MORE-CONNECT
Development and advanced prefabrication of innovative, multifunctional building envelope elements for
MOdular REtrofitting and CONNECTions
(No. 633477)

D5.5 Realization of 2 Real life lab environments for in deep testing of basic modules and special features

H2020-EE-2014-1-PPP (EE-01-2014)

This project has received funding from the European Union's H2020 framework programme for research and innovation under grant agreement no 633477.
The sole responsibility for the content lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible to any use that may be made of the information contained therein.

Table of content

1 Introduction 3
2 Czech Republic 4
2.1 Preparation (making the building ready) for the mounting of elements 4
2.2 Production of elements – incl. design, characteristics of elements and testing 5
2.3 Design of HVAC engine and monitoring and control system) 5
2.4 Mounting of elements – carrying out the renovation 6
2.5 After the renovation – showing the final result 6
3 The Netherlands 7
3.1 Introduction 7
3.2 The two RLLL dwellings 9
3.3 Renovation measures and experiments 9
3.4 Production of the elements – incl. design, characteristics of elements and testing 10
3.5 Production of the 'house engines' – incl. design, characteristics and testing 12
3.6 The actual renovation and mounting on site 14
3.7 Final result 16
3.8 Special experiments 17

1 Introduction

The objective of work package 5 is the testing, pilot implementations and demonstration in real settings, as well as in industrial settings (demonstration of production), as in practice (demonstration and testing of the developed modular renovation elements both in real settings as in real life learning lab (RLLL) settings. The testing and demonstration in practice will be organised on six locations:

- Czech Republic (RLLL setting for in deep testing)
- Denmark (full real setting)
- Estonia (full real setting)
- Latvia (full real setting)
- The Netherlands (full reals setting and RLLL setting for in deep testing)
- Portugal (partial real setting)

The work package comprises 6 tasks of which this deliverable presents the part of the results of task **5.4 Construction work**, which concerns the actual renovation of real life learning lab (RLLL) buildings. This may include the partial or total removal of existing structures (facades, roofs, installations), depending on the renovation methodology (total replacement, partial replacement, addition of elements). It also contains the recording of the essential steps and evaluation of the working of the smart plug & play connectors in practice. This is in turn used for the total evaluation in task 5.6.
Task leader: Cenergia.
Other participants knowledge: RTU, TUT, Cenergia, UMinho, CVUT
Other participants industry: BJW, WEBO, LWCC, REF, Matek, ZTC, Invela, Innogie & Darkglobe.
The content of this deliverable is constituted by two parts:

1. A word part which reports the outcome of the tasks. This part hold a country by country (Czech Republic and the Netherlands) report in a standardized format following these headings:
    - Preparation (making the building ready) for the mounting of elements
    - Production of elements – incl. design, characteristics of elements and testing
    - Design of HVAC engine and monitoring and control system)
    - Mounting of elements – carrying out the renovation
    - After the renovation – showing the final result

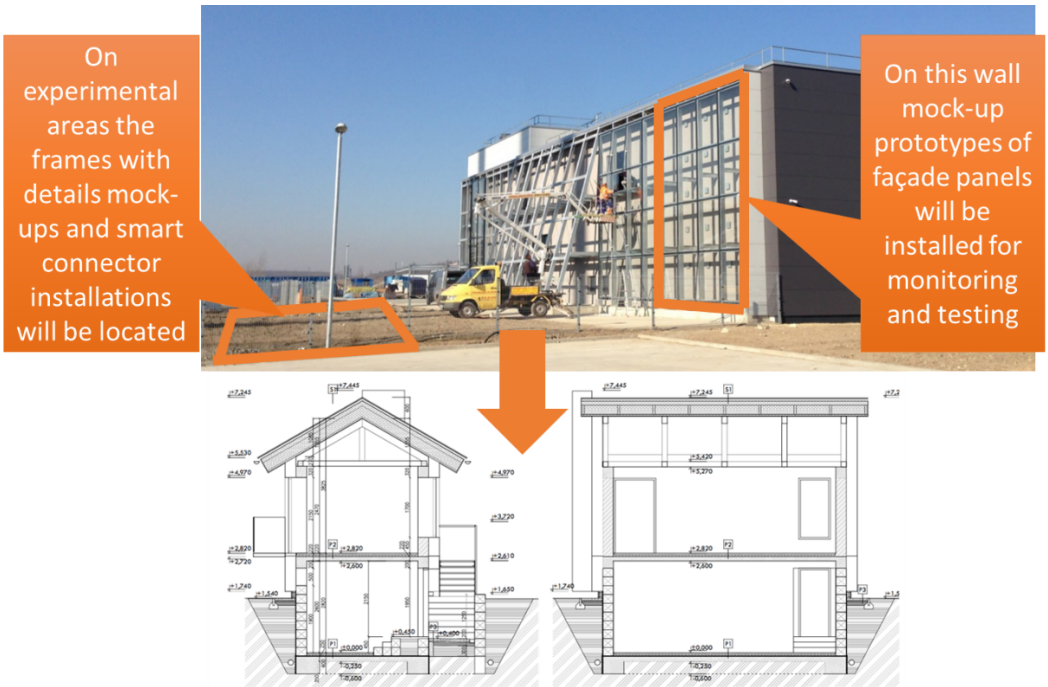
2. A PowerPoint part which can be used for the presentation of the results at international and international conferences, workshops and webinars.

This PowerPoint part can be downloaded from the project website and it is also added as an abbreviated version after the word report as an appendix.

2 Czech Republic

2.1 Preparation (making the building ready) for the mounting of elements

Originally, when we were submitting the project, we proposed that we would test the MORE-CONNECT modules on the frame of the southern façade and adjacent lot of the CVUT-UCEEB research centre (see slide 5).



Slide 5: Original placement of the RLLL – and the design of the mock-up building

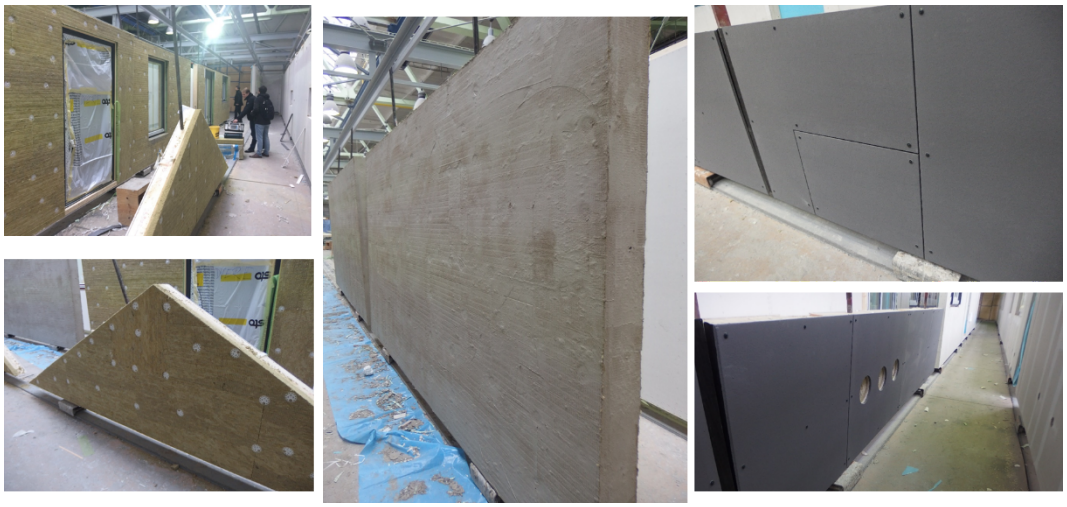
But then over the course of the project it turned out that it would be much more needed to test the 3D connections of the modules, including corner and roof joints and thus we decided to make change a change to the original plan and to build a small mock up building that would enable to test all the critical details that can be found on a typical multifamily residential building – the typology of our concern in the MORE-CONNECT project (see slides 6-9). Thankfully, CVUT-UCEEB agreed that we can place the mock up building at the experimental lot behind the research centre. We prepared sets of designs, went through the process of building permit (see selection of drawings for the building permit in slide 14), planned integration of a control system (slide 15) and prepared 3D visualisation of the construction.

Then in combination of work efforts of our technicians with subcontractors we have built the small mock up house (see slides 18-22).

Slide 22: Mock-up building

2.2 Production of elements – incl. design, characteristics of elements and testing

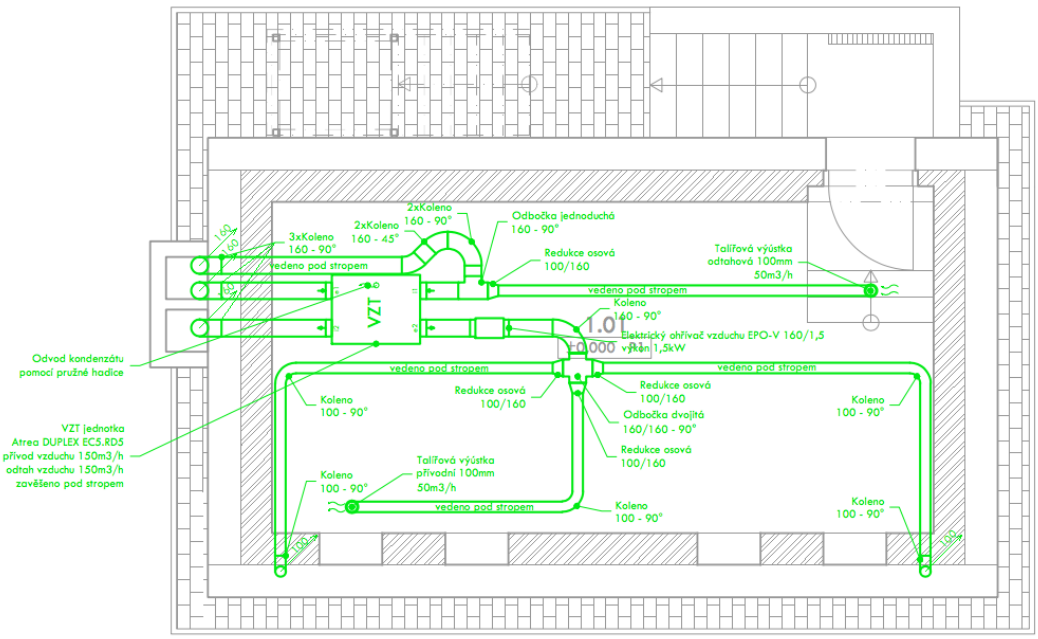
The MORE-COONECT modules were produced at the production facility of RD Rýmařov (slides 23-24) and our colleagues researchers went there to install the technologies (slides 25-26) and to make the quality control procedures.



Slide 24 – assembly of modules

2.3 Design of HVAC engine and monitoring and control system)

The design drawings and tools of the HVAC engine and control system for the mock up house are in slides 12 and 13 and the construction design drawing of making the encapsulation of the switchboxes airtight is in the slide 14.



Slide 12: Design of the HVAC engine of the building

2.4 Mounting of elements – carrying out the renovation

The construction elements were mounted in one day and the whole process is documented in slides 27-33 and also in the video available at https://www.youtube.com/watch?v=wbltRnaSpjg .
Afterwards the PV roof was finished by our colleagues (slide 34).

Slide 34 Installation of PV roof

2.5 After the renovation – showing the final result

The final result is in slide 35. The mock up building is part of an excursion route for the visitors of CVUT-UCEEB and we show them the building, which has a tags for the visitors describing the particular elements of the modular retrofitting (slides 36 and 37) and the movie from construction (slide 38).

Slide 35: The completed Czech RLLL.

3 The Netherlands

3.1 Introduction

Since 2007 in the Netherlands several deep retrofitting projects have been completed, based on an application of prefabricated, modular building envelope elements. These projects involve mostly typical Dutch terraced (single family) housing owned by social housing associations.
The majority of these experiences have been carried out in the national program 'Stroomversnelling' However, directions for improvement have been identified and possibilities for upscaling (new markets) have been suggested. Following suggestions for further improvements and developments have been given:

Technological innovations:
- Plug-and-play connection between façade module and building structure: using click-and-span connections
- Retrofitting without the application of scaffolding on-site.
- Improvement prefabrication efficiency (improvement of both the design and the production of façade elements)

Process innovation:
- Minimal hindrance, dwellings remain occupied during the project: retrofitting within a single day
- Improvement office processes: supply chain average office cost in chain is approximately 30%
- Shorten the supply chain: approximately 10% profit and marketing costs per cut out
- Smoothen the supply chain by multidisciplinary design and integrated processes
- Scale, production and purchase: this should be upscaled from 500 pc to 10,000 pc, appr. 30%; design and materials innovation for production

New markets for prefab deep renovation:
- Private housing market (homeowners)
- Apartment buildings

These were the starting point for a number of experiments, to be carried out for the renovation of two single family dwellings in Heerlen the Netherlands.
Following table summarizes the innovations to be made in these two dwellings:

Theme	State of Art	S&T deadlocks	Progress to be made
Components	Separate components necessary for deep renovation and for nZEB are available	The components are designed as standalone elements. No optimisation of production and use of materials trough integration in multi-functional building elements	Integration of several technical components, corresponding with the function of the element in multifunctional elements

Connections 1	Components, as part of renovation concepts needs specific connection materials en are often assembled on the building site	Connections now needs space, connection materials, specialised tools and time. Connections increase the chance of failures	Re-design of components and renovation concepts for industrial assembling the component for reducing the amount of materials, time and cost
Connections 2	Prefabricated concepts are on the market but connections are still made on site	Weak point in mounting process, air and water tightness of joints still problematic. No plug & Play connections for ultra fast installation	Development of smart Plug&Play connectors: - mechanical - hydraulic - air - thermal - electric - ICT
Concepts	Prefab concepts are developed for specific large scale projects, often fixed concepts offered by supply side of the market	No individual configuration of industrial produced concepts by the end-user	The functionalities of industrial produced renovation concepts and aesthetics can be configured by the end-user (like a car or kitchen)
Process 1	The market of renovation concepts is a supply-market	There is no structural influence of the end-user on the composite of the concepts.	Tools will developed tot inventory the wishes of the end-user en to translate the wishes in a programme for seceding and producing of the concept
Process 2	Geomatics, BIM, decision tools available but not integrated and less used in renovation process	Fragmentation of use of computer design tools, potential of digital tools still not fully used.	Linking of advanced geomatics, decision and configuration tools and BIM for one integrated process
Process 3	Renovation works are long-lasting weather-dependent.	Traditional renovation process	Smart connectors, exact dimensions from geomatics and BIM, careful design
Financial and environmental costs	Decisions made on basis of initial investment costs LCA occasionally taken into account, not standard	Sub-optimization of cost-effectiveness by lack of methods to determine total financial- and environmental cost optimal solutions	Use of new methodologies to determine cost optimal configurations, related to energy use/environmental costs / financial costs and responsible investments
Production process	The production of building components and HVAC components are two separated pads	Integration of the production of building- and HVAC components Energy production on site (presumption for nZEB)	Re-design and to a integrated product, industrial, cost efficient, sustainable and demand driven produced. The MORE-CONNECT 'motor' as a prefabricated multifunctional unit plug&play connected on the most suitable place (against a facade, on an attic etc.) Integrated HVAC and energy production systems

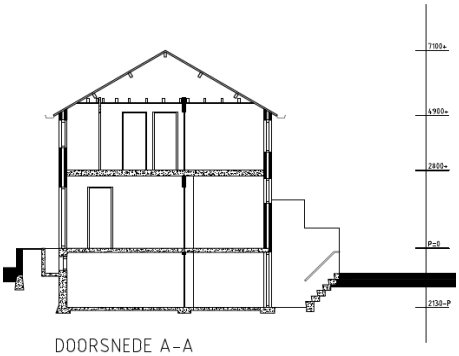
3.2 The two RLLL dwellings

The two real Life Learning Lab houses are situated in the Breitnerstraat 23 and 28 Heerlen, the Netherlands. These are terraced houses, built around 1960 en 1961, mostly in blocks of 3 to 6 houses. This building style is typical for that period in this part of the Netherlands (South Limburg).

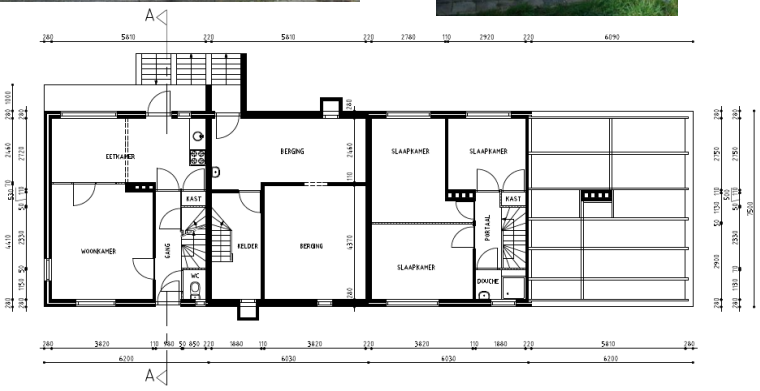
The general idea is that the building envelope totally removed and replaced by:

- Multifunctional facades (prefab): these are new types of prefab facade including decentral combined heating and ventilation units (heat recovery, CO2 controlled) for the living room and combined heating and ventilation units (convectors with fresh air supply) for the bedrooms
- Partly prefab solar roof
- Existing building services replaced by so called 'prefab engines', i.e. a prefab installation platform

The renovation of both dwellings is completed during 2015.



DOORSNEDE A-A



BEGANE GROND SOUTERRAIN VERDIEPING KAPPLAN

3.3 Renovation measures and experiments

In general following renovation measures have been applied:

- All duct work and piping/plumbing integrated in prefabricated facade and roof elements, i.e., ventilation, heating, electricity water
- Facade and roof elements have a modular composition and will be installed 'plug & play'
- Exact sizing by 3D measuring (using the advanced geomatics technologies from WP4, task 4.1)
- Casings with Low Emitting glazing
- Roofs, two types of roofs are tested:
  - Dwelling Breitnerstraat 23: timber frame elements with integrated PV
  - Dwelling Breitnerstraat 28: SCX-solar System
- A unique designed separate prefab module for the building services (box or house engine), including a heat pump, DHW supply, storage, exhaust fan, PV inverters and controls. This module is is placed in a special space, integrated in the roof. This box can be removed out of the dwelling from outside for replacements, service and repairs.
- Special features:
  - End facade dwelling Breitnerstraat 28 is equipped with solar collector wall
  - Long term measurements on personal thermal comfort and personal health reception for two personas in dwelling Breitnerstraat 23.

Details on technologies :

Dwelling23:

- BIPV for renewable electricity production. Double glass panels, cemented in special frames (100% recyclable) with traditional PV panels. DC/AC => Kaco with logsysteem
- Air/water heat pump with inverter technology for heating and DHW
- Storage tank 200l coupled with heat pump .
- Decentral Ventilation systems (DC motor) combined with decentral convectors, integrated heat recovery for living rooms; demand controlled (CO_2), integrated in the facades.
- Combined heating emission and ventilation systems by convectors ('Low H_2O' with forced convection) for low temperature heating, also integrated in the facades.

Dwelling 28:

- BIPV for renewable electricity production. Pilot project developed by SCX: DC/AC; SMA with integrated web connect.
- Water/water heat pump (closed source): heat collection by capillary tubes in the facade (Solar Collector Climate Wall)
- Heating and cooling by Climate wall direct or indirect, supported by heat pump (Roth, CTC of Vaillant)
- Demand controlled ventilation system, Renson Healthbox 2

- Emission by capillary tubes integrated in the wall (Climate Wall)

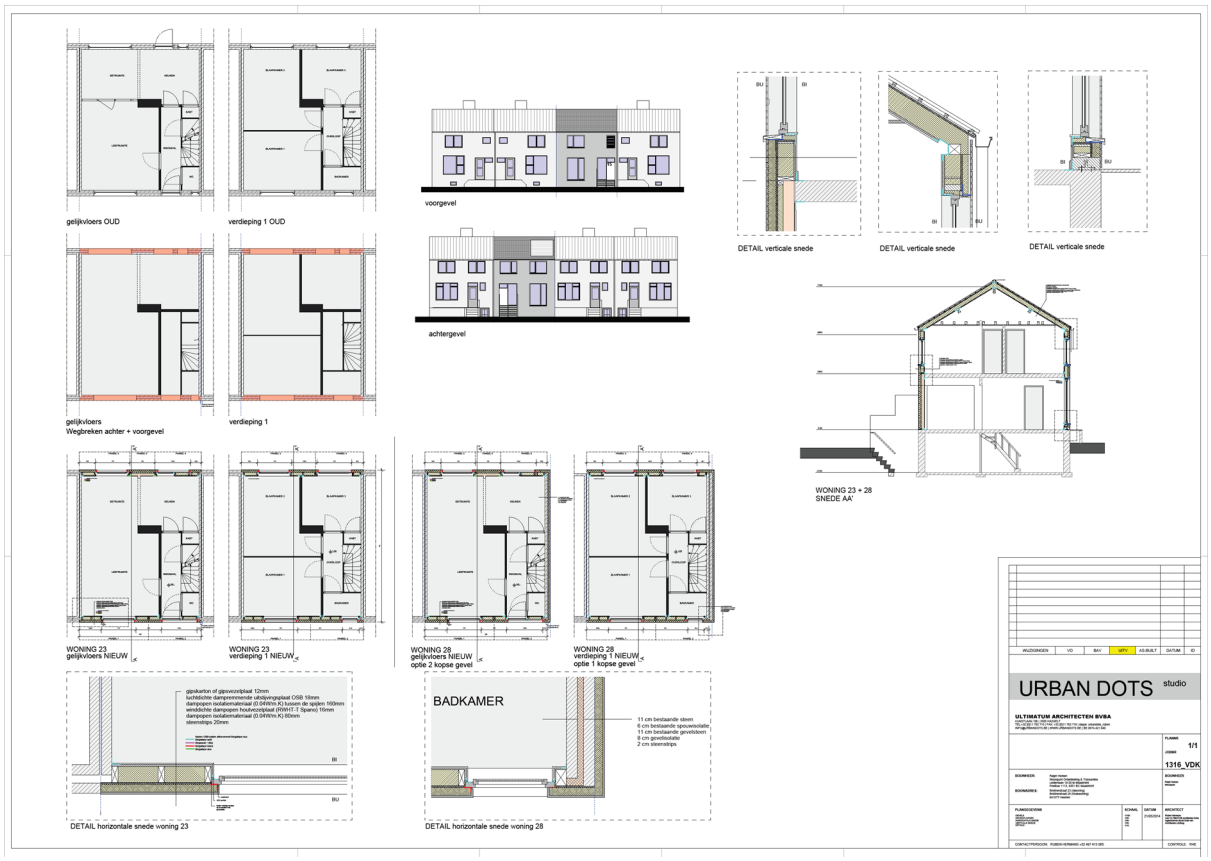
Some performance indicators:

Rc facades:	5,5 m^2K/W
Rc roofs:	6 m^2K/W
EPC value conform Dutch standards:	0.0 (= energy zero on the meter)
Yearly energy demand:	ca. 1.400 kWh
Yearly energy supply by PV: c	a 4.000 kWh
Yearly surplus of non-building bound energy:	ca 2.600 kWh

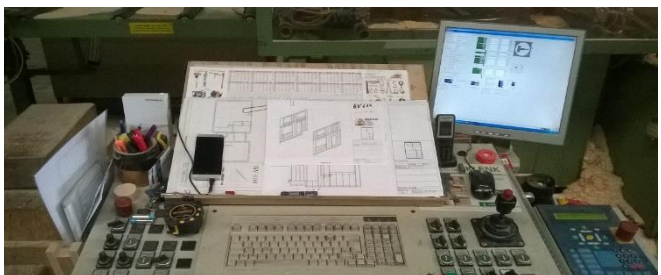
Heating generation:	air/water heat pump
Ventilation:	ground floor: local MVHR
	first floor: forced air intake by fan driven convectors
	mechanical exhaust in kitchen and service rooms

3.4 Production of the elements – incl. design, characteristics of elements and testing

For the renovation of the two RLLL houses both the facades and the roofs were totally removed. In following figure some details of the design of the new façade and roof elements including connection are given:



The basic prefab elements were manufactured at HEDACH, Bullingen, Belgium and assembled at Lambrechts, Genk, Belgium. The manufacturing of the basic elements were done in a BIM controlled automated process:



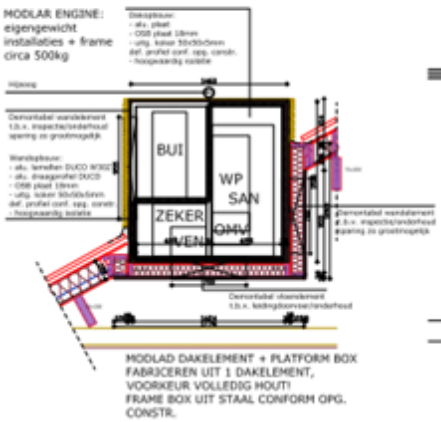
However, as these facades and roofs were still experimental types, the assembling was done manually:

Assembling of the integrated prefab facades

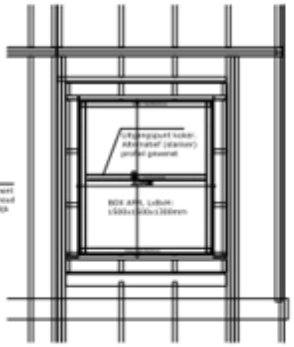
Assembling of the PV roofs

3.5 Production of the 'house engines' – incl. design, characteristics and testing

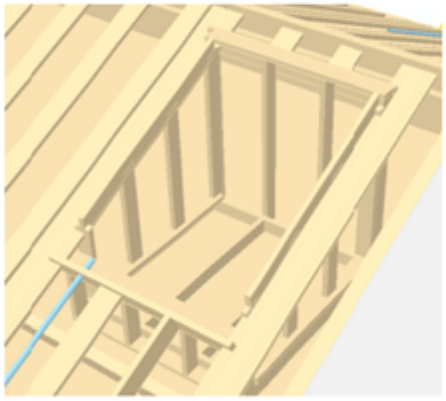
A special feature of the renovation of the RLLL houses is a special designed and prefab constructed platform for the building services: a box with the dimensions of 1,5 x 1,5 x 1,5 m for the heat pump, DHW production and storage, exhaust fans and PV inverters.



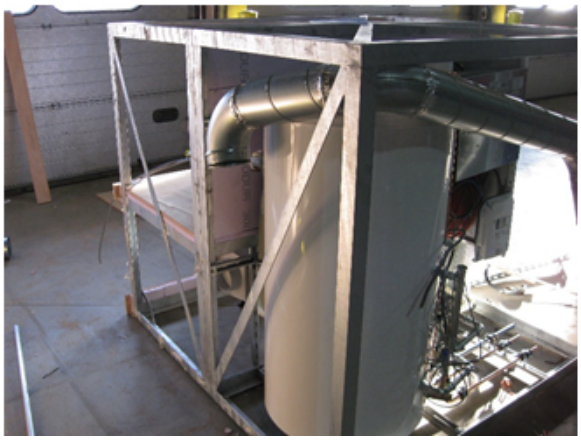
DOORSNEDE



BOV. AANZICHT



3D AANZICHT



Overview of components:

1 Heat pump (for heating dwelling)
Manufacturer: Atlantic
Type: Alféa Extensa+ 6Kw air- water

Performances

T out °C	T supply °C	Thermal capacity kW	Consumed power kW	COP
+7	35	6.0	1.4	4.26
-7	35	4.6	1.74	2.64
+7	45	5.1	1.5	3.4
-7	45	4.4	2.04	2.18

2 Central Ventilation exhaust unit
Extract air in kitchen, bath room and toilet
Manufacturer: Jaga
Type: Ventiline
Maximum air flow: 360 m^3/h
Consumed power: 6 – 81 W

3 PV installation
PV - panels
Manufacturer: ECOslate
Type ECOslate 30
Size 962 x 980 mm
E-performance at 1000 W/ m2: 121 Wp
Number of panels: 50 panels: 30 south and 20 north
Total capacity: ~4000 kWh/ year

Inverter
Manufacturer: SMA
Type: Sunny Boy 5000 TL - 21
Max DC power: 5.250 Wp
Max DC voltage: 750 V
Nominal power @230V-50Hz: 4.600 W

4 DHW boiler
DHW supply for bathroom.
Manufacturer: Aquarea Panasonic
Type: WH- TD20E3E5
Volume: 200 Ltr
Max. temp: 75 °C
Electric heater: 3 kW

5 DHW supply kitchen: electric close-in boiler, 10 liter

3.6 The actual renovation and mounting on site

For the actual renovation the existing facades and roofs were removed. This took less than one day. The prefab elements were transported to the site were they were put in place by using a crane. However, there was still scaffolding used in the test phase. (This will be avoided in other projects).

Transport to the renovation site

Removal of old façade and mounting of new façade

Mounting of the PV roof and housed engine in the roof

3.7 Final result

Following pictures show the final results of the renovation:

Front façade, back façade and interior living room.

3.8 Special experiments

In this real life learning lab setting a number of special experiments took place, The total extended monitoring campaign was performed in collaboration with the Dutch TKI project 'TRECO' (Towards Real Energy performance and Control by predicting, monitoring, comparing and controlling). The monitoring campaign had two main subjects:

- Monitoring occupant behavior and thermal comfort in a renovated house.
- Monitoring the real energy use with comparison of the predicted energy performance.

The monitoring and evaluation of the thermal comfort and perception was done in collaboration with Maastricht University, Department of Human Biology. The monitoring of the real energy use and comparison with the predicted energy use as well as the analyses of the performance gaps was done in collaboration with TU Eindhoven, department of Building Physics and Services. For both topics the work was executed in the framework of the master thesis of Ms. Loes Visser (TU/e), under supervision of Huygen IA and in collaboration with the MORE-CONNECT project.

A summary of the monitoring campaign is reported in Deliverable D.5.7 Monitoring reports of the pilot sites and the lab environments.