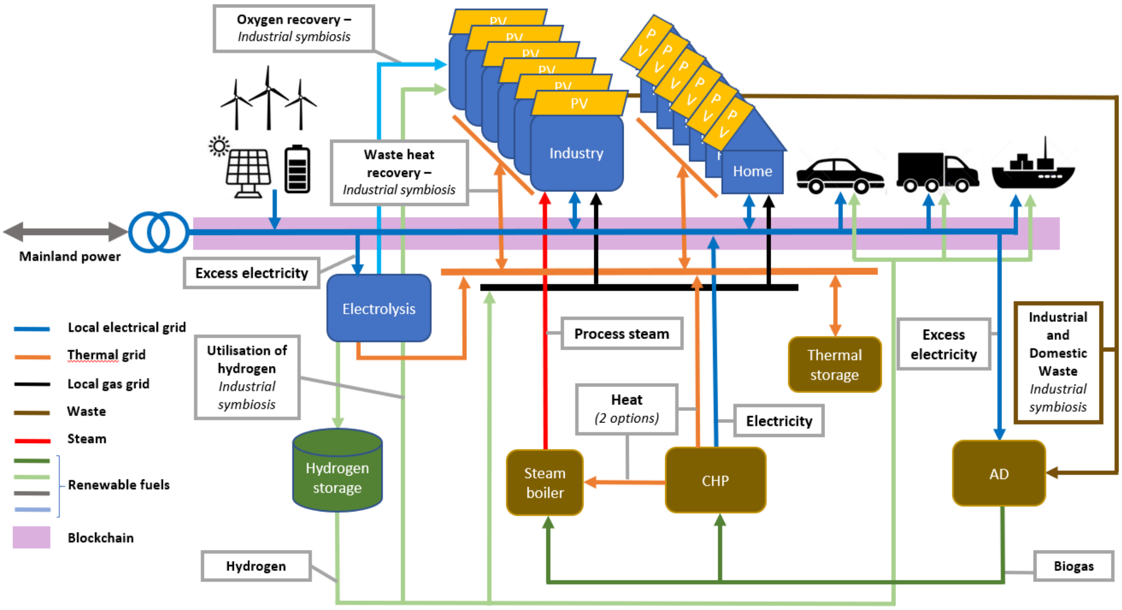

Figure 43 Theoretical replication of ROBINSON system on Western Isles

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5. Replication tool services for roadmaps preparation

The replication tool, namely Robinson Evidence Base (EB) tool provides to end-users two distinct services, which can be used independently or as complementary to each other:

- The "**Information Service**" which helps users familiarize themselves with solutions and technologies, by providing information and data on energy sources, relevant technologies, demo sites and applications, and benefits of choosing combined systems.
- The "**Support Tools Service**" which provides computational tools supporting different decision stages concerning the replication tool.
- The "**Roadmap Service**" which represents the highest level of decision support integration, as it draws and combines information and knowledge from all the other services. It provides exploitable replication plans to the end-user, based on a 6-stage analysis and capitalizing the knowledge core of the developed Web Evidence base. It exploits the experience gained from a large number of successful application cases, in order to apply it to new cases, by providing Roadmaps, i.e. validated workflow procedures, for achieving specific Goals in any cNES related decision stage, utilizing available knowledge, tools, data and expert advice.

In the following sections, the purpose, objectives and functionalities of these services are described in detail.

5.1 The Information Service

The Information Service provides information and knowledge on RES. It enables users to:

- Obtain information on the potential sources, uses and users of treated water/wastewater.
- Familiarize themselves with treatment technology attributes, function and applicability.
- Find information regarding the cNES applications
- Be informed on the benefits of choosing combined systems.

The Information Service contains three different sections which provide information concerning RES:

1. RES Solutions and Technologies section.
2. Applications Sites section.
3. Legal Framework and Policies section.

The **RES Solutions and Technologies** section provides to users the opportunity to familiarize themselves with technologies utilized in the field. In the **Applications Sites** section, all the Robinson Demo Sites are presented providing to users information regarding the background of each scheme (i.e. location and purpose, local conditions that justify implementation, ambition for improvement), and the description of the sites (i.e. technical layout and involved technologies, operation of the scheme and costs considerations). The **Legal Framework and Policies** section provides all the regulatory information necessary for the implementation and operation of the aforementioned technologies and solutions.

5.2 The Support Tools Service

The **Support Tools** Service of the Robinson EB integrates already existing tools in order to provide technical/analytical support to end-users, at all decision stages that relate to energy systems.

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The Service fulfils the following **end-user requirements**, as presented in the upper part of Figure 44:

a) Assist users in selecting the appropriate tools for performing particular tasks.
b) Provides the appropriate tools (in case of open source tools) or direct users to use tools for performing particular tasks.
c) Provide detailed information about the features of the tools and instructions on their use.

5.3 The Roadmap Service

The Roadmap Service of the Roadmap EB is at the highest level among the Services provided, as it draws and combines information and knowledge from all others. It exploits the experience gained from a large number of successful RES application cases, in order to apply it to new cases.

The **Roadmap Service** provides analytical procedures that can help the user to achieve a stated **Goal**. The Goal is specific for each of the different **Decision Stages** in the design, implementation and operation of a RES.

The generic question answered by the Roadmap Service can be expressed as:

<How to achieve a specific goal under stated conditions?>

The Roadmap Service provides three functionalities: (1) Assists the user in framing the question/goal, (2) Provides the relevant roadmap, and (3) Assists the user in applying the steps of the roadmap (Figure 44).

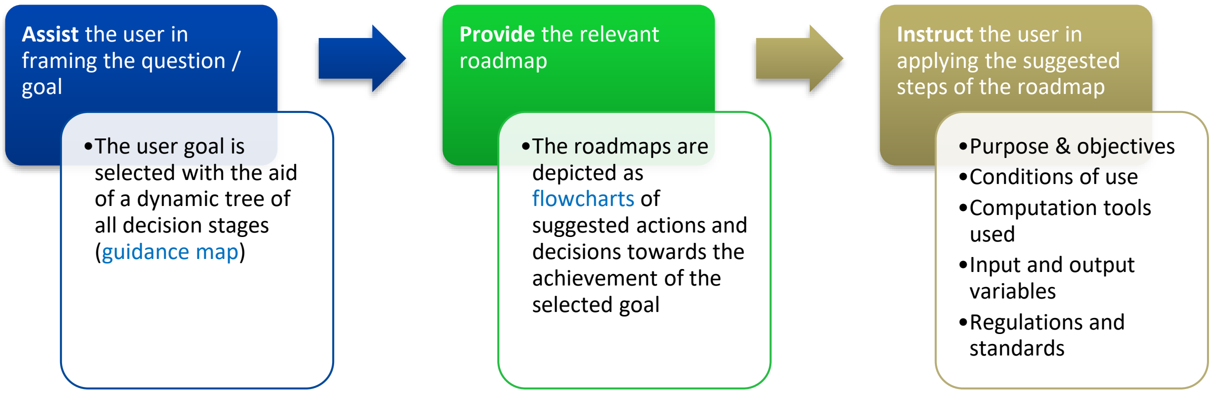

Figure 44: Core functionalities provided by the Roadmap Service.

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6. Replication methodology for roadmaps preparation

Dominant objective of Robinson's project was the demonstration of the integrated system's replicability on the two follower islands, Crete and Western Isles, based on the system's deployment in the island of Eigerøy in Norway, ensuring in parallel a wider dissemination across the EU islands. The methodological approach to reach the objective of a common methodology for demonstration included six (6) steps, developed complementarily.

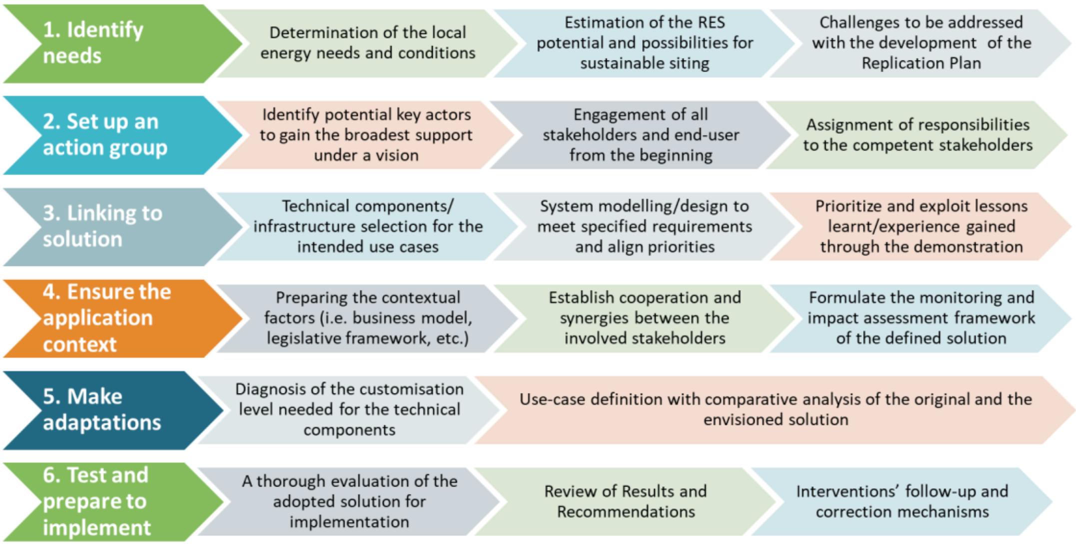

Figure 45: Roadmap development processl for the preparation of replication plans

6.1 Identify needs

- ***What this step implies?***

This step implies the identification of needs that will define the following actions to be taken concerning a replication of the ROBINSON concept.

Firstly, the '***Determination of the local energy needs and conditions'*** is based on recorded interannual and/or seasonal data of previous years referring to the local environmental conditions and the needs of the possible stakeholders. The needs may be discerned in electricity and/or thermal ones, thus defining the solutions to be examined for combined or stand-alone units. Moreover, any strategic planning including certain activities or roadmaps that shall be adopted from the stakeholders -e.g., for their energy policy or environmental impact- may be taken into account.

Following is the '***Estimation of RES potential and possibilities for sustainable siting***'. RES shall be examined not only concerning their potential in the surrounding area but also after the investigation of possible transportation procedures and storing costs with possible accompanying premises and/or hardware. In terms of sustainable siting, the vicinity of available areas for the implementation of PVs, wind turbines or any other RES, is crucial since not only the RES will be more effective, but also the O&M (Operation and Maintenance) and Security/Surveillance costs will be more affordable for the installed hardware.

In this step are also included the '***Challenges to be addressed with the development of the Replication Plan***'. Such a project like the replication of the ROBINSON concept may rise differences concerning

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locality, since there is not yet common legislation between EU countries. Governing laws and requirements of the host area must be fulfilled, and these prerequisites may differ from country to country, either for the installation of RES per-se, or for the integration and connection of RES with the local grid.

- ***Which should be the results of the step?***

The results of this step facilitate the formation of the specific context where the ROBINSON concept is going to be replicated. This context shall clarify the needs that the possible stakeholders aim to address, while examining the RES potential of the local environment. Integration of RES shall be in good agreement with sustainable practices, the latter in the context of the local legislation and how such projects of installing RES are implemented and operate in the respective area.

Example: *Needs identification in the island of Crete*

General description

Crete is the biggest Greek island, interconnected with the continental energy network by an undersea cable. Apart from the electricity grid, no additional energy networks, such as natural gas networks or decentralized CHP plants, are currently installed in Crete. Crete is heavily based on imported fossil fuels to cover its energy consumption. Particularly regarding electricity, Crete is depended on 78 % on heavy fuel and diesel oil, consumed in three centralised thermal power plants, located at the western, central, and eastern part of the island.

Name	Country	Location	Size	Population	Climate
Crete	Greece	160 km south of Greek mainland	8,336 km^2	635.000 in about 214.150 households	Mediterranean

Current energy situation at a glance

The use of renewable energy sources in Crete is primarily limited to power generation from wind farms and photovoltaics, as well as hot water generation from solar collectors. Biomass and geothermal potential can potentially provide limited thermal energy demands, while there are significantly underexploited, for the time being

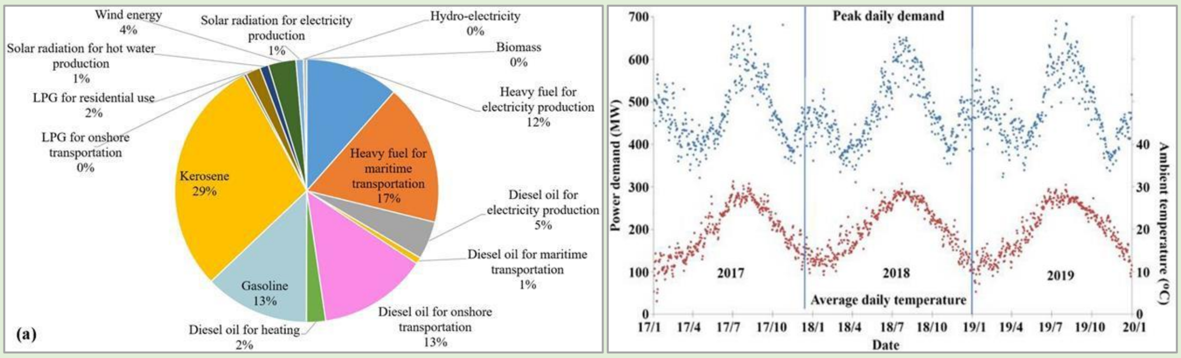

Figure 46: Share of energy sources in energy consumption on Crete (left), Daily peak power demand for 2017 – 2019 (right) Electricity demand in Crete exhibits intensive seasonal fluctuations due to the considerable increase of the population in the island and the corresponding activities during the tourist period (from April to October).

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RES Penetration & Potential

RES penetration in Crete is currently limited owing to local electrical network reliability difficulties. The majority of Crete's power is generated by fossil fuels transferred from the mainland. Heavy fuel oil (58%) and diesel (20.4%) were the most commonly utilized fuels in 2017. Only 21.6% of total energy output is from RES, with wind (turbines) accounting for 17%, solar (mostly PVs) accounting for 4.6%, and minor hydro accounting for 0.01%. Crete presents great potential for RES integration for solar energy systems, biomass, and wind energy.

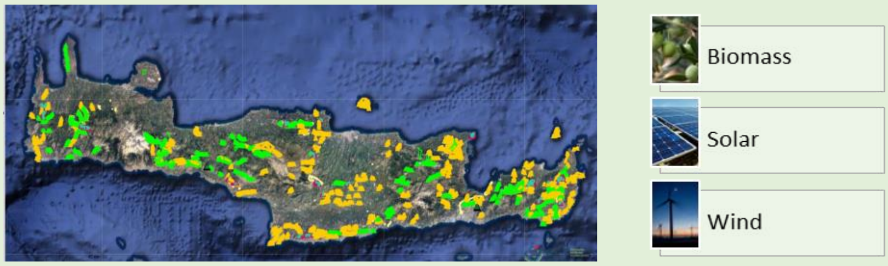

Figure 47: Interactive map of Crete's RES potential delivered by Regulatory Authority for Energy (RAE) of Greece

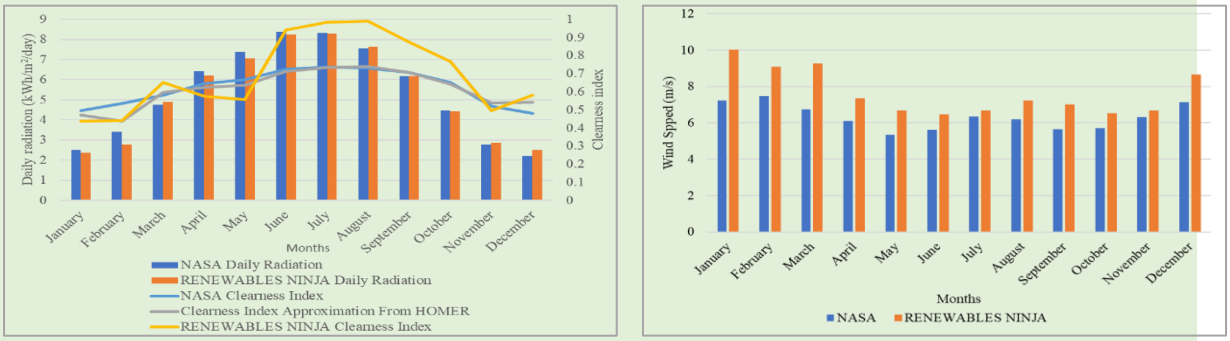

Figure 48: Average monthly radiation and clearness index in Crete (left), Monthly average wind speed in Crete (right)

Challenges to be adressed

- Cretan terrain hinders the construction of large-scale RES
- A potential significant increase in RES penetration may cause major network instabilities in the island of Crete
- Deployment of extended RES facilities is challenging due to the huge mountain ranges with considerable number of peaks
- Social acceptance of RES at local level, protests from citizens concering the installation of RES in Cretan mountains
- Crete includes numerous Natura protected zones amd locations with unique charateristics, especially in mountainous terrains

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Needs identification in the investigated Cretan Industry

The “Manna” Tsatsaronakis bakery company was case study for the Crete’s system in which the replicability of the suggested tool/energy system was evaluated. The “Manna” has a significant electricity and heat demand on Crete. Moreover, the touristic character of the wider territory, Kissamos, provides the potential for further benefits from the Robinson solution, especially for the small size hotels around the “Manna” facility. Electricity and heat are used in the majority of manufacturing activities. There is a considerable correlation between energy use and the time of year. The increase in output during the summer months causes this seasonality.

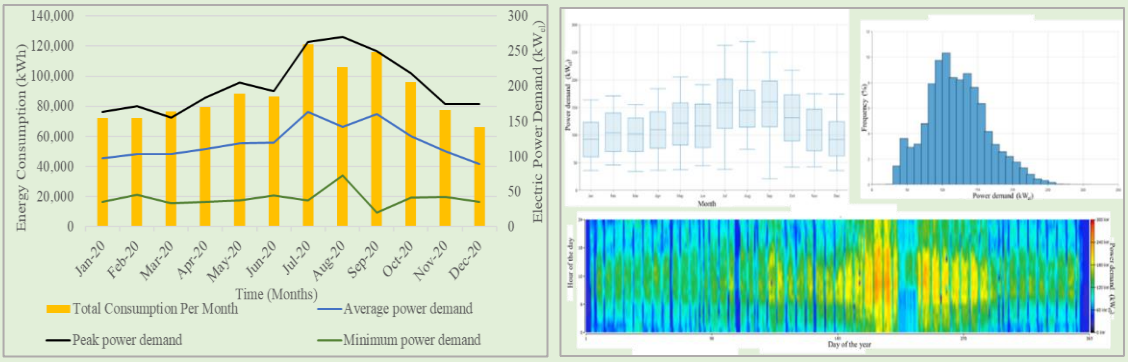

Figure 49: Total electricity consumption and electric power demand profiles for the “Manna” bakery (left), Annual active electric power demand information (right)

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6.2 Set up an action group

- ***What this step implies?***

This step implies the setup of an action group that is going to be related with the replication of the ROBINSON concept through the various stages of its implementation. The engagement of possible stakeholders from the early stages of the replication may be of added value since any various aspects that may rise will be taken into account earlier.

Consequently, is of major importance to '***Identify potential key actors to gain the broadest support***' for the beneficiary of the ROBINSON concept. These key actors apart may include the local society, regional and municipal authorities, technical and economical chambers and possible stakeholders. The local society may play a crucial role in the acceptance of any RES installations in the local environment. Furthermore, local society -or part of it- may also be stakeholders, since depending on possible traits (e.g., farmers, fishermen, hotel owners) may provide biomass from leftovers. Local regional and municipal authorities - legislative or managerial oriented, could assist and determine licensing procedures for the installation and operation of RES, also provide integrating solutions in the framework of a strategical plan or roadmap locally, if existed. The enrolment of a local technical and economical chamber may provide valuable information referring to construction procedures, RES legislation, grid connection and economy practices adaptation, respectively, since the replication of the ROBINSON concept could empower in economic terms comprising of tax policy, local economy indexes, local market characteristics, etc. Furthermore, Academic or Research/Technology Institution that is hosted or is related to the replication area could be a beneficial stakeholder, since it may provide state-of-the-art support for technical, societal, environmental, and economical aspects. Finally, the provision of financial support from selected stakeholders is possibly, especially the authorities, or in-directly through the connection of stakeholders with funding opportunities; local, national, or European grants as being beneficiary-partners.

The '***Engagement of all stakeholders and end-users from the beginning***' in order to secure the commitment and the interests of every involved party in a ROBINSON replication project is a crucial next step. Thus, it is needed to clarify both the needs that were referred to the previous step, and the advantages that the ROBINSON solution may offer.

Following the previous actions of this step, the '***Assignment of responsibilities to the component stakeholders***, is based on their expertise. Thus, the project will be organised in a time and cost-efficient manner, role, milestones, and feedback will be referred to the respective stakeholder, and the overarching monitoring of the ROBINSON replication will be easier and more accurate.

- ***Which should be the results of the step?***

Aim of this step is the identification of the key actors and potential stakeholders for the replication of the ROBINSON concept. Thus, resulting in the acceptance of the ROBINSON concept and the assignment of responsibilities to the stakeholders from zeroth day. This is important in the scope of the various legislative, financial and operational issues that need to be addressed in an effective and easy-to-adapt way from each respective assignee.

Setting up an action group in Western Isles

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Stakeholders mapping was conducted for the Western Isles since the design phase, identifying all the key-stakeholders for developing green energy generation technologies at local level. The identification of stakeholders has focused specifically on the Creed Site where the EMS system will seek to be replicated, as presented in the figure below.

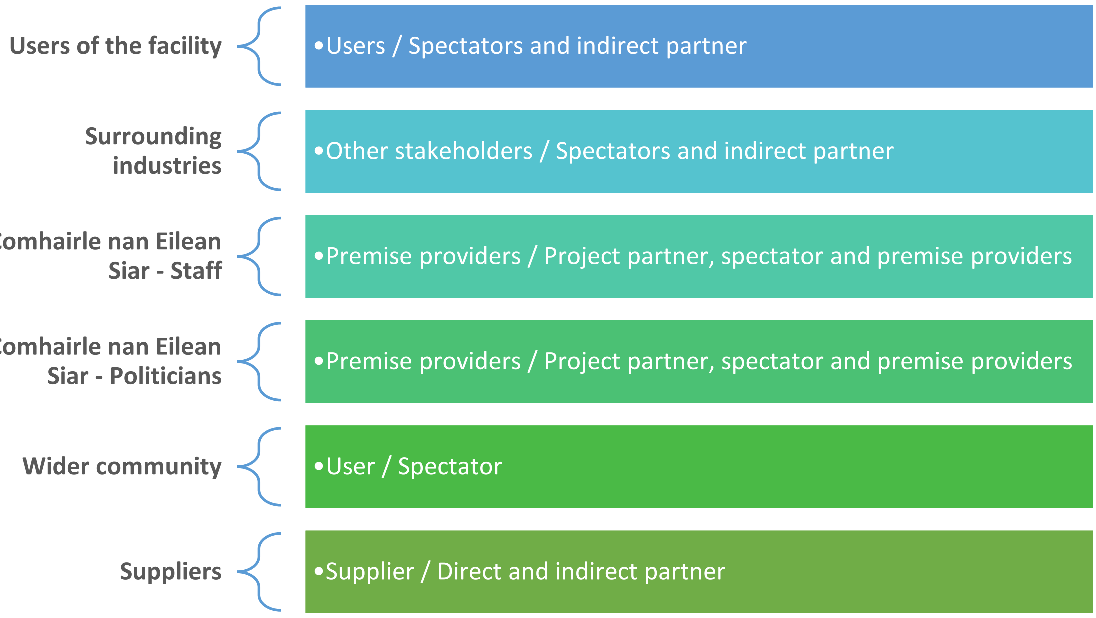

Figure 50: Main stakeholders for Western Isles

Moving on the next step, the analysis for their level of interest, willingness to cooperate and to outline the general attitude of the mapped stakeholders. Different levels of interest were identified according to the role of involvement; neutral, positive, medium, and high. The lack of knowledge and information at this level has resulted in neutral expectations. It is expected that Comhairle personnel and politicians would be supportive of any new Creed ideas and will be prepared to work with the EMS application, being the actors with the highest interest.

	Expectations and attitudes to the project	Interest and willingness / ability to cooperate	Influence and power / willingness to influence
Users of the facility	Neutral	Medium	Medium
Surrounding industries	Neutral positive	Medium	Medium
Comhairle nan Eilean Siar - Staff	Positive	High	High
Comhairle nan Eilean Siar - Politicians	Positive	High	High
Wider community	Neutral	Medium	Medium
Suppliers	Positive	High	High

Figure 51: Interest analysis of Western Isles stakeholders

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6.3 Linking to solution

- ***What this step implies?***

This step implies the very existence of the ROBINSON concept since it refers to the '***Technical components/infrastructure selection for the intended use cases***' that will be integrated after the thorough investigation of the local RES potential of Step 1. This integration refers and precisely describes the specific machinery, installations and facilities that are going to be exploited towards the intended implementation of ROBINSON, considering the specifications of the selected components depend on economic cost, expected returns, expected lifespan, maintenance difficulties, efficient exploitation of the available RES, energy demands, thermal demands, exceptions or obligations due to legislation, etc.

Only after the cautious selection of components and infrastructure will the '***System modelling/design to meet specified requirements and align priorities***' be realistic and efficient. Since ROBINSON may be implemented in an already operating infrastructure, thus already energy and economic resources consuming, it is of high importance the results of modelling to be as accurate as possible. This to convince any prospective adopters of the ROBINSON concept for its efficiency, both in terms of the obvious environmental profits (by harnessing RES potential) and in the accompanying economic terms, since in the long run such an adaptation may be profitable if properly implemented. This is also the fore-step towards the upcoming **Business Model** since the detailed energy, environmental and economics assessments are going to be therein included. Moreover, based on these assessments, future supervising and control procedures are going to be determined and realized via the Business Model.

Advantages of the system modelling are the parameterization depending on various scenarios and the investigation of separate components' efficiency, aiming to achieve the best possible results and solutions. To '***Prioritise and exploit lessons learnt/experience gained through the demonstration***' is crucial for the future steps of replicating the ROBINSON concept. Priorities are dictated by various factors including the legislation differences between locations/countries, also technical differences apply from case to case; diverse energy and/or thermal needs, RES potential, environmental conditions, available budget, constitution of potential stakeholders, etc. Experience is gained both from simulations and feedback of former respective projects, giving the opportunity of dynamic and easy-to-adapt guidelines and decision-making support tools.

- ***Which should be the results of the step?***

This step investigates the technical aspects of replicating the ROBINSON. Possibly the technical aspects are the easiest to predict in such an initiative, rather than the socio-economic ones (as recently proved by the COVID-19 pandemic) or others. Thus, the thorough and as realistic as possible modelling and design for the ROBINSON implementation, is the hands-on linking to the proposed solution by demonstrating results and providing support for various decisions to any key actors.

Defining the technical solutions in Western Isles and Crete

The case study of Western Isles is focused on a Waste Management Facility: the Creed Enterprise Park (Creed IWM Facility) on the Isles of Lewis and Harris in Scotland. The Creed Integrated Waste

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Management Facility (IWMF) is a cutting-edge facility that illustrates how various renewable energy technologies may be used to support local energy economies and circular supply chains. The facility currently has an anaerobic digester (AD), a combined heat and power plant (CHP), an electric boiler and thermal store, a wind turbine, and a hydrogen system consisting of an electrolyser, storage, and refuelling station.

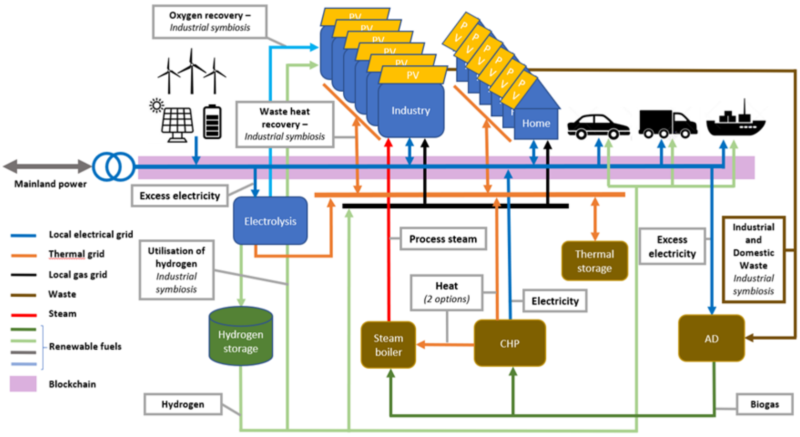

Figure 52: The ROBINSON concept applied on Western Isles

The Creed hydrogen system includes a refuelling station, and part of the hydrogen will be utilized to replenish a dual-fuel waste collecting vehicle (RCV) that runs on diesel/hydrogen. The RCV will be utilized to collect local garbage, with a portion of it ending up in the biogas production system. Under Robinson, in the Creed Enterprise Park is investigated the integration of an onshore wind, storage, and hydrogen generation system, within a repeatable and scalable framework, aiming to be adaptable on various geographical islands.

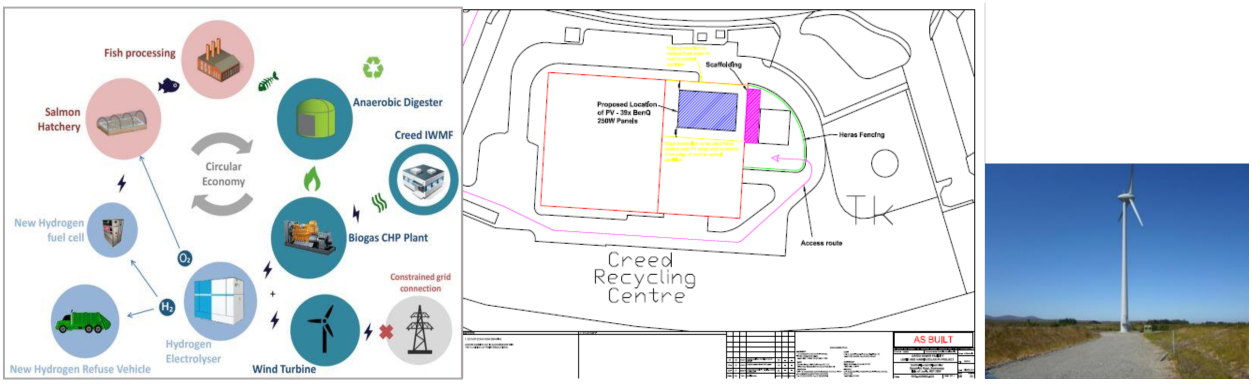

Figure 53: Industrial symbiosis at Creed Park (left), the PV design at Creed (middle), the wind turbine at Creed (right)

Due to the low interconnection of the Crete's Island to the mainland Greece, further increase of the percentage of the overall green energy that will be produced in the Region of Crete using RES may cause significant instabilities in the network. As already mentioned, more than 21% of the overall energy production comes from RES, but according to the European rules, by 2030 the rate must be increased to at least 57%. By replicating the developed EMS, smart control systems and the other proposed incentives such as storage and waste valorization, Crete expects that ROBINSON will contribute to addressing this challenge. The initial brainstorming on how the ROBINSON system can be replicated in Crete is shown in Figure 54.

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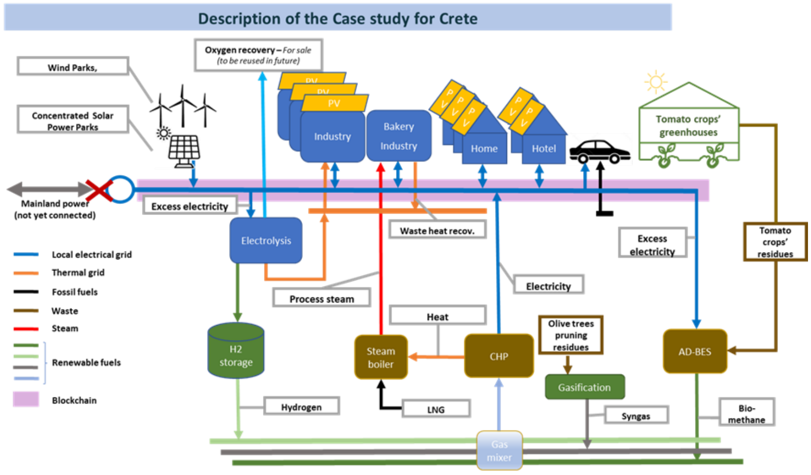

Figure 54: Components of the Robinson replication scheme on Crete

Technological components for evaluation in the Cretan industry are the combined heat and power unit, the steam boiler, the wind turbine, the electrolyser, the AD-BES system, the gasifier, the gas fuel mixer, the PV systems, and the energy storage systems.

6.4 Ensure the application context

- ***What this step implies?***

This step refers to ensuring the application context for the replication of the ROBINSON concept. Firstly, is the '***Preparation of the contextual factors***' that are going to assist the project, like the Business Model, the legislative framework, and the financial tools -if any-. The Business model shall include all the finance and resources allocations, the organizational plan that describes the relations between the key actors, various thorough analyses (SWOT and PEST(EL)), risk assessment scenaria in different conditions and the co-operative structure. The co-operative structure depends on the national legislation and it may shape numerous outcomes of the ROBINSON concept replication. Legislation may also promote or exclude financial support tools that may be crucial for the implementation of ROBINSON project. Nevertheless, financial tools shall be sought through different sources, like enlisting ROBINSON replication in the framework of national or European programmes, municipal or regional financing, or even with obtaining funds from loans, venture/angel capitals or with the participation of local stakeholders.

'***Establishing cooperation and synergies between the involved stakeholders'*** is also included in this step. As mentioned before, possible key actors may be included as stakeholders that have portion/shares in a 'start-up' scheme that is going to replicate and manage the ROBINSON concept. In this case, the key actors shall be tied by the context of the Business Plan, and since their role is going to be fully defined, their role and responsibilities in the scope of synergies shall have been already fulfilled. Otherwise, if any key actor is not included in a co-operative scheme, a Memorandum of Synergy may be signed or other similar actions could be taken, in order to secure the commitment and the respective roles of each stakeholder.

Moreover, since any ROBINSON replication initiative is going to be part of and in good accordance with the principles and practices of a certain concept, to '***Formulate the monitoring and impact assessment framework of the defined solution***' is of high importance. Constant monitoring of the

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outcomes of a specific ROBINSON project must provide sufficient feedback to the Evidence Base Tool, so that any future replications may be fit-to-purpose in order to be efficiently implemented.

- ***Which should be the results of the step?***

This step refers to the necessary managerial tasks aiming to '***Ensure the application context***' of ROBINSON replication. Preparing a Business Plan, according to legislation and funding opportunities, with the simultaneous commitment of the involved stakeholders is the recipe not only for the successful replication, but also for the provision of the necessary monitoring tools to control and re-evaluate each defined solution. Thus, obtaining accurate and goals-related feedback, for the better future replication projects that shall be fit-to-purpose designed to achieve maximum efficiency.

Application context of the follower islands

The forming of application context, involves a wide range of parameters, including the Business models, the regulatory framework, the monitoring, and impact assessment framework, shaping a tailored-made formula for each investigated location. Since document D6.1 is a living document with continuous feed of information from the use cases and the relevant deliverable, an indicative example for this section will be completed at a later stage of the project's lifetime, according to the scheduled workplan.

6.5 Make adaptations

- ***What this step implies?***

The ability to make adaptations reflects the innate accurate understanding while implementing a project. This can be achieved with concise description of the problem to be solved and careful parameterization in order to account each detail or component that may affect the outcome both qualitatively and quantitatively. '***The diagnosis of the customisation level needed for the technical components'*** is crucial because it provides a holistic 'guideline' of how a component is integrated and interacts in a greater context of such a project like ROBINSON. Every replication case shall provide information for various demands depending either on each specific technical component per RES item/facility, or for the whole project. Replicating ROBINSON is a mixture of technical, energy, socio-economic and environmental aspects, so the investigation and implementation of the technical components should take in account technical/energy-efficient decisions and cost-efficient solutions at the same time. Selecting these components may be slightly or highly differentiated among different cases but nonetheless, this differentiation shall be countable, decision-driven and efficiently designed in order to adopt adaptations.

Adaptations that may need to be done cover a broad context that will possibly require radical changes to the original characteristics of the actors that intent to adopt the ROBINSON project. '***Use-case definition with comparative analysis of the original and the envisioned solution***' will provide the tools to convince the actors for the feasibility of any possible actions and changes to be made. Adapting to RES and shifting to different facilities from the existing ones will be easier if examining different scenaria and comparing advantages and disadvantages. Possible changes may include shifts that are directed by regulations and legislation, there is a possible change in the co-operative scheme

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which will adopt the ROBINSON concept and, finally, reallocating resources to invest in RES facilities must be sufficiently documented in order to convince and commit all the possible stakeholders.

- ***Which should be the results of the step?***

In this step the importance to '***Make adaptations***' is highlighted. Implementing a project like ROBINSON, which aims to address various aspects, requires sufficient description of the required customisation level so that comparison case-studies may be performed. Consequently, a dynamic planning and managerial tool is realised, based on the very nature of ROBINSON project -adapting towards attaining desired state-of-the-art solutions of RES implementation. If properly developed and applied, adaptations to be made may also provide feedback for determining the future bottom-line for 'reinventing' the ROBINSON replication concept itself.

Making adaptations in the islands of Crete and Western Isles

The customisation of the technical components for the two follower islands have been identified and described as presented in Table 22 below. Since the present document is foreseen to be continuously updated, data for the socio-economic and environmental aspects and the provision of different scenarios and their comparison, will be included at a later stage.

	Western Isles	Crete
Combined heat and power unit	CHP-biogas. Generator capacities: 240 kWe & 370 kWth. Max biogas volume 125 m3/h, methane up to 60%.	CHP-biogas. Generator capacities: 3,5 MWe & 4,5 MWth.
Steam boiler	Electric steam boiler 180 kW power, thermal efficiency 100%	Same to Eigeroy – 22 MWth, 98% efficiency
Wind Turbine	300 kW Enercon	5 MW wind power plant
Electrolyzer	31-kW alkaline electrolyzer for hydrogen and oxygen manufacturing from the excess power of wind turbine	Alkaline electrolyzer (AE) or polymer electrolyte membrane based (PEM)
Anaerobic digestion (AD)	Dry thermophilic flow digester, capacity: 960 m^3, fluid volume: 700 m^3	Anaerobic digestion (AD) supported by bioelectrochemical unit (AD-BES) – tomato leftovers as waste feedstock (biomass-based) to utilize CHP plant
PV systems	38 multi-crystalline PV modules, peak power output of 240-260 W. Total installed capacity: 9,75 kWp, power generation 7.668 kWh	Under investigation
Energy storage systems	Two hydrogen storage media: a low-pressure and a high-pressure. Also, thermal energy storage: 875kWh	Under investigation
Gasifier & Gas fuel mixer	Not applied	Type of gasifier is under investigation Cost and life cycle analysis for defined the size and requirements of gas fuel mixet

Table 22: Technical characteristics customization for the islands of Crete and Western Isles

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6.6 Test and prepare to implement

- ***What this step implies?***

Following the latter, this step implies ***'a thorough evaluation of the adopted solution for implementation***', for addressing possible issues may concern all involved stakeholders. The adopted solution must be evaluated in terms of legislation, sustainability, energy needs, economic impact and in the framework of a strategic plan or roadmap -if any-, so that replication of ROBINSON concept is going to be aligned with directives and practices in the long-run.

A '***Review of Results and Recommendations***' is critical to be carried out by each stakeholder, key-actor, policy maker and local authority (managerial and/or legislative) separately, to ensure its interests. Concerning the commitment of each key-actor to the project, a round-table review and recommendations shall be realised to ensure mutual interests of each stakeholder towards the efficient replication of ROBINSON concept.

However, the complexity and differentiation of replicating the ROBINSON project, requests the **'*intervention's follow up and correction mechanisms***' must be constantly available to all key-actors, since each detail during the replicating steps may cause inconveniences and unforeseen impacts. The adoption of possibly amendments might be feasible and efficient, thus providing the tools for correcting potential upcoming issues.

- ***Which should be the results of the step?***

This step refers to '**test and prepare to implement**' the ROBINSON project for a certain case-study. Since this is the final step of the replication tool, every potential issue must be resolved via thorough evaluation, detailed review of the results and ensuring the effectiveness of the correction mechanisms. The commitment of the stakeholders to act both independently and jointly with the other key-actors must be clarified end ensured as a result of the previous steps. By doing so, assessing and following-up of any upcoming interventions will be feasible towards achieving higher efficiency and more benefits for every involved party.

Testing and implementation in follower islands

The actions described in the last step of the replication methodological approach for Crete and Western Isles will be presented in a later stage, according to the time plan for evaluation of solutions, follow up and adjustment interventions and review on the overall methodological steps and replication actions. At this phase actions are still on going.

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7. First Prototype

The first prototype version of the Robinson EB was developed in June 2022, achieving Milestone 15: “Milestone Title Here”. The layout and the implementation of the services and functionalities, as described in the previous Chapter, are presented in the following sessions.

7.1 Prototype Layout

The landing page of the Robinson EB (available at https://www.indigo.tuc.gr:8443/RobinsonEB/) comprises five discrete parts, as presented in Figure 55.

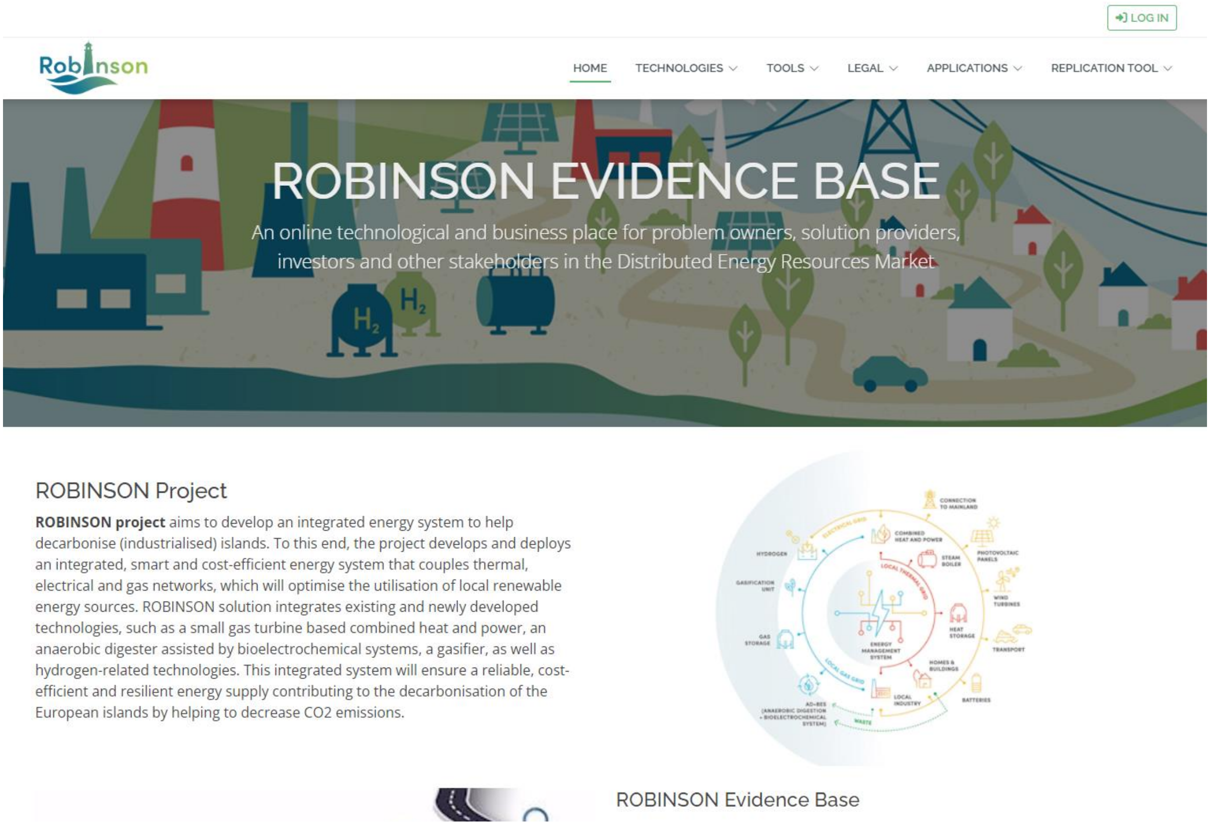

Figure 55: Screenshot of the Robinson EB landing page

The Information service is implemented through the **Technologies**, the **Legal** framework and policies, and the **Applications**. The support tools are included in the **Tools** section while the roadmaps are provided by the **Replication Tool**. The implementation of the three provided services (Knowledge, Support Tools, and Roadmaps Service) is presented in detail in the following sections.

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Conclusions

This report summarizes the Evidence Base for the scale-up and uptake concept of Robinson project, which aims to implement a real demonstration case on the Norwegian island of Eigerøy, also exploiting the follower islands of Crete (Greece) and Western Isles (Scotland) for developing a structured replication methodology and tool, capable for being adopted and replicated by a wide range of insular territories. Deliverable 6.1 provides the methodological approach to define the replicability framework, presents the design and components of the Web Evidence Platform, and analyses its components and structure by incorporating input from WP4 and results of thorough literature review and desk research. Moreover, the deliverable describes the preparation steps for the replication tool services and the replication methodology, together with a first depiction of the Prototype Layout of the digital platform. Subsequent versions of the document will integrate the input and information derived from the forthcoming tasks according to the scheduled workplan, since the D6.1 is a living document.

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References

Al-Hinai, H. A., & Al-Alawi, S. M. (1995). Typical solar radiation data for Oman. *Applied Energy*, *52*(2–3), 153–163. https://doi.org/10.1016/0306-2619(95)00035-Q

Amoatey, P., Al-Hinai, A., Al-Mamun, A., & Said Baawain, M. (2022). A review of recent renewable energy status and potentials in Oman. *Sustainable Energy Technologies and Assessments*, *51*. https://doi.org/10.1016/j.seta.2021.101919

Aragón, G., Pandian, V., Krauß, V., Werner-Kytölä, O., Thybo, G., & Pautasso, E. (2022). Feasibility and economical analysis of energy storage systems as enabler of higher renewable energy sources penetration in an existing grid. *Energy*, *251*, 123889. https://doi.org/10.1016/j.energy.2022.123889

Aryal, S., & Dhakal, S. (2022). *Medium-term assessment of cross border trading potential of Nepal's renewable energy using TIMES energy system optimization platform*. https://doi.org/10.1016/j.enpol.2022.113098

Aurelia. (2019, January 15). Technical Data sheet (Aurelia A400).

Aurelia. (2022, July 15).

Asakereh, A., Soleymani, M., & Safieddin Ardebili, S. M. (2022). Multi-criteria evaluation of renewable energy technologies for electricity generation: A case study in Khuzestan province, Iran. *Sustainable Energy Technologies and Assessments*, *52*. https://doi.org/10.1016/j.seta.2022.102220

Ažman Momirski, L., Mušič, B., & Cotič, B. (2021). Urban Strategies Enabling Industrial and Urban Symbiosis: The Case of Slovenia. *Sustainability*, *13*(9), 4616. https://doi.org/10.3390/su13094616

Bauer et. al. (2021). Electricity storage and hydrogen: Technologies, costs and environmental burdens. . *Villigen PSI*.

Behera, B., Mari Selvam, S., & Balasubramanian, P. (2022). Hydrothermal processing of microalgal biomass: Circular bio-economy perspectives for addressing food-water-energy nexus. *Bioresource Technology*, *359*, 127443. https://doi.org/10.1016/j.biortech.2022.127443

Caralis, G., Christakopoulos, T., Karellas, S., & Gao, Z. (2019). Analysis of energy storage systems to exploit wind energy curtailment in Crete. *Renewable and Sustainable Energy Reviews*, *103*, 122–139. https://doi.org/10.1016/j.rser.2018.12.017

CLEAN ENERGY BUSINESS MODEL MANUAL. (2018).

European Commission, Directorate-General for Energy, Kielichowska, I., Sach, T., Koulouri, A., et al., ASSET study on islands and energy islands in the EU energy system, Publications Office, 2021, https://data.europa.eu/doi/10.2833/702065

European Commission. (2022a). *Directorate General for Energy, Clean Energy for EU islands – From vision to action: how to tackle transition on EU islands*.

European Commission. (2022b). *Directorate-General for Energy, Quarterly report om n EU electricity markets, Market Observatory for Energy*.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957752. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

European Commission. (2021). In focus: EU islands and the clean energy transition. https://ec.europa.eu/info/news/focus-eu-islands-and-clean-energy-transition-2021-jul-15_en

European Commission. (2022c). *Europe's islands are leading the charge in the clean energy transition.* https://ec.europa.eu/research-and-innovation/en/horizon-magazine/europes-islands-are-leading-charge-clean-energy-transition

European Commission. (2022d). *Industrial Symbiosis*. https://ec.europa.eu/environment/europeangreencapital

European Commission. (2022e). *URBAN SYMBIOSIS: RECOMMENDATIONS FOR CITIES TO RE-USE RESOURCES. https://ec.europa.eu/environment/ecoap/news/urban-symbiosis-recommendations-cities-re-use-resources_en*

European Parliament. (2022). *Fact Sheets on the European Union: Energy policy (general principles). https://www.europarl.europa.eu/factsheets/en/sheet/68/energy-policy-general-principles*

Fuentes-Grünewald, C., Ignacio Gayo-Peláez, J., Ndovela, V., Wood, E., Vijay Kapoore, R., & Anne Llewellyn, C. (2021). Towards a circular economy: A novel microalgal two-step growth approach to treat excess nutrients from digestate and to produce biomass for animal feed. *Bioresource Technology*, *320*. https://doi.org/10.1016/j.biortech.2020.124349

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Gong, X., Yang, M., & Du, P. (2021). Renewable energy accommodation potential evaluation of distribution network: A hybrid decision-making framework under interval type-2 fuzzy environment. *Journal of Cleaner Production*, *286*. https://doi.org/10.1016/j.jclepro.2020.124918

Groppi, D., Astiaso Garcia, D., lo Basso, G., & de Santoli, L. (2019). Synergy between smart energy systems simulation tools for greening small Mediterranean islands. *Renewable Energy*, *135*, 515–524. https://doi.org/10.1016/j.renene.2018.12.043

Hasapis, D., Savvakis, N., Tsoutsos, T., Kalaitzakis, K., Psychis, S., & Nikolaidis, N. P. (2017). Design of large scale prosuming in Universities: The solar energy vision of the TUC campus. *Energy and Buildings*, *141*, 39–55. https://doi.org/10.1016/j.enbuild.2017.01.074

Herenčić, L., Melnjak, M., Capuder, T., Andročec, I., & Rajšl, I. (2021). Techno-economic and environmental assessment of energy vectors in decarbonization of energy islands. *Energy Conversion and Management*, *236*, 114064. https://doi.org/10.1016/j.enconman.2021.114064

Hoang, A. T., Varbanov, P. S., Nižetić, S., Sirohi, R., Pandey, A., Luque, R., Ng, K. H., & Pham, V. V. (2022). Perspective review on Municipal Solid Waste-to-energy route: Characteristics, management strategy, and role in circular economy. *Journal of Cleaner Production*, *359*, 131897. https://doi.org/10.1016/j.jclepro.2022.131897

H2B2. (2021). *Company's General Presentation. https://h2b2.es/wp-content/uploads/2021/03/H2B2-21-005-General-Intro.0.pdf*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957752. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

ISO. (2006a). *ISO, 2006a. 14040, Environmental managemement. Life cycle assessment, Principles and framework. Geneve: International Standards Organisation.*

ISO. (2006b). *14044, Environmental management. Life cycle assessment, Requirements and guidelines. Geneve: International Standards Organisation.*

Katsaprakakis, D. Al. (2016). Hybrid power plants in non-interconnected insular systems. *Applied Energy*, *164*, 268–283. https://doi.org/10.1016/j.apenergy.2015.11.085

Koo, J., Park, K., Shin, D., & Yoon, E. S. (2011). Economic evaluation of renewable energy systems under varying scenarios and its implications to Korea's renewable energy plan. *Applied Energy*, *88*(6), 2254–2260. https://doi.org/10.1016/j.apenergy.2010.12.063

Kumar, A., & Samadder, S. R. (2022). Assessment of energy recovery potential and analysis of environmental impacts of waste to energy options using life cycle assessment. *Journal of Cleaner Production*, *365*, 132854. https://doi.org/10.1016/j.jclepro.2022.132854

Martin, M., Svensson, N., & Eklund, M. (2015). Who gets the benefits? An approach for assessing the environmental performance of industrial symbiosis. *Journal of Cleaner Production*, *98*, 263–271. https://doi.org/10.1016/j.jclepro.2013.06.024

Molino, A., Chianese, S., & Musmarra, D. (2016). Biomass gasification technology: The state of the art overview. *Journal of Energy Chemistry*, *25*(1), 10–25. https://doi.org/10.1016/j.jechem.2015.11.005

Neves, A., Godina, R., Azevedo, S. G., & Matias, J. C. O. (2020). A comprehensive review of industrial symbiosis. In *Journal of Cleaner Production* (Vol. 247). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.119113

Neves, A., Godina, R., G. Azevedo, S., Pimentel, C., & C.O. Matias, J. (2019). The Potential of Industrial Symbiosis: Case Analysis and Main Drivers and Barriers to Its Implementation. *Sustainability*, *11*(24), 7095. https://doi.org/10.3390/su11247095

Østergaard, P. A., & Lund, H. (2011). A renewable energy system in Frederikshavn using low-temperature geothermal energy for district heating. *Applied Energy*, *88*(2), 479–487. https://doi.org/10.1016/j.apenergy.2010.03.018

Päivärinne. (2019). *PROCESS SIMULATION TOOL DEVELOPMENT FOR A SMALL GAS TURBINE (Master Thesis).* Tampere University, Faculty of Engineering Sciences

PVGIS. (2022). PVGIS.

Rakpho, P., & Yamaka, W. (2021). The forecasting power of economic policy uncertainty for energy demand and supply. *Energy Reports*, *7*, 338–343. https://doi.org/10.1016/j.egyr.2021.06.059

Ribó-Pérez, D., Herraiz-Cañete, Á., Alfonso-Solar, D., Vargas-Salgado, C., & Gómez-Navarro, T. (2021). Modelling biomass gasifiers in hybrid renewable energy microgrids; a complete procedure for enabling gasifiers simulation in HOMER. *Renewable Energy*, *174*, 501–512. https://doi.org/10.1016/j.renene.2021.04.083

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957752. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

Schmidt, J., Schönhart, M., Biberacher, M., Guggenberger, T., Hausl, S., Kalt, G., Leduc, S., Schardinger, I., & Schmid, E. (2012). Regional energy autarky: Potentials, costs and consequences for an Austrian region. *Energy Policy*, *47*, 211–221. https://doi.org/10.1016/j.enpol.2012.04.059

Sherwood, J. (2020). The significance of biomass in a circular economy. *Bioresource Technology*, *300*, 122755. https://doi.org/10.1016/j.biortech.2020.122755

Sifakis, N., Konidakis, S., & Tsoutsos, T. (2021). Hybrid renewable energy system optimum design and smart dispatch for nearly Zero Energy Ports. *Journal of Cleaner Production*, *310*, 127397. https://doi.org/10.1016/j.jclepro.2021.127397

Sims, R. E. H. (2013). *The Brilliance of Bioenergy*. Routledge. https://doi.org/10.4324/9781315067155

SP Energy Networks. (2022). https://www.spenergynetworks.co.uk/pages/finance_funding.aspx

Takase, M., Aboah, M., & Kipkoech, R. (2022). A review on renewable energy potentials and energy usage statistics in Ghana. *Fuel Communications*, *11*, 100065. https://doi.org/10.1016/j.jfueco.2022.100065

Tang, J. P., Lam, H. L., Aziz, M. K. A., & Morad, N. A. (2016). Enhanced Biomass Characteristics Index in palm biomass calorific value estimation. *Applied Thermal Engineering*, *105*, 941–949. https://doi.org/10.1016/j.applthermaleng.2016.05.090

Terlouw, T., Bauer, C., Rosa, L., & Mazzotti, M. (2021). Life cycle assessment of carbon dioxide removal technologies: a critical review. *Energy & Environmental Science*, *14*(4), 1701–1721. https://doi.org/10.1039/D0EE03757E

Tiwary, A., Spasova, S., & Williams, I. D. (2019). A community-scale hybrid energy system integrating biomass for localised solid waste and renewable energy solution: Evaluations in UK and Bulgaria. *Renewable Energy*, *139*, 960–967. https://doi.org/10.1016/j.renene.2019.02.129

van Berkel, R., Fujita, T., Hashimoto, S., & Geng, Y. (2009). Industrial and urban symbiosis in Japan: Analysis of the Eco-Town program 1997–2006. *Journal of Environmental Management*, *90*(3), 1544–1556. https://doi.org/10.1016/j.jenvman.2008.11.010

van Hoesen, J., & Letendre, S. (2010). Evaluating potential renewable energy resources in Poultney, Vermont: A GIS-based approach to supporting rural community energy planning. *Renewable Energy*, *35*(9), 2114–2122. https://doi.org/10.1016/j.renene.2010.01.018

Velenturf, A. P. M., & Purnell, P. (2021). Principles for a sustainable circular economy. *Sustainable Production and Consumption*, *27*, 1437–1457. https://doi.org/10.1016/j.spc.2021.02.018

Velvizhi, G., Balakumar, K., Shetti, N. P., Ahmad, E., Kishore Pant, K., & Aminabhavi, T. M. (2022). Integrated biorefinery processes for conversion of lignocellulosic biomass to value added materials: Paving a path towards circular economy. In *Bioresource Technology* (Vol. 343). Elsevier Ltd. https://doi.org/10.1016/j.biortech.2021.126151

Voivontas, D., Assimacopoulos, D., Mourelatos, A., & Corominas, J. (1998). Evaluation of Renewable Energy potential using a GIS decision support system. *Renewable Energy*, *13*(3), 333–344. https://doi.org/10.1016/S0960-1481(98)00006-8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957752. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.

Wakeyama, T., & Ehara, S. (2010). Renewable Energy Potential Evaluation and Analysis for Use by using GIS -A Case Study of Northern-Tohoku Area and Tokyo Metropolis, Japan. *International Journal of Environmental Science and Development*, 446–453. https://doi.org/10.7763/IJESD.2010.V1.86

Wakeyama, T., & Ehara, S. (2011). *Estimation of Renewable Energy Potential and Use: A Case Study of Hokkaido, Northern-Tohoku Area and Tokyo Metropolitan, Japan*. 3090–3097. https://doi.org/10.3384/ecp110573090

Weishaupt (2022) *WK-series industrial burners*. Available at: https://www.weishaupt-corp.com/products/burners/weishaupt-wk-series-burners-up-to-32-000-kw#tab-747-2/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957752. This publication reflects only the author's views and the European Union is not liable for any use that may be made of the information contained therein.