ARV

CLIMATE POSITIVE CIRCULAR COMMUNITIES

D4.2 DESIGN CONFIGURATION FOR A MODULAR, SCALABLE, INTEGRATED RETROFITTING CONCEPT FOR POSITIVE ENERGY MID- & HIGHRISE BUILDINGS EMBEDDED IN A GREEN NEIGHBOURHOOD IN UTRECHT

WP4 SUSTAINABLE BUILDING (RE) DESIGN

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[1] *ARV is a Norwegian word meaning "heritage" or "legacy". It reflects the emphasis on circularity, a key aspect in reaching the project's main goal of boosting the building renovation rate in Europe.*

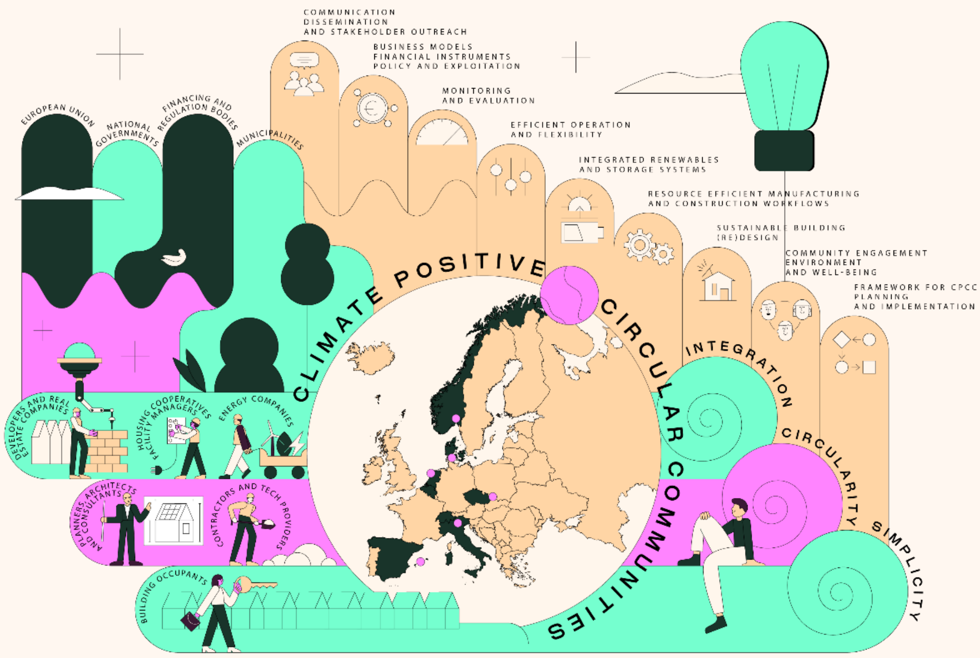
ABOUT THE ARV PROJECT

The vision of the ARV project is to contribute to speedy and wide scale implementation of Climate Positive Circular Communities (CPCC) where people can thrive and prosper for generations to come. The overall aim is to demonstrate and validate attractive, resilient, and affordable solutions for CPCC that will significantly speed up the deep energy renovations and the deployment of energy and climate measures in the construction and energy industries. To achieve this, the ARV project will employ a novel concept relying on a combination of 3 conceptual pillars, 6 demonstration projects, and 9 thematic focus areas.

The 3 conceptual pillars are integration, circularity, and simplicity. **Integration** in ARV means the coupling of people, buildings, and energy systems, through multi-stakeholder co-creation and use of innovative digital tools. **Circularity** in ARV means a systematic way of addressing circular economy through the integrated use of Life Cycle Assessment, digital logbooks, and material banks. **Simplicity** in ARV means to make the solutions easy to understand and use for all stakeholders, from manufacturers to end-users.

The 6 demonstration projects are urban regeneration projects in 6 locations around Europe. They have been carefully selected to represent the different European climates and contexts, and due to their high ambitions in environmental, social, and economic sustainability. Renovation of social housing and public buildings are specifically focused. Together, they will demonstrate more than 50 innovations in more than 150,000 m^2 of buildings.

The 9 thematic focus areas are 1) Effective planning and implementation of CPCCs, 2) Enhancing citizen engagement, environment, and well-being, 3) Sustainable building re(design) 4) Resource-efficient manufacturing and construction workflows, 5) Smart integration of renewables and storage systems, 6) Effective management of energy and flexibility, 7) Continuous monitoring and evaluation, 8) New business models and financial mechanisms, policy instruments and exploitation, and 9) Effective communication, dissemination, and stakeholder outreach.



The ARV project is an Innovation Action that has received funding under the Green Deal Call LC-GD-4-1-2020 - Building and renovating in an energy and resource efficient way. The project started in January 2022 and has a project period of 4 years, until December 2025. The Norwegian University of Science and Technology coordinates the project and involves 35 partners from 8 different European Countries.

EXECUTIVE SUMMARY

Task 4.3 of the Utrecht demonstration project aims to develop a design guideline of climate positive circular community in Utrecht, focusing on resource-efficient retrofitting of mid-rise residential buildings into Positive Energy Buildings. Collaborating with housing associations and companies, the project aims to enhance the Inside-Out Retrofitting concept, achieving a 30% cost reduction compared to traditional systems while significantly reducing greenhouse gas emissions. Key developments include modular HVAC design, architectural diversity in renovation concepts, standardization, infrastructure compactness, material data storage integration, minimal disruption during renovation, Plug & Play installation solutions, and architectural integration of photovoltaics.

The energy transition poses a significant challenge, particularly in making housing more sustainable. Despite obstacles such as rising energy prices and construction costs, Inside Out advocates for an integrated approach to design and construction to accelerate sustainability efforts. Following a stepwise strategy outlined by Prof A. van den Dobbelsteen, it focuses on optimizing the thermal envelope, utilizing residual energy flows efficiently, and maximizing renewable energy sources. The approach emphasises "No regret measures," facilitating sustainable progress despite challenges.

The Utrecht demo aims to address Key Performance Indicators (KPIs) outlined in the ARV Project, focusing on retrofitting Bredero buildings. These KPIs include circular economy practices, social-environmental qualities, smartness, energy flexibility, affordability, job creation, standards and regulations, knowledge creation, and contribution to key EU policy goals. Targets such as GHG emission reduction and improvement in indoor environmental quality are set, with planned actions for the procurement process in 2024. Not all indicators have been calculated yet, but the demo aims to integrate them into the configurator.

The process of creating renovation solutions for the building stock begins with identifying building typologies, based on research by Thijs Barkmeijer and subsequent studies on building stock characteristics. This research, conducted by the University of Applied Sciences Utrecht in collaboration with Stroomversnelling, aims to identify the need for standardization and flexibility to renovate homes into Positive Energy Buildings (PEB) with an industrial approach. The focus lies on high-rise buildings, with research methods including mapping existing systems and analyzing 11 dominant building systems. System documents for each system were created, validated by fieldwork, and incorporated typical features and performance variants. Due to execution differences, grouping is based on building components rather than system nodes, resulting in four renovation principles: insulate inside, insulate outside, demolish the outer wall, and demolish the entire façade, determined by implementation variants. Grouping is done based on building components and their variants.

The Utrecht demo site, comprising four Bredero flats on Rooseveltlaan and Alexander de Grotelaan, each with 65 dwellings, needs extensive renovation due to severe outdatedness and failure to meet sustainability requirements. Surveys revealed various issues, including outdated installations, poor condition of window frames, and balcony drainage problems. Structural surveys by Nebest B.V. highlighted defects in masonry, unsafe cavity construction, and concrete element damage, with urgent needs such as cavity wall anchor addition. The heating and hot water supply are managed by a condensing boiler, with gas cooking, radiator placement under window frames, and central extraction in the bathroom, kitchen, and toilet.

Mex Architects has designed an aesthetic overhaul for the Brederoflats on Rooseveltlaan and Alexander de Grotelaan, preserving the original design principles while modernising with a smart facade. The facade retains the appearance of masonry, concealing access hatches for technology. Sealed sections fitted with PV panels provide energy generation and space for technology, maintaining the building's structural rhythm inspired by 1960s architecture. The design blends contemporary elements with the neighbourhood's aesthetic.

Building blocks for sustainable apartment buildings are developed by Inside Out, allowing step-by-step progress towards energy positive. The six modules include Alpha (roof PV panels), Bravo (energy module), Charlie (ventilation and heating), Delta (façade insulation), Echo (balcony system), and Foxtrot (home energy management). These modules, factory-assembled and suitable for various heating systems, aim to minimize inconvenience for residents while scaling up the energy transition. The "Inside Out" approach emphasizes renovating from the inside, integrating existing installations into external modules. Notably, the Delta module provides prefabricated façades with high insulation and aesthetic versatility. The Climate module (Bravo) replaces gas heating with sustainable alternatives. The Charlie module integrates heating, ventilation, and electricity generation into the façade, tested for performance. Balcony renovation (Echo) addresses poor conditions, offering larger spaces. The Alpha module focuses on renewable energy generation, aiming for energy-neutral homes. Lastly, the Foxtrot module enables smart monitoring and management, optimizing energy usage and maintenance.

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1. INTRODUCTION

Task 4.3 of the Utrecht demonstration project aims to develop a design guideline of climate positive circular community in Utrecht. The activities extend from Month 1 to Month 36 with a housing association Bo-Ex, companies Rc Panels, Bos Groep and Mex.
The demo actions in Utrecht focus on resource efficient, systematic retrofitting of four mid-rise residential apartment buildings from the 1960s into Positive Energy Buildings embedded in a green neighbourhood. The innovations & research will assess the current retrofitting approach of
Inside-Out 1.0 (previously applied in one nationally funded project ending in 2021) and will develop application in the Inside-Out concept 2.0. The integrated design will include specific building components that result in 30% cost reduction compared to traditional systems and will reduce GHGs substantially. To achieve these goals the re-design will focus on roof, façade, and balcony systems by exploring the following:

- The retrofit solutions will be designed for industrialization and will be scalable to serve different post war building typologies, such as 4 story, 6 story &10 story high-rise and other façade characteristics, through modular & adaptable roof, façade & balcony sections.

The following actions will be taken up in 2024.

- For four mid-rise residential apartment buildings (type Bredero-4) the Inside-Out 2.0 retrofit solution will be designed and tailor made.
- For four mid-rise residential apartment buildings (type Intervam-4) and two high-rise residential apartment buildings (type Intervam-10) the HeMuBo retrofit solution, which is in pre-planning in 2022, will be assessed and advancements to this retrofit solution will be designed based on Inside-Out components.

The expected improvements relate to increased energy performance from NZEB to PEB and lower retrofitting time and costs through the application of Inside-Out components (energy and HVAC installations facades using sandwich panels) produced off-site and installed plug-and-play on-site and the application of additional BIPV / BAPV. The decision to implement these changes depends on outcomes of this task and external factors, such as existing contractual agreements between Bo-Ex, Woonin and their contractors (outside of ARV consortium) and the required investment.

The improvements to the Inside Out Retrofitting concept are the following developments and will be explored:

- Modular HVAC design which allows different types of heating & ventilation per dwelling related to the needs of the occupant & location.
- Renovation concepts to create the architectural diversity of appearance, adapted to the context. An important part is the architectural connection of design in post-war renovations and the design of the adaptable retrofitting solution.
- Design for standardization and flexibility of the interfaces connecting modules e.g., detailing. Including flexible façade fixing that gains a higher adaptation potential.
- Design for infrastructure compactness, at the outside of the building & integrated in the roof, balcony & façade components, including connection of PV modules for optimal energy harvesting.
- Integration of material data storage in a resource track system i.e. materials passport.
- Design for minimal disruption: Users will have the choice to sleep in their apartments during the renovation.
- Design for Integrated Plug & Play installation solutions to link multiple facades (including integrated energy a/o ventilation installations) to enhance modularity and reduce the total cost of ownership.
- Demonstration of architectural and aesthetic plug-and-play integration of BIPV/BAPV solutions.

1.1. READING GUIDE

This Guideline for Design is based on the configurator principle (Figure 1). The construction sector is traditionally a project-based industry. With these guidelines, we explore/design a completely different process towards a project independent approach. In the essence, we need to solve the split within the design/engineering and construction. Commonly the advisers (architects, structural engineers, energy specialists, etc..) design and develop solutions for specific clients and projects with a wide variety of (unique) materials. The contractor will build what is designed but often in these phases time and money is lost through redesign. Through the development of pre-engineered project-independent renovation systems, the product is completely defined. The modules are the jigsaw puzzle pieces. With these pieces, different puzzles can be made. So, the flexibility of the modules with its interfaces needs to be defined and suited for different situations. In this guideline we address this transition.

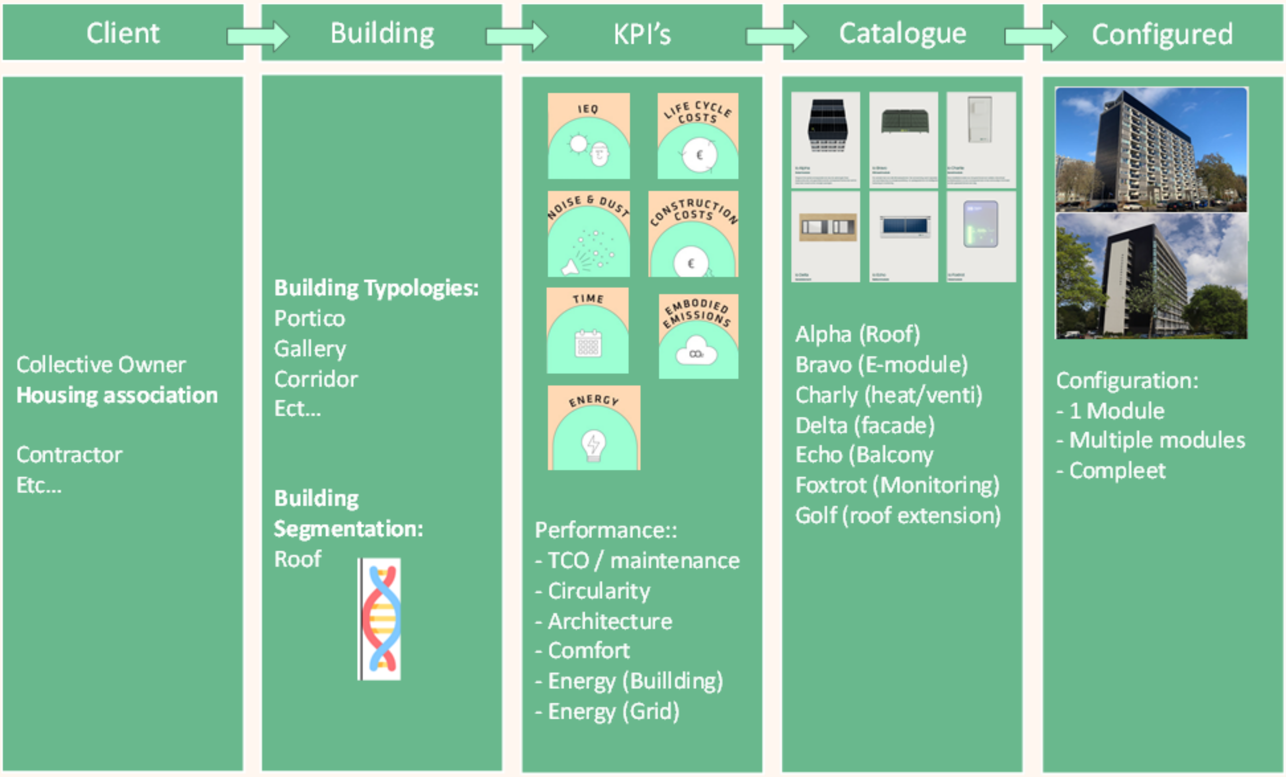

Figure 1. *Main configuration process*

2. EXECUTIVE SUMMARY OF THE PROJECT– UTRECHT, THE NETHERLANDS

Type	Description
Project type and ambition level	Design of retrofitting solutions of medium high rise apartment building towards Positive Energy Building
Building types	The existing building is a typology of the porch flat and has a stacked block system with poured concrete as a main structure.
Location	Utrecht, Kanaleneiland, Rooseveltlaan and Alexander de Grotelaan
Building owner	Housing association Bo-Ex
Design team	Companies: BOS Installation Works (main developer Inside Out), Rc Panels, Mex Architects, Research: University of Applied Sciences Utrecht

Bo-Ex and BOS Installation Works have already proven to be good cooperation partners in the past. From this sustainable partnership, the intention arose to comprehensively renovate high-rise flats. With the aim of reducing inconvenience for residents, saving costs and accelerating the energy transition. This joint idea led to the formation of the Inside Out consortium.

2.1. OVERVIEW

Situation
At the Rooseveltlaan and Alexander de Grotelaan are four (Bredero) flats situated (Figure 2), each of which has ***65*** dwellings. The appartement buildings are classified as porch flats. Each apartment building has five porches and also five residential floors. There are thirteen flats per porch. On the ground floor there is one large flat of 78 m^2 and thirteen storerooms. Floors one to four all have the same structure. Per floor, there are two relatively large flats of 71 m^2 and one smaller flat of 41 m^2.
The (flat) buildings are currently severely outdated, have an energy label G and therefore no longer meet the sustainability requirements of the future. Large-scale renovation cannot be avoided as a result.

Challenges
New requirements for sustainability, high energy costs, shortage of rental/ temporary housing and a shortage of staff means Bo-Ex is ready for an integrated solution for planned renovation.

Question
To this end, Bo-Ex and Inside Out started a journey to renovate the Bredero flats. Based on the Inside Out renovation concept, the aim was to renovate the flats to energy-neutral / energy-producing status.

***Figure** 2. Location of Bredero flats typology*

3. VISION AND KPI'S

3.1. VISION

Energy transition is the challenge of the century. An important part of the energy transition is making the housing stock more sustainable. This principle is accompanied by a number of bottlenecks such as rising energy prices; affordability of living; rising construction costs; homes overheating, etc. As a result of this complexity, making the built environment sustainable is not moving fast enough. Traditional building methods, occupied housing and the increasing shortage of quality professionals do not help. Inside Out aims for a new integral way of designing and building so that, despite these barriers, a major step towards sustainability can be accelerated.

Stepwise energy neutral
In determining the sustainability steps, the sustainability strategy of "the New Steps strategy" developed by Prof A. van den Dobbelsteen was taken into as a starting point. Here, the first step is to optimise the thermal envelope and minimize unnecessary energy losses. The second step involves making optimal use of residual flows. When energy is still used, it should consist of renewable energy as much as possible. In the last step, finite energy sources should be used in an efficient way as possible.
Inside Out uses future-proof "No regret measures". No-regret measures are improvements that assume a desired end picture and reason backwards from there.

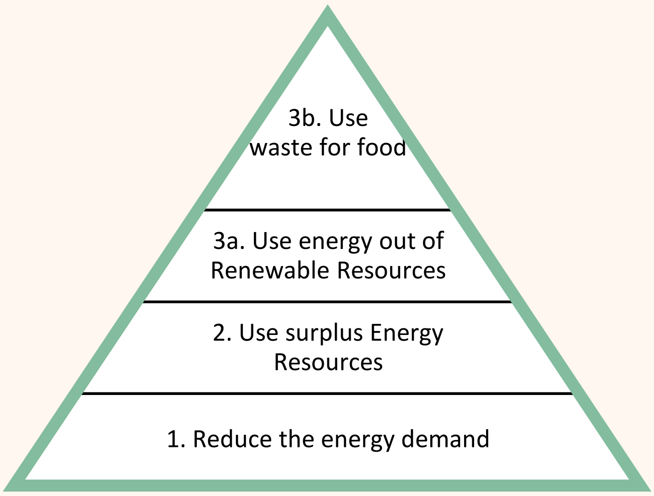

***Figure** 3. Principle of the New Stepped Strategy [Dobbelsteen, 2009]*

3.2. KEY PERFORMANCE INDICATORS

As the demo Utrecht we need to address the Key Performance Indicators (KPIs) as mentioned in work package 8. Below we give an overview of these indicators for the retrofitting of the Bredero and the scores. Because we are in the next stage of the procurement process, we didn't calculate all the indicators. In 2024 the KPIs will be calculated and integrated into the configurator and connected to the procurement process.

Impact category	How ARV will contribute to achieving the impacts	Targets	KPIs	Retrofit Bo-Ex Bredero (17436 m²)
1) Circular Economy and Resiliency	Maximizing reuse of buildings by lean renovation applying life cycle analyses (WP5, 8), minimize waste and pollution by prefabrication and industrialization (WP5), design for long-lasting, easy to repair, reuse and recycling of building components (WP4, 5). Use of local bio-based materials (WP4, 5). Design for flexibility of building use (WP4), and flexible and secure energy systems and storage (WP6,7).	50% reduction in life cycle GHG emissions compared to ex-ante condition or current practice. Apply all relevant Level(s)[1] CEIs.	kg CO_2-eq/m2 over 60-100-year lifetime.	104%
2) Social-environmental qualities	Design for well-being and good indoor environment qualities including good daylight and visual qualities, indoor air quality, thermal comfort, acoustics, and accessibility for persons with disabilities and senior citizens (WP4-5). Included in multiple benefit analysis (WP3 and WP8)	At least 30% improvement compared to ex-ante condition	% of users moving up the satisfaction scale	Not yet available (D8.4)
	Design for comfortable outdoor conditions, i.e. solar and daylight access, visual qualities, and shielding from wind and noise (WP4-5).	At least 30% improvement compared to ex-ante condition	% of users moving up the satisfaction scale.	Not yet available (D8.4)
	Minimize disruption to occupants during renovation by off-site prefabrication and	30% reduced construction time. Close to zero disruption	Construction time and intervention	Not yet available (D8.4)

	minimizing the time spent on site (WP5).			
	Awareness raising, engagement and education by arranging Living Labs with co-creation, (WP3), creation of Citizen Energy Communities (WP2)	At least 12 activities per year involving at 1000 people.	Number and scope of activities per year	247 one-on-one meetings with tenants as part of the Social Renovation program (T3.3) 15 people in the human capital for construction sector as part of 2 Bouw=Wouw workshops (T3.3) 82 one-on-one meetings with tenants as part of the Energy Coaching program (T3.3)
3) Smartness	Design for high energy efficiency and make use of smart home services and controls, smart building components, and smart but simple systems for user interaction/ involvement (WP4-7).	Average impact score more than 70%.	Smart Readiness Indicator (SRI)	Reported in WP7 and in 2024 integrated in D4.3
4) Energy flexibility and security of supply	Design for high energy efficiency and make use of smart home services and controls, smart building components, and smart but simple systems for user interaction/involvement. Exchange of data between buildings, energy systems and people through community digital hub. Automated algorithms for weather and performance forecasting. (WP4-7)	At least 30% improvement compared to ex-ante performance	Daily net load profile in kW; utilisation factor in %, share of self-consumption / self-generation in %.	Reported in WP7 and in 2024 integrated in D4.3
5) Affordability and alleviation of energy poverty	ARV will demonstrate scalable solutions for renovation of social housing and public buildings that will give significant reductions in construction and operation costs, while provide good indoor climate and architectural qualities (WPs 2-9).	30% reduction in construction costs and at least 50% reduction in energy/power bills.	Reduction in Euro compared to current standards.	328 euro/year/apartment reduction for tenants, after substraction of EPV-fee. This is a 28% reduction. Based on LCC calculations D8.5.

6) Job creation, innovation capacity and industrial competitiveness	All stakeholders: reinforce or establish new collaborations in the value chain of CPCC, PPPs, increased understanding of customer needs (all WPs).	At least 20% increase in value creation of ARV partners and the creation of about 12-20 000 new jobs per year[2] (based on the investment of the ARV developers 2022-2024).	Revenue in Euros, # of jobs created	
	Increased health and well-being of citizens (WP2-8), value creation from reduced energy and power use (WP3,4,5), use of on-site RES and storage + EVs (WP6), and increased flexibility (WP7, 9), human capital program for job creation (WP3), standardization and industry 4.0 processes (WP5),			
7) Standards and regulations	ARV will contribute to revised building and energy regulations, in particular on benchmarks and documentation needs for GHG accounting and for revised energy/power performance codes, and to the SRI. For financing ARV will contribute to a new standard for green digital bonds (green STOs).	Provide input to national and EU level through at least 20 meetings and publications	# of publications and meetings with regulation bodies	In the first reporting period M1-M18 no publications and meetings with regulation bodies were held as part of the ARV project in the Utrecht cluster.
8) Knowledge creation	ARV will contribute to knowledge creation among all stakeholders in the consortium, to the group of associated innovation clusters, to the occupants in the demo projects through Living Labs (WP3), Energy Communities (WP2), and to a wider audience through communication and dissemination activities (WP10)	Ref dissemination and communication plan	Number and scope of events	

9) Contribution to key EU policy goals	The renovation wave[3]: ARV will demonstrate a streamlined, efficient and replicable workflow for resource efficient renovation of social housing and cultural heritage public buildings (WP5).	133 400 m^2 of buildings renovated to nZEB standard or better	# of m^2 buildings renovated	17436 m^2 planned
	Climate targets: ARV will contribute to the targets of 50-55% reduction of GHG emission by 2030 and 90-95% by 2050, by demonstrating and validating scalable CPCCs.	50% reduction in life cycle GHG emissions compared to ex-ante condition/current practice.	kg CO_2-eq/m^2 over 60 years lifetime.	D8.6 (planned). For now based on D8.5 projections.
				104%

4. BUILDING STOCK

4.1. GENERAL BUILDING STOCK

To create the necessary renovation solutions, it all starts with the identification of building typologies. The foundation of this approach lies in the research of Thijs Barkmeijer in 2017 and the follow-up research on the characteristics of the building stock.

The base research was done by the University of Applied Sciences Utrecht in collaboration with the Stroomversnelling (a non-profit organisation also called Energiesprong). It is part of the necessity of the identification of the characteristics of the building stock to identify the need for standardization and flexibility. The goal is through these characteristics to identify the amount of standardization and need for flexibility to renovate as many homes as possible to PEB with an industrial approach. To achieve this goal, ARV works on all topics that affect this. The development of the high-rise table (Figure 4) has focused on the renovation of high-rise buildings in the Netherlands. This research focuses on one of the challenges in high-rise buildings. To this end, an answer was sought to the question: "What are the properties (technical, aesthetic, building physics) of the high-rise building systems that influence scaling up to PEB and what can be done with current solutions to accelerate this transition?" To answer this question, several research methods were applied.
Existing high-rise building systems from the period 1945-1975 were mapped. In total, there are 89 building systems, many of which were developed for low-rise buildings. There are 11 dominant building systems and have an 88% market share, about 211,000 houses, in high-rise system construction. More than half of this number is in the provinces North Holland and South Holland. This is where scale-up opportunities are greatest.

After systematic research based on 11 post war building systems, these eleven building systems were built using different construction methods and therefore show a number of differences. All properties have been incorporated into system documents for each building system. All data was validated by fieldwork, among other methods. In the fieldwork, 125 buildings were analysed. This showed that the data is correct. In addition to the typical features, implementation variants were observed within the building systems in the building sections' end façade, longitudinal façade, and exterior space. These performance variants are system-independent and occur in all buildings regardless of the building system. Each of these building sections is implemented in only four variants.

The differences in execution within the building systems has meant that grouping based on nodes does not work because the building parts are leading for the renovation. Due to the four implementation variants, each building system requires four renovation principles, namely: insulate inside, insulate outside, demolish outer wall, and demolish entire façade. The implementation variant determines the renovation principle. The grouping was therefore carried out based on the building components and their implementation variants. In this grouping, the buildings, i.e. not the building systems, are grouped into the variants of the end façade, longitudinal façade, and exterior space.

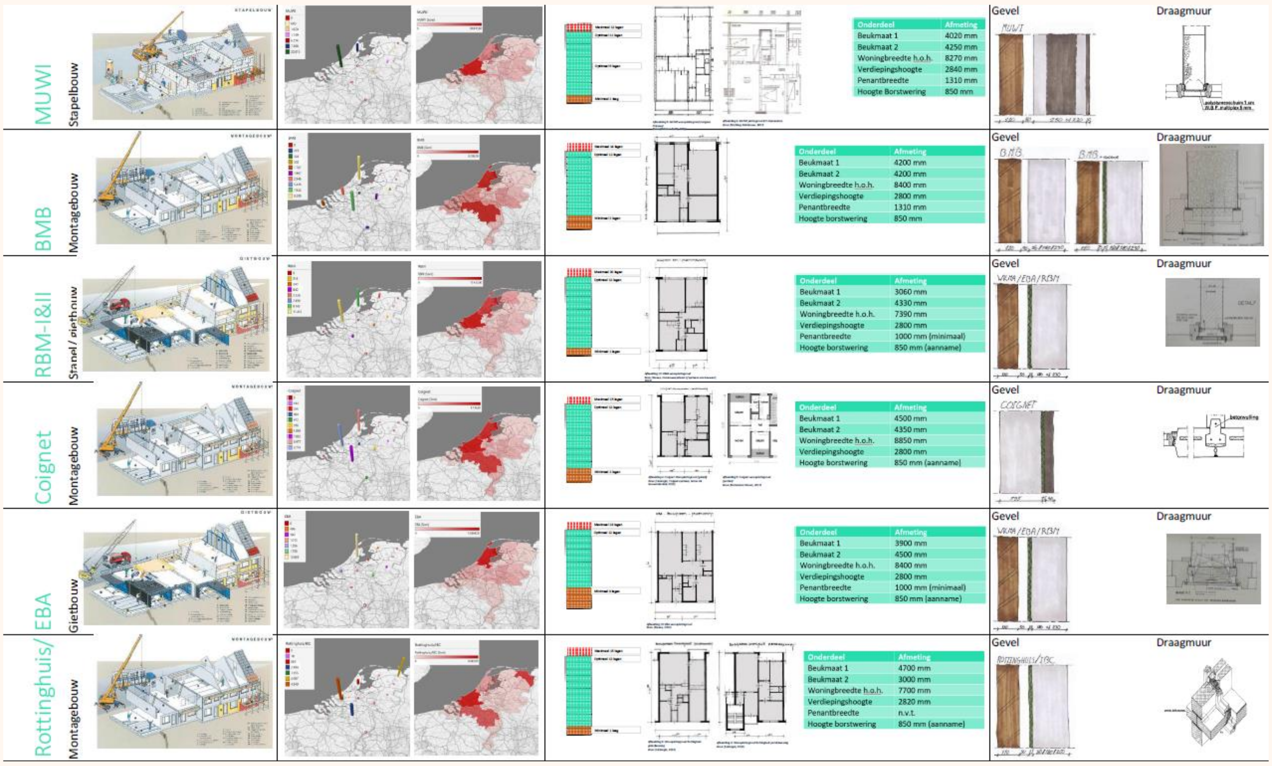

***Figure** 4. Examples of building systems of high rise apartments*

4.2. EXISTING SITUATION

The main Utrecht demo site is located at the Rooseveltlaan and Alexander de Grotelaan. These consist of four Bredero flats, each of which has 65 dwellings. The buildings are classified as porch flats. Each building consists of five five-storey porches. Each porch has thirteen flats of which four are two-room flats (41 m²) and nine are four-room flats (71 m²).
Each porch is laid out as follows:

- On the ground floor, there is one four-room flat and 13 storage rooms (**Figure** 5. Ground floorplan Bredero buildings).
- The first to fourth floors each have two four-room flats and one two-room flat (Figure 6).

The buildings are severely outdated and no longer meet sustainability requirements, making large-scale renovation inevitable.

***Figure** 5. Ground floorplan Bredero buildings*

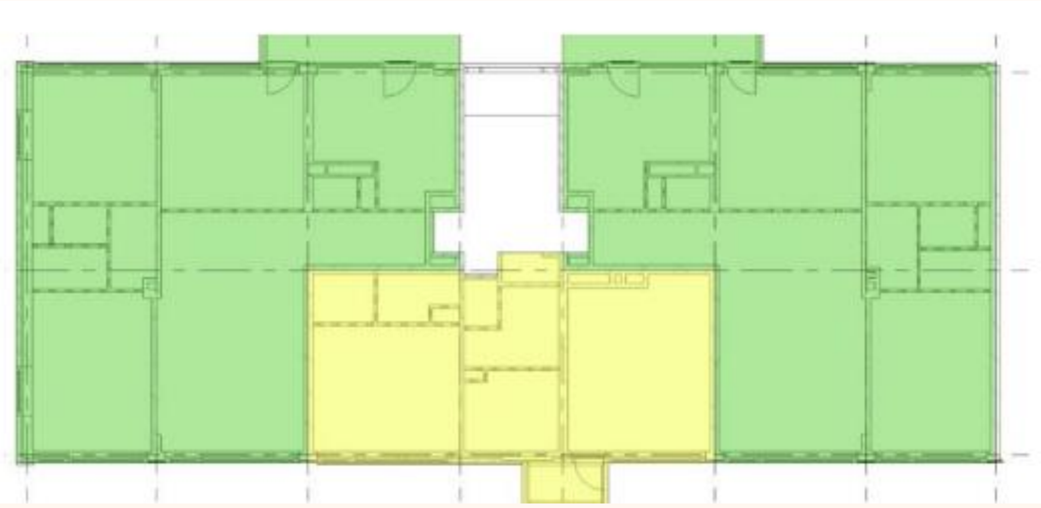

***Figure** 6. Floorplan stories Bredero buildings*

Dwelling survey

Two surveys have taken place during the engineering process, one at the Roosevelt Avenue and the other on Alexander de Grotelaan. These surveys revealed several findings regarding the condition of the houses. The installations, the window frames and the balconies of the houses are severely outdated.

- Outdated installations:

During the house surveys, it was found that the installations in both houses are severely outdated. This particularly concerns the heating installations. The heating installations are inefficient and do not meet modern energy standards.

- Poor condition of window frames:

The window frames in both the Rooseveltlaan and Alexander the Great Avenue properties are considered to be in poor condition. Signs of wood rot and peeling paint have been observed. This not only affects the aesthetics of the houses, but can also lead to structural problems, complaints of draughts and energy loss due to poor insulation.

- **-** Balcony problems:

The property on Alexander the Great avenue shows problems with the balcony. The balcony shows signs of neglect. Green deposits have accumulated, and there is an obvious problem with water drainage (Figure 7). Water does not drain from the balcony, resulting in a puddle of water more than 5 cm deep remaining on the balcony.

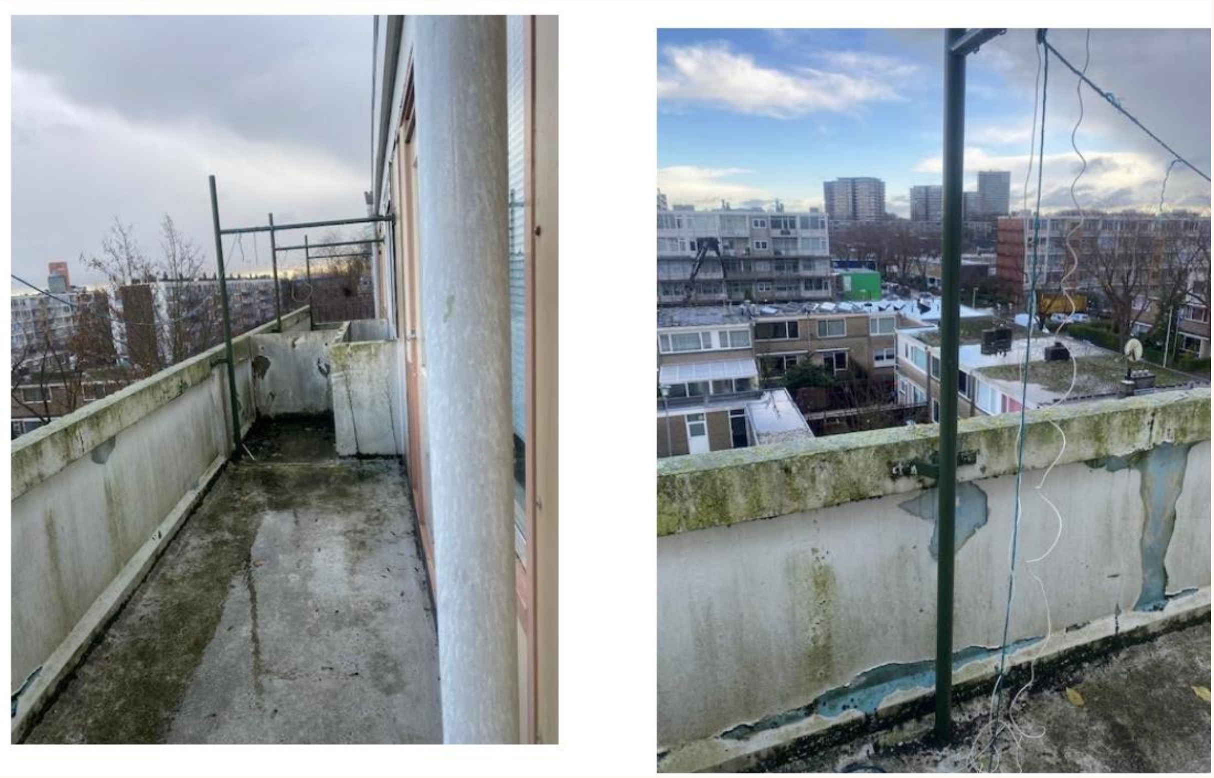

Figure 7. Balcony survey

Load bearing structure

With the aim of assessing the structural safety of the anchored masonry facades, Nebest B.V. was commissioned by Bo-Ex to carry out a facade survey.

The main findings arising from the survey are as follows:

- The masonry shows defects such as cracks that adversely affect its sustainable functioning. In addition, the structural integrity of the masonry and the quality of the pointing is inadequate. Also, no cavity insulation has been applied.
- The cavity construction is assessed as unsafe. Insufficient cavity anchors have been applied, except for the anchors on the front facades.
- The concrete elements in the facades are damaged, but these damages are not structural in nature.

A number of items emerged from this survey with high urgency. Such as the addition of cavity wall anchors. In the current design the renovation concept, the anchors of the new facade will replace the cavity wall anchors.

HVAC

Heating and hot water supply are controlled by a condensing boiler. In the current situation, cooking is done using gas. The radiators are mounted under the window frame in the parapet. In addition, there is a tilt-up window in the window frame with an integrated ventilation grille. In addition, central extraction has been installed in the bathroom, kitchen and toilet as shown in Figure 9 (highlighted in green). The old chimneys have already been bricked up and are indicated in blue. Finally, the meter boxes are marked in yellow.

Figure 8. Current central heating boiler

***Figure** 9. Location of shafts (green), air extraction (blue) and meter boxes (yellow)*

5. DESIGN CONCEPTS

Mex Architects has made a design for Rooseveltlaan and Alexander de Grotelaan. This clearly shows how the Brederoflats will undergo aesthetic improvements. The architects' design vision is described as follows: "As architects, we believe that when carrying out major maintenance, the quality of the original design and principles of a building and neighbourhood should be respected. For the residential buildings on Rooseveltlaan, this means that the brickwork facades and the rhythm of the window openings are a recognisable theme. A building that is characteristic of the period in which it was built. A building that fits and matches the look and feel of the neighbourhood. The new smart façade is placed in front of the existing façades. We deliberately chose to retain the appearance of a masonry volume. The low window sills in the windows overlooking the canal contribute to the residents' living comfort and will also be retained."

The technology in the smart façade is accessible from the outside. By executing the parapets in upright and tiled 'masonry' (mineral stone strips), the access hatches (clad in 'masonry') can be executed invisibly.

Figure 10. *Visuals front of building MEX architects B.V.*

Figure 11. *Visuals back of a renovated Bredero building by MEX architects B.V.*

The existing continuous facade openings are retained in this design. Part of the frame facade is sealed to reduce heating in the house. The sealed section is then fitted in a PV panel. Behind the PV panel is part of the smart technology. This thus becomes a win-win. Less heating in the house, energy generation and space in the facade for technology.
The rhythm of window, PV panel and penant (at the location of the load-bearing walls) gives the building a clear structure inspired by the architectural stylistic features of the 1960s. The contemporary application of masonry bonding and the chosen colour scheme also make it a contemporary building.
The residential buildings on Roosevelt Avenue will have an appearance that fits in with the neighbourhood.

Figure 12. *Visuals of Bredero buildings by MEX architects B.V.*

6. RETROFIT MODULES

6.1. GENERAL

Building blocks
Step-by-step sustainability towards energy-neutral apartment buildings can be divided into several building blocks. Together, these building blocks form a comprehensive solution for energy-efficient apartment buildings. Depending on the customer's ambition level, one or more building blocks can be chosen. These are the following six building blocks:

- Alpha module (Super structure for PV panels on roofs)
- Bravo module (Energy module on top of buildings)
- Charlie module (Ventilation and heating delivery system with BIPV)
- Delta module (Insulation panel for the façade where the Charly is integrated)
- Echo module (Balcony system with possible integrated PV panels)
- Foxtrot module (Home Energy Management System, HEMS)

The building blocks are integrally applicable and are factory-assembled with the consortium. The building blocks are suitable for any type of source system, both for low-temperature heating such as heat pumps, as well as for district heating. All building blocks then arrive at the construction site prefabricated and assembled at high speed. As a result, residents experience as little inconvenience as possible. In addition, this method of construction ensures that the energy transition is scalable. The Henriettedreef in Overvecht is the first (apartment) building where all building blocks have been realised.

From the inside out
The name Inside Out comes from the idea of renovating from the inside out. This means that as many existing installations as possible are taken from the inside of the house and integrated into the building blocks at the outside. For example, the Facade module can insulate, ventilate, heat and generate energy. By linking all these properties, all installations are immediately connected when the façade is installed. This increases construction speed, and the house remains habitable throughout the renovation. By renovating according to this philosophy, Inside Out can fulfil its mission: to make the energy transition scalable and affordable. In the core of this is making comfortable, affordable and self-sufficient multi-family housing.

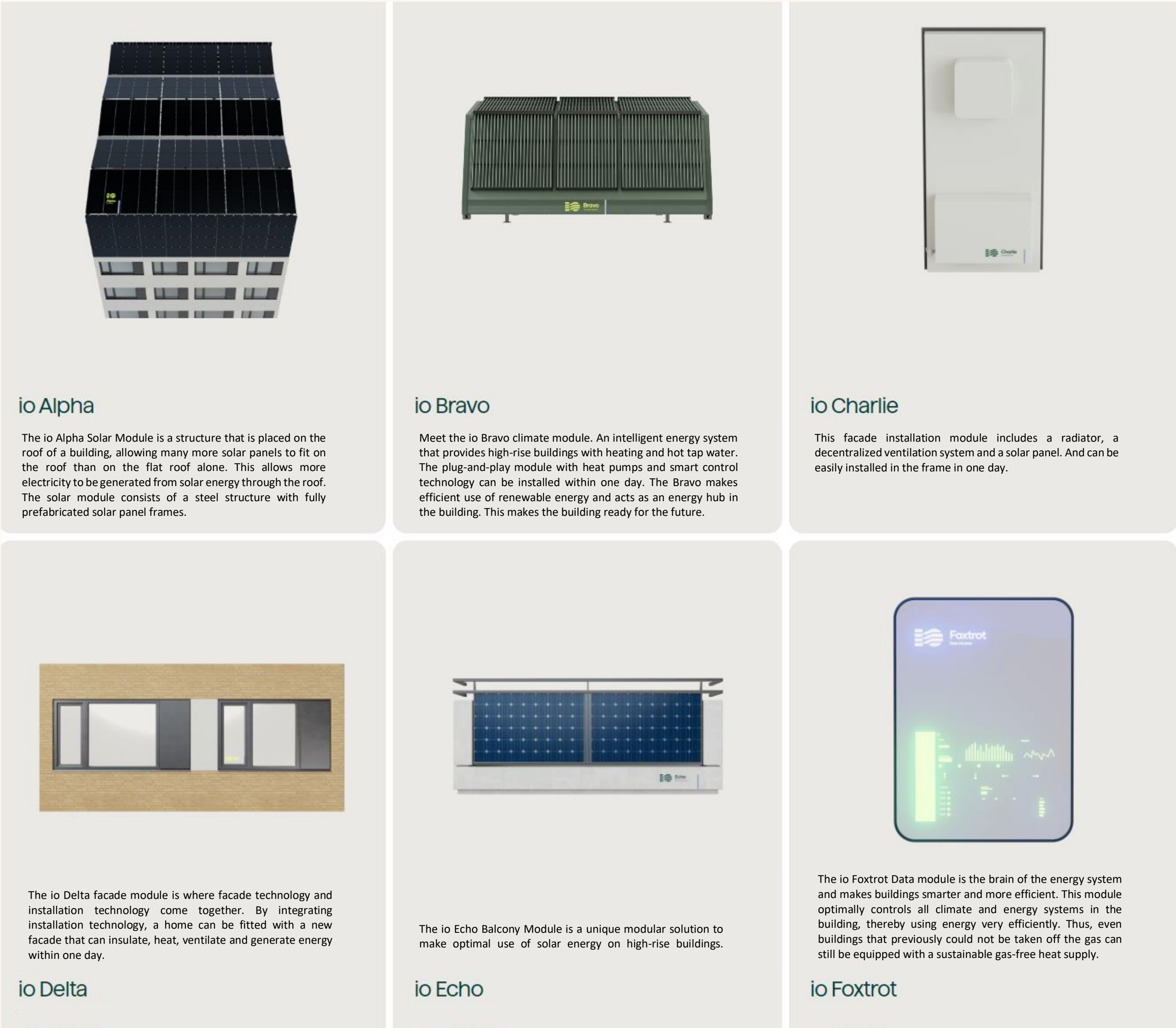

***Figure** 13. Overview modules Inside Out 2023*

6.2. A NEW COAT (DELTA)

The first step focuses on improving the quality of the building facade. The building will be given a new coat to minimise heat demand and improve comfort. The measures can achieve a label jump from energy label G to A+.

Renovation work

As the first part of the envelope renovation, the Façade module is installed. The façade module consists of a number of components such as an LTV convector suitable for heating and cooling, decentralised CO_2 ventilation system with built-in heat exchanger in the living room. Furthermore, the south façade is equipped with solar screens to prevent overheating of the house. The Façade Module will be attached to the existing external cavity wall. The existing parapet can be retained, reducing demolition and asbestos costs and minimising inconvenience. The plastic window frames with triple glazing are also part of the Facade Module, which is attached to the existing structure as a prefabricated element. With the installation of the façade module, the façades of the Bredero flats will have a Rc value of 6 m^2K/W.

The second part of the shell renovation involves improving the roof. Thus, the roof is insulated, waterproofed with circular roofing and prepared for the installation of the Step 2 Climate module. With this renovation, the roof will have an average Rc value of 8 m^2K/W.

With the renovation of the envelope, the buildings meet all the performances set by the central government and as much as possible the KPI's of the ARV Project as shown in the KPI section of this report.

Delta is therefore an innovative prefabricated facade developed in collaboration with RC Panels. This facade offers an integrated solution to house various installations, such as central heating pipes, electrical cables and PV cables. This leads to significantly reduced work in the houses and simplifies the transport of central heating water to the facades of the houses, where heat emission takes place.
The Delta has a high thermal insulation capacity, with an Rc value of 6–7 m^2K/W and good airtightness. This ensures that the facade plays an important role in achieving a comfortable and energy-efficient indoor environment.
In terms of finishing, the Delta offers versatility and aesthetic flexibility. It can be finished in various ways, including with mineral stone strips or stucco.
The Delta will be extensively tested through a test rig on the roof of the University of Applied Sciences Utrecht where a replica airframe of the current situation is simulated (**Figure** 14). Several Delta modules are placed on this shell, integrating several Charlie modules (**Figure** 14). The main purpose of this test is to evaluate the construction method and speed. Moreover, all complex installation engineering details are put into practice. This identifies all possible challenges, allowing any risks to be managed. Thus, any obstacles during actual implementation can be minimised.

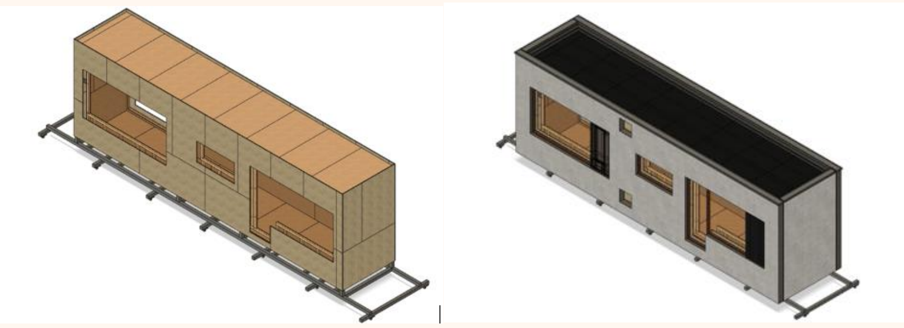

***Figure** 14. Test setting simulated existing building and test setting renovated situation*

The interface was developed to make the process of mounting the panels as short as possible and up to standard quality. Below is shown a mock-up of the Plug&Play connection of the distribution of warmth towards the Charly (Delivery system). In figure 15 there is a collage of the test environment built at the University of Applied Sciences Utrecht:

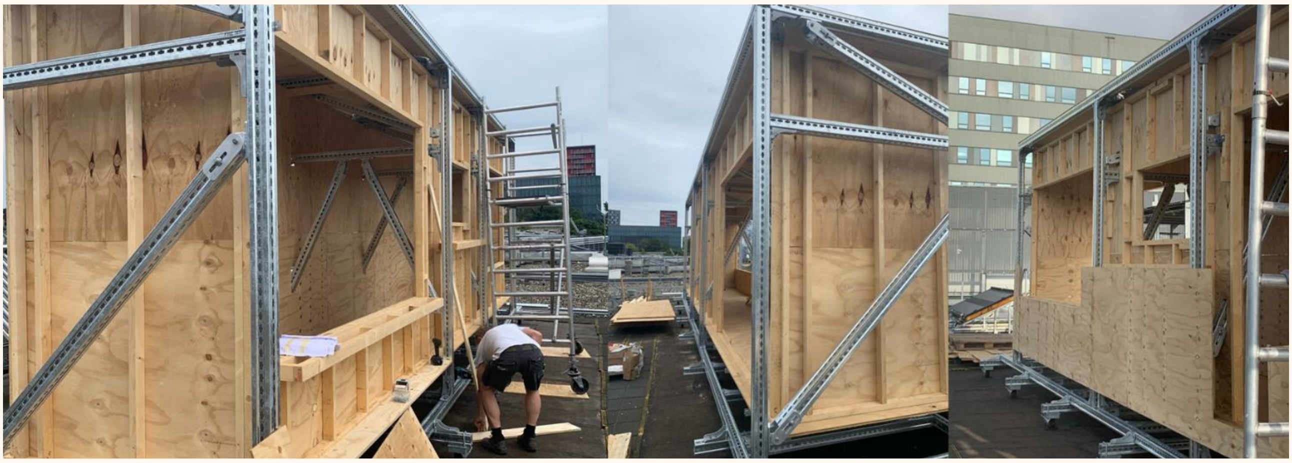

***Figure** 15 Pictures of the main structure for testing integrated facades and its connections*

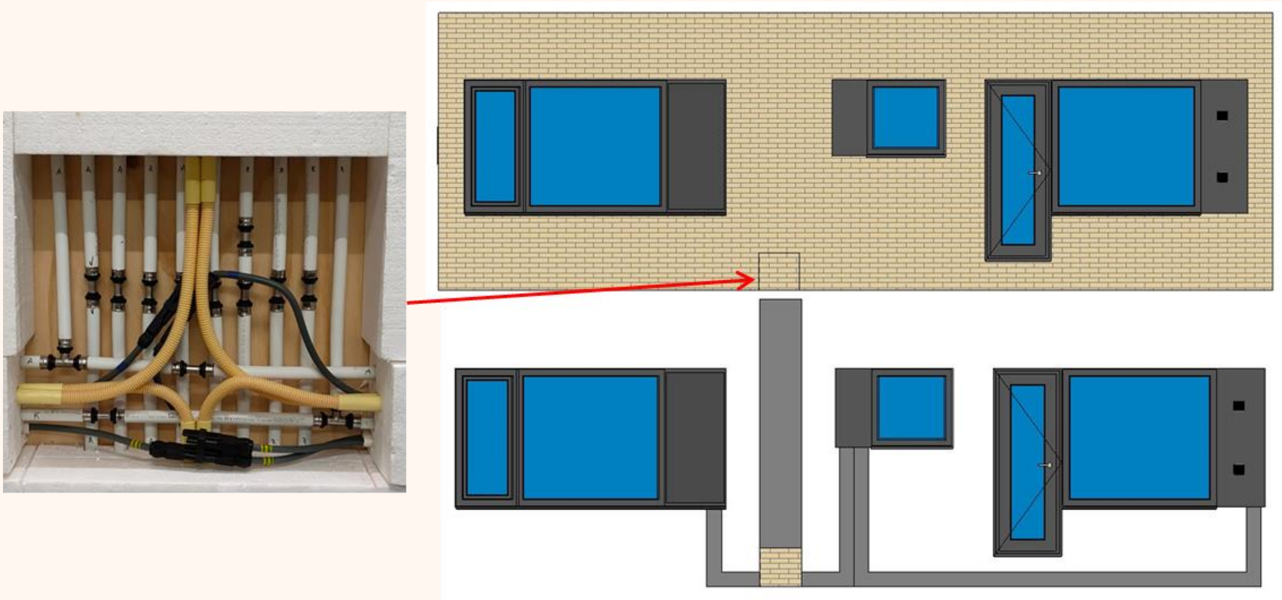

Figure 16. Plug&Play connection between facade panels

Residents' impact

The integrated Facade module is attached to the existing facade like a new coat. The existing window frames are then removed, after which new plastic window frames are replaced. Each house will have a new facade within one week and will remain habitable for residents at all times. During the roof renovation, residents will experience minimal inconvenience. Roof works will take between 25 and 40 days. Maintenance work will be carried out within ten days.

Figure 17. Presentation 3D detail of the facade

6.3. CLIMATE MODULE (BRAVO)

The starting point of step 2 is to realise a gas-free heating source. To this end, Inside Out has developed the all-electric Climate module. The Climate module is a sustainable alternative to district heating where affordability can be controlled for tenants and the price of energy is not linked to the price of gas. This can be seen at Henriettedreef. Here, residents pay the same price for energy as before the energy crisis. The modular Climate module can be scaled up and down in its capacity and heating temperature. This makes the Climate module also applicable for flats where there is less budget available for minimising heat demand.

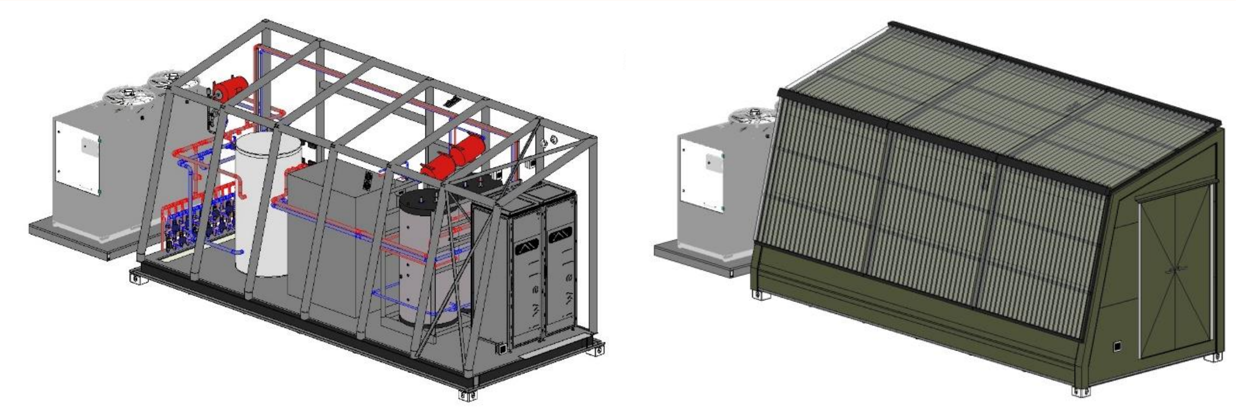

***Figure** 18. Preliminary design of the BRAVO module*

Renovation work

Each portico will be equipped with one Climate Module. The Climate Module includes a solar boiler, buffer tank, (air-water) heat pumps and electric boilers. The solar boiler is a system that uses thermal energy from the sun to heat hot water and central heating water. Heat pumps heat water by extracting heat from the air. The hot water from the heat pumps can be used for both the domestic hot water system and the central heating system. In cold winter months, the heat pumps cannot always extract enough heat from the air, so the electric boilers can step in. All the hot water preheated by the various systems is stored in the buffer tank. Circulation pipes run from the buffer tank to the homes for hot water. A smart boiler then hangs in each dwelling to raise the water to 60 °C.

The envelope renovation at passing station 1 significantly reduces the heat demand per dwelling. This makes the dwelling suitable for low-temperature heating. Research through calculations showed that Bredero flats can already be heated with a supply temperature of 35- 40 °C at an outside temperature of -10 °C.

A major advantage of the Climate module is that it can make use of thermal heat in summer, significantly reducing energy consumption for domestic hot water. In addition, the design of the Climate module allows for thermal buffering. This also makes the Climate module suitable when the energy-saving scheme is phased out and energy buffering becomes more advantageous.

Figure 19, shows the principle diagram of the Bravo designed for Roosevelt Avenue. In it, 4 heat pumps in combination with solar collectors are used to provide the homes with heat, both for heating and hot water. Figure 4 visualises the Bravo, which will be installed on the roof.

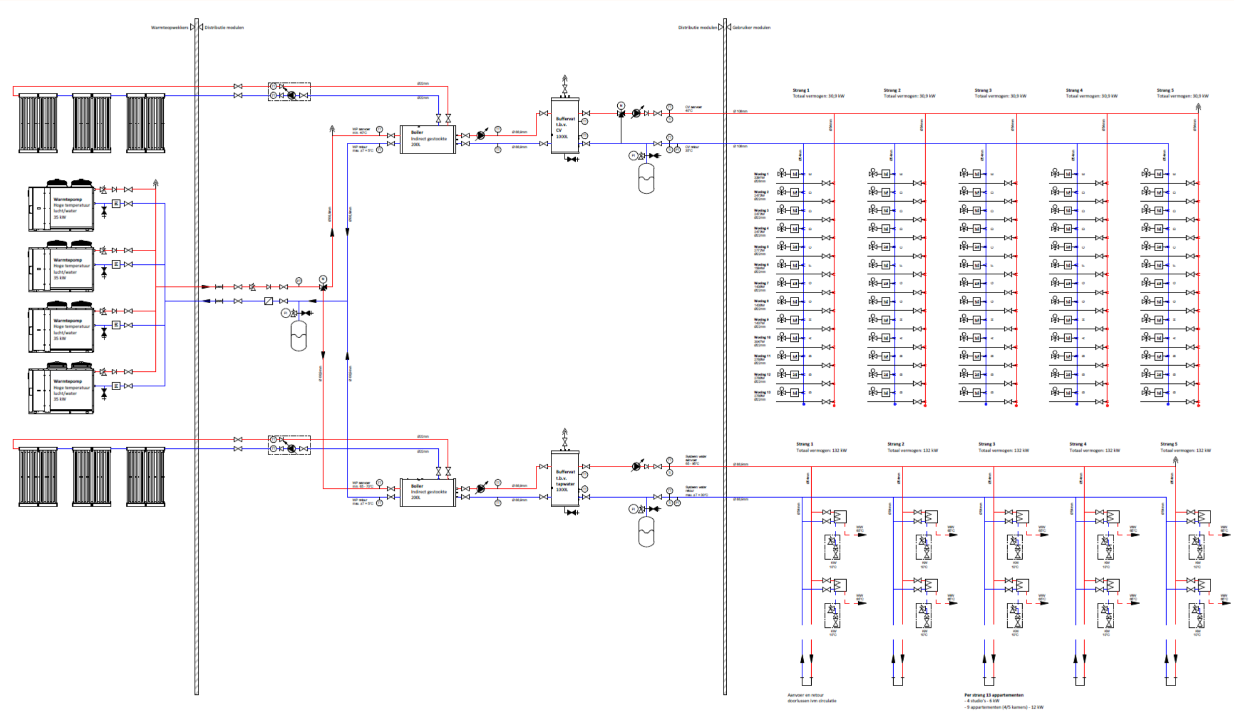

***Figure** 19. Schematic representation of the preliminary design BRAVO module*

Residents' impact

After the Climate Module is lifted (prefabricated and all) onto the roof, the electricity and water pipes are connected from the central supply as a power supply for the Climate Module. Next, the Climate Module is connected to the infrastructure in the roof. After that, the facades can be connected and can heat immediately after being connected. For the new domestic hot water system, a new boiler will be installed in the closet space of the house. A circulation pipe will be installed in the porch. The circulation pipe feeds hot water to the individual boilers.
The installation of the Climate module will therefore provide minimal inconvenience, as little work is done in the homes themselves. Inside Out can install the Climate module in a few days.

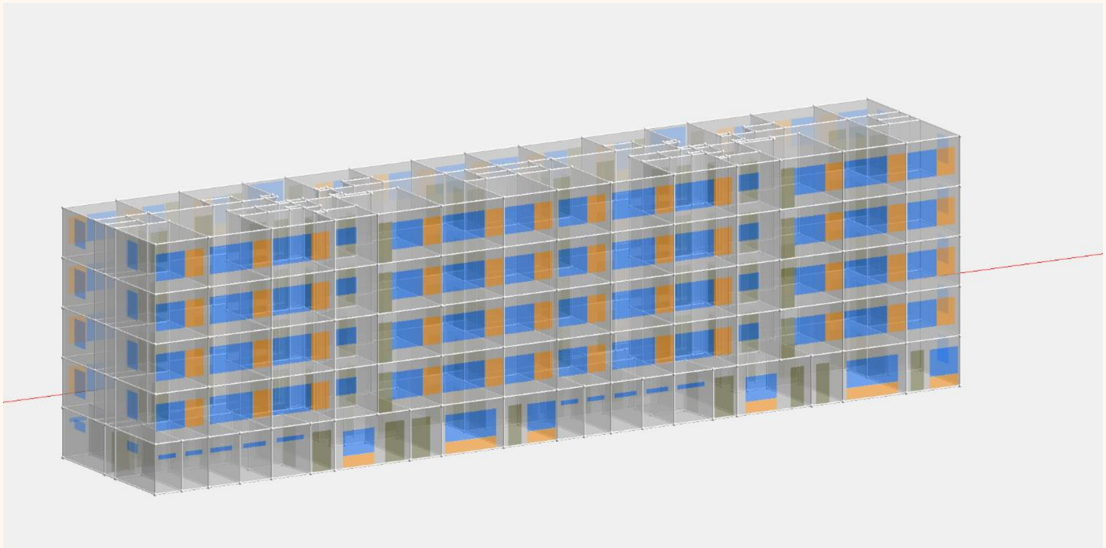

***Figure 20.** Energy simulation in VABI elements*

6.4. INTEGRATED DELIVERY SYSTEM (CHARLIE)

Inside Out Technologies and the partners have developed an installation module called Charlie (Figure 21). Charlie is a facade component that can both release and generate heat, as well as provide ventilation. The Charlie module is installed in the window frame and consists of four sub-modules:

1. The frame: this is the insulating part to which the other components are attached.
2. The convector: this is a low-temperature convector.
3. The ventilation unit: this draws in outside air and can also circulate (heating is an optional function).
4. BIPV panel: for electricity generation.

***Figure** 21. Placement Charlie in climate chamber*

Charlie's frame provides airtightness, thermal insulation and soundproofing. The frame features an insulation layer with cut-outs for the radiator's pipes and the PV panel's cables. Moreover, the resident can operate the convector itself in the same way as a traditional radiator, using a turning knob. Also visible on the inside is the CO_2-controlled ventilation unit, which ensures constant air quality within the living space. As an option, the installation components can be finished on the inside to achieve a more aesthetically pleasing result.

Validation

The operation of the Charlie was simulated in the climate chamber of Utrecht University of Applied Sciences. The climate chamber consists of two separate rooms, a large and a small room, separated by a reconstructed facade. These two spaces can be heated or cooled independently of each other, which provided an opportunity to simulate the conditions of a flat. The Charlie is fixed in the reconstructed facade, with the radiator located in the larger of the two spaces, which then acts as a living space.
Figure 18 shows a schematic top view of the climate chamber. The large room has a dimension of about 5.9 m by 5 m and the small room has a dimension of 2.9 m by 5 m, totalling 2.7 m in height. The Charlie hangs 1.2 m from the left wall. There are squares in the figure, these are the grilles that are in the ceiling and are used for extraction. When they are not used, plugs were placed on the grilles so that they are airtight. Extraction is achieved by a Duco ventilation box. This ventilation unit has 3 different settings, but only the lowest and the highest will be used. In order to keep the difference in results as clear as possible. The lowest setting of the Duco is 90 m^3/h and the highest 300 m^3/h.

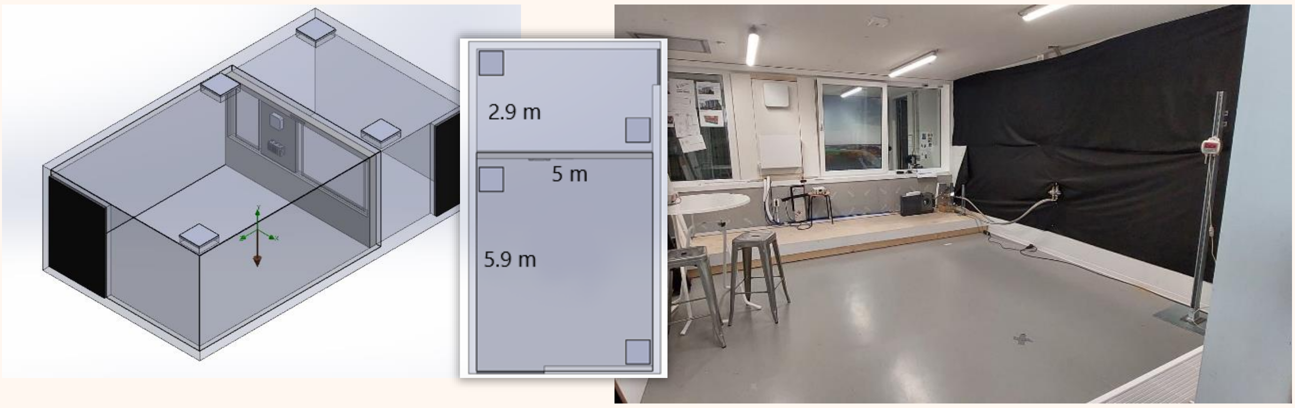

***Figure 22.** Schematic view of climate chamber with picture of test setup Charly*

For the simulation, the climate chamber was recreated in SolidWorks, see Figure 23, which includes the grilles in the ceiling of the model, the doors are included separately and the Charlie is also drawn in the model. The dimensions of the Charlie are the same as the reality on Roosevelt Avenue.

Conclusion

This research successfully laid the foundations for developing a CFD simulation of the Charlie in relation to the renovation at Rooseveltlaan. Paying attention to both the physical aspects of the installation and the relevant physics principles and simulation parameters, the necessary building blocks were identified and evaluated for an accurate simulation.

The Charlie was accurately positioned in an existing frame of the renovation façade. The CFD simulation will model this installation in a realistic environment, taking into account physical principles such as the Coandă effect, Bernoulli's principle, vortex flows and buoyancy.

Within SolidWorks Flow Simulations, parameters including Computational Domain, Boundary Conditions, Fans, Sources, Goals and Meshes were thoroughly investigated in the context of the simulation. A detailed 3D model of the climate chamber was also developed, acting as an accurate physical environment in which the Charlie was simulated.

The research in the climate chamber at the Utrecht University of Applied Sciences has shown that the operation of the Charlie is expected to meet the specified requirements and performance criteria.

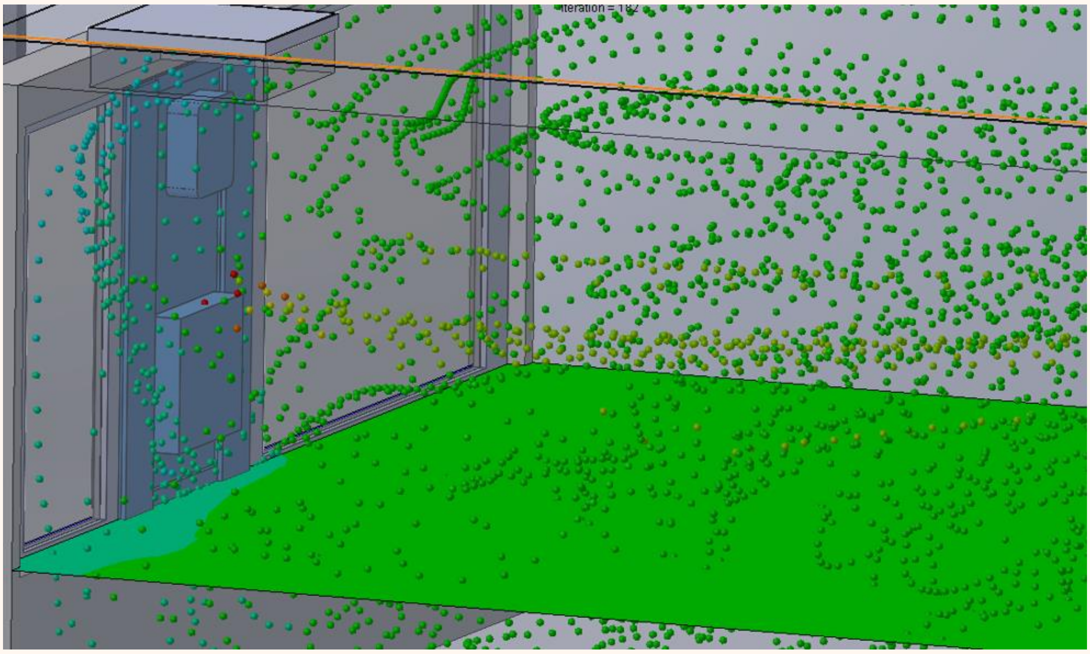

Figure 23. *CFD model with air flows in CFD simulation of Charly*

6.5. BALCONY – OUTDOOR LIVING (ECHO)

The third step focuses on the balcony renovation. Façade and cavity anchor surveys carried out by Nebest revealed that the balconies are technically in poor condition and cause thermal bridges. Residents themselves also noticed this. One resident writes the following about this:
"Very badly affected by mould in bedroom, combined with poor ventilation we feel it is unsafe for our baby. I suffer very badly from dampness and often have to collect water in buckets 2 times a day and take it away. Balcony is very dirty and not tidy.".
The external space of the houses is also often a point of criticism. For instance, it is repeatedly mentioned that the balconies are small and often in poor condition. Renovation is therefore inevitable.

Renovation work
Inside Out has developed a Balcony module to replace the existing balcony. For Brederoflats, Inside Out will adapt the Balcony module to accommodate a fully freestanding balcony. To install this module, the existing balcony will be removed. The original construction drawings show that the existing balcony floor plates can be easily dismantled. The brackets can then be cut off, creating a flat façade. This is ideal for even faster installation of the Facade module, guaranteeing airtightness and removing thermal bridges. A larger freestanding balcony can then be installed. This new freestanding balcony gives space to create a larger outdoor space and ensures that the outdoor space is once again fit for the next 50 years.

Impact for residents
The removal of the balconies will be integrated with the installation of the Facade module, minimising inconvenience. However, it cannot be prevented that residents will experience noise nuisance and temporarily be unable to use the outdoor space. On the other hand, residents will receive a new and larger balcony in return, increasing resident satisfaction.
The large new balcony also offers opportunities to use for the placement of temporary bathroom units. This will allow residents to stay in their homes even during the BKT renovation, reducing the need for guest houses for the renovation.

Figure 24. *3D presentation of the front façade of a renovated Bredero building*

6.6. ENERGY NEUTRALITY (ALPHA)

With the elaboration of the first three steps, the (flat) buildings have already made a big step towards sustainability. For instance, the (flat) buildings have been energetically and aesthetically improved, balconies renovated and connected to a sustainable heat source. The stopover at station 4 focuses on renewable energy generation. After passing station 4, the buildings can be characterised as energy-neutral homes. This means that as much energy is generated annually as is consumed by the residents.

Energy calculation
The energy consumption of a home can be divided into four categories:

- Heating;
- Hot water;
- Central facilities (CVZ);
- Household energy.

The energy bundle for heating is determined with a Vabi-Elements calculation. In Vabi-Elements, the house is calculated and the expected energy consumption over the heating season is calculated. The bundle for hot water is the energy consumption required to have hot water. Here, an available amount of tap water per dwelling typology is taken into account. The domestic energy consumption is about the power needed for in the house. This is power for the washing machine, cooking and lighting. Finally, a bundle is included for the energy costs of the central facilities. This is for lighting in the stairwells, entrances and storerooms.
When calculating the bundles, the applicable EPV rules were taken into account. According to the EPV rules, a home must generate at least as much energy sustainably as is needed for heating, hot water (15 kWh/m^2.year), auxiliary energy and domestic use (26 kWh/m^2.year). This is subject to a minimum of 1800 kWh and a maximum of 2600 kWh. By complying with the EPV rules, Bo-Ex can claim a maximum allowance of €1.51 per m^2 per month.

Renewable Energy
To generate its total energy needs, Inside Out is installing 900 PV panels. These panels will be integrated into building elements at the end and longitudinal facades. Together with Mex Architects, a design was made in which standard full-black solar panels are incorporated next to the frame surface.
"The rhythm of window, PV panel and pennant gives the building a clear structure inspired by the architecture characteristic of the 1960s. The contemporary application of the masonry bond and the chosen colour scheme also make it a building of today" - Frank Stedehouder, Mex Architects
The roof can be fitted with PV frames. Figure shows a representation of the PV design on the roof. There will be a raised roof arrangement to meet the energy requirements.

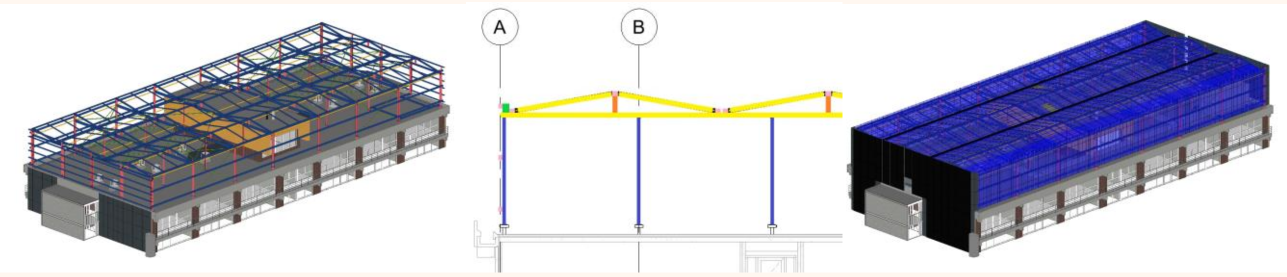

Figure 25. *REVIT BIM model of the ALPHA*

Opportunities
The EPV states that a minimum of 23 kWh/m^2 must be generated. A minimum of 1,800 kWh and a maximum of 2,600 kWh has been introduced per dwelling. For Henriettedreef, it was concluded at the time that EPV rules were written for single-family houses and not multi-family houses. This is reflected in the measurement results for Henriettedreef. According to the EPV rules, the studios on Henriettedreef

should generate a minimum of 1,800 kWh. The ESV was therefore created for Henriettedreef. A derivative of the EPV, but for domestic energy consumption with different calculation rules. For instance, the minimum energy to be generated is not 1,800 kWh but 1,500 kWh. This can reduce the required installed capacity of PV.
In addition, a change in the law is imminent which will make virtual balancing possible. Virtual balancing will ensure that only a few large inverters are needed, and no individual home connections need to be made. This will save costs, reduce inconvenience, and distribute power more fairly among tenants. This will prevent the greatest benefit from falling on the energy companies but on the housing association and its tenants. The law has not yet been passed, but the European-subsidised ARV project may provide a space for experimentation to explore these opportunities.

Figure 26. *Pictures of Inside Out application of the ALPHA module on roofs. (both appartement blocks)*

Impact residents
The PV panels in the facade will be pre-mounted in the facades, so residents will not experience any additional inconvenience from this. To connect the solar panels to the homes, work will take place in the meter boxes. Holes will also have to be drilled so that cables can be drawn through them. Residents may experience inconvenience from this.

6.7. SMART BUILDING (FOXTROT)

The final station focuses on monitoring and management. Inside Out's Data Module ensures that the corporation is EPV entitled. All consumption is monitored according to the applicable requirements and can be viewed by residents in the Inside Out monitoring platform. Inside Out also plans to use the platform for coaching residents and additional explanation through instructional videos in multiple languages. This will enable the next step in helping residents with their new energy-efficient home.

Management and maintenance
The monitoring data is not only used to understand residents' consumption. Inside Out also uses this data to maintain the Installations. Using the Data Module, Inside Out can intelligently control the heat pumps from a distance. This distributes running hours of the heat pumps, prevents unnecessary switching on of electrical elements and enables a higher COP. The smart control ensures better and longer life of the installations. This is reflected in the expected maintenance cycle for the installations. Monitoring data also allows maintenance to be signalled and preventive.

Optimise
Inside Out is continuously developing new and sustainable insights of our system. Through artificial intelligence and internet of things, the new insights can be incorporated into the already running installations through updates. Thus, the building becomes smarter and smarter and performs more and more efficiently. The advantages of the Data module are:

- Ensuring energetic building performance;
- EPV entitled monitoring platform;
- Resident instructions and access to instructional videos;
- Longer plant life by distributing workload;
- Continuous performance optimisation of the system;
- Inside Out system updates.

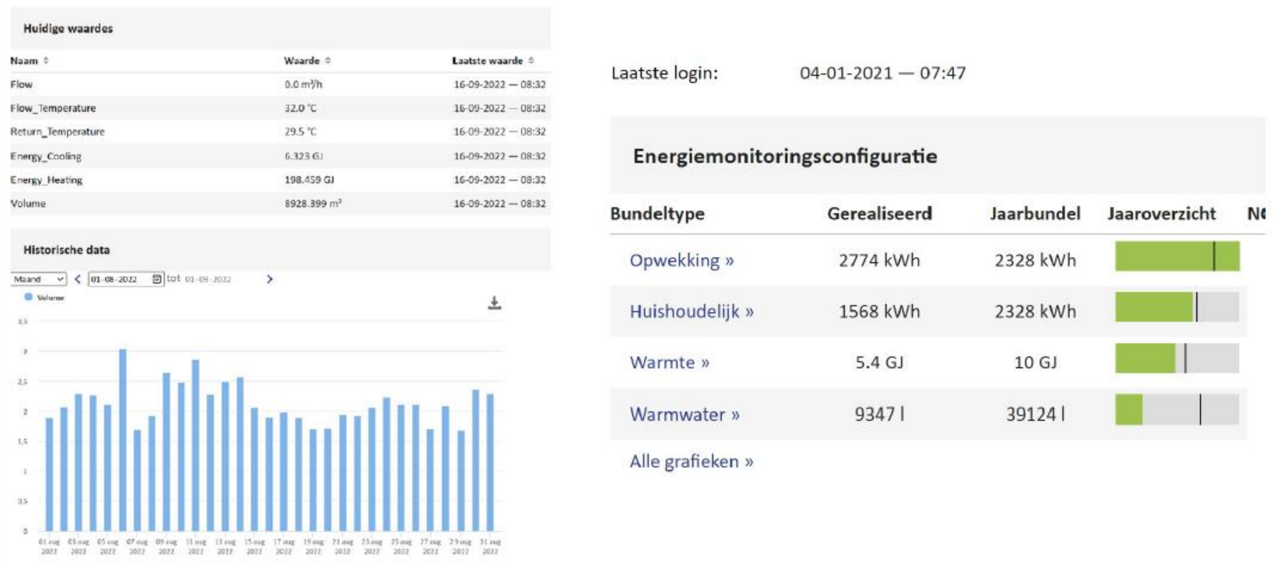

Figure 27. *Example of the current monitoring module, This picture is meant to be blury and only gives an overview of the visualisation.*

Opportunity

With the removal of net-metering in the future, it will become increasingly important to use and store power. Inside Out is working with partners to further develop the system to anticipate this. This will allow it to respond to grid congestion issues and provide a better financial business case when balancing is scaled down and eventually abolished.

7. CONFIGURED SOLUTIONS

As mentioned in the reading guidelines we are focusing on the development of a Configurator

The following shows examples of configured solutions with the Inside Out components.
Noordertogtflat has an application of the Alpha module which is being developed as a modular system and is the integration with the architecture of the building is a significant improvement.

Figure 28. *Renovation of the Noorderflat apartment building by Inside Out*

Figure 29*. Renovation of the Henriettedreef apartment building, by Inside Out*

***Figure** 30. Visuals from a renovated Bredero building by MEX architects B.V.*

BEST PRACTICES/INNOVATIONS, CHALLENGES, FUTURE UPDATES

BEST PRACTICES

The innovation that is the focus of this Deliverable is the design of the Inside Out concept and how this is to be applied to the Bredero buildings and other building typologies.

INNOVATION: BRAVO ENERGY MODULE

Inside Out development of the Bravo module was a success and ready to launch. In the ARV Project we did intensive research how this module can be modular and can be configured on different buildings and to reduce the need for a heavy upgrade of the energy net.

Figure 31 part of a linkedin post related to the developement of the Bravo energie module. (translation of dutch text is: "With making highrise more sustainable we can create a high impact")

Figure 32 Pictures of the Bravo energy module as a key piece of the puzzle to create a sustainable appartmentbuilding

DESIGN BREDEROFLATS

As a mayor result we can say that the design of the Bredroflats are finished and ready for the next phase. Mex Architects has designed a renovation as an aesthetically fitting solution on Rooseveltlaan and Alexander de Grotelaan, preserving the original design principles while modernising with a smart facade. The facade retains the appearance of masonry, concealing access hatches for technology. Sealed sections fitted with PV panels provide energy generation and space for technology, maintaining the building's structural rhythm inspired by 1960s architecture. The design blends contemporary elements with the neighbourhood's aesthetic.

***Figure** 33. Visuals from the design of the renovated Bredero building by MEX architects B.V.*

The process of creating renovation solutions for the building stock begins with identifying building typologies, based on research by Thijs Barkmeijer and subsequent studies on building stock characteristics. This research, conducted by the University of Applied Sciences Utrecht in collaboration with Stroomversnelling, aims to identify the need for standardization and flexibility to renovate homes into Positive Energy Buildings (PEB) with an industrial approach. The focus lies on high-rise buildings, with research methods including mapping existing systems and analyzing 11 dominant building systems. System documents for each system were created, validated by fieldwork, and incorporated typical features and performance variants. Due to execution differences, grouping is based on building components rather than system nodes, resulting in four renovation principles: insulate inside, insulate outside, demolish the outer wall, and demolish the entire façade, determined by implementation variants. Grouping is done based on building components and their variants.

BUILDING BLOCKS (PIECES OF THE PUZZLE)

Building blocks for sustainable apartment buildings are developed and researched by Inside Out and ARV Utrecht partners, allowing step-by-step progress towards energy positive. The six modules include Alpha (roof PV panels), Bravo (energy module), Charlie (ventilation and heating), Delta (façade insulation), Echo (balcony system), and Foxtrot (home energy management). These modules, factory-assembled and suitable for various heating systems, aim to minimize inconvenience for residents while scaling up the energy transition. The "Inside Out" approach emphasizes renovating from the inside, integrating existing installations into external modules. Notably, the Delta module provides prefabricated façades with high insulation and aesthetic versatility. The Climate module (Bravo) replaces gas heating with sustainable alternatives. The Charlie module integrates heating, ventilation, and electricity generation into the façade, tested for performance. Balcony renovation (Echo) addresses poor conditions, offering larger spaces. The Alpha module focuses on renewable energy generation, aiming for energy-neutral homes. Lastly, the Foxtrot module enables smart monitoring and management, optimizing energy usage and maintenance.

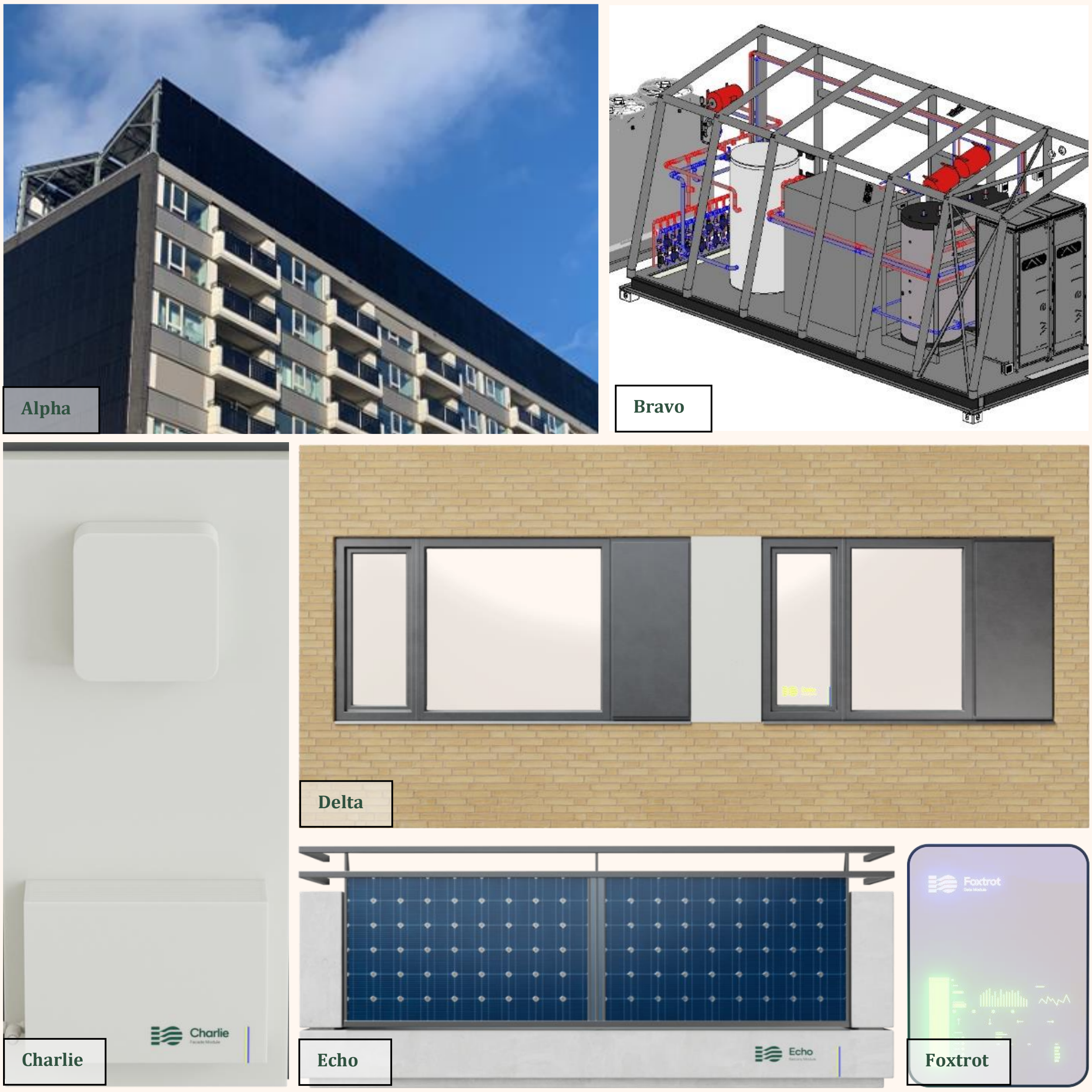

Figure 34 Overview of the Inside Out modules

CHALLENGES

The challenges in this approach are the upscaling of the modules to adress different locations with different clients with different ambitions. Also the net congestion is a really big issue. All electric solutions are not feasible in a large part of the netherland and esepecially in the Province of Utrecht. An increasingly large risk is the increase of cost for materials and higher interest rates causing higher retrofit costs for the developer than anticipated requiring additional study costs and time to prepare investment decision by social housing board. And reducing the ambitions related to the cost factor.

A major challenge for the dutch demo is that at the front end of the proposal phase, a situation was envisioned in which four Bredero flats would be renovated to a high standard within the term of ARV. While carrying out a scenario study, it turned out that the returns of all scenarios were not good, mainly due to significantly increased costs over time. This led to further development of scenarios. A choice was then made for the renovation-high-performance variant. During the development of this variant, in which choices still had to be made regarding the energy concept, it turned out that circumstances had changed so much that the Inside Out proposal was not the preferred direction. Grid congestion is a growing problem in the Netherlands and the rules regarding EPV have changed. This also caused a delay in the process of arriving at the right scenario, as well as a modified preferred variant. This insight will be part of the deliverable at the end of month 36 of the project.

FUTURE UPDATES

The end result of this design research from the Utrecht demo perspective will a design for a configurator that will be able to address the current and future situations in the Dutch context. The Modules will be further developed in multiple applicable technologies that can be adapted to the local circumstances with a flexible business case.
To this configurator will be added the knowledge of the modules of the Hemubo concept and it's performances that are applied to the Woonin renovation buildings.
Also the application is studied trough design research of the inside out concept on different types of buildings to ascertain the knowledge about the needed amount of flexibility.

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PARTNER LOGOS

WWW.GREENDEAL-ARV.EU