HORIZON EUROPE PROGRAMME - HORIZON-CL5-2023-D3-01-01

Renewable Energy Valleys to increase energy security while accelerating the green transition in Europe - Innovation action (IA)

REFORMERS

Regional **E**cosystems **FOR** **M**ultiple-**E**nergy **R**esilient **S**ystems

Grant Agreement No. 101136211

Duration: 60 months | 1st November 2023 - 31st October 2028

D3.2: THE REFORMERS IMPLEMENTATION PLAN

Funded by the European Union

Document Info

Deliverable number	**D3.2**
Deliverable title	The REFORMERS Implementation plan
Work Package	WP3
Deliverable type	R-Document, Report
Dissemination level	Public
Due date	M10 (August 2024)
Pages	104
Document version	3.0
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Contributors	All Partners

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Document change history

Version	Date	Author	Description
DRAFT			
0.1	02/01/2024	Ben Tubben (ALI)	Structure
0.2	02/04/2024	Ben Tubben (ALI)	REFORMERS template; enhanced content structure
0.3	06/08/2024	Ben Tubben (ALI); Bart Kaas (TNO); Wouter Parys (VUB)	Concept 0.1C - review
FIRST REVIEW			
1.0	20/08/2024	Nikolaos Nikolopoulos (CERTH), Phillip Heer (EMPA), Tim van Gemert (ALI), Roberto Rocca (CIRCE)	Reviewer comments added;
1.1	22/08/2024	Ben Tubben (ALI), Wouter Parys (VUB), Bart Kaas (TNO)	Reviewers comments incorporated
1.2	28/08/2024	Ben Tubben (ALI)	Pre-final; layout checks
COORDINATOR APPROVAL			
2.0	28/8/2024	Thierry Coosemans (VUB)	Coordinator review
2.1	29/8/2024	Stella Arapoglou (VUB)	Consolidated version for coordinator approval
FINAL VERSION			
3.0	29/08/2024	Stella Arapoglou (VUB)	Format review, version ready for submission

EXECUTIVE SUMMARY

D3.2 REFORMERS Implementation plan describes the implementation aspects of the Flagship Energy Valley in the Netherlands. It is a conceptual description of which innovative assets will be deployed, where and how they will be implemented to meet the REFORMERS objectives (describing their integration pathway with the existing networks) and when they will be ready for commissioning and demonstration.

The Ecosystem Southrand, Alkmaar is the geographical location of the Flagship Energy Valley of REFORMERS. The Ecosystem itself is part of a wider system, being the Region Alkmaar which is part of the province of North Holland. The Ecosystem has an interaction with its “outside world” as far as energy is concerned with connections to the (inter)national infrastructure mainly for gas and electricity. A district heating network is available within Southrand, providing mainly residential housing with heating.

It has been a goal of the municipality of Alkmaar for a long time to make the Southrand area more sustainable. This has already been started in previous projects. REFORMERS seizes the opportunity to concretely implement sustainability in the further development of the area.

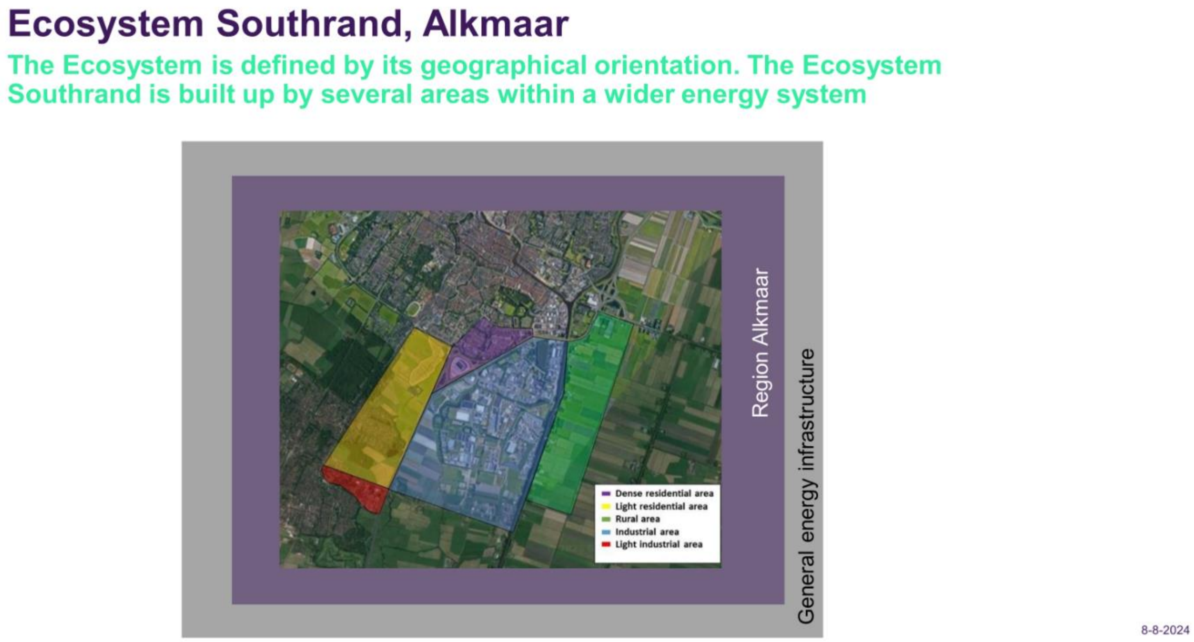

Figure 1 Schematic view of Ecosystem Southrand, within its wider perspective

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Flagship Energy Valley Areas

The FEV Ecosystem is geographically divided into 5 areas

1 Boekelermeer Business Park- Industrial

2 Overdie - Residential

3 Heiloo - Residential

4 Heiloo - Industrial

5 Rural Southrand

Figure 2 Overview of the 5 areas within the Flagship Energy Valley

Inside the Ecosystem, from now on called the Flagship Energy Valley (FEV), five areas are distinguished. One of which, the Boekelermeer Business Park, consisting of three subareas. This results in the following overview of five geographical areas and corresponding subareas, namely the:

1. Boekelermeer Business Park
   - Subarea Investa
   - Subarea Harbour Area
2. Residential area Heiloo
3. Residential area Overdie
4. Industrial area Heiloo
5. Rural area Southrand

Within the ecosystem special attention is paid to the control system of the Energy Valley, the broader stakeholder approach and the supporting modelling environment.

By using modelling techniques, it is possible to calculate performance indicators of the energy system in a (sub)area under different scenarios of configuration and operation. These calculations are based on real-life measurements and projected load-, storage and production curves of assets to be installed. In the initial steps scenarios focus on the areas and subareas as a local system. In a later stage, when more insights are gathered, the FEV as a whole will be modelled to assess the performance of the complete valley.

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Controlling and managing the FEV is made possible with different subsystems at different hierarchical levels. In the figure below several levels of control are made visible from local energy management systems (EMS) to a FEV operating system as the main control over the FEV.

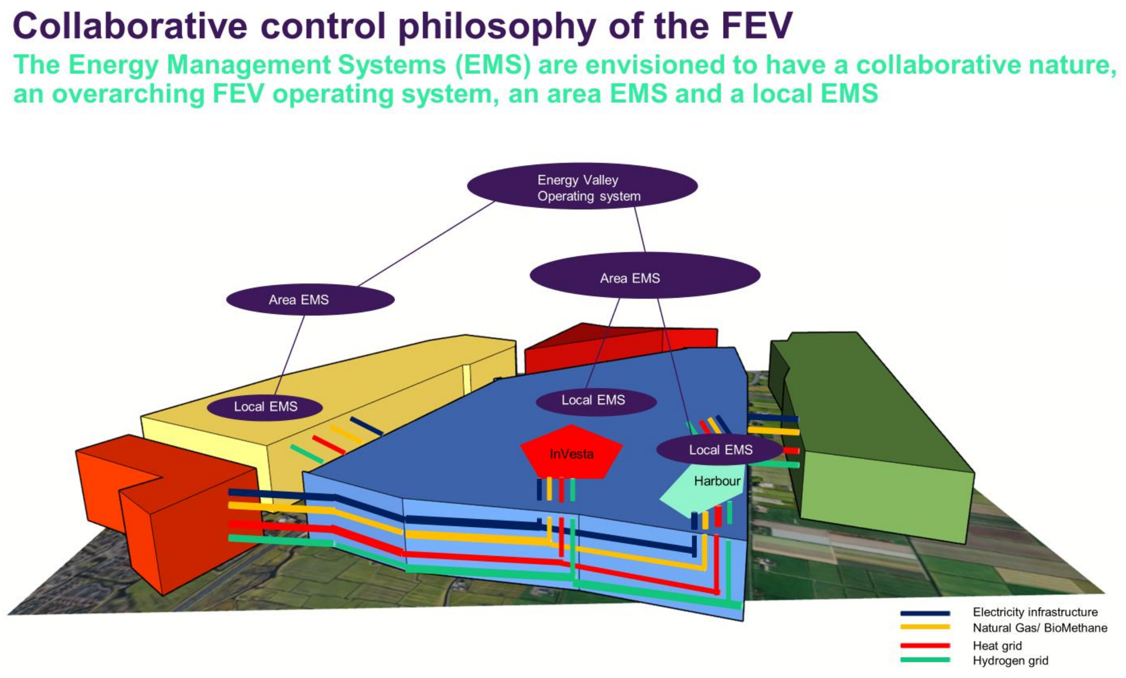

Figure 3 Schematic overview of the collaborative control philosophy

Inside a (sub)area different actors, like DSO, gas operator, heating network operator but also residing presuming and consuming companies play a role in the energy balance and control of the local EMS within that specific (sub)area or towards other (sub)areas. From a REFORMERS perspective, projects will be started by different actors (consortium partners as well as non-consortium partners) to fulfill the requirements and achieve the goals set for the FEV as described in the REFORMERS grant agreement.

The energy innovations within REFORMERS as well as stakeholders already present in the FEV area, have a considerable role in the various on-going initiatives and investments being made within the boundaries of the FEV. Such investments are either entirely own-funded or co-funded by national and/or European projects as in the case of the REFORMERS project.

A distinction can be made into two types of energy projects:

1. Consortium Energy Projects
2. Other Energy Projects within the FEV

Consortium energy projects are those that are executed by the partners in the REFORMERS project. Any other energy related project executed by stakeholders present in the FEV is part of the other energy projects category. As there are hundreds of stakeholders and businesses present in the FEV, the challenge is to get an overview of the most impactful energy projects in the second category, Hence, stakeholders' engagement exercises are carried out in order to obtain insights in current and future projects throughout the FEV However, all type of projects focus on Sustainable Energy production, Consumption, Storage, Conversion and Smart Control for balancing purposes.

Below is a schematic view of the geographical spread of the consortium energy projects within the FEV.

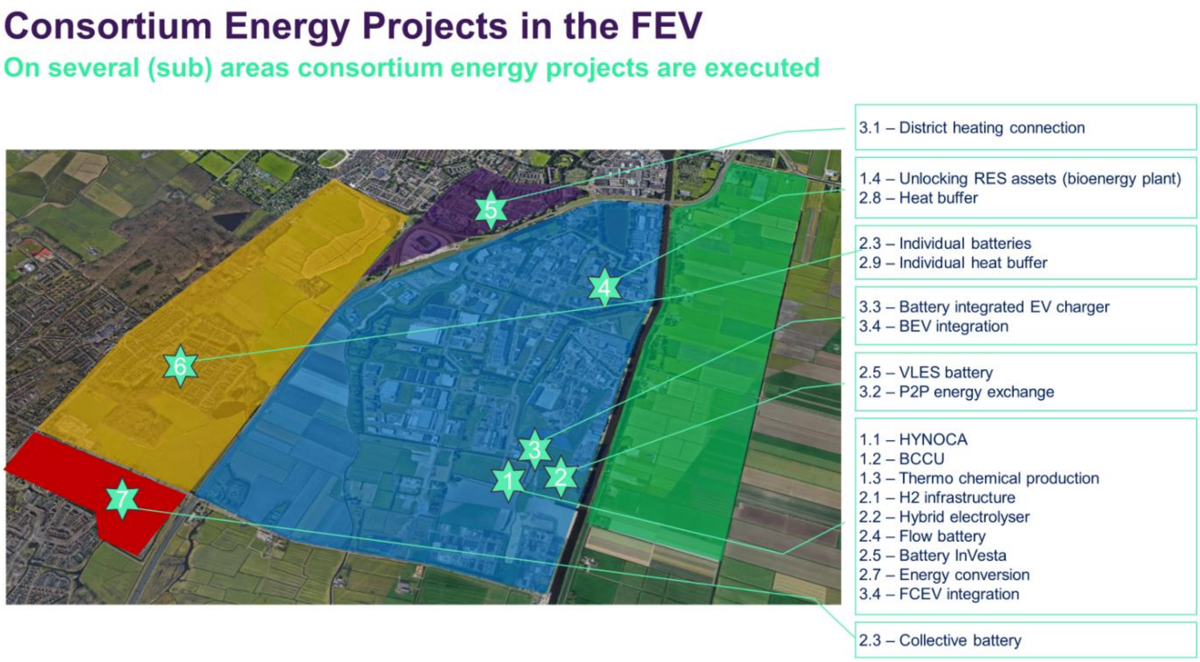

Figure 4 Overview of the Consortium Energy Projects in the FEV

Below is a schematic view of the geographical spread of some of the expected impactful other energy projects within the FEV.

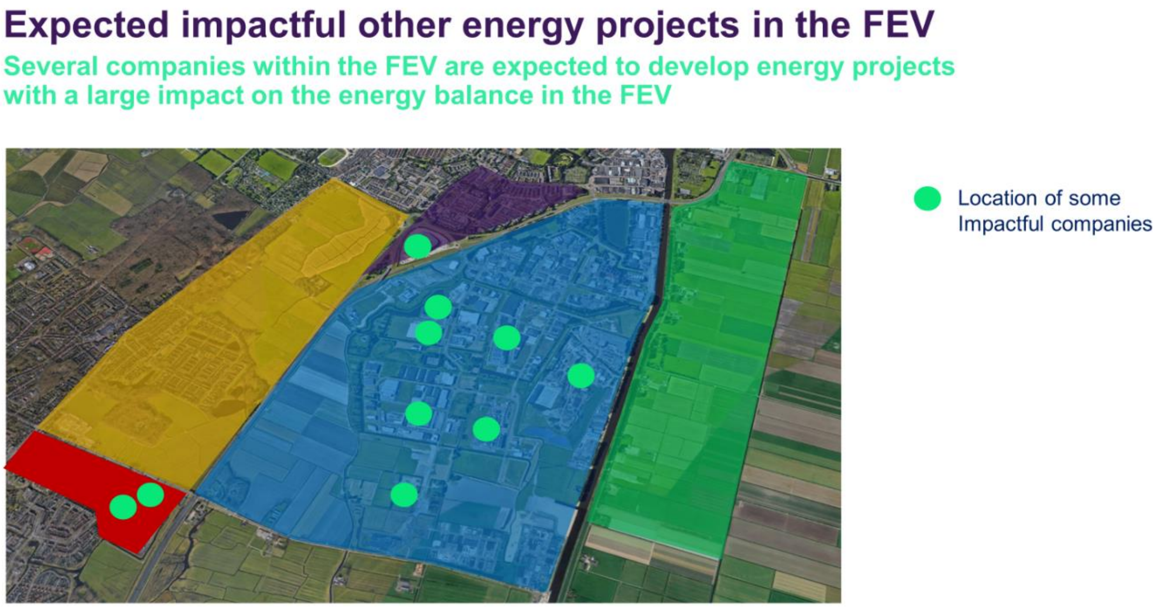

Figure 5 Overview of some of the expected impactful other energy projects in the FEV

The projects have impact on several aspects of the FEV energy system. The structure of such a complex smart energy system can be represented by a Smart Grid Architectural Model (SGAM) as displayed in the figure below. It can be indicated per project on what layer or layers of the SGAM it has an impact. In this way, the complex FEV energy system is structured in a methodical approach. In the figure below the SGAM layer structure is shown.

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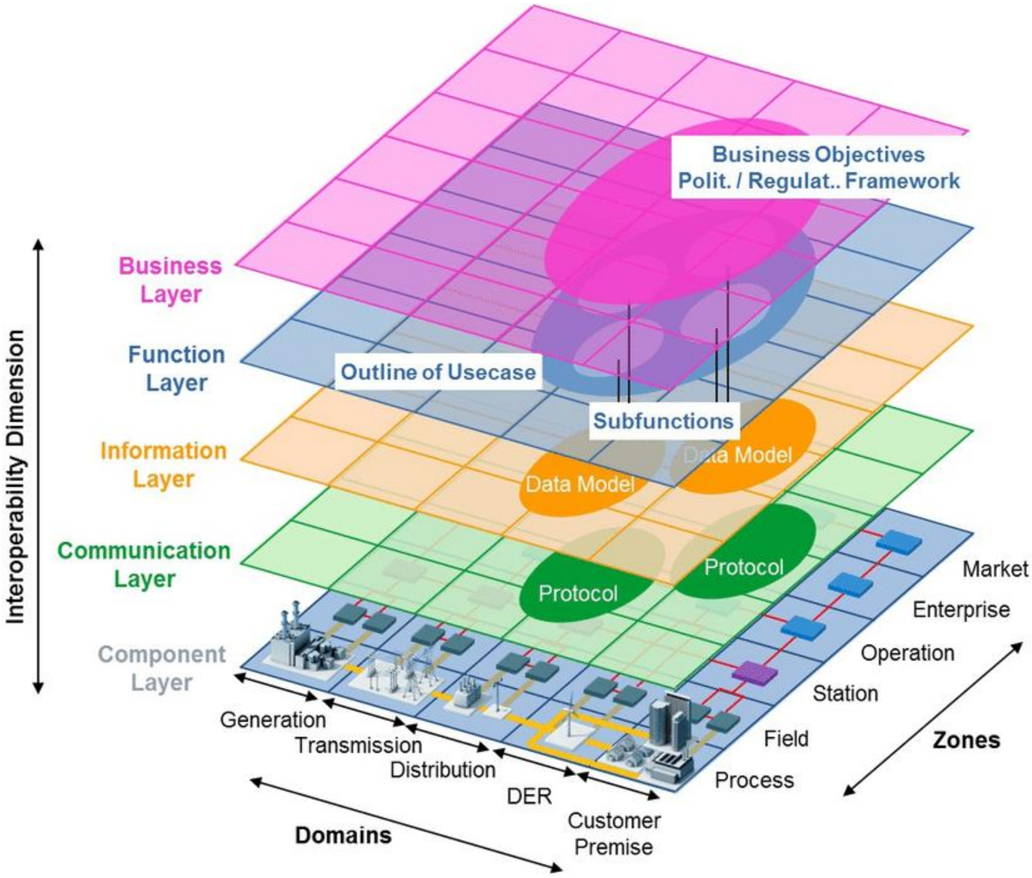

Figure 6 Schematic overview of the Smart Grid Architecture Model (SGAM)

Implementing the FEV is executed through a step-by-step approach using 4 phases, as adopted from the Dutch MOOI EIGEN project[1]. Every phase has its own characteristics.

[1] [Home - EIGEN (eigen-energyhubs.nl)](eigen-energyhubs.nl)

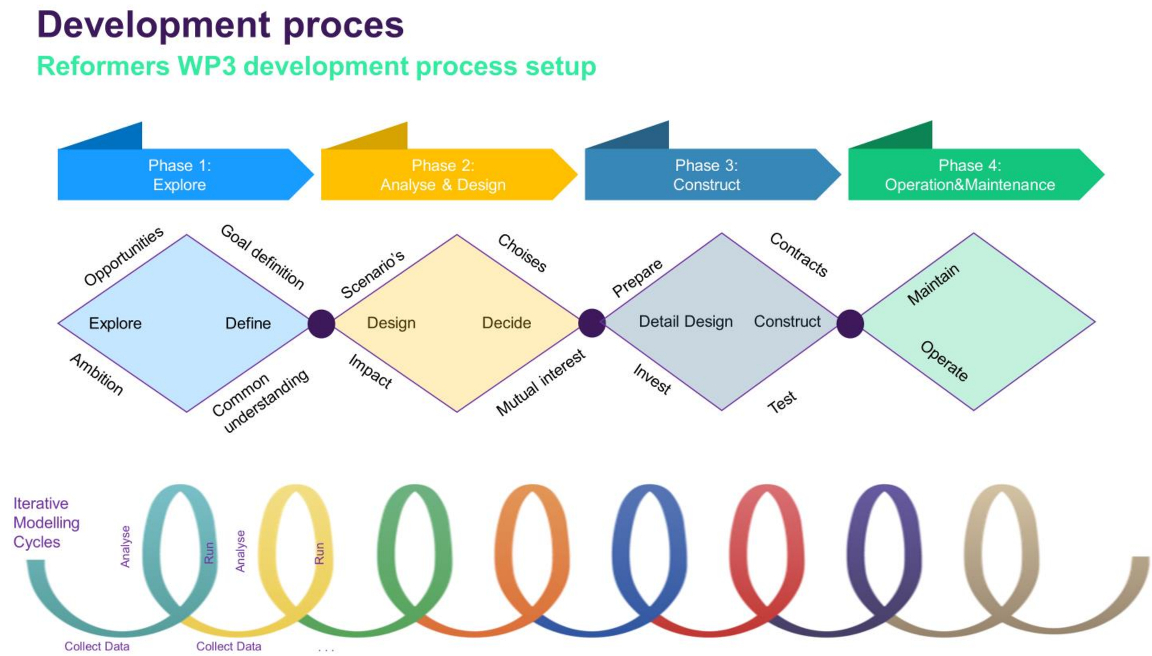

Figure 7 Overview of development phases for Renewable Energy Valleys, as adopted from the MOOI EIGEN project

At this moment the Consortium Energy Projects of the REFORMERS project are mainly in the explore and/ or Analyse and Design phase. Meaning, the concepts of what elements are building up the Energy Valley energy system are described. This conceptual description leads to a more concrete design of how this will be done. WP4 of Reformers will fill in this specific task: come to real implementations. In WP4 the details will be elaborated on, and real implementations will take place.

The current document D3.2 includes descriptions of:

- The systematic approach to set up the Energy Valley and the methodologies used
- The current state of the Energy Valley and the subsequent phases in which it will be realized
- Specific implementation related aspects during the development phases of the projects
- The assets and infrastructure needed
- Design of the multi-commodity energy system

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Acronyms	
DT	Digital Twin
EVRT	Energy Valley Replication Toolbox
FV	Flagship Valley
GDPR	General Data Protection Regulation – EU Directive
LCA	Life-cycle assessment
LLCOE	Local Levelized Cost of Energy
LEC/REC	Local Energy Community / renewable Energy Community
LES	Local Energy System
PV	Photovoltaic
REV	Renewable Energy Valley
RE	Renewable Energy
RV	Replication Valley

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1. Introduction

This implementation plan is the final result of the work performed in Work Package 3 of the REFORMERS project. It describes the pathway to the implementation and operation of the Flagship valley on a conceptual level. It details the necessary actions that have been undertaken as well as the planification of the further steps to be followed during the coming years to come to a fully functioning living lab that serves as an open infrastructure for the participating companies and stakeholders. For this purpose, it considers the current state of the FV as a starting point, and projects in close collaboration with WP4 and the stakeholder community the necessary technological and collaborative deployments that are necessary to obtain objectives that are put as targets in the REFORMERS proposal. It takes into account hardware and software deployments, operational-, governance- and business aspects, interactions between actors and systems, control and measurement methods and -infrastructure, and aims to project timelines for each of these aspects.

In Chapter 2 a description of the current state and structure of the flagship valley is given, with a strong focus on the functioning of the FV as a whole, its subsystems and layers, and the interactions between the different actors and systems.

In Chapter 3 the methodology for the implementation planning is given, including planification and modelling tools and objectives to be achieved

In Chapter 4 the current deployment state of each of the subareas, layers and project is described, as well as the next steps to take.

Chapter 5 states the setup of the operating system (control and management environment) with the different platforms that are going to be used.

Chapter 6 summarizes the pathway forward and links to the actions and deliverables to follow in the remainder of the project, with a strong link to WP4.

2. SYSTEMATIC APPROACH OF THE FLAGSHIP ENERGY VALLEY

The systematic approach of the FEV presents the outline on how the FEV is organized. There are 3 levels of description in this approach:

1. Energy Ecosystem
2. Architectural Layers
3. Actors and projects

2.1. Ecosystem and geographical introduction

The FEV can be seen as an Ecosystem. The Ecosystem is on itself part of a wider perspective, being the local (geographical connected) municipality of Alkmaar, the Province of North Holland and the Netherlands.

Below is a schematic view of the FEV Ecosystem.

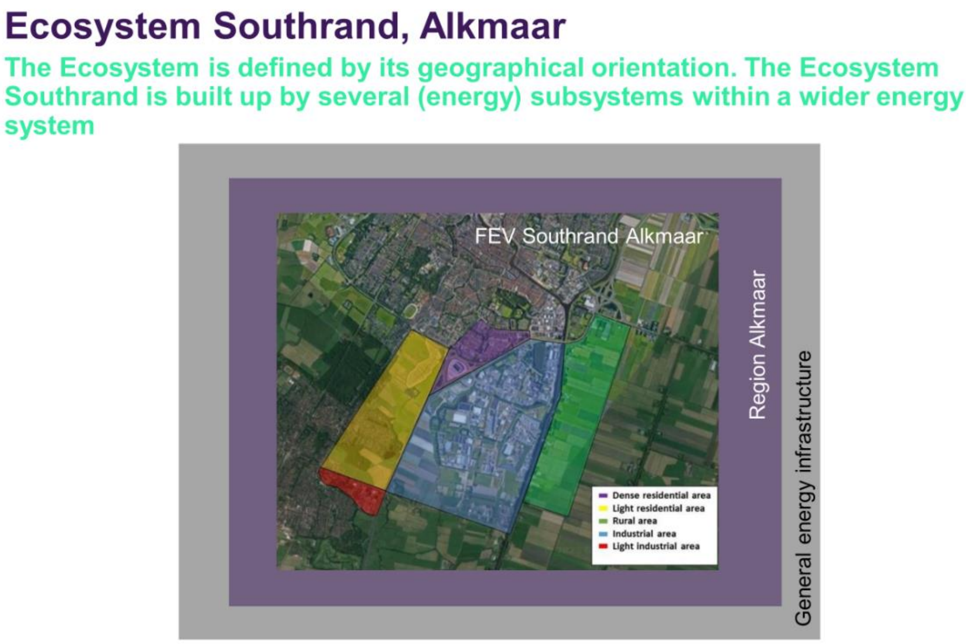

Figure 8 Schematic view of Ecosystem Southrand, within its wider perspective

Within the Flagship Energy Valley (FEV) five areas can be distinguished, depicted below in the colored areas. Within these areas subareas can be distinguished based on their geographical orientation and characteristics.

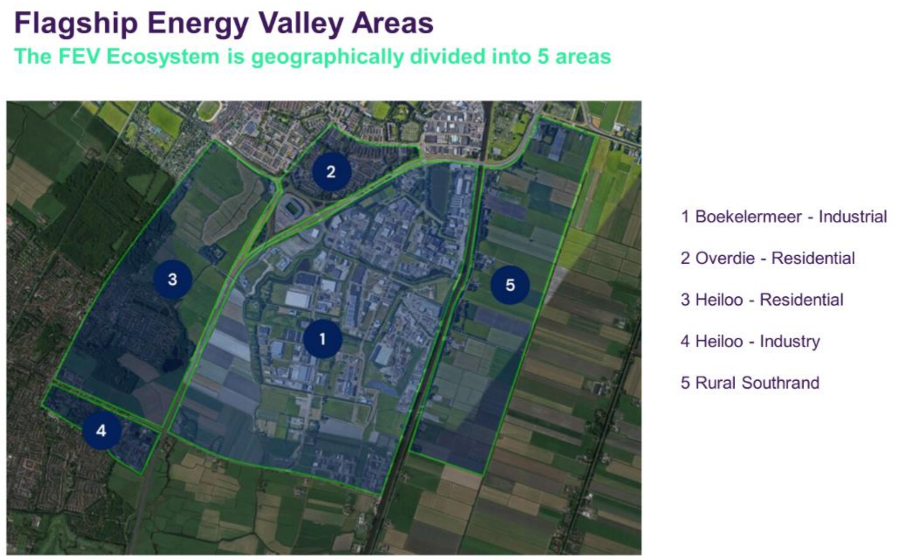

Figure 9 Overview of the 5 areas in the FEV

The industrial area of Boekelermeer Business Park (number 1 in figure above) has two identified subareas, being InVesta and Harbour subarea. Most of the Consortium Energy projects of REFORMERS are located in these two subareas.

Figure 10 Overview of the subareas in the Industrial area Boekelermeer

Industrial area Boekelermeer Business Park

The Boekelermeer, the centre of the ecosystem, is characterized by its abundance in Renewable Energy Sources (RES), extensive natural gas infrastructure and gas assets, and the localization of Energy Innovation Park Alkmaar (EIPA). Historically, these characteristics are related to one another.

The localization of company TAQA – and their accompanying gas treatment, distribution and storage assets – went hand in hand with the start of EIPA. The ‘danger’ of these gas assets requires a certain risk contour within which no ‘vulnerable objects’ – such as schools, hospitals and residential areas. Instead, in alignment with the Municipality of Alkmaar this specific area has been labelled as EIPA to stimulate renewable energy technologies and companies.

It has been because of this reason that Boekelermeer was designated as one of the *Replication Districts* of the Alkmaar *Lighthouse City* within the Horizon 2020 POCITYF project that aims to make cultural historical cities greener, smart and more liveable through the application of the *Positive Energy District* (PED) concept.

Within POCITYF, Boekelermeer was considered as an early replicator due to its role as the “*engine of the energy transition of the city (Alkmaar) towards 2050”.* Innovative elements such as solar roofs and facades, energy storage, energy management and energy trading were identified for making the replication district energy positive and to match demand and supply and thereby alleviating the pressure on the grid.

2.2. Architectural layers of the FEV Ecosystem

As stated in the previous paragraph multiple geographical sub-areas builds up the FEV Ecosystem. In the REFORMERS project the focus is on the energy systems of these areas and the FEV as a whole. To understand how the energy systems in the different areas are to be build up, the SGAM (Smart Grid Architectural Model) structure as defined by IEC-SEG-CG[2] is used to describe the different layers of the energy system.

Below a schematic view of the SGAM layers is shown.

[2] https://syc-se.iec.ch/deliveries/sgam-basics/

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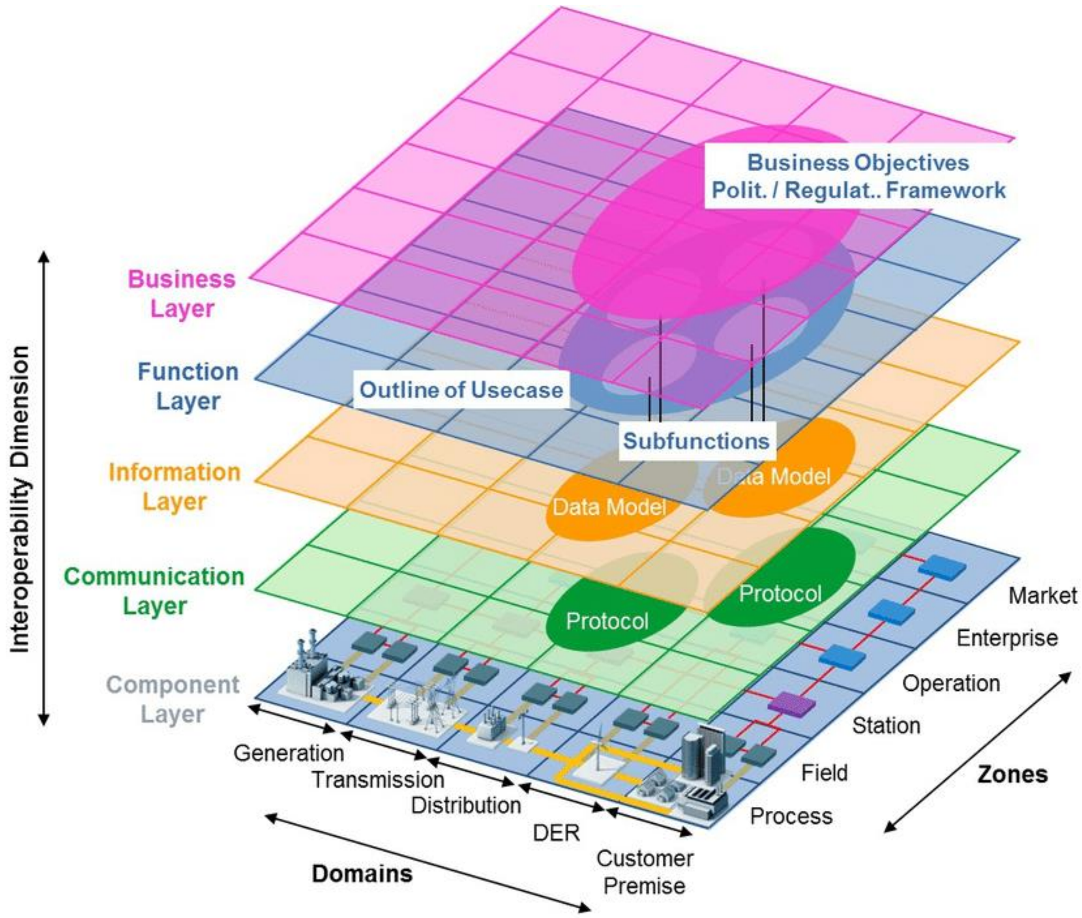

Figure 11 The Smart Grid Architecture Model (SGAM)

In following paragraphs, the layers of the SGAM model are described related to the REFORMERS project.

Business Layer

The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also, business capabilities and business processes can be represented in this layer. In this way it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models.

In order to support the implementation of business cases in the FEV an operating system is needed. This system can be seen as the management system where business rules will define how the overall energy system will be operated, for example maximize use of available locally produced sustainable energy, or maximize market value. This operating system will have control over the assets in the energy system using different software platforms to connect to and control the assets. These assets consist of the Consortium Energy Projects to be deployed and the Other Energy Projects as introduced in the next section. The management and control system will follow a certain philosophy that handles the principles of optimal governance and management and in which automation plays a key enabling role. It is indeed by automation that energy-related services and business cases can be adequately build and exploited, and moreover automation allows close monitoring of KPIs of the FEV and its components. These KPI's with respect to technical, environmental impact, economic, and social aspects, are listed in D3.1. The proposed KPI's are defined at a holistic and general level so that they serve to adequately quantify the achievement of the objectives of the Flagship Valley (FV) as a whole but will be refined to address the specifics of components and (sub) systems. Additionally, project-level KPIs that apply to the wider impact of REFORMERS have been included.

To be able to deploy and implement a well-controlled and balanced FEV several aspects, services and systems need to be realized. Ranging from management systems with different functions for balancing of the energy system, to implementation of the various energy innovations that fill in specific needs of the energy system (production, conversion, storage of energy). Given the complexity of the FEV, several scenarios are possible to realize this, where every scenario consists of different components and or assets, sizes of the assets, energy flows etcetera to build up the FEV energy system. The consortium uses a modelling environment to predict the outcome of a certain "scenario" with respect to the defined KPIs. Besides modelling also setting up the Digital Twin in Work Package 5 will give insight in the outcome of scenario's, more precisely it will give indications with respect to improved energy management.

Governance is also defined within the business layer. How are the (sub) areas organized and what is necessary for control. By describing the governance structure, it becomes clear what entities, roles and responsibilities are needed, to be able to control the FEV. Still, on governance level certain choices need to be made.

Function Layer

In general, five typical functions need to be implemented in an energy system:

1. Sustainable energy production
2. Balanced use of energy
3. Conversion and storage of energy
4. Energy distribution
5. Smart control system

Not every (sub) area within the FEV needs to have all 5 functions. It is possible that one area fills in the need on specific function(s) for other area(s). As an example: in the rural area it is most likely that sustainable energy production with windmills will be realized, where in an urban environment this isn't possible.

By finding the right balance between the functions in the energy system a balanced system can be realized

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Information Layer

Data exchange from components up to a business level is crucial to be able to have control over the energy system. It is crucial to understand what information needs to be provided to which system. Data management and how data will be provided is part of the information layer description.

Communication Layer

The physical aspect of interoperability, how do different components interact, is handled within the communication layer. Data exchange protocols, interface definitions and implementation is carried out in this layer. By implementing standardized tooling that will cover the different interfaces to the physical components the communication layer can be connected to the information layer in a structured way.

Component layer

The physical components will be implemented in the components layer. Within the REFORMERS project the Energy Innovations which will be implemented belong to this layer. In addition, data exchange components and energy infrastructural components belong to this layer as well.

The energy infrastructure provides the sub areas of energy, or transports/stores a surplus of (produced) energy across sub areas. Physical energy exchange is possible through the connected energy infrastructures. By optimizing the energy flows in and between the sub areas, a balanced energy system is created.

Because of grid congestion in the electricity grid in the FEV, constraints to the available capacity are set. Because of this aspect, solutions are investigated to make sufficient energy available locally, either for a limited period until the grid operator is able to supply sufficient capacity or a more long-term solution if it fits in with the energy concept of the (sub)area within the Energy Valley

All the sub-areas and components are connected to each other in different ways.

- Geographically: companies are situated in (sub) areas of the FEV
- Physically: by the energy infrastructure, where the projects use the different infrastructures for their purposes
- Balancing of energy flows with an operating system within a certain energy carrier (for example electricity) but also across energy carriers (conversion) to optimize energy availability in a specific way.
- Contractual connections of actors within a (sub) area for direct energy exchange, related to energy markets/prices and/or energy capacity constraints.

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2.3. Projects in the FEV

In the FEV projects are started to build up the energy system. It concerns energy innovation projects and projects to setup the operating system of the FEV energy system.

Energy innovation projects

The energy innovations within REFORMERS as well as stakeholders already present in the FEV will start projects. A distinction can be made into two types of energy projects:

1. Consortium Energy Projects
2. Other Energy Projects

In general, the Energy innovations projects are seen as black boxes in this phase. From the black boxes we need to know the basic specifics in terms of input; output; external control to be able to model the impact on the energy system and get a better understanding of how to balance the energy flows. In the figure below this approach is shown.

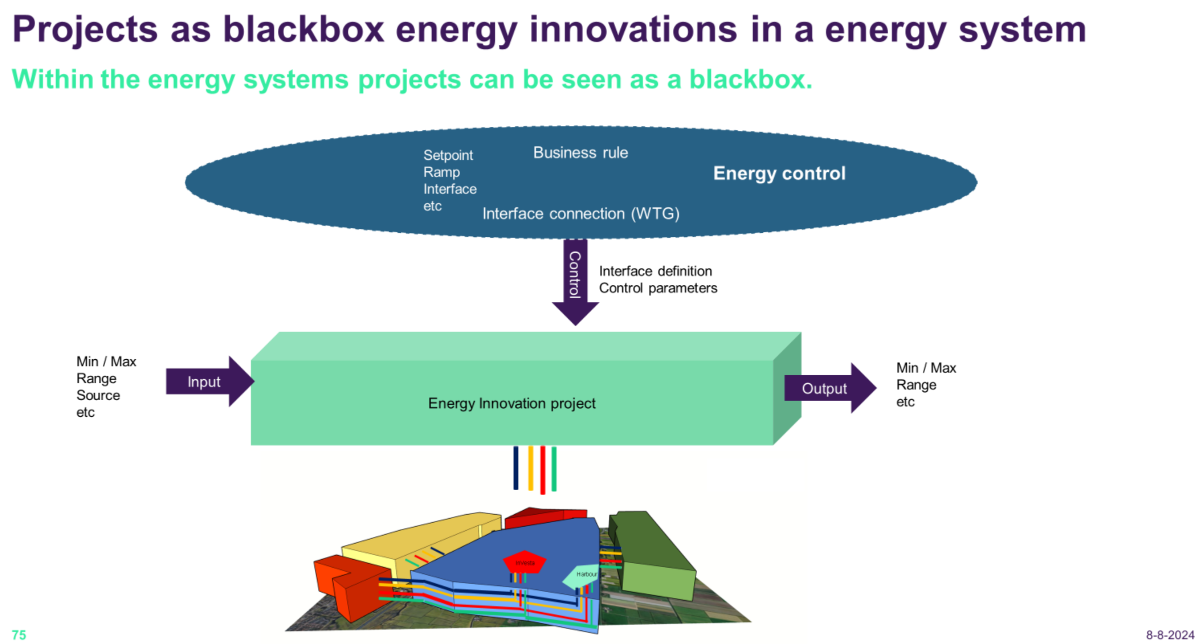


Figure 12: Black-box energy innovation project approach

Consortium energy projects are those that are executed by the partners in the REFORMERS consortium. Any other energy related project executed by stakeholders present in the FEV is part of the other energy projects category. As there are hundreds of stakeholders and businesses present in the FEV, the challenge is to get an overview of the most impactful energy projects in the second category. However, both type of projects focus on sustainable energy production, consumption, storage, conversion and smart control for balancing purposes.

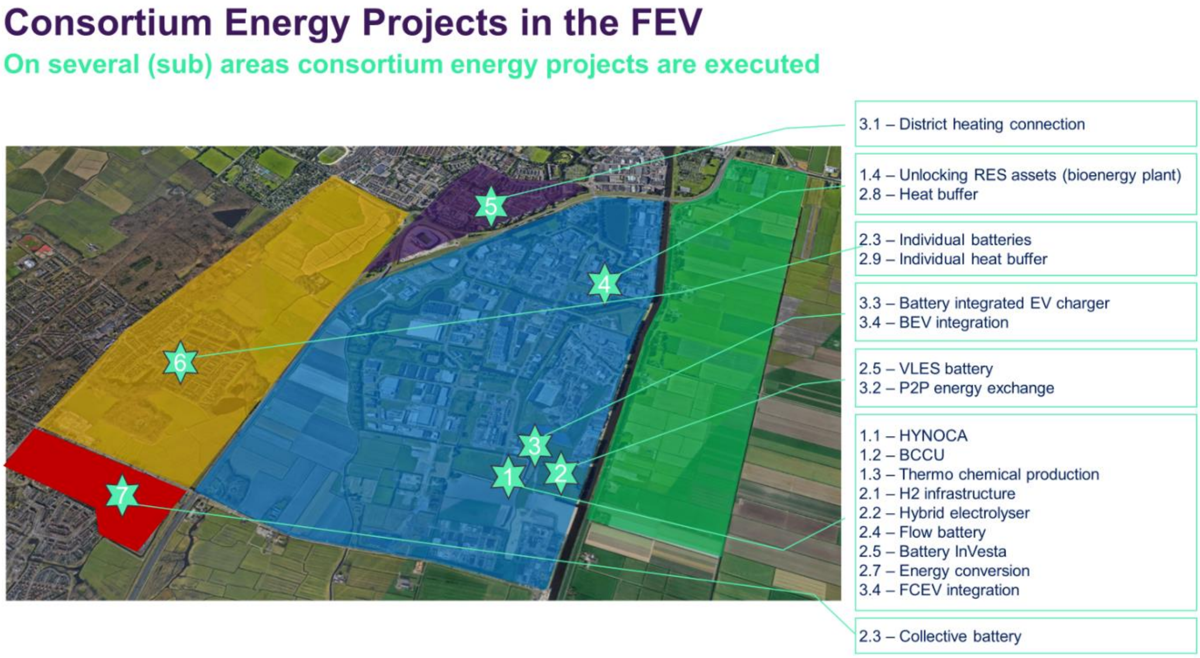


Figure 13 Consortium Energy Projects

Although very impactful, the energy innovation projects geographically cover a small area within Boekelermeer and the FEV as a whole. For this reason, first stakeholder engagement especially focusses on the impactful, non-consortium partner companies in the FEV, as they can have a big impact on balancing the energy system of the FEV, and in a broader sense contribute to the deployments of renewables in the FEV. The energy profiles of these companies can provide flexibility to the FEV in terms of optimization of energy consumption over time, relief of unused contracted capacity to be able to connect (new) users to the energy system.

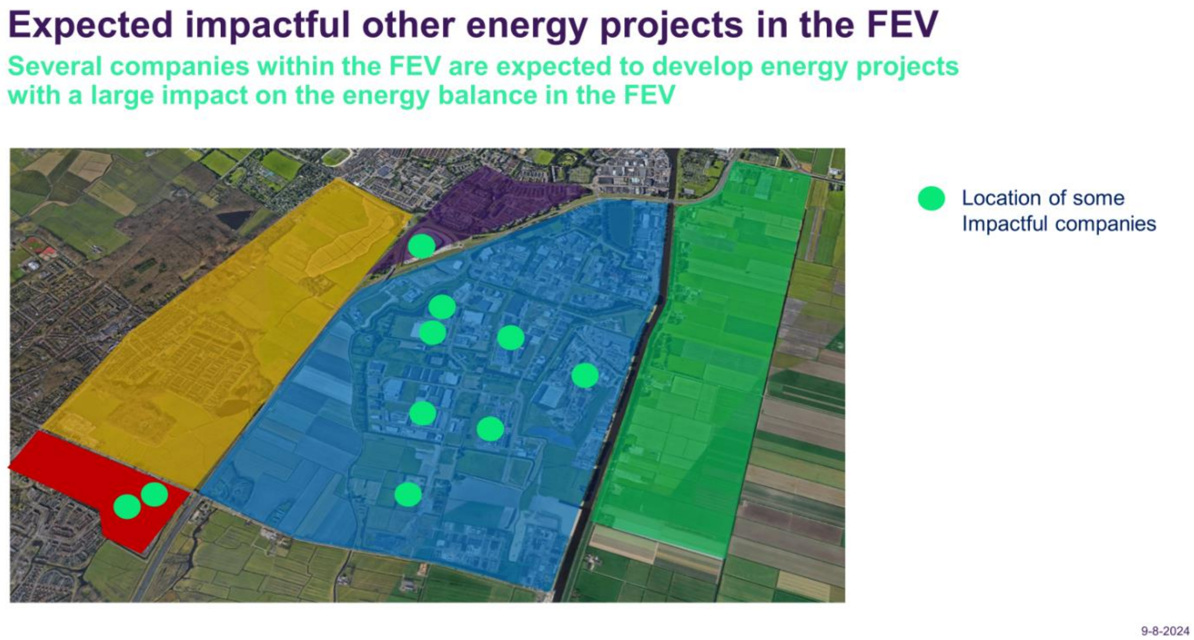


Figure 14 Impactful other energy projects

Within the (sub) areas of the FEV, actors and their projects build up the energy system by implementing different aspects across the layers as described in previous paragraph.

Most projects implement components of the different energy (sub) systems. Besides the physical component projects (or energy innovation projects) also projects with impactful companies have an impact on the energy system of the FEV.

Operating system projects

A specific project is setting up the operating system of the FEV. Specific aspects are identified, analyzed and designed and are described in more detail in chapter 5.

The operating system covers 2 major aspects:

- the management system, which covers:
    - business rules
    - governance structure
    - roles & responsibilities
- the physical control mechanism, with:
    - Control philosophy definition
    - Functions of the energy system
    - Control of components of the energy system
    - Interfaces to the components

- Safety functions of the energy system

As the projects are still in an early stage of development a lot of aspects are still to be defined and are not final yet.

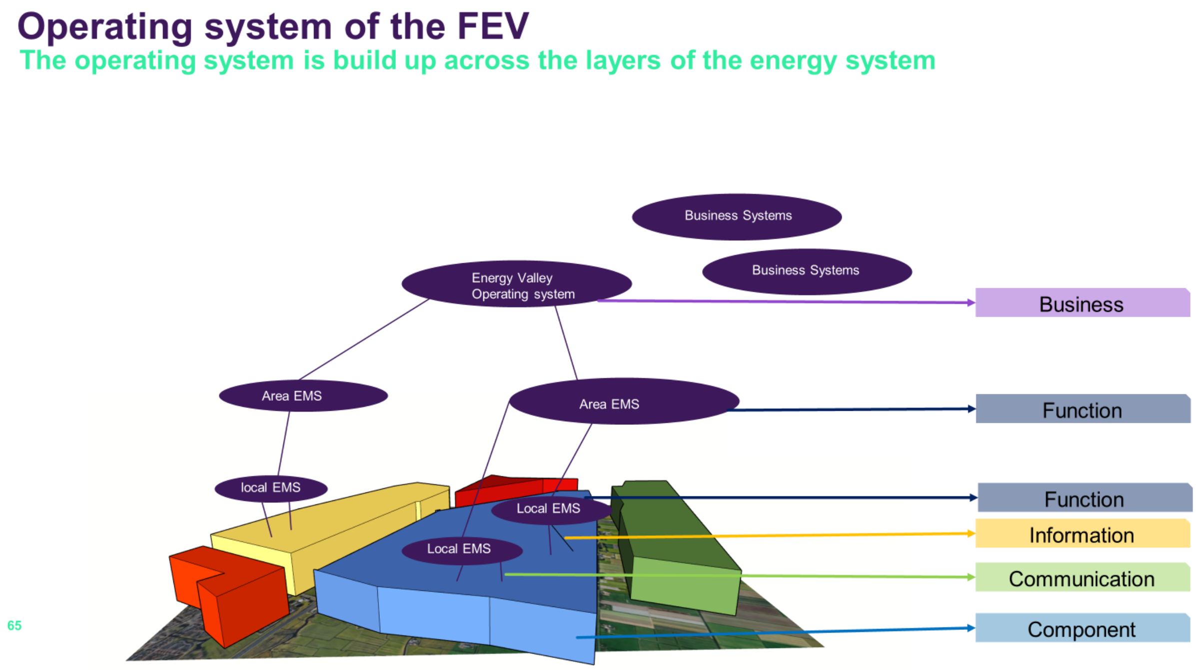


Figure 15 Operating system of the FEV

In the figure above only the perspective of the operating system from the FEV as a whole is made visible. Also on sub-area or component level an operating system with all layers can be present. For example, InVesta area can have its own operating system, which communicates with an operating system on a higher abstraction level. A component, as for instance the NXT mobility hub can have its own operating system to balance energy specific in that component. In this way a "system-of-systems" setup is made.

In chapter 4 both the Consortium Energy Projects and the approach to align with the Other Energy Projects of the FEV will be described in more detail.

3. Setting up the Flagship Energy Valley

In chapter 2 the structural elements of the FEV are described. This chapter describes how the implementation in the FEV is carried out. The implementation planning and development process consisting of 4 phases are described as well as the collaborative approach within the FEV to involve different stakeholders. Also the modelling tools and how they are going to be used are described.

3.1. Implementation Planning and Development Process

Implementing the FEV is executed through a step-by-step approach using 4 phases. Every phase has its own characteristics, whereas the first phase is about exploring & analyzing current situation, ambitions, and the last phase is about maintaining the system. By using a modelling environment, the impact of insights can be made visible. In this paragraph the setup of the development process is described.

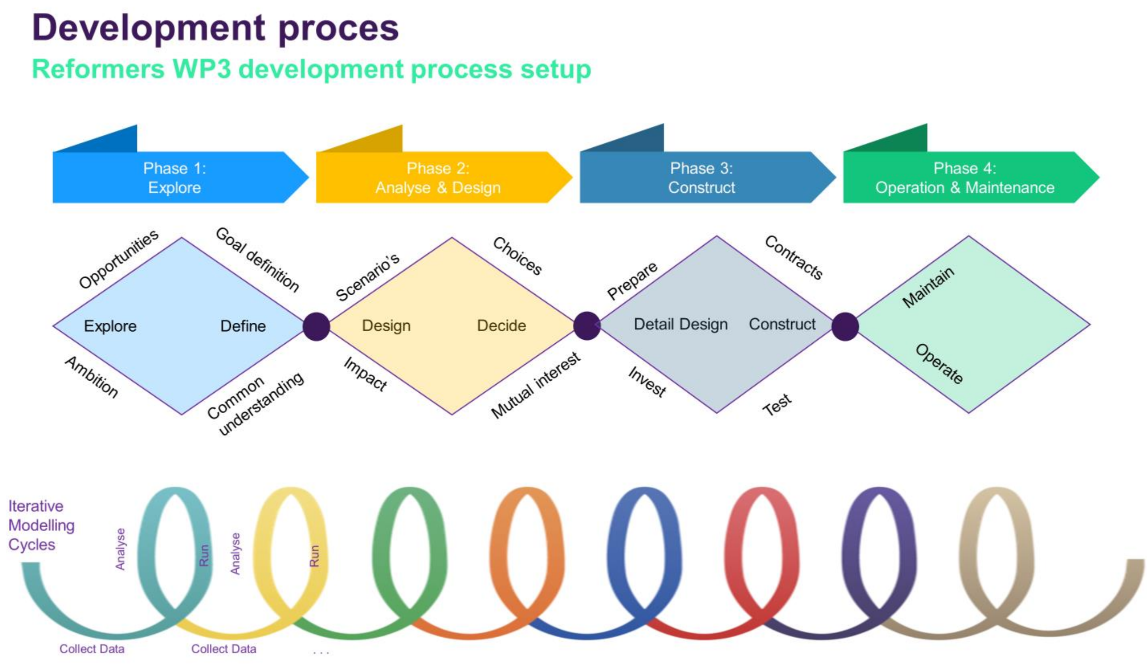


Figure 16 Development process WP3

In the ***Explore Phase*** of development the focus of activities is on identifying opportunities, describe the ambitions of important stakeholder and get a better understanding of the local situation. From an Energy System perspective, the current electricity grid structure is analyzed on the High, Mid and Low voltage levels. With the gained knowledge a better definition of the goals for the energy system can be described with a common understanding of these goals.

In the ***Analyze and Design Phase*** multiple scenarios are setup and examined, with the support of modelling tools. Scenarios are alternatives on how the goals can be achieved, which components are necessary to implement etc. In an iterative way scenarios are defined and with a better knowledge on impact, choices can be made to really orchestrate the ecosystem.

After the design, the energy system can be built. In the ***Construct* Phase** designs can be refined and systems are built based on these. At the end of the *construct* phase, tests will take place. First local on component level, later integrated system tests need to be executed.

In the ***Operation and Maintenance Phase*** the energy system is built and the main activities move towards monitoring and analyzing if requirements are met, and potentially how things need to be changed to meet these requirements.

By using a modelling environment, the outcomes and KPIs of scenarios can be predicted. These modelling outcomes are used to improve scenarios or even setup new scenarios. From the early explore phase to operation and maintenance the modelling environment is valuable to the different phases. Before initial scenarios are defined a very basic model is produced based on a range of assumptions serving to explore different high-level pathways. By then defining more detailed scenarios these assumptions can be. investigated in more detail so the outcome comes close to a realistic implementation. In addition, the models become more adequate as more measurements become available throughout the project. During the construct phase the model can be used to predict outcomes to verify if changes need to be made.

3.2. Collaborative approach in the FEV

This paragraph discusses the collaborative approach in the FEV and alignment with the other energy projects and stakeholders in the region. These activities align with Task 4.4 in the project. It focuses on setting up a collaborative approach for Energy Valleys, which will also be part of the Energy Valleys Toolbox of WP6. The approach will be a holistic approach to decision making in the FEV, incorporating the following main elements:

1. Governance
2. Business Models and financial aspects
3. Legal aspects
4. Social dimension

In the Netherlands congested electricity grids are a major hurdle for businesses who want to grow their activities or electrify their fleet of trucks for example. One of the ways to deal with congestion is to start a collaboration, on business parks often referred to as Energy Hubs in the Netherlands. In REFORMERS the household perspective of several neighborhoods is incorporated, allowing the area to grow into a Renewable Energy Valley. However, setting up this collaboration is a time-consuming process as many aspects need to be explored and decided upon, in alignment with Phase 1 and 2 of the Development Process shown in Figure 16.

Governance in the FEV

For the vast majority of entrepreneurs in an industrial area, energy is not their core business, but part of their business process. However, over the past few decades, it has become an increasingly important component. Nowadays, more and more entrepreneurs are actively involved in producing, conversion, storing, supplying, and distributing energy; i.e. electricity and often also heat. Parts of this can include sharing and balancing energy. It is beneficial to do this collectively, as a group of companies. How this can be developed in the Boekelermeer region needs further elaboration.

It is already visible that groups of companies in the Boekelermeer are reaching out to each other, as well as others, such as residents in surrounding areas and the government. They also find companies for whom energy is their core business and who offer their services. Coordination between all these parties is setup, resulting in contracts between companies, or the government learning how to implement its policies. How can a more formal governance structure develop, allowing companies, residents and the government to collaborate?

The establishment of an association is a no-regret measure. This would create a board that can perform tasks and be accountable to the members, on a one-man-one-vote basis. This association does not need to be a legal entity, as long as it is limited to coordinating between members, with other similar groups of companies that have united on a local or regional level, and with governments. The time to change comes when an association starts to undertake business activities, such as investing together or entering into contracts with companies for whom energy is their core business.

The association can start to undertake business in two ways: 1) by becoming the owner of enterprises, or 2) by transforming into a cooperative. A foundation, limited liability company (Dutch: BV), and public limited company (Dutch: NV) are less suitable for organizing collective participation and ownership. However, a collective can house activities in a foundation, BV, or NV, which would then be owned by the association or the collective's cooperative. These steps all fit within European energy law, where the energy community has been introduced as a legal entity that provides space for collectives of energy users and in which the government can also participate.

Joint entrepreneurship could involve, for example, jointly setting up a wind turbine or a battery. As mentioned, it is wise to house these in a separate legal entity, such as a BV. In more detail, many steps could follow, such as whether the BV is 100% owned by the association or cooperative of the collective, or whether shares are also held by others. Coordination of the work of this BV with requirements from energy law and tax law also requires attention to ensure that it can truly operate in the service of the collective; different legal areas sometimes tend to work against each other.

In the figure below a schematic overview of what the governance structure could look is visualized. It is build up by local- , area- and Energy Valley associations.

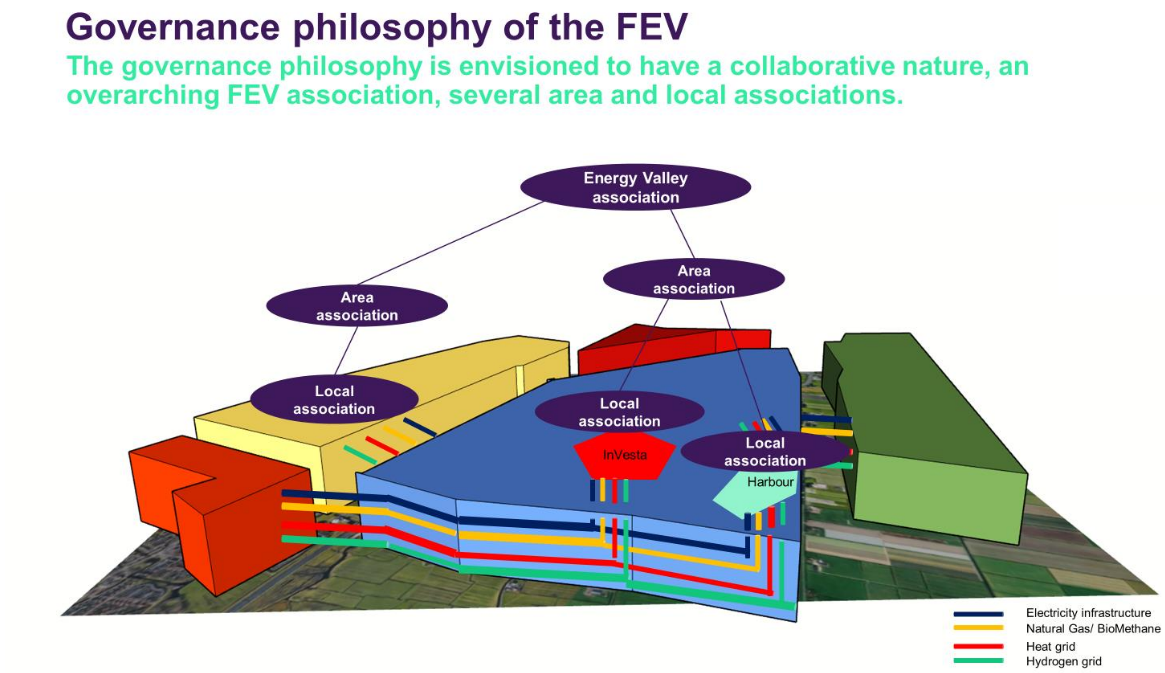


Figure 17 Governance Philosophy of the FEV

3.3. Modelling tool

The modelling tool is designed to be fitted in the broader implementation plan in a useful manner. It connects the physical implementation of new technologies & innovations with the goals and objectives of the project and is able to track and estimate the progress on the most important energetic and environmental KPIs. The next paragraphs discuss consecutively the context wherein the model is deployed, the interrelation with the FEV KPI calculation and the model methodology.

Context description: model as a tool during the project implementation

The purpose of the modelling tool is to analyze, estimate and track the expected impact of different energy innovations and developments on the FEV KPIs during the implementation and operation phase of the site. The model is used as a living tool and thus will be updated regularly when the different planned energy innovations and developments are moving towards new phases and new data and operational strategies are available. In the first iteration of the modelling tool calculates the 'Reference' scenario and the 'Expected developments' scenario at the start of the project (see figure 18). The 'Reference scenario' calculates the KPIs at the start of the REFORMERS project and the 'Expected Developments' scenario calculates the impact on the same KPIs of all the planned energy innovations and other certain deployments (project 1 to N in figure 18) inside of the FEV towards the end of the project with the knowledge at the start of the project.

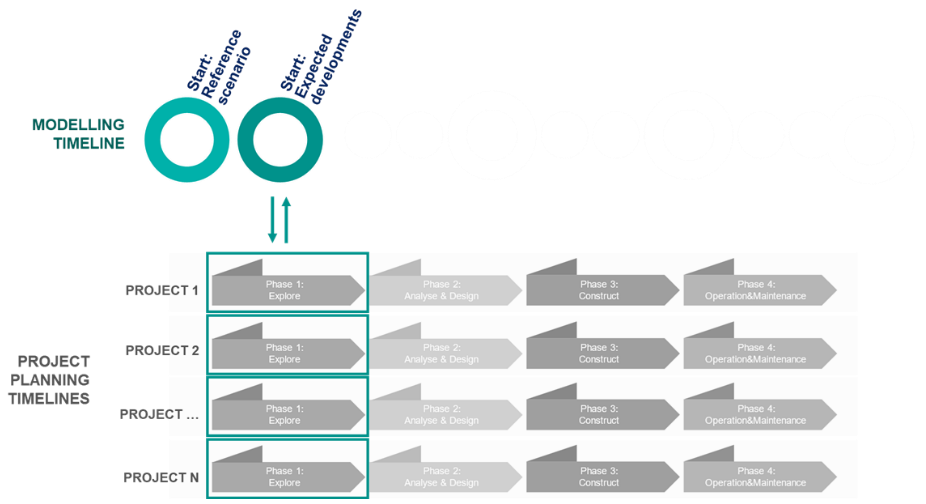


Figure 18: Modelling timeline in perspective to the development of the different energy innovations and energy developments inside the valley (projects 1-N) in the FEV at the start of the project

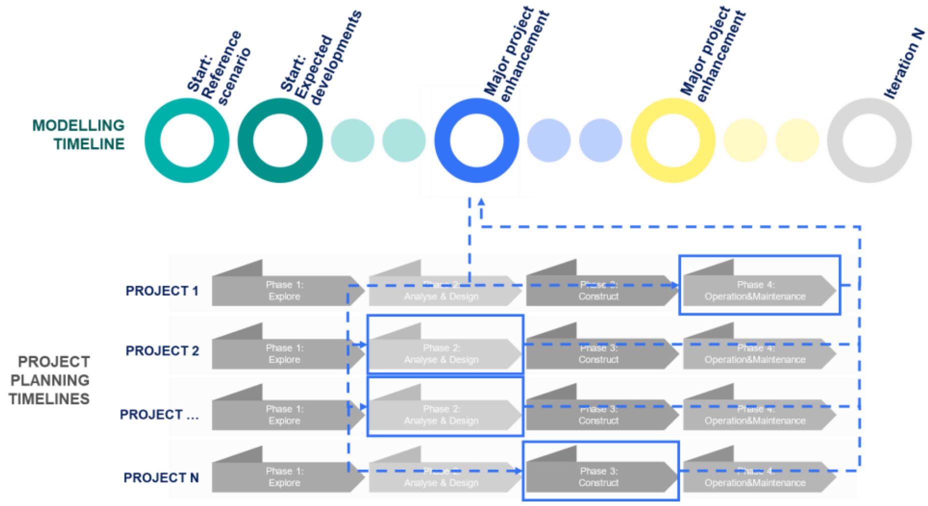


Figure 19 Modelling timeline in perspective to the development of the different energy innovations and energy developments inside the valley (projects 1-N) in the FEV during the project

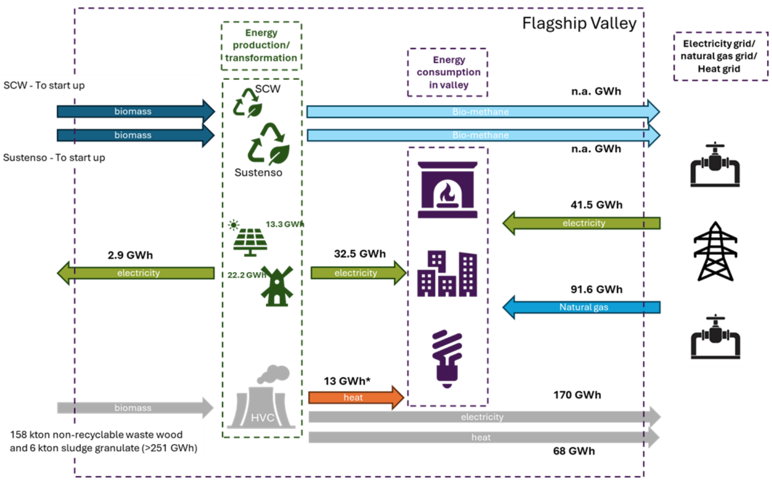
The output of the calculations of the Reference scenario and the Expected developments scenario at the start of the project (figure 15) serve as an input for the developments of the different energy innovations and other new energy deployments in the FEV. Over time, these different energy projects that are developed in the FEV make progress and go from one phase to the next and new or more detailed data will become available (figure 16). This new data could be for example a smaller or bigger size, changes in the production rates, new operational strategies or more detailed information on energy transformation and - production efficiencies. When the changes and the new available information on project level together are extensive, the need for a new model iteration is assessed. If a positive assessment, the model is fed with the newest information and the impact on the energy related KPIs is calculated. The output of the new model is then again used as an input for the separate energy projects, especially during the analyse and design phase but as well in the operational phase. Which makes the process fully iterative over time.

Model as a tool for predicting progress on main FEV KPIs

Five major energetic and environmental targets for the *FEV as a whole* are set in the REFORMERS Grant Agreement to be reached at the end of the project (from hereunder referenced as *main FEV KPI Targets*):

1. 75% CO2 reduction
2. Energy positivity
3. Self-sufficiency of 75%
4. Fossil fuel fade out
5. Diversification of gas supply

The KPIs can be directly or indirectly predicted from the output numbers of the model and will be validated by real-life measurements. The modelling tool is hierarchical layered and considers as much as possible the specific behaviour of deployed assets and their connections to the grid. The next paragraph discusses the set-up of the modelling tool in detail. However, for the calculation of the main FEV KPIs only the behaviour of the FEV as a whole is relevant, which means the specific behaviour of all the assets and areas in the valley are aggregated to perform the FEV KPI analysis. Figure 20 shows on the left side the aggregated energy balance of the FEV for the *Reference* scenario. On the right side the result of the main FEV KPI calculation is shown.



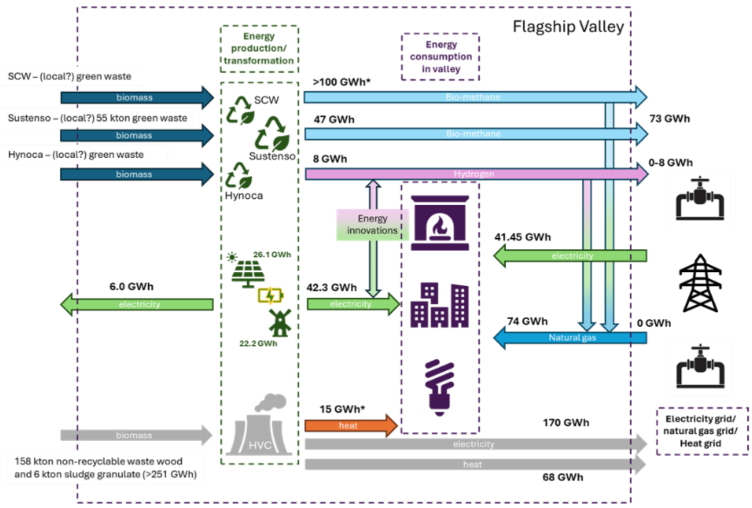
KPI name	Scen. output	EOP target
CO2 emissions	26,8 kton	6,7 kton
Energy positivity	-35 %	?
Prod-cons ratio (excl. biomass import)	160 %	286 %
Self sufficiency	25,5 %	75 %
Divers. gas supply	0 %	100 %
Ff fade out	0 %	100 %

Figure 20: Energy balance (left) and main FEV KPI calculation (right) for the *Reference* scenario in relation to the end of project (EOP) targets.

To reach the energetic and environmental targets at the end of the project, a number of sub targets are discussed. These sub targets are set based on planned energy innovations inside of the project consortium and expected behaviour of key stakeholders in the FEV. The main sub targets to achieve at the end of the project in 2028 are listed below:

- Yearly solar PV production increase with 12,9 GWh
- Yearly bio-methane production of 147 GWh
- Yearly hydrogen production from biomass of 8 GWh
- Installed battery capacity of 7 MWh
- New yearly hydrogen consumption of 250 MWh
- New district heating connections with a yearly consumption of 2 GWh
- Heat buffer of 200-300 MWh
- A series of smaller high flex projects (hybrid electrolysis, flow battery…)

These sub targets are the best estimation of the future at the start of the project and are adopted in the *Expected Developments* scenario. The results are shown in figure 21.



KPI name	Scen. output	EOP target
CO2 emissions	10,3 kton	6,7 kton
Energy positivity	-12 %	?
Prod-cons ratio (excl. biomass import)	270 %	286 %
Self sufficiency	76 %	75 %
Divers. gas supply	100 %	100 %
Ff fade out	100 %	100 %

Figure 21: Energy balance (left) and main FEV KPI calculation (right) for the *Expected developments* scenario

Figure 21 shows how the planned future production of bio-methane from biomass would be able to replace the current (fossil based) natural gas off take, which results in achieving main FEV KPIs 4 and 5 (diversification of gas supply and fossil fuel fade out respectively). Together with the additional solar PV installations and the planned battery investments, also FEV KPI 3 (self-sufficiency) is reached. Although strongly improved FEV KPI 1 (CO2 emission reduction) will not be 100% reached if based only upon the listed expected energy deployments. However, the results that are shown in figure 21, are based upon a conservative approach for the calculation of imported CO2 emissions from the electricity grid. Yet the total CO2 emissions will further decrease when adopting a more progressive CO2 intensity scenario for the electricity grid. In addition, the activation of flexibility in the FEV could have a positive impact on this KPI by further minimizing import of electricity or importing energy at moments the grid is producing more renewable energy. FEV KPI 2 (Energy positivity) is potentially not reached because the import of biomass for the production of hydrogen and bio-methane are taken along in the calculation of the energy balance. On the other hand, one could also consider captured energy that is then exported out of the FEV through outgoing goods and materials. This matter will be further elaborated in WP7.

Model methodology

Introduction

The modelling environment is built up to support multi-dimensional analysis of the whole flagship valley. Multi-dimensional means that different targets could be set (co2-emissions, costs, self-sufficiency) and different constraints could be adopted (new investment limitations, energy flow limits, energy consumption limits) for different energy carriers (electricity, heat, natural gas, biomethane, hydrogen) in one overarching simulation.

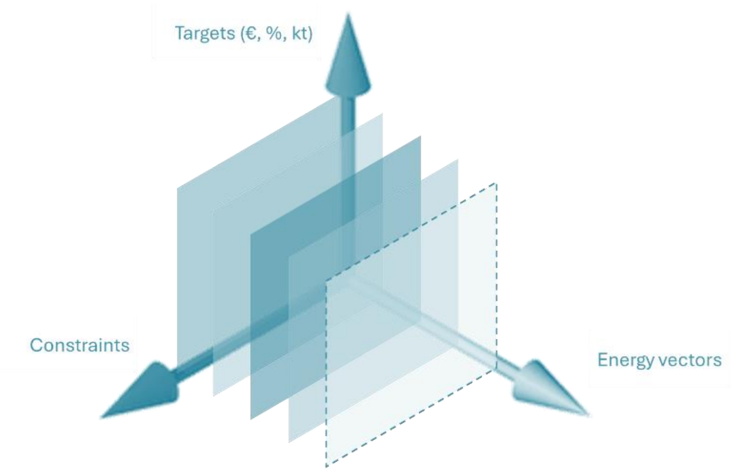


Figure 22: Multi-dimensional modelling environment

The model follows a hierarchical node-based methodology in which each node is a contained environment with specific needs and constraints in which different (new) assets can be modelled and optimized. Nodes can interact with the outside world (public grids for electricity and natural gas) or with other nodes. Energy flows in between nodes can be modelled based on real physical conditions (e.g. private heat grid with its specific capacity) or based on virtual trading schemes (e.g. energy sharing contracts).

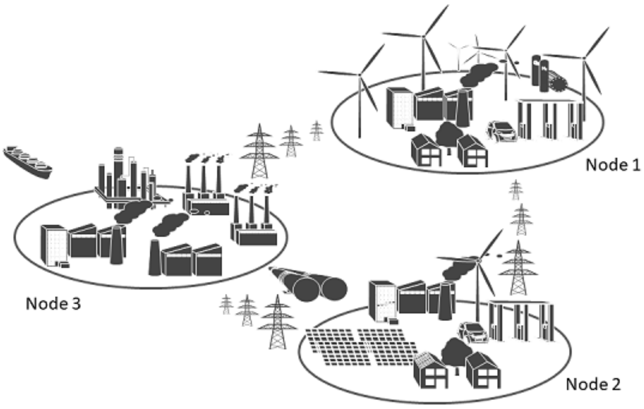


Figure 23: Hierarchial node based methodology

The model is adopted on a temporal basis and focuses on energy balance at each timestep (including storage possibilities). An hourly base is chosen as the optimal in between accuracy and calculation time. One full passed reference year is chosen as a relevant time period in order to include daily-, monthly- and seasonal variations for consumption, production and weather parameters.

2-level analysis

The valley is not homogeneous in function and characteristics but also not in terms of goals, needs and challenges. To be able to enforce different targets, strategies or needs for different parts of the energy valley, different geographical areas and subareas are defined as parts of the bigger valley. A (sub)area is – as described in chapter 2 - a conceptual group of consumers, prosumers and/or producers that can be logically grouped together based on their typology, based on their geographics or based on how and where they are integrated in the different energy grids. From modelling perspective each area could be a single or multi node model and will be first simulated and optimized separately. In a second iteration the areas will be combined to find mutually reinforcing strategies in the whole valley. Each area will then be defined as a node in the model with resulting time series data and some degrees of freedom. This results in two model levels named accordingly:

- Level 1: Area models (described below in separate paragraph)
- Level 2: FEV model (described below in separate paragraph)

Both the levels make use of the same three-layer model structure. The layers however are filled in slightly different for both levels which is explained in detail in the next paragraphs.

The final goal of the modelling is to be able to:

i. perform an impact analysis for different future energy system implementations,
ii. detect current and future bottlenecks in the energy system,
iii. built up strategies and pathways for the valley to reach specific targets, and

iv. get insights in how different energy innovations can reinforce each other.

Level 1: Area models

For each area or subarea as defined in chapter 2 a separate and individual model is built up. The energetic behavior of the subarea is excluded from the behavior of the parent area. The subarea models are positioned on the same level as the area models and coexist next to the other area models (figure 24).

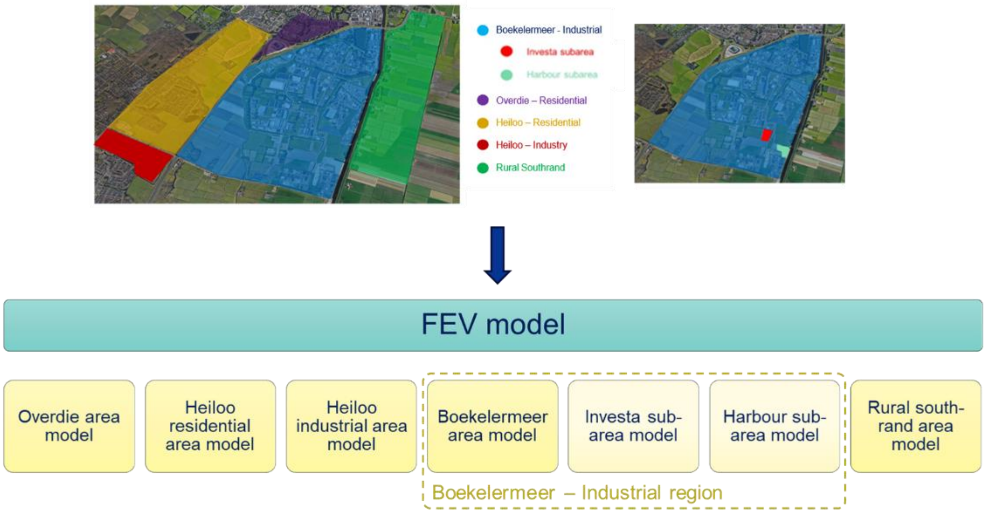


Figure 24: The flagship valley is split up in seven (sub-)area models.

The (sub-)area models describe the behaviour of the energy valley as a whole. There are 5 area models and 2 sub-area models, both the sub-areas are located inside the Boekelermeer Industrial region. The Boekelermeer area model describes the energy behaviour of the Boekelermeer area exluding all the energy behaviour of the Investa site and the harbour region. The Boekelermeer Business Park area as a whole is described by the combination of three area models: the Boekelermeer area model, the Investa subarea model and the harbour subarea model.

Each area model has hierarchical three-layer structure. The energy behavior of the area is split up into one or more nodes and all of the nodes hold one or more energy assets. The single-node or multi-node choice is typically driven by the way the modelled area is connected to the different energy grids. For this reason, the Investa subarea model would be single node (based on the single connection to the electric and gas grid) whereas energy transfer in between assets within the Investa subarea can still be tracked with the model. The Boekelermeer area model (which holds most of the impactful companies) will be multi-node, based on the connections to different feeders with different renewable production and different capacities. Energy (e.g. electricity and natural gas) transfers in between the nodes will have to go over the public grid or via new private grids.

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Main KPIs, targets and constraints (e.g. CO2 reduction, self-sufficiency…) are imposed on the overarching area model layer and thus one layer above the node layer.

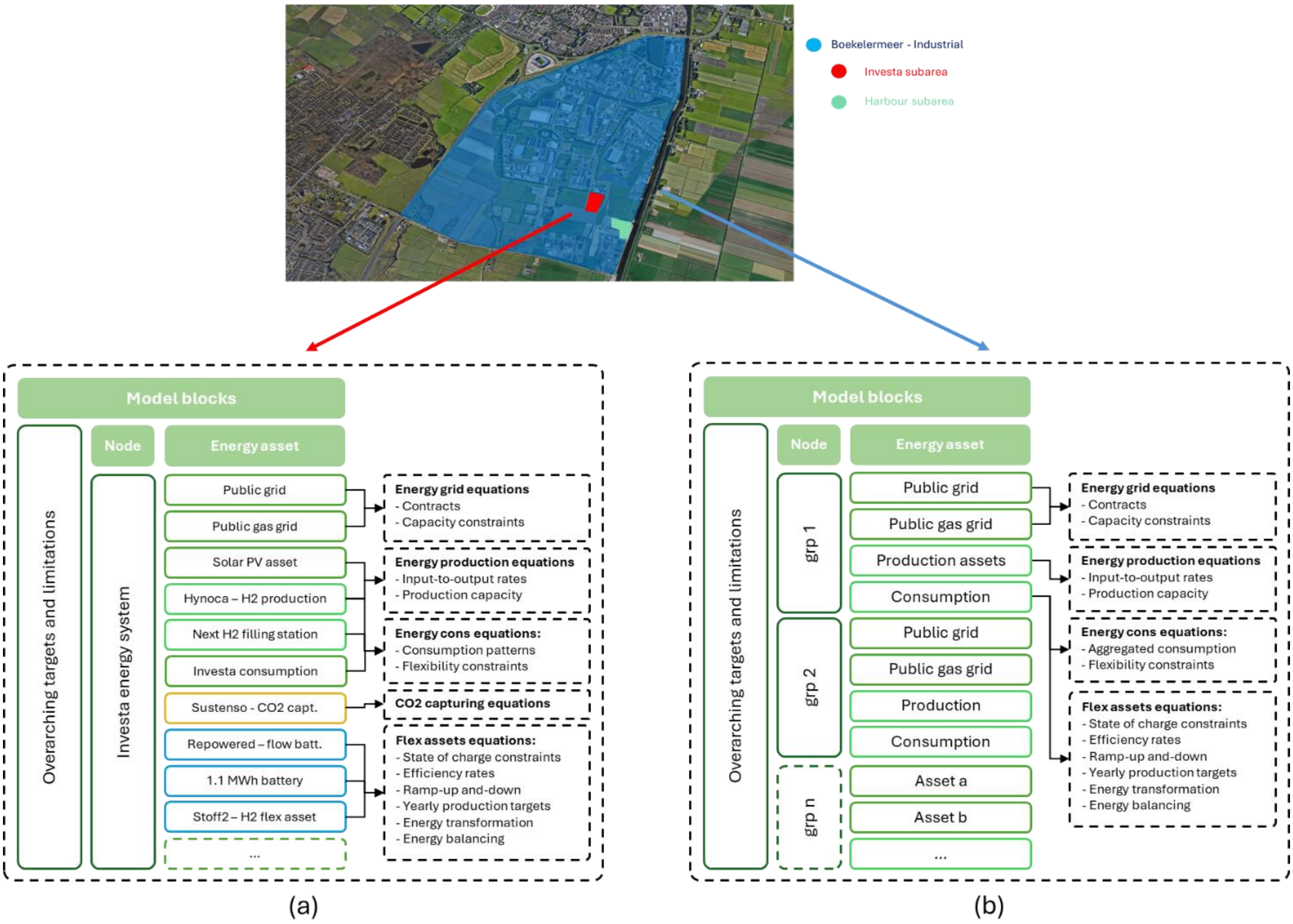

Figure 25 : Conceptual representation of the Investa subarea model (a) and the Boekelermeer area model (b).

Figure 25 shows two examples of how the (sub)areas are transformed to a group of conceptual (hierarchical) modelling blocks. For each area three layers of model blocks are used:

1. Energy asset layer: This is the lowest level of aggregation that is implemented in the model. Each energy asset represents a separated energy system. Examples of energy assets are: one specific consumer, one wind turbine, one solar PV installation or one specific energy innovation (e.g.: the flow battery inside the Investa site). HOn the other hand, an energy asset could also be a group of energy assets that can be logical aggregated based on their similar behaviour (e.g. multiple wind turbines, multiple non-flexible consumers, multiple similar home batteries that are operated with comparable settings). Each of the different types of energy assets (producers, consumers, flex assets) hold different equations whereas each type of energy asset

can hold a combination of production, consumption or flex behaviour. Known energy consumption or production profiles are also allocated to the corresponding asset block on this level.

2. Node layer: This layer groups energy assets inside an area that have a 'logical' connection and should be separated from other groups of assets inside the area. Typically, the reason for these groups comes from a similar connection to (public) energy grids. The different companies or other energy technologies inside the Boekelermeer Business Park area are for example connected to different medium voltage lines. Because each of these lines have their own capacity restrictions, it is useful to group the different consumers of this area in different nodes based on their electrical grid connections which allows to set physical grid-based constraints when simulating for example the impact of new renewable energy production plants.
   The Investa subarea model holds only one node because of the single electrical and natural gas grid connection. The node model will then regulate the internal energy flows and makes sure energy is transferred correctly in between the different energy assets (e.g. the solar production is first used inside of the local energy system before the surplus is injected into the public electricity grid).
3. Overarching system layer: Specific objectives or limitations for the area as a whole are set up in this highest-level modelling block. Examples of objectives that are set in this model block are CO2 reduction percentage, minimal total RES production or self-sufficiency targets. Limitations could include the maximal amount of natural gas usage.

Steps to set up the area models

i. create an abstract representation of each area or sub-area (into nodes and assets, see figure 25)
ii. define all the energy related asset inputs
    a. consumption profiles (measured if possible, otherwise use of Synthetic Load Profiles (SLP))
    b. production profiles (measured if possible, otherwise estimation based on weather parameters)
    c. limitations and characteristics of flexible assets (e.g. state of charge, ramping rates, minimal production limitations, efficiency rates…)
iii. define aera specific constraints (e.g. grid connection limit, max PV potential…)
iv. define area specific targets
    a. economic targets (e.g. low cost)
    b. sustainability targets (e.g. low CO2 emissions)
    c. grid impact targets (e.g. limited peak capacity)
    d. flexibility targets (e.g. grid flexibility/reserve markets capacity reservation)

General requirements

To deploy all the area models, there are specific requirements on the availability of data whereas the most important ones are listed below:

- Historical data for energy consumption for the different energy carriers on hourly basis for all the consumers in the area at the lowest possible aggregation level

- Historical data for energy production for the different energy carriers on hourly basis for all the producers in the area at the lowest possible aggregation level
- Estimations on change in consumption and production behavior in the near and mid-term future
- Weather data on hourly basis (under which but not exhaustive: temperature, wind speed, solar radiation)
- Constraints on energy flows
    - Electricity grid capacity limits
    - Physical layout of heat grid (where is the grid situated and who is connected)
    - Physical layout and flow limits of hydrogen pipelines
    - Biomethane injection potential in public natural gas grid
- Potential and location of possible future renewable energy sources (mainly wind turbines and solar PV installations)
- Technical characteristics (operational behavior) of planned energy innovations (electrolysers, batteries, biomethane/hydrogen production plants)

Next to data availability, the second requirement is a very clear framework and the degrees of freedom in which the simulation and optimization model needs to operate, the most important ones are listed below:

- Minimal conditions on self-consumption and/or self-sufficiency
- How to handle energy sharing / peer-to-peer trading
- Limitations on the use of external energy sources (natural gas, electricity, biomass,…)
- Targets for CO2 reduction and renewable energy production

Level 2: FEV model

The FEV model is the second level of modelling performed on the flagship valley. Once the area models have generated results, these results are inserted into the FEV model to perform an overarching FEV analysis.

The FEV model will use the exact same three-layer model as the area models, however the structure and implementation are different. Each area will be aggerated and handled as one separate node and the assets inside such a node does not reflect a real physical asset anymore, but the assets aggregated together describe the behaviour of the node area as a whole.

This set-up makes sure that the FEV model does not become too complex but is able to combine all the insights and results of the area models, and reroute the energy flows and flexibility in a such a way that it is optimal for the flagship valley without violating constraints imposed on the area level.

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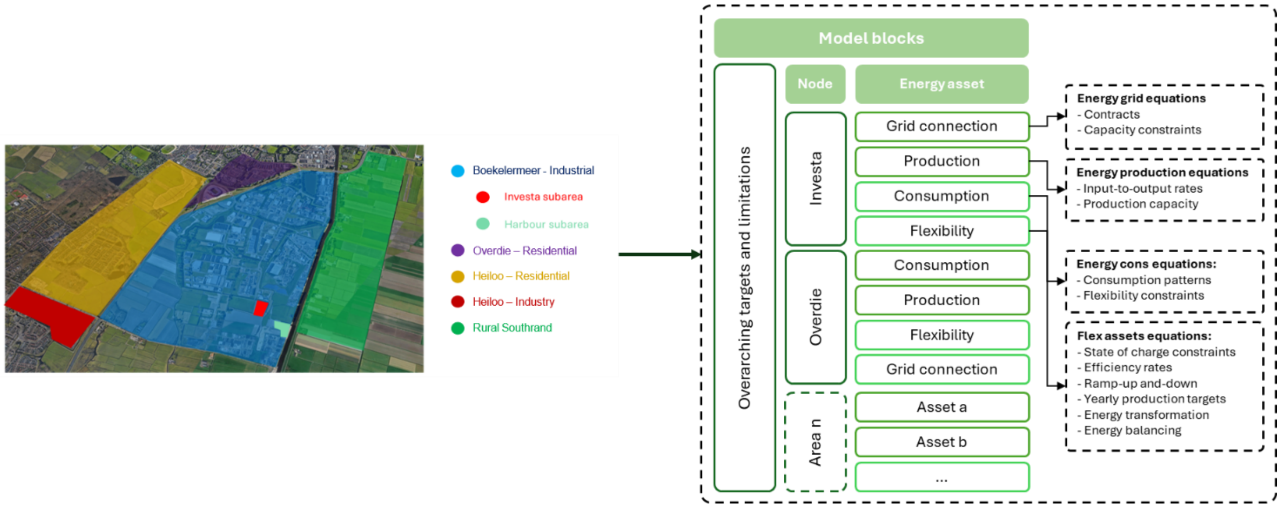

Figure 26 : model block representation for the FEV model.

Figure 26 shows how the whole flagship valley is represented in the three-layer model. Each area or sub-area will be represented by one node in the FEV model at the same level. The detailed use of the three layers is described below:

- Energy asset layer: The energy assets in this layer describe the aggregated behavior of different unique assets of the area models. Because the sizing and optimization of the operation of the assets is done by the area models, it is possible to aggregate the behavior of multiple assets into a limited amount of generic energy assets (e.g.: production, consumption, flexibility, grid connection)
- Node layer: In the FEV model, each area is represented by a single node. This separate node level enables the possibility of trading energy over the flagship valley as a whole. Whereas limitations on and costs for these energy flows can be still managed in the model. Not-used flexibility can also be activated based on the description of the flexibility in the lower energy asset layer and the needs of the other nodes.
- Overarching system layer: Specific objectives or limitations for the flagship valley as a whole are set-up in this highest-level modelling block. Examples of objectives that are set in this model block are CO2 reduction percentage, minimal total RES production or self-sufficiency targets. Limitations could include the maximal amount of natural gas usage.

Steps to set up the FEV model

i. Create abstract representation of the flagship valley as a whole: each area or sub-area will be defined as a node and a limited amount of basic energy assets inside each node will capture the energetic behavior of the area.
ii. Transform the output of the area models to the relevant input to the FEV model.
iii. Define global flagship constraints (e.g. fade out of natural gas consumption)
iv. Define global flagship targets

a. economic targets (e.g. low cost)
b. sustainability targets (e.g. low CO_2 emissions)
c. grid impact targets (e.g. limited peak capacity)
d. flexibility targets (e.g. grid flexibility/reserve markets capacity reservation)

General requirements

The FEV model can only be used after the different area models are complete and have generated their final results. The data requirements are thus the same data requirements that are needed for setting up the area models.

On top of this, there is also a need for an in-depth analysis of the technical and legal possibilities for energy trading over different parts of the energy valley and what the constraints, limitations and costs are for this. Based on this information, the model can be configured correctly and is able to perform the analysis that is needed for the FEV development and deployment process.

Model implementation and utilisation

The implementation of the model is an iterative process. This means that the data output of the model can be used to refine the design and operation of the different energy innovations and developments inside of the valley, while new steps in the roll out of such projects will feed new information to the model. This iterative process should make sure that progress on the energetic and environmental KPIs and targets for the FEV is continuously tracked. When deviations towards reaching the project goals are noticed, the model output will be used as a guiding tool for new decisions to ensure that all energy developments together are moving the valley in the right direction towards the project goals.

As discussed before, at the start of the project, both the reference scenario and the expected developments scenario are calculated. The expected developments scenario can be seen as a virtual point in the future with the current knowledge and the result should be as close as possible to the five main FEV KPIs. This scenario will be recalculated over time when new important information is available. The model also has the possibility to incorporate some degrees of freedom to find different pathways towards reaching the main projected FEV KPI values. The degrees of freedom are determined in different set-ups of the model. Examples of these set-ups are: the inclusion or exclusion of different new assets (Solar PV, Wind Turbines, Batteries, Heat Pumps), favor or limit capacities of specific technologies, allow or don't allow new connections to the heat grid, and a high-medium-low activation scenario of flexibility from existing consumers (e.g. cooling warehouses). Figure 27 shows this process in an abstract way: in 2024 a first simulation is executed which calculates the reference scenario as well as the first *expected developments* scenario. As an example, the investigated and modelled KPI is expected - with the knowledge at the time of modelling – not to achieve its targeted value, be it with by a small margin. In 2025 a new iteration of the model is executed and with the new information and planned developments at that time it is estimated that the targeted value of the KPI will be reached at the end of the project. Different uncertainty set-ups (typically a *low* and *high* scenario) are also calculated to see how this uncertainty towards the future would influence the researched KPI. A concrete example would be to calculate how the uncertainty on the future CO_2 intensity of the electrical grid would influence the FEV CO2 reduction target. For each of the five main FEV KPIs a graph like the one in Figure 27 will exist and each major modelling iteration a new curve will be added to the graphs.

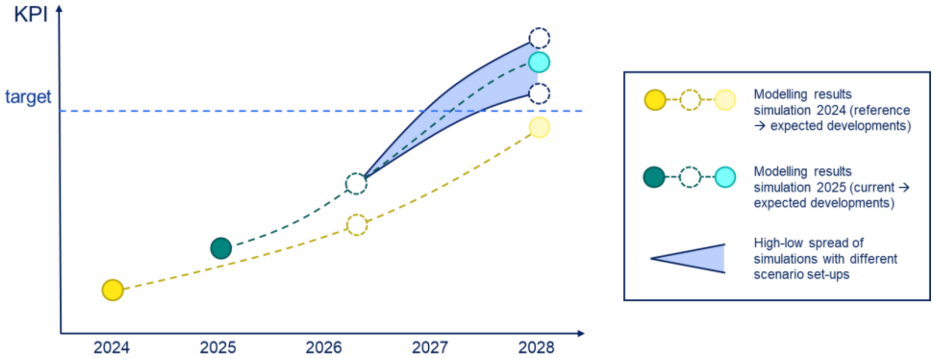

Figure 27 : conceptual example of the calculation of the current and expected future prognosis on the main FEV KPIs over time

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4. Energy Projects in the Flagship Energy Valley

In this chapter the projects in the different areas as well in the FEV as a whole are described. The developments in the areas will be given as well as the status of the projects per area. These conceptual implementation aspects per project will be described related to the 4 development phases of the implementation approach. In this way insight will be given in the implementation aspects, status and planning of the projects.

At the start of every paragraph the development characteristics are given in a table. With these characteristics it is made clear by the highlighted colour what kind of subfunctions are applicable and in what phase of development the project is.

First the consortium energy projects are introduced per area in sections 4.1 until 4.3. In section 4.4 the approach for alignment with the other energy projects is explained and in section 4.5 the modelling results of the FEV are discussed.

4.1. Boekelermeer Business Park

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

The Boekelermeer Business Park (in short Boekelrmeer) is characterized by its abundance in Renewable Energy Sources (RES), extensive natural gas infrastructure and gas assets, and the localization of Energy Innovation Park Alkmaar (EIPA).

Within REFORMERS the **explore phase** mainly focused on the current situation at Boekelermeer. The characteristics of the area are determined with focus on:

- Energy infrastructure
- Energy profiles
- Area plans
- Subsystem definitions

In general, the current situation is investigated. It is very clear that the local grid capacity does not meet the requirement (capacity need) of the energy innovations that are planned to be installed in the Boekelermeer area, and then specific on the Investa subsystem.

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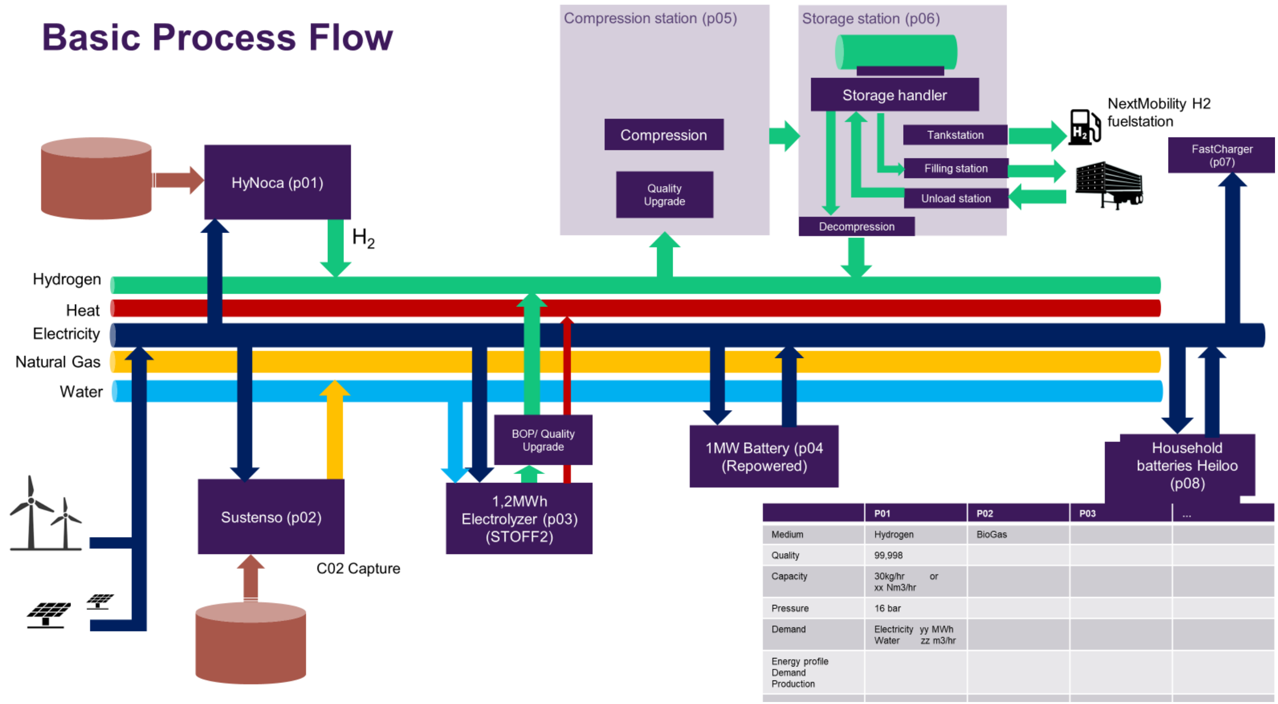
As a result of the Explore phase the basic elements of the FEV are identified and a schematic process flow model is setup. Main focus is elaborate on how different elements of the FEV are connected to each other and through which energy carrier. This has led to initial insights and conclusions, which served as a basis for further developing plans.



	P01	P02	P03	...
Medium	Hydrogen	BioGas		
Quality	99,998			
Capacity	30kg/hr or xx Nm3/hr			
Pressure	16 bar			
Demand	Electricity yy MWh Water zz m3/hr			
Energy profile Demand Production				

Figure 28: Basis connections of components in the FEV

Analyse & Design phase

By Analyzing the current situation a better understanding of the (energy related) issues is setup. By making schematic views on the coherence of the different subsystems and projects with their aim, a schematic overview is made which was build up starting with the Investa subsystem

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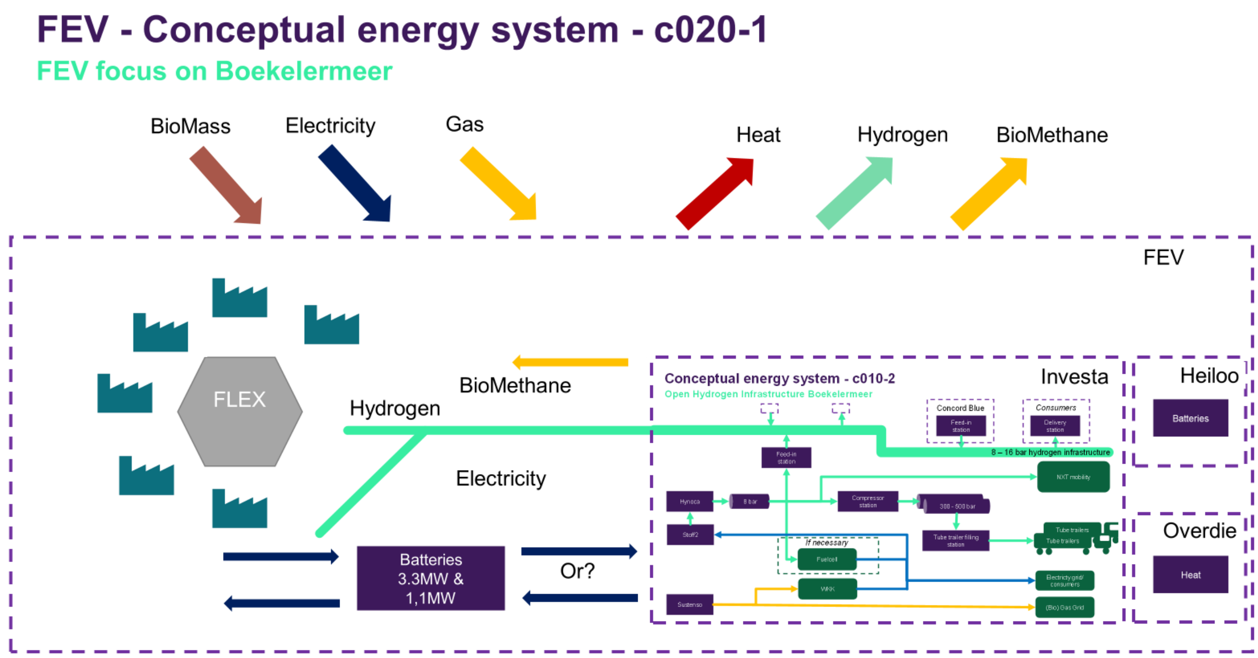

Figure 29: Conceptual Energy System Design of the FEV

For the physical implementation of the energy innovation projects and other projects it is of course necessary to understand the development path of the realization of the specific projects. In next paragraphs the development path of all the projects are described.

In the analyse and design phase also the first modelling activities are executed. Activities on modelling tools are described in chapter 3.

InVesta Subarea

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

Stichting InVesta is an expertise centre that stimulates and facilitates SME's in the development and marketing of innovative green technologies. It offers a test-, pilot and demonstration facilities and Utilities. Its focus lies on the entire value chain from biomass / waste and (green) electricity to product like BioMethane (Green Gas) and hydrogen, and their potential fields of application as depicted in the flow chart below.

Furthermore, InVesta is bringing together entrepreneurs, InVestors, Researchers, Education and governmental bodies to accelerate the innovative projects.

To house SMEs in the REFORMERS project, InVesta will open up and further expand their test and infrastructural facilities for pilot and demonstration projects. Conversion technologies such as G2P, G2H, P2H, G2H, and P2G will be demonstrated and utilized to balance the local energy system (VLES) and with it the overall energy system of the FEV.

General description of developments at InVesta area

Investa is located at one of the locations around the Gas Storage Bergermeer. In total the plot of InVesta is around 8.000 m^2. At this plot a building with office facilities and connected indoor workshop are available for the SME's or projects. Furthermore, InVesta has 6000 m^2 outside space available for larger demonstration activities. Very important for the SMEs is the presence of an umbrella permit at InVesta, which allows a quick start of the demonstration activity.

Assumptions to be made

At this moment InVesta has no grid connection to the electricity network of Liander. This is due to the congestion problem that originated in the Boekelermeer. Until 2028, insufficient network capacity will be available to supply InVesta with electricity. As an interim solution, InVesta is still running on the construction power, which is around 50 kW and sufficient for the energy supply for the office facilities and small (little electricity-using) demonstrations that are now taking place within InVesta. In addition, InVesta has its own generation installation consisting of approximately 120 PV and PVT panels with a total capacity of approximately 60 kWp.

Future energy usage/ profiles

InVesta has applied to Liander for an electricity connection of 1.7 MVA. This is sufficient for all planned demos that have currently registered with InVesta for location.

Interaction with other subsystems

InVesta has arranged a connection to Liander's natural gas network. This connection, with a contracted capacity of approximately 800 m3/hour, is now used by Sustenso to feed the produced gas into the network.

As the HVC's district heating network is also present, it is possible for new companies to connect to this infrastructure as well. Until now InVesta is not connected to it yet.

What has already been researched (interaction batteries/ GP Groot; Taqa)

Within other R&D programs such as Kansen voor West 'Duurzame Moleculen' and Pocityf, the construction of hydrogen infrastructure and the installation of small building-related batteries have already been investigated. Both systems have not been realized due to the congestion problem.

The local InVesta energy system

An energy management system is in place to monitor electricity generation. This system, called Ferro Amp, continuously monitors the electricity produced, supplied and purchased.

In addition to the energy infrastructure that InVesta has realized itself, the possibility of a Virtual Local Energy System (VLES) has already been investigated in an earlier phase. However, due to the high demand for electricity at InVesta, this has been deemed difficult to achieve. This has led to a separate VLES for the Harbour area part based on the residual capacity of the NXT filling station and a separate approach for InVesta.

For InVesta itself, we are working on a step-by-step expansion of capacity. This will look at the possible generation of electricity from companies based on gasification technology in combination with the installation of batteries from the REFORMERS project and as a robust solution the use of generators based on green gas and, if possible, hydrogen.

In concrete terms, this means that as a first step, InVesta will realize the original grid connection in Q1-2025. However, with a much lower delivery capacity similar to the current construction power connection, which can then be expanded step by step in the coming years, internally at InVesta or via a VLES solution.

Possible future Grid operator development/ product that can help setting up the energy system at InVesta:

- Max capacity constraint contracts
- GDS (closed distribution system)
- ..

Within the context of REFORMERS demo projects are setup at InVesta area which has an impact on energy usage and thus the energy system of InVesta. These projects Hynoca; Stoff2; Sustenso and Flow battery are separately described in following paragraphs.

Hynoca

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain

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Infrastructure	

General introduction

The HYNOCA ALKMAAR project located in the Investa Expertise Centre for biomass gasification, will produce Hydrogen and biochar from biomass feedstock.

The project will have an hourly input of biomass of 3.000 kWh and after three years the project will have an hourly output of 30 kg of 5.0 quality of hydrogen, 170 kg of biochar and potentially a limited quantity of heat and green CO_2. In the first three years, there will be a ramp-up toward full operations. The project is anticipated to reach Financial Close end 2024.

With the environmental permit in place, biomass contracted, hydrogen offtake pré-agreement and multiple potential biochar offtakers the project is ready to go.

Goal

The hydrogen will be supplied to GP Groot, a client on the Investa site or Rijngas or equivalent off-taker.

The Biochar will be supplied to dedicated off takers in accordance with its composition and quality, depending on the definitive feedstock of the project.

The purpose of this project is to show the feasibility of producing Hydrogen from Biomass and avoiding dependency to the electric grid.

Explore phase

Overall process description/ basic elements of the project:

HYNOCA® allows the conversion of biomass and organic inputs into high quality, very rich synthesis gas (HYPERGAS®). Hypergas® has a higher energy LCV (Lower Calorific Value) than almost all commercial gasifiers, H2S less than 10 ppm, tar less than 10 ppm.

The first step for HYNOCA® is the thermolysis of the organic matter in the absence of oxygen, followed by cracking at very high temperature.

The thermolysis stage enables the natural cycle for the transformation of biomass into fossil fuels to be reproduced in a few minutes, enabling more than 99% of the solid inorganic elements (metals and minerals) to be separated.

This thermolysis stage produces thermolysis vapors and a concentration of carbon and solid inorganic elements (particularly metals and minerals), which can be used for energy recovery (average LHV 8 kWh/kg), agronomic recovery (biochar) and carbon sequestration in a non-biodegradable and dehydrated form.

The thermolysis gas, which is free of ash and mineral or metallic dust, undergoes a very high temperature cracking stage followed by gas washing. This last stage is based on conventional technologies used in industrial gas scrubbing.

The gases are then cleaned of undesirable elements by several treatment stages integrating, at the date of this document, a water scrubbing, a solvent scrubbing, an activated carbon bed, a hydrogenation reactor, a zinc oxide bed, a WGSR unit (water gas shift reaction) and finally a purification module by a PSA (Pressure Swing Adsorber), specifically adapted for the process, allowing the production of pure hydrogen.

General Requirements:

The technical data below are provided for the entire installation and characterize the expected nominal production and consumption:

Nominal biomass flow rate	1,000kg/h;
Storage time in days	3 days;
Indicative nominal biochar production	170 kg/h
(depending on the quality and type of biomass);	
Nominal hydrogen production	30 kg/h;
Hydrogen outlet pressure (in relative bar or effective bar)	30 bar(g)bar effective;
Nominal electrical power of auxiliary consumption	~350 kWel;
Installed electrical power	900 kWel;
Estimated raw water consumption	265 l/h.

Analyse & Design phase

In this phase the high-level system design was made, as shown in the figure below.

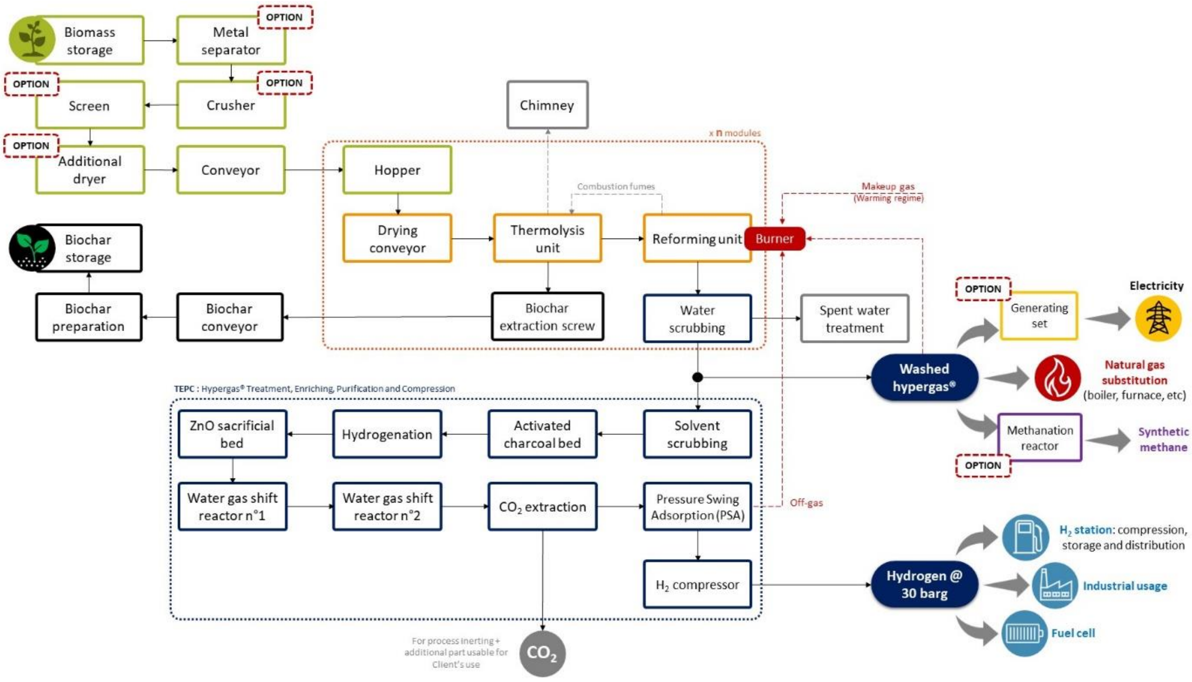


Figure 30 : Schematic overview of Hynoca system

Input: 8000 tons of biomass per year

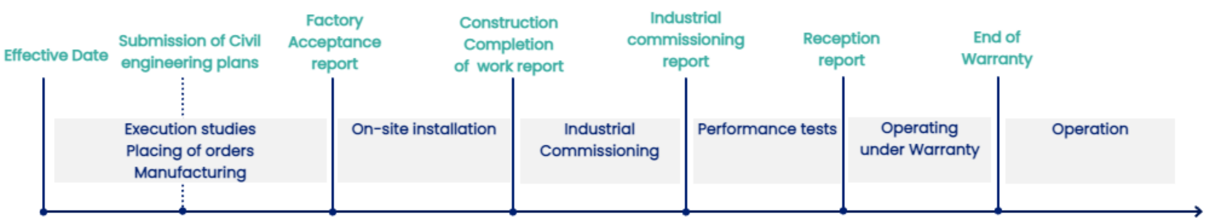
Output: 240 t of Hydrogen per year

Control principle: Automated operations, remote supervision of the installation, with operating data reported to the Haffner Energy unit.

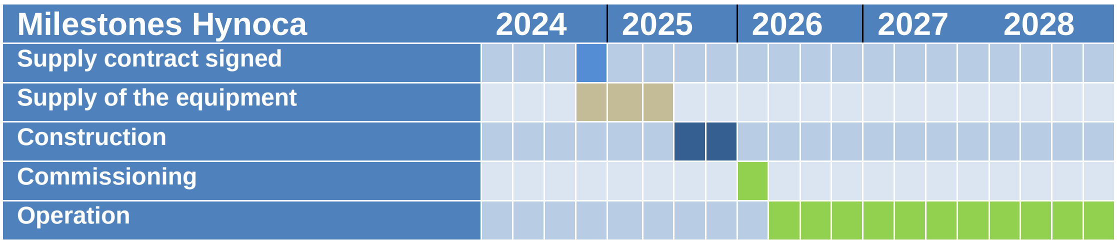
Construct phase

The Planning (milestones) of crucial aspects of realizing the system are described in this paragraph

The Effective date is the date of signature of the energy supply contract which launches the order of the equipment.



Milestone planning



= Explore = Analyse & Design = Construct = Operation & Maintenance

Operation & Maintainance

Operations will be managed by a supervisor and two operators. For the first two years of operation, Haffner Energy offers to handle operations and guarantee the installation availability. Once the installation will have proven stable operations and performances, the O&M contract will be taken in charge by the company Stork.

The operation team will be in charge of:

- the Supply of energy and utilities required for the operation of equipment, such as biomass and electricity.

- Operation and "routine" maintenance of facilities corresponding to maintenance levels 1 to 3e- Major overhauls" are maintenance level 4 and 5 operations involving dismantling. They may involve the replacement of spare parts or renewals, and this level of Maintenance will be subcontracted to the supplier Haffner Energy.

Maintenance consists of two parts, preventive and corrective, and the interventions (corrective and preventive) are characterised by the 5 levels of the FD X60000 standard.

4.1.1.2 Stoff2

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

STOFF2 develops and builds a new type of electrolyzers for the production of green hydrogen. The Zinc Zwischenschritt Electrolysis (ZZE) combines hydrogen production and energy storage function in one, and thus offer the perfect solution for the efficient grid-serving use of renewable energies. The ZZE uses renewable energy e.g. solar and wind power in phases of high energy production and low electricity prices. The energy is stored in the system as solid zinc, and can be stored for several minutes, hours or days. If energy is required, the system can be discharged at any time and hydrogen is generated. The system thus combines the properties of a energy storrage and an electrolyzer.

Goal

Within REFORMERS, we aim to have a functional field test and combine our system with other technologies along the hydrogen value chain. The ZZE reduces the load on the electricity grid and provides security of hydro-gen supply to H2 customers. Our main targets for the project are validation of technical key figures such as efficiency, charging and discharging ramps, storage losses, maintenance requirements, safety concept and interoperability with electricity and gas grid operators (TRL 6 → TRL 7).

Explore phase

Overall process description/ basic elements of the project are described.

The Basic elements of the project are two 20-feet-container-systems (structure like the following picture) and one extra container for control systems and probably the storage for our destilled IBC-water tanks.

Figure 31: Stoff2 system concept

In the upper container is the cell technology, which functions both as a storage unit and as an electrolyzer. The lower container contains all the electronics and circuitry, as well as the control system. We aim to install two ZZE systems e.g. a total of four 20ft containers at Investa. In addition, an extra container will be standing next to the two container-systems and will contain the destilled IBC-water tanks, which is necessary for the hole process. The main functions of the system are electrical charging, energy storage and hydrogen discharging.

The charging process begins when electrical energy is supplied to the system, with a minimum of 50 kW and a maximum of 360 kW for each ZZE system. Charging capacity can rise to a maximum of 720 kW to charge both ZZE-systems at the same time. During the charging process, oxygen is produced internally, which is removed from the system via an internal gas separation system and released into the environment. The charging process can be stopped and continued at any time. Due to the cell technology, it is recommended not to run partial cycles and to alternate between charging and discharging.

When the system is fully charged, the storage process begins in which the supplied electrical energy is stored in the system in the form of solid zinc. Storage can take place over several hours or days, and the system has a low self-discharge rate which has not yet been precisely defined.

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The discharging process is triggered by the control system. The stored energy is primarily released as hydrogen, the small fraction of electrical energy is discarded together with the waste heat due to the low efficiency in a small system context. During the discharging process, the zinc dissolves internally and hydrogen is produced and is led out of the system through an internal gas separation. The processed amount of water per cycle needs to refill as DI-water. The hydrogen produced will most probably be fed to the Hynoca plant, where it will be combined with their hydrogen. There it is dried, purified and compressed by their system.

The entire system requires approximately 40 - 50 square meters of space and should be placed close to Hynoca to keep the connection to their system as short as possible. The exact alignment must be agreed with InVesta.

General Requirements:

- Foundation
  To set up and run the system as descripted above, some general requirements are necessary. Foundations for the containers are required to set up the ZZE container-systems (two 20 ft container) and must be able to withstand a load of around 60 tons.

- Electricity connection
  To run and test the system, a electricity connection is necessary. The minimum charging power is 50 kW, if both containers will be charged a power of 720 kW is needed.

- Hydrogen connection
  During discharging hydrogen will be generated. We plan to connect our system with the system of Hynoca to run jointly use washing, cleaning and compression of hydrogen. To connect both system, a hydrogen pipeline to the plant of Hynoca is necessary.

- Water connection
  A water connection with distilled water is necessary for the entire process of the system.

- Heat connection
  Theoretically, it is possible to extract thermal energy from the system during discharge and feed it into a dedicated heat network. However, this is not realized in the REFORMERS project.

Analyse & Design phase

Input: 50 – 720 kW electricity, 420 l DI-water per cycle for both ZZE container systems

Output: 1,06 – 2,11 kg/h hydrogen (for 12-24h)

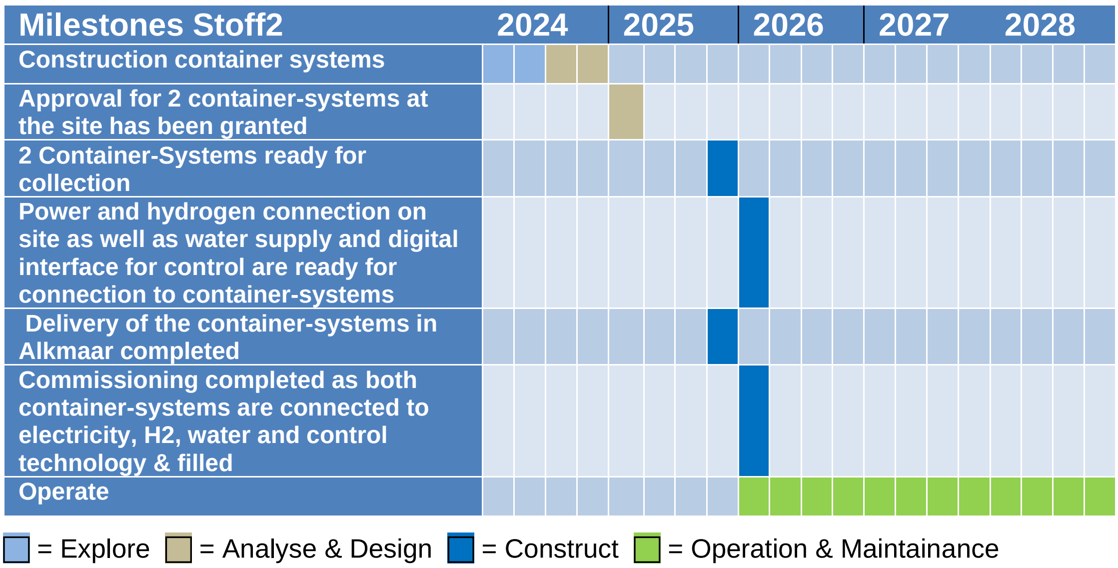
Control principle: If grid capacity is available at the Investa site the ZZE-containers charge for 4-8h per cycle when electricity prices are low. We expect one cycle per day. If no grid capacity is available, we hope to be able to use local electricity generation in order to conduct the necessary tests with our system.

Due to the stage of development, no precise statements can yet be made about the control of the system. However, it can be assumed that data such as state of charge, charging and discharging voltage and current as well as temperature, pressure and fill level will be passed on to monitor and control the ZZE-System. The four system states, charge, idle, discharge and error are displayed. The two states of charging and discharging remain as described above. The idle state occurs when either no charging or discharging takes place or the state is changed from charging to discharging or vice versa. The error state occurs in the event of a system error and stops the process until the error has been rectified.

Construct phase

Planning (milestones) of crucial aspects of realizing the system:

Milestone planning



Assumptions to be made

- Construction of the container-systems according to current internal STOFF2 schedule successful
- Function test of pilots at STOFF2 manufacturing site successful
- Required electricity capacity and supply is available

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- Hydrogen supply with Hynoca is possibleInterface between container-systems and the REFORMERS control system can be implemented

Operation & Maintenance

Operations of both ZZE-container systems will be organised jointly with project partners in 2025. Maintenance of the system is covered by STOFF2 engineers during the testing period.

4.1.1.3 Sustenso Boekelermeer CO2

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

Sustenso Boekelermeer CO2 is a Boekelermeer-based company that focuses on increasing the circularity and sustainability of *any* process that produces CO2. Within the scope of the REFORMERS project, Sustenso Boekelermeer CO2 is open to collaborate with all the partners within the REFORMERS consortium to implement its technology to their initiatives.

Goal

For photosynthetic organisms like plants and many bacterial species (here for convenience called micro-algae) CO2 can serve as a carbon source for growth. These organisms use photon energy for the chemical reduction of CO2 to cell constituents like fatty acids, proteins and sugars. Like for all living organisms, nitrogen, phosphate and sulfur are needed for growth.

Thus, the *Biological* Carbon Capturing and Application (*B*CCA) concept of Sustenso Boekelermeer CO_2 can chemically be presented as:

CO2 + light +(“N,P,S”) $\longrightarrow$ micro-algae

Many micro-algae species are considered as healthy food food constituents (the New Food) due to their high content of proteins, omega-fatty acids, vitamins and minerals. In addition, they contain vaulable pigments that serve as antioxidants.

Sustenso Boekelermeer CO_2 aims to optimize above process with respect to sustainability and circularity:

- CO_2 as waste product from any industrial process is used as input
- Light is provided by the sun with addition of LED light
- All other nutrients are extracted from the digestate produced by the Engie plant waste digester at the Boekelermeer (Diamantweg 39).

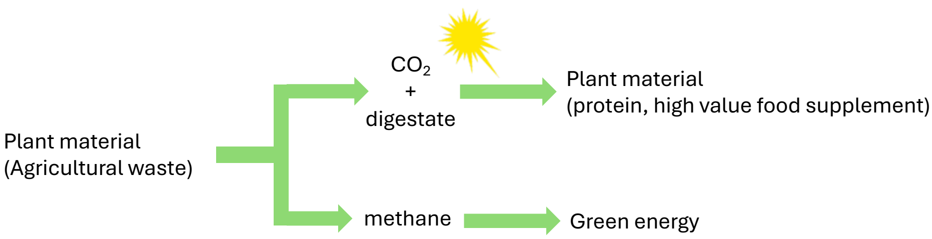


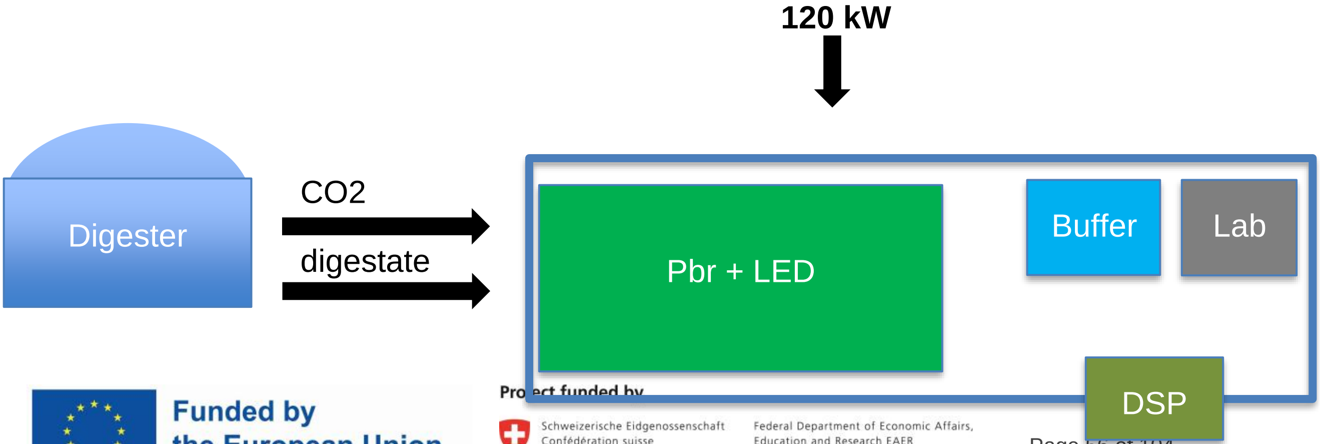
Figure 32: Sustense CO2 system principle

General Requirements:

- Input of CO2 (Engie's Digester, Diamantweg 39)
- Input of digestate (Engie's Digester, Diamantweg 39)
- Green house (1500 m2) (Engie's Digester, Diamantweg 39/InVesta) containing:
  1. Photobioreactor (pbr)
  2. Buffertanks nutrients
  3. RO equipment
  4. Down Stream Processing equipment (centrifuge, sieves) (DSP)
  5. Analytical/Microbiological laboratory (30 m2)
- Energy 120 kW

System setup: Schematic overview

Engie   Greenhouse Sustenso Boekelermeer CO2



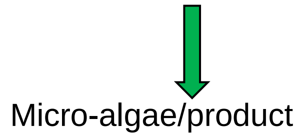


Figure 33: Sustense CO2 schematic system design

Input: CO_2, digestate, 120 kW

Output: proteins, fatty acids, vitamins, whole (food allowed) micro-algae

Control principle: chemical/microbiological analysis. Data logging, webcam.

Construct phase

Milestone planning

Milestones Sustenso CO2	2024	2025	2026	2027	2028
Preparation, design, contracts					
Setting up pilot plant at final location					
experimental, optimization, testing various strains, testing dsp protocols, testing purity of products					
construction green house, installation pbr					
demoplant (1500 m2) operational, testing pilot plant results at demo level					
Operate					

= Explore = Analyse & Design = Construct = Operation & Maintainance

Operation & Maintenance

To be defined.

4.1.1.4 Flow Battery

Energy System Function	Development phase
Production	Explore

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Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

Currently, most battery systems installed in the Netherlands are rated at 1C or 0.5C, primarily designed for short-term energy trading and ancillary services such as FCR. However, as the energy landscape evolves towards greater reliance on renewable sources, there is a growing need for storage solutions that can manage energy over longer periods. Flow batteries, with their capacity to store more energy relative to their power, compared to conventional lithium-ion (Li-ion) batteries, present a promising solution for (local) energy balancing over extended durations. Unlike Li-ion batteries, which are typically optimized for high power and short discharge cycles, flow batteries offer the advantage of scalability in energy capacity, making them suitable for applications that require sustained energy output.

Goal:

The primary goal of this project is to demonstrate the energetic impact of flow batteries within the context of the REFORMERS project and explore viable business models that could be applied to such systems. This involves not only technical validation but also an analysis of economic feasibility in the energy market.

Explore phase

- **Installation Prerequisite**: To initiate the system design and tender process, it must be clear that sufficient connection capacity will be available at the installation site.

- **Tender Process**: The tender process must be launched on time to ensure project timelines are met. It is crucial that the tender attracts a sufficient number of qualified parties to enable competitive bidding.

Analyse & Design phase

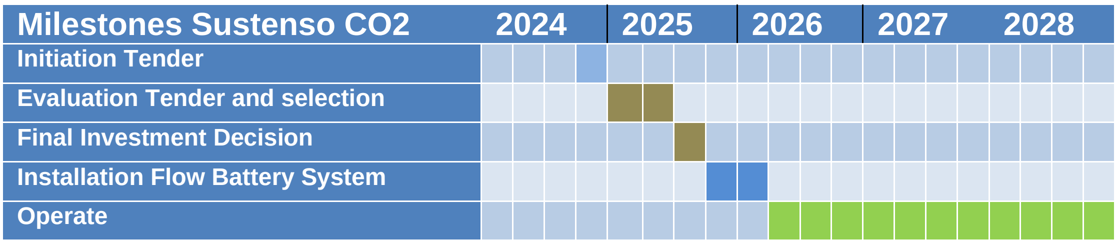
- **System Specifications**: The flow battery will be designed with a rated power in the range of 100 to 200 kW and a capacity of 1 MWh. The system sizing must align with the allocated budget as proposed.

- **Control Philosophy**: The flow battery will be operated using the Repowered Smart Energy Platform. It will be controlled in conjunction with other energy innovations in the Renewable Energy Valley using a layered control principle, prioritizing self-consumption first and then participating in energy market trading to optimize financial returns and grid stability.

Construct phase

The construction phase will focus on the detailed planning and execution of the flow battery system. Key milestones are visbible in th etabel below:

Milestone planning



- = Explore = Analyse & Design = Construct = Operation & Maintenance

Operation & Maintenance

The main operation of the flow battery, in line with the overall project goals, will be managed through the Repowered Smart Energy Platform, whereas local control is taken care of by WithTheGrid using their Teleport gateway.

Maintenance activities are not the primary focus at this stage of the project and will be addressed in a subsequent phase.

Harbour subarea – 3,3 MW battery

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General description of developments at Harbour subarea

At the recent newly developed industrial “Harbour subarea” some new companies will be located. Due to grid congestion, companies will only invest if a grid connection can be assured. To meet this issue, the municipality of Alkmaar will install a 3,3 MW battery to fill in the gap for energy demand. Also the way of how to connect companies to infrastructure is investigated in the development of the Harbour subarea.

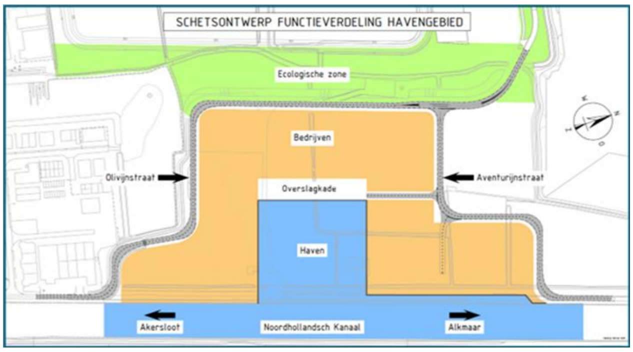


Figure 34: Boekelermeer Harbour area development

By using a local energy organisation “Boekelermeernet B.V.” grid development, energy management and value proposition come together at the Harbour subarea itself. tThe local EMS (Energy Management System) and the battery, as part of the local energy system, is one of the energy innovations of the REFORMERS project. The local energy system and how this will be implemented as part of the whole FEV, is described in chapter 5.

In the figure below a schematic view on the Harbour energy system is presented.

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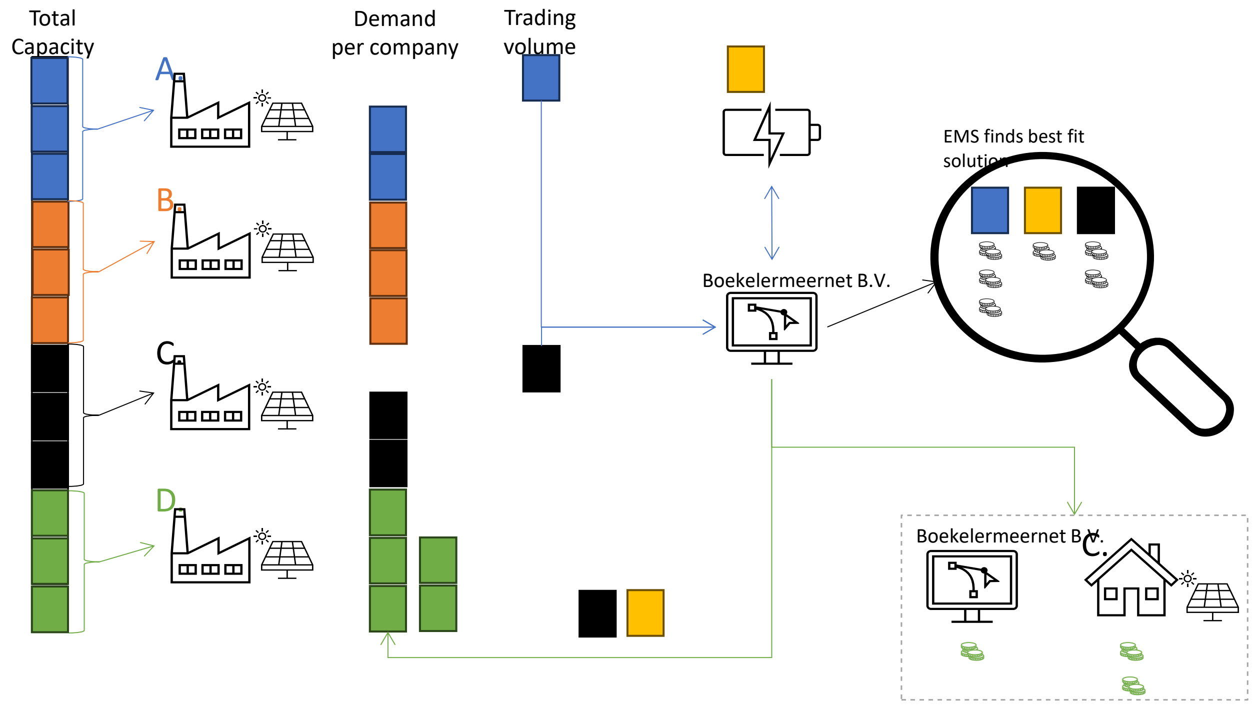


Figure 35: Harbour area energy system setup

When the grid operator Liander is not able to realize the infrastructure, the municipality itself realizes the power network in the port area. This concerns both the hardware (cables, pipes, battery and all other materials required) and the software (control systems). The network is operated by the joint companies located in the port area. A separate organization is being set up for this purpose: the Boekelermeernet energy cooperative.

The future companies in the Harbour area must make agreements with each other about dividing the available transport capacity. By installing a battery, surpluses and shortages on energy can be better absorbed.Assumptions to be made for the Harbour area:

- 6-7 commercial lots means 6 – 7 connections to the energy infrastructure
- equal right to fixed energy capacity, graduated issuance of flexible capacity
- 3,3 MWh/1,65 MW battery
- technical design in accordance with the requirements of the grid operator (Liander)

The connection to the infrastructure is investigated and depends on possibilities within the current regulatory framework.

Possibilities within current legislation and regulations:

- Direct line (DL): can only be used immediately after reporting to ACM.
- Closed Distribution System (GDS): use only after ACM exemption (procedural time approx. 1 year).

- Capacity Limiting Contract (CBC)

Aspects to keep in mind on the above options:

- Independent of grid operator Liander, means to respect the limitations of the connection to the grid
- System anticipates expansions in the new Dutch Energy Act (expected for 2024)

Construct phase

The Battery system of 3.3 MW will be realized in the Harbour area. It is most likely be build up by two containers. The local energy management system will be used for operations.

Figure 36: Impression of the battery system

Milestone planning

Milestones Harbour Subarea	2024				2025				2026				2027				2028			
GoNoGo decision																				
Tender battery by Municipality																				
Realisation of infrastructure and fist connections based on direct line																				
Battery implementation, scale up to GDS and extra 2 connections																				
Extend connections of companies																				
Operate																				

= Explore = Analyse & Design = Construct = Operation & Maintenance

Operation&Maintenance

To be defined.

Project NXT mobility: Battery integrated fast charger

System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

The energy transition is in full swing, which means the demand for new (fast) charging points is also increasing. Due to the limited capacity of the power grid, this demand cannot be met in many locations. This is an increasing problem that will not be solved for the time being. It is also a fact in the Boekelermeer

NXT Mobility will install an Energy ChargePost and ChargeBox at their premises. This makies ultra-fast charging of up to 320kW possible with just a small-scale connection.

Goal

The aim is to realise a battery-integrated fast charger for heavy-duty battery electric vehicles (BEV) at the NXT mobility premises.

Figure 37: NXT mobility battery-integrated charger system setup

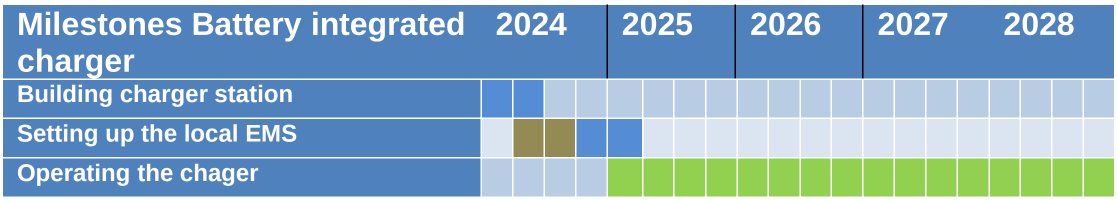
Analyse & Design phase

The Charger technology is ready. Setting up the local EMS has now the focus

Figure 38: Realized charger at NXT Mobility

Construct phase

Milestone planning



= Explore = Analyse & Design = Construct = Operation & Maintenance

Operation & Maintenance

NXT Mobilty will operate the charger as part of their filling station at the Boekelermeer.

Heat Buffer

Funded by the European Union
Project funded by
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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State Secretariat for Education, Research and Innovation SERI

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

HVC has, within the Boekelermeer, amongst others a biomass energy plant in which steam is produced. This steam can be used to produce electricity via a steam turbine/generator and/or to produce heat for the district heating grid. HVC intends to build a heat buffer with 2 primary goals:

1) Disconnect the heat production (by the Bio energy plant) from the heat demand from the district heating grid. By doing so HVC has the flexibility to produce either more electricity or more heat instead of following the heat demand pattern from the district heating grid. By doing so HVC can produce more electricity when needed by the grid and support the unbalance market
2) Being able to supply peak heat demand and serve as a back-up heat source for the Boekelermeer/Alkmaar heat grid

Explore phase

Hot water of 120oC will be stored in a pressurized heat buffer of 2000~4000m3. The heat to produce the hot water is being produced in the biomass energy plant. From this heat buffer hot water is being pumped into the district heating grid. By mixing water from the heat buffer with relative cold water from the cold return string of the district heating grid the optimized temperature for the district heating grid can be produced.

The Heat buffer will be filled with hot water at times that electricity demand and/or electricity prices are low. Hot water from the buffer will be extracted when electricity demand is high or when peak heat capacity is needed. Analyse & Design

Analyse & Design phase

System setup: Steam from the energy plants is being transferred to the district heating grid via heat exchangers. This heat is being used to heat up the cold return water from the district heating grid to the right temperature. The heat buffer will be placed process wise alongside these heat exchangers. A schematic view of the heat buffer and the system is depicted in the underneath figures

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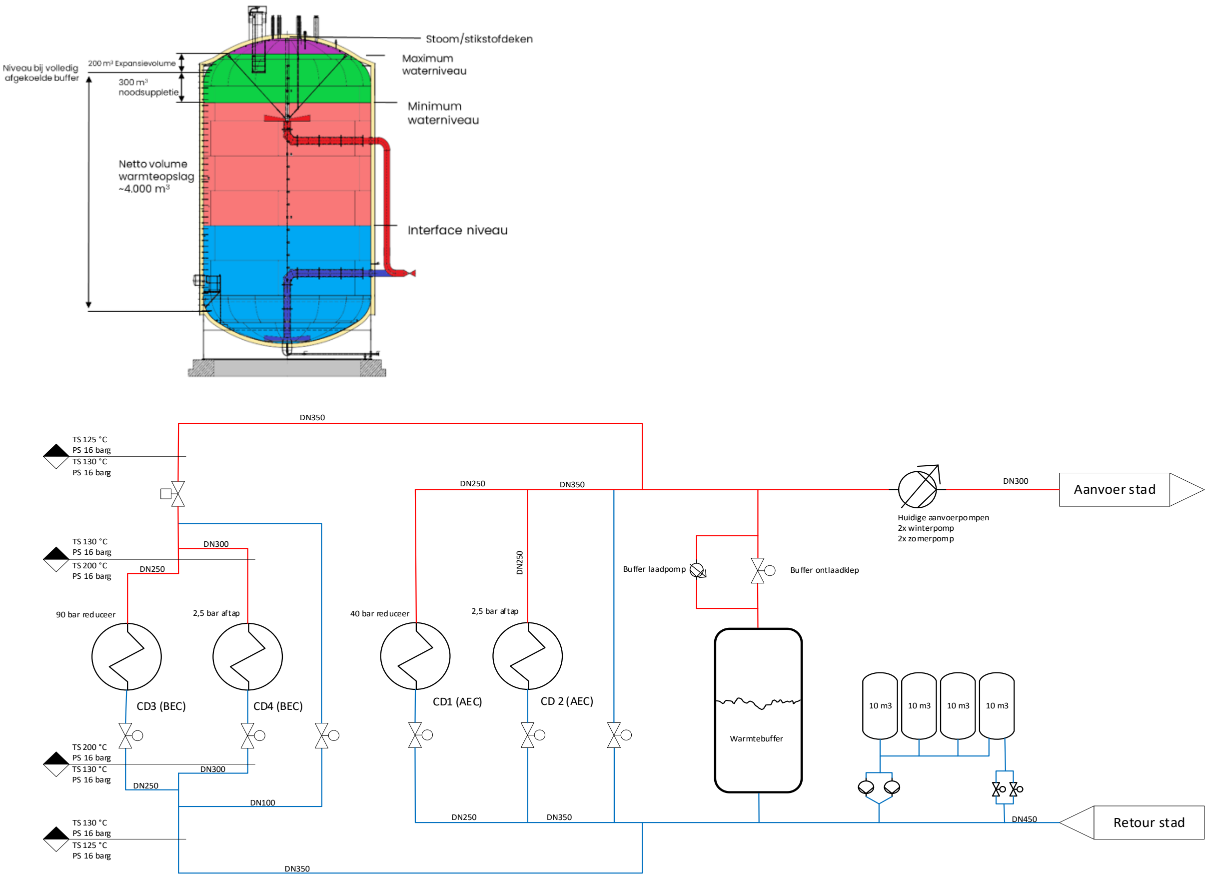


Figure 39: Schematic design of the Heat buffer

In underneath picture the in-/output parameters and control mechanisms for the heat buffer have been described:

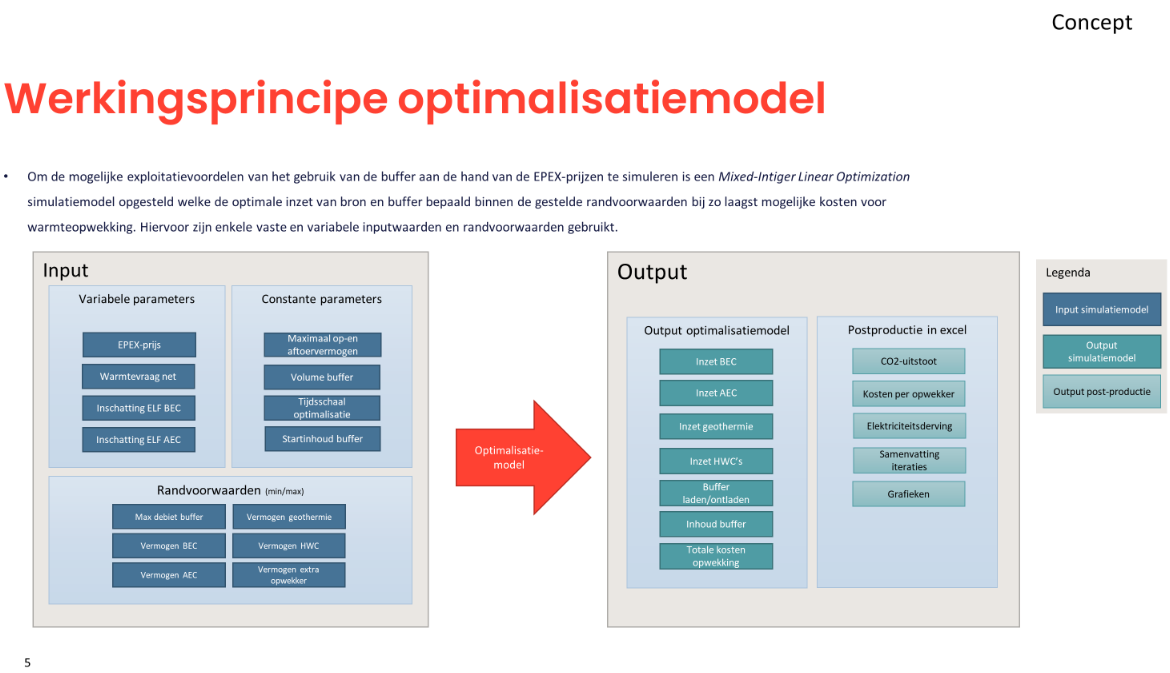
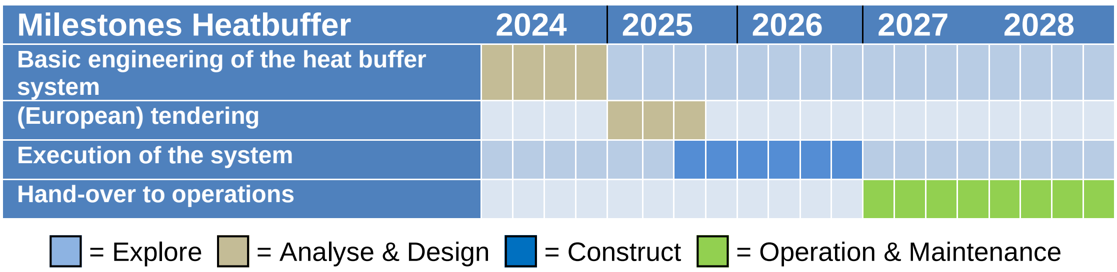


Figure 40: input and output parameters of the heatbuffer

Realize

The general schedule for realization of the heat buffer is:



Operation & Maintenance

The heat buffer will be part of the production site of HVC in Alkmaar. Operations will be done by the 24/7 operations department.

4.2. Heiloo

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General description of developments at Heiloo

Heiloo is an adjacent village to the city of Alkmaar. The municipality is home to 24,000 residents on 19 square kilometers. Duurzaam Heiloo (volunteer foundation) already conducted orientating studies in 2018 into a neighborhood battery (partly financed by the province) and into PVT with heat storage. This is in recognition that heat is the biggest problem within the energy transition for existing homes in areas with low building density and storage of sustainable energy can prevent bottlenecks with heat pumps that can lead to congestion problems.

As part of REFORMERS, the neighborhoods will be equipped with additional solar panels on rooftops, 10 individual and 1 collective battery unit, and 5 individual small heat storage units for the residents and businesses. Also, WiththeGrid will install a "Teleport home innovation" to allow the optimization of electricity flows.

Assumptions to be made
There are three main assumptions:

- The implementation happens to private individuals. The implementation path must be done in a good manner with a good proposal for the residents. It is assumed that this will go well in collaboration with partners.
- The Teleport/ control system must work according to the requirements of Duurzaam Heiloo. (If that does not work, adjustments are necessary)
- The permits with the municipality and contacts with residents (setting up a kind of cooperative) must be finalized, as well as the connections with Liander.

Interaction with other subsystems

Residential homes and the battery are sub-subsystems who also need to internally optimize their own energy system with or together with the Teleport system and Control System. This concerns everything electrically, but also in connection with PVT and heat storage. In doing so, the forecast and dynamic prices must be considered as much as possible. There may be situations with only electrical storage, electric storage together with heat storage, only heat storage and without any form of storage. Results and differences can be compared later in the digital twin.

Project community battery

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

In 2018, a study was conducted based on the philosophy that solar energy from large roofs of industrial estates and private homes would be stored during the day and that if companies close after working time, residents could use that energy in the evening when they need it.

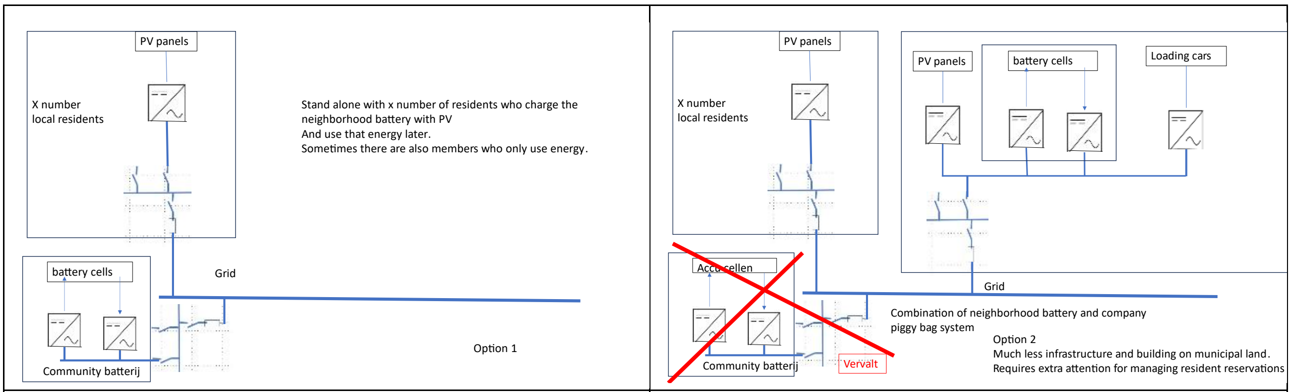
Explore phase

The goals is to install a 100 kWh battery or a larger one at a company of which 100 kWh is reserved for nearby buildings with a control linked to the grid (Teleport) for grid congestion, but also taking into account dynamic prices and trading on the energy market. Charging should be possible from the grid when there is a large supply of energy (low price) and no sun.

Analyse & Design phase

System setup: Schematic overview

There are two options for the design that are being investigated and developed in this regard with 3 providers making an offer. Option 1 is (perhaps too) expensive and requires a lot of infrastructure (and consultation with the municipality). Option 2 requires a little more from the energy management system. For both, a legal solution must be found option 2 where option 2 offers more flexibility with but also some different legal considerations. Consultation with Liander is necessary in both cases.



Option 1; Separate battery	Option 2; battery together with a company

Figure 41: Schematic design of the community battery

Input:

Energy (electrical) from PV panels or from grid if supply is high (low price) without energy from PV panels.

Output:

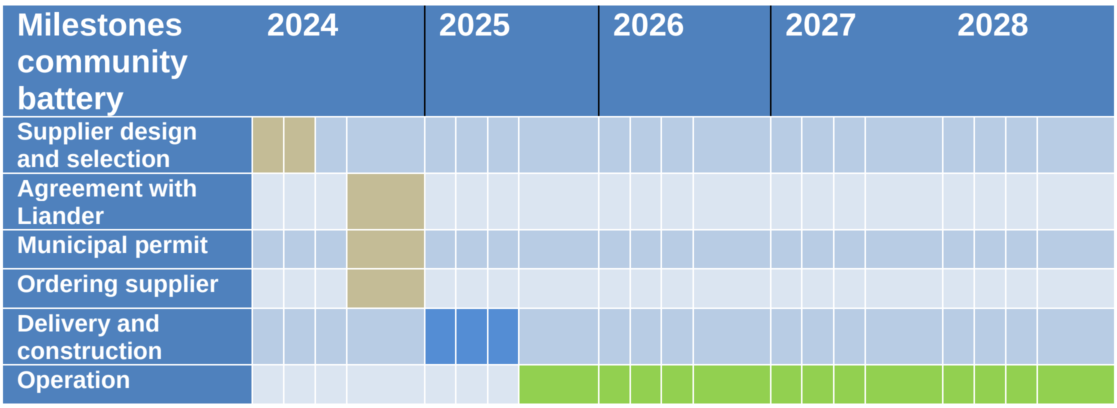
Energy to houses from PV if demand is high en supply is low. Delivery to the grid is possible.

Control principle:

Battery management system for requirements system supplemented with control from the Control System or Liander for net congestion

Construct phase

Planning (milestones) of crucial aspects of realizing the system
Depending on which option is used.



= Explore = Analyse & Design = Construct = Operation & Maintenance

Assumptions to be made

- Reasonable business case
- Agreements en permission municipality, Liander (government)
- Proper management system Withthegrid and Control System.

Operation & Maintenance

Operations: Depending on the legal setup, either the company that manages the battery or a cooperative will become responsible.

Maintenance: The company that supplies the battery and Withthegrid/ Control System provider for communication and energy management with the grid.

Project Household battery system

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

Smaller batteries could become important for balancing the electricity grid. They then help to absorb fluctuations in the supply of sun and wind, so that fewer fossil power plants are needed. In addition, producing and consuming in the same place reduces transport losses. The condition is that there are sufficient private homes that have a battery, with good management systems that communicate with the grid. This in now discouraged by current Dutch legislation via the netmetering scheme (salderingsregeling). That legislation will change and Duurzaam Heiloo believes that in the long term, with more heat pumps, more attention will be paid to congestion on low-voltage grids. Because control for balancing has not yet been properly developed in Heiloo, Duurzaam Heiloo believes it is important to participate in a flagship with REFORMERS to explore and show the possibilities.

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Next to that Teleport is used in house without batteries.

Explore phase

The goal of the project is that self-consumption can increase between 60% and 80% and avoiding consumption peaks in the context of capacity and grid congestion, if sufficient batteries are installed in the future.

Analyse & Design phase

The figure below shows the schematic view of the household battery system.

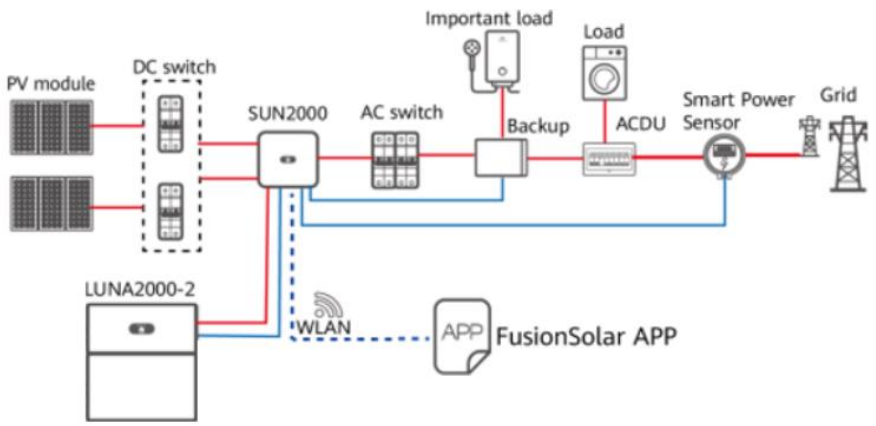


Figure 42: Schematic design of the household battery

Sensors and management is under construction with Withthegrid and the Control System provider.

Input:

Energy (electrical) from PV panels or from grid if supply is high (low price) without energy from PV panels (grid congestion can be a steering mechanism).

Output:

Energy to house if demand is high and supply is low from PV. In some cases to the grid

Control principle:

Battery management system supplemented with control from the Control System or Liander for net congestion

Construct phase

Planning (milestones) of crucial aspects of realizing the system

See preliminary planning below to be discussed with relevant project partners

	Lev= leverancier Gem= gemeente bew = bewoners		DEC '23	JAN '24	FEB '24	MARCH '24	APRIL '24	MAY '24	JUNE '24	JULY '24	AUG '24	SEPT '24	OCT '24	NOV '24	DEC '24	JAN '25	FEB '25	MARCH '25	APRIL '25	MAY '25	JUNE '25	JULY '25	AUG '25	SEPT '25	OCT '25	NOV '25	DEC '25	JAN '26	FEB '26	MARCH '26	APRIL '26	MAY '26
	Omschrijving	Betrokken	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	Overall surveillance																															
2																																
3	**Preparation**																															
4	Protocols/home battery selection	wtg/ lev			4																											
5	Added value statement Repowered	Rep/wtg						5																								
6	Compose proposition	wtg/gem/bew										6																				
7	Compile introduction plan	gem/bew												7																		
8																																
9	**Project implementation**																															
10	Preparing neighborhood action	gem/bew													10																	
11	Promotional campaign	gem/bew															11															
12	Selection of participants	wtg																		12												
13	Levering componenten	lev																			13											
14	Installation	lev																														
15	Home battery	lev																							15							
16	Heat battery	lev																										16				
17	mount Teleport	wtg																											17			

Assumptions to be made

- The implementation happens to private individuals. The implementation path must be done in a good manner with a good proposal for te residents. It is assumed that this will go well in collaboration with partners.
- The Teleport/ control system must work according to the requirements of Duurzaam Heiloo. (If that does not work, adjustments are necessary)

Operation & Maintenance

Operations: Responsibility for resident after delivery.

Is part of an agreement in which is also use of information for research is mentioned

Maintenance: Responsibility for resident after delivery.

Project Household heat storage

System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

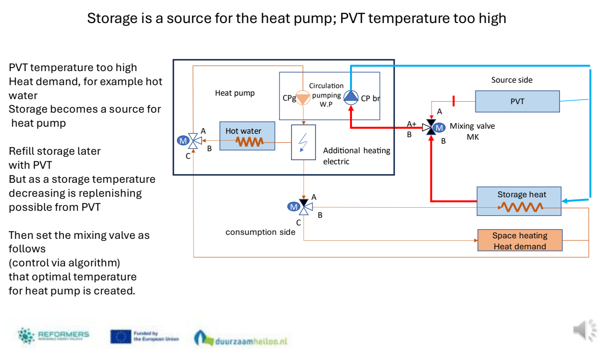
Heating homes uses a lot of energy in the Netherlands, especially in neighbourhoods with a low building density and detached houses. The lower building density also makes district heating expensive. With PVT you can generate electricity as well as heat, so you get extra energy from the sun. The problem is that when the sun shines you have no demand for heat and there is no way to connect the energy to a public grid. That is why Duurzaam Heiloo considers heat storage for the private homeowner to be important. In addition, storing heat can sometimes be cheaper and more environmentally friendly than storing electricity.

Explore phase

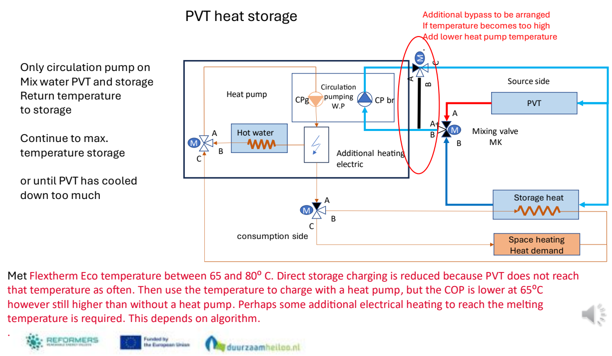
The goal is to generate extra energy in the form of heat, which can also be stored and thus avoid consumption peaks, just like with the electric battery. An optimization program for optimization energy flows that also includes the electricity grid, weather forecast and energy prices can be useful here.

Analyse & Design phase

A test that initially seemed to work well is disappointing. A better system is now being considered where the problem lies in the temperature ranges. An alternative is being worked on (see diagrams).



Original diagram



Explore sysem with a higer temperature

Figure 43: Overview of household heat storage system

Input:
Heat from PVT panels or heat pump depending on temperatures.
Output:
Energy in form of heat and input heat pump.
Control principle:
Management system take temperature and weather forecast into account supplemented with control from the Control System

Construct phase

Runs synchronously with home battery planning as above. Because more problems are expected with the control system, delivery is expected in mid-2026.

Assumptions to be made

- The implementation happens to private individuals. The implementation path must be done in a good manner with a good proposal for the residents. It is assumed that this will go well in collaboration with partners.
- The assumption is that the system that later turned out not to work properly can now be replaced by a good system.
- The Teleport/ control system must work according to the requirements of Duurzaam Heiloo. (If that does not work, adjustments are necessary). Together with heat storage it is a little bit more complicated.

Operation & Maintenance

Operations:Responsibility for resident after delivery.

Is part of an agreement in which is also use of information for research is mentioned
Maintenance: Responsibility for resident after delivery.

4.3. Overdie

More business and citizens within the Overdie will be connected to the heat grid in which natural gas consumption is replaced by heat from the bio energy plant.

Connecting existing buildings is one of the most important challenges in the phase-out of natural gas within cities in the Netherlands. Alkmaar has one of the most sustainable district heating systems in the Netherlands, because it's connected to a Bio-Energy Plant (incineration of wood waste). At the moment, approximately 10.000 housing equivalents in the region of Alkmaar have been connected to the district heating. In addition to housing, public services as the AFAS football stadium, school buildings and the municipal swimming pool are also connected to the network. Gas and central heating boilers are no longer needed there. Apart from connecting new buildings, the greatest goal/task is to connect existing, older buildings. The apartment building "de Vooruitgang" which is owned by the local social housing corporation Woonwaard wil be connected to the heatgrid which is possible by a new connection between the heatgrid en the new Energy Valley Boekelermeer. The experienced gained will be used to connect buildings in other parts of the city and other cities in the Netherlands

Project Heat grid connection "de Vooruitgang"

System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction / Goal

As part of REFORMERS, a highrise building "De Vooruitgang", consisting of 112 dwellings and owned by the housing cooperation Woonwaard, will be connected to the district heating grid.

This building is owned by the social housing corporation Woonwaard who has committed itself to this project with a letter of commitment.

The dwellings, located at Overdie, will be equipped with indirect delivery sets that HVC and Woonwaard first demonstrated as part of POCITYF.

This will increase the share of the heat consumption from the regional heat grid fed by the bio energy plant operated by HVC.

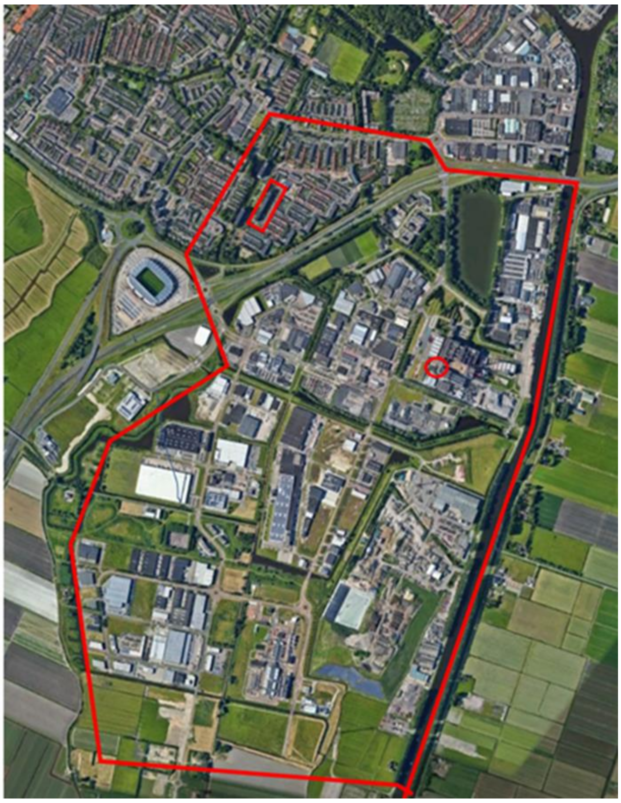


Figure 44: Highrise building "De Vooruitgang and its location in Southrand

Explore phase

The possibilities of connecting the Overdie Area and the highrise "De Vooruitgang" will be investigated and will be documented in contracts. Agreements about the routing and use of public space will be agreed upon with the municipality of Alkmaar.

After that a period of engineering will follow from which the realisation can be prepared.

Analyse & Design phase

System setup: Schematic overview

Different scenarios for connecting the area to the existing heatgrid will be determined and a choice will be made guaranteeing the connection of the highrisebuilding and the future possibility of connecting other building in the Overdie area.

Funded by the European Union

Project funded by

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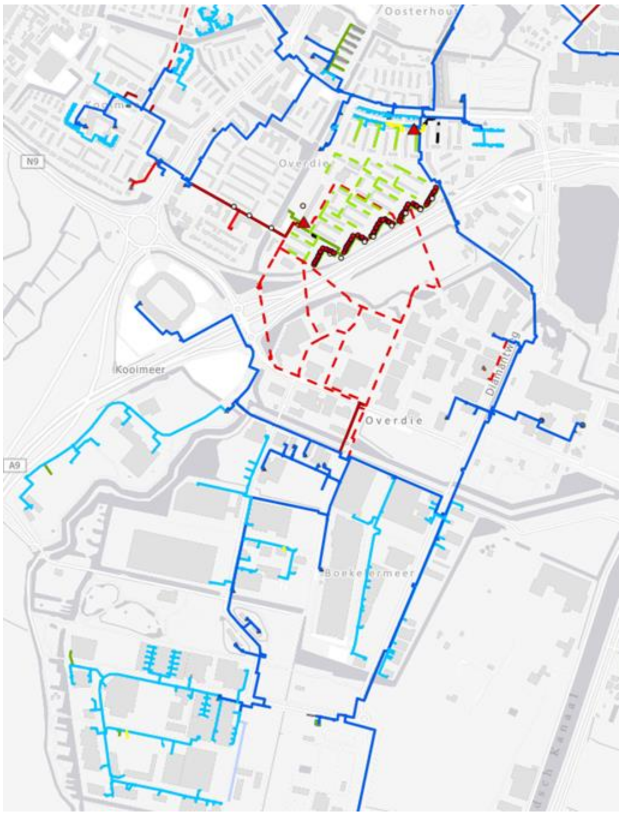

Figure 45: Heat grid conceptual design for connecting Overdie-De Vooruitgang

Construct phase

Planning (milestones) of crucial aspects of realizing the system

Milestones De vooruitgang	2024	2025	2026	2027	2028
Preparation and investigation					
Realisation Heatgrid and connect dwellings					
Heat delivery, operation and maintenance					

= Explore = Analyse & Design = Construct = Operation & Maintenance

4.4. Alignment with other energy projects in the FEV

As part of the collaborative approach as described in Section 3.2, this section will focus on alignment with the Other Energy Projects in the FEV. These Other Energy Projects are initiated by partners outside of the REFORMERS project and do have an impact on the larger FEV Energy Balance, potentially a large impact. In order to reach the impact goals of REFORMERS, it is as such very relevant to align with these Other Energy Projects.

General description

In the FEV hundreds of business are located, many of them on the Boekelermeer area but also in the other areas business are located. In the FEV also several residential areas are located, although typically of limited size, also those regions will deploy Other Energy Projects. In the approach to align with the Other Energy Projects first the most impactful/largest consumers in the FEV are contacted.

To be able to design an ecosystem that fulfils the needs of its members it is important that an in-depth understanding is obtained of the challenges as well as the energy demands and experienced barriers of all its actors. Only then can the developed “theoretical” solutions be rolled out and operationalized successfully. Engaging all crucial stakeholders from the outset not only allows for the direct collection of technical information but also fosters understanding and enthusiasm among them. By giving these stakeholders an active voice in the process, and letting them express their requirements and concerns, they feel more connected to the project. This increases participation willingness. The collected input also enables the design of a system that better meets participants’ requirements.

Explore phase

For the first step of the engagement process for the FEV, a list of companies with large electricity and/or gas consumption or production was compiled and contact details were collected. In cooperation with Bedrijvenvereniging Boekelermeer the REFORMERS project was introduced shortly, and the companies were given the opportunity to register for an interview with consortium partners.

In the course of August through the interviews with companies information will be collected on the following aspects:

- Company activities and processes
- Energy consumption, production, and installations
- Experienced energy challenges
- Energy needs and future plans
- Willingness to join a collective initiative
- Interest in the project and willingness to further participation

This first contact moment will also be used to motivate the companies to actively participate

Analyze & Design phase

In the next phase a group of frontrunners will be formed with which the first version of the governance and control system will be set up.

4.5 Modelling Results of the FEV

As discussed before Chapter 3, before the start of the effective implementation, the first two main scenarios are calculated that together will form a baseline during the project: 1a: Reference Scenario and 1b: Expected developments (see Figure 46) following the methodology as described in paragraph 3.3 . By starting the modelling in an early stage of the project, some key preliminary conclusions could be reached already early in the process. More precisely with respect to the general FEV KPIs (like CO2 emissions, self-sufficiency and energy positivity), which are often the result of entangled interactions inside the valley it is interesting to see how different energy developments influence the targets and if all the planned developments together will result in reaching the targets at the end of the project.

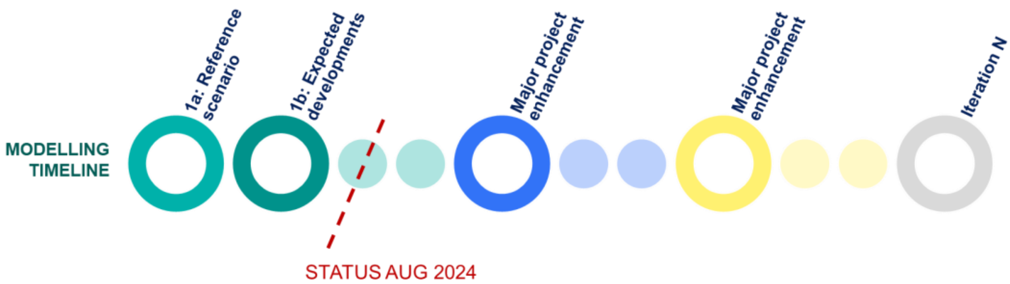

Figure 46: 1a Reference Scenario and 1b Expected developments modelling moment

The methodology in paragraph 3.3 describes a two-level model (lower level: area models and the upper level: FEV model). At this point in time, not all the gathered data could be split out based on the defined areas (especially in the Boekermeer Industrial area) as well no specific targets or goals are pushed for one specific area. Because of these reasons, combining both model levels at this stage iss possible and convenient, which results in a one-level model with 24 nodes (see Figure 47) In this set-up, there are more nodes than areas and subareas. Some areas coincide exactly with one of the nodes, some areas are divided into multiple nodes and some (sub)areas are only a part of a node. The result is one complete FEV model with 24 nodes, covering the whole energy system. In the next iteration of the model, when all (sub-)area data is available in more detail, the model nodes will be restructured in a new logical set-up fully based on the areas and subareas (in line with the description in paragraph 3.3).

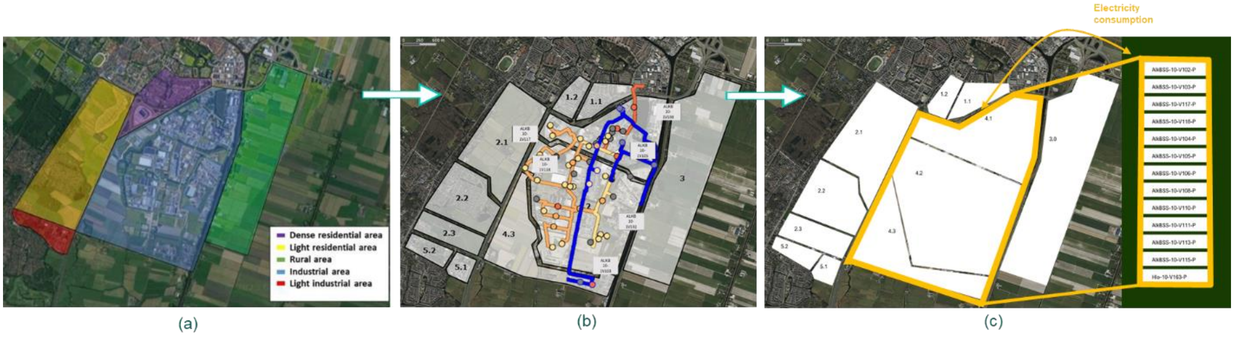

Figure 47: process to split up the flagship valley into nodes based on geographical information and energy grid topologies..

In the figure above, sub figure (a) shows a functional split up based on the activities inside the area. These geographical areas are divided upon even further into 11 smaller geographical areas based upon data collection strategies (sub figure b). Sub figure b shows on top of this smaller geographical split up as well the medium voltage lines in the Boekelermeer area. Sub figure (c) then shows how the electrical medium voltage line topology results in 13 additional logical nodes that cross the geographical regions 4.1, 4.2 and 4.3. This means that the electrical, natural gas and heat behaviour of some of the consumers is captured in different nodes.

Each of the current 24 nodes consists of consumption profiles for electricity, gas & heat and the size, energetic parameters & operational regime of production assets. The year 2023 is used as the reference year for the simulations of scenario 1a and scenario 1b. Figure 48 shows the electrical profiles of consumption and (renewable) production for area 5.1 (a) and one of the medium voltage lines (b) for the reference scenario. The production profiles are extracted from hourly feeder data and area information on solar PV and wind capacity. Similar data is generated for all 24 nodes and for natural gas consumption and heat consumption from the heat grid.

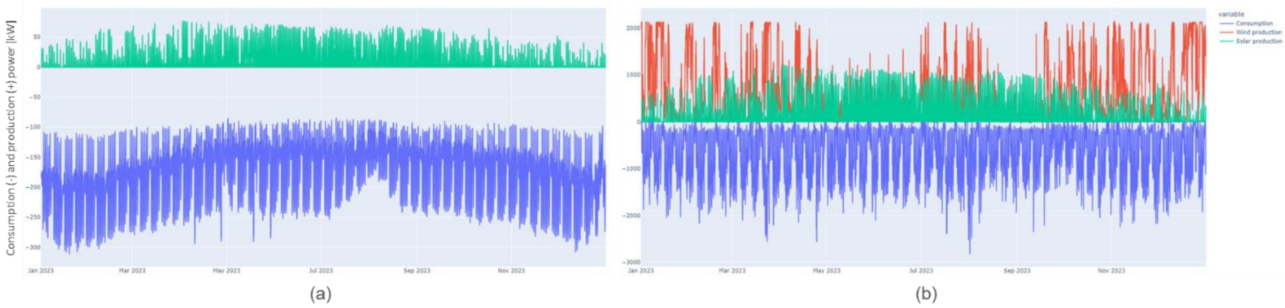

Figure 48 : Electrical consumption, Solar PV production and Wind production for area 5.1 (a) and medium voltage line AlkBSS-10-V115-P (b)

Figure 49 shows for each of the 24 FEV model nodes, their yearly consumption for electricity and gas in the reference scenario. This number equals the integral over the consumption profiles for the year 2023 and shows how the total energy consumption of the FEV is divided geographically over the valley area. The Boekelermeer Business Park area is described by 16 nodes in total: 13 nodes that hold the electricity consumption based on medium voltage line data and 3 nodes that hold the natural gas consumption data based on geographical consumption data. The numbers depicted in both Figure 48 and Figure 49 are important input numbers for the modelling tool.

Figure 49 : Yearly total electricity (a) and natural gas (b) consumption per node for the reference scenario.

Results Reference Scenario (1a)

The key input numbers for the reference scenario are depicted in Table 1. The number shown in the table is the yearly total of reference year 2023, which means that behind each of these numbers an hourly profile is contained.

Table 1: Key input numbers for the reference scenario (scenario 1a)

Energy carrier	*Parameter*	*Unit*	*Value*
Electricity	Electricity consumption	[GWh]	74,03
	Solar production	[GWh]	13.27
	Wind production	[GWh]	22.14
Natural gas	Natural gas consumption	[GWh]	91,63
	Natural gas production	[GWh]	0,0
Heat	Heat consumption	[GWh]	13,0
	Heat production	[GWh]	81,0
Biomethane	Biomethane production	[GWh]	0,0
Hydrogen	Hydrogen production	[GWh]	0,0
	Hydrogen consumption	[GWh]	0,0

The key output numbers of the reference scenario are depicted in Table 2. As the model simulates and optimizes each hour for each asset, The output numbers are the result of the integral over a timestep-by-timestep calculation based on hourly data of production, consumption, weather parameters and CO2 intensity of the electricity grid for all the nodes and assets inside the model.

Table 2: key output numbers for the simulation of the reference scenario (scenario 1a)

Type	*Parameter*	*Unit*	*Value*
*Energy exchange from and to the valley**	Electricity inwards	[GWh]	41,50
	Electricity outwards	[GWh]	2,88
	ng inwards	[GWh]	91,63
	ng outwards	[GWh]	0,0
	Heat inwards	[GWh]	0,0
	Heat outwards	[GWh]	68,0
CO2 KPIs	Total CO2 emissions	[kton]	26,86
Energy KPIs	Self-consumption	[%]	35,3%
	Self-sufficiency	[%]	25,5%

*excluding existing HVC electricity production

Results Expected Developments Scenario (1b)

The expected developments scenario takes into account following developments:

- Yearly solar PV production increase with 12,9 GWh
- Yearly bio-methane production of 147 GWh
- Yearly hydrogen production from biomass of 8 GWh
- Installed battery capacity of 7 MWh
- New yearly hydrogen consumption of 250 MWh
- New district heating connections with a yearly consumption of 2 GWh
- Heat buffer of 200-300 MWh
- A series of smaller high flex projects (hybrid electrolyser, flow battery…)

Table 3 depicts the input numbers - and Table 4 depicts the key output numbers from the simulation for the expected developments scenario (scenario 1b)

Table 3: Key input numbers for the expected developments scenario (scenario 1b)

Energy carrier	*Parameter*	*Unit*	*Value*
Electricity	Electricity consumption	[GWh]	83.73
	Solar production	[GWh]	26,1
	Wind production	[GWh]	22.14
Natural gas (ng)/ biomethane	ng / biomethane consumption	[GWh]	73
	Natural gas production	[GWh]	0
	Biomethane production	[GWh]	147
Heat	Heat consumption	[GWh]	15
	Heat production	[GWh]	81
Biomethane	Biomethane production	[GWh]	147
Hydrogen	Hydrogen production	[GWh]	8,6
	Hydrogen consumption	[GWh]	0.25-8.6

Table 4: key output numbers for the simulation of the expected developments scenario (scenario 1b)

Type	*Parameter*	*Unit*	*Value*
*Energy exchange from and to the valley**	Electricity inwards	[GWh]	41,45
	Electricity outwards	[GWh]	5,98
	ng inwards	[GWh]	0-5
	biomethane outwards	[GWh]	74-79
	Heat inwards	[GWh]	0
	Heat outwards	[GWh]	66
	Hydrogen inwards	[GWh]	0
	Hydrogen outwards	[GWh]	0-8,35
CO2 KPIs	Total CO2 emissions	[kton]	10,3
Energy KPIs	Self-consumption*	[%]	45,3
	Self-sufficiency*	[%]	76,0

*excluding existing HVC electricity production

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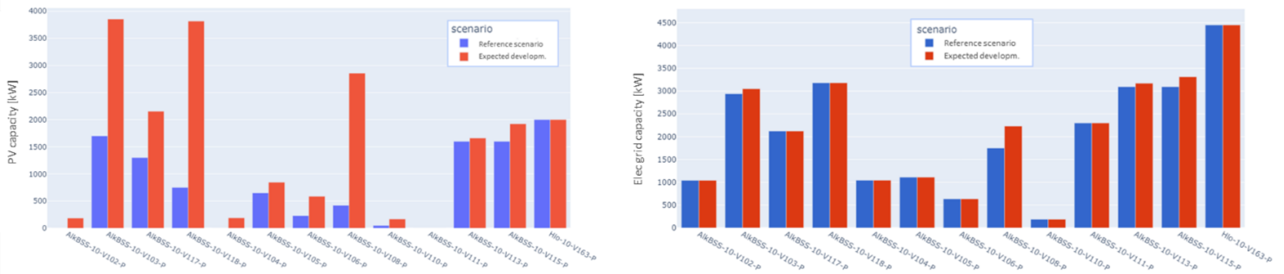
Case study: solar capacity increase in the Boekelermeer area.

To show the abilities and the use of the model, the example case study of solar PV capacity increase in the Boekelermeer area is discussed in more detail. As it is currently not clear yet where the new PV investments will be deployed exactly, the model has optimised the location of the expected new solar PV investments in the Boekelermeer industrial area. The optimisation is based on grid limits and based on current consumption patterns. Figure 50 shows the energetic most optimal solar production in the flagship area spread over the model nodes. The column on the left side of both vigures a and b represent the 13 medium voltage lines feeding the Boekelermeer industrial area.

(a) (b)

Figure 50 : Solar PV production spread [GWh] for reference scenario (a) and expected developments scenario (b) at flagship level..

Figure 51 below shows the impact of the new solar capacity (a) and the related grid impact without curtailment (b). The figure shows how a strong increase (factor 2) in solar production (if located on the right spots) can be implemented with a limited grid impact.



(a) (b)

Figure 51 : PV capacity increase (a) and impact on max line power (b) in the Boekelermeer area

The model allows to do similar analysis for battery investments, battery operation, heat pump installations, heat grid connections, new (flexible) consumption or new production/consumption of renewable gases. Each of these types of case studies can be developed at any point in time for each area whenever it appears useful during the project developments.

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5. Control System of the Flagship Energy Valley

A specific project is setting up the Control System of the FEV. Specific aspects are identified, analyzed and designed. In general the Control System is split into 2 aspects:

- the organizational aspects, with:
  - business rules
  - governance structure
  - roles & responsibilities
- the physical control mechanisms, with:
  - Control philosophy definition
  - Functions of the energy system
  - Control of components of the energy system
  - Interfaces to the components
  - Safety functions of the energy system

As the projects are still in an early stage of development a lot of aspects are still to be defined and are not final yet.

Development of the operating system is based on the layer definitions, as described in chapter 2.

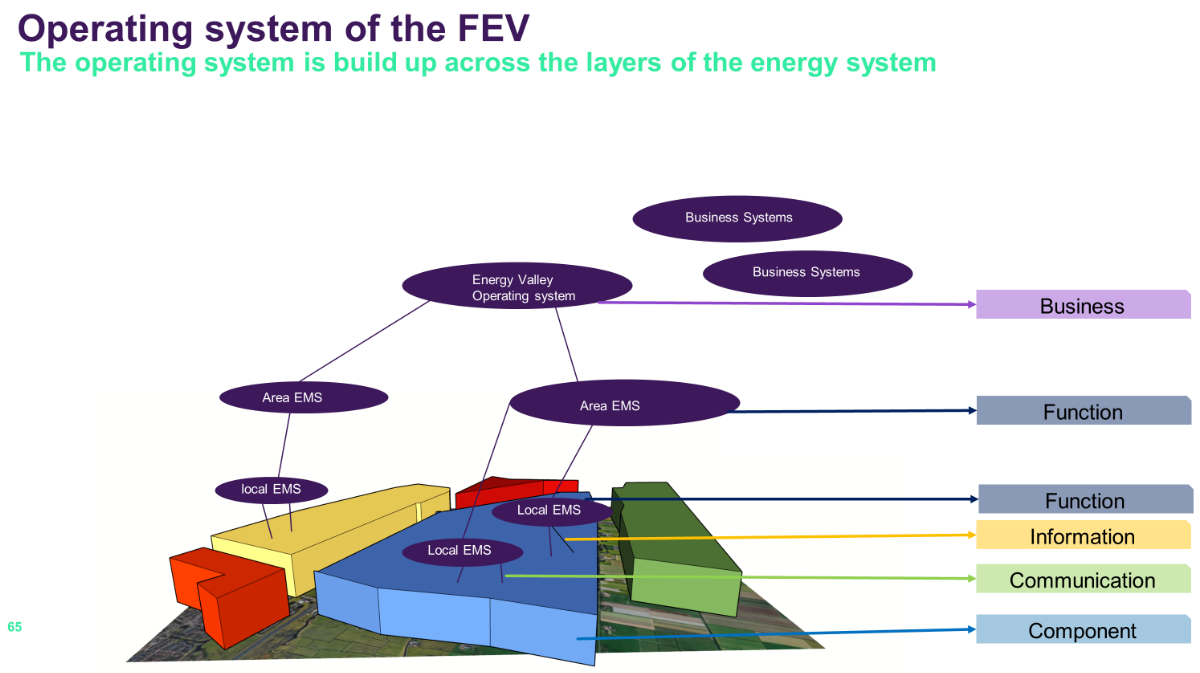

Figure 52: Schematic view on the operating system of the FEV

In the next paragraphs the elements of the operating system will be described in more detail.

5.1. Control the FEV

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

The production of solar and wind energy is weather dependent, which makes it less easy to control. Matching the power demand of users to the available locally generated electricity, supplemented with imported electricity, is important to achieve the right balance. We must take into account the available grid capacity, the ability to influence power demand and the presence of storage and conversion systems. Conscious local balancing creates a more socially efficient system with tailor-made availability.

Energy Valleys or Energy hubs are considered an important new entity in the energy system because more and more (decentralized) sustainable generation must be integrated into the existing infrastructure. There are countless possibilities for smart nodes on industrial estates, with which various companies and surrounding residential areas in smart-city target areas can take advantage from the benefits that these nodes offer. The nodes are nested as well, from the local EMS (Energy Management System) to the overall control system of the Energy Valley.

Within REFORMERS an integrated approach and a sustainable implementation of Energy Valleys will be followed, rendering it attractive for companies to participate. Not because it is the only solution, but because it is the best way to realize the balanced energy system of the future.

The operating system of the FEV is an integration of various software components which leads to a well-functioning system, including making it possible to measure (real time) at sufficient locations in the network and also to control different types of assets, including the energy innovations of the FEV.

The different software components are described in the layers of the FEV operating system in the next paragraphs.

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5.2. Business layer: the Management system

In the business layer several software components fill in different functions of controlling the FEV. As such, the functions layer is described in this section as well.

In general the integrated software components or platforms together balance the energy system, using direct controllable assets, FLEX markets and energy markets for the control algorithms. These control algorithms are setup following the business rules for controlling the FEV as a whole. In the business layer we distinguish by now following platforms/ systems:

- ENTRNCE: the solution for energy delivery via new local energy exchange
- Repowered Smart Energy Platform: Unlock flexibility for (national) energy markets
- FIRAN Energy Hub Platform: Unlock flexibility for (local) physical energy balance

The three foreseen platforms act together to balance the local energy system and use market impulses to get the best price for energy use.

In the figure below a schematic overview of platforms / systems and their connections.

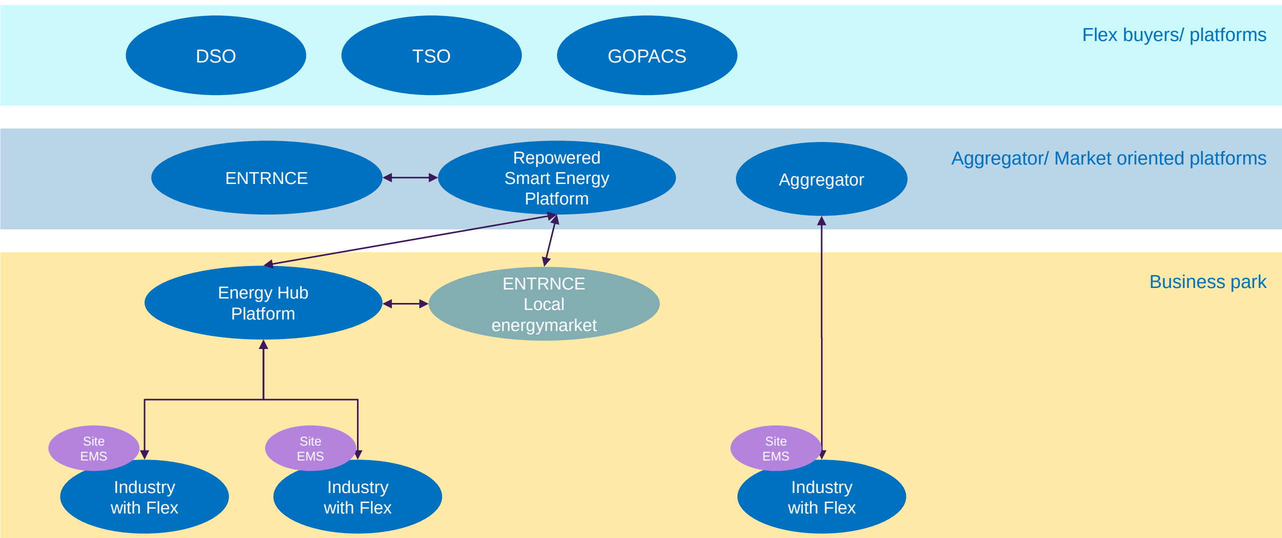

Figure 53: Possible connections between platforms and energy management systems

In the picture above the business layer mainly consists of the two areas on top of the picture. Although in a local energy management system also a business layer can be seen, for this description it is mainly to indicate the different aggregating levels in the business layer.

ENTRNCE

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Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

ENTRNCE, a sub-organization of Alliander, develops digital solutions for the energy market of the future. For example, we have developed a platform that can make the combination between local green energy and centrally purchased electricity, called the Trader.

This allows owners of the local energy systems (for example municipalities) to determine any desired combination of locally and centrally generated energy. This new approach to purchasing appears to work better in practice than the traditional route. More than 10 municipalities already work successfully according to this method.

The advantages of this new approach:

- Local and regional authorities can choose from which sources they want to purchase. This way they can opt for local or regional green sources (owned or, for example, via energy cooperatives or other owners of local generation).
- At times when there is not enough local or regional energy available, this can be supplemented via the wholesale market. Surpluses can also be traded here.
- A circular municipality is being created based on sustainable generation and consumption. Local expenditure for green energy becomes local income for green generators and that leads to reinvestment of resources.
- Increase support for local generation through local ownership. Generators receive more financing from banks if they have a contract with a municipality.
- A local energy price makes local and regional governments less dependent on the vagaries of the global market.
- More flexibility in the energy supply, allowing local and regional authorities to respond directly to changes in the (local) energy market.
- Direct insight into truly sustainable purchasing, this transparent and detailed information provision is unique in the Netherlands. Unlike other providers of self-delivery via local sources, this is done at the connection level and data is available for this. There is complete transparency and insight into sustainable energy purchasing. This is therefore not administratively linked afterwards.
- Prevent grid congestion by making better use of the network.
- CO_2 reduction so that the KPI's of REFORMERS can be met and in general the goals of the Climate Agreement and the Regional Energy Strategy can be achieved

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Repowered Smart Energy Platform

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General introduction

The Repowered Smart Energy Platform, formerly known as JOEP, serves as a central hub for aggregating flexibility and production data from all energy assets within the Energy Valley. By intelligently controlling these assets, the Repowered Smart Energy Platform ensures that energy production and demand are managed in the most optimal way, contributing to the overall efficiency and stability of the energy system. The platform's ability to integrate and optimize various energy sources and flexible assets is key to achieving the project's goals of balancing energy supply and demand at both local and market levels.

Goal

The first goal of the Repowered Smart Energy Platform is to optimize match local production and demand on an hourly basis using the ENTRNCE platform from Alliander. After this matching process an hourly imbalance will remain between production and demand. The Repowered Smart Energy Platform is designed to optimize this imbalance by leveraging the available flexibility within the Energy Valley and participating in energy markets where necessary. This multi-layered approach not only ensures that energy is utilized locally as much as possible but also maximizes financial returns by participating in broader energy markets.

First all local production and demand will be matched on hourly basis using the ENTRNCE platform from Alliander. This will result in an unbalance between production and demand for every hour. This unbalance will be optimized using the available flexibility in the Energy Valley and possible energy markets.

Explore phase

- **Controllable Assets**: The platform will require assets equipped with a Teleport, enabling real-time control and data aggregation. The Teleport is described in paragraph 5.3 and is of the interface layer. With the Teleport a physical connection is setup with the controllable assets.
- **ENTRNCE Platform Integration**: A connection with the ENTRNCE platform is essential for the initial matching of local production and demand. This integration will form the backbone of the platform's local optimization strategy

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Analyse & Design phase

- **Inputs**: Day-ahead forecasts of production and demand; real-time measurements; market data.
- **Output**: Day-ahead hourly imbalance positions; real-time steering signals to the flexible assets.
- **Control Principle**: The control principle will be multi-layered, firstly focusing on local utilization of energy (peer-to-peer and congestion management) and secondly optimizing for financial returns through participation in energy markets.

Construct phase

Milestone planning:

- **Q3 2024**: Finalization of the (initial) control philosophy, ensuring that the operational strategies and objectives are clearly defined.
- **Q4 2024**: Development of the ENTRNCE platform integration, allowing for the initial matching of local production and demand.
- **Q1 2025**: Testing of the first algorithms for local optimization.
- **Q2 2025 and Onwards**: Expansion of algorithms to include congestion management and participation in the imbalance market, further enhancing the platform's optimization capabilities.

Testing of the algorithms in a real-world setting is dependent on the availability of assets which are unlocked through the Teleport. As part of WP 4 it will be determined which innovations and local energy systems are going to be controlled in which order.

Milestones Repowered Smart Energy Platform	2024				2025				2026				2027				2028			
Setting up control phylosophy																				
ENTRNCE integration development																				
Test first algorithms																				
Extansion of algorithms (development and test/operate)																				

= Explore = Analyse & Design = Construct = Operation & Maintenance

Operation & Maintenance

Operations:

- **Assets with Teleport**: Ensuring that all connected assets are equipped with the Teleport is essential for real-time data aggregation and control.

- **Full Flex Energy Contract**: To fully demonstrate the platform's capabilities in a real-world setting, it is important that every flexible asset is covered by a full flex energy contract. This will enable the Repowered Smart Energy Platform to leverage these assets for both local and market-based optimizations.

- **ENTRNCE Integration**: The integration with the ENTRNCE platform must be maintained to ensure ongoing optimization of local energy matching. Further developments of the ENTRNCE platform must be accompanied by updates of the Repowered Smart Energy Platform.

Energy Hub Platform

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

General description

The Energy Hub Platform (EHP) is the set of different applications that makes it possible for companies on an industrial estate to share and optimize electricity (kWh) and power (kW) within the preconditions of company profiles (consumption, generation, storage, flex), the energy grid (contractual and physical) and collective agreements (local merit order).

The Energy Hub Platform basically consists of the following layers:

- Trading markets – Enabling trading transactions (regular market and P2P)
- Energy hub control box (core functionality) – Enabling collective (re)distribution of kW and kWh and control at connection level (from Day-Ahead and Intraday operating plan to real-time control system)
- Interfaces – The interfaces of the Energy Hub Control Box with adjacent systems
- Adjacent systems – Systems that are necessary for collective (re)distribution and control
- Physical infrastructure – The physical energy system (energy network infrastructure and company assets)

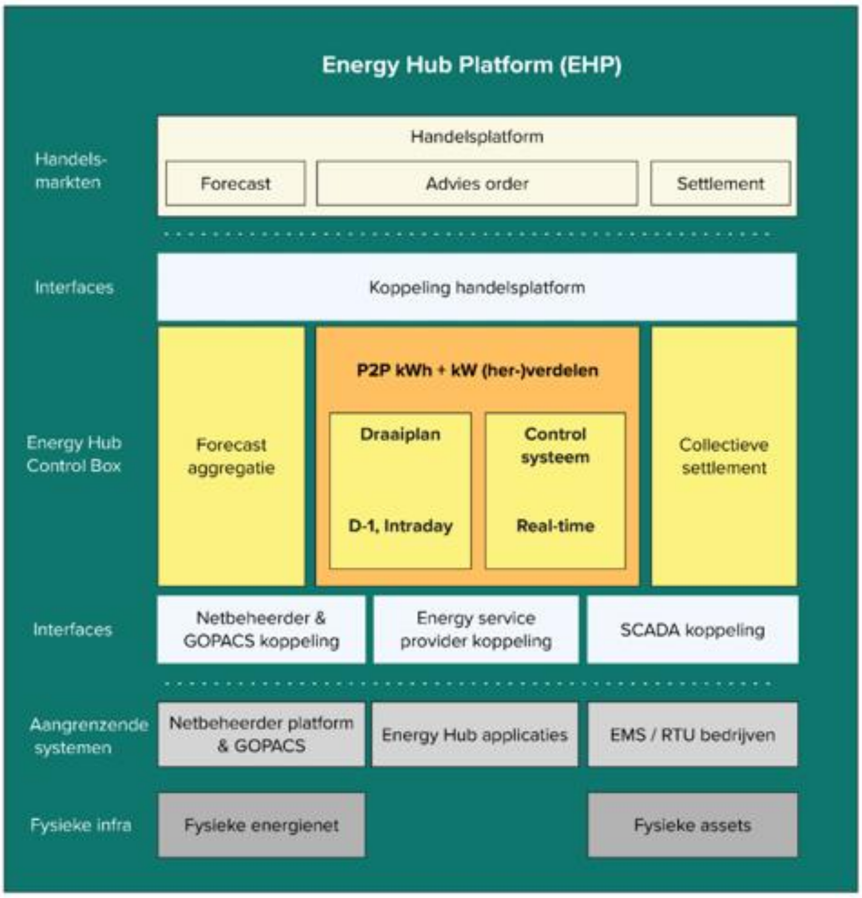

Figure 54: Energy Hub Platform layers

Explore phase

The core functionality is the centre of an energy hub, which makes it possible to determine, dynamically adjust and adjust (near) real-time collective redistribution of capacity (kW) and energy (kWh) for companies on an industrial estate. to steer.

We call this core application and the necessary connections with adjacent systems the Energy Hub Control Box.

The Energy Hub Control Box consists of 4 main processes:

- Forecast aggregation - Different types of forecasts are part of an energy hub. The core functionality focuses on its aggregation at the kW and kWh level over time. It thus provides dynamic input to the collective operating plan to be determined
- Collective operating plan (Operating plan) - The collective operating plan (24 hours, 15 minute interval) makes it possible based on (individual and aggregated) forecasts, company profiles (consumption, generation, flex capacity, contract values), mutually contracted rules (local merit order) and the preconditions from the grid, determine the collective (re)distribution of kW and kWh for the local energy system, dynamically adjust (within market mechanisms of Day Ahead and Intraday) and optimize on the basis of security of supply, price and /or sustainability. The aim is to match demand

to local generation as much as possible, taking into account the maximum exchanges with higher grid areas.

- Control system - The collective asset control system makes it possible to measure, monitor and control controllable assets of the local energy system (near-) real-time by means of. sending setpoints at connection level (settings/control settings) (via SCADA system). Various (third) parties can actually control the assets. (Near) real-time optimization takes place based on the operating plan, the actual behavior of assets, short-term predictions of assets (by third parties). In many cases, a collective will want to organize a joint reserve system. This is included in the merit order in the same way as the other assets to optimize security of supply, price and/or sustainability. A monitoring system is necessary to take into account the state of charge (charging level) of storage systems, ramp rate (control speed) of other flexible assets and maximum increase and decrease capacity.
- Collective settlement (settlement) - Parallel to the regular settlement processes, settlement will take place within the collective for the application of the mutually agreed and established rules, whereby one party is compensated for offering flexibility to other parties.

The core functionality of the Energy Hub Platform basically has interfaces with: trading platform, energy service providers, customer systems, grid operator platform and GOPACS. Our system offers open interfaces. The figure below shows the interfaces and boundaries of the Energy Hub Control Box

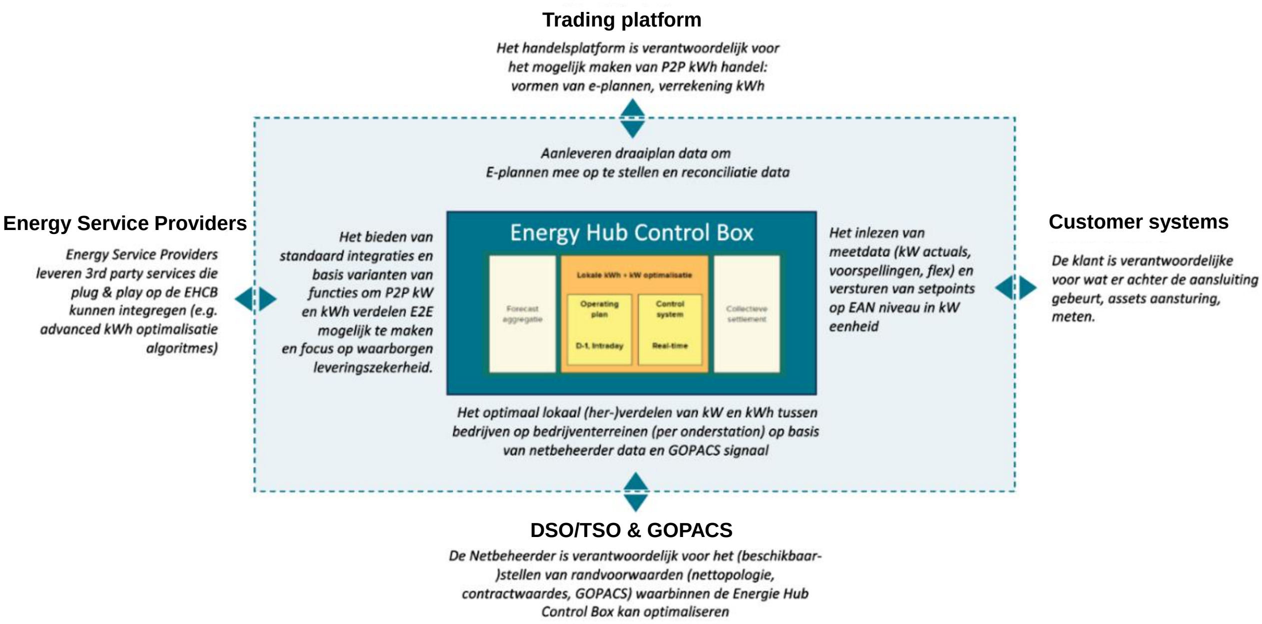

Figure 55: Energy Hub Control Box interfaces and boundaries

Analyse & Design phase

The Energy Hub Platform will be first implemented on a local EMS level, connecting controllable assets in the area. When multiple local EMS are operated, a higher level Energy Hub Platform is foreseen to be developed, connecting multiple local Energy Hub Platforms.

In this phase the functionality of the Energy Hub Platform and the interfaces are being investigated. The platform is developed in an Open Source environment. Missing functionality or interfaces in the platform will be designed and build as time progresses.

Construct phase

Indicative planning:

Milestones Energy Hub Platform	2024	2025	2026	2027	2028
Exploration of requirements to the platform					
Analyse functionality and gaps					
Platform implementation					
operations					

= Explore = Analyse & Design = Construct = Operation & Maintenance

5.3. Interface Layer: the interface between business rules and component control

The interface layer covers the information and communication layers. As part of information a data model will be setup in which it is made clear which data needs to be available to be able to have control by the systems at Business level, but also what kind of data is necessary to receive from the business layer to be able to execute control through the interfaces to the controllable assets.

The communications layer covers the real physical interface to the controllable assets. In these interface data will be translated into instructions the controllable assets can receive. Also data form these assets are made available to the data exchange and instructions to and data from the controllable assets to the data layer

Data management

The data model which needs to be implemented defines the way how (transactional) data will be stored in databases. This kind of data will be used by the software controlling the assets, but also to provide information for other purposes, like the city information system of the Municipality of Alkmaar. Transactional data is necessary to make energy exchange and related settlement processes possible. As platforms and software systems can store data by themselves the definition of data exchange must be made very clear.

The operating system of the EV will also log data to store data of events that occurred. With this kind of data the behavior of the energy system and actions executed can be monitored in near real time.

At this moment a full definition of the data model still needs to be setup. In WP4 this will be further elaborated by analyzing the platforms and their interoperability.

TelePort: Unlocking asset flexibility

Energy System Function	Development phase
Production	Explore
Balanced consumption	Analyse & Design
Storage & conversion	Construct
Smart control	Operate&Maintain
Infrastructure	

The most important system for the interface layer is the TelePort Gateway. It makes it possible to connect the business platforms to the controllable assets. In this way the flexibility of the controllable assets can be used to control the local EMS.

General introduction

Managing assets without a Teleport Gateway means navigating assets complex integrations and managing maintenance tasks. Moreover, a grid connection is exposed to risks of overloading, leading to operational disruptions and non-compliance with the DSO. With the Teleport, integration processes and maintenance efforts are streamlined. Use a single API for monitoring and control and ensure that the grid connection remains within limits, safeguarding against overloading and non-compliance. In the figure below the difference between a setup without and with a Teleport is made visible.

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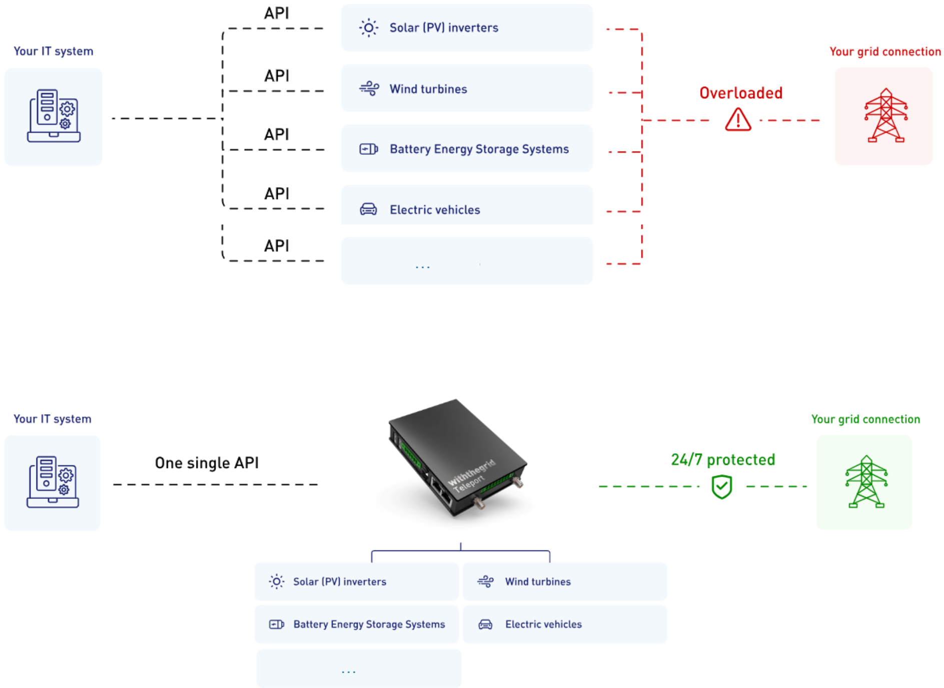

Figure 56: Schematic view managing energy assets without and with Teleport

Goal

With the Teleport assets can be easily and standardized connected and integrated in the local energy management system. The Teleport connects to the Teleport Cloud in which the data will be made available to be read out by the management system through the Teleport API interface. By using a standardized component unlocking energy assets for control is made very easy, instead of building unique complex interfaces to every asset over and over. The Teleport covers:

- Data forwarding management
- API management

Explore phase

All energy innovation assets within REFORMERS will be connected with Teleport. Besides these assets, flexibility is present at companies already residing in the FEV area, especially in the industrial area of Boekelermeer. With the stakeholder engagement progressing it is foreseen that the first Teleports will be implemented at these (impactfull) companies. In this way the first local energy systems can be setup

Analyse & Design phase

The Teleport supports energy assets that can be controlled over RS232, RS485, and Ethernet, through protocols like Modbus, OPC XML-DA, SunSpec, and EN61850 (Real-time interface). Think of PV inverters and loggers (e.g. Huawei, Sungrow, ABB), Power analyzers (e.g. Janitza), battery inverters (e.g. Victron), wind turbines (e.g. Enercon), charging stations, and heat pumps. If an integration with a specific asset doesn't exist yet, it is most likely the integration can be build. With this in mind the expectation is that the assets that are going to be controlled can be unlocked through the Teleport.

The Teleport implementation will follow the development of unlocking controllable assets. It is foreseen that a number of Teleports are going to be installed. The exact number is still to be decided.

Construct phase

The Teleport supports a number of local control strategies. Such solutions include but are not limited to:

- Grid power control: adjust power production of solar, wind, and battery assets in order to keep within grid feed-in and/or consumption limits, also in case of fluctuating self-consumption
- Control for balancing and congestion markets: provide FCR and aFRR services to grid operators an enable scheduling of grid limits to adhere to capacity limiting contracts (CBC) for GOPACS

In close collaboration with the setup of the energy management platforms the local control strategy will be implemented

Milestone planning

To be defined, depending on platform implementation

Operation & Maintenance

Operations:

The Teleports will be monitored by WithTheGrid. In this way it covers:

- Device Management
- Firmware management
- Cybersecurity/ patch management

5.4. Component layer: external control of assets

In the component layer the controllable assets are connected to the TelePort gateway. The protocols for connecting assets are most likely specific per asset. With the Teleport multiple protocol standards are covered. If a new connection type is necessary, it will be developed by WithTheGrid, the owner of the TelePort.

In this way multiple assets are going to be connected to the controlled energy system of the FEV. All the energy innovations assets/projects as described in chapter 4 are going to be connected. Besides those assets also controllable assets of other energy projects (impactful companies) and sustainable energy production facilities are being connected.

On the control layer the interoperability, the way different components interact together, is a crucial aspect. In the figure below a visual interpretation of the interoperability aspects of components.

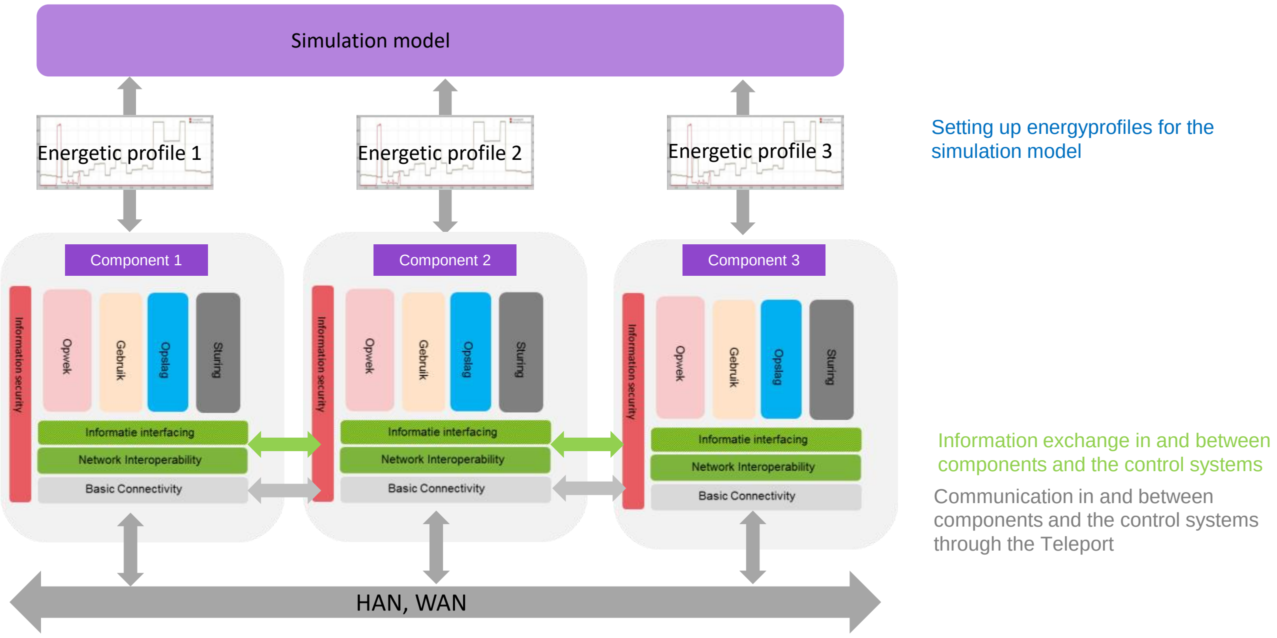

Figure 57: Interoperability aspects

6. Next steps of the Flagship Energy Valley

Introduction

Within Work Package 4 of the REFORMERS project, activities already have been started. In close collaboration with WP3 the setup of the FEV is to be made more detailed, so work really can start.

Based on the approach as setup in WP3, WP4 will fill in the specifics for design, detailed descriptions of all the subsystems and projects of the FEV, to be able to realize the elements of the FEV. So in a nutshell:

- The development phase "Analyze & Design" will be finalized
- Real implementation will be started
- Operate & maintain will be setup

In addition, the governance structure, collaboration forms and ecosystem building through stakeholder engagement needs to be further pursued, to arrive to a viable and sustainable FEV.

6.1. Planning of further actions.

Planning for the energy projects: As stated in the various chapters of this document the concepts of what elements are building up the FEV are described, as well as their interactions and embedding in the FEV system. Current status of each (sub)system and project is discussed, next steps are indicated and some projects already have a milestone planning. As such guidelines for the further deployment of the FEV are given. The necessary actions towards deployment, implementation and operation will be further detailed and carried out within WP4.

The table below shows the different projects with the associated (milestone) timelines.

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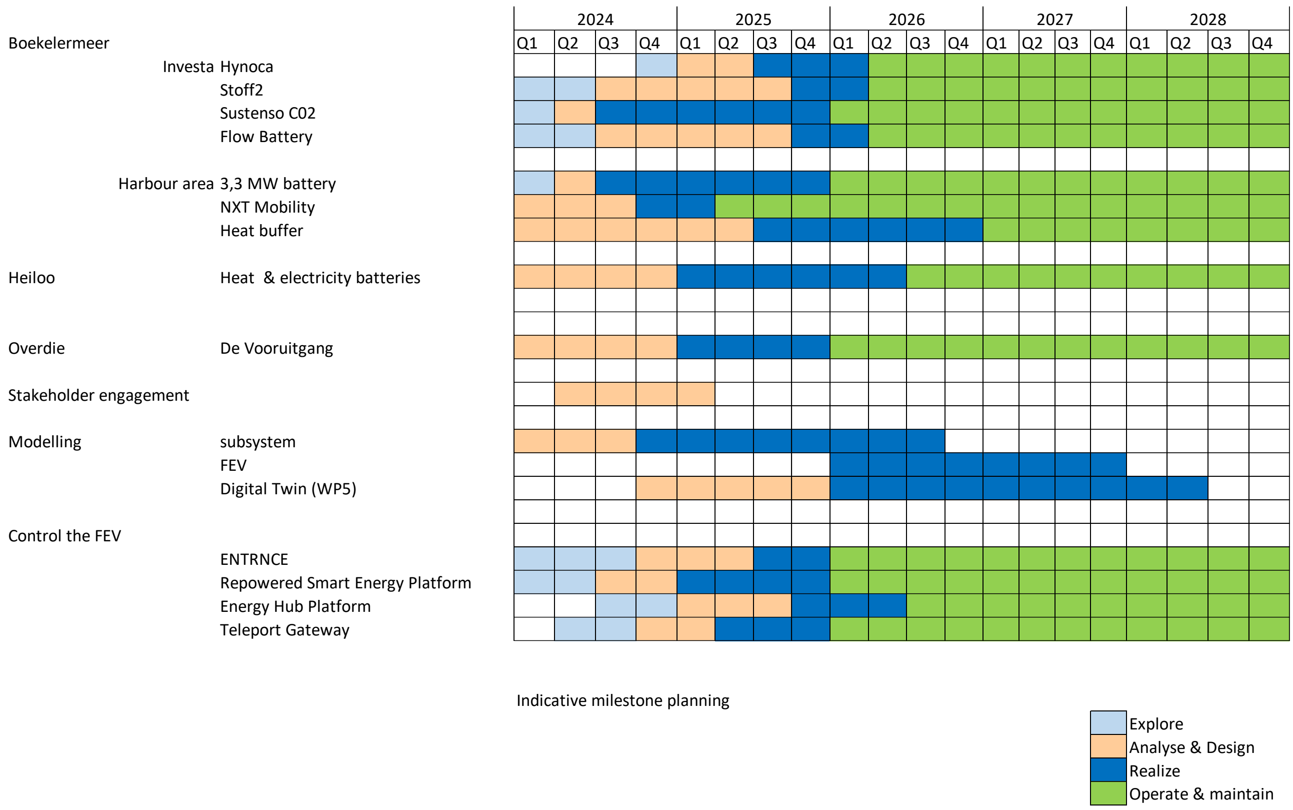
Table 5: Indicative development phase planning per project



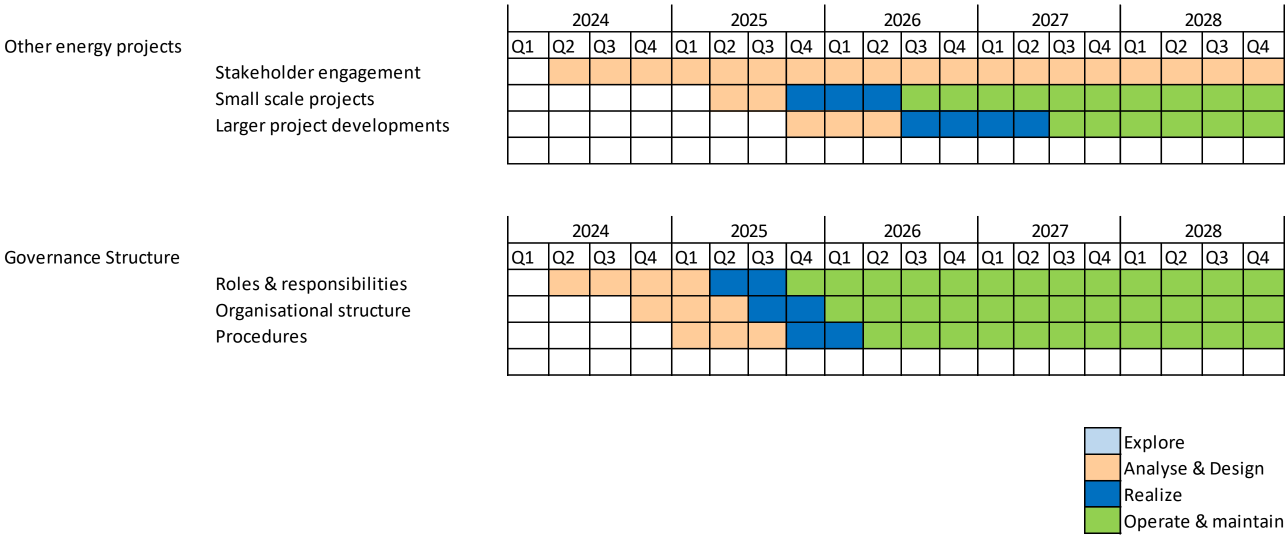
In general, 2024 until mid-2025 design and realisation preparation activities are executed. From early 2025 the first realisation is started. Focus on operations starts around mid-2026.

In every project a more specific planning will be setup with a work breakdown (WBS) structure. This makes it possible to monitor progress more specific. This will be reported upon in the subsequent deliverables of WP4.

Planning Governance and stakeholder engagement: As the other energy projects (being the non-REFORMERS consortium partners) within the FEV will be started, also the organisational structure (governance of the FEV) needs to be setup. As we expect an organisation (the form still to be decided) will be responsible running the FEV, this organisation can be the owner of the contracts with the different platform owners, transactional data etc. The stakeholder engagement for other energy projects is just started so it is hard to indicate when the first companies will join the FEV energy system and unlock flex. In WP4 this will be made operational.

In WP4 also the governance structure as well as the organisational form of the ecosystem will be further elaborated. In the figure below an indicative milestone planning of further elaboration on other energy projects and governance structure is given.

Table 6: Indicative phase planning of other energy projects and Governance structure



Regarding stakeholder engagement, not only the impactful companies but also all other relevant actors of the ecosystem (such as smaller companies, residents, local nature and agriculture representatives, etc.) will be invited to actively participate in the process. In October a ‘World Café’ event will be organized for a wide array of stakeholders. During this meet-up participants can discuss in small groups which energy-related problems they experience, what solutions might look like, what their specific energy needs are, the effort they are willing to put into cooperation in the project, the collaboration challenges they see, etc. The contacts established during this event will also be used further along the process to ask for feedback and to collect more detailed technical as well as social input. According to these activities at first small scale projects will be setup, with a limited group of interested stakeholders. These small scale projects are also the trigger to setup large scale projects as we expect stakeholders get enthusiastic about te results of the small scale projects startup.

Planning for supporting modelling tools. The modelling environment will further support the design of the (sub)systems and the FEV toward optimal KPI values To do so, VUB will model first on area level and then on FEV level as a whole. Results from these modelling activities can be expected in fall 2024 and will follow the timeline of the projects as shown in table5 . In this way designs can be finalized and implementation work started. Modelling exercises will continue after the FEV as a whole is operational in 2027, since collected data will be used to improve the modelling tools. Also modelling tools will be used in relation to the Digital

Twin, setup in Work Package 5, to improve the energy system according to the insights from the Digital Twin environment.