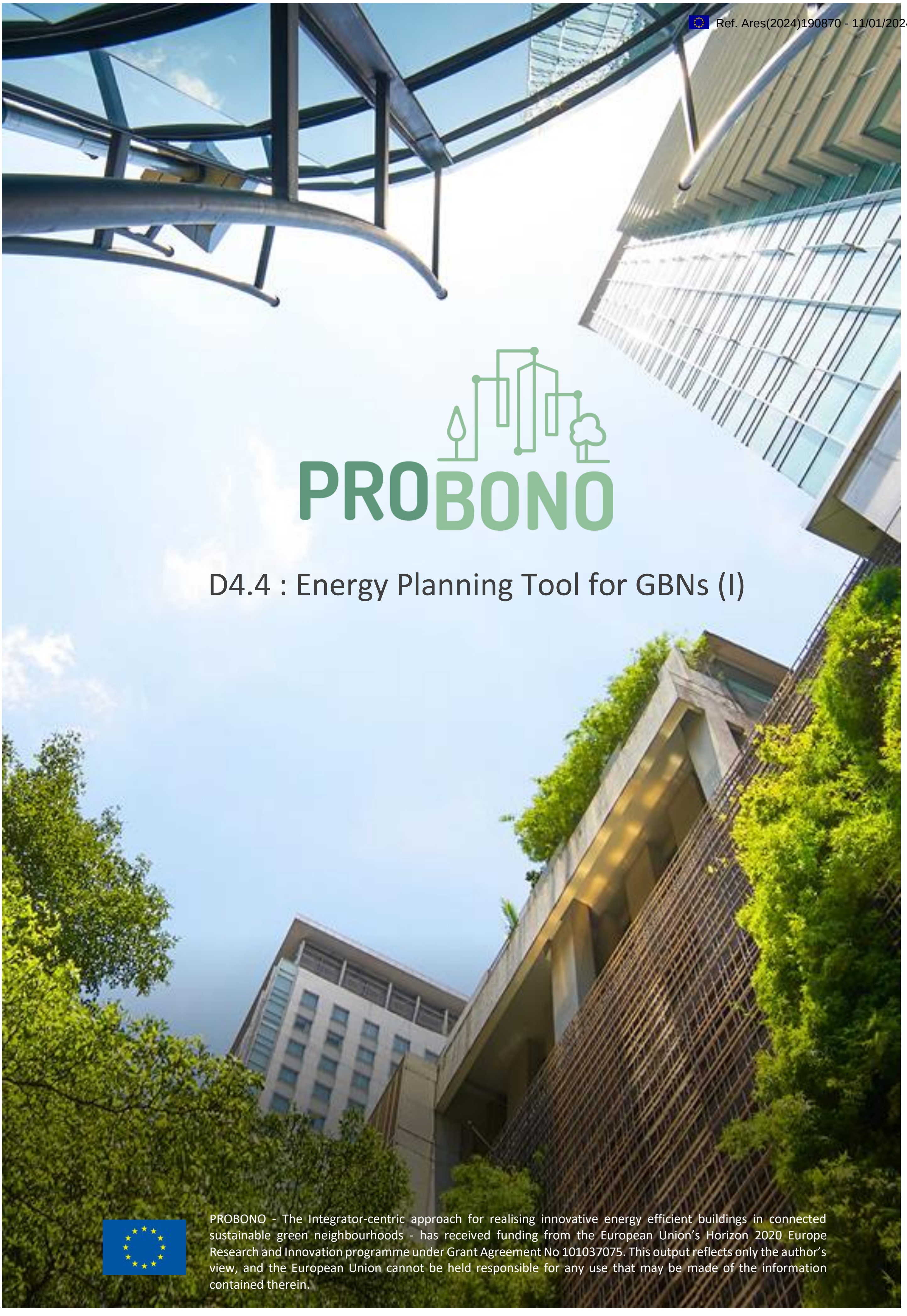

D4.4 : Energy Planning Tool for GBNs (I)

PROBONO - The Integrator-centric approach for realising innovative energy efficient buildings in connected sustainable green neighbourhoods - has received funding from the European Union's Horizon 2020 Europe Research and Innovation programme under Grant Agreement No 101037075. This output reflects only the author's view, and the European Union cannot be held responsible for any use that may be made of the information contained therein.

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Author:	**TPF – de Bellefroid Martin, Razzetti Silvia & Tahernejad Soheil,** **STAM – Mattia Reposi & Lorenzo Farina**

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Contributors:

Partner	Contributor
STAM	Repossi Mattia & Farina Lorenzo
TPF	Razzetti Silvia & Tahernejad Soheil
TSRV	Spyros Polychronopoulos

Peer reviewed by:

Partner	Reviewer
TUC	Nikolaos Kampelis

FRHF	Gerhard Stryi-Hipp
INLE	Marina Laskari

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WP2
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DEFINITIONS[1]

A Green Building (GB) (new or retrofit) is a building that, in its design, construction and operation, reduces or eliminates negative impacts, and can create positive impacts, on the climate, social, and natural environment. GBs preserve precious natural resources and improve quality of life[2]. Specifically, this means that GBs should be very energy efficient, use extensively the potential of locally available renewable energy, use sustainable materials, and aim for a low environmental impact over the entire life cycle. GBs offer their users and residents a healthy climate and a high quality of stay, they are resilient e.g., to environmental change and contribute to social inclusion.

Green Neighbourhoods aligned with the European Green Deal[3], is a set of buildings over a delimited area, at a scale that is smaller than a district, with potential synergies, in particular in the area of energy. A green neighbourhood is a neighbourhood that allows for environmentally friendly, sustainable patterns and behaviours to flourish e.g., bioclimatic architecture, renewable energy, soft and zero-emission mobility etc. Green neighbourhoods are the building blocks of Positive Energy Districts (PEDs)[4] by implementing key elements of PED energy systems. For example, the exchange of energy between buildings increases the share of local self-supply with climate-neutral energy and system efficiency. They also provide the technical conditions to enable Citizen Energy Communities[5] and Renewable Energy Communities[6] to be implemented.

Green Buildings and Neighbourhoods (GBN) in PROBONO are GBs integrated at delimited area or district level with green energy and green mobility management and appropriate infrastructure supported by policies, investments and stakeholders' engagement and behaviours that ensures just transition that maximise the economic and social cobenefits considering a district profile (population size, socio-economic structure, and geographical and climate characteristics). Delivered in the right way, GBN infrastructure is a key enabler of inclusive growth, can improve the accessibility of housing and amenities,

[1] Please refer to the last submitted reports for the latest status of the definitions

[2] https://www.worldgbc.org/what-green-building

[3] European_Green_Deal_EN_200710_fin

[4] SET-Plan Action 3.2: https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf

[5] Internal Electricity Market Directive (EU) 2019/944 5 Renewable Energy Directive (EU)

[6] Renewable Energy Directive (EU) 2018/20012018/2001

reduce poverty and inequality, widen access to jobs and education, make communities more resilient to climate change, and promote public health and wellbeing.

DGNB certification serves as a quality stamp ensuring the state of the building for buyers. The Green Building Council Denmark (2010) established the German certification DGNB meaning 'German Society for Sustainable Buildings'. The Danish version of DGNB was created to obtain a common definition of what sustainability is towards and making it measurable. A consortium of experts was established from all parts of the construction sector. DGNB had to be reshaped for the Danish standards, practice, traditions, and laws but is now available to certify any construction project. They chose DGNB as an innovation-forward and sustainable future guarantee. DGNB diversifies itself by focusing on sustainability and not just the environment. DGNB creates a standardised framework for the construction operations conditions and creates a common language which facilitates communication between professions and helps organize and prioritize the efforts in long and complicated development phases.

Life cycle assessment (LCA)[7] is a tool used for the systematic quantitative assessment of each material used, energy flows and environmental impacts of products or processes. LCA assesses various aspects associated with development of a product and its potential impact throughout a product's life (i.e., cradle to grave) from raw material acquisition, processing, manufacturing, use and finally its disposal. In PROBONO, LCA represents the statement of a building's total energy, resource consumption and environmental impact in the manufacture, transport, and replacement of materials and for its operation over its expected life. Social life cycle assessment (S-LCA)[8] is a method to assess the social and sociological aspects of products, their actual and potential positive as well as negative impacts along the life cycle. Life-cycle costing (LCC)[9] considers all the costs incurred during the lifetime of the product, work, or service.

An **Energy Entity (E.E.)** is defined by an electricity demand, a heating (general heat and sanitary hot water) demand that are identifiable and quantifiable, and thus their consumption are monitored by meters with at least a yearly granularity. Here are a few examples of E.E. :

- A building of multiple apartments and central heating unit;
- An apartment with its own electricity demand and heating unit;
- A site of multiple buildings all heated by a central heating unit supplying heat through a heat network.

Energy Demand and **Energy Response** are two concepts used in this deliverable respectively refering to the energy consumptions (electricity, heating, sanitary hot water) and energy productions responding to these demands (electricity: grid, PV, wind turbines; heating and sanitary hot wáter: boiler, heatpump, cogeneration, etc.).

An **Energy components** is a type of appliance supplying and/or storing energy (electricity, heat and/or cold) to an Energy Entity. For example: PV panels, batteries, boilers, heat pumps, hot water tanks, cogenerations, fuel cells, etc.

[7] https://op.europa.eu/en/publication-detail/-/publication/16cd2d1d-2216-11e8-ac73-01aa75ed71a1/language-en

[8] https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/social-lca/

[9] https://ec.europa.eu/environment/gpp/lcc.htm

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Abbreviations and Acronyms

Acronym	Description
DR	Demand and Response
EE	Energy Entity
EPB	Energy Performance of Building
EPC	Energy Performance Contract
GA	Grant Agreement
GHG	Greenhouse Gas
HWT	Hot Water Tank
PMC	Project Management Committee
WP	Work Package

Table 1: Abbreviations and acronyms

Executive summary

The aim of this report is to cover the requirements defined in the PROBONO Grant Agreement, under **task T4.2** which can be summarized as "**to develop a GBN energy demand and response platform, based on monitored data and applicable on building and community Level**". Specifically, the report covers the objectives listed for the deliverable **D4.4** (**Tool optimized for LL's and designed for Brussels LL**), which is a first step to be completed by deliverables D4.5 (M36) and D4.6 (M54). **D4.5 (M36)** will explore the integration of new appliances on the platform (as fuel cell, cogeneration, solar thermal, geothermy), initiate the developments of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), initiate Digital Twin integration with AKKA, explore user experience with SIN, and implement the platform on Aarhus and Dublin use cases.

D4.6 (M36) will further develop the concept of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), further develop Digital Twin integration with AKKA, deeper explore User Experience with SIN, and implement the platform on Madrid and Porto use cases.

In this deliverable, we first detail the **requirements collection** for such a demand and response platform, both by **collecting state of the art** information about green buildings and green neighbourhoods, and by collecting **feedback** from the Probono project itself (Living Laboratories and different previous deliverables).

In a second time, we cover the **vision and objectives of the in-development platform** answering the requirements collected previously. We **introduce** the **concepts** of *Recipes, Energy Entities and Energy connectors as* the main concepts used for the tool usage, and explore the possibilities and decision-making solutions brought by our approach.

In chapter 4, we go through the **platform design and implementation for Probono** and give detailed insights about the **monitoring and data collection plan**, the **software solution** and its architecture, and mention the action plan for **DT integration within PROBONO** (WP5).

The report finishes with the analysis of the Brussels Living Lab use case, the **practical installation** of the detailed monitoring plan in the school, and the implementation of the three first steps of our platform on this concrete example. We also explore the interest of other LL's for the energy Demand & Response (D&R) platform, and conclude with the next steps to be implemented.

1. Introduction

1.1. Mapping PROBONO Outputs

GA Component Title	GA Component Outline	Respective Document Chapter(s)	Justification
TASKS			
Task 4.2. GBN demand and response platform (M1-M54)	The aim of T4.2 is to develop a GBN demand and response platform based on TPF proven baseline technology for metering different utilities (electricity – gas – warm energy – cold energy – water).	Chapter 3-5 and Annexe A	This version (I) of the GBN Demand and response platform (D4.4.), due in month 18, represents the vision of the platform, its requirements, the analysis of a use case, and the implementation of the first steps.
	The platform is expected to be linked to the Energy Optimisation AI Platform from STAM at Building level	Chapter 4.1 – 4.3	In chapters 4.1 to 4.3, we explain the optimization concept on a building level developed by TPF.
	and Community level	Chapter 3.4 – 3.5	In chapters 3.4 and 3.5, we explain the optimization of loads concept on a community level developed by STAM.
	and GBN Sensors linked to Smart IoT gateway from TS.	Chapter 4.1.1	Chapters 4.1.1 give the details of the meters (provided by TSRV and TPF) that ultimately send the data to STAM's cloud.
	The platform includes HVAC specific applications matching local situation. Version 1 (M18) designed for the Brussels LL.	Chapter 5.2	In Chapter 5.2, we develop in detail the first implementation version designed for Brussels LL. This includes the parametrization of the school, the monitoring system installed, and the results of energy simulations for the building.
	Replication versions integrated in GBN DT for Porto, Madrid, Aarhus, Prague ,and Dublin.	Chapter 4.3	Chapter 4.3 gives a short state of progress for DT integration within PROBONO (WP5). Stating integration will be further developed in D4.5 (M36).
DELIVERABLE			
D4.4: Energy planning tool for GBNs (I) This report formulates the findings of T4.2, and explores step/s. A) Tool optimised for LL's.			

Table 2: Adherence to PROBONO's GA Deliverable & Tasks Descriptions

1.2. Purpose and scope of the document

The aim of this report is to describe the key features of the first version of the Demand and Response optimisation tool, conceived according to the requirements defined in the PROBONO Grant Agreement, under Task 4.2 (see Table 1).

The currently available version of the platform is the result of **18 months of collaborative work**, organised in different steps: T4.2 started with the analysis of the concept of GNB, to better identify the platform specifications; it followed with the definition of a **plan of several collateral activities** (such as the metering installations), impacting other WPs and Tasks; finally, it is currently proceeding with the development of the platform itself.

D4.4's purpose is to provide an overview of T4.2 activities and it aims to:

- **Describe the demand and response platform vision** (co-developed by TPF and STAM);
- **Describe the sensors and Smart IoT gateway** (TSRV) **plan** for Brussels Living Lab (co-developed by TSRV and STAM, installed by TPF) ;
- **Detail a demo of the tool applied in the Brussels LL** ;
- Describe many **additional features** that are **expected** to be developed in next months.

1.3. Structure of the document and its relationship with other WPs/Deliverables

In this deliverable, we first detail the **requirements collection** for such a demand and response platform, both by **collecting state of the art** information about green buildings and green neighbourhoods, and by collecting **feedback** from the Probono project itself (Living Laboratories and different previous deliverables). We particularly **learn from reports "*D1.1: Definition of a GBN*"** and **"*D1.3B: Strategic vision and KPI formalisation*"**.

In a second time, we cover the **vision and objectives of the in-development platform** answering the requirements collected previously. We **introduce** the **concepts** of *Recipes, Energy Entities and Energy connectors as* the main concepts used for the tool usage, and explore the possibilities and decision-making solutions brought by our approach.

In chapter 4, we go through the **platform design and implementation for Probono** and give detailed insights about the monitoring and data collection plan, the software solution and its architecture.

The report finishes with the **analysis of the Brussels Living Lab** use case. We use the **report "D6.2: baseline Evaluation"** to gather **most of the parameters** needed for our platform to run. This report seems to be a good replication mean for the other Living Labs. We detail the practical installation of the detailed **monitoring plan in the school**, and the implementation of the three first steps of our platform on this concrete example. We also explore the **interest of other LL's** for the energy D&R platform and conclude with the **next steps to be implemented** and reported in both **D4.5** (**implemented in initial LL's** for M36) and **D4.6** (**implemented in final LL's** for M54).

D4.5 (M36) will explore the integration of new appliances on the platform (as fuel cell, cogeneration, solar thermal, geothermy), initiate the developments of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), initiate Digital Twin integration with AKA, explore user experience with SIN, and implement the platform on Aarhus and Dublin use cases.

D4.6 (M36) will further develop the concept of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), further develop Digital Twin integration with AKA, deeper explore User experience with SIN, and implement the platform on Madrid and Porto use cases.

1.4. Contribution to creating GBN

There are **two main concepts** to underline form the Green Buildings (1) and Neighbourhoods (2) concept:

1. **Green buildings** are structures that are designed, built, and operated in an environmentally sustainable way. They incorporate practices and technologies that reduce their impact on the environment and promote the health and wellbeing of their occupants. As 85% of today's buildings are likely to still be in use in 2050, renovations will play a crucial role in buildings to reach the net zero GHG emissions objective.
2. **Green neighbourhoods** are communities that are designed, built, and managed with a focus on sustainability, environmental responsibility, and community wellbeing. This concept is slowly growing with the emergence of energy communities.

The D4.4 is a first step (I) in the creation of a demand and response platform that will help GBN decision makers in creating a GBN in the two concepts detailed before:

1. The platform will help them in their **energy renovations decisions** by comparing different scenarios of investments from the actual baseline. It will also **facilitate the access of funding** by financially comparing scenarios to this baseline and **output key values as *CAPEX*, *NVP* and *RoI***.
2. When talking about energy at a neighbourhood or community level, the main concept to explore is the **sharing of energy and change of habits to optimize the overall consumption**. The platform will be able to propose optimization of loads between different buildings to achieve this greater objective. Doing this will also help the designers give tailored propositions of behavioural change that could optimize even more the global consumption of the neighbourhood.

More specifically, the platform will help Living Labs to simulate their renovation plans and access to knowledge that will help them in the development of their objectives such as: request for subsidies and bank loans, revue of Energy Performance Contracts, and evaluation of investments.

2. Setting the scene

In the framework of green buildings and neighbourhoods, the case of energy becomes increasingly important.

First, the concept of green buildings and green neighbourhoods refers directly to a transition to climate neutrality, which is underpinned by an objective of net zero (or negative) greenhouse gases emission of the building and neighbourhood. *Homes and commercial buildings use large amounts of energy for heating, cooling, lighting, and other functions. "Green building" techniques and retrofits can allow new and existing buildings to use less energy to accomplish the same functions, leading to fewer greenhouse gas emissions.*[10]

In the same horizon, public actors support more and more *local actors to take ownership of energy consumption and production,*[11] enabling incentives as subsides for green investments and new concepts as Energy Communities.

The objective of this chapter is to present an overview of:

- the situation for green building renovations and green neighbourhoods' creation, from the public incentives to the problems faced;
- to stress the importance of implementing a platform able to properly identify the energy demand;
- to match the energy demand with the energy supply;
- possibly, to minimise the consumption and the cashflow.

2.1. Green buildings renovations and investments

As more than 85% of today's buildings are likely to still be in use in 2050, renovations will play a crucial role in buildings to reach the net zero GHG emissions objective.

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[10] https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[11] Energy communities repository: https://energy-communities-repository.ec.europa.eu/about_en

The renovation of a building is triggered and motivated by various incentives as well as tools and evaluation benchmarks, which are described below.

- **Incentives** → to ease the investor's effort and make the renovation affordable also to whom does not own large capitals;
- **Design studies** → to highlight improvements to be put in place inside the building;
- **Total cost of ownership** → to have evidence of the building's costs, running the day-to-day activities;
- **Investment plans** → to give a comprehensive overview of a project and ease funding decision, by banks or other investors, expecting a consistent ROI afterwards.

2.1.1. Incentives

With buildings accounting for 40% of the European Union's annual energy consumption and 36% of its annual greenhouse gas emissions from the energy sector, it is imperative to enhance the sustainability of the building industry to align with EU climate objectives. The European Green Deal endeavours to bolster the sustainability of the building sector primarily through two key initiatives: firstly, by strengthening legislation pertaining to energy efficiency and the Energy Performance of Buildings (EPB) certificates, and secondly, by incentivizing the adoption of end-user electrification in the residential sector through subsidies.

2.1.2. EPB classification

The Energy Performance of Buildings (EPB) classification is a system developed to assess and rate the energy efficiency of buildings. The system considers numerous factors that affect the energy consumption of buildings, such as insulation, ventilation, heating, and cooling systems, and lighting.

The EPB classification is usually presented in the form of an energy performance certificate (EPC), which provides a rating for the building based on its energy efficiency. As depicted in Figure 1, EPC uses a scale from A to G, with A being the most energy-efficient and G being the least energy-efficient. Buildings with higher ratings on the EPC scale are considered more energy-efficient and environmentally friendly.

Figure 1: EPB Classification[12]

There are several incentives that can be generated by the EPB classification system. For example, in many countries, buildings with higher ratings on the EPC scale are eligible for financial incentives, such as tax breaks, rebates, or lower interest rates on loans. Additionally, buildings with higher ratings may have higher resale values and be more attractive to potential tenants or buyers, which can lead to increased demand and higher rental or sale prices.

Another significant incentive of the EPB classification is the potential to reduce energy costs. By improving the energy efficiency of a building, owners can save money on energy bills, which can result in significant cost savings over time. Furthermore, reducing energy consumption can help to reduce carbon emissions, contributing to the fight against climate change.

In summary, the EPB classification system provides a useful tool for assessing and improving the energy efficiency of buildings. By encouraging building owners to make energy-efficient upgrades, the system can generate significant financial incentives and help to reduce energy consumption and carbon emissions.

2.1.3. Subsides

Subsidies can have a significant impact on the energy efficiency of buildings by incentivizing building owners to make energy-efficient upgrades. There are several ways in which subsidies can encourage energy-efficient building practices.

Firstly, subsidies can help **to offset the cost of energy-efficient upgrades**. Energy-efficient upgrades, such as insulation, high-efficiency HVAC systems, and energy-efficient lighting, can be

[12] Picture found on : https://www.energuide.be/en/questions-answers/what-is-the-epb-certificate/63/

expensive. By offering subsidies, governments or organizations can make these upgrades more accessible to building owners, who may otherwise be deterred by the cost.

Secondly, subsidies can encourage **the adoption of energy-efficient building practices by making them more financially attractive**. For example, subsidies may offer financial rewards to building owners who implement energy-efficient practices, such as installing solar panels or upgrading to high-efficiency HVAC systems.

Thirdly, subsidies can promote the adoption of energy-efficient building practices by **setting minimum standards for energy efficiency**. For example, some countries (Belgium with EPB 2013, Germany with Gebäudeenergiegesetz 2020 and France with RT2012) have implemented building codes that require new buildings to meet specific energy efficiency standards. Building owners who comply with these standards may be eligible for subsidies or other incentives.

Finally, subsidies can help **to raise awareness about the benefits of energy efficiency** and encourage building owners to make energy-efficient upgrades. By promoting the benefits of energy efficiency and providing information on energy-efficient upgrades, subsidies can help to educate building owners about the importance of energy efficiency and encourage them to act.

In summary, subsidies can have a significant impact on the energy efficiency of buildings by making energy-efficient upgrades more accessible and financially attractive, promoting energy-efficient building practices, setting minimum standards for energy efficiency, and raising awareness about the benefits of energy efficiency.

2.1.4. Design studies – choice of the investment

A HVAC (Heating, Ventilation, and Air Conditioning) design study is a detailed analysis of the HVAC system of a building, aimed at optimizing its performance and energy efficiency. The study involves a comprehensive analysis of the building's heating, cooling, and ventilation needs and an assessment of the existing HVAC system's performance and potential for improvement.

The objectives of a HVAC design study can vary depending on the building's specific needs and goals. However, in general, the primary objectives of a HVAC design study include:

- Identifying areas where the HVAC system can be improved to increase energy efficiency, reduce operating costs, and decrease carbon emissions.
- Evaluating the existing HVAC system's performance and identifying any shortcomings or inefficiencies.

- Developing a plan for optimizing the HVAC system's performance, including recommendations for system upgrades or replacement.
- Providing recommendations for implementing energy-efficient HVAC technologies and strategies, such as high-efficiency HVAC equipment, energy recovery systems, and building automation systems.
- Ensuring that the HVAC system is designed to meet the building's specific heating, cooling, and ventilation needs.

The expected results of an HVAC design study can also vary depending on the building's specific needs and goals. However, in general, the expected results of a HVAC design study include:

- Improved energy efficiency and reduced operating costs.
- Improved indoor air quality and occupant comfort.
- Reduced carbon emissions and environmental impact.
- Improved system reliability and reduced maintenance costs.
- Compliance with building codes and standards for energy efficiency and indoor air quality.

While a HVAC design study can be particularly useful in optimizing the performance and energy efficiency of a building's HVAC system, it is not without its drawbacks. One of the main drawbacks is that **it can be costly and time-consuming to conduct a thorough study**. The study **requires specialized expertise and equipment** to analyze the HVAC system's performance and make recommendations for improvements, which can add to the cost of the study. Additionally, the implementation of the recommended upgrades or replacements can also be costly, which may deter some building owners from pursuing the study's recommendations.

Another potential drawback of a HVAC design study is that it may not always result in significant energy savings or cost reductions. Depending on the building's existing HVAC system and energy use, the recommended upgrades or replacements may not yield significant improvements in energy efficiency or cost savings. In some cases, the cost of implementing the recommended upgrades may outweigh the cost savings from improved energy efficiency.

Lastly, a HVAC design study may not always be feasible for all types of buildings. Small buildings or buildings with simple HVAC systems may not require a detailed design study, while larger or more complex buildings may require more extensive studies and analyses, which can be costly and time-consuming.

2.1.5. Total cost of Ownership (TCO)

The concept of Total Cost of Ownership (TCO) refers to the total cost associated with owning, operating, and maintaining a particular asset or investment over its entire lifetime. It is a financial metric that considers all costs associated with owning and using an asset, including not only the initial purchase price but also ongoing expenses such as maintenance, repairs, replacement, and disposal.

TCO is often used to evaluate and compare different investment options, such as purchasing a piece of equipment or software, or investing in a building or a vehicle. By looking beyond, the initial purchase price and considering the long-term costs of ownership, TCO can help organizations make more informed decisions about which investments will provide the best value over time.

To calculate TCO, all costs associated with owning and operating an asset are added up over its expected useful life. This includes the initial purchase price, installation costs, ongoing maintenance and repair costs, energy and fuel costs, insurance costs, and any other costs associated with owning and operating the asset. The total cost is then divided by the asset's expected useful life to arrive at an average annual cost of ownership.

The benefits of calculating TCO include:

- Better decision making: TCO allows organizations to make more informed decisions about investments by **providing a more accurate picture of the total costs associated with owning and operating an asset**.
- Identifying cost-saving opportunities: TCO can **help identify areas where cost savings can be achieved**, such as by choosing a more energy-efficient asset or implementing a more effective maintenance program.
- Improved budgeting: TCO provides **a more accurate estimate of the long-term costs of ownership**, which can help organizations develop more accurate budgets and financial plans.

Overall, TCO is a useful tool for organizations looking to make informed investment decisions and manage their financial resources more effectively. By considering all costs associated with owning and operating an asset, organizations can make more informed decisions that maximize value and minimize total costs over the asset's lifetime.

2.1.6. Investment plans

Investment plans are made to evaluate the feasibility and potential of proposed investment projects. They serve as a blueprint for the project, providing a comprehensive overview of the project's objectives, scope, timeline, financial requirements, and potential risks and rewards. Investment plans are typically prepared when seeking funding from banks or other investors to secure financing for the project.

Investment plans are evaluated based on several key parameters, including:

- ROI (Return on Investment): The ROI is a key parameter used to evaluate investment projects. It measures the expected financial return of the investment project, considering the initial investment, expected cash flows, and expected returns over the project's lifetime. A higher ROI indicates a more profitable investment opportunity.
- NPV (Net Present Value): The NPV measures the present value of the expected cash flows from the investment project, considering the time value of money. A positive NPV indicates that the investment project is expected to generate a positive return, while a negative NPV indicates that the project is expected to generate a negative return.
- IRR (Internal Rate of Return): The IRR is the discount rate that makes the present value of the expected cash flows equal to the initial investment. It is a measure of the investment project's profitability, with higher IRR indicating a more profitable investment opportunity.
- Payback Period: The payback period is the amount of time it takes for the initial investment to be recouped through the project's cash flows. A shorter payback period indicates a more attractive investment opportunity, as it allows for a quicker return on investment.
- Risk Analysis: Investment plans also evaluate potential risks associated with the investment project, including market risks, operational risks, financial risks, and regulatory risks. Risk analysis helps investors understand the potential risks and rewards associated with the investment project and develop strategies to mitigate risks.

Overall, investment plans are evaluated based on a combination of financial and non-financial factors. By considering all factors, investors can make informed decisions about which investment projects are most likely to generate positive returns and achieve their desired objectives.

2.2. Green neighbourhoods creation

Green neighbourhood creation is an approach to urban planning that emphasizes sustainable development, environmental conservation, and community engagement. It involves the design and construction and renovation of neighbourhoods that promote energy efficiency, reduce waste, and provide residents with access to green spaces, public transportation, and other amenities. Green neighbourhoods are intended to improve the quality of life for residents while also reducing the environmental impact of urban development. This approach has gained popularity in recent years as cities around the world have grappled with the challenges of climate change and urbanization. By prioritizing sustainability and community engagement, green neighbourhoods offer a promising model for creating more liveable, equitable, and environmentally responsible cities.

When focalizing on energy in neighbourhoods, some emerging concepts can help, such as Energy performance contracts and Energy Communities.

2.2.1. Energy Performance Contracts (EPC)

An Energy Performance Contract (EPC) is a contractual agreement between a client and an energy services company (ESCO), in which the ESCO agrees to implement energy efficiency measures and guarantee a certain level of energy savings for a specified period of time. The client pays for the energy efficiency upgrades using a portion of the savings generated by the project.

Advantages for the client:

- **No upfront costs**: The client does not have to invest any capital upfront, as the ESCO covers the cost of the energy efficiency measures.
- **Guaranteed savings**: The ESCO guarantees a certain level of energy savings, providing the client with a predictable return on investment.
- **Reduced energy costs**: The energy efficiency measures implemented by the ESCO typically result in reduced energy consumption and lower energy costs for the client.
- **Reduced maintenance costs**: Energy efficiency measures can also reduce maintenance costs by improving the performance and lifespan of building systems.
- **Increased asset value**: Energy efficiency upgrades can increase the value of the building or facility, providing long-term benefits for the client.

Advantages for the contractor:

- **Revenue stream**: EPCs provide a steady revenue stream for the ESCO over the duration of the contract.
- **Guaranteed savings**: The ESCO's reputation is tied to the energy savings guarantee, providing an incentive to deliver high-quality energy efficiency measures and services.
- **Long-term customer relationships**: EPCs can lead to long-term relationships with clients, providing opportunities for additional projects and services in the future.

Drawbacks for the client:

- **Contractual obligations**: The client is typically required to maintain certain energy usage levels and pay for energy costs in accordance with the contract, which can limit flexibility.
- **Contract duration**: EPCs typically have a long-term duration, ranging from 5 to 20 years, which can limit the client's ability to switch to other energy efficiency solutions or ESCOs.
- **Performance risk**: If the energy savings guarantee is not met, the client may be required to pay the difference, which can result in unexpected costs.

Drawbacks for the contractor:

- **Performance risk**: The ESCO assumes the risk of not achieving the guaranteed energy savings, which can result in financial losses.
- **Limited revenue**: The ESCO's revenue is limited to the energy savings generated by the project, which can limit profitability.
- **Technical challenges**: Implementing energy efficiency measures can involve technical challenges, such as integrating new systems with existing building systems or overcoming regulatory hurdles.

Overall, EPCs provide a flexible financing option for energy efficiency projects, allowing clients to achieve energy savings and reduce energy costs without upfront capital investments. However, clients should carefully evaluate the terms of the contract and the risks involved before entering into an EPC agreement. ESCOs also need to carefully assess the performance risk and technical challenges associated with implementing energy efficiency measures to ensure the success of the project.

2.2.2. Energy communities

A European Energy Community (EEC) is a concept driven by European directives that member states have to transpose into national laws under which national energy communities are established. Their aim is to promote the development of renewable energy and energy efficiency measures at the local level. The legal framework for EECs is provided by the Renewable Energy Directive (RED) and the Energy Efficiency Directive (EED), which set out the requirements for the establishment and operation of EECs.

EECs can take many forms, ranging from cooperatives and associations to companies and municipalities. The key feature of an EEC is that it is owned and operated by its members, who are typically residents or businesses in a specific geographical area. Members of an EEC share the costs and benefits of renewable energy and energy efficiency projects, such as solar panels, wind turbines, and energy-efficient buildings.

The legal framework for EECs provides several possibilities for their operation and benefits, including:

- **Access to funding**: EECs can access funding from the EU and national governments to support the development of renewable energy and energy efficiency projects.
- **Lower energy costs**: Members of an EEC can benefit from lower energy costs by sharing in the savings generated by renewable energy and energy efficiency projects.
- **Increased energy independence**: EECs can help to reduce dependence on fossil fuels and increase local energy independence by promoting the use of renewable energy sources.
- **Environmental benefits**: EECs can help to reduce greenhouse gas emissions and promote environmental sustainability by promoting the use of renewable energy and energy efficiency measures.

To establish an EEC, a legal entity must be formed under national law, and must meet certain requirements set out in the RED and the EED. These requirements include the adoption of a governance structure that ensures democratic decision-making and fair representation of members, as well as the adoption of transparent accounting and reporting practices.

Overall, EECs provide a means for local communities to take ownership of their energy future, promoting the development of renewable energy and energy efficiency measures at the local level. By pooling resources and sharing the costs and benefits of energy projects, EECs can help to reduce energy costs, increase energy independence, and promote environmental sustainability.

2.3. Summary of the main concepts

2.1 Green buildings renovations and investments	
2.1.1 Incentives	EPB Classification: system developed to assess and rate the energy performance of the buildings through a scale from A (very high) to G (very low). Financial incentives can be applied by Public authorities based on this classification: tax breaks, rebates, adjustment of loan interest rate, … Subsides: - Offset the cost of energy-efficient upgrades - Making energy-efficient building practice more financially attractive - Compliance with minimum standards for energy efficiency - Raise awareness about the benefits of energy efficiency
1.1.2.Design Studies	- objective: optimize building's HVAC system for performance and energy efficiency. - expected results: improved energy efficiency, indoor air quality, and compliance with building codes and standards. - drawbacks: include cost and time-consuming nature of the study, potential for minimal energy savings, and feasibility concerns for small or simple buildings.
2.1.3 Total Cost of Ownership (TCO)	- objective: consideration of all costs associated with owning and using an asset over its lifetime. - use: comparison of investment options and make more informed decisions about value over time. - benefits: improved decision-making, identifying cost-saving opportunities, and improved budgeting.
2.1.4 Investment plans	- objective: evaluation of the feasibility and potential of proposed investment projects - use: comprehensive overview of the project's objectives, scope, timeline, financial requirements, and potential risks and rewards - key parameters: Net Present Value, Return on Investment, payback period
2.2 Green neighbourhoods creation	

2.2.1 Energy Performance Contracts (EPC)	- Contract between a client and an Energy Service Company), in which the ESCO agrees to implement energy efficiency measures and to guarantee a certain level of energy savings for a specified period of time. - advantages: no upfront costs, guaranteed savings, reduced energy & maintenance costs, fixed financial stream, long-term relation. - Disadvantages: contractual obligations, contract duration, performance risk, technical challenges.
2.2.2 Energy Communities	- Entities developed under national laws following EU directives and promoting the development of renewable energy and energy efficiency measures at the local level; - Members share in the costs and benefits of renewable energy and energy efficiency projects - means for local communities to take ownership of their energy future, promoting the development of renewable energy and energy efficiency measures at the local level.

Table 3: Summary of the main concepts described in chapter 2

3. Our approach

The objective of our energy demand and response platform is to address the problems and limitations highlighted in the previous chapter. Our approach is to create a tool that helps decision-makers to make informed investment decisions without incurring the high costs and delays associated with design studies.

Amongst other, our platform helps to identify the best set of appliances to be installed in a building to reduce the energy costs while responding to the real demand. Furthermore, in the sum of "energy costs", costs related to CO2 emissions are included, to consider also the environmental impact deriving from the building's usage.

Figure 2 is a block diagram listing the main steps you will get through using the Demand & Response platform.

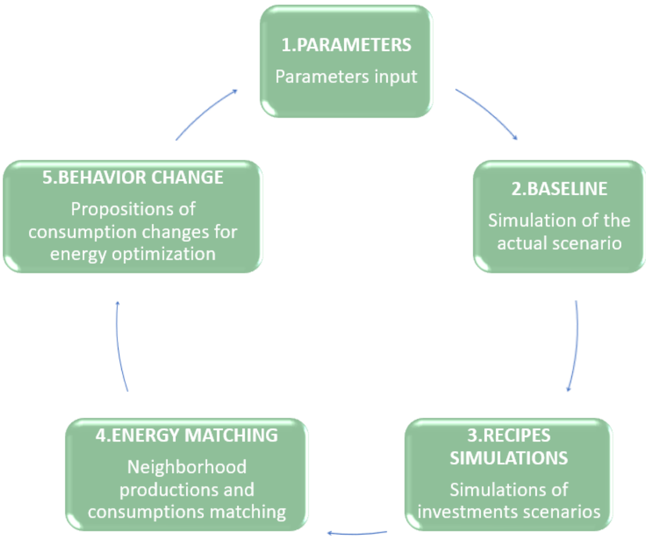

Figure 2: overview scheme of the D&R platform 5 steps

The platform begins by using a few parameters about the Energy Entity, such as its location and associated prices, to represent its actual consumption and production curves as a baseline. The consumption and production curves can be measured or estimated, according to the amount and quality of available data. We then evaluate different investment options based on the client's needs, budget, and site constraints. These investment options are automatically designed and adapted to meet the demands of the site while maximizing or minimizing specific variables such as net present value, return on investment, and CO2 emissions. The optimised analysis may be complemented with a manual design, to increase the awareness of the viable solutions impact.

If the concept of a neighbourhood can be applied (such as a site with multiple Energy Entities or an Energy Community), the next step is to optimize the energy production and consumption of the neighbourhood by matching the surplus of produced energy that could be shared between different energy communities.

Finally, we propose behavioural changes on the building's scale to further optimize the energy distribution in the neighbourhood. If any of these proposals are selected, we begin the loop again with the new parameters.

The advantage of adopting the platform is manifold:

- Both the **sensitivity** and **optimised analysis** are fundamental to identify the best solutions to increase the EPB of the building(s), to reduce costs and reduce the environmental impact;
- The possibility of setting some constraints (on the type/size of the appliances, …) makes the simulation more realistic;
- Running the platform does not require specific skills; the results are returned quite in real time and, according to the level of precision required, few and complex inputs are required;

Until now, steps 1 to 3 have been implemented to the tool. Steps 4 and 5 are described here to give an idea of the final product we aim to deliver.

3.1. STEP 1: Input parameters

We can gain a comprehensive understanding of an Energy Entity by considering a few key parameters that can be grouped into three categories, as shown in Figure 3: localization, technical characteristics, and investments. In the subsequent sub-chapters, we will provide a detailed explanation of these parameters and their significance in utilizing our tool.

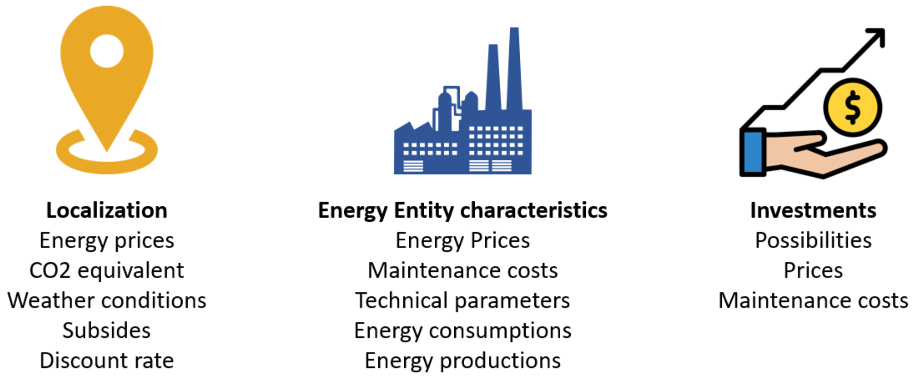

Figure 3: Input parameters necessary for the D&R platform

These parameters will come from different sources: the user, the API and the design builder.

3.1.1. Localization parameters

The user is required to provide the city where the building(s) is located. Given the coordinates of the facility, the platform automatically collects the related information, by calling some APIs[13] and by retrieving data from an historical database that we created.

From the localization of the Energy Entity, we can determine different useful information:

- The Weather conditions will have various impacts on the decision making because they will influence consumptions and/or productions;

Weather parameter	Impact on energy consumption of the Energy Entities	Impact on energy production of the building
Outdoor Temperature	Outdoor temperature will play a key role in building heat gain or losses, and in heating / cooling consumptions.	Air-to-air heat pumps efficiency are directly correlated with outdoor temperature.
Solar irradiance	For poorly insulated buildings, the solar irradiance will have a high	The production of solar panels (electricity) or solar thermal (hot

[13] API are used with the PVGIS that provides information about solar radiation and photovoltaic (PV) system performance for any location in Europe and Africa, as well as a large part of Asia and America. https://re.jrc.ec.europa.eu/pvg_tools/en/

	impact on the heat gains and thus on heating and cooling conditions.	water) will directly vary with the solar irradiance.
Geothermal		Geothermal heat pump really is efficient in places meeting specific conditions.

Table 4: weather conditions impact on consumption and production curves

- Depending on the country or region, one can have access to financial incentives as <u>subsides</u> (see 2.1.3.) from the authorities in specific investments (green electricity certificates, subsides on thermal insulation or other consumption reducing investments, …);
- The <u>discount rate</u> is a key financial concept used to calculate the present value of future cash flows, considering the time value of money, inflation, and risk. Thus, the discount rate can vary by country and by economic conditions. It is a valuable tool in financial analysis and decision-making, particularly in determining the economic performance of long-term investments or projects.
- The <u>CO2 equivalent</u> of the electricity strongly depends on the country/region where the electricity is produced, as well as the energy costs (electricity and fuels) that varies from region to region;
- Regional habits influence the way to live and work, thus localization directly impacts the <u>consumption profiles</u>;
- Some pre-defined generic energy prices that can be drafted from the region of the considered *Energy Entity*.

3.1.2. Energy Entity characteristics

The user is required to provide some information about the Energy Entity itself so that the platform can match the reality as close as possible. Here is a list of the different parameters that could be specific to the Energy Entity itself, and that could not be drafted from the localization parameters.

- <u>Energy prices</u> could be negotiated with the supplier in a specific contract and thus be specific for every Energy Entity. The users can choose between selecting generic Energy prices drafted from its localization parameters, or introduce in the platform more specific Energy Prices from their own bills;

- Maintenance costs are also dependent of the contract in place on site. Indeed, the prices will be influenced by the length of the contract, the relationship client/provider, etc.
- Technical parameters: appliances already in use, size and consumption profile of the building, EPB classification (see 2.1.2.), etc.
- Energy consumptions and productions will be gathered by meters with a certain granularity: the ideal situation appears when we have access to detailed data (IoT monitoring), but it is still frequent to only access data from the monthly/annual energy bills.

As mentioned before, the platform is directly connected to a database where we already stored much information related to energy (type, cost, CO2 equivalent, etc.) and appliances (type, cost and operational cost, efficiency, the required maintenance, etc.). The database is constantly updated and verified to stay close to reality.

3.1.3. Investments parameters

Now that the Energy Entity is clearly defined, we need to elaborate and construct a list of possible energy efficiency investments to improve the performance of the building. This step will be done in collaboration with the clients (assessment of their needs and desires). Once this list is clearly defined, we will have to assess different questions such as: the technical possibility for such an investment, its capital cost as well as its operation and maintenance costs:

- For every investment option, we first need to evaluate the possibility for a specific Energy Entity. Some options will not be applicable because of the localization (for example, geothermal heat pumps where no geothermal activity exists, wind turbines with a poor wind exposition, PV’s with a poor sun exposure, etc.) or because of the Energy Entity’s technical requirements (roof not adapted to support solar panels structure, no place for a specific appliance, …).
- The price of every investment will vary: installation costs, hardware costs, …
- The maintenance cost of investment options will depend on the maintenance costs applied by the utilities operator of the *Energy Entity*.

3.2. STEP 2: Demand and response baseline

To compare different investment plans, it is necessary to establish a baseline of the current situation. This can be achieved through several parameters outlined in section 3.1. , including:

- Generating energy demand and response curves based on energy consumption's and production's correlated with the building energy profiles.
- Determining actual energy costs of the building based on demand and response curves, energy costs, and maintenance costs.

3.2.1. Demand and response curves

The demand and response curves will be based on information gathered through monitoring and will help us represent the baseline "behaviour" of the Energy Entity[14]. In case such data is not available, the demand and response curve can be simulated, based on generic building profiles. For our platform, we work with hourly demand and response curves on a period of a typical meteorological year for setting the baseline[15].

Below, you will find some means graphs outputted by the platform. For each energy considered here you will find in the following order:

- Two slider screenshots of the hourly slider charts of a whole year of demand and response:
    - A screenshot of the hourly slider graph on a year from the 29 January 0 AM to 30 January 12 PM.
    - Another screenshot of the hourly slider graph on a year from the 5th of July 0 AM to the 6th of July 12 PM.
- A monthly consumption graph for the whole year;
- The seasonal typical days (Fall, Winter, Spring and Summer) that show means of the daily results for each season.

[15] A typical meteorological year (TMY) is a set of meteorological data with data values for every hour in a year for a given geographical location (link).

For this example, we consider a building having an "**Office**" profile, and the following annual consumptions:

- **Annual electricity consumption**: **245.292 kWh** supplied only by the grid through a ***grey electricity*[16] *- unitary cost contract*** [17]
- **Annual heating consumption**: **371.594 kWh** with **sanitary hot water** share of **5%** covered only by a **150-kW gas boiler**. This means that we consider that 5% of the annual heating consumption is used for sanitary hot water, using the main heating system but having a different consumption profile (consumption even in summer due to showers).

3.2.2. Heat demand and response charts of the baseline:

Following graphs represent the simulated heat demand and response of the baseline situation introduced in 3.2.1.

Figure 4 shows an hour-by-hour graph of the Heat Demand (blue line) and heat response (orange surface) simulated by the platform. On the platform, it is possible to navigate through the whole typical year (last 5 years average).

[16] An energy provider can differentiate its production of green electricity (from green sources such as PV, wind power, ...), with grey electricity (from gas, coal, …). These two types of contracts will have different prices.

[17] An energy provider can sell its electricity with variable prices comparing to the production and network capacities. In general, electricity tends to be cheaper during the night as the network will be less used. In this regard, two main contracts do exist: unitary cost contracts do not make any difference of the time the electricity is used while peak/off-peak contracts will do the difference.

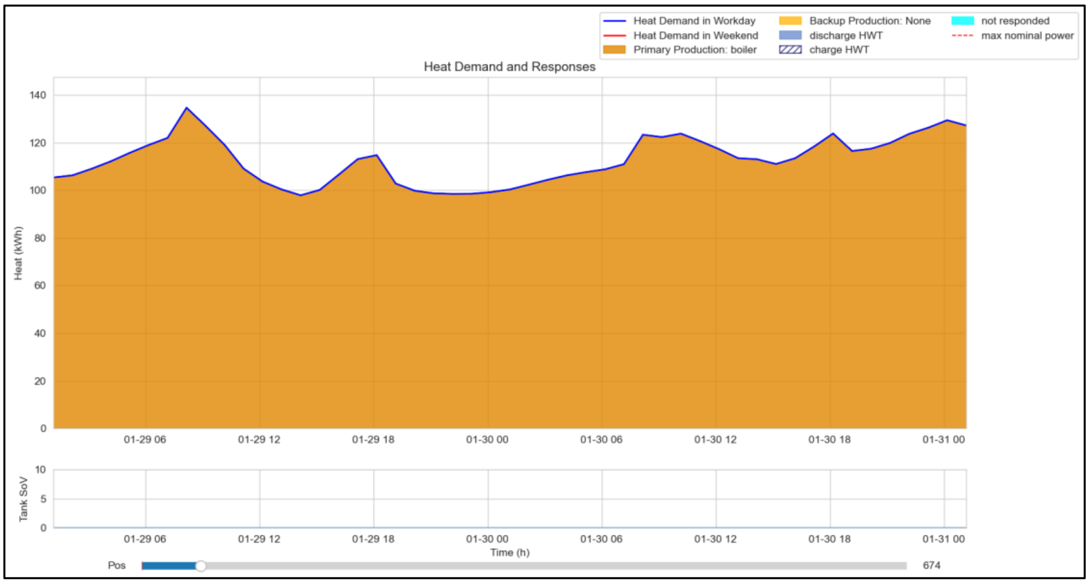

Figure 4: Hourly heating D&R from 29 January 0 AM to 30 January 12 PM curve on a slider graph for the baseline scenario

Figure 5 draws the Demands and response for every month of a typical year (last 5 years average).
Figure 6 draws seasonal heating Demand & Response for the baseline scenario.
We logically observe that the demand is higher in winter while nearly non-existent in summer as there is no need for heating the building to reach the setpoint of 24°C.

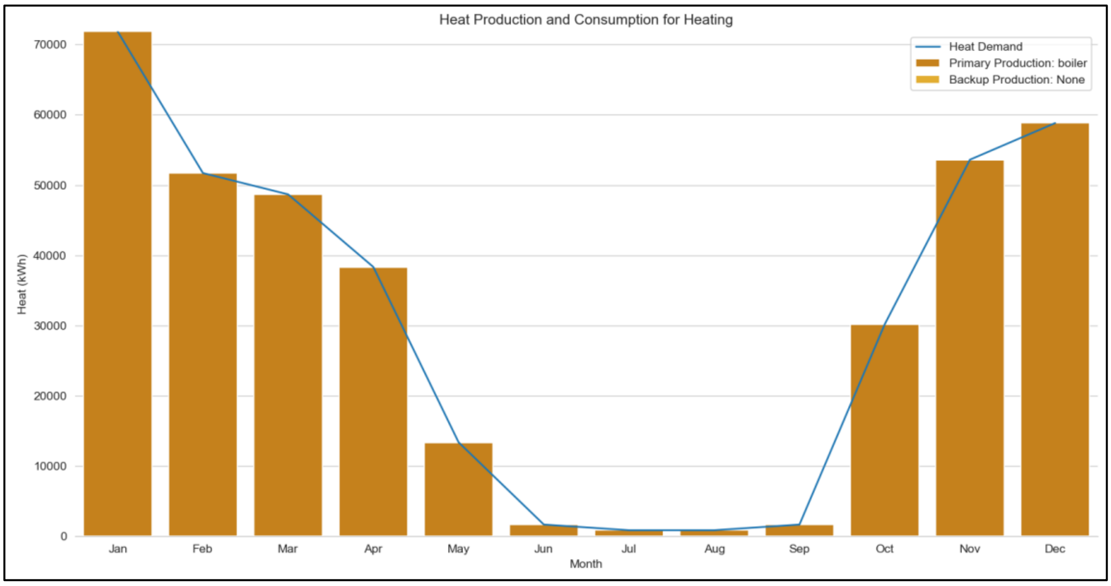

Figure 5: Monthly heating D&R curve for the baseline scenario

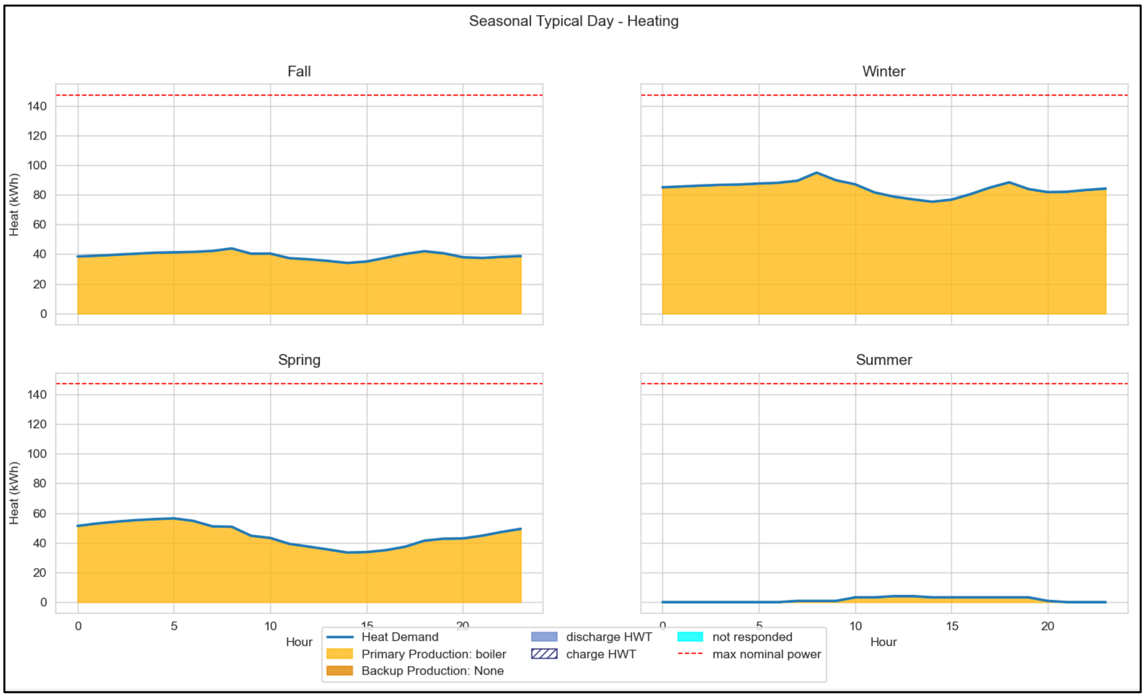

Figure 6: Seasonal heating D&R typical day for the baseline scenario

3.2.3. Electricity demand and response charts of the baseline:

Following graphs represent the simulated electricity demand and response of the baseline situation introduced in 3.2.1.

Figure 7 and Figure 8 shows an hour-by-hour graph of the electricity Demand (blue line) and heat response (red surface) simulated by the platform. On the platform, it is possible to navigate through the whole typical year (last 5 years average).

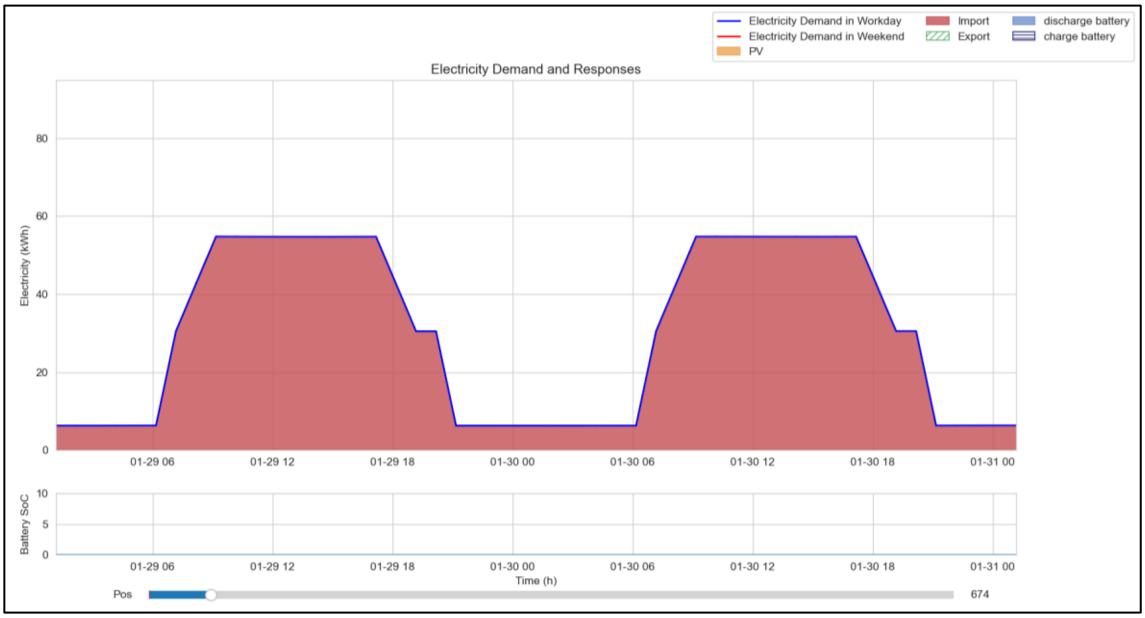

Figure 7: Hourly electricity D&R from 29 January 0 AM to 30 January 12 PM curve on slider graph for the baseline scenario

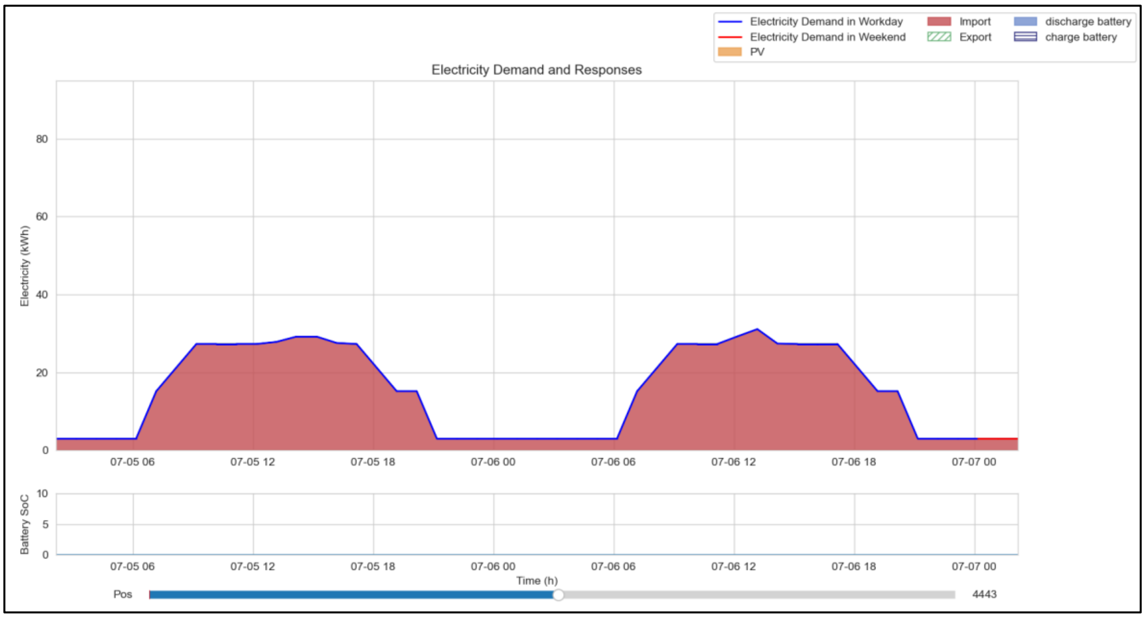

Figure 8: Hourly electricity D&R from 5th of July 0 AM to 6th of July 12 PM curve on slider graph for the baseline scenario

Figure 9 draws the electricity demands and response for every month of a typical year (last 5 years average). *Figure 10* draws seasonal electricity Demand & Response for the baseline scenario. In summer, we observe a diminution of the demand corresponding to holiday period in Belgium.

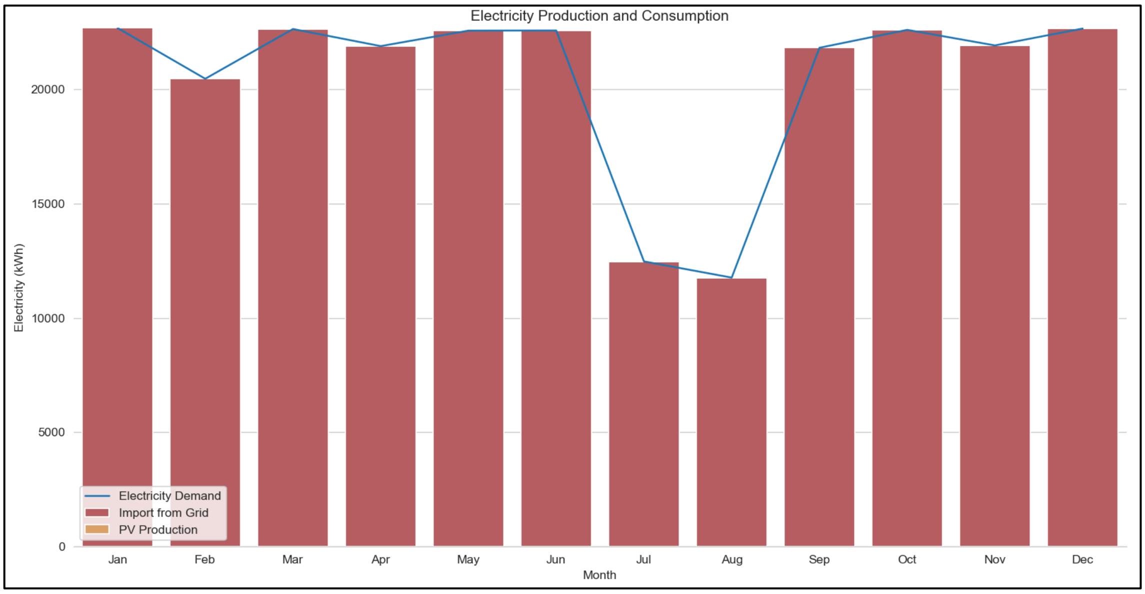

Figure 9: Monthly electricity demand and response curve for the baseline scenario

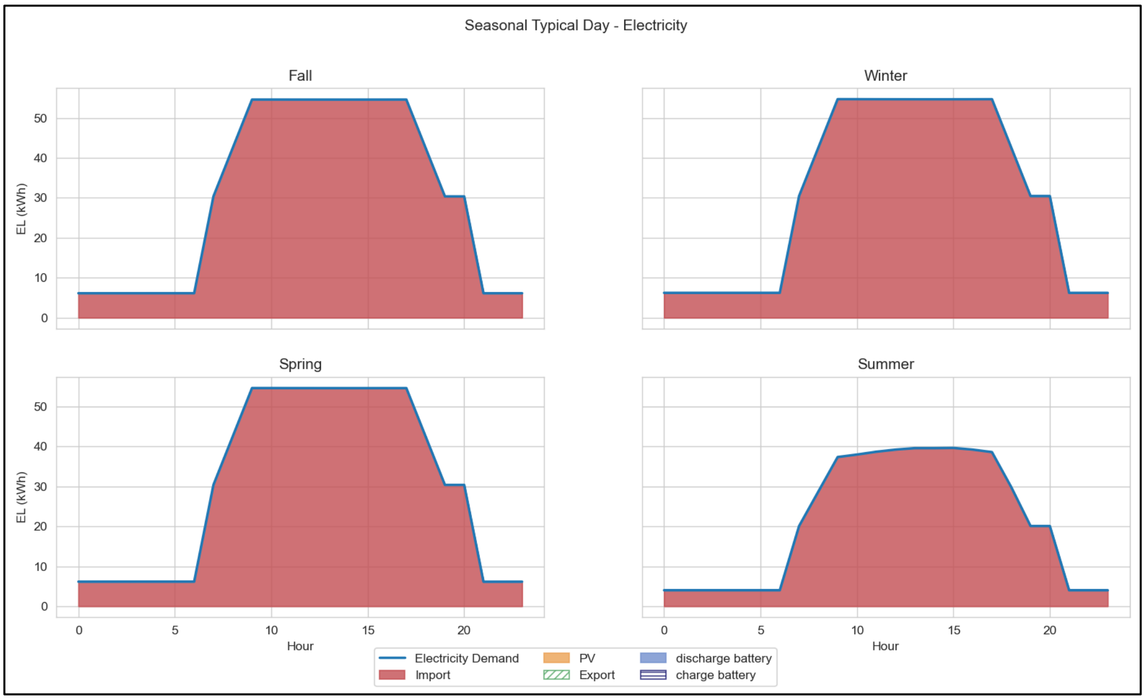

Figure 10: Seasonal electricity demand and response typical day for the baseline scenario

As mentioned, these curves can be obtained by two separate ways depending on the granularity of the data gathered: simulated curves from annual data or monitored curves from hourly data.

3.2.4. Simulated demand curves from annual data

In energy efficiency analysis, it is common to simulate a consumption curve for a building based on its annual energy consumption and the consumption profile of the building.

To simulate the consumption curve, the annual energy consumption of the building is first determined based on energy bills or other sources of data. Then, four consumption profiles of the building are analyzed to determine how energy is used throughout the day, week, month, and year: the electricity, the heating, the sanitary hot water, and the AC usages.

The resulting consumption curves provide a detailed view of how energy is used by the building over time. This can be used to identify opportunities for energy savings by pinpointing periods of high energy usage and identifying areas where energy-efficient technologies or behaviors can be implemented.

3.2.5. Monitored demand curves from hourly data

Hourly monitoring is a process of collecting and analysing data on energy usage and performance of a building or facility. This is typically done by installing a network of sensors that measure different parameters, such as temperature, humidity, and energy consumption, at regular intervals throughout the day. The collected data is then processed and analysed to identify patterns and trends in energy usage, which can be used to optimize building performance and reduce energy costs.

By monitoring energy usage on an hourly basis, facility managers can gain a detailed understanding of how the building is using energy, and identify areas where energy is being wasted or where improvements can be made. For example, if the data shows that energy usage spikes during certain times of the day, this may indicate that a particular piece of equipment or system is not operating efficiently and requires attention.

Hourly monitoring also allows for real-time feedback on building performance, which can be used to make immediate adjustments to energy usage. For example, if the data shows that energy usage is higher than expected, facility managers can take action to reduce usage, such as turning off lights or adjusting HVAC settings.

This solution is more complicated to put in place (price of the hardware and of the installation, time of installation and time for gathering the data), but is way more efficient than in 3.2.4. because it gives real-time data and not just annual data projected over a consumption profile.

3.3. STEP 3: Simulations of alternative recipes and comparison with the baseline

Now that the baseline curves are generated, we have everything in hand to simulate other configurations to identify opportunities for improvement. From the investment parameters, we can have a discussion with the client orienting the investments and / or the budget that they would consider. Once this first idea is decided, we can simulate different combinations of investments that we will call recipes.

3.3.1. Investment simulations: the concept of recipes

A *recipe* is a possible design of the energy systems composed of different energy components that can meet the Energy Entity's demands. As an example, let us consider an Energy Entity Baseline consisting of an office with electricity demand provided by the grid, and heating demand provided by a gas boiler. We could have the following recipes to simulate:

Recipe 1 : Installation of Solar Panels on the roof while keeping the old gas boiler;

Recipe 2 : Installation of Solar Panels on the roof and of a Battery while keeping the old gas boiler;

Recipe 3 : Installation of a heat pump with a Hot water Tank with all electricity taken from the grid;

Recipe 4 : Installation of Solar Panels on the roof and of a Battery while keeping the old gas boiler + installation of a heat pump with a Hot water Tank;

Each recipe will have a unique way of responding the demand, and there could be cases where the recipe will influence the demand curve. For example, the installation of a heat pump will have an impact on the electricity consumption curve.

The platform will automatically optimize the usage of the Energy components so that they match the hourly demands in the most efficient way. At this point, the platform will provide as output electricity, heating, sanitary hot water and financial graphs showing the simulated results for each recipe.

In order to keep the report readable, we will illustrate only one example in the text of the report, you will find a more complete showcase with different examples in Annex B. "Outputs of the platform on multiple different scenarios".

For this example, we will consider the case of the building illustrated in the baseline scenario in subchapter 3.2.2.

- **Annual electricity consumption**: **245.292 kWh** covered only by the grid through a **grey electricity - unitary cost contract**
- **Annual heating consumption**: **371.594 kWh** with **sanitary hot water** share of **5%** covered only by a **150 kW gas boiler**. This means that we consider that 5% of the annual heating consumption is used for sanitary hot water, using the main heating system but having a different consumption profile (consumption even in summer).

For which we will evaluate the following investments:

- Electricity:
  - Installation of a **1.000 m^2 solar panels field**;
  - Installation of **150 kWh Battery** with **50 kW rating**;
- Heating:
  - Installation of a **15 kW heat pump** as primary heat unit;
  - Keeping the **old 150 kW gas boiler** as a secondary heating unit;
  - Installation of a **10.000L hot water tank**;

The plotted graphs are the same as the ones described for the baseline, for each considered energy (heating and electricity) in the following order:

- Two slider screenshots of the hourly slider charts of a whole year of demand and response:
  - A screenshot of the hourly slider graph on a year from the 29 January 0 AM to 30 January 12 PM.
  - Another screenshot of the hourly slider graph on a year from the 5th of July 0 AM to the 6th of July 12 PM.
- A monthly consumption graph for the whole year;
- The seasonal typical days (Fall, Winter, Spring and Summer) that show means of the daily results for each season.

Comparing the charts plotted for the baseline and below will give us a full disclosure of the impact of the potential investment.

3.3.2. Heat demand and supply charts

Beginning with the hourly simulation for two days in January in Figure 11, we clearly see the full heating system working as the heat demand is pretty heavy (winter). The heat pump works at full power and the back-up boiler complements the heat demand. We make use of the hot water tank as a "heat storage" to minimize the overproductions of the boiler.

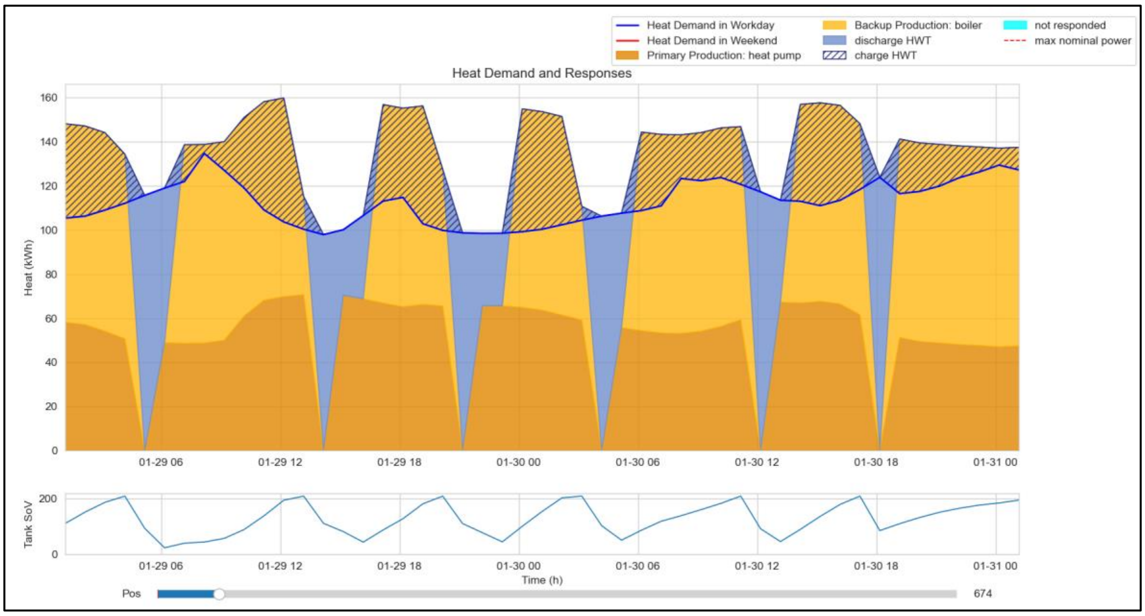

Figure 11: Hourly heating D&S from 29 January 0 AM to 30 January 12 PM curve on a slider graph for the investment scenario

During summer as shown in Figure 12, the small heating load generated by the sanitary hot water demand is fully covered by the heat pump alone.

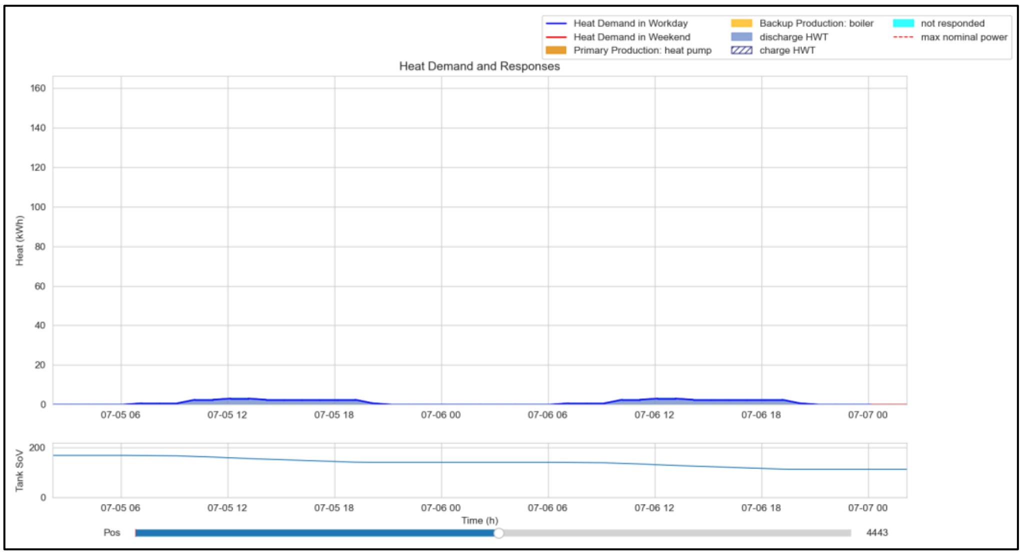

Figure 12: Figure 11: Hourly heating D&S from 5th of July 0 AM to 6th of July 12 PM curve on a slider graph for the investment scenario

Seeing an overview of the demand and supply chart per month in Figure 13 gives a clear idea of the efficiency of the system. Most of the demand is covered by the heat pump while the peak demands are covered by the gas boiler.

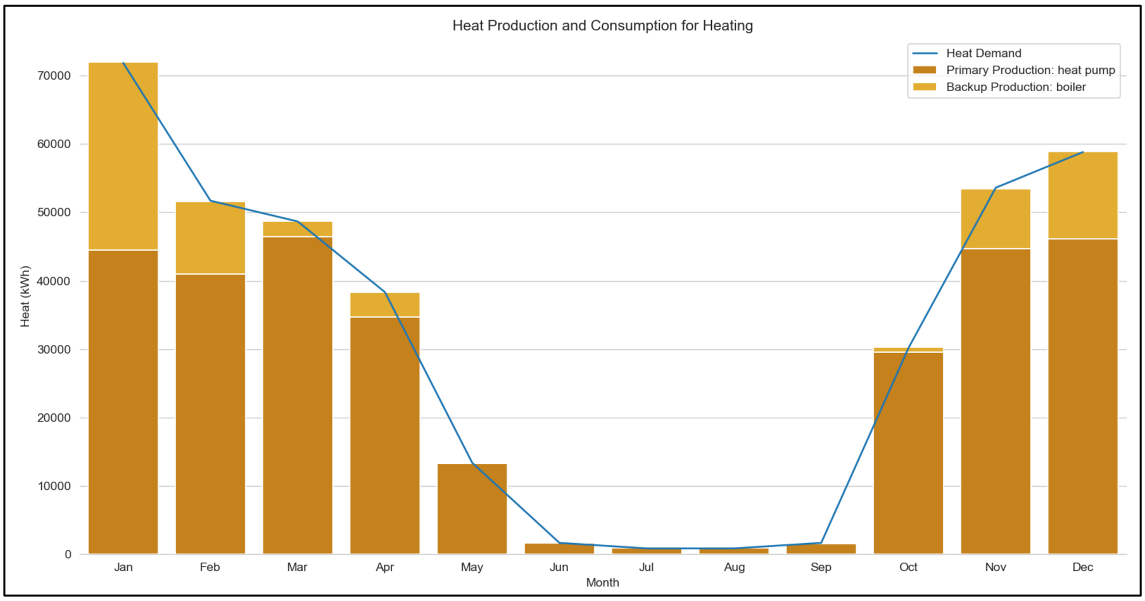

Figure 13: Monthly heating D&S curve for the investment scenario

Comparing the seasonal typical days with Figure 14 gives a great usage overview of each element of the system. The back-up gas boiler is mainly used in winter to complete the demand while the heat pump nearly works alone during the other seasons.

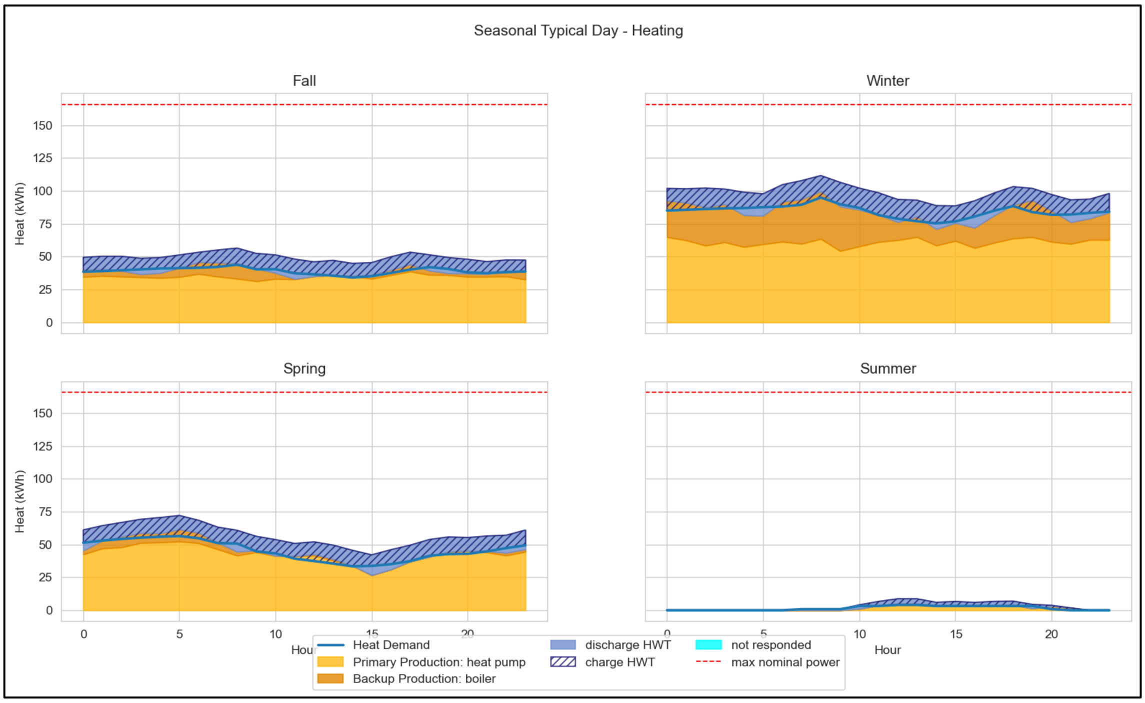

Figure 14: Seasonal heating D&R typical day for the investment scenario

Electricity demand and supply charts:

In Figure 15, we see clearly that the electricity produced by the solar panels during winter does not cover the electricity demand of the site.

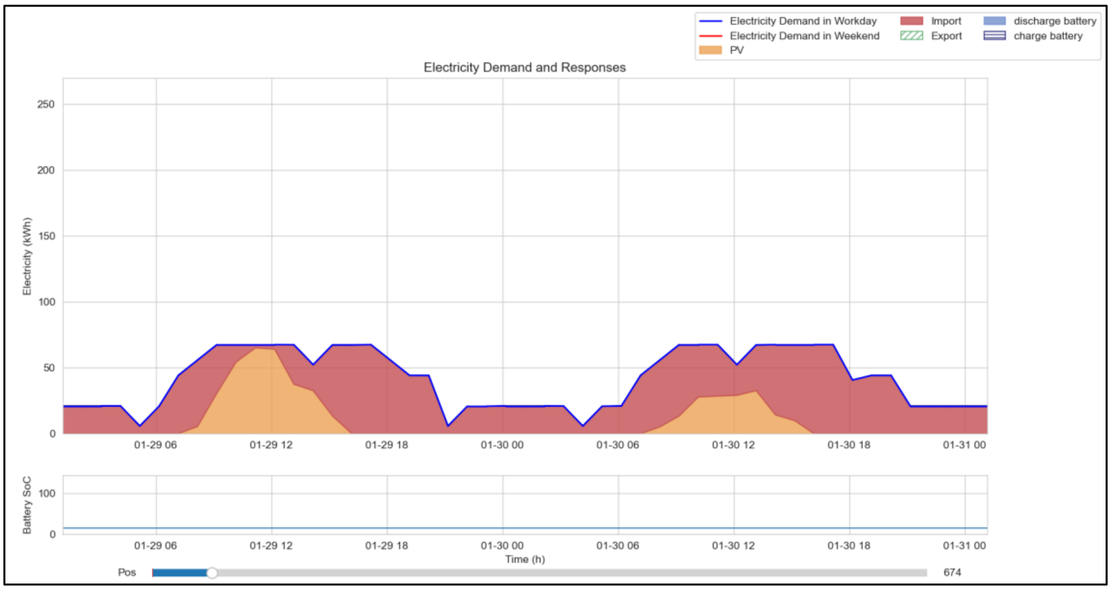

Figure 15: Hourly electricity D&S from 29 January 0 AM to 30 January 12 PM curve on slider graph for the investment scenario

A completely different case happens during summer, as seen on Figure 16, where we can see the solar panels' overproductions stored by the battery to be used during the night hours and the part of overproduction which cannot be used in the building sold to the grid. The building is completely self-sufficient on the evaluated period.

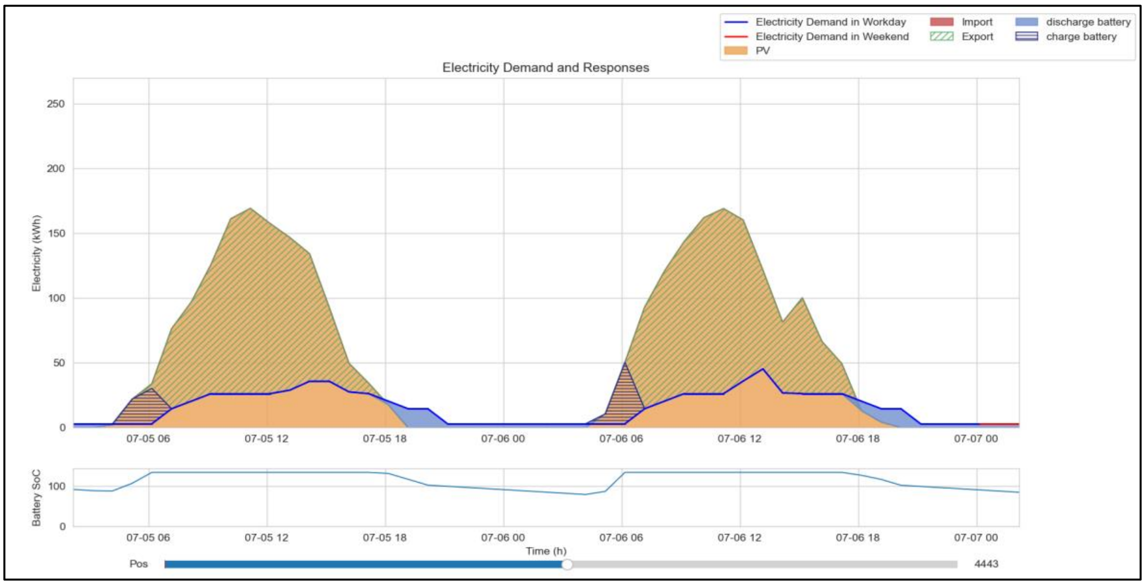

Figure 16: Hourly electricity D&S from 5th of July 0 AM to 6th of July 12 PM curve on slider graph for the investment scenario

The monthly electricity chart (Figure 17) gives a clear idea of the electricity generated by the solar panels and electricity imported from the grid, and also gives an idea of solar electricity which cannot be used within the building. Comparing this chart to the baseline chart, we see an increase of electricity demand due to the heat pump electricity consumption.

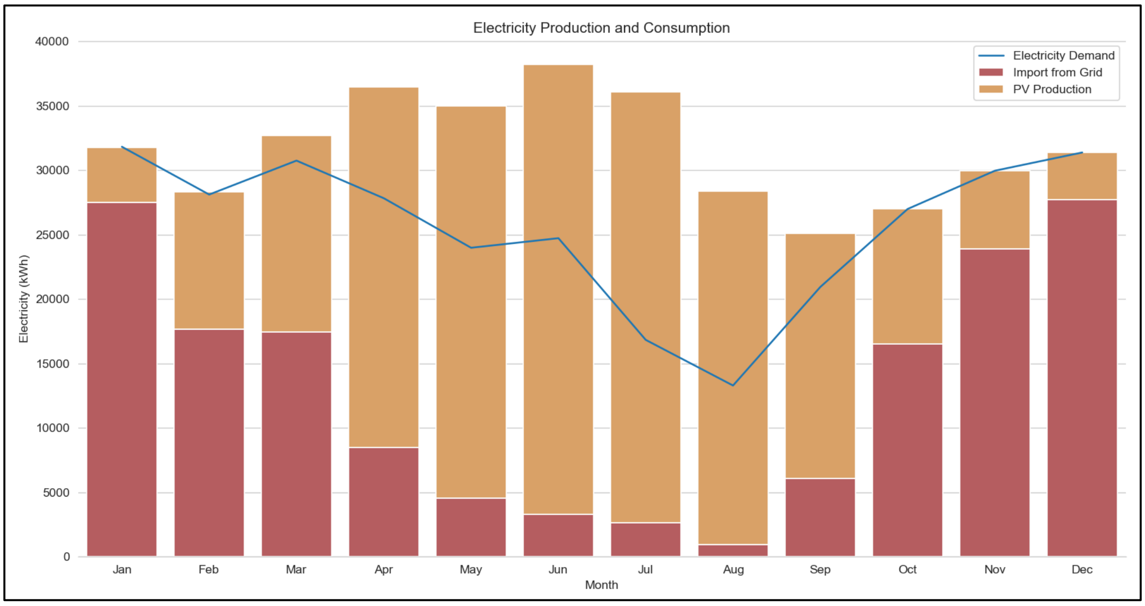

Figure 17: Monthly electricity demand and response curve for the investment scenario

Comparing the seasonal typical days with Figure 18, we have a clear idea of the building's dependency to the grid during each season, the part of solar electricity fed into the grid, and the impact of the battery.

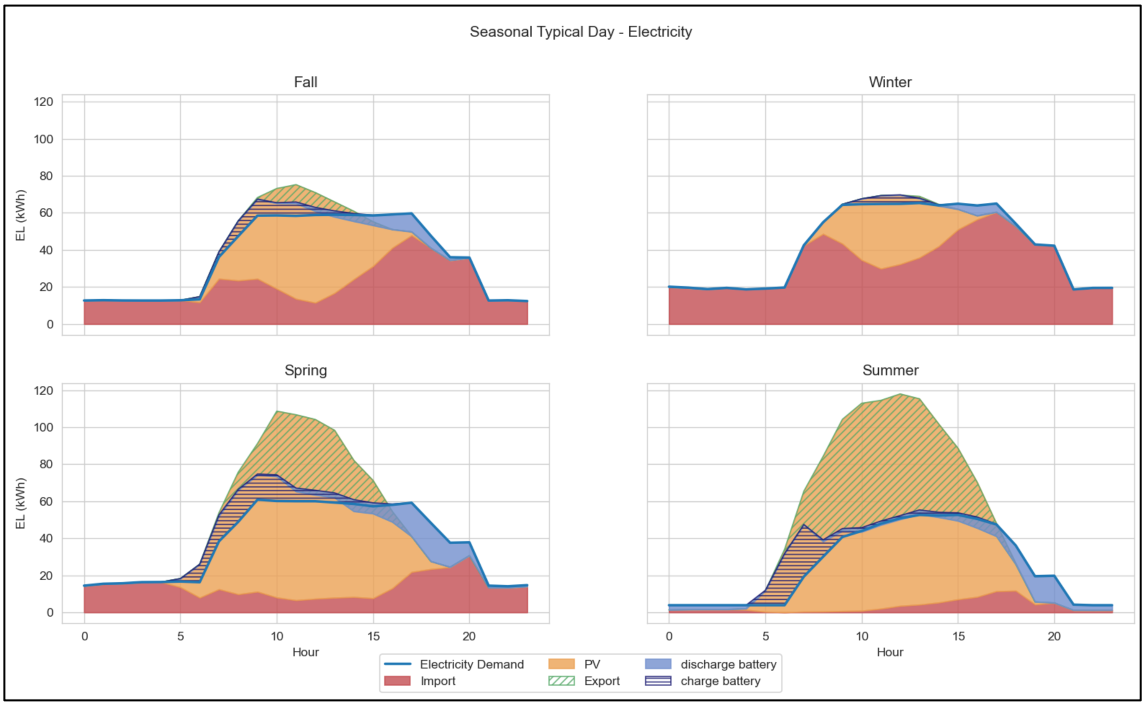

Figure 18: Seasonal electricity demand and response typical day for the baseline scenario

3.3.3. Cumulated savings in comparison with the baseline

Once the different recipes are simulated, we can compare the financial outputs with respect to the baseline. In these results, the primary energy prices (the operational costs of electricity, gas, …), the maintenance costs of each appliance (Energy Component), the CAPEX (that is, initial investment cost of the hardware and the related installation), and the replacement cycle are considered.

Many different values of interest are calculated, to drive the final decision:

- The **Net Present Value** calculated on 30 years. By default, the NPV includes the CAPEX, the operational costs and the cost of the CO2 emitted, but it can be easily customized.
- The **Cumulated savings graph** that shows the savings in comparison with the baseline. The investments are considered as negative in comparison to the baseline (which is equal to zero by definition), but then the gain in consumptions influences the long-term value of the investment.
- The **Return on Investment** that gives the time after which the gains generated by the investment (lower consumptions of primary sources of energy) compared to the baseline counterbalance the initial investment. On Figure 20 , this corresponds to the crossing between the curves and the horizontal axis.

Taking back the example used before in "STEP 2: Demand and response baseline" and "Investment simulations: the concept of recipes" permits us to give a financial overview of the investment proposal.

In the following table (Figure 19), the platform gives a financial overview comparing the Baseline with the *Recipe* tested. Where the main outputs are the following:

- Electricity from the grid: savings of 76.000€ per year from reduced consumption and income of 3.000€ per year from selling electricity to the grid. This means that even if we increase the electricity demand of the building with the installation of the heat pump, the solar panel field lowers the dependency from the grid.
- Heating costs: the heat pump installation has a big impact on the gas purchase as we save 74.000€ per year.
- In total, the CAPEX (investments) needed is around 630.000€.
- In conclusion, we see that the NPV gives us a gain of nearly 1 million euro over 30 years.

Financial Table	Baseline	Recipe	Difference
CAPEX			
PV (€)	0	500,000	-500,000
Battery (€)	0	85,000	-85,000
heat pump- Primary (€)	0	14,710	-14,710
Hot Water Tank (€)	0	30,000	-30,000
CAPEX Replacements			
boiler - Primary (€)	24,400	0	24,400
Battery (€)	0	85,000	-85,000
heat pump - Primary (€)	0	29,420	-29,420
boiler - Secondary (€)	0	24,400	-24,400
Hot Water Tank (€)	0	30,000	-30,000
OPEX			
Electricity Purchases (€/y)	-123,018	-46,828	76,190
Electricity Sold (€/y)	0	8,413	8,413
Fuel Purchases (€/y)	-78,230	-3,618	74,612
Maintenance Cost (€/y)	-510	-11,110	-10,600
CO_2eq Emissions Cost (€/y)	0	0	0
NPV			
NPV (€)	-3,113,250	-1,529,662	1,583,589

Figure 19: Financial evaluation of the investment scenario compared to the baseline scenario

The financial chart plotted by the platform is the Payback time showing a return on investment in about 5 years. The NPV calculated over 30 years gives approximately 2 million euros.

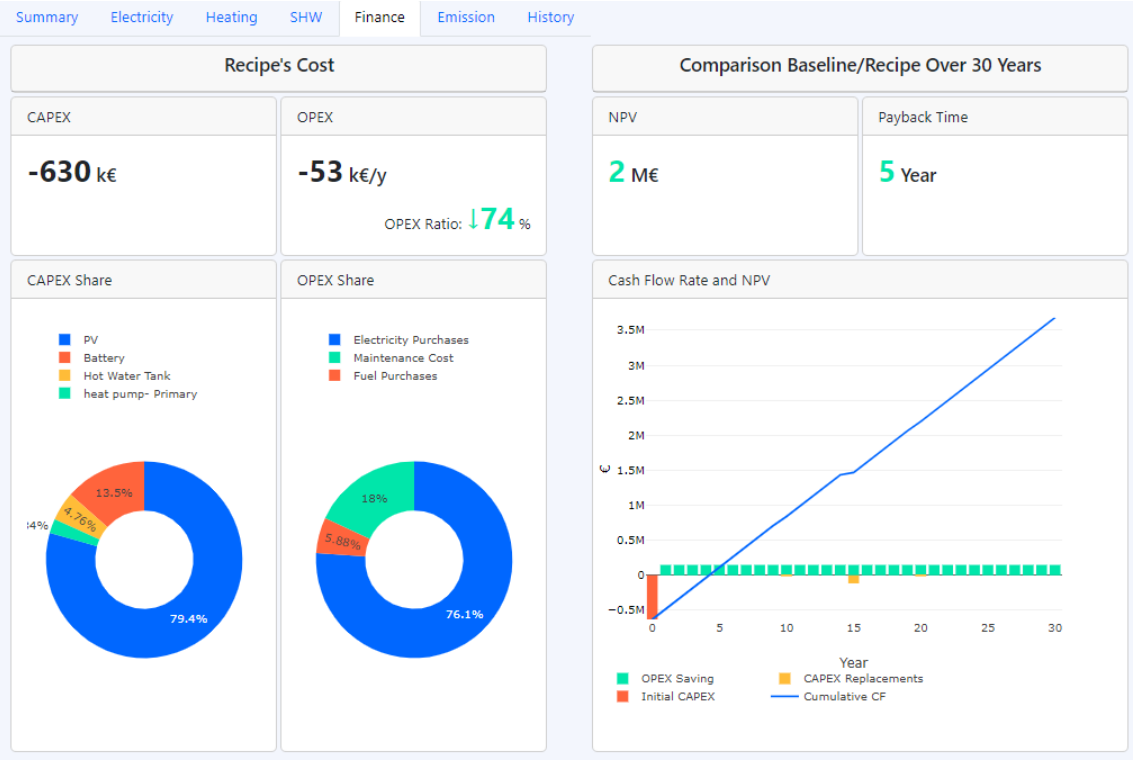

Figure 20: Payback time of the investment scenario compared to the baseline scenario

3.4. STEP 4: Optimized business models

At the house/building level, Energy Systems optimization focuses on individual residential or commercial units. It operates at a smaller scale, targeting specific appliances, systems, or loads within a single building. Participants at this level utilize devices such as smart thermostats, smart plugs, or energy management systems to exercise control over their energy consumption. The primary motivations for participation at this level are often cost savings, energy efficiency, or personal convenience. Communication predominantly occurs between end-users and utility providers or demand response aggregators. House/building level DR offers benefits such as peak demand reduction, lower electricity bills, improved grid reliability, and enhanced integration of renewable energy sources.

In contrast, district/city level DR encompasses a larger geographical area, such as a neighbourhood, community, or an entire city. It considers the aggregate energy consumption of multiple buildings or even entire districts, focusing on overall load profiles. The potential for demand response at this level is higher due to the involvement of numerous participants. Coordination among multiple stakeholders, including building owners, utilities, grid operators, and local authorities, is required for successful implementation.

District/city level DR aims to achieve objectives beyond cost savings and energy efficiency, such as grid stability, demand-side management, renewable energy integration, and carbon reduction targets. Advanced communication networks, such as in smart grids or in energy management systems, facilitate efficient coordination and data exchange. The benefits of district/city level DR include peak demand mitigation, avoidance of infrastructure upgrades, enhanced grid resilience, reduced greenhouse gas emissions, and more efficient resource utilization.

In the context of a neighbourhood, in addition to investments in other energy plants and changed modes of operation, interesting optimisation options can also arise from sharing energy with neighbours, if the regulatory framework allows this business model. In Figure 21, the green building has solar panels installed on its roof and has a surplus of production compared to its demand during high solar intensity periods. Our platform would bring the possibility to highlight the options of one neighbour selling its surplus of electricity to its neighbour and thus arriving to a new optimal solution.

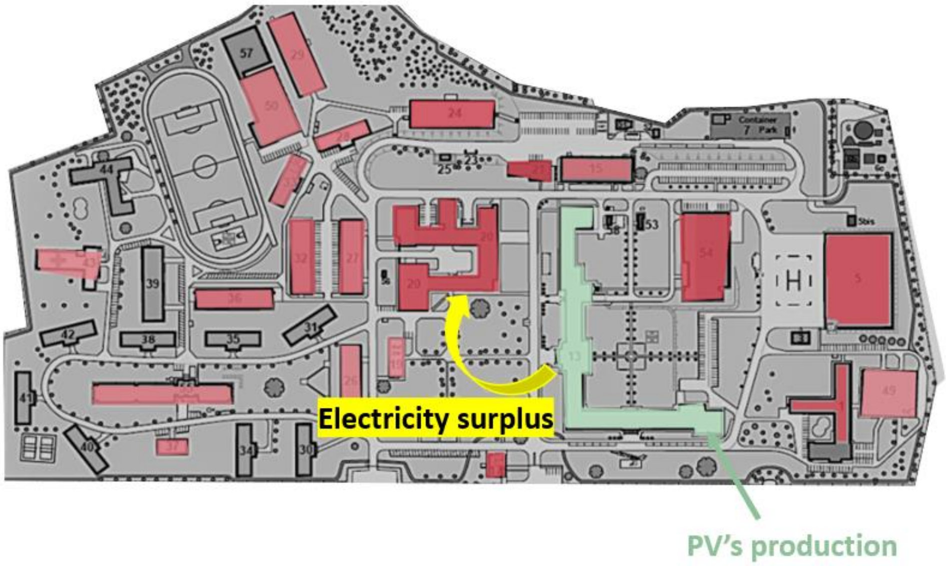

Figure 21: sharing electricity loads between Energy Entities

To enable this business model, we need to introduce the concept of connectors between *Energy Entities*. Indeed, there are some specifications to take into account while speaking about sharing energy, such as the possibility of doing it, the type of sharing and the costs related to sharing this energy.

3.4.1. Possibility of sharing energy

Assessing the possibility to share energy between two buildings is important because it can lead to several benefits such as energy savings, cost reductions, increased energy independency by increasing the share of locally generated energy on the energy demand, and environmental benefits.

In many cases, buildings located close to each other may have different energy needs and consumption patterns, resulting in one building having an excess of generated energy while the other has a shortage. By sharing energy, both buildings can benefit from a more efficient use of resources and reduce their energy costs.

To assess the technical possibility of sharing energy between two buildings, several factors need to be considered, including the distance between the buildings, the type of energy being shared (such as electricity, heat or cooling), the energy demand of each building in temporal resolution, the availability of energy infrastructure such as heat networks or grids, and possible restrictions of energy sharing due to the regulatory framework.

For example, sharing heat between two buildings can be done through a district heating system, where hot water is circulated between the buildings through a network of pipes. This can result in energy savings and reduced emissions compared to using individual heating systems for each building. Similarly, sharing electricity can be done through a microgrid or a peer-to-peer energy trading system, where excess energy from one building can be sold or shared with the other building.

However, there are also potential drawbacks to consider when assessing the possibility of sharing energy between buildings. For instance, there may be technical challenges related to the compatibility of energy systems or the cost of retrofitting existing buildings to accommodate new energy infrastructure. Additionally, there may be legal or regulatory barriers to overcome, such as obtaining permits or meeting energy efficiency standards.

3.4.2. Types of energy sharing

Sharing energy between two buildings can involve different scenarios.

One scenario is when two buildings belong to the same party, for example, two buildings owned by the same company or household. In this case, the objective is often to optimize energy use and reduce costs by sharing excess energy produced by one building with another building that requires energy. This can be achieved through various technical means, such as using a microgrid or installing energy storage systems to facilitate energy exchange.

Another scenario is when two buildings belong to different parties, for example, a residential building and a commercial building. In this case, the objective is often to create an energy community, where multiple buildings or energy consumers cooperate to optimize energy use, reduce costs, and improve energy efficiency. This can be achieved through various technical means, such as connecting the buildings through a district heating and cooling network or using a shared renewable energy system.

Assessing the technical possibility of sharing energy between two buildings in both scenarios is crucial to determine the feasibility of the project. Factors such as distance, energy demand, and available infrastructure should be evaluated to determine the most appropriate technical solution for energy sharing. Additionally, legal and regulatory frameworks should be considered to ensure that the energy exchange is compliant with local laws and regulations.

Another challenge is the legal and regulatory framework surrounding energy sharing. This can include issues related to property ownership, liability, and responsibility for maintenance and repairs. Additionally, energy sharing may be subject to government regulations and policies, which can be complex and vary by region.

Finally, there may be social and behavioural barriers to energy sharing, such as concerns over privacy and security, differences in energy usage patterns, and the need for cooperation and trust between neighbours. Overcoming these challenges will require effective communication, collaboration, and planning between stakeholders, including homeowners, utilities, regulators, and policymakers.

3.4.3. Energy transfer fees

There are several types of energy transfer fees that may apply when sharing energy between different buildings or entities within an energy community:

- **Connection fees:** These are fees charged by the energy supplier or network operator for connecting buildings to the grid or network. The cost may depend on the distance between the buildings, the capacity of the connection, and any necessary upgrades to the network.

- **Distribution fees:** These are fees charged by the energy supplier or network operator for distributing energy from the point of connection to the building. The cost may depend on the amount of energy transferred, the time of day, and the location of the building.
- **Transmission fees:** These are fees charged by the energy supplier or network operator for transmitting energy across long distances between different regions or countries. The cost may depend on the amount of energy transferred, the type of energy (electricity or gas), and the distance travelled.
- **Energy supply fees:** These are fees charged by the energy supplier for the actual energy consumed by the building. The cost may depend on the type of energy (electricity or gas), the amount consumed, and the time of day. Here, the context is particular as an *Energy Entity* will become the provider. There will be a need to negotiate the shared energy (price, amount, etc.).
- **Metering fees:** These are fees charged by the energy supplier or network operator for installing and maintaining meters to measure energy consumption. The cost may depend on the type of meter, the number of meters installed, and the frequency of meter readings.

The actual cost of these fees may vary depending on the country, the energy supplier or network operator, and the specific terms of the energy transfer agreement. It is important for parties involved in energy communities to understand these fees and negotiate favourable terms to ensure cost-effective energy sharing. The objective of the tool would be to represent these fees and see what new optimum could be reached by creating energy communities and sharing excess of energy productions.

3.5. STEP 5: Behaviour change

At this time, we introduce a way of optimizing the response of energy from a fixed demand of each energy entity. But in the context of green building neighbourhoods, we could also find other ways to further optimize the external needs of the neighbourhood (gas and electricity from the grid) by proposing behavioural changes. In this case, we do not focus on individual behaviours but structural changes in behaviours on an *Energy Entity* scale.

A simple use case illustrating a structural change in behaviour on an Energy Entity scale would be a surplus of free electricity produced by solar panels during the day. We could install a heat pump and a hot water tank to use this free energy to heat hot water for the showers at night.

Demand response plays a crucial role in balancing electricity supply and demand while promoting energy efficiency and sustainability. At the neighbourhood level, fostering behavioural change becomes paramount to maximize the impact of Demand Response (DR) initiatives. Digital platforms can promote this by engaging the users while guiding them in the process by following a set of underling guidelines:

- **User-centric design**:

  The foundation of a successful digital platform lies in its user-centric design. Understanding the needs, preferences, and motivations of residents is crucial. By conducting comprehensive user research, developers can create intuitive and user-friendly platforms that cater to the diverse profiles and demographics within the neighbourhood. This approach ensures that the digital platform is accessible and engaging to all users, promoting active participation.

- **Personalized Recommendations**:

  Leveraging machine learning algorithms and data analytics, digital platforms can generate personalized recommendations for energy-saving behaviours. By analysing users' energy consumption patterns, the platform can offer tailored suggestions, tips, and goals. Personalization enhances engagement, as residents feel motivated by the platform's customized guidance, leading to increased participation in DR initiatives and improved energy efficiency.

- **Gamification and Incentives**:

  Integrating gamification elements within the digital platform enhances the overall user experience and encourages energy-saving behaviours. Challenges, competitions, and rewards systems create a sense of excitement and friendly competition among residents. By achieving energy-saving milestones, users earn rewards, fostering a positive reinforcement loop that sustains motivation and engagement in DR activities.

- **Community Engagement**:

  Digital platforms can serve as hubs for community engagement by providing avenues for residents to connect, interact, and share their energy-saving achievements. Forums, discussion boards, and community events within the platform create opportunities for knowledge exchange and collective participation. Encouraging social interaction and peer support strengthens the sense of community, fostering a shared commitment to DR and energy conservation.

- **Education and Awareness**:

  A digital platform dedicated to neighbourhood-level DR should incorporate educational resources, tutorials, and informative content. Raising awareness about the benefits of DR, energy conservation practices, and the environmental impact of energy consumption is vital. By equipping users with relevant information, the platform empowers them to make informed decisions, amplifying their engagement and contributions to DR initiatives.

- **Integration with Smart Devices**:

  Seamless integration with smart devices and Internet of Things (IoT) technologies enhances the functionality and effectiveness of the digital platform. Users can remotely control and monitor their energy-consuming devices through the platform. This integration enables residents to adjust thermostat settings, schedule appliance usage, and optimize energy efficiency effortlessly. By leveraging smart technology, the platform facilitates real-time energy management, further promoting behavioral change.

- **Data Privacy and Security**:

  To foster trust and ensure user confidence, robust data privacy and security measures must be implemented. Compliance with relevant regulations and industry standards safeguards users' personal information and energy consumption data. By maintaining the integrity and security of the platform, residents can freely engage in DR initiatives, knowing their privacy is protected.

3.6. Summary of the D&R platform usage steps

3.1 STEP 1: Input parameters	
3.1.1 Localization	Regional parameters can have an impact on the HVAC energy performance analysis such as: weather conditions, financial incentives, discount rate, CO2 equivalent price, generic prices and generic behavioural profiles.
3.1.2 Energy Entity characteristics	Some specific parameters can be drawn from the Energy Entity itself such as: specific energy and maintenance costs, technical parameters, consumption and production profiles.
3.1.3 Investments	Parameters about the different investment considered such as: the technical possibility of the investment, its price (hardware + installation) and the associated maintenance costs.

3.2 STEP 2: Demand and response baseline	
3.2.1 Demand and response curves	In order to have the actual demand and response hourly curves of the *Energy Entity*, we can either: - create simulations based on annual demands, profiles of consumption and meteorological variables (irradiance, degree-day, etc.); - use monitoring tools to have an accurate and detailed view of the consumption in real time all year long;
3.3 STEP 3: Investment simulations and comparison with the baseline	
3.3.1 Investment simulations: the concept of recipes	A *recipe* is a combination of the investments (ingredients) responding to the demand curves of an *Energy Entity.* Each recipe will have a unique way of responding the demand. Each recipe is a simulation of a different way to invest in the energy performance of the *Energy Entity*.
3.3.2 Cumulated savings in comparison with the baseline	Evaluation of the different drafted recipes in comparison with the actual situation (baseline). This will help making the best decision with a clear vision of each financial and ecological impact on the long term.
3.4 STEP 4: Demand and response load optimization	
3.4.1 Possibility of sharing energy	Exploration of the physical and legal barriers to sharing energy and thus the possibilities of doing so.
3.4.2 Type of sharing energy	Assessment of the different scenarios of sharing energy: sharing between buildings of the same owner, sharing between close neighbours, sharing between distanced neighbours.
3.4.3 Energy transfer fees	Overview of the different transfer fees to take into account while sharing energy: connection, distribution, transmission, energy surplus and metering fees.
3.5 STEP 5: Behaviour change	
	Briefly explaining the idea of "building" behaviour change to reach a neighbourhood optimum and the user engagement possibilities brought by digital platforms.

Table 5: Summary of D&R platform usage steps

4. Design and implementations of D&R platform in Probono

4.1. Data collection

Figure 22 depicts a block diagram showcasing the seamless flow of data from the meters to the user interface through a Wi-Fi network. The meters are depicted as the primary source of data, which are transmitted wirelessly via Wi-Fi to a Wi-Fi router. The router is responsible for routing the data to the data center after passing through the Ingester, where the data is processed and integrated for further analysis. Finally, the processed data is sent to the user interface, where it is displayed in a comprehensible and meaningful way.

This diagram effectively illustrates the complexity and interconnectedness of the various components involved in transmitting data wirelessly from sensors to the user interface. It provides a clear and concise overview of the entire process, from the source of the data to its ultimate destination.

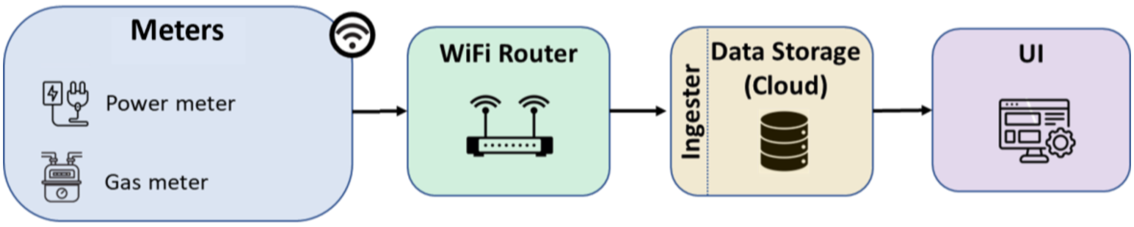

Figure 22: The block diagram of meter transmitting data wirelessly via Wi-Fi to a router, which sends it to the data center for processing before displaying it on a user interface

4.1.1. Meters

As explained in sub-sub section 3.2.1. , the best way to introduce the demand and response curves of the Energy Entity is through monitoring. Indeed, a full year of monitored consumptions gives us a real-life profile of the Energy Entity, which is obviously better than a theoretical profile simulation.

In Figure 23 the Brussels Living Laboratory energy arrivals network is represented. As the school is one of the tenants of the building and because of the history of the building, the networks are not straightforward (one general inlet per type of resource: water, gas and electricity). As you can see below, the Brussels LL has:

- One general inlet of electricity;
- Two inlets of gas (one is coming from the neighbour building Lanson, the other is located in the “Poste” part of the building);
- Two inlets of water (one is coming from the neighbour building Lanson, the other is located in the “Poste” part of the building);

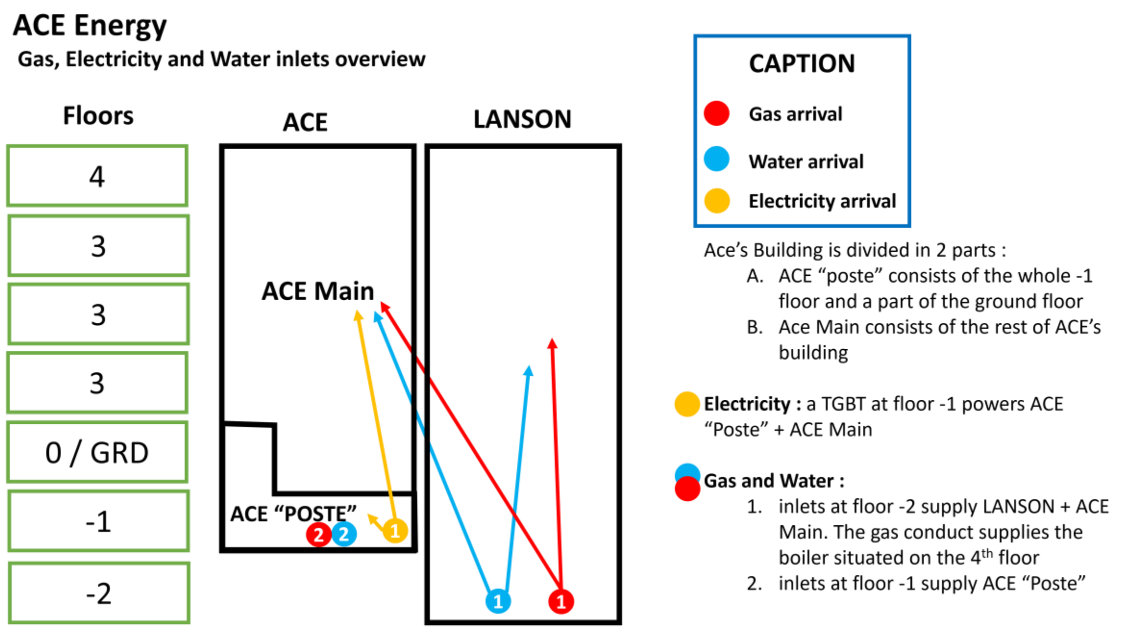

Figure 23: schematics of Brussels LL Energy Network

In the case of the demand and response platform, the resources of interest are the gas consumption for heating demand and the electrical consumption for electrical demand.

We will then install the following hardware:

- One 3-phases electricity meter calculating the total consumption in electricity of the Brussels LL Energy Entity. This meter will be installed in the General Low Voltage Panel situated in ACE "Poste" on the -1 floor (Figure 24). We will be installing an **ACREL ADW300 Three-phases electronic meter with a build-in Wi-Fi transmitter** (datasheet Appendix 6.2. This meter functions as follows:
    - Three Current Transformers (CT) will be installed on the 3 phases of the General inlet of electricity. These current transformers are inductive coils installed around the cables that will transform the high current passing through the cables into proportional currents connected to the meter that will retro-calculate the amount of energy used.
    - One Short Circuit Terminal block (CT Terminal) that operates like a switch helping disconnecting the CT's safely.
    - One **ACREL ADW300 Three-phases electronic meter with a build-in Wi-Fi transmitter.**
    - One fuse for protecting the power supply of the meter itself

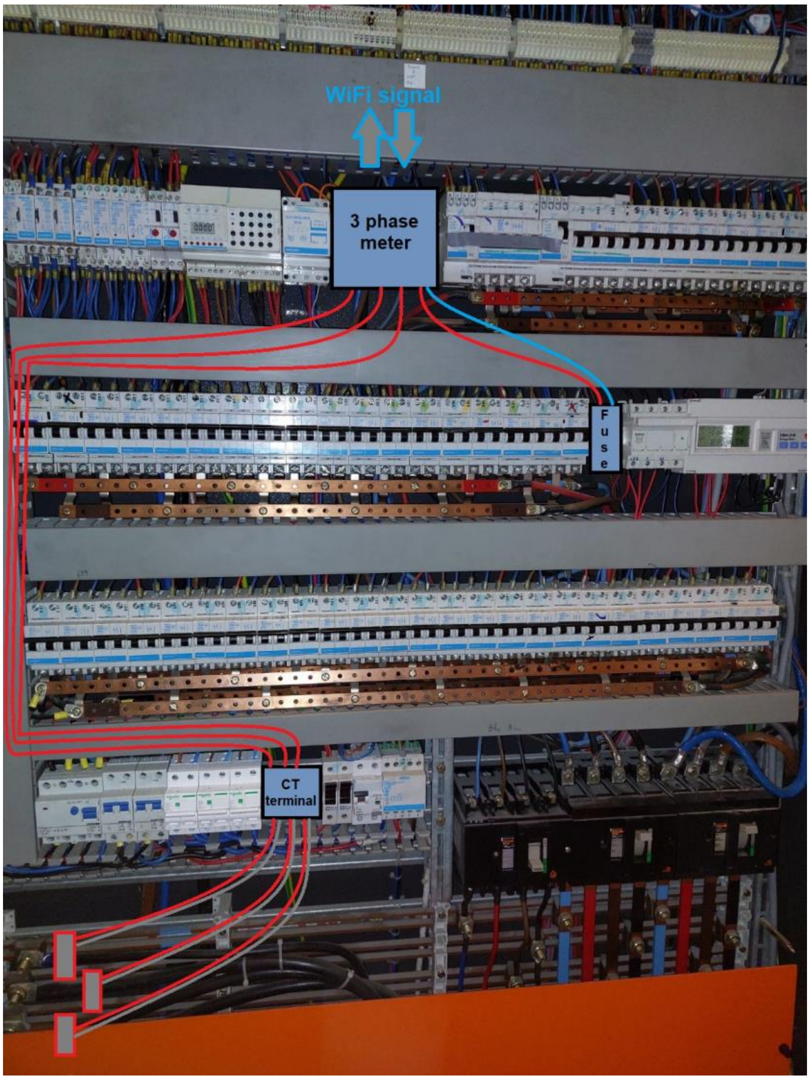

Figure 24: Plan of installation for the electrical meter on the GLVDB of Brussels LL on -1 Floor

- One gas meter calculating the consumption of the 110 kW gas boiler situated in the ACE "Poste" part of the building (Figure 25). This meter will be directly installed in the boiler room on the DN65 gas arrival pipe. As no DN65 gas meters exist on the market, we will be installing a **Delta Compact G25 – DN50, 171mm** (datasheet appendix 6.3. meter by reducing the diameter of the pipes. This meter will be connected to a M-Bus Cyble v2.0 connecter digitalizing the measure and communicating through M-Bus to a Wi-Fi gateway that will itself send the data.

Figure 25: Pictures and description of the Brussels LL boiler room on -1 Floor

- One gas meter calculating the consumption of the 5 x 110 kW gas boilers installed in series situated in the ACE Main part of the building (Figure 26). This meter will be directly installed in the boiler room, situated on the fourth floor of the building, on the DN80 gas arrival pipe. In particular, we will be installing a **PI-Delta Silver edition G100 – DN80, 171mm** (datasheet appendix 6.3.) directly matching the pipes of the boiler room. This meter will be connected to a M-Bus Cyble v2.0 connecter digitalizing the measure and communicating through M-Bus to a Wi-Fi gateway that will itself send the data.

Figure 26: Pictures and description of the Brussels LL boiler room on the 4th Floor

4.1.2. Cloud-based IoT Platform

In the realm of the Internet of Things (IoT), deploying and managing applications in a scalable and efficient manner is complex. To address this need, the infrastructure based on Kubernetes on Google Cloud Platform (GCP) emerges as a robust solution, when coupled with the open-source community version of Thingsboard. Kubernetes, an open-source container orchestration platform, automates deployment, scaling, and management of containerized applications, while Thingsboard provides an open-source IoT platform with a plethora of functionalities.

Thingsboard encompasses a comprehensive set of functionalities that contribute to effective IoT device management and data processing:

1. **Device Management**: Thingsboard facilitates seamless management of IoT devices, supporting multiple protocols like MQTT, CoAP, and HTTP. It enables effortless device connectivity, monitoring, and control.
2. **Telemetry Collection**: The platform excels in the collection and storage of telemetry data from IoT devices. Real-time data visualization, advanced analytics, and the creation of customized dashboards and reports are enabled, empowering users with actionable insights.
3. **Rule Engine**: With a powerful rule engine, Thingsboard allows users to automate actions based on predefined rules and conditions. This feature enables efficient decision-making and automation in response to specific events or data patterns from IoT devices.
4. **Device Attributes and Metadata**: Thingsboard supports the management of device attributes and metadata. This functionality provides flexibility in storing additional information about devices, facilitating categorization, searching, and filtering based on various parameters.
5. **User Management and Access Control**: The platform offers robust user management capabilities, allowing the creation and administration of user accounts with diverse access levels. Role-based access control (RBAC) ensures secure access to the system and its resources.
6. **Extensibility and Customization**: Thingsboard boasts a plugin framework that allows users to extend its functionalities and integrate with other systems or services. By developing custom plugins, users can add new features or seamlessly integrate the platform with existing enterprise systems, rendering it highly adaptable to specific use cases.

By leveraging Kubernetes on GCP for hosting Thingsboard, organizations unlock a range of strengths and advantages:

1. **Scalability**: Kubernetes offers automated scaling capabilities, dynamically allocating resources and managing container instances based on demand. This ensures that the Thingsboard application can seamlessly handle increased traffic and device connections, guaranteeing a consistent user experience.
2. **High Availability**: Kubernetes provides built-in features for high availability, mitigating the impact of node failures or disruptions. By automatically scheduling and distributing application containers across multiple nodes, Kubernetes minimizes downtime, ensuring continuous accessibility to the Thingsboard application.
3. **Containerization and Isolation**: The adoption of containerization enables enhanced resource utilization, simplified application management, and streamlined deployment and updates. Kubernetes ensures that each component of Thingsboard runs in its own isolated environment, bolstering security and stability.
4. **Monitoring and Logging**: Kubernetes offers comprehensive monitoring and logging capabilities, allowing organizations to closely monitor the health and performance of the Thingsboard application. Metrics, logs, and events can be collected and analyzed using tools like Prometheus and Grafana, providing valuable insights and facilitating efficient troubleshooting.
5. **Infrastructure Flexibility**: GCP serves as a reliable and flexible infrastructure for hosting Kubernetes-based applications. Managed Kubernetes services, such as Google Kubernetes Engine (GKE), simplify cluster management and offer additional features like auto-scaling, load balancing, and seamless integration with other GCP services. This synergy ensures a robust foundation for running Thingsboard in a scalable and efficient manner.

Deploying the community version of Thingsboard on a Kubernetes infrastructure on Google Cloud Platform provides a **cost efficient yet powerful and versatile IoT solution**. Thingsboard's comprehensive functionalities for device management, telemetry collection, rule engine, device attributes, and user access control empower businesses to effectively harness the potential of their IoT devices. Meanwhile, Kubernetes on GCP brings scalability, high availability, containerization, monitoring, and infrastructure flexibility to the table, creating a robust ecosystem for hosting and managing Thingsboard.

4.2. Software solution

The Demand and Response Platform consists of many components, all of them linked together as represented in Figure 27 Figure 27:

- **User interface**, to allow the user to input data in a friendly way. The current version of the user interface is written in HTML/CSS, supported by Java Script.

The UI is connected to the SQL database, to display in the dropdown selections only the available options (in term of countries/cities, appliances/devices, profiles, …) that the user can choose. It is connected also to the Python script to instantiate the parameters according to input values.

The input provided by the users are the following:

  - The “platform mode”, choosing between “**optimisation mode**" and "**manual mode**”. In the first case, it is the platform that chooses the best recipe that minimises the total cost; in the second case, the user precisely determines the recipe that he/she wants to simulate;
  - The **country/city** of the building;
  - The **profile** of the building (office, residential, school, …);
  - The **total electricity demand**, specifying the share for AC;
  - The **total heating demand**, specifying the share for heat and sanitary hot water;
  - The **grid** contract;
  - The specifications of the **electricity production systems**, if any. So far, the only available electricity production system that can be chosen is solar panels.
  - The specifications of the **batteries,** linked to the electricity production system, if any;
  - The specifications of the **primary heat unit**, both for heat and sanitary hot water. So far, the available heat units that can be chosen are boiler and heat pump.
  - The specifications of the **backup heat unit**, if any, both for heat and sanitary hot water;
  - The specifications of the **hot water tank,** linked to the heating system, if any.

- **Python script**, the core of the platform, including a number of well-known libraries. It simulates the behaviour of both the current Energy demand and response solution and of the hypothetical one, according to the recipes selected by the user.

It is connected to the SQL database to retrieve the details of the selected profile, the energy costs and the appliances' specifications, as unitary cost, maintenance's frequency, … Other customisable information is provided directly by the user, in the UI.

- **SQL database,** directly connected both to the user interface and the Python script. It is structured as a catalogue of profiles, energy sources and appliances/devices. For each profile, the hourly/seasonal behaviour is described; for energy, the energy cost and CO2 emissions by country are stored; for the appliances, the main information useful to simulate the production/response are stored, as unitary cost and maintenance's frequency. In case the user is provided with its specific profile (typically coming from installed meters and sensors), the SQL database can be easily enriched including also that one.
- **Weather API,** to retrieve the meteorological information based on the geography. For European countries[18], the JRC database[19] has been selected. APIs return a large amount of weather information, as temperature, humidity, wind speed, solar irradiation, …, available on hourly base, at city granularity.
- **Output,** to show the results. The platform returns some tables, summarising the parameters chosen (in input or by the optimiser) and the expected final costs. Moreover, some charts are plotted, showing on a temporal basis, the expected behaviour in terms of energy demand and response.

The user doesn't have access to anything except to the UI, of course.

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[18] In the scope of PROBONO project, to limit the list of countries/cities to the single Europe is enough. However, for the next platform's releases, it is envisaged to extend it to many other countries outside Europe's borders, so additional APIs will be integrated.

[19] https://joint-research-centre.ec.europa.eu/pvgis-online-tool/getting-started-pvgis/api-non-interactive-service_en

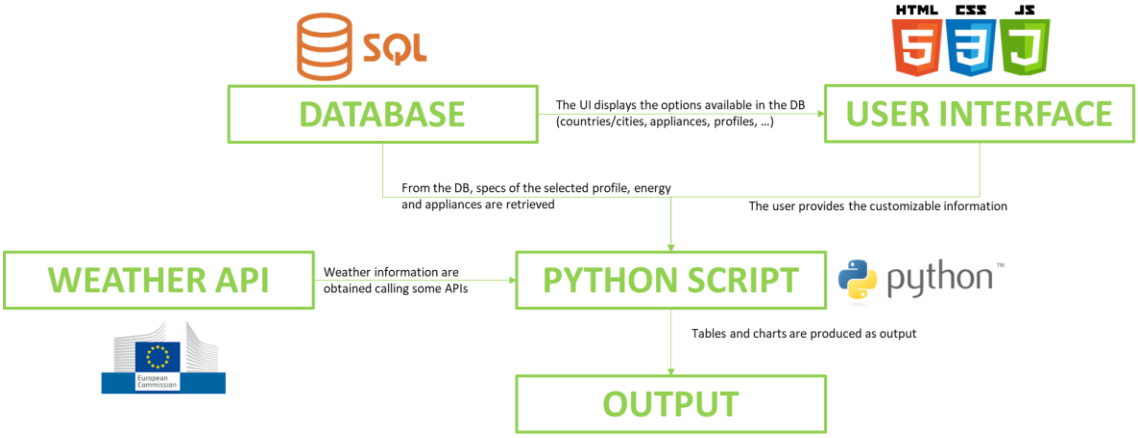

Figure 27: Main components of the Energy Demand and Response Platform

As mentioned, the core of the platform is the Python script, that runs the simulation and produces the output.

For each appliance, a dedicated Python class has been created, keeping a common structure. Doing so, **adding to the model new appliances will be rather straightforward**. For instance, so far only solar PVs have been included as Electricity Production Unit; in next releases, Eolic Production may be added, following the same structure of solar PVs.

Each "appliance – class" is structured as follow:

- **Type**: to identify the device model in the database. Of course, the same family of appliances may have different types and brands, with different costs, power, … Knowing the Type, the SQL database returns all the information related to the specific model, that will be used in following functions.
- **Electricity production()**: a function that returns the total electricity produced by the device. It may be 0 in case the appliance is not a Production Unit.
- **Electricity consumption()**: a function that returns the total electricity consumed by the device to operate. It may be 0 in case of zero consumption.
- **CAPEX()**: a function that returns the cost for purchasing and installing it.
- **Replacement cost()**: a function that returns the cost for the replacement, according to a given frequency. Since it is a future cost, the NPV is calculated.

- **Operational cost()**: a function that returns the daily cost to make the appliance work (including maintenance), for a 30 years interval. Since it is a future cost, the NPV is calculated.

For fuel-based appliances (typically those related to heat production), in addition, the following attributes/functions are available:

- **Fuel**: to identify the fuel used by the appliance. Knowing it, the SQL database returns all the related information, as the unitary cost, the CO_2 emissions, ...
- **Fuel consumption()**: a function that returns the total fuel consumed by the device to operate.

So far, the following classes have been created:

Class	Appliance/Unit	Scope
Grid.py	The electrical grid	Response to **Electricity Demand**
solarPV.py	The solar panel	Response to **Electricity Demand**
Battery.py	The electrical battery that may be connected to solar panels, to store the electricity in case of overproduction	Response to **Electricity Demand**
Boiler.py	The boiler, linked to different types of energy sources (as electricity, gas, oil, …)	Response to **Heating Demand** (Heat or Sanitary Hot Water)
Heatpump.py	The heat pump	Response to **Heating Demand** (Heat or Sanitary Hot Water)
hotWaterTank.py	The tank that may be connected to any heating unit, to store the heating.	Response to **Heating Demand** (Heat or Sanitary Hot Water)

Table 6: List of available classes for appliances

After both the baseline and the future recipes are simulated, the platform returns the main output, which is the comparison of the **total cost (over a 30-year interval)** of the two different scenarios, including the equipment's purchase (not for the baseline), the maintenance and the day-by-day operational costs. **The total cost includes also the CO_2 emissions costs; it means that a very polluting solution** (even if it is cheap) **is penalised when the total cost is calculated.**

In case of “optimisation mode”, the platform chooses the best recipe that minimises the total cost; in case of “manual mode”, the platform returns the total cost deriving from the specific user’s choices.

So far, the optimisation is more basic: the chosen optimiser is scipy.py, that allows to successfully run the code, optimising some appliances’ parameters but not the appliances themselves. Very likely, in next releases, a new optimiser will be integrated, allowing more flexibility in the operations.

4.3. Integration to PROBONO Digital Twin (WP5)

As the platform is simulating the energy behaviour of a building, it is perfectly suitable for integration in the Probono Digital Twin. So far, no integration has been realized. Now that the first version of the platform has been published internally, we have enough material to initiate the integration of the platform with the DT developed in WP5. First contacts will be initiated after submission of D4.4, and progress will be stated in D4.5 (M36).

4.4. Summary table of design and implementation concepts for PROBONO

4.1 Data collection	Explaining the data collection plan with a block diagram. Going from sensors, to a gateway, to a cloud platform and finally on a user interface.
4.1.1 Meters	Insights on the meters planned to be installed in Brussels Living Lab.
4.1.2 Cloud based platform	Explaining the concept of cloud-based platform and giving some details about STAM’s “Thingsboard” platform to be used and its advantages.
4.2 Software solution	Defining with more details the in-development energy demand and response platform: the user interface, the SQL databases, the software python back-end, the different called APIs, …
4.3 Integration to PROBONO Digital Twin (WP5)	Mentioning possibilities of integration with PROBONO Digital Twin and plan to initiate integration for next deliverable D4.5 (M36).

Table 7: Summary of the main design and implementation concepts of the D&R platform for PROBONO

5. Key results and findings

5.1. Interest from the Living Laboratories

We presented the platform to most of the Living Laboratories in order to see their interest in it. All of the ones that we had the chance to present to did seem interested in it and we will thus get back to them once the first version of the platform will be live. We summarized these contacts in *Table 8*:

Living Lab	Comment	Interest
LL1: Dublin	**Potential interest:** Energy Performance contract (mentioned during WS in Chania)	Interested but want to see parallels with Energy Planning tool developed by FRHF
LL2: Madrid	**To discuss:** Interest of TPF for designing new technologies in the tool (geothermy)	Yes, need to schedule a meeting with IDOM
LL3: Porto	**Potential interest:** Investment plan overview and ROI (mentioned during WS in Chania)	Platform not presented yet.
LL4: Brussels	**Potential interest:** Need to present solid investment cases for funding	Yes
LL5: Aarhus	**Probono GA:** Must be done for deliverable D4.5	Could be applied in the university but in a part that is not the Probono Living Lab
LL6: Prague	**Large interest:** Focused on Digital Twin: building part, wanting energy positive building, planning to install PV's and monitoring before renovation works	Interest → Need to send PowerPoint and discuss with architects

Table 8: Recapitulative table of communication with Probono LL Leaders

5.2. Brussels Living Lab

Some integrations in the case of the platform have been done in the Brussels Living Lab:

- A complete technical audit of the Brussels Living Lab was done by TPF together with ACE and resulted in a full description of its energy behaviour: yearly consumptions, consumptions profiles simulation, renovation plans, appliances used on site. This audit will permit us to do a real time DEMO of the platform on the case of the Brussels LL;

- In September 2023 two gas meters and one electrical meter were installed in the school to monitor the real consumptions. This will help us to use the Demand and Response Platform on a real case with actual consumptions, and to monitor the effects of the planned renovations on the energy consumptions.

5.2.1. Monitoring plan of the Living Lab

As described in section 4.1.1. , some meters were planned to be installed in Brussels LL in order to get detailed electricity and heating consumptions of the school. In this chapter, we will give an insight of the installation status.

5.2.1.1. Electricity consumption of Brussels LL

In Figure 28, we observe the installed 3-phases ACREL electrical meter following the scheme of Figure 24.

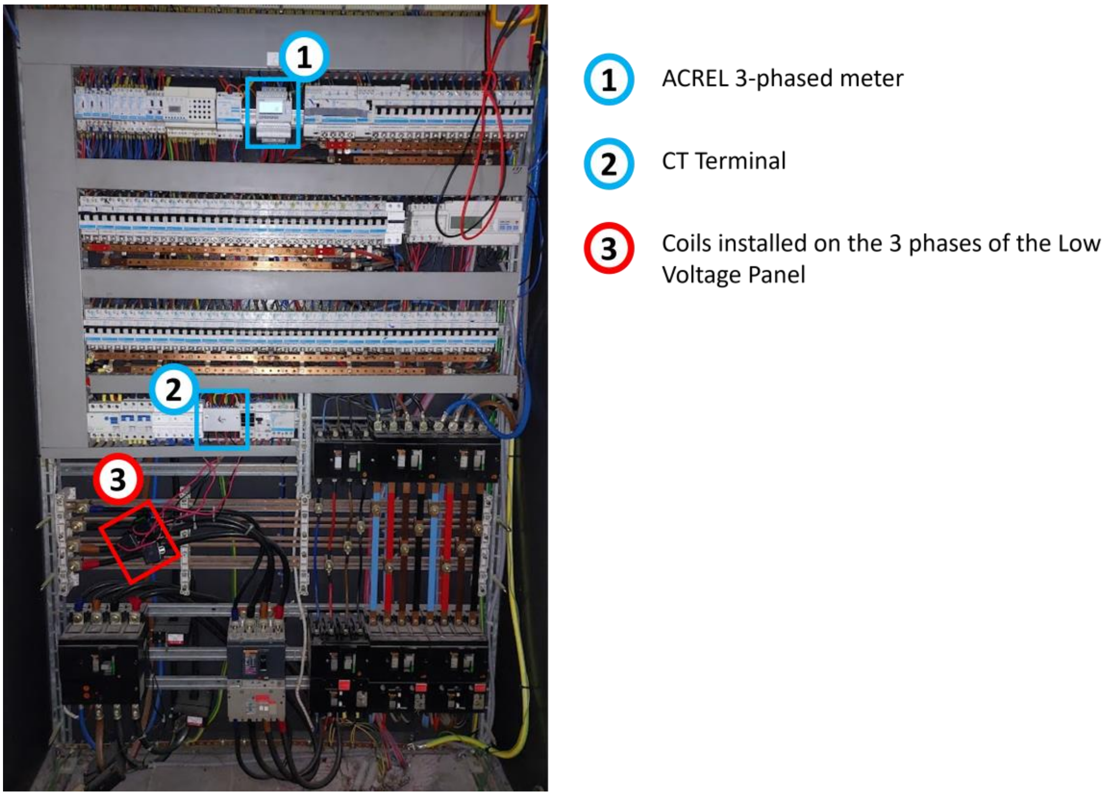

Figure 28: 3-phases ACREL electrical meter installed in Brussels LL

As planned, we configured the meter to send data through wifi using a MQTT protocol to STAM's monitoring platform. Figure 29 and Figure 30 are screenshots of the first data, respectively the total Power and the currents per phase, received by STAM's platform.

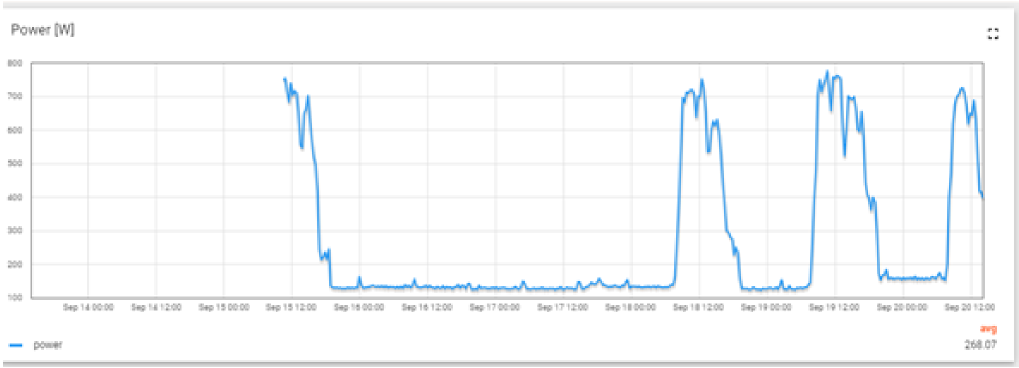

Figure 29: Electricity power consumption of Brussels LL

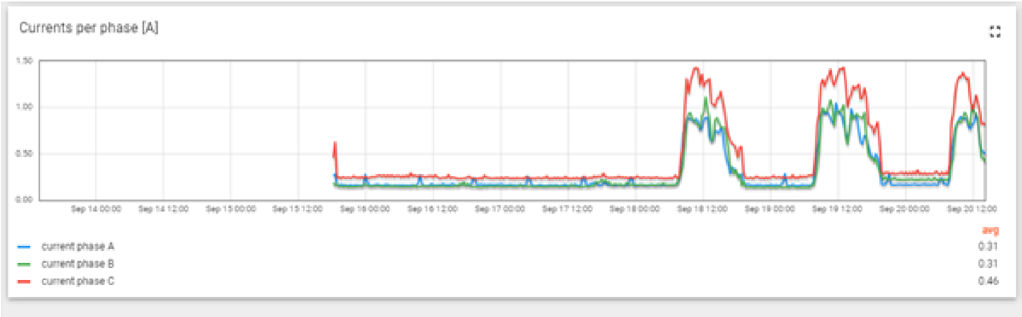

Figure 30: Monitored current on each of the 3 phases of Brussels LL main inlet of electricity

5.2.1.2. Gas consumption of Brussels LL

Two gas meters (Figure 31) have already been acquired. They will be installed in the Brussels LL in October. These gas meters will be measuring: (left) ACE Poste - heating + SHW, (right) ACE Main - heating + SHW (see Figure 23 to recall the parts of the building).

Figure 31: Delta rotary gas meters to be installed in Brussels LL.
(left) Delta Compact G25 – DN50, 171mm (right) PI-Delta Silver edition G100 – DN80

5.2.2. STEP 1: Input parameters

The complete audit of Brussels Living Lab permitted us to regroup all information needed to run the platform on this specific case.

5.2.2.1. Fixed parameters

First, we regrouped all fixed information having an impact on the simulations (Figure 32):

FIXED DATA

LOCALISATION		
City	Brussels	
Geolocalisation	50.815900, 4.429468	
Discount rate	5	%

ENERGY ENTITY CHARACTERISTICS		
GENERAL		
Energy entity		
Building profile	School	
Total Floor Area	7.523 m2	
EPB rating	B+	
Maintenance costs	66495	€

ENERGY CONSUMPTIONS		
Electricity demand		
Annual Electricity Demand	110.000	kWh
Monitored Demand?	no	
Specific profile?	yes	
Central heating demand		
Annual central heat Demand	67502	kWh
Monitored Demand?	no	
Specific profile?	yes	
Sanitary hot water demand		
Annual sanitary hot water Demand	500	kWh
Monitored Demand?	no	
Specific profile?	yes	
Total heating demand		
Common Central and Sanitary hot water heating system?	no	

Contracts

	Energy source	Contract	peak price [€/kWh]	off-peak price [€/kWh]
1	Green electricity	peak / off-peak	€ 0,21	€ 0,18
2	Gas	average	€ 0,0303	€ 0,0303
3				
4				
5				
6				
7				

TECHNICAL PARAMETERS

Solar Panels possible suface

	name	Azimut [°]	Inclination min[%]	Max Area [m^2]
1	Nord	0	20%	90 m2
2	Nord-Ouest	315	20%	50 m2
3	Nord-Est	45	20%	80 m2
4	Sud	180	20%	90 m2
5	South-East	135	20%	90 m2
6	West	90	20%	50 m2
7	Flat roof	free	free	380 m2

Figure 32: Fixed Parameters of the Brussels LL

5.2.2.2. Profiles

Through discussions with some people in the Brussels Living Lab, we managed to define the different consumption profiles of the school. As the school has a very specific profile (school hours, working hours of the staff, holidays, …), we defined each profile as such: an hourly profile for each day of the week matched with a daily profile for each day of the year to create an hourly profile on a whole year that would be applied on the yearly consumption.

For example, on Figure 33, if the first of January is a Monday, then the proportional consumption of the first January at 08:00 would be: $0{,}8 \times 0{,}25 = 0{,}2$. Once every hour of the year has been computed as such, we do a repartition of the yearly consumption (mentioned in *5.2.2.1.*) in comparison with the sum of the hourly repartition (Figure 33, Figure 34 and Figure 35).

ELECTRICITY DEMAND

Hourly profile

	Day	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	Monday	0	0	0	0	0	0	0	0,1	0,8	1	1	1	1	1	1	1	0,8	0	0	0	0	0	0	0
2	Tuesday	0	0	0	0	0	0	0	0,1	0,8	1	1	1	1	1	1	1	0,8	0	0	0	0	0	0	0
3	Wednesday	0	0	0	0	0	0	0	0,1	0,8	1	1	1	1	0,2	0,1	0,1	0,1	0	0	0	0	0	0	0
4	Thurdsay	0	0	0	0	0	0	0	0,1	0,8	1	1	1	1	1	1	1	0,8	0	0	0	0	0	0	0
5	Friday	0	0	0	0	0	0	0	0,1	0,8	1	1	1	1	1	1	1	0,8	0	0	0	0	0	0	0
6	Saterday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Daily profile

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0,25	1	1	0	0,25	0,9	0	0,5	0,9	0	0,25	1
2	0,25	1	1	1	0,25	0	0,9	0,5	0,9	0	0,25	1
3	0,25	0	0	1	0,25	0	0,9	0,5	0	1	0,25	0
4	0,25	0	0	1	0,25	0,9	0,9	0	0	1	0,25	0
5	0,25	1	1	1	0	0,9	0,9	0	0,9	1	0	1
6	0	1	1	1	0	0,9	0,9	0,5	0,9	1	0	1
7	0	1	1	0	0,25	0,9	0	0,5	0,9	1	1	1
8	1	1	1	0	0,25	0,9	0	0,5	0,9	0	1	1
9	1	1	1	0	0,25	0	0,5	0,5	0,9	0	1	1
10	1	0	0	1	0,25	0	0,5	0,5	0	1	1	0
11	1	0	0	1	0,25	0,9	0,5	0	0	1	1	0
12	1	1	1	1	0	0,9	0,5	0	0,9	1	0	1
13	0	1	1	1	0	0,9	0,5	0,5	0,9	1	0	1
14	0	1	1	0	0,9	0,9	0	0,5	0,9	1	1	1
15	1	1	1	0	0,9	0,9	0	0,5	0,9	0	1	1
16	1	1	1	1	0,9	0	0,5	0,5	0,9	0	1	1
17	1	0	0	1	0,9	0	0,5	0,5	0	1	1	0
18	1	0	0	1	0	0,9	0,5	0	0	1	1	0
19	1	1	1	1	0	0,9	0,5	0	0,9	1	0	1
20	0	1	1	1	0	0,9	0,5	0,5	0,9	1	0	1
21	0	1	1	0	0,9	0,9	0	0,5	0,9	1	1	1
22	1	1	1	0	0,9	0,9	0	0,5	0,9	0	1	1
23	1	1	1	1	0,9	0	0,5	0,5	0,9	0	1	1
24	1	0	0	1	0,9	0	0,5	0,5	0	0,25	1	0
25	1	0	0	1	0,9	0,9	0,5	0	0	0,25	1	0
26	1	1	1	1	0	0,9	0,5	0	0,9	0,25	0	0,25
27	0	1	1	1	0	0,9	0,5	0,5	0	0,25	0	0,25
28	0	1	1	0	0,9	0,9	0	0,5	0,9	0,25	1	0,25
29	1		1	0	0	0,9	0	0,9	0,9	0	1	0,25
30	1		1	0,25	0,9	0	0,5	0,9	0,9	0	1	0,25
31	1		0		0,9		0,5	0,9		0,25		0

COMMENTS

Considerations : ? ???
0,9 in summer due to ventilloconvector shut down
0,5 in plain summer because seems to have a demand from electrical demands

Figure 33: Electricity consumption profile of Brussels LL

GENERAL HEAT DEMAND

Hourly profile

	Day	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	Monday					1	1	1	1	1	1	1	1	1	1	1	0,5								
2	Tuesday					1	1	1	1	1	1	1	1	1	1	1	0,5								
3	Wednesday					1	1	1	1	1	1	1	1	1	1	1	0,5								
4	Thurdsay					1	1	1	1	1	1	1	1	1	1	1	0,5								
5	Friday					1	1	1	1	1	1	1	1	1	1	1	0,5								
6	Saterday																								
7	Sunday																								

Daily profile

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	1	1	1	0	0	0	0	0	0	0	1
2	0	1	1	1	0	0	0	0	0	0	0	1
3	0	1	1	1	0	0	0	0	0	1	0	1
4	0	1	1	1	0	0	0	0	0	1	0	1
5	0	1	1	1	0	0	0	0	0	1	0	1
6	0	1	1	1	0	0	0	0	0	1	0	1
7	0	1	1	1	0	0	0	0	0	1	1	1
8	1	1	1	1	0	0	0	0	0	1	1	1
9	1	1	1	1	0	0	0	0	0	1	1	1
10	1	1	1	1	0	0	0	0	0	1	1	1
11	1	1	1	1	0	0	0	0	0	1	1	1
12	1	1	1	1	0	0	0	0	0	1	1	1
13	1	1	1	1	0	0	0	0	0	1	1	1
14	1	1	1	1	0	0	0	0	0	1	1	1
15	1	1	1	1	0	0	0	0	0	1	1	1
16	1	1	1	1	0	0	0	0	0	1	1	1
17	1	1	1	1	0	0	0	0	0	1	1	1
18	1	1	1	1	0	0	0	0	0	1	1	1
19	1	1	1	1	0	0	0	0	0	1	1	1
20	1	1	1	1	0	0	0	0	0	1	1	1
21	1	1	1	1	0	0	0	0	0	1	1	1
22	1	1	1	1	0	0	0	0	0	0	1	1
23	1	1	1	1	0	0	0	0	0	0	1	1
24	1	1	1	1	0	0	0	0	0	0	1	0
25	1	1	1	1	0	0	0	0	0	0	1	0
26	1	1	1	1	0	0	0	0	0	0	1	0
27	1	1	1	1	0	0	0	0	0	0	1	0
28	1	1	1	0	0	0	0	0	0	0	1	0
29	1		1	0	0	0	0	0	0	0	1	0
30	1		1	0	0	0	0	0	0	0	1	0
31	1		1		0		0	0		0		0

COMMENTS

On during Winter
Off during summer

Main gas Boiler (+4)
Off during the weekends
On weekday morning 4am
Off Weekday afternoon 3:30pm
Wednseday afternoon? **--> TBV**

Secondary gas Boiler (-1)
heating continuously this part of the building during the winter period
Manually set of during hollydays and summer period

Figure 34: Heating consumption profile of Brussels LL

SANITARY HOT WATER DEMAND

Hourly profile

	Day	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1	Monday	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
2	Tuesday	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
3	Wednesday	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
4	Thurdsay	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
5	Friday	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0
6	Saterday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Sunday	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Daily profile

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0	1	1	0	0	1	0	0	1	0	0	1
2	0	1	1	1	0	0	1	0	1	0	0	1
3	0	0	0	1	0	0	1	0	0	1	0	0
4	0	0	0	1	0	1	1	0	0	1	0	0
5	0	1	1	1	0	1	1	0	1	1	0	1
6	0	1	1	1	0	1	1	0	1	1	0	1
7	0	1	1	0	0	1	0	0	1	1	1	1
8	1	1	1	0	0	1	0	0	1	0	1	1
9	1	1	1	0	0	0	0	0	1	0	1	1
10	1	0	0	1	0	0	0	0	0	1	1	0
11	1	0	0	1	0	1	0	0	0	1	1	0
12	1	1	1	1	0	1	0	0	1	1	0	1
13	0	1	1	1	0	1	0	0	1	1	0	1
14	0	1	1	0	1	1	0	0	1	1	1	1
15	1	1	1	0	1	1	0	0	1	0	1	1
16	1	1	1	1	1	0	0	0	1	0	1	1
17	1	0	0	1	1	0	0	0	0	1	1	0
18	1	0	0	1	0	1	0	0	0	1	1	0
19	1	1	1	1	0	1	0	0	1	1	0	1
20	0	1	1	1	0	1	0	0	1	1	0	1
21	0	1	1	0	1	1	0	0	1	1	1	1
22	1	1	1	0	1	1	0	0	1	0	1	1
23	1	1	1	1	1	0	0	0	1	0	1	1
24	1	0	0	1	1	0	0	0	0	0	1	0
25	1	0	0	1	1	1	0	0	0	0	1	0
26	1	1	1	1	0	1	0	0	1	0	0	0
27	0	1	1	1	0	1	0	0	0	0	0	0
28	0	1	1	0	1	1	0	0	1	0	1	0
29	1		1	0	0	1	0	1	1	0	1	0
30	1		1		1	0	0	1	1	0	1	0
31	1		0		1		0	1		0		0

COMMENTS

There are 6 local electrical boilers in the school :
- 2 (15 liters) boilers at +4 for the art classrooms
- 1 (15 liters) boiler in physics/biology Lab
- 1 (15 liters) boiler in the teachers room
- 1 (15 liters) boiler in the Refectory
- 1 (150 liters) boiler in the Chemical Lab

As the 5 first boilers are small and little used, we decided not to take them into account because the client will not be planning to do an investment there, and that they would have a small impact on the total electrical consumption.

The 150 liters electrical boiler will be considered here mostly so that its electrical consumption is taken into account in the model.

Simulated the boiler consumption by repartition of the demand during class hours (0 during lunch).

Figure 35: Sanitary Hot water consumption profile of Brussels LL

5.2.2.3. Baseline

The baseline scenario of the Brussels LL, detailed in Figure 36, is simple: electricity is drawn from the grid and heating is supplied by two gas boilers.

BASELINE

ELECTRICITY

PRODUCTION

Solar Panels installed surface

	name	Orientation [°]	Max Area [m^2]	Installed [m^2]	Maintenance [€]
1	Nord		90	0 m^2	
2	Nord-Ouest	315	50	0 m^2	
3	Nord-Est	45	80	0 m^2	
4	Sud	180	90	0 m^2	
5	South-East	135	90	0 m^2	
5	West	90	50	0 m^2	
5	Flat roof	free	380	0 m^2	

Maintenance cost

Wind turbines

1					
2					
3					
4					
5					

STORAGE

Batteries

	name	Storage Size [kWh]	Rating [kW]	Maintenance [€]
1	none			
2				
3				
4				
5				

Hydrogen storage

	name	Storage Size [L]	Pressure [bar]	Maintenance [€]
1	none			
2				
3				

CENTRAL HEATING

PRODUCTION

Primary Heat Unit

	Type	Energy Source	Power [kW]	Maintenance [€]
1	Boiler	Gas	550 kW	

Secondary Heat Unit

	Type	Energy Source	Power [kW]	Maintenance [€]
2	Boiler	Gas	131 kW	

STORAGE

Hot Water Tank

name	Storage Size [L]	Maintenance [€]

Figure 36: Baseline parameters of Brussels LL

5.2.3. DEMO of the platform (STEP 1 to STEP 3 for Brussels LL)

Before conclusion, let us present to you a short demo of the first version of the platform detailed in this deliverable. We used the concrete example of the Brussels Living Lab to showcase the platform. During this demo, the steps 1 to 3 will be clearly detailed.

6. Conclusion

This report summarizes the exploration and findings of Task 4.2 that involves the creation and implementation of an GBN energy demand and response platform.

As a first step, we evaluated the requirements of such a platform both from a theorical (State of the Art) and a practical (Living Labs) point of view. We explored the different difficulties met by building owners when talking about energy investment choices such as a lack of expertise, time-consuming design studies and fundraising and loaning. We also introduced concepts such as Total Cost of Ownership (TCO), Energy Performance of Buildings (EPB), Energy Performance Contracts (EPC) and Energy Communities (EC). We structured these findings separating them on a Green Building and a Green Neighbourhood point of view in order to highlight the interests that the in-development Demand and response platform could bring to these decision makers.

Then, we clearly explained the vision of the Energy Demand and Response Platform co-developed by TPF and STAM. We first explained the overall idea of the platform and went further on in details in every one of the 5 steps of its use : The input of parameters from the client (STEP 1), the simulation of the baseline (STEP 2), the simulation of different investment ideas (called recipes) and their financial comparison to the baseline (STEP 3), the optimization of loads between different Energy Entities (STEP 4), and finally the proposition of “building stage” behaviour changes in order to find a new optimum solution (STEP 5). Through the chapter, we used the actual version platform to explain each already implemented and give a first clear idea of the possibilities.

After, we described the design and implementations choices for the platform in the case of Probono (section 4.), where we specified the requirements of the platform, the data collection monitoring plan codesigned by TPF, STAM and TSRV, and the software solution architecture. We also briefly mentioned the state of progress of DT integration within PROBONO (WP5) and plan to initiate this integration for D4.5 (M36).

As key results and findings, we first validated the interest of the Living Labs in the concept of our platform. We then used the Brussels Living Lab as a demonstrator and use case with the installation of a whole monitoring plan (meters) and a first use of our platform on a concrete example.

As this deliverable is a first step within T4.2, we will close this report by briefly detailing the next steps of development and implementation that can be expected of D4.5 and D4.6.

D4.5 (M36) will explore the integration of new appliances on the platform (as fuel cell, cogeneration, solar thermal, geothermy), initiate the developments of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), initiate Digital Twin integration with AKKA, explore user experience with SIN, and implement the platform on Aarhus and Dublin use cases.

D4.6 (M36) will further develop the concept of a neighbourhood energy D&R with STAM (STEP 4 and STEP 5 detailed in sections 3.4. and 3.5.), further develop Digital Twin integration with AKKA, deeper explore User Experience with SIN, and implement the platform on Madrid and Porto use cases.

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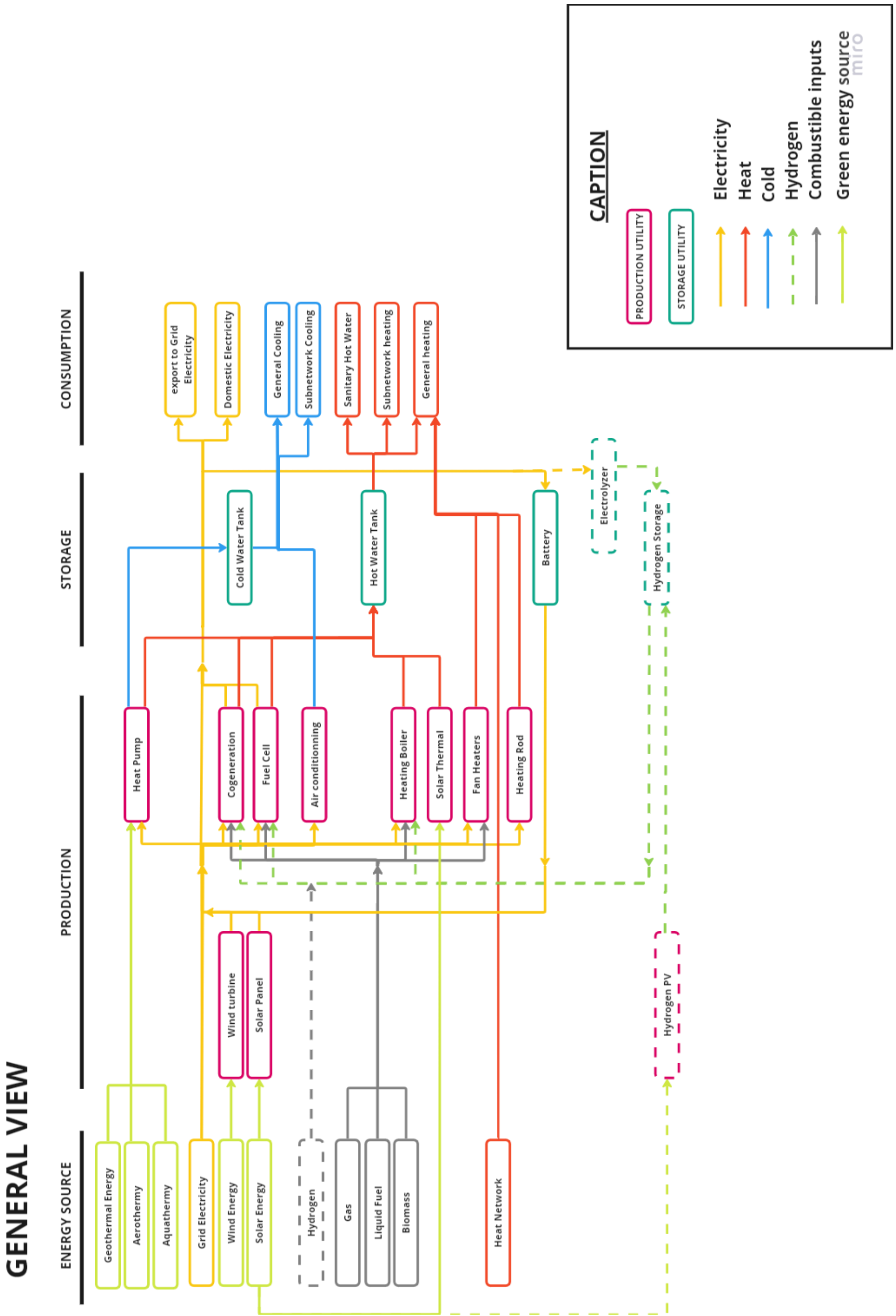
Appendix

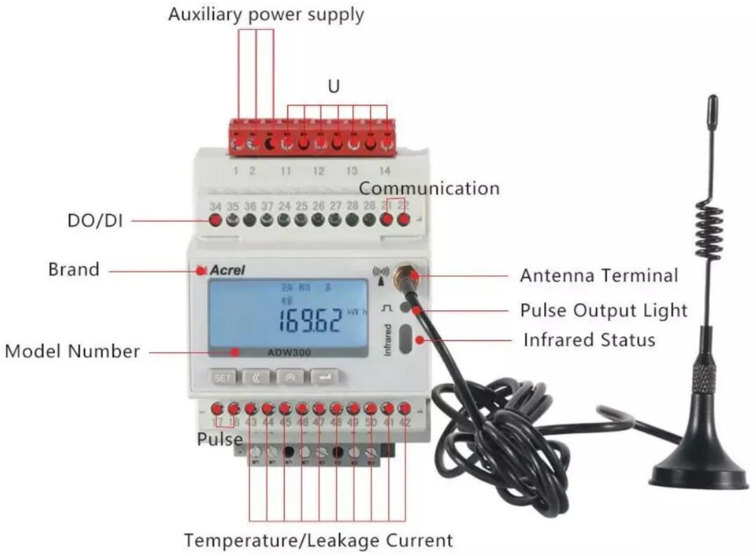
6.1. Overview of the platform



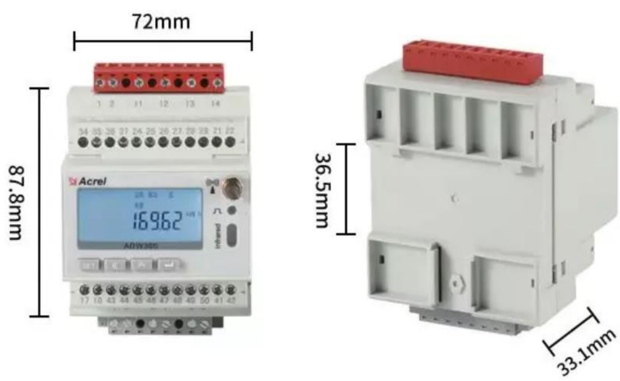
6.2. ADW300 IOT Wireless Smart Energy Meter

- Communication: 4G LTE/WiFi/LoRa/LoRaWAN/NB-IoT/RS485(MODBUS-RTU)
- Measurement: 3 phase active power/reactive power/current/voltage/harmonic and etc.
- HMI Programming: setting of CT/PT ratio, phase wiring, communication and etc
- Application Scenario: building/factory/smart grids/DB room and etc
- Rated Voltage: Up to 3*660~792Vac L-L
- Rated Current: 3*1(6)A AC (via CTs)
- Active Power Accuracy: class 0.5S
- Reactive Power Accuracy: class 2
- Certificate: CE/IEC/LVD

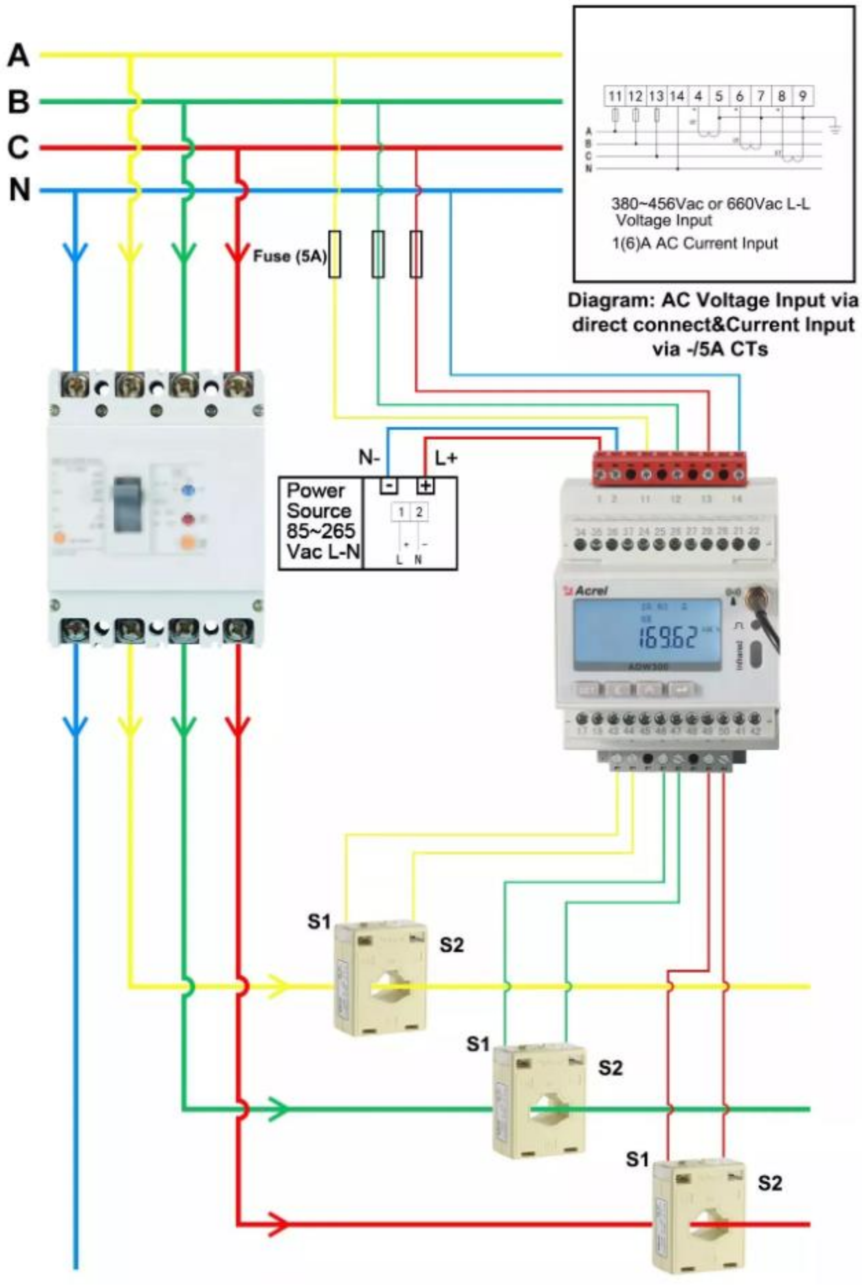
6.2.1. Front Panel



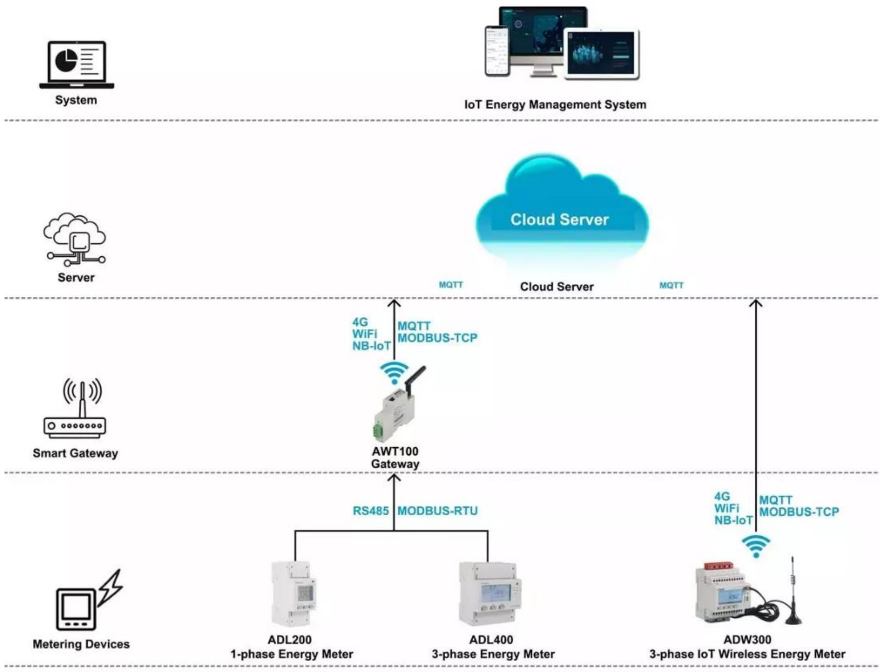
6.2.2. Dimensions



6.2.3. Wiring


A
B
C
N
Fuse (5A)
380~456Vac or 660Vac L-L
Voltage Input
1(6)A AC Current Input
Diagram: AC Voltage Input via direct connect&Current Input via -/5A CTs
N-
L+
Power Source 85~265 Vac L-N
Acrel
S1
S2
S1
S2
S1
S2

6.2.4. Network


System
IoT Energy Management System
Cloud Server
Server
MQTT
Cloud Server
MQTT
4G
WiFi
NB-IoT
MQTT
MODBUS-TCP
Smart Gateway
AWT100
Gateway
RS485
MODBUS-RTU
4G
WiFi
NB-IoT
MQTT
MODBUS-TCP
Metering Devices
ADL200
1-phase Energy Meter
ADL400
3-phase Energy Meter
ADW300
3-phase IoT Wireless Energy Meter

6.3. Delta gas meters (Pi-Delta Silver Edition and Delta Compact)

Actaris Gas's Delta range of rotary gas meters comprises innovative and high quality products. Characterized by compact dimensions and easy maintenance, the Delta range is built on proven robust technology and provides reliable and accurate measurement and performance for commercial and industrial natural gas applications.

Key Benefits

- Excellent metrological stability attested by customers over the years
- No influence of installation conditions nor stop-and-go flow rate on the metrology
- Optimised pressure loss for low pressure network
- Multi-position meter, changeable on the field
- 360° rotating totalizer
- Cyble technology

Operating Principle

Delta meters are volumetric meters. The flow gas moves the pistons and each rotation traps and transfers a specific volume of gas. The movement is mechanically transmitted to the totaliser through the magnetic coupling.

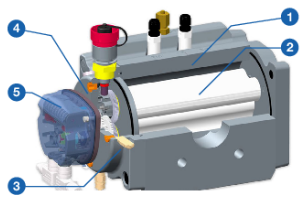
Description

A Delta meter is made of 5 main parts:

- A measuring chamber that is limited by the body and the 2 base plates (1)
- 2 pistons, which are synchronised by 2 gears and which rotate in opposite directions (2)
- lubrificant cover (3)
- A magnetic coupling to transmit the movement of the pistons to the totaliser (4)
- A totaliser to register the measured gas (5)

Technical Specifications

Flow rate	From 0.25 m³/h to 1000 m³/h, G10 to G650	
Nominal Diameters	DN 25 to DN 150 (1" to 6")	
Maximum Working Pressure	Up to 100 bar depending on the body material and flanging	
Body Materials	Aluminium, ductile iron or steel. Compliant with the Pressure Equipment Directive 2014/68/EU	
Temperature Range	ATEX/PED: MID: Storage temperature:	-30° C to +60° C -25° C to +55° C -40° C to +70° C
Metrology	In accordance with MID and OIML, large rangeability up to 1:200. Compliant with the Measuring Instrument Directive 2014/32/EU	
Intrinsic Safety Approval	L.C.I.E. 06 ATEX 6031 X - Compliant with the Directive 2014/34/EU	

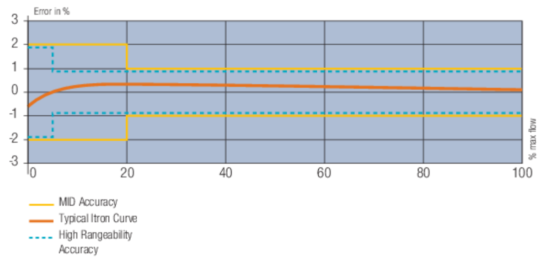


Applications

Delta meters are designed to measure natural gas and various filtered, and non-corrosive gases. They are used when very accurate measurement is required, when the gas flow can be low or irregular.

Due to the volumetric principle of the Delta meter, its metrology is not influenced by installation conditions. Consequently, it can be used to build very compact stations without installing a straight pipe inlet before the meter.

Delta meters are approved for fiscal use.



Totaliser:

- 9-digit index to register a larger volume
- 45° orientation for an easy reading
- 360°rotating totalizer
- Equipped as standard with the cyble target: it allows the installation of the cyble sensor at any time
- Equipped with 1 built-in silicagel cartridge; as an option, equipped with an external cartridge to enable easy maintenance even in extreme conditions
- Integrated optical disc to facilitate the periodic calibration of the meter
- Customised name plate (logo, bar-code, customer serial number…)
- IP67 protection
- UV resistant
- Unit: m^3

Interfaces:

- Double Low Frequency fitted as standard on the whole range
- Anti-tampering is supplied as standard
- Medium Frequency is supplied as an option on the DN50 to DN150
- High Frequency is supplied as an option on the whole range
- Mechanical drive according to EN 12480 is supplied as an option
- The cyble sensor can be delivered mounted onto the meter or installed afterwards at any time.
  It is a bounce-free transmitter. It allows also the counting of eventual back flows

Universal totaliser fitted as standard with the Cyble target

Cyble module ATEX

Low Frequency pulse transmitters (LF):

The LF transmitter consists of 2 dry Reed switches, normally open, and controlled by a magnet situated in the first drum of the totaliser. The LF connections are without polarity.

1) Internal Reed contacts

- Hermetically sealed contacts

2) Cyble sensor

- It conforms to CENELEC standard EN 60079-11

Anti-tampering transmitter (AT):

This consists of one dry Reed switch, normally closed. Attempts at magnetic tampering will open the contact. The electrical characteristics are the same as those for the LF transmitter.

Inductive transmitters (HF and MF):

They are inductive sensors actuated by a toothed disc. The frequency is proportional to the instantaneous flow. The polarity of the connections is indicated on the name plate of the meter.

1) High Frequency transmitter

- Proximity detectors conform to EN 60947-5-6 (NAMUR) standards.
- They conform to CENELEC standards (EN 60079-0 and EN 60079-11)

2) Medium Frequency transmitter

- It conforms to CENELEC standards (EN 60079-0 and EN 60079-11)

LF plug

HF plug

Mechanical drive according to EN 12480

Aluminium Series

Delta Silver Edition

The Delta Silver Edition range combines Actaris Gas's proven Delta range with an eco-friendly design resulting in a lighter smaller and easy to maintain product

Delta Silver Edition range

Main Characteristics

- Only the front cover must be filled with a lubricant.
- Thermowells: supplied as an option.
- Double Low Frequency transmitter connected on a Binder 6 pins plug. Anti-tampering is supplied as a standard.
- MF is supplied as an option.
- HF is supplied as an option, connected on a 3 pin binder. Possible to be retrofitted.

Technical Features

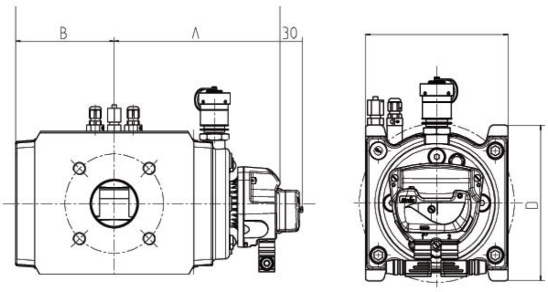
Flow rate	0.4 m³/h to 250 m³/h
G size	G16, G25, G40, G65 G100 and G160
Rangeability	1:20 to 1:200
Nominal diameter	50 and 80 (2" and 3")
Flanging	PN 10/16 and Class 150 (125)
Pressure range	19.3 bar

DN50/DN80 :

G size	Qmax (m³/h)	DN	Flange to flange distance Dim.: L	Rangea-bility	Pressure loss Δpr[1] (mbar)	1 Imp LF& Cyble (m³/Imp)	1 Imp MF (dm³/Imp)	Freq MF at Qmax (Hz)	1 Imp HF (dm³/Imp) (Std. Gears 32/40)	Freq HF at Qmax (Hz)	A	B	C	D	Vc (dm³)	Weight (Kg)
G16	25	50	171	20 to 50	0.14	0.1	2.72	2.55	0.0583	119	172	87	259	182	0.59	9
G25	40	50	171	20 to 100	0.28	0.1	2.72	4.08	0.0583	191	172	87	259	182	0.59	9
G40	65	50	171	20 to 160	1.10	0.1	2.72	6.64	0.0583	310	172	87	259	182	0.59	9
G65	100	50	171	20 to 200	2.07	0.1	2.72	10.2	0.0583	476	172	87	259	182	0.59	9
G65	100	80	171	20 to 200	1.03	0.1	4.36	6.36	0.0935	297	210	125	335	182	0.94	13
G100	160	50	171	20 to 200	3.03	0.1	4.36	10.2	0.0935	475	210	125	335	182	0.94	13
G100	160	80	171	20 to 200	2.76	0.1	4.36	10.2	0.0935	475	210	125	335	182	0.94	13
G160	250	80	171	20 to 200	3.45	0.1	5.28	13.2	0.113	614	234	149	383	182	1.16	15

[1] Δpr: Pressure loss (mbar) with ρ = 0.83Kg/m³ and at Qmax

Delta Silver DN50 G40



Delta Compact

The Actaris Gas meter is ideal for installation in extremely small cabinets.

Main Characteristics

- Available in thread version (L=121mm) or flanged version (L=171mm).
- Only the front cover has to be filled with lubricant.
- Thermowell: supplied as an option.
- Double Low Frequency transmitter connected on a Binder 6 pins plug. Anti-tampering is supplied as a standard.
- HF is supplied as an option, connected on a Binder 6 pins plug.

Technical Features

Flow rate	0.25 m^3/h to 65 m^3/h
G size	G10, G16, G25 and G40
Rangeability	1:20 to 1:200
Threaded version	DN40 1½" BSP or NPT
Flanged version	DN25, DN40 and DN50
	(1", 1½", 2")
	ISO PN10/16
	Class 150 (125)
Pressure range	Up to 19.3 bar

Threaded version DN40 :

G size	Qmax (m^3/h)	DN	Flange to flange distance Dim.: L	Rangea-bility	Pressure loss Δpr[1] (mbar)	1 Imp LF (m^3/Imp)	1 Imp HF (dm^3/Imp) (Std. Gears 32/40)	Freq HF at Qmax (Hz)	A	B	C	D	Vc (dm^3)	Weight (Kg)
G10	16	40	121	20 to 50	0.48	0.01	0.218	20.4	126	46	172	126	0.19	4
G16	25	40	121	20 to 100	1.03	0.01	0.218	31.8	126	46	172	126	0.19	4
G25	40	40	121	20 to 160	1.93	0.01	0.218	50.9	126	46	172	126	0.19	4
G40	65	40	121	20 to 200	4.82	0.01	0.218	82.8	126	46	172	126	0.19	4

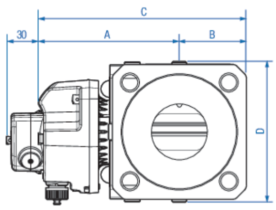
Flanged version DN25/DN40/DN50 :

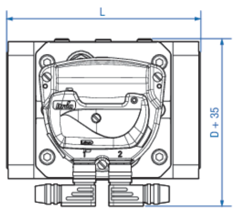
G size	Qmax (m^3/h)	DN	Flange to flange distance Dim.: L	Rangea-bility	Pressure loss Δpr[1] (mbar)	1 Imp LF (m^3/Imp)	1 Imp HF (dm^3/Imp) (Std. Gears 32/40)	Freq HF at Qmax (Hz)	A	B	C	D	Vc (dm^3)	Weight (Kg)
G10	16	25	171	20 to 50	1.38	0.01	0.218	20.4	126	60	186	126	0.19	6
G10	16	40	171	20 to 50	0.48	0.01	0.218	20.4	126	60	186	126	0.19	6
G10	16	50	171	20 to 50	0.55	0.01	0.218	20.4	126	60	186	126	0.19	6
G16	25	25	171	20 to 100	3.10	0.01	0.218	31.8	126	60	186	126	0.19	6
G16	25	40	171	20 to 100	1.03	0.01	0.218	31.8	126	60	186	126	0.19	6
G16	25	50	171	20 to 100	1.03	0.01	0.218	31.8	126	60	186	126	0.19	6
G25	40	40	171	20 to 160	1.93	0.01	0.218	50.9	126	60	186	126	0.19	6
G25	40	50	171	20 to 160	1.93	0.01	0.218	50.9	126	60	186	126	0.19	6
G40	65	40	171	20 to 200	4.82	0.01	0.218	82.8	126	60	186	126	0.19	6
G40	65	50	171	20 to 200	4.82	0.01	0.218	82.8	126	60	186	126	0.19	6

[1] Δpr: Pressure loss (mbar) with ρ = 0.83Kg/m^3 and at Qmax

Delta DN40 G16

Delta DN50 G40 fitted with Cyble sensor





Pressure loss of the Delta meters

Calculation of pressure loss: $\Delta p = \Delta p_r \times \frac{\rho n}{0.83} \times (Pb+1) \times \left[\frac{q}{Qmax}\right]^2 \times \left[\frac{273}{(273+Tb)}\right]$

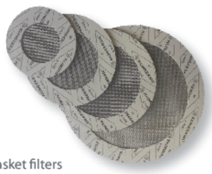
where:

- Δp: Pressure loss in the calculated conditions
- Δpr: Pressure loss in the reference conditions
- ρn: Gas density (kg/m^3) at 0° C and 1013 mbar
- Pb: Operating pressure (Bar gauge)
- q: Flow rate (m^3/h)
- Qmax: Maximum flow rate (m^3/h)
- Tb: Gas temperature (°C).

Installation

Each meter is delivered with binder plugs for the installed transmitters and oil for the lubrication. Please refer to the instruction manual supplied with the meter.

The advice given therein will ensure optimal use of the Delta meter over the years.



Flat gasket filters from DN25 to DN150

Delta DN80 G100 with Corus PTZ

Thermowell fitted with sealing holes

Delta DN50 G65 S1-Flow equipped with extension for the totaliser and by-pass

Accessories / Options

Flat gasket-filter:

» Flat gasket-filter, to be fit between flanges DN25 to DN150, High Temperature Resistant and with a level of filtration of 100.

External silicagel cartridge:

» Accessory for maintenance on the installed external silicagel cartridge for extreme conditions.

Pete´s plug®:

» Ideal device for filling lubricant in the cover of the meter while equipment is in service. It must be fitted instead of the tap plug of the cover.
Plugged on the pressure tapping, it can be used to measure the pressure and the temperature of the measured gas.
Connection size: 1/4” NPT or 1/4” BSP.
Maximum pressure of gas: 20 bar.

Bracket for mounting a volume converter:

» This device permits the Actaris Gas Corus PTZ volume converter to be adapted directly onto the meter, or at the most convenient place to the meter to enable the converter index to be easily read.

Thermowells:

» These threaded 1/4” NPT thermowells, can be plugged onto the meter. They can be retrofitted on to the standard version (plugged onto the existing pressure tapping), or they can be installed on the versions equipped with extra-tapping.
The internal diameter of the thermowell is 7 mm; it enables mounting of most standard temperature probes.

Extension for the totaliser:

» This option allows the possibility to increase the distance between the body of the meter and the index, to facilitate the reading when the meter is covered with ice due to measurement at low temperatures.

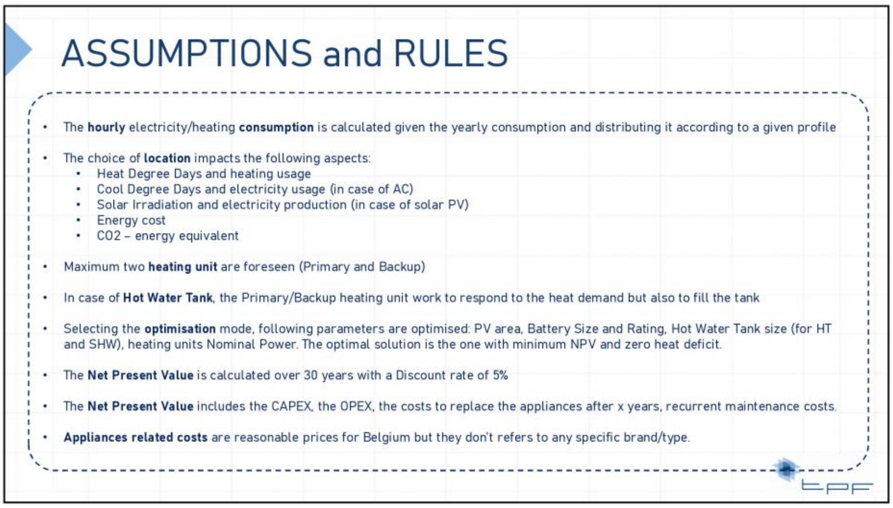
By-pass:

» It can be installed as an option on the steel version DN50. It enables the gas to flow even if the meter is blocked for any reason.

6.4. Outputs of the platform on multiple different scenarios

31/05/2023

1



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1

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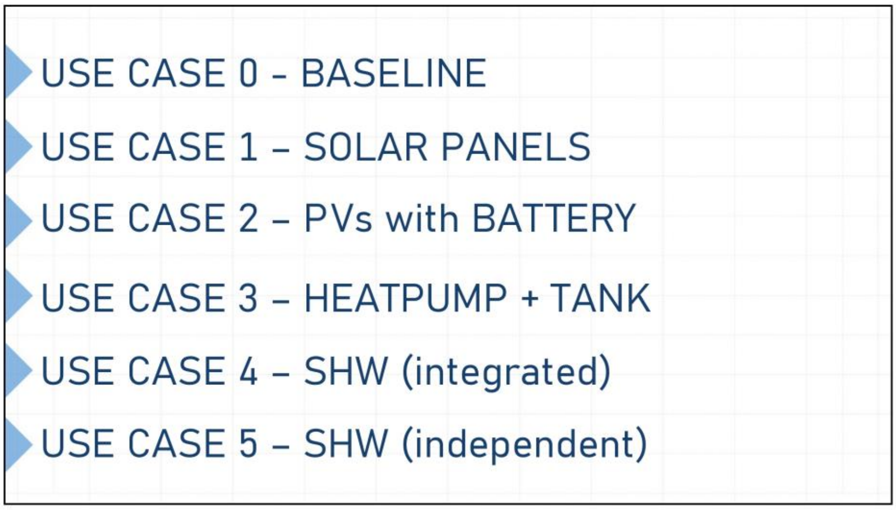
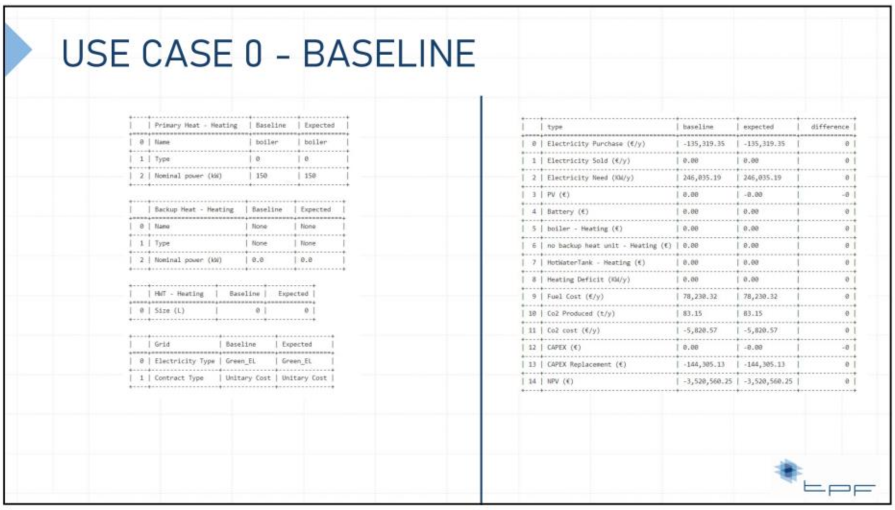


3



	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	boiler
1	Type	0	0
2	Nominal power (kW)	150	150

	Backup Heat - Heating	Baseline	Expected
0	Name	None	None
1	Type	None	None
2	Nominal power (kW)	0.0	0.0

	HWT - Heating	Baseline	Expected
0	Size (L)	0	0

	Grid	Baseline	Expected
0	Electricity Type	Green_EL	Green_EL
1	Contract Type	Unitary Cost	Unitary Cost

	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-135,319.35	-135,319.35	0
1	Electricity Sold (€/y)	0.00	0.00	0
2	Electricity Need (KW/y)	246,035.19	246,035.19	0
3	PV (€)	0.00	-0.00	-0
4	Battery (€)	0.00	0.00	0
5	boiler - Heating (€)	0.00	0.00	0
6	no backup heat unit - Heating (€)	0.00	0.00	0
7	HotWaterTank - Heating (€)	0.00	0.00	0
8	Heating Deficit (KW/y)	0.00	0.00	0
9	Fuel Cost (€/y)	78,230.32	78,230.32	0
10	Co2 Produced (t/y)	83.15	83.15	0
11	Co2 cost (€/y)	-5,820.57	-5,820.57	0
12	CAPEX (€)	0.00	-0.00	-0
13	CAPEX Replacement (€)	-144,305.13	-144,305.13	0
14	NPV (€)	-3,520,560.25	-3,520,560.25	0

4

2

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5

6

3

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USE CASE 1 – SOLAR PANELS

	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	boiler
1	Type	0	0
2	Nominal power (kW)	50	50

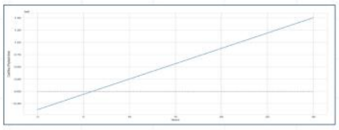
	Backup Heat - Heating	Baseline	Expected
0	Name	None	None
1	Type	None	None
2	Nominal power (kW)	0.0	0.0

	HWT - Heating	Baseline	Expected
0	Size (l)	0	0

	Solar PV	Baseline	Expected	Detail
0	Area (m2)	0	1000	
1	PV Tech	None	crystSi	"crystSi", "CIS", "CdTe" and "Unknown"
2	Mounting Place	None	free	"free" for free-standing and "building" for building-integrated
3	Tracking Tech	None	0	0=fixed, 1=single horizontal axis aligned north-south, 2=two-axis tracking, 3=vertical axis tracking, 4=single horizontal axis aligned east-west, 5=single inclined axis aligned north-south

	Battery	Baseline	Expected
0	Size (kWh)	0	151.54
1	Raiting (kW)	0	32.88

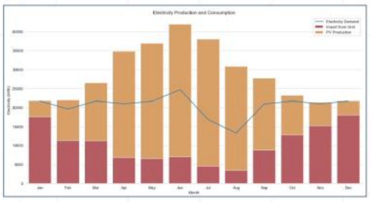
	Grid	Baseline	Expected
0	Electricity Type	Grey_El	Green_El
1	Contract Type	Unitary Cost	Unitary Cost

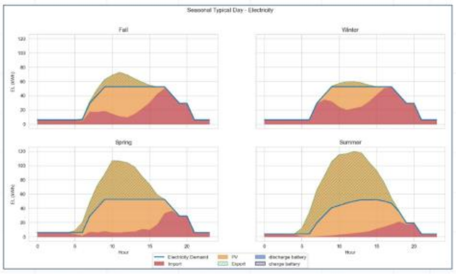


	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-122,092.26	-67,766.36	55,125.90
1	Electricity Sold (€/y)	0.00	4,040.14	4,040.14
2	Electricity Need (KW/y)	245,784.52	245,784.52	0.00
3	PV (€)	0.00	-375,000.00	-375,000.00
4	Battery (€)	0.00	0.00	0.00
5	boiler - Heating (€)	0.00	0.00	0.00
6	no backup heat unit - Heating (€)	0.00	0.00	0.00
7	HotWaterTank - Heating (€)	0.00	0.00	0.00
8	Heating Deficit (KW/y)	-125,332.24	-125,332.24	0.00
9	Fuel Cost (€/y)	51,844.58	51,844.58	0.00
10	Co2 Produced (t/y)	105.92	54.31	51.61
11	Co2 cost (€/y)	-7,414.20	-3,801.62	3,612.59
12	CAPEX (€)	0.00	-375,000.00	-375,000.00
13	CAPEX Replacement (€)	-48,101.71	-48,101.71	0.00
14	NPV (€)	-2,852,206.58	-2,265,219.80	586,986.78

7

UC1 - ELECTRICITY





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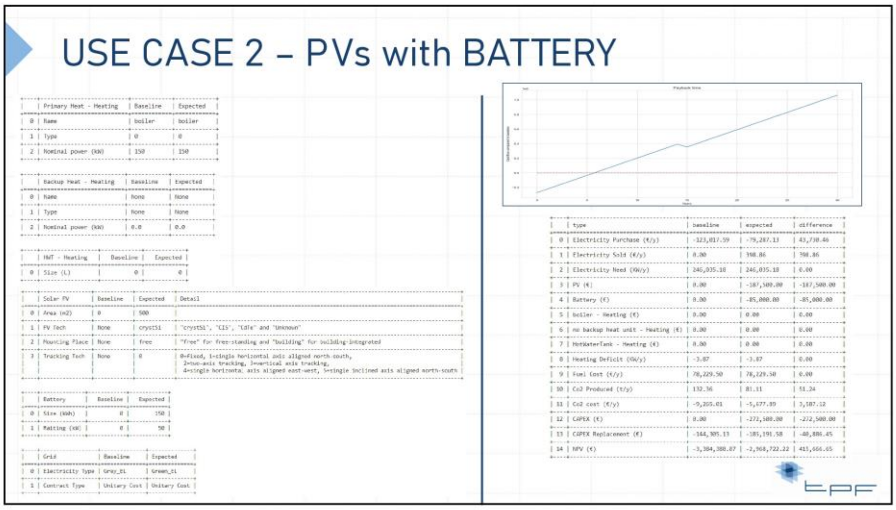

	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	boiler
1	Type	0	0
2	Nominal power (kW)	150	150

	Backup Heat - Heating	Baseline	Expected
0	Name	None	None
1	Type	None	None
2	Nominal power (kW)	0.0	0.0

	HWT - Heating	Baseline	Expected
0	Size (L)	0	0

	Solar PV	Baseline	Expected	Detail
0	Area (m2)	0	500	
1	PV Tech	None	crystSi	"crystSi", "CIS", "CdTe" and "Unknown"
2	Mounting Place	None	free	"free" for free-standing and "building" for building-integrated
3	Tracking Tech	None	0	0=Fixed, 1=single horizontal axis aligned north-south, 2=two-axis tracking, 3=vertical axis tracking, 4=single horizontal axis aligned east-west, 5=single inclined axis aligned north-south

	Battery	Baseline	Expected
0	Size (kWh)	0	150
1	Raiting (kW)	0	50

	Grid	Baseline	Expected
0	Electricity Type	Grey_El	Green_El
1	Contract Type	Unitary Cost	Unitary Cost

	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-123,017.59	-79,287.13	43,730.46
1	Electricity Sold (€/y)	0.00	398.86	398.86
2	Electricity Need (KW/y)	246,035.18	246,035.18	0.00
3	PV (€)	0.00	-187,500.00	-187,500.00
4	Battery (€)	0.00	-85,000.00	-85,000.00
5	boiler - Heating (€)	0.00	0.00	0.00
6	no backup heat unit - Heating (€)	0.00	0.00	0.00
7	HotWaterTank - Heating (€)	0.00	0.00	0.00
8	Heating Deficit (KW/y)	-3.87	-3.87	0.00
9	Fuel Cost (€/y)	78,229.50	78,229.50	0.00
10	Co2 Produced (t/y)	132.36	81.11	51.24
11	Co2 cost (€/y)	-9,265.01	-5,677.89	3,587.12
12	CAPEX (€)	0.00	-272,500.00	-272,500.00
13	CAPEX Replacement (€)	-144,305.13	-185,191.58	-40,886.45
14	NPV (€)	-3,384,388.87	-2,968,722.22	415,666.65

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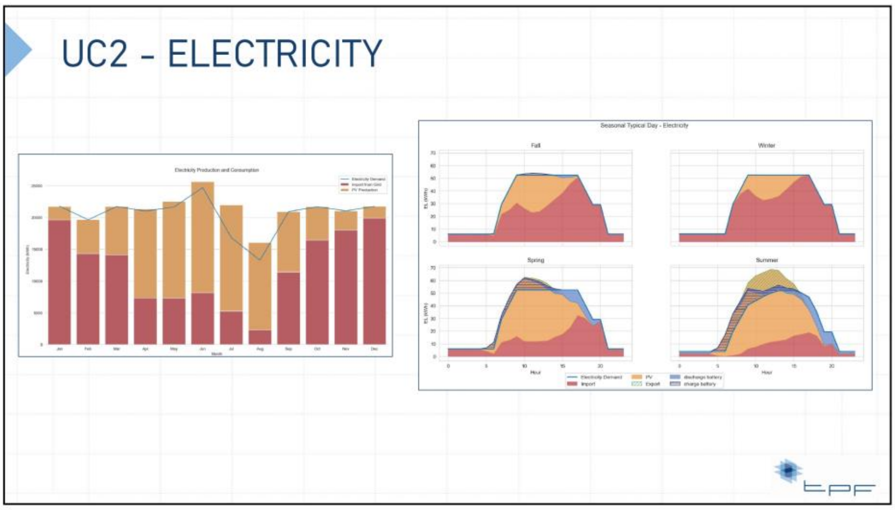

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USE CASE 3 – HEATPUMP + TANK

	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	heat pump
1	Type	0	0
2	Nominal power (kW)	150	15

	Backup Heat - Heating	Baseline	Expected
0	Name	None	boiler
1	Type	None	0
2	Nominal power (kW)	0.0	90

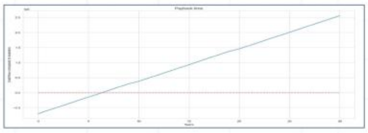
	HWT - Heating	Baseline	Expected
0	Size (L)	0	10000

	Solar PV	Baseline	Expected
0	Area (m2)	0	1000
1	PV Tech	None	crystSi
2	Mounting Place	None	free
3	Tracking Tech	None	0

	Battery	Baseline	Expected
0	Size (kWh)	0	150
1	Raiting (kW)	0	50

	Battery	Baseline	Expected
0	Size (kWh)	0	150
1	Raiting (kW)	0	50

	Grid	Baseline	Expected
0	Electricity Type	Grey_EL	Green_EL
1	Contract Type	Unitary Cost	Unitary Cost



	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-123,017.59	-86,120.40	36,897.19
1	Electricity Sold (€/y)	0.00	2,949.12	2,949.12
2	Electricity Need (KW/y)	246,035.18	306,490.95	60,455.77
3	PV (€)	0.00	-375,000.00	-375,000.00
4	Battery (€)	0.00	-85,000.00	-85,000.00
5	heat pump - Heating (€)	0.00	-27,000.00	-27,000.00
6	boiler - Heating (€)	0.00	-180,000.00	-180,000.00
7	HotWaterTank - Heating (€)	0.00	-30,000.00	-30,000.00
8	Heating Deficit (KW/y)	-3.87	-0.00	-3.87
9	Fuel Cost (€/y)	78,229.50	15,331.32	-62,898.18
10	Co2 Produced (t/y)	132.36	18.46	113.89
11	Co2 cost (€/y)	-9,265.01	-1,292.41	7,972.60
12	CAPEX (€)	0.00	-697,000.00	-697,000.00
13	CAPEX Replacement (€)	-144,305.13	-168,651.72	-24,346.59
14	NPV (€)	-3,384,388.87	-2,412,673.57	971,715.30

tpf

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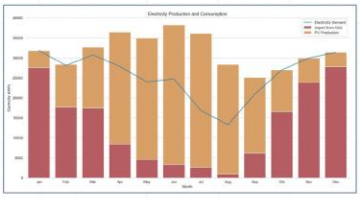
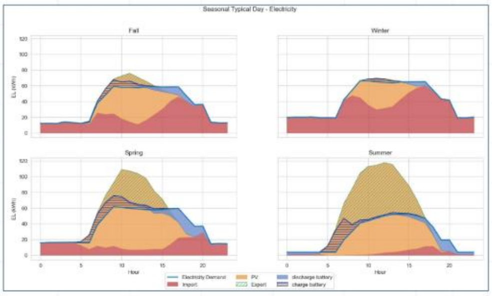
UC3 - ELECTRICITY





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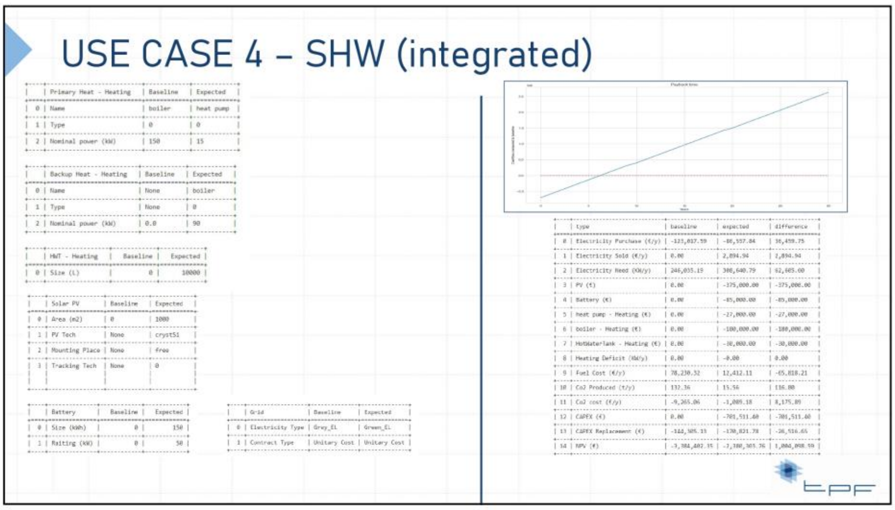

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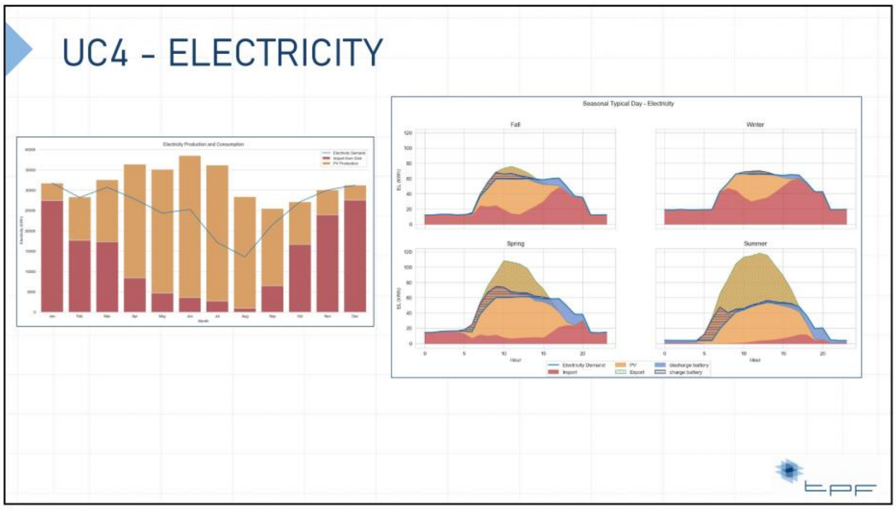

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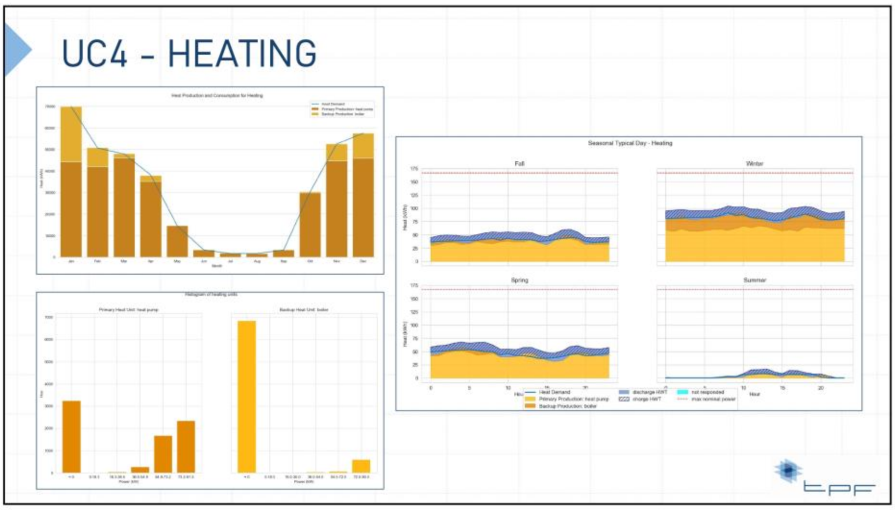

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OPTIMISATION of USE CASE 4

	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	heat pump
1	Type	0	0
2	Nominal power (kW)	150	15

	Backup Heat - Heating	Baseline	Expected
0	Name	None	boiler
1	Type	None	0
2	Nominal power (kW)	0.0	90

	HWT - Heating	Baseline	Expected
0	Size (L)	0	10000

	Solar PV	Baseline	Expected
0	Area (m2)	0	1000.0
1	PV Tech	None	crystSi
2	Mounting Place	None	free
3	Tracking Tech	None	0

	Battery	Baseline	Expected
0	Size (kWh)	0	130.72
1	Raiting (kW)	0	33.18

	Grid	Baseline	Expected
0	Electricity Type	Grey_EL	Green_EL
1	Contract Type	Unitary Cost	Unitary Cost

	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-123,017.59	-87,675.52	35,342.07
1	Electricity Sold (€/y)	0.00	2,975.91	2,975.91
2	Electricity Need (KW/y)	246,035.19	308,640.79	62,605.60
3	PV (€)	0.00	-375,000.00	-375,000.00
4	Battery (€)	0.00	-71,995.89	-71,995.89
5	heat pump - Heating (€)	0.00	-27,000.00	-27,000.00
6	boiler - Heating (€)	0.00	-180,000.00	-180,000.00
7	HotWaterTank - Heating (€)	0.00	-30,000.00	-30,000.00
8	Heating Deficit (KW/y)	0.00	-0.00	0.00
9	Fuel Cost (€/y)	78,230.32	12,412.11	-65,818.21
10	Co2 Produced (t/y)	132.36	15.60	116.76
11	Co2 cost (€/y)	-9,265.06	-1,092.02	8,173.04
12	CAPEX (€)	0.00	-683,995.89	-683,995.89
13	CAPEX Replacement (€)	-144,305.13	-162,396.52	-18,091.39
14	NPV (€)	-3,384,402.35	-2,368,952.38	1,015,449.97

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USE CASE 5 – SHW (independent)

	Primary Heat - Heating	Baseline	Expected
0	Name	boiler	heat pump
1	Type	0	0
2	Nominal power (kW)	150	15

	Backup Heat - Heating	Baseline	Expected
0	Name	None	boiler
1	Type	None	0
2	Nominal power (kW)	0.0	90

	HWT - Heating	Baseline	Expected
0	Size (L)	0	10000

	Primary Heat - SHW	Baseline	Expected
0	Name	boiler	heat pump
1	Type	0	0
2	Nominal power (kW)	0	3

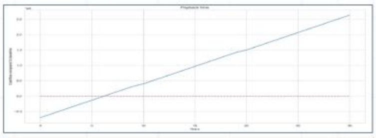
	Backup Heat - SHW	Baseline	Expected
0	Name	None	None
1	Type	None	None
2	Nominal power (kW)	0.0	0.0

	HWT - SHW	Baseline	Expected
0	Size (L)	0	1503.80

	Solar PV	Baseline	Expected
0	Area (m2)	0	1000
1	PV Tech	None	crystSi
2	Mounting Place	None	free
3	Tracking Tech	None	0

	Battery	Baseline	Expected
0	Size (kWh)	0	150
1	Raiting (kW)	0	50

	Grid	Baseline	Expected
0	Electricity Type	Grey_EL	Green_EL
1	Contract Type	Unitary Cost	Unitary Cost



	type	baseline	expected	difference
0	Electricity Purchase (€/y)	-123,017.59	[illegible]	[illegible]
1	Electricity Sold (€/y)	0.00	[illegible]	[illegible]
2	Electricity Need (KW/y)	246,035.19	[illegible]	[illegible]
3	PV (€)	0.00	-375,000.00	-375,000.00
4	Battery (€)	0.00	-85,000.00	-85,000.00
5	heat pump - Heating (€)	0.00	-27,000.00	-27,000.00
6	boiler - Heating (€)	0.00	-180,000.00	-180,000.00
7	HotWaterTank - Heating (€)	0.00	-30,000.00	-30,000.00
8	Heating Deficit (KW/y)	0.00	-0.00	0.00
9	heat pump - SHW (€)	0.00	-5,400.00	-5,400.00
10	no backup heat unit - SHW (€)	0.00	0.00	0.00
11	HotWaterTank - SHW (€)	0.00	[illegible]	[illegible]
12	SHW Deficit (KW/y)	0.00	-0.00	0.00
13	Fuel Cost (€/y)	78,230.32	[illegible]	[illegible]
14	Co2 Produced (t/y)	132.36	[illegible]	[illegible]
15	Co2 cost (€/y)	-9,265.06	[illegible]	[illegible]
16	CAPEX (€)	0.00	[illegible]	[illegible]
17	CAPEX Replacement (€)	-144,305.13	[illegible]	[illegible]
18	NPV (€)	-3,384,402.35	[illegible]	[illegible]

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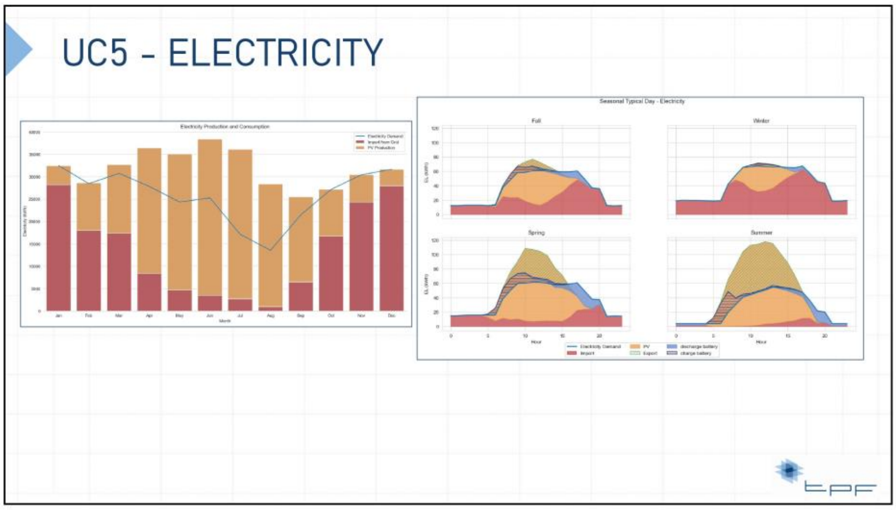

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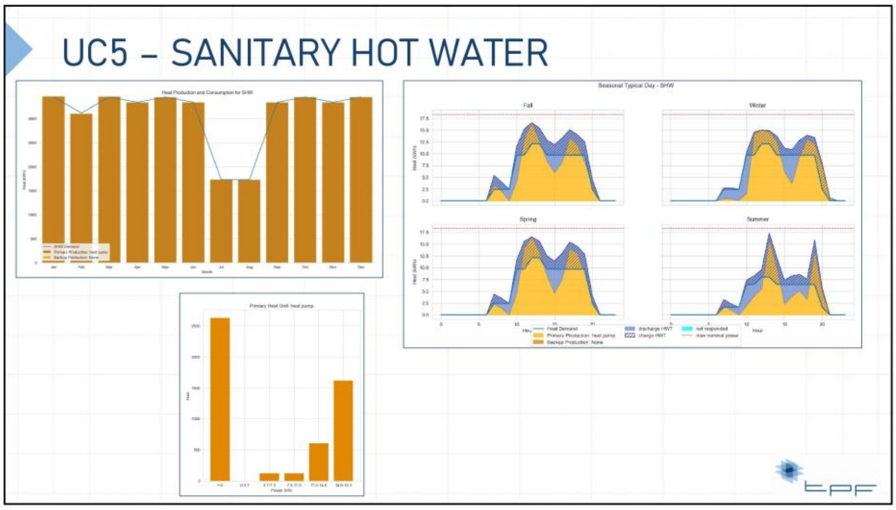

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