Large Scale Smart Home Pilot

Final report

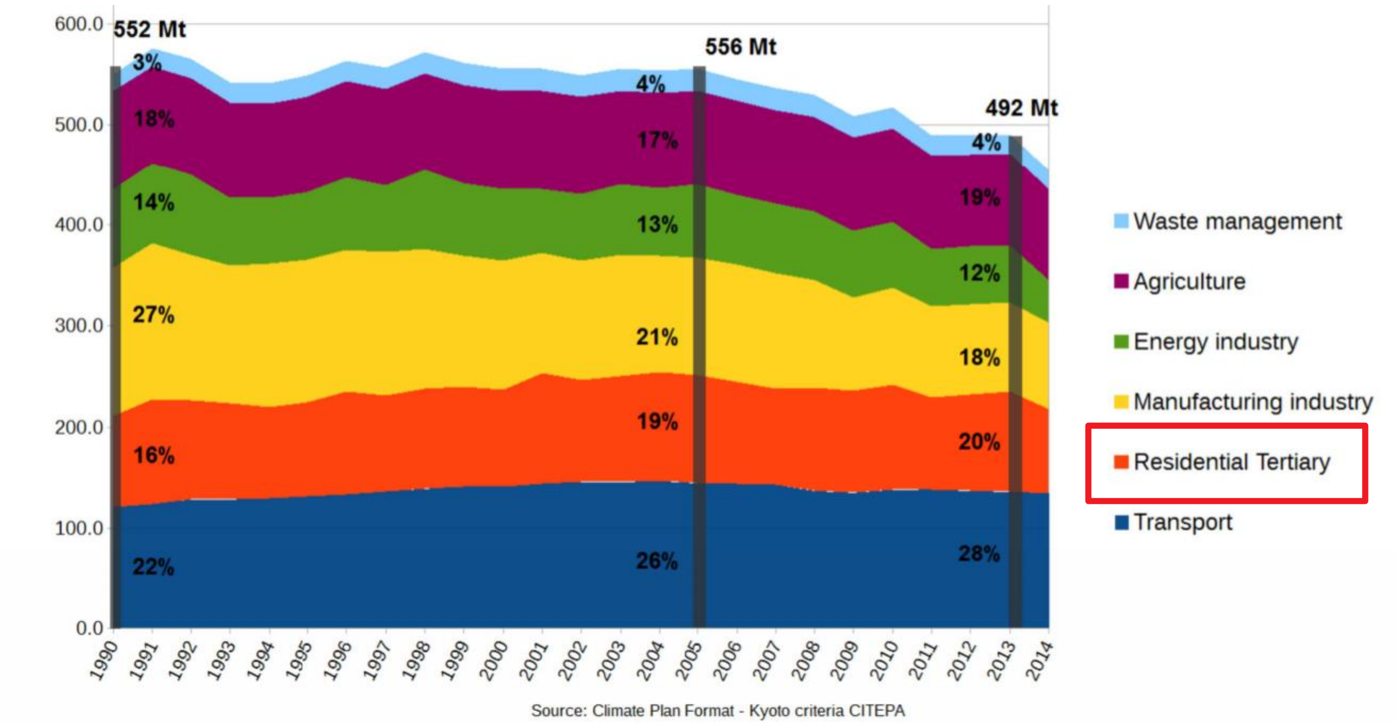
Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
INCASE
European Regional Development Fund

Introduction

Context

The large-scale smart home pilot built by CITC has been developed as part of workpackage 2 of the INCASE 2 Seas Interreg project. Workpackage 2 aims at developing pilots showing best practices for smart automation and reducing energy consumption in both smart buildings and industrial contexts. With its pilot CITC will focus solely on the smart building use case.

According to French ministry for ecology and sustainable development, the residential and tertiary sectors are responsible for about 20% of greenhouse gas emissions in France



Source: Climate Plan Format - Kyoto criteria CITEPA

Cutting them fourfold by 2050 ("The Factor 4" principle) will require substantial efforts and innovations.

***The « factor 4 » principle** (cut greenhouse gas emissions fourfold by 2050 compared with 1990) is the official target that France has set in law the 13th of july 2005 (Loi de Programmation fixant les Orientations de la Politique Énergétique - POPE)*

Three complementary approaches are considered:

- Constructing new buildings with high energy and environmental performance (see Passive Haus label for instance)
- Renovating existing buildings' envelope and improving of the energy and climate efficiency of systems (see BBC standard and réglementation thermique française – RT2012)
- **Improving the management of consumption relating to behaviors and the use of electricity**

This last point is the main focus of the smart home pilot developed by CITC.

Pilot description

Objectives

Improving the management of consumption relating to behaviors and the use of electricity implies three things:

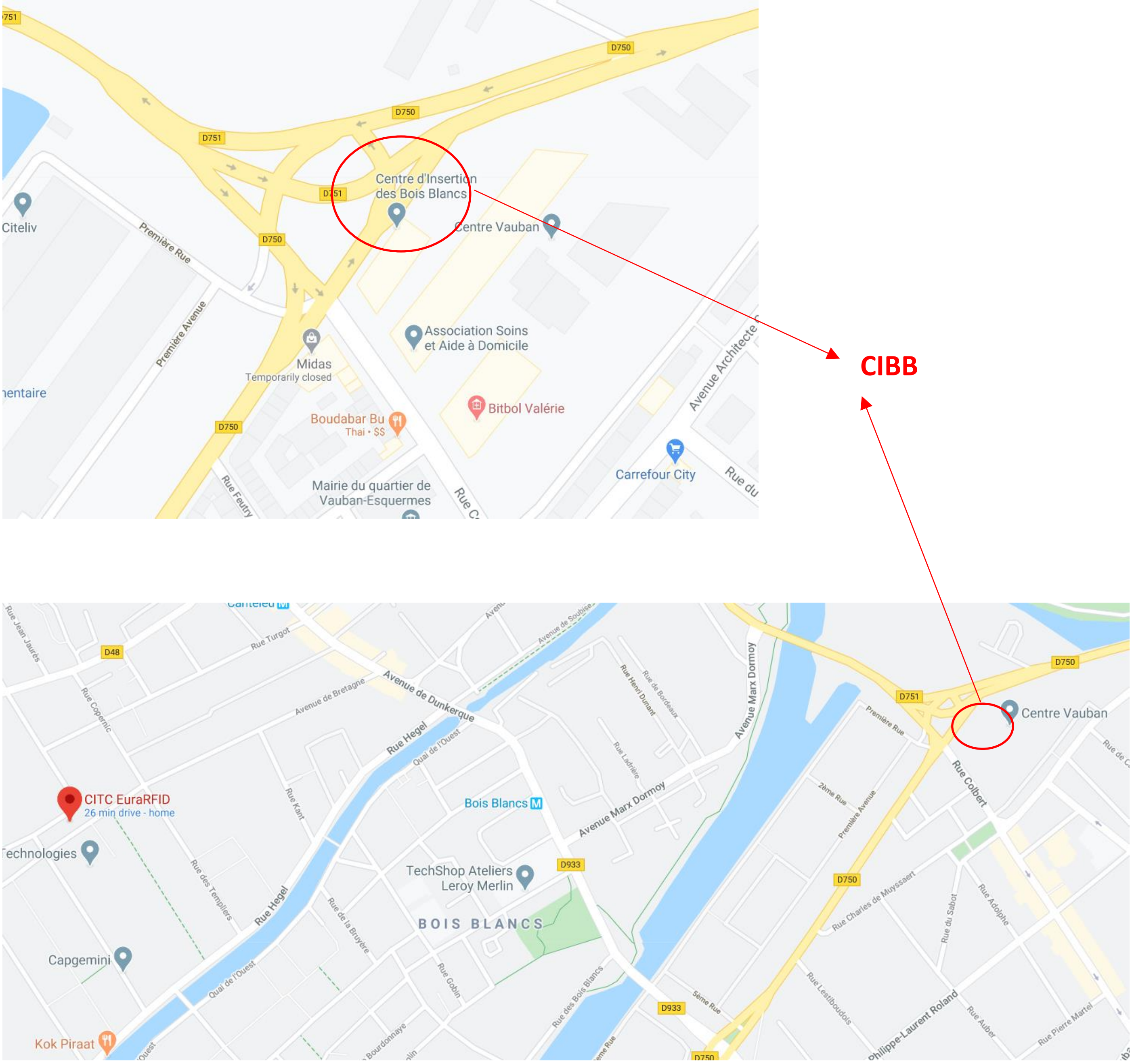
- Performing a detailed measurement of consumption (by room, by appliance, by function: e.g. lighting)
- Informing users on their energy use (real-time consumption, charts, notifications, …)
- Helping users to reduce unnecessary consumption by implementing energy saving automated scenarios.

The objectives of the large-scale pilot developed by CITC is to showcase these three aspects in a live environment, a building that is really inhabited.

Building detailed description

The CIBB, an organization specialized in the training of future non-medical care giver, granted us access to a flat in Lille, not so far from CITC location (see maps below). At CIBB they use this place to train the people, that will serve as care giver once the training's over. The flat looks like a regular apartment, except for the small classroom located at the back of the apartment and the medical bed in the living room.

People are living in the apartment during the day, which means we can collect meaningful real-life data for our pilot.

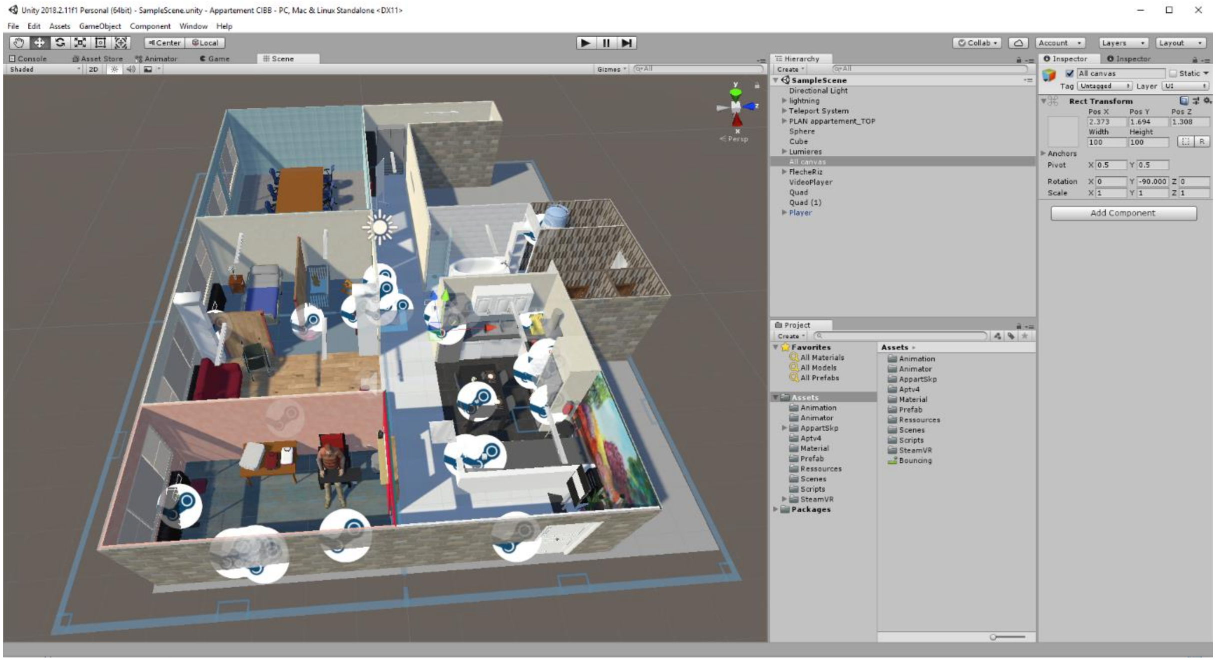


Before getting the apartment and setting up all the equipment to present our large-scale demonstrator, one of the first steps was the 3D modeling of the whole apartment itself. This phase served two distinct purposes:

- Having a high-fidelity digital model to plan and design the adjustments and works to be done for the large-scale pilot

- Being able to show case, this 2-Seas Interreg large-scale pilot to people that could not visit it in Lille (for example in trade shows)

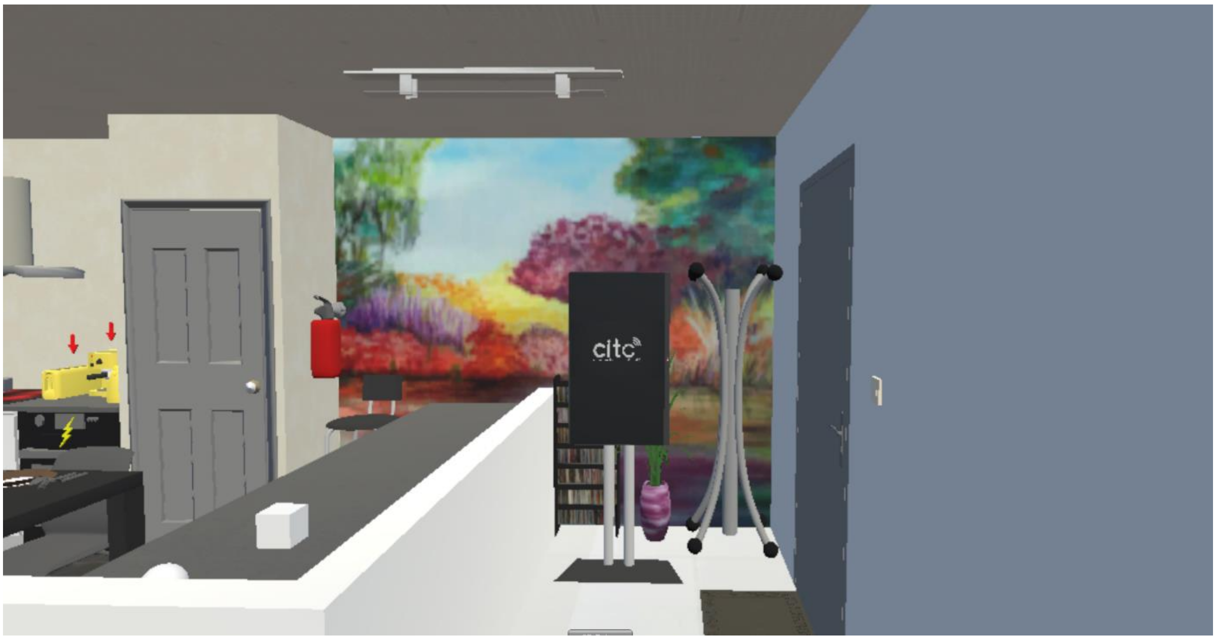
In order to make that 3D modeling, we used the free version of Sketch Up and open source software such as Sweet Home 3D. After exporting the model under the OBJ format, we were able to import the apartment model to Unity, as we can see on the image below.



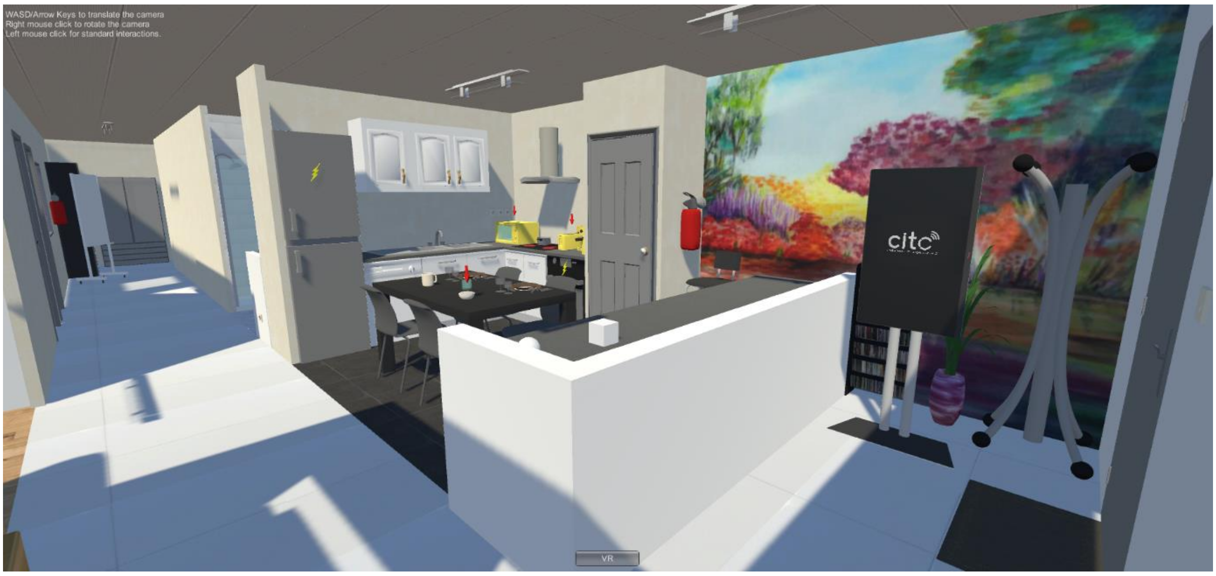
Pos X 2.373
Pos Y 1.694
Pos Z 1.308
Width 100
Height 100
Pivot X 0.5 Y 0.5
Rotation X 0 Y -90.000 Z 0
Scale X 1 Y 1 Z 1

This 3D modelling allowed us to work in a smart and optimum way on the equipment we set up, the position of this equipment and the scenarios around it as well, while the administrative was getting done.

The images below present each room of the apartment/large scale demonstrator:



Entrance with the Majord'Home


WASD/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.

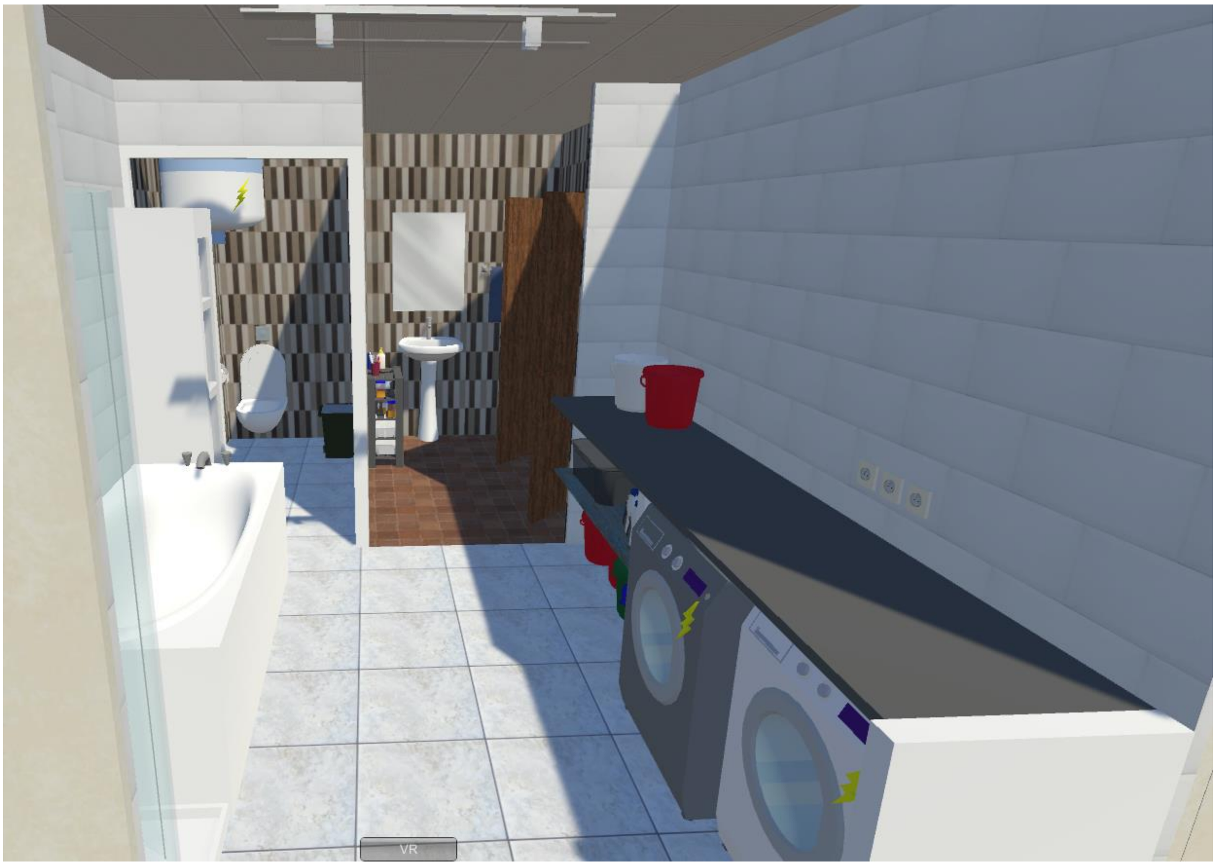
Entrance with a view on the kitchen and the corridor

WASD/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
VR

Laundry room

WASD/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
VR

Living room with a view on the two “bedrooms”

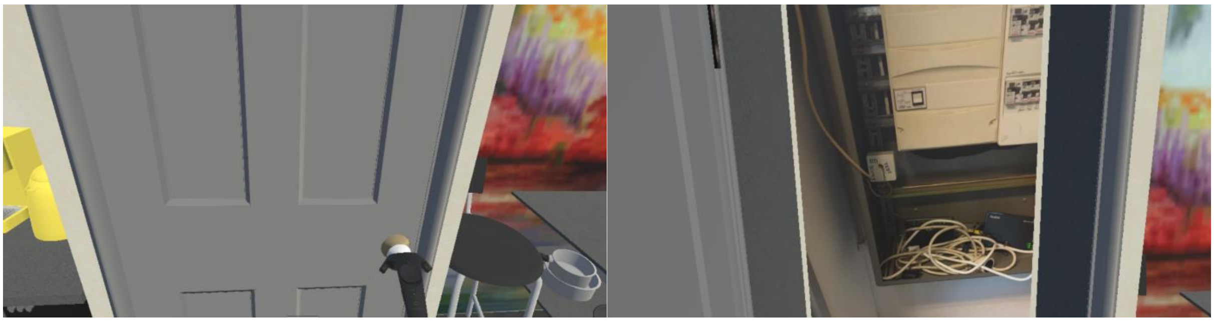


Bathroom and restroom

Classroom

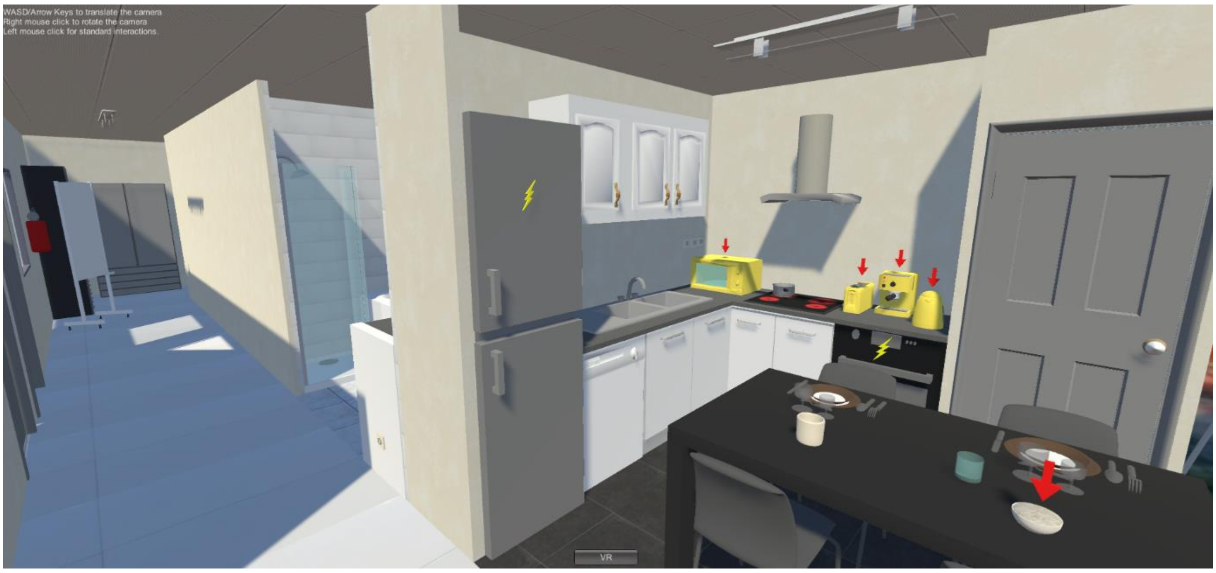
There was a huge work on the virtual reality thanks to the HTC Vive Headset. The main goal is to allow people to visit our large-scale demonstrator from anywhere and have a comfortable immersion into the virtual apartment. To do so, we added and programmed interactions with the objects. Thus, it is possible to teleport in anywhere in the apartment, grab objects and place them elsewhere, turn the light on and off, open the doors … Last but not least is the addition of a real time feedback of the energy consumption.

Switching on and off the light

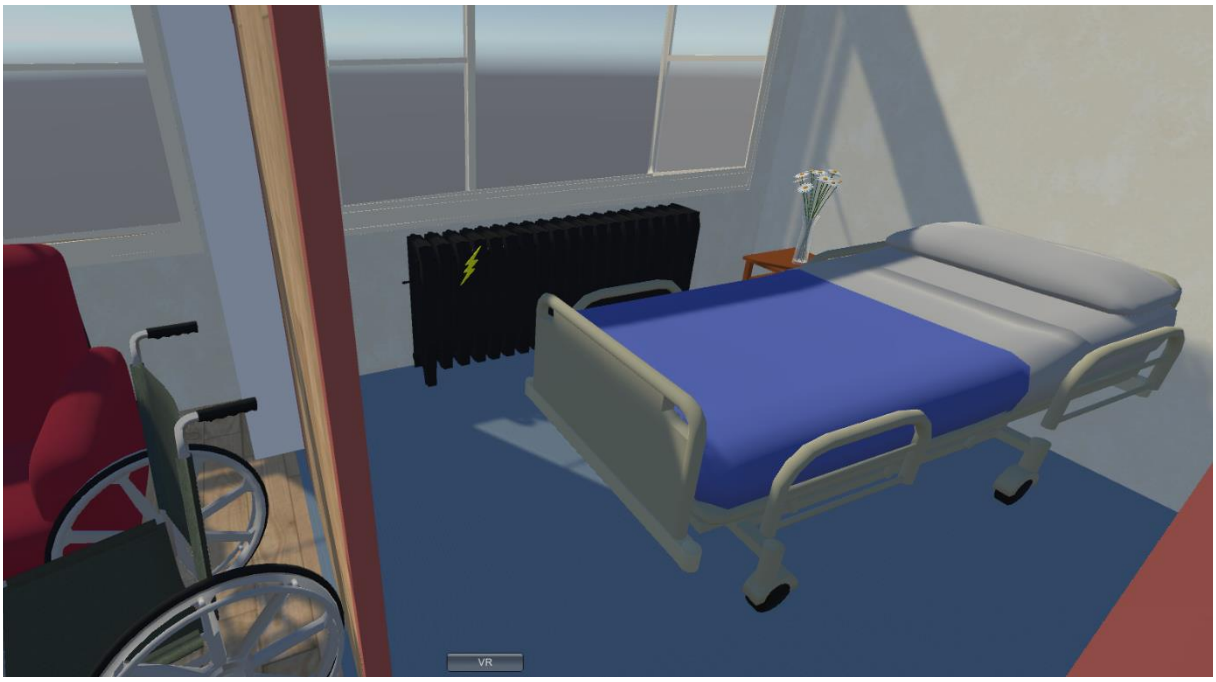


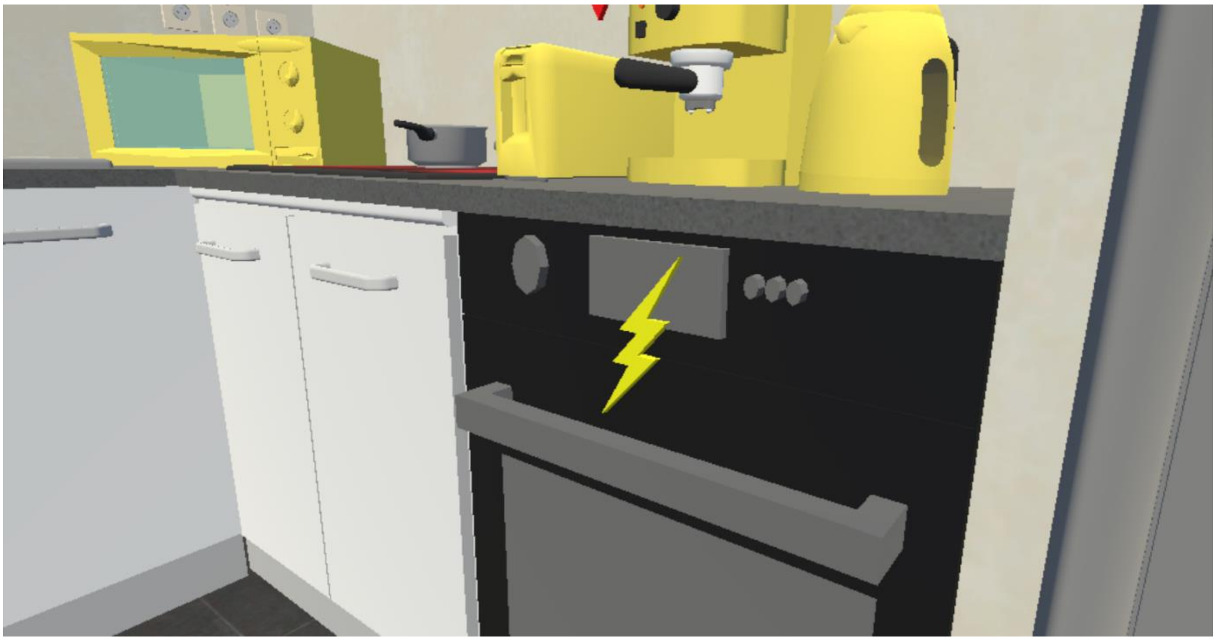
Opening the door of the kitchen – Video to check the power box/fusebox

Inside the apartment and on some equipment only, we positioned some lightning and some red arrows, as we can see on the picture below:

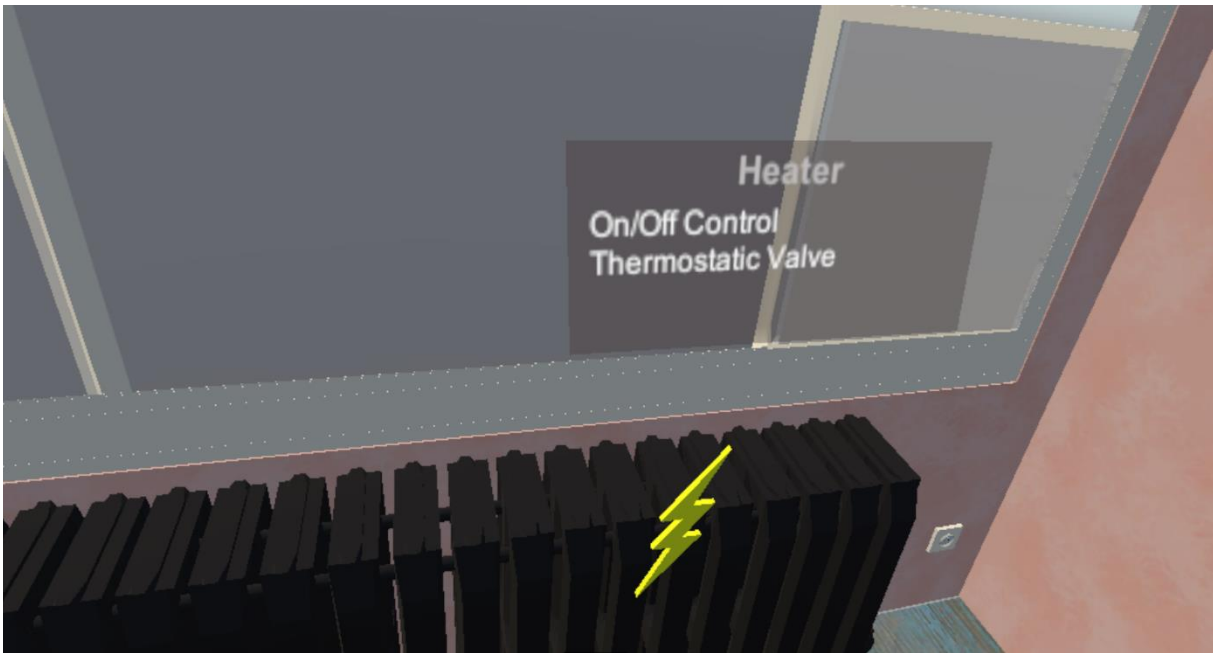

WASD/Arrow Keys to translate the camera
Right mouse click to rotate the camera
Left mouse click for standard interactions.
VR

On one hand, the lightnings are placed on the fridge, the oven, the heaters, the dishwasher, the washing machine etc. as we can see on the pictures below:

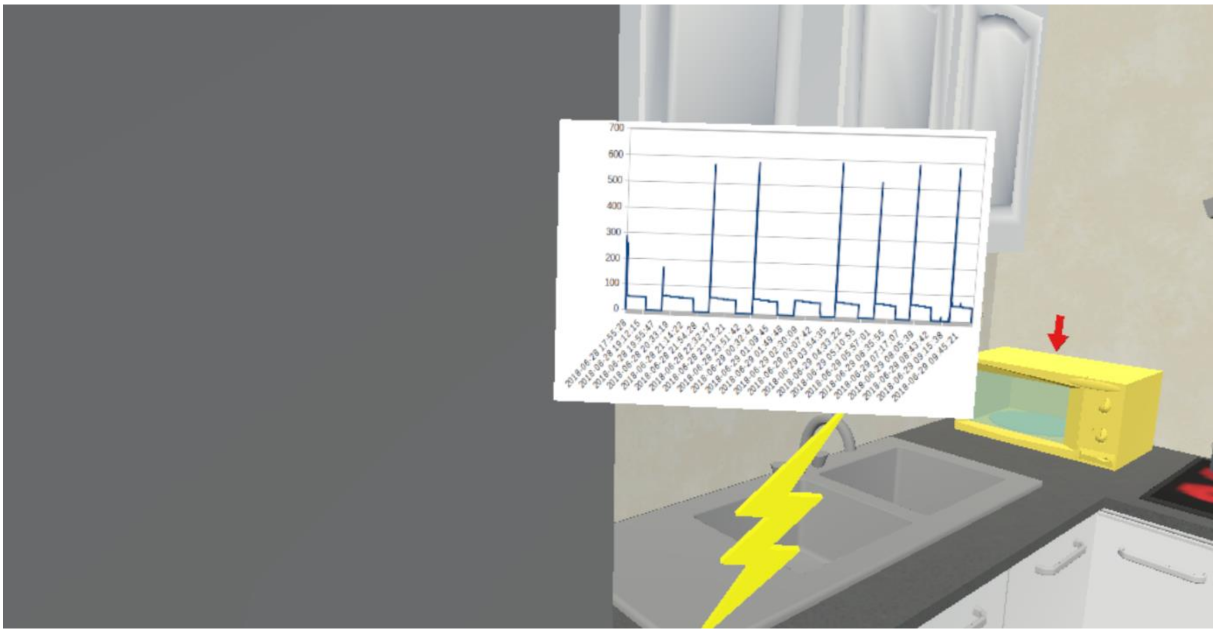




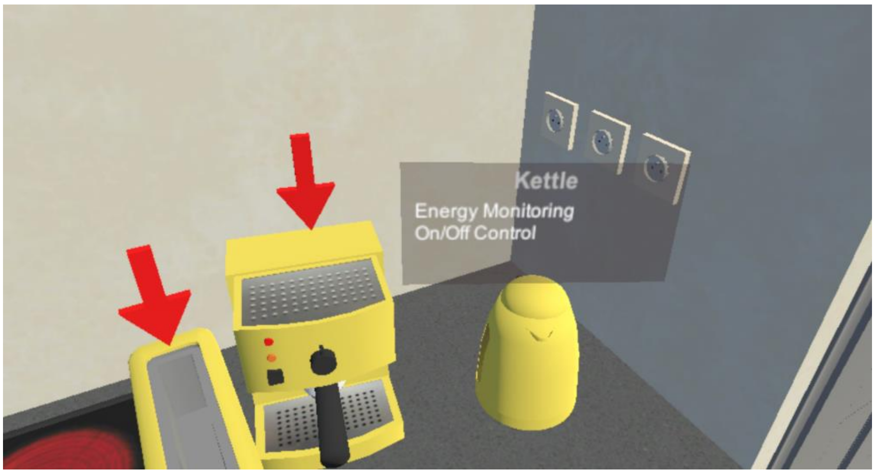
It is possible to grab those lightnings and get information about the object: the equipment set up, the controller, the possible actions …

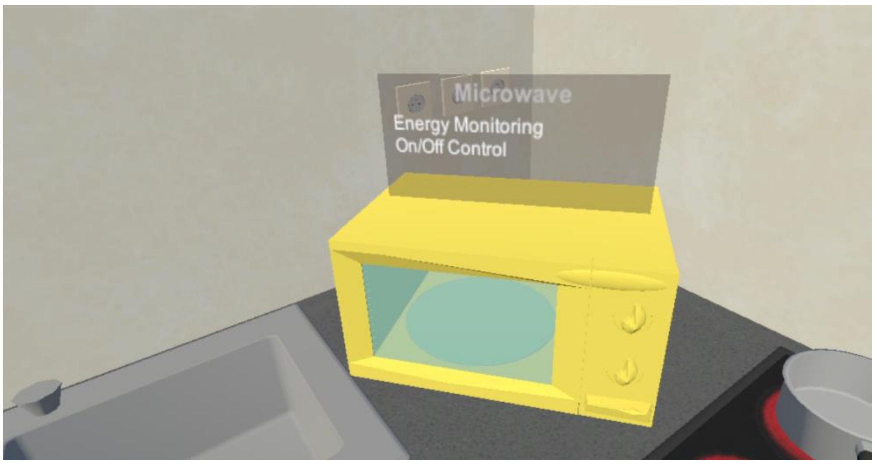


It is also possible to get a historic of the current consumption pictured in curves. The picture below shows us an example of the current consumption of the fridge:



On the other hand, the red arrows indicate the object we can grab in the virtual reality. When grabbed, those objects give information about the controls, the state and the energy consumption.




Microwave
Energy Monitoring
On/Off Control

Technical architecture

The technical architecture developed for the large-scale pilot is shown below. It relies heavily on openHAB, an open source, technology and vendor agnostic Smart Building Software Platform built on top of Eclipse Smart Home Framework.

OpenHAB enables easy integration of energy measurement devices (smart plug, energy meters, …), energy consuming devices (smart plugs, led drivers, HVAC controllers, …) with other sensors and data sources related behaviors and energy use (motion detectors, CO2 sensors, weather forecast, peak demand forecast.

OpenHAB enables also easy awareness of users by providing adapted mobile / web HMIs and the possibility to push notifications (SMS, mail, social media and voice notifications).

And last but not least, openHAB enables to easily define and execute automation processes via automated rules, which can thus be used to implement energy saving scenarios (acting on energy consuming devices based on data coming from sensors, behavior data, planned room use, weather forecast, peak demand forecast, ….).

The openHAB platform runs on a dedicated embedded server, a raspberry pi version 3.

Two types of energy meters have been chosen, so-called smart plugs that measure consumption from a single electrical outlet and broadcast it using some radio technology (Enocean, Z-Wave, …) and also DIN-rail compatible energy meters that measure consumption on an electrical sub-network directly in the fuse box.

This last kind of energy meter devices tend to use Modbus as a communication technology and this explains why the architecture below includes an Loxone mini-Server controller, which acts as gateway between modbus energy meters and the openHAB server. It would have been possible to spare the Loxone server and use instead some Modbus extension card directly on the Raspberry embedded server.

Consumption data gathered by the openHAB platform are pushed to a remote server in order to be able to store it at some central location, in a database shared with HZ University of Applied Sciences in The Nederlands (they replicated and adapted the architecture below to fit they own needs).

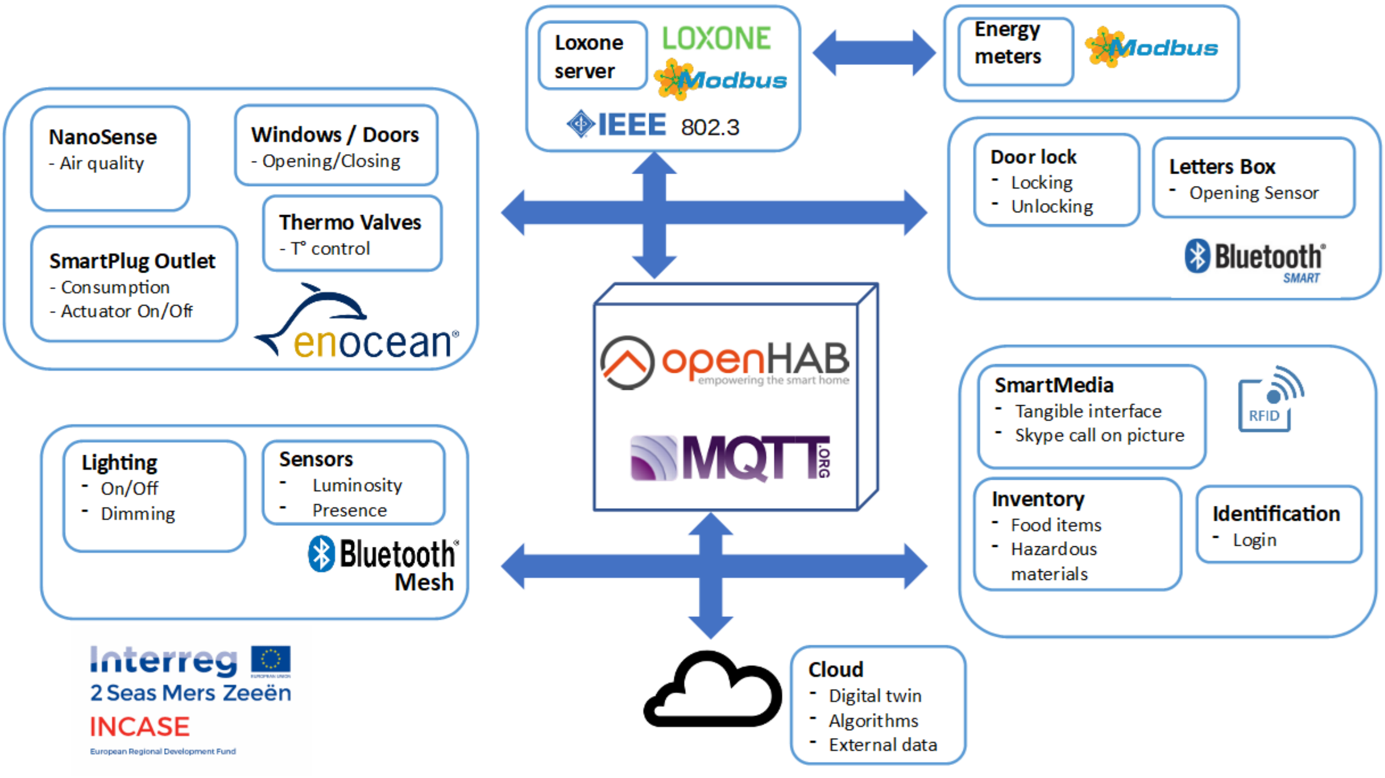


Figure 1 Large-Scale pilot technical architecture

The MQTT (Message Queuing Telemetry Transport) technology has been chosen for pushing consumption data to the central database. This is ISO/Standard publish/subscribe-based messaging protocol, that works on top of TCP/IP and that is widely used for the Internet of Things as it is lightweight and easy to use.

Status

The architecture describe above has been implemented in the apartment from CIBB.

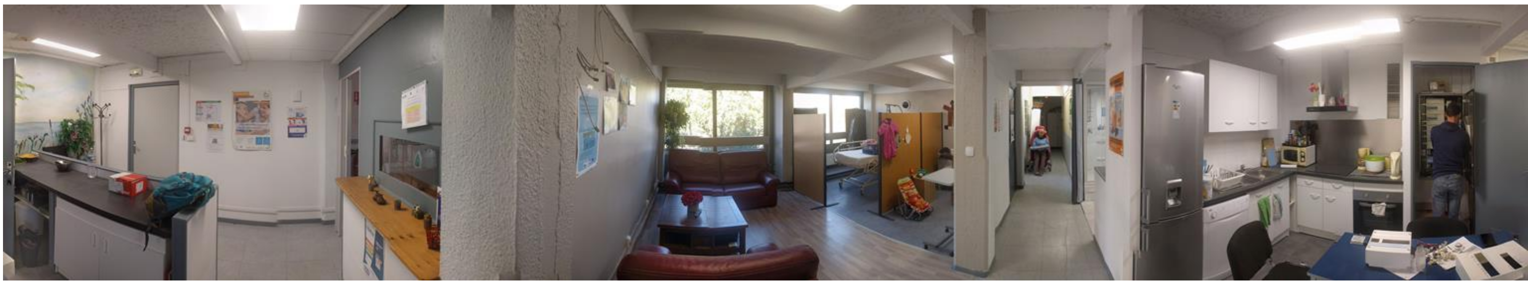


Figure 2 360° Vue of light upgrade with LED Panels and wireless LED drivers

An electrician has removed in every room all conventional lights and replaced them by LED panels controlled by Enocan LED drivers (see panorama pictures below). Each panel, can be individually remotely controller and dimmed.

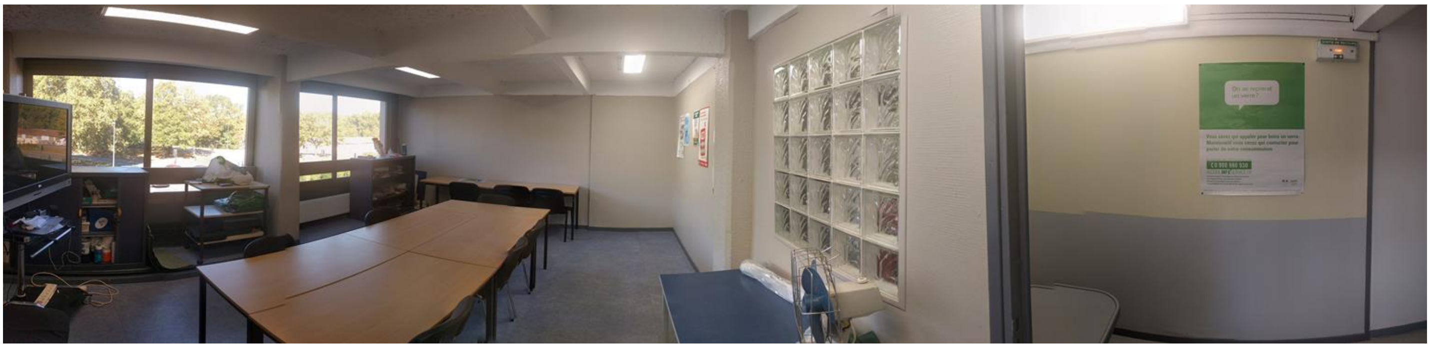


Figure 3 360° Vue (classroom) of light upgrade with LED Panels and wireless LED drivers

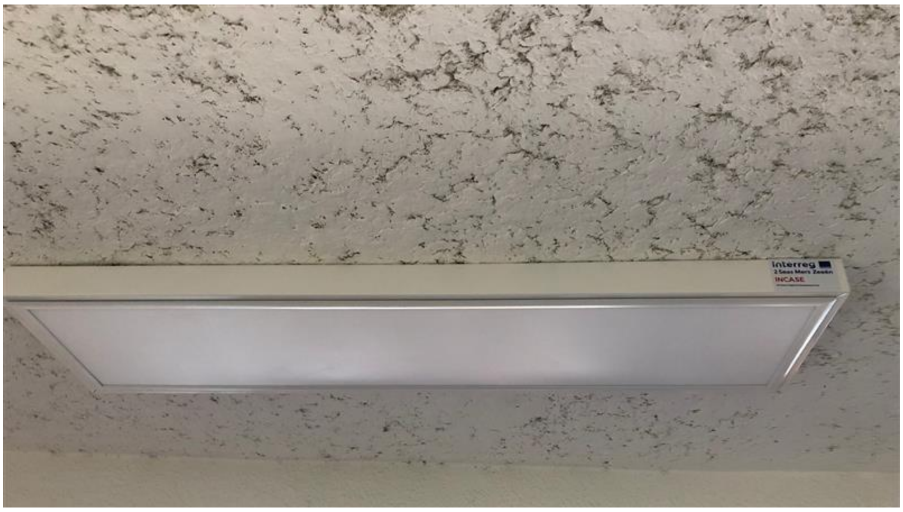


Figure 4 Led panel with integrated LED driver (hall entry)

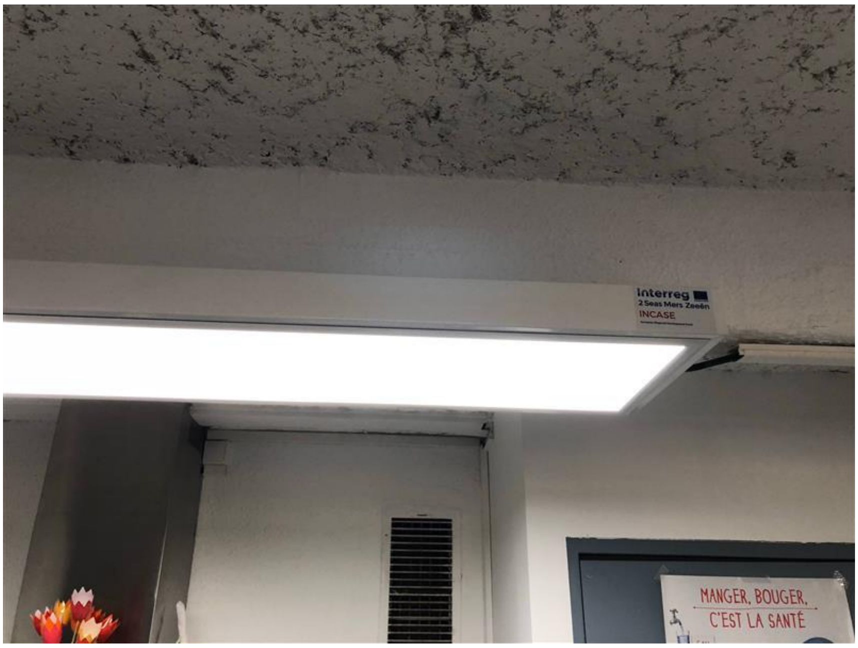


Figure 5 Led Panel with integrated Led driver (kitchen)

The electrician also re-organized from scratch the wiring in the fuse box, in order to be able to measure consumption from specific appliances and functions with our RAIL DIN compatible energy meters (see pictures below)

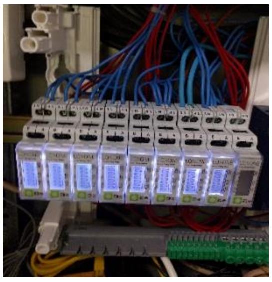


 Figure 6 Electrician Early Work (before connecting Loxone Server)	 *Figure 7 Fuse Box, once Loxone server and OpenHab are in place*

Figure 8 Presentation of technical architecture to Dutch partners

The Loxone and openHAB server have been installed in the fuse box, the lighting system is working fine, and energy consumption data are pushed to a central database.

In order to be able to remotely and securely access the large-scale pilot system, a network VPN (vitual private network) with a 4G/IP gateway has been installed and configured (see diagram below).

The network we deployed within the large-scale pilot is completely independent from the one already in place at the beginning of the project, a network belonging to the building owner, CIBB. We first tried to use that existing network, but the subcontractor that is responsible for managing the network was a bit sluggish and at the end not able to implement the changes we required to put in place a working VPN. A serious cyberattack occurred also during that period, an event the subcontractor blamed us to be responsible for. This achieved to convince us, that we needed a completely independent network. This was required to restore trust with CIBB and not risk jeopardizing the whole project.

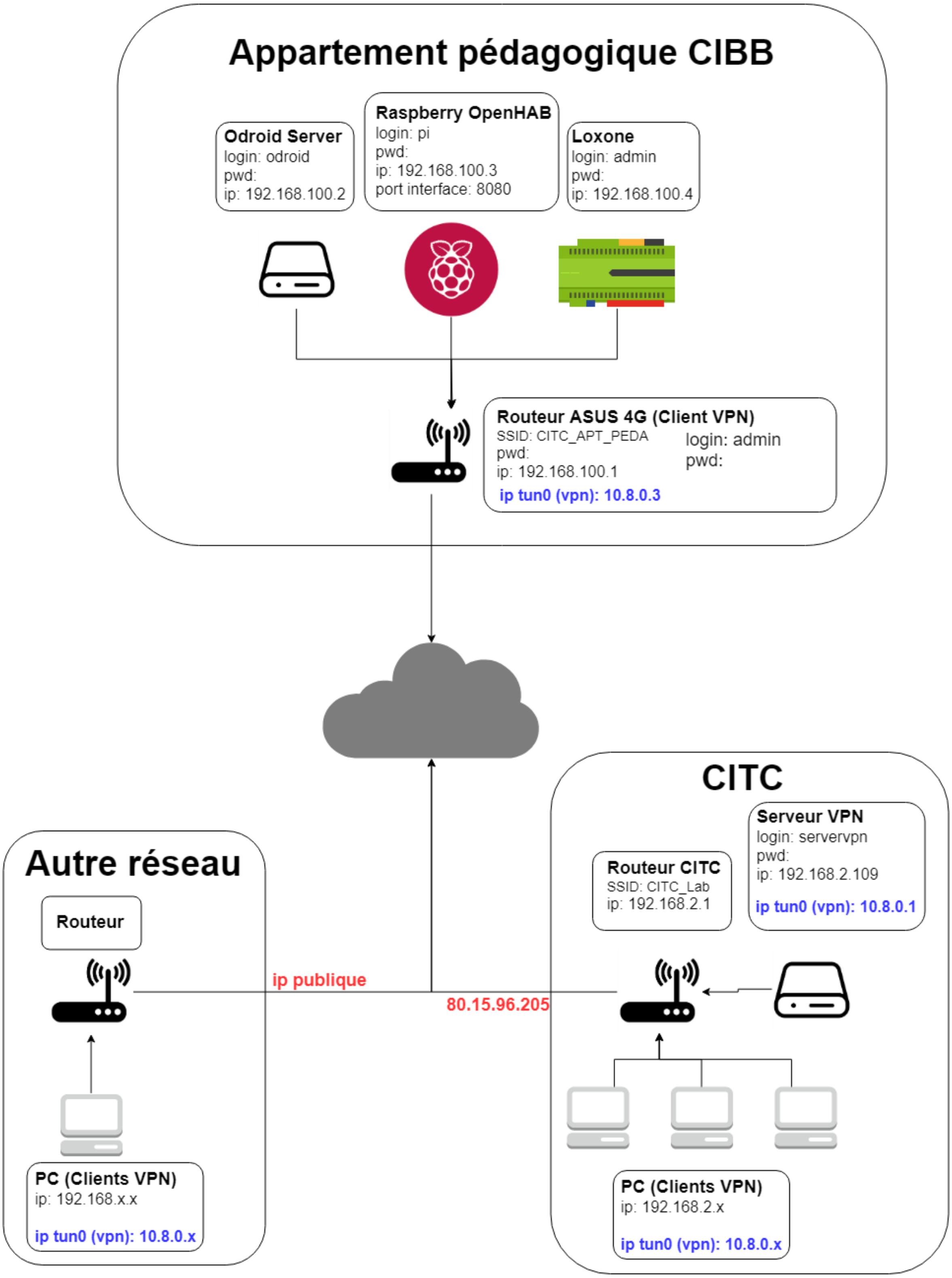


Figure 9 Network architecture for the large-scale pilot

The lighting system is currently working with the Enocean radio technology, except for the kitchen and the main entrance where we were able to deploy a home-made Bluetooth Mesh solution.

Bluetooth Mesh is a disruptive new technology for the smart building sector, but also for other sectors like industry and healthcare. Our Bluetooth-Mesh platforms have also been integrated in smaller scale pilots, that have been demonstrated during the 2Seas Interreg closing conference in Gent (see picture below)

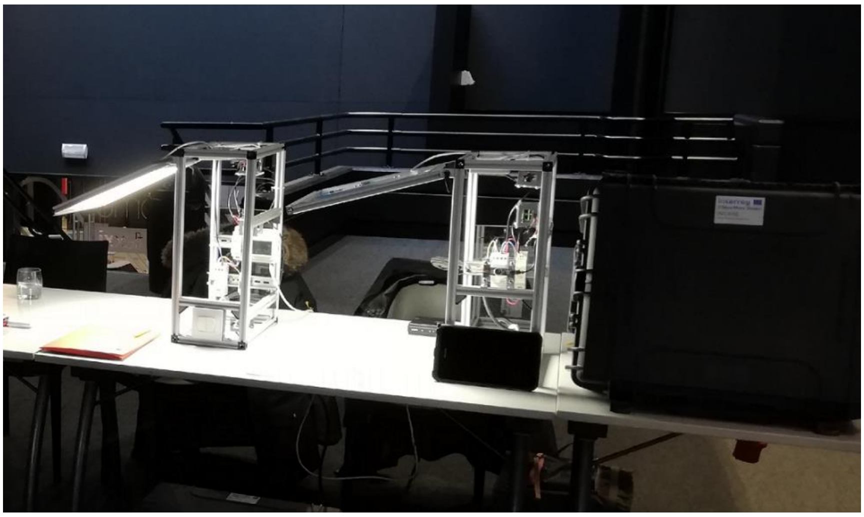


Figure 10 Small-Scale Smart lighting system demonstrated during closing conference

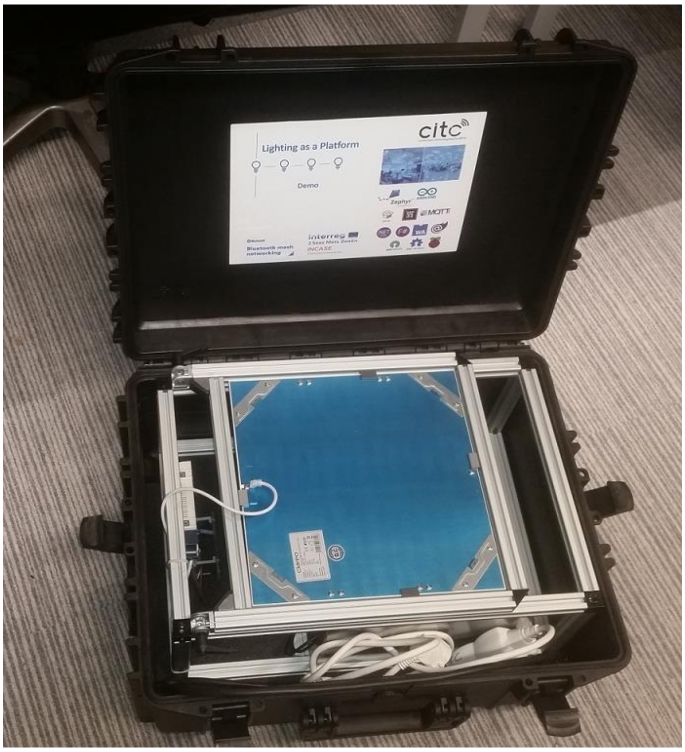
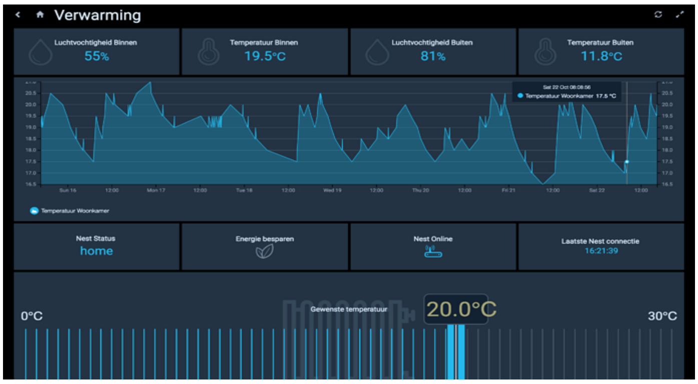


Figure 11 Small-scale Smart lighting system folded back in transportation case

An HMI has been deployed to enable users (residents) to pilot the equipments and inform them on their real-time energy consumption, consumption trends. A additional step would include the pushing of appropriate advices and timely notifications.

The HMI has been developed on top of the OpenHab open source home automation framework, with the extension called HabPanel (see below)



Verwarming

Luchtvochtigheid Binnen 55%

Temperatuur Binnen 19.5°C

Luchtvochtigheid Buiten 81%

Temperatuur Buiten 11.8°C

Sat 22 Oct 08:08:56
Temperatuur Woonkamer 17.5 °C

Nest Status home

Energie besparen

Nest Online

Laatste Nest connectie 16:21:39

Gewenste temperatuur 20.0°C

Figure 12 Example HMI with HabPanel

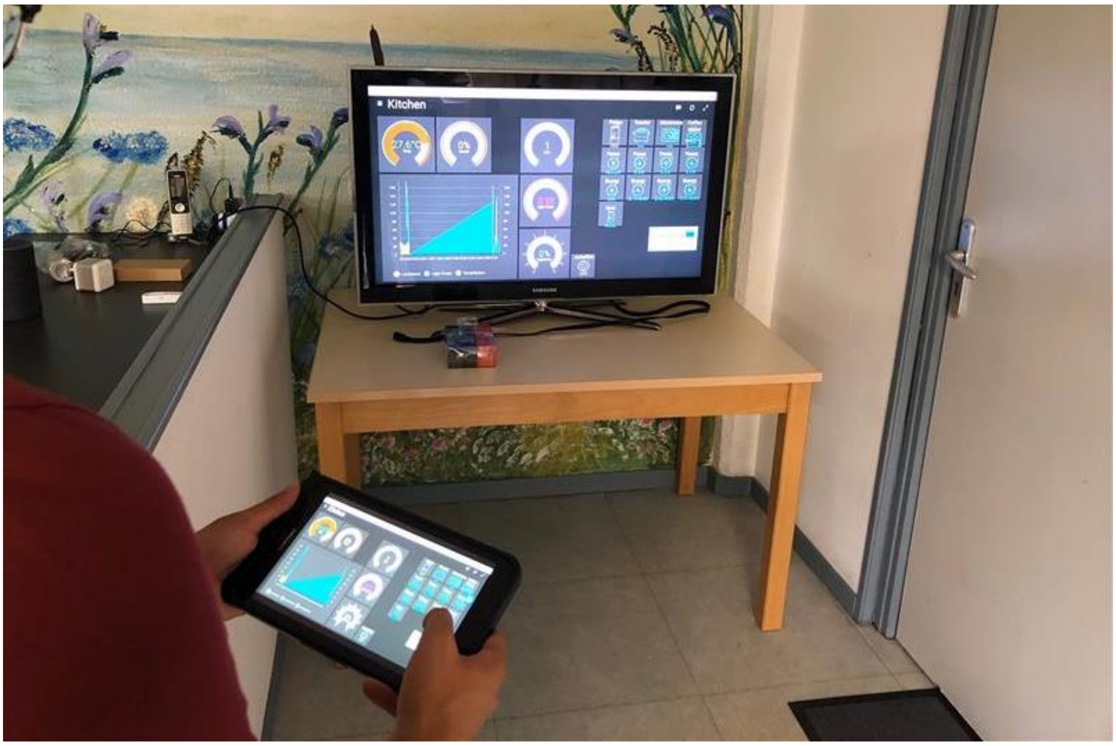
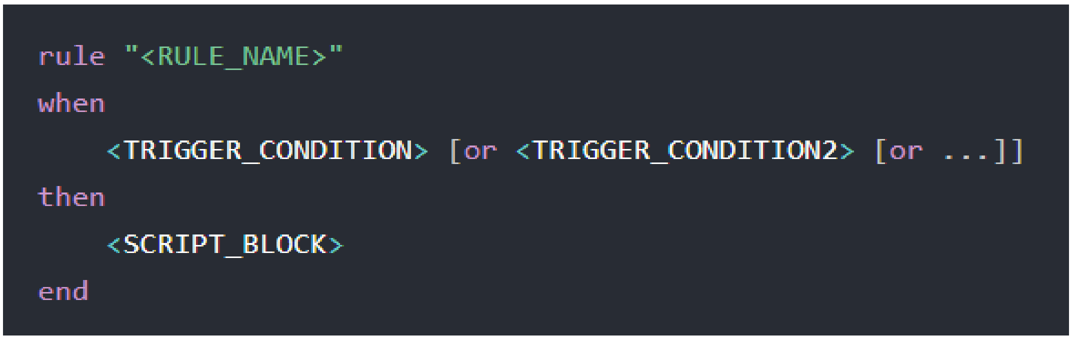


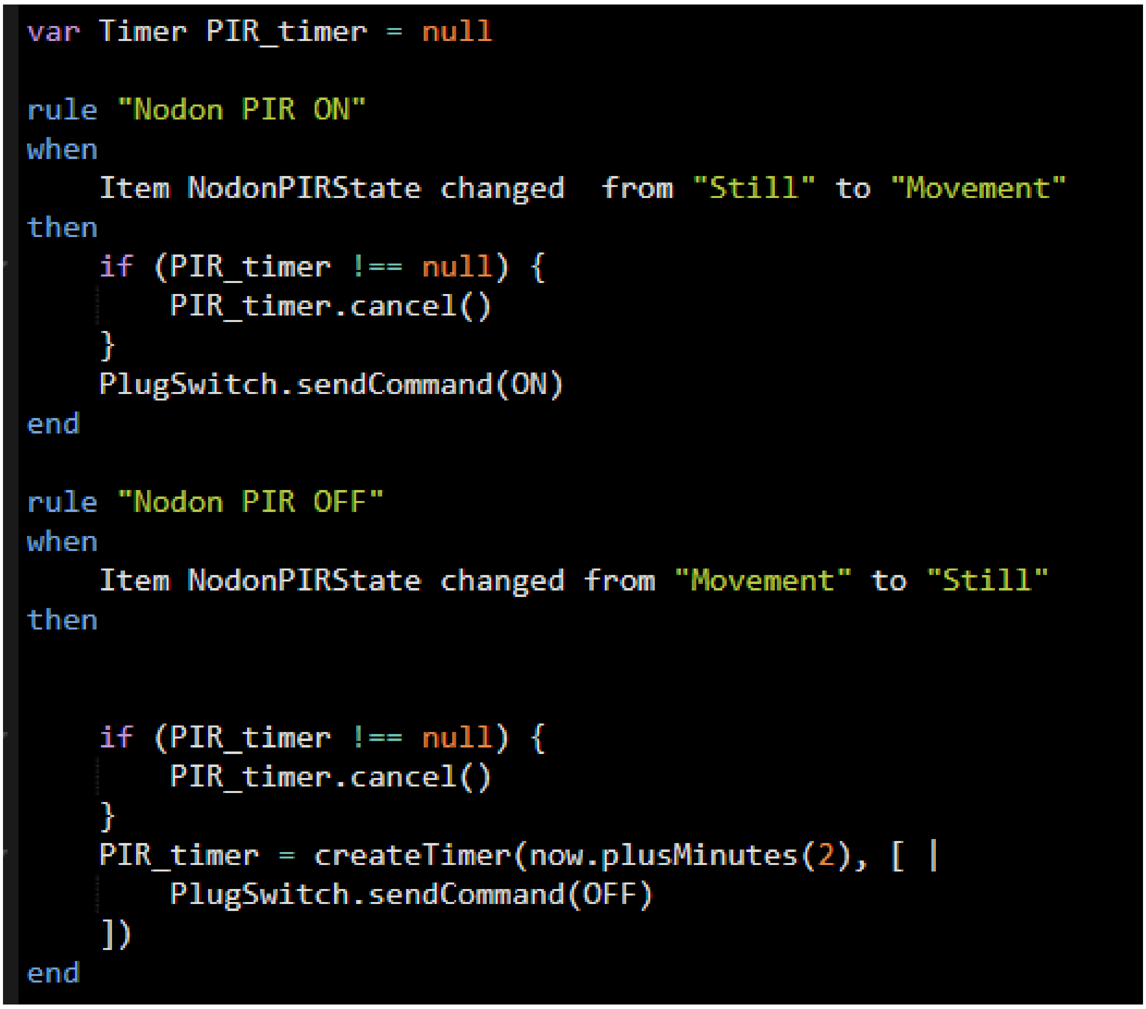
Figure 13 Large-scale pilot HMI & mobile HMI (in the hall entry)

Automated rules for energy saving scenarios have also been developed within the OpenHab framework. Automated rules in OpehHab are implemented like popular IFTTT (If This Then That) rules (see below)



```
rule "<RULE_NAME>"
when
    <TRIGGER_CONDITION> [or <TRIGGER_CONDITION2> [or ...]]
then
    <SCRIPT_BLOCK>
end
```

Figure 14 Typical Openhab automated rule



```
var Timer PIR_timer = null

rule "Nodon PIR ON"
when
    Item NodonPIRState changed  from "Still" to "Movement"
then
    if (PIR_timer !== null) {
        PIR_timer.cancel()
    }
    PlugSwitch.sendCommand(ON)
end

rule "Nodon PIR OFF"
when
    Item NodonPIRState changed from "Movement" to "Still"
then


    if (PIR_timer !== null) {
        PIR_timer.cancel()
    }
    PIR_timer = createTimer(now.plusMinutes(2), [ |
        PlugSwitch.sendCommand(OFF)
    ])
end
```

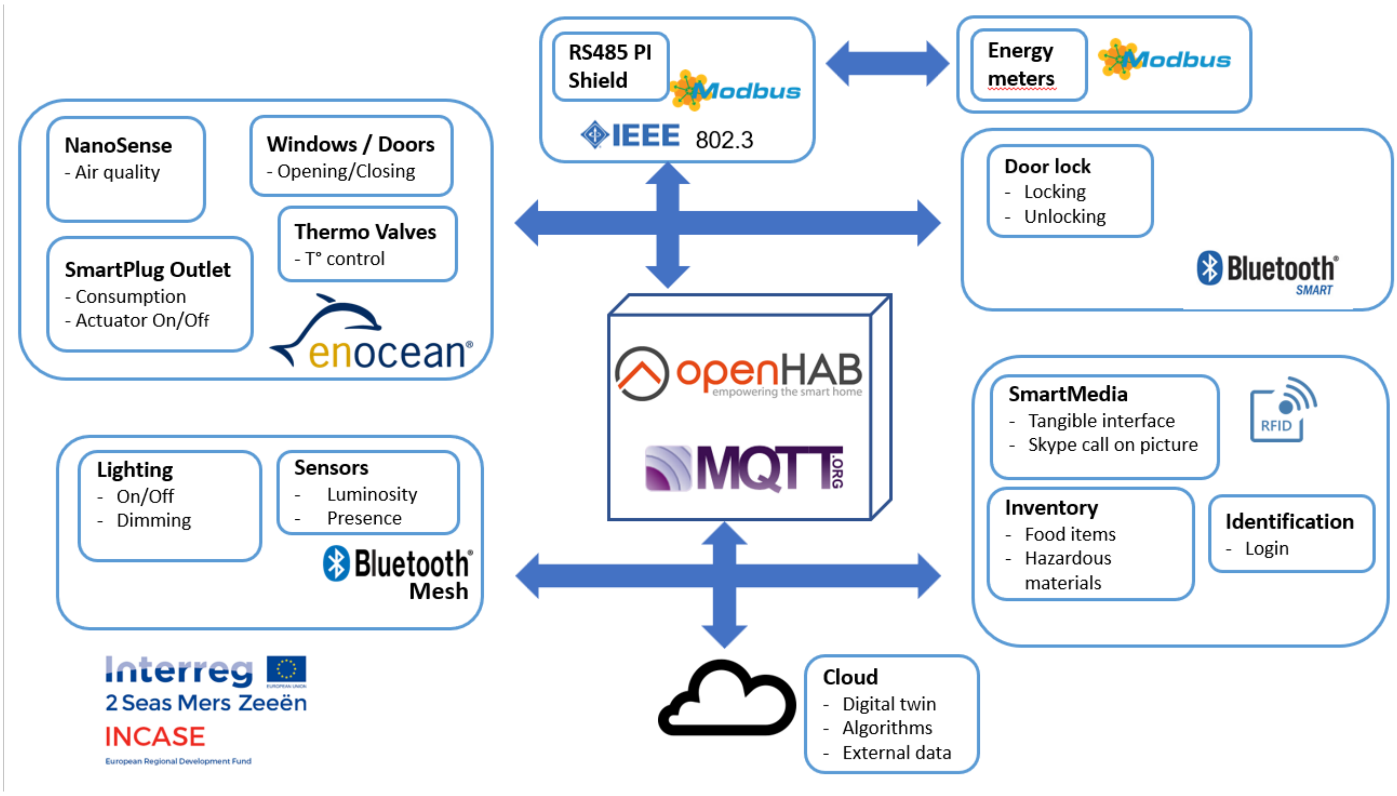
Figure 15 An example set of two simple rules to link a power plug with PIR sensor

The whole architecture has not been fully deployed, some features are still missing, mostly because the building owner decided in 2019 to initiate some renovation work and to reconfigure the rooms (removing some walls, expanding some rooms, …). The works are not yet ready.

- Thermostatic valves, the Bluetooth Smart lock and air quality sensors will be deployed once the works are finished
- RFID-based smart inventory and smart mirror require the laundry room and bathroom to be ready

The Bluetooth Letter-box application will not be deployed and for the Bluetooth Smart Lock, we are waiting for the agreement of our partner CIBB before installing it as it requires to change the keys and distribute them to all trainers and teachers.

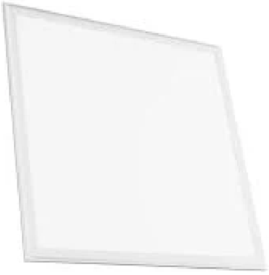
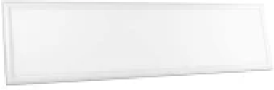
Unfortunately, also, during the renovation work one piece of equipment has been damaged, the Loxone server. It is normally acting as a gateway between the modbus energy meters and the Openhab Server. Since this is a quite expensive device, we went for a cheaper replacement solution: An RS485 / Modbus hardware shield that we can directly plug on the raspberry pi running the OpenHab server. The final technical architecture is thus depicted in the diagram below.



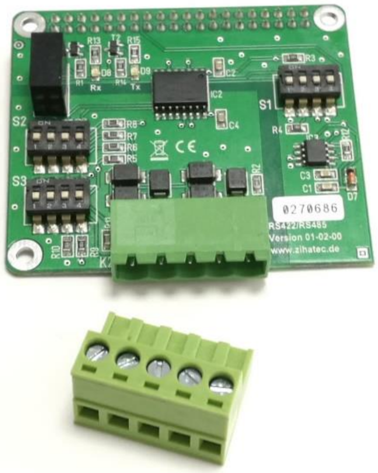
At the end of this document there is also a table with the final list of equipments and devices that make up the large-scale pilot.

LIST OF EQUIPMENTS

Nodon Micro-SmartPlug / Enocean	10	
Enocean radio module for RPI	1	
Nodon Enocean PIR Sensor	10	

LCM-60E0 Dimmable Enocean LED Driver	15	
LED Light panels 600 x 600	3	
LED Light panel 1200 x 300	12	
Enocean Nodon switch	10	
Loxone Mini-Server (removed in final version, since not working anymore)	1	

Loxone Power Supply	1	
Loxone Modbus extension	1	
Modbus Energy Meters (single phase)	8	
Raspberry PI 3 + enclosure	1	

Odroid VPN server (removed from final arechitecture / VPN is now running directly on Asus Gateway)	1	
Asus 4G / Wi-Fi Gateway	1	
Nukki Bluetooth connected Lock + Bluetooth WiFi gateway	1	
RS4845 / Modbus shield for Raspberry pi	1	

citc
contactless technologies•EuraRFID

Centre d'Expertise, de Ressources et de Formation
- Cluster, Internet des Objets -

Franck Gaultier
R&D Project manager
fgaultier@citc-eurarfid.com

CITC Innovation Center for Contacless Technologies
Région Hauts-de-France
WWW.IOTCLUSTER.FR
CITC - EuraTechnologies - 165 avenue de Bretagne - 59000 LILLE
Tél. : +33 (0) 320 191 852 - Fax : +33 (0) 320 936 963 - Association loi 1901 - Parution au JO le 07 mars 2009
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