KUBIK

Energy Efficiency Research Platform

Document history			
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Contents

Abbreviations

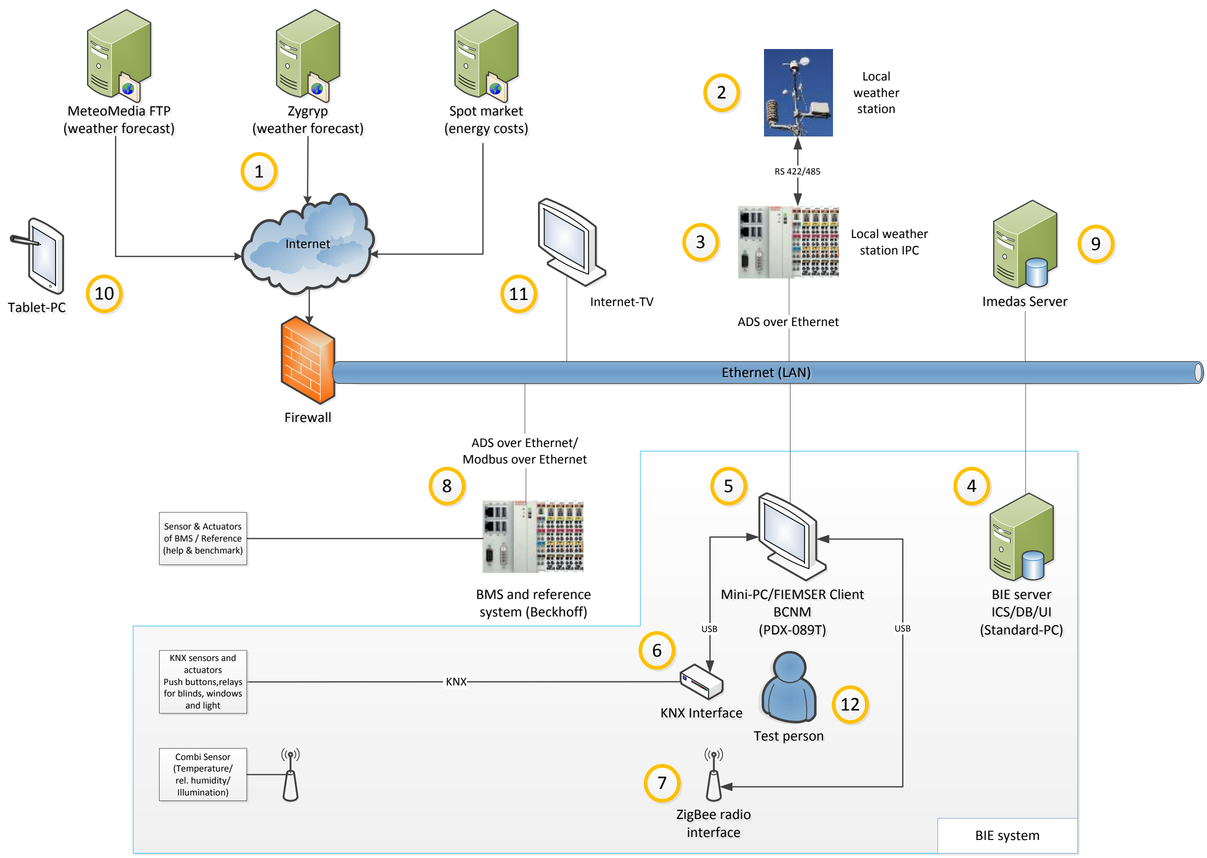
CHP	Combined Heat and Power
EEB	Energy Efficiency in Buildings
BIE	Friendly Intelligent Energy Management System for Existing Residential Buildings
RES	Renewable Energy Sources
PV	Photovoltaic
BIE	Building Intelligent Energy
BMS	Building management system
IPC	Industrial PC
PLC	Programmable logic controller = industrial control unit
XML	Extensible Markup Language (XML) is a markup language which is human-readable and machine-readable
KNX	A international standard fieldbus for home and building control
Modbus	Modbus is a serial communications protocol published by Modicon in 1979 for use with (PLCs). Several protocol versions are in use: Modbus RTU, Modbus TCP/IP, Modbus ASCII and further more
6LowPAN	6LoWPAN is an acronym of “IPv6 over Low power Wireless Personal Area Networks”. An IPv6 standard for small and low power devices
EtherCAT	EtherCAT is an acronym for “Ethernet for Control Automation Technology” - an open high performance and real-time Ethernet-based fieldbus system
SOAP	Simple Object Access Protocol – network protocol basing on XML for data exchange between systems and objects
Http/Rest	REpresentational State Transfer Architecture (web service architecture model similar to SOAP)

OSGI	Open Services Gateway Initiative (software platform and framework dedicated for communication between devices of any kind)
Imedas	Web based expert system (software) for measurement, control and analyse.

1 Introduction

The aim of the current document is to describe the IT platform and equipment used for the TECNALIA's BIE validation. The BIE is an energy optimization module that taking into consideration the forecasted energy demand, local generation and the weather conditions for the next 24, optimizes the indoor comfort settings and as well as schedules the available RES sources.

All the devices used in the BIE development and validation phase are part of the KUBIK core framework for energy efficiency domain research.



BIE interconnected systems

2 Buildings configuration

This section describes the KUBIK as validation building to be used in Energy Efficiency Research activities. This section also describes the equipment available for the validation process and the monitoring and control devices.

2.1 KUBIK validation environment

2.1.1 General Overview of KUBIK

KUBIK is an innovative testing environment developed by Tecnalia. It is located at Derio (close to Bilbao) within the Technology Park of Bizkaia (Spain)

This environment is an experimental building which consists of modular and removable structures that allows the installation and monitoring of a wide range of structural elements, devices and energy efficiency control systems. It is divided into three a 100 m^2 dedicated floors and a larger cellar at which different HVAC equipment is installed.

The dedicated floors are called: ground floor, 1st floor and 2nd floor contains seven test cells, one control cell and an entrance area. The particular test cells can be combined to larger test rooms (measuring rooms).

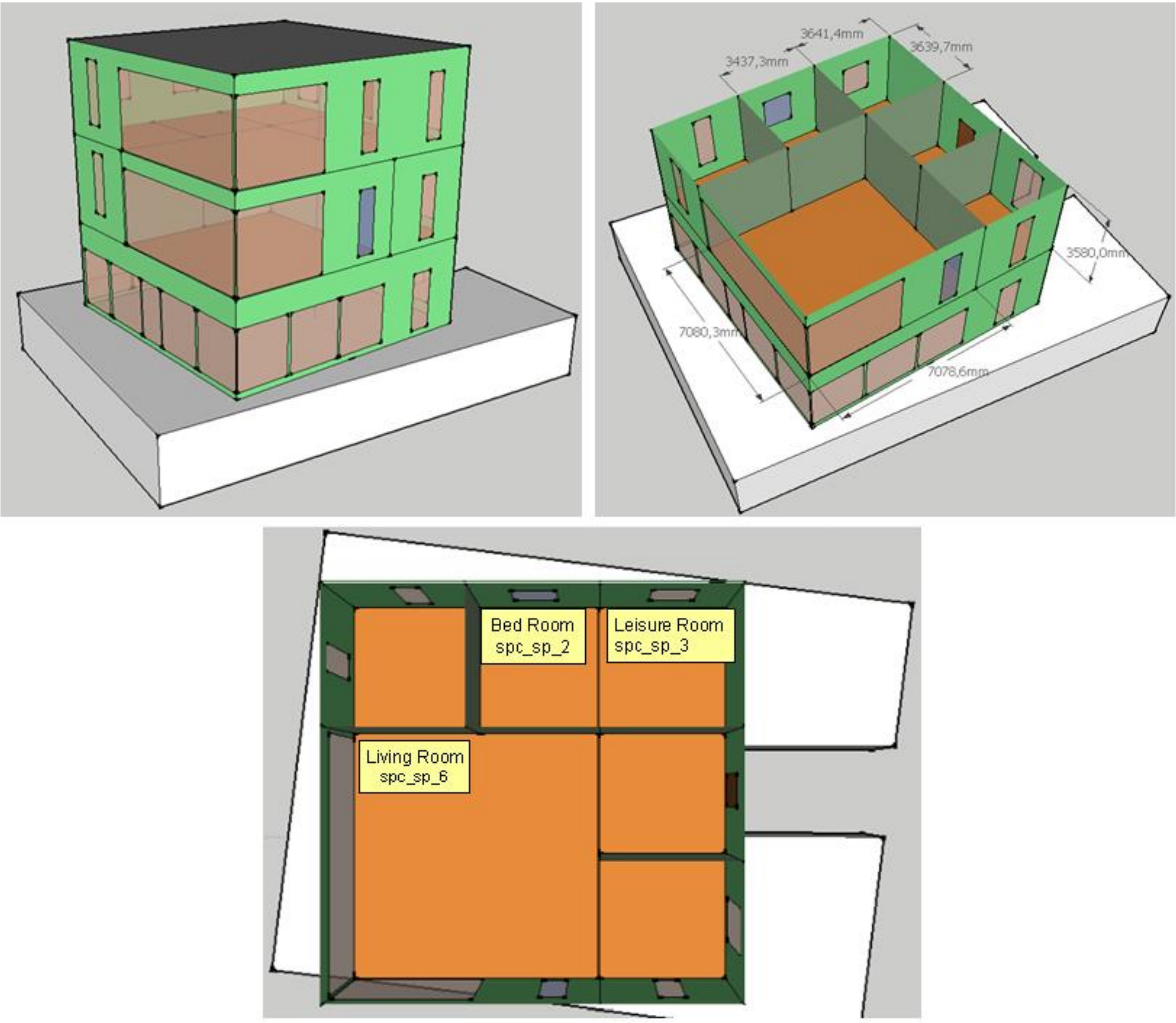
KUBIK building

The supply of energy is based on the combination of conventional and renewable energy equipment. The KUBIK facility is equipped with a CHP system, a windmill and solar panels.

The building is additional equipped with advanced monitoring and control systems and a configuration of sensors and actuators as well as with basic HVAC components. For measuring and analysing the client/server software system “Imedas©” is installed.

2.1.2 Validation area

For the purposes of the BIE, the 1st floor of the building will be used during the validation process. Within this floor, the three rooms that appear in the next are equipped and used for the evaluation process.



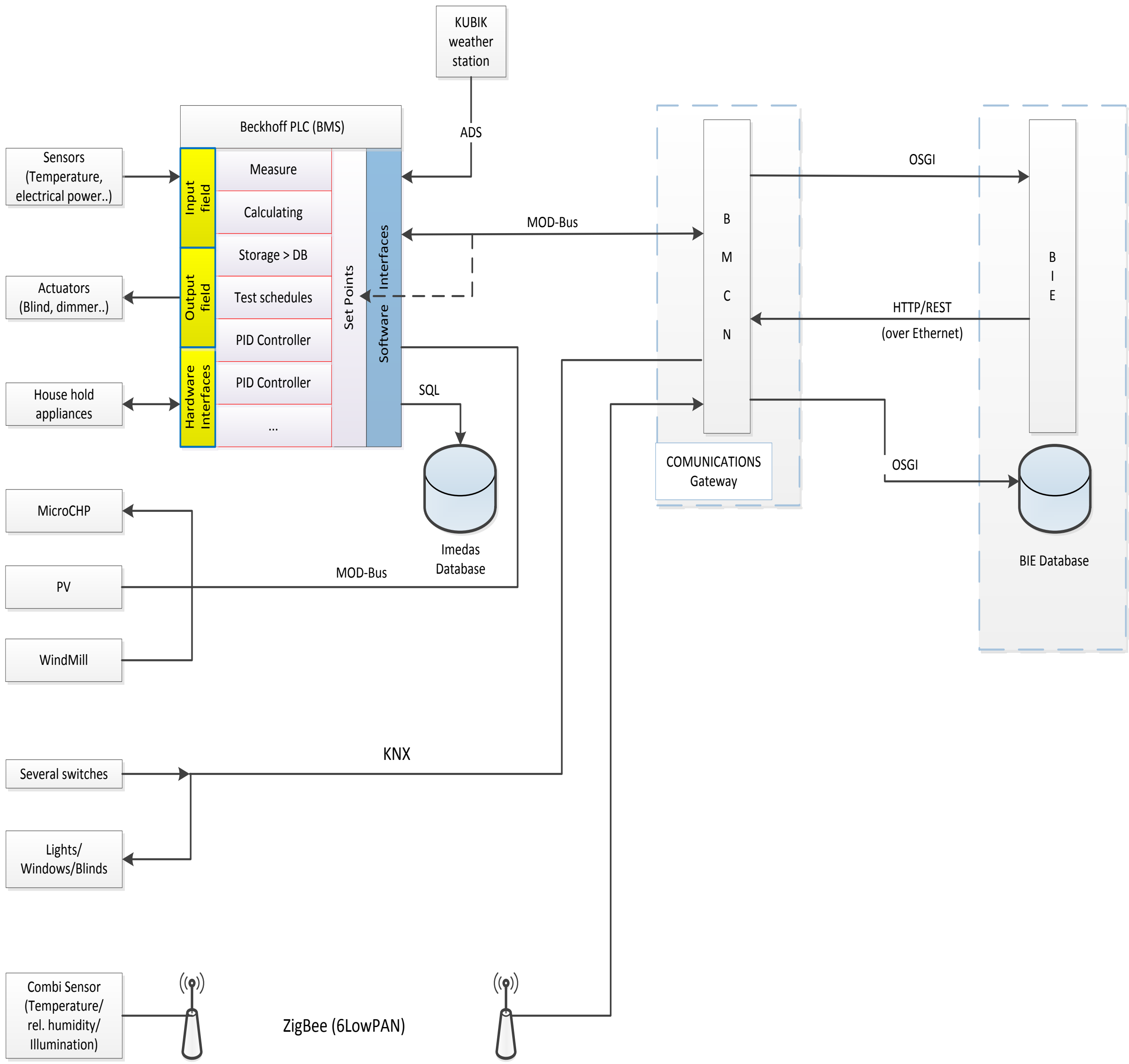
Schematic view of used test cells

There will be two controlled and measured cells, and the third one, which is called leisure room (spc_sp_3), will be used only to collect measurements through 6LowPan devices.The following table lists all the equipment, detailing their location as well as the number of them at each room:

	Living Room (spc_sp_6)	**Bed Room (spc_sp_2)**	**Leisure room (spc_sp_3)**
Automated Blind	**2**	**0**	**0**
Blinds Push Button	**2**	**0**	**0**
Automated Window	**1**	**1**	**0**
Windows Push Button	**1**	**1**	**0**
Automated Lighting	**1**	**1**	**0**
Light Push Button	**1**	**1**	**0**
Light Wireless Sensor[1]	**1**	**1**	**1**
Temperature Wireless Sensor	**1**	**1**	**1**
Humidity Wireless Sensor	**1**	**1**	**1**
Controlled Loads	**2**	**0**	**0**

KUBIK equipment locations

2.1.3 BIE installation at KUBIK

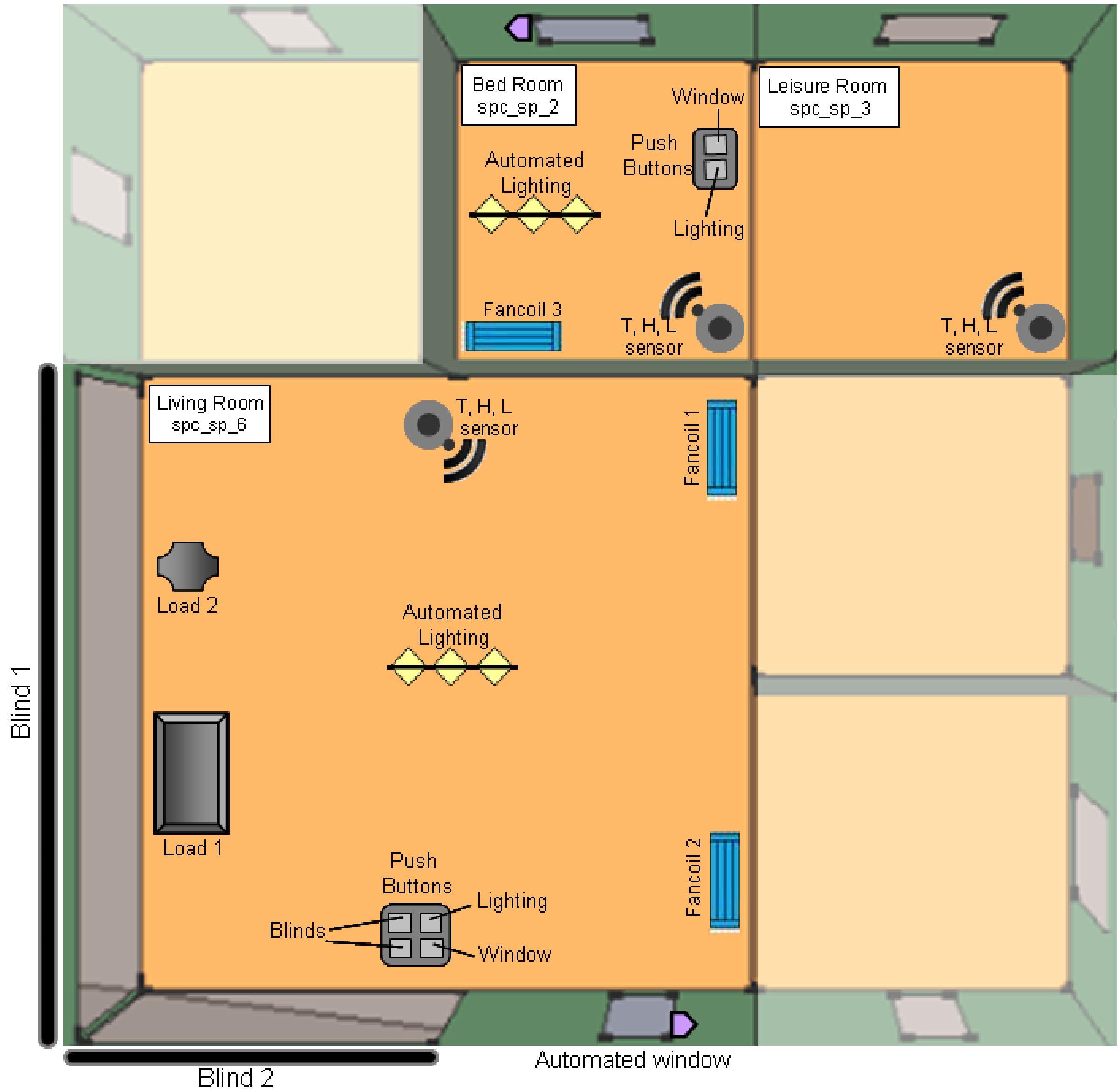


Overview about the BIE computer structure at KUBIK building

The above drawing shows the principle computer structure in the BIE KUBIK test area. The BIE system consists of the server- and the client-component – last with the connected I/O structure. This structure consists of the KNX field bus with operating elements and actuators for illumination (lights), blinds and automatic windows. The second part is the wireless network, over which the ZigBee sensors are connected. For all the remaining sensors, actuators and the household device a BMS/IPC system is responsible. The communication between the BMS and the BIE client is realised over the common Modbus protocol. This runs over a standard Ethernet connection. A secondary Modbus network is connected on the BMS. Over it data are received from the MicroCHP, the PV system and the wind generator. The MicroCHP is additionally steered over it.

2.1.4 Monitoring and Control Devices

The following figure visualizes the deployment of the main monitoring and control devices.



Overview about activated devices inside KUBIK

2.1.4.1 Sensors

2.1.4.1.1 Weather station sensors

KUBIK building already has a weather station that is complemented with radiation sensors. The data that are provided by this station are collected by the KUBIK's monitoring system. These data are offered to the BIE system through the KUBIK's MODBUS interfaces (see

Figure 3 4 Overview off the IT structure at KUBIK BIE building). From the BIE system point of view, weather data will be read as a standard MODBUS sensor.

Id	**Type[2]**	**Model[3]**	**Manufacturer**	**Interface[4]**	**Monitored Equipment[5]**
SE.01	PT100	WXT520 weather station	Vaisala	Modbus [6]	Outdoor temperature
SE.02	Air humidity sensor	WXT520 weather station	Vaisala	Modbus	Outdoor air humidity
SE.03	Ultra sonic anemometer	WXT520 weather station	Vaisala	Modbus	Wind speed
SE.04	Ultra sonic meter	WXT520 weather station	Vaisala	Modbus	Rain meter
SE.05	Pyranometer	CMP11	Kipp+Zonen	Modbus	Global radiation
SE.06	Pyranometer/ shading ring	CMP11 SR	Kipp+Zonen	Modbus	Diffuse radiation

KUBIK weather station data

[2] Physical sensor type of thermostat, light push button…

[3] Name of the manufacturer classification

[4] Name of the interface, over which the sensor is connected to the BIE or control system

[5] Name of the physical value or technical unit, which is captured over the sensor

[6] Although the internal KUBIK architecture is based on a Beckhoff Industrial PC that takes over the role of a building management system (BMS) with connected weather station, from the BIE point of view they are just another MODBUS sensor.

KUBIK's Local weather station and Solar radiation meters

2.1.4.1.2 KUBIK BIE sensors

Id	Type	Model	Manufacturer	Interface	Monitored Equipment[7]
SE.07	Push Button	MTN628319	Schneider	KNX	spc_sp_6 blind 1 up/down
SE.08	Push Button	MTN628319	Schneider	KNX	spc_sp_6 blind 2 up/down
SE.09	Push Button	MTN628319	Schneider	KNX	spc_sp_6 light on/off
SE.10	Push Button	MTN628319	Schneider	KNX	spc_sp_6 window open/close
SE.11	Push Button	MTN628319	Schneider	KNX	spc_sp_2 light on/off
SE.12	Push Button	MTN628319	Schneider	KNX	spc_sp_2 window open/close
SE.13	Tempera ture sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_6 air temperature
SE.14	Humidit y sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_6 relative air humidity
SE.15	Illumina tion sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_6 illumination strength
SE.16	Tempera ture sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_2air temperature
SE.17	Humidit y sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_2 relative air humidity

[7] All sensors are in 1st floor.

SE.18	Illumination sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_2 illumination strength
SE.19	Temperature sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_3 air temperature
SE.20	Humidity sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_3 relative air humidity
SE.21	Illumination sensor	CM5000-SMA	Advantic	6LowPAN	spc_sp_3 illumination strength
SE.22	Temperature sensor	CM5000-SMA	Advantic	6LowPAN	Base station (BMCN)
SE.23	Humidity sensor	CM5000-SMA	Advantic	6LowPAN	Base station (BMCN)
SE.24	Illumination sensor	CM5000-SMA	Advantic	6LowPAN	Base station (BMCN)
SE.25	Current meter[8]	MTN647595	Schneider	KNX	spc_sp_6 light current consumption
SE.26	Current meter	MTN647595	Schneider	KNX	spc_sp_2 light current consumption
SE.27	Current meter	MTN647595	Schneider	KNX	spc_sp_6 load 1 current consumption
SE.28	Current meter	MTN647595	Schneider	KNX	spc_sp_6 load 2 current consumption

SE.29	Thermal Meter	PT100 (Immersion sensor) + PT100 (Immersion sensor) + SIM flow meter (COPA-XM)	Beckhoff / BMS	MODBUS	spc_sp_6 fan coil 1 register thermal power consumption.[9]
SE.30	Thermal Meter	PT100 (Immersion sensor) + PT100 (Immersion sensor) + SIM flow meter (COPA-XM)	Beckhoff / BMS	MODBUS	spc_sp_6 fan coil 2 register thermal power consumption.
SE.31	Thermal Meter	PT100 (Immersion sensor) + PT100 (Immersion sensor) + SIM flow meter (COPA-XM)	Beckhoff / BMS	MODBUS	spc_sp_2 fan coil 1 register thermal power consumption.
SE.32	Thermal Meter	3x PT100 (Immersion sensor) + 3x PT100 (Immersion sensor) + 3xSIM flow meter (COPA-XM)	Beckhoff / BMS	MODBUS	spc_sp_6+2 total thermal power consumption

fancoil's temperatures and the water flow.

SE.33	3-phase power meter	EL3403 + current transformer	Beckhoff / BMS	MODBUS	spc_sp_6+2 total electrical power consumption
SE.34	3-phase power meter	CIRCUTOR CVM-Mini-ITF-MC-RS485-C2	Beckhoff / BMS	MODBUS	Renewable electrical energy generation power
SE.35	Calc. Value	MODBUS	Beckhoff / BMS	MODBUS	Thermal power generation by the microCHP
SE.36	Calc. Value	MODBUS	Beckhoff / BMS	MODBUS	Electrical power generation by the microCHP
SE.37	Calc. Value	MODBUS	Beckhoff / BMS	MODBUS	Total Gas consumption µCHP + Boiler)
SE.38	Thermal Meter	PT100 (Immersion sensor) + PT100 (Immersion sensor)	Beckhoff / BMS	MODBUS	Temperature at buffer vessel. It is calculated as the average between the upper section and the lower section temperature.
SE.39	PT100	Air temp. sensor	Beckhoff / BMS	MODBUS	spc_sp_6 air temperature height 10 cm
SE.40	PT100	Air temp. sensor	Beckhoff / BMS	MODBUS	spc_sp_6 air temperature height 110 cm
SE.41	PT100	Air temp. sensor	Beckhoff / BMS	MODBUS	spc_sp_6 air temperature height 170 cm
SE.42	PT100	Air temp. Sensor	Beckhoff / BMS	MODBUS	spc_sp_2 air temperature

SE.43	PT100	Air temp. Sensor	Beckhoff / BMS	MODBUS	spc_sp_3 air temperature

Table KUBIK BIE Sensors

2.1.4.2 Actuators

Id	Final controlling device	Actuator	Control interface/signal	Interface	Controlled Value / Unit
AC.01	Relay	MTN649908	Schneider	KNX	spc_sp_6 blind 1 up/down
AC.02	Relay	MTN649908	Schneider	KNX	spc_sp_6 blind 2 up/down
AC.03	Relay	MTN649908	Schneider	KNX	spc_sp_6 window open/close
AC.04	Relay	MTN649908	Schneider	KNX	spc_sp_2 window open/close
AC.05	Relay	MTN649908	Schneider	KNX	spc_sp_6 light on/off
AC.06	Relay	MTN649908	Schneider	KNX	spc_sp_2 light on/off
AC.07	Relay	MTN649908	Schneider	KNX	spc_sp_6 load 1 on/off
AC.08	Relay	MTN649908	Schneider	KNX	spc_sp_6 load 2 on/off
AC.09	Director[10]	Cx1010	Beckhoff / MBS	MODBUS	spc_sp_6 set point value for air temperature input device
AC.10	Director	Cx1010	Beckhoff / MBS	MODBUS	spc_sp_2 set point value for air temperature input device
AC.11	Director	Cx1010	Beckhoff / MBS	MODBUS	spc_sp_3 set point value for air temperature input device

[10] Value to be written by the BMCN to the KUBIK's BMS to provide cells with a temperature set point

AC.12	Person simulation dummy	Relay	½ EL2602 EtherCAT	Beckhoff IPC	spc_sp_6 Dummy 1 on/off

KUBIK BIE actuators

2.1.4.3 Energy generators

The following energy generators will be available at KUBIK:

- µCHP system: It is an integrated solution called *Dachs SE G5.5*, consisting of a µCHP unit and a buffer vessel
- Windmill: The available windmill is a Bornay INCLIN 6000,
- Photovoltaic module: There is a BP3150 module of polycrystalline silicon.

In the following table are summarized the main features of Kubik generators.

Feature	Value	Unit
µCHP Thermal power	12.5	kWt
µCHP Electrical power	5.5	kWe
µCHP Global efficiency	88%	[]
Buffer vessel volume	750	L
Buffer vessel maximum temperature	78	ºC
Buffer vessel minimum temperature	60[11]	ºC
Windmill nominal power	6	kW
PV module nominal power	3.6	kW

KUBIK generators data

RES integration at KUBIK

CHP+ Storage tank, Boiler and Chiller installed in KUBIK

2.1.5 Loads

The following loads, located at Living Room (spc_sp_6) are used at BIE validation:

- Load 1 (shift-able): Any shiftable Load
- Load 2 (curtail-able): Any shiftable Load

Apart from these, the following lighting consumption will be taken into account:

- Living Room (spc_sp_6): Lighting module
- Bedroom (spc_sp_2): Lighting module

Fan coils: Electrical power consumption of the fans and thermal consumption:

- Living Room (spc_sp_6): fan coils 1 and 2
- Bedroom (spc_sp_2): fan coil

3 Thermal network schema

KUBIK pilot site follows the apartment building or multi-dwelling approach with centralized HVAC supply. In this approach each apartment has an independent meter to measure its cooling and heating energy consumption.

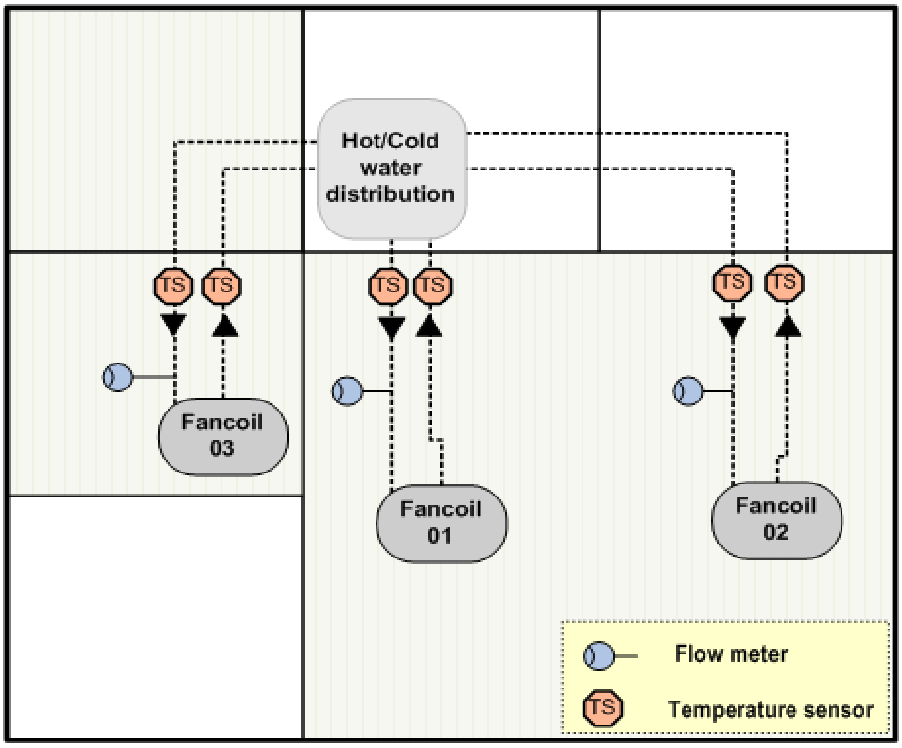
The heating/cooling energy meters, thermal meters, base their measures in the temperature drop/gain of a fluid (air or water) at the terminal units. Taking into account the mentioned temperature drop/gain, fluid's specific heat and the flow ratio it is possible to calculate the consumed thermal energy.

Due to some constraints imposed by the KUBIK's HVAC system design it is not possible to use a single meter to measure pilot site thermal consumption. The workaround has been to create a virtual thermal meter composed as aggregation of multiple (three) fancoil unit level thermal meters.

There are three water based fancoils involved at BIE pilot deployment. Two of them are in the Living room, while the third one is located at the Bed room. Regarding to the room temperature, the fancoils get cold or hot water from the KUBIK distribution system in order to maintain the desired temperature set-point.

For each of the fan coils there are installed water supply/return temperature probes as well as water flow meters. These values are only available at KUBIK's BMS level, there are not accessible from the BIE platform. The KUBIK's BMS makes the calculation of the energy balance at each of the units and calculates the aggregated value for all of them. Once this calculation process is done, the KUBIK's BMS makes the aggregated values available for the BIE platform through its ModBus gateway.

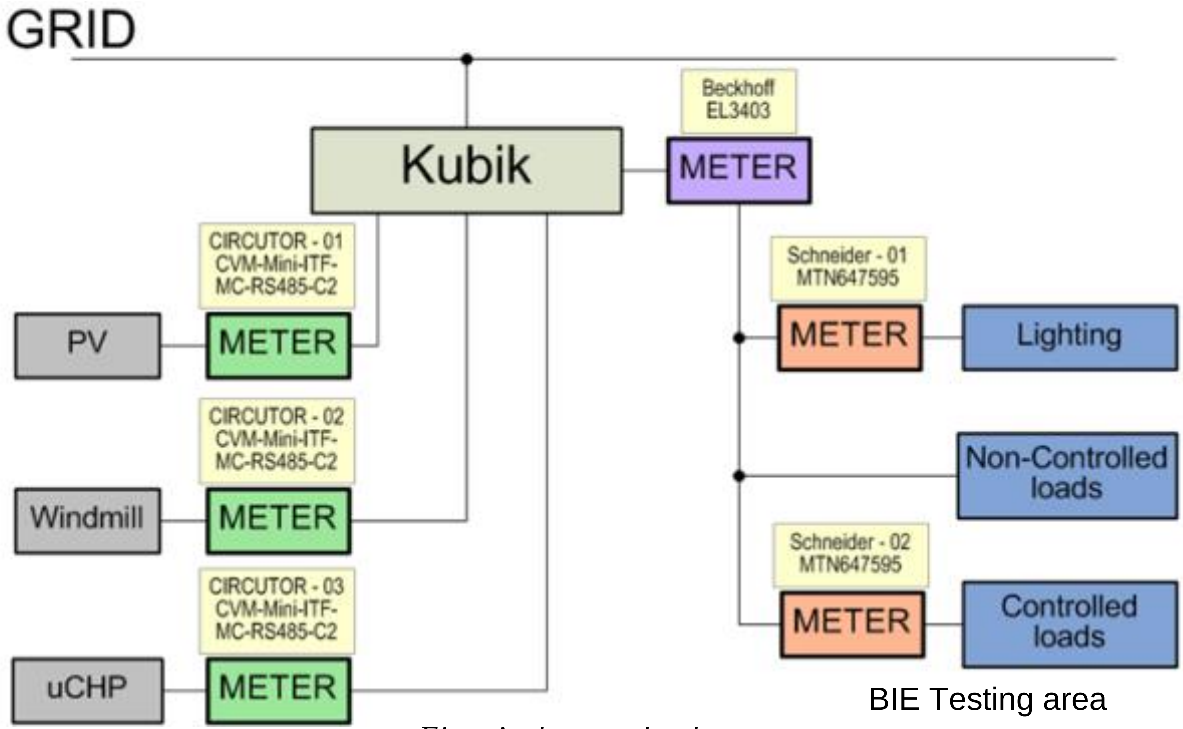
The following schema visualizes the thermal network handled by the KUBIK's BMS in which relay the thermal consumption calculation.



Thermal network schema

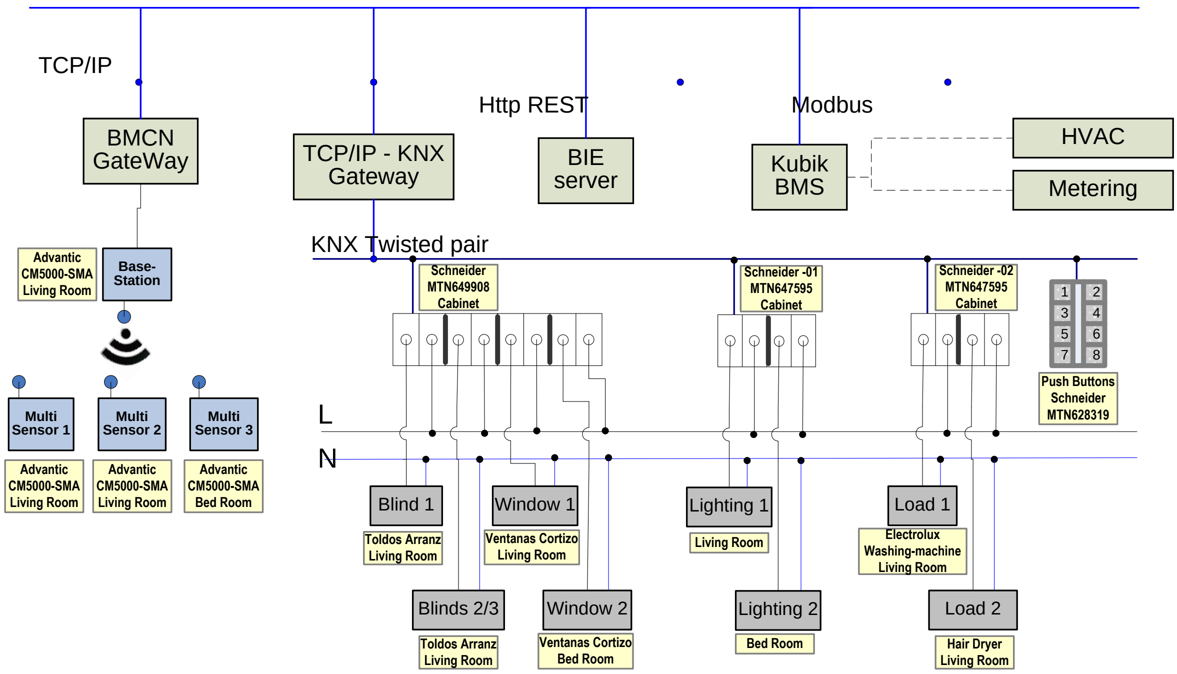
4 Electrical metering and Building automation network

The following schema visualizes the electrical metering energy network used during the BIE development and evaluation phase.



Electrical network schema

The electrical metering network is complemented with the building automation network shown in the following figure. It has to be noted that for the TECNALIA's BIE validation KUBIK's BMS has been accessed through the BMNC gateway but it can be accessed directly using the MODBUS TCP/IP interface.



Monitoring and control schema