D3.7 - Sets of embedded integrated control systems

H2020 MORE-CONNECT_633477_PERFORMANCE_MONITORING_AND_CONTROL_OF_INTEGRATED_SYSTEMS

Performance Monitoring and Control of Integrated Systems

D3.7 - Sets of embedded integrated control systems

Development and advanced prefabrication of innovative, multifunctional building envelope elements for **MO**dular **RE**trofitting and **CONNECT**ions (MORE-CONNECT)

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D3.7 - Sets of embedded integrated control systems and Task 3.6 Performance Monitoring and Control of Integrated Systems

Presented task regarding the advanced controls (task 2.7) and its integration (features and modular elements) to the panel evolved continuously. In the terms of working progress, the More Connect (M-C) progressed from prototype panels to pilots projects and able to prove and demonstrate its concepts.

M-C experimental house

General description of main components, including the implementation of the hybrid photovoltaic system with energy storage system

The concept of M-C experimental house project falls perfectly under the Horizon 2020 program and the EU Strategic Energy Technology Plan (EU SET-plan). The European energy system (and its transformation) is facing new challenges. The rapid implementation of intermittent renewable energy sources connecting to the power grids is creating disruptions to the EU energy market because of RES inherent volatility.

The key issue is to maintain a stable and safe electricity supply all the time. The grid stability and energy security have major economic implications as well. This situation requires innovative solutions related to these issues. It is well discussed that the consumption of electricity has to be perfectly matched with its generation at any moment in time. This system is called the Demand and Response (DR).

EU SET-plan with the aim of a single, smart European electricity grid is considering energy storage technologies as one of the key elements. Energy storage system (ESS) could help deal with fluctuations in demand and generation. The ESS allows the excess electricity to be stored and consequently released when there is a higher electricity demand.

Energy storage has other benefits as a grid stabilization, quality of power (in terms of voltage and frequency) sent back to the grid, improving the grid´s operating capabilities and peak-load shifting. Controlled energy storage at the time of surpluses and controlled supply of electricity in case of shortages or disruptions also have a great economic potential for both the large utilities as well as for domestic use.

Furthermore, the implications of energy concept of Demand and Response together with the energy storage automatically leads to efforts to accurately predict the weather fluctuations as well. There is a direct correlation between weather patterns and the energy output from RES. For example, the accurate prediction of short-term performance of the photovoltaic power plants together with the prediction of solar radiation plays a key role in addressing both the technical and economic impacts of the use of RES mentioned previously.

The M-C experimental house project would try to implement and thoroughly test the key innovative components in response to actual challenges and issues described above related to EU SET-plan.

The main components proposed for the M-C experimental house:

A. **Façade/roof hybrid photovoltaic system**
B. **Energy storage system**
C. **UCEEB PV Forecast service**
D. **Microgrid**
E. **Advanced controls, monitoring, optimization, application of multi-sensors**

Control system for modular components

Data and electrical connections in M-C panels

Figure 1 shows the schematic of the planned connections demonstrated in the prototype panel and later in Czech M-C pilot project. The control and home automation systems were based on the Czech company Teco a.s., which provides solutions that suit the projects goals and have a relevant market in the field.

As can be seen, were installed junction boxes in each panel that will have any electrical connections. In the shown scheme, a set of circuit breakers is provided to connect a possible 230 VAC socket, motor for blinds, electric heating control and RFox network router, besides RCD protection device. There was an individual energy meter that can be located in the box as well in the case of each flat in a M-C retrofitted building will need to separately provide energy consumption to the utility. All the standard procedures of electrical installations and protection measures for them stand.

An additional visualization of part of the electrical installations to be located in the M-C engine is shown in Figure 12. In it, the central unit for control and communication of all the indoor environments, electrical protection devices, and the communication buses and networks can be seen.

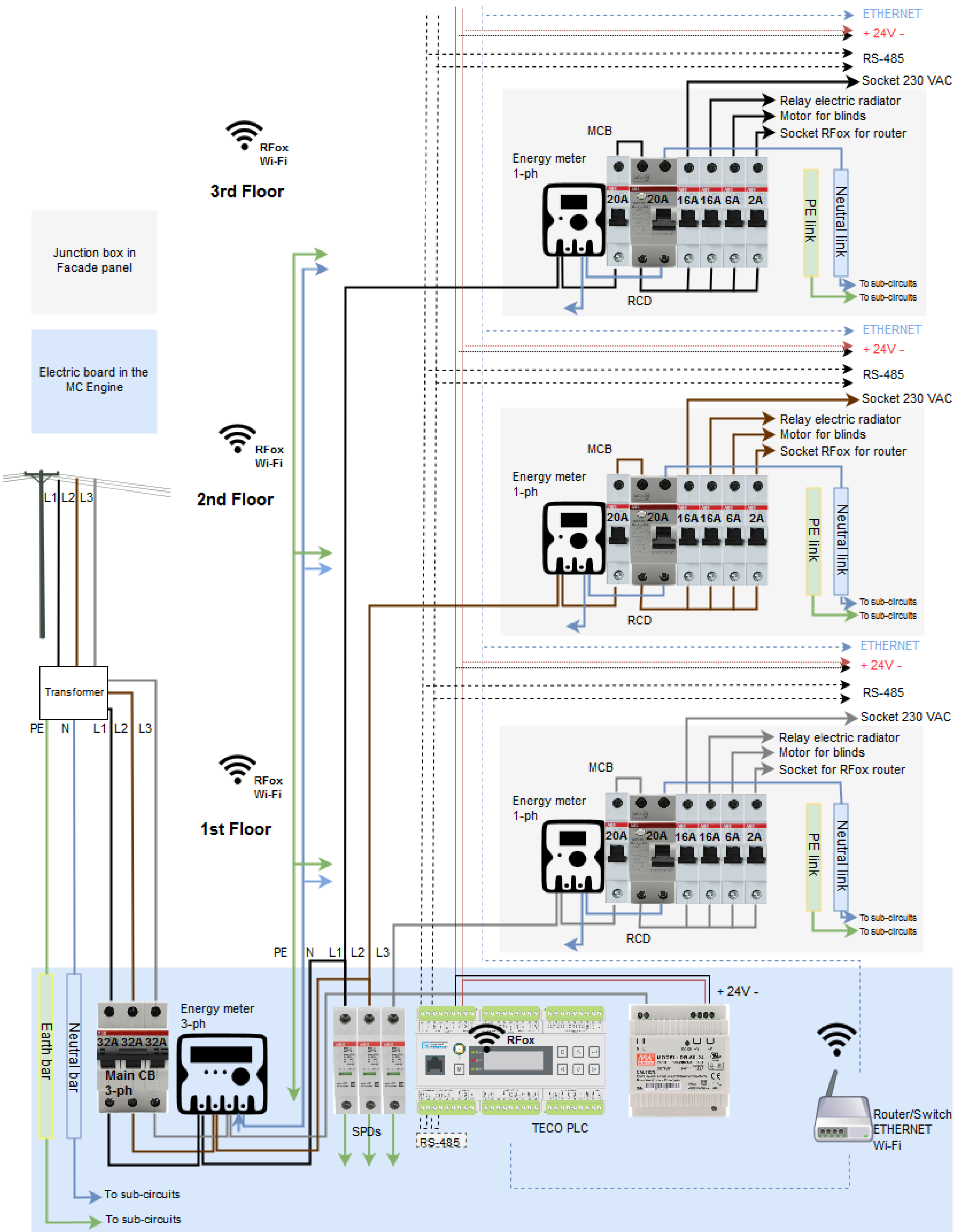


Figure 1 - Schematic of connections in the panel

List of devices present in the diagram

Junction boxes
Circuit breaker:
- Overcurrent: 1 x 20A as MCB; 2 x 16A for 230VAC socket and relay; 1 x 6A for motor; 1 x 2A for RFox router
- Residual current device: 1 x 20A;

Energy meter: 1 x single phase

M-C engine board
- Circuit breaker: 1 x overcurrent 3-phase 32A as MCB
- Energy meter: 1 x three-phase
- Surge arrester: 1 for each phase installed in accordance with standards' procedures
- TECO PLC: 1 x as central unit control for the devices present in the façade an in the indoor environment (blinds, heating, environmental sensors, operator panel, ventilation, moisture guard, etc. depending on what is offered)
- DC supply: 1x 24V as supply for PLC and as a possible supply bus present for connecting the operator panel on the façade panel (a device with LCD display and touch screen allowing the complete control of the whole environment)
- Router and ETHERNET Switch: Provides Wi-Fi and LAN connectivity.

Buses
- ETHERNET: For provision of internet, TV and communication of TECO operator panel
- RS-485: serial communication via MODBUS for MoistureGuard, Environmental Sensor and control of blinds; possibility of connecting any other devices that need serial communication (Ventilation control, e.g.)
- 24V: Power supply for TECO operator panel

Networks
- Wi-Fi: Wireless internet
- RFox: Wireless radio communication for TECO devices (see section Wireless sensor systems)

Control system description: programmable controllers produced by Teco a.s. company

PLC
A programmable logic controller (thereinafter PLC) is a digital control electronic system designed for control of industrial machines and processes within industrial environment. Through digital or analog inputs and outputs, the PLC receives and sends information from/into the unit being controlled. Control algorithms are saved in the memory of the user program that is executed cyclically.
TECOMAT FOXTROT
The TECOMAT FOXTROT PLCs are small and compact automatic controllers with a number of modular enhancements designed for any application in industry, transport, measurement and energy control etc. They unify the advantages of compact automatic controllers in size and the advantages of modules in expandability and variability. You may find in it all functions of big programmable controllers with IEC EN

61131 standard compatibility, even combined with latest technologies known better from IT, telecommunication and internet.

External modules

TECOMAT FOXTROT offers with CFox and RFox protocol modules, which are a logical extension of Foxtrot system especially for the field of intelligent building control and building management systems.

Communication

FOXTROT systems support basic transmissions via the Ethernet network or the EPSNET industrial Network (besides wireless RFox protocol). Also fitted with various types of physical interfaces for serial communication according to customer's specifications (RS-232, RS-485, and RS-422), industrial protocols and buses can be supported, such as MODBUS, PROFIBUS DP, CAN, etc. Eventually, asynchronous communication. Through universal transmission channels controlled directly from the user program is possible, too. All central units are standardly equipped with a 10/100Mb Ethernet interface allowing operation of more logic connections at a time.

Connection with PC

A PC can be used as a programming device and as a direct monitoring of the system. The computer configuration must be selected according to the software features (Mosaic, Reliance, ...). The TECOMAT FOXTROT offers a number of useful system services that makes the programming more simple and user-friendly. An example can be a wide range of time data, current date and time displayed or system support of the states handling while switching on the PLC power supply.

CP-1018 as basic module into M-C pilot house

The CP-1018 was chosen to be the central unit in the Czech pilot project as it differs from other basic modules by the number and type of inputs and outputs and indication or operation elements. The device is equipped with great number of multipurpose, analog and binary inputs, and offer also a good set of different outputs (TRIAC, PWM, analog and relays). The basic operation and displaying elements have a and 6 user push buttons, between other features, such as the expansibility and others, this CP offers.

Teco a.s. control unit (Programmable controller) - PLC Tecomat Foxtrot – basic module

CP-1018 - Basic module with 28 I/O for use in HVAC

DI	**1**	1x 230 V AC
DO	**11**	7x Relay, 4x SSR
AI	**10** **(4+6)** **+2**	AI0 - AI9 (RTD, can be configured as DI (24 V DC); AI4-AI9 (4-20mA,); AI10-AI11 (-20..+50mV, 0-2V)
AO	**2**	
COM		1x Eth 100, 2-3x Serial, 1x CIB, 1x TCL2, LCD 4x20 char., 6 keys
DESIGN		9 modules for DIN rail
CONNECTION		Removable screw type connectors

User's interactive device

ID-28 / ID-32: Operator graphic touch display & Microbrowser

Display	ID-28 640x480 pixels / ID-32 480x272 pixels
Keyboard	touch screen
I/O	
Power supply	24 V DC, screw terminal
COM	100Mbit Ethernet, RJ-45
DESIGN	Assembly into cover or door of control cabinet
SW	Built-in microbrowser for fast access to internal web pages of central modules Foxtrot and TC700

Operator panels ID-28 or ID-32 are meant to be used in co-operation with Foxtrot systems. Designed for built-in installation, the screen interface with the use can be created using Teco's WebMaker tool (in Teco's Mosaic development environment) and accessed via web server. They can interpret built-in web - displaying www pages in the central module and thus allowing the user complete control of its environment. Via this web feature, it is possible to access and monitor the states of system via any browser whether in a laptop or a smartphone.

Panels have a backlit LCD with a resolution of 640×480 pixels in ID-28, and 480×272 pixels in the case of ID-32. They are supplied from an external power supply of 24 V DC and communicates with a control system via Ethernet 100Base-TX with EPSNET protocol.

Such panels are intended to be demonstrated as a high-tech concept with the interaction between the user, sensor, and systems into what the controls will be a key feature to the consumer. An illustrative diagram of such idea is shown in the next section.

User control and data presentation

Tecomat control systems come with a built-in web server implemented. The web server is a standard part of the last series of processor modules developed by Teco and it can be used for two purposes. The first one is the control system with diagnostics, its basic settings and monitoring of basic states via common web browsers, without necessity of installing any special software. Further, the web server can be used for running of user's web pages. Customer can create for his device, machine, technology or building a web site with his own graphical interface. Web pages are stored in a memory card in XML format.

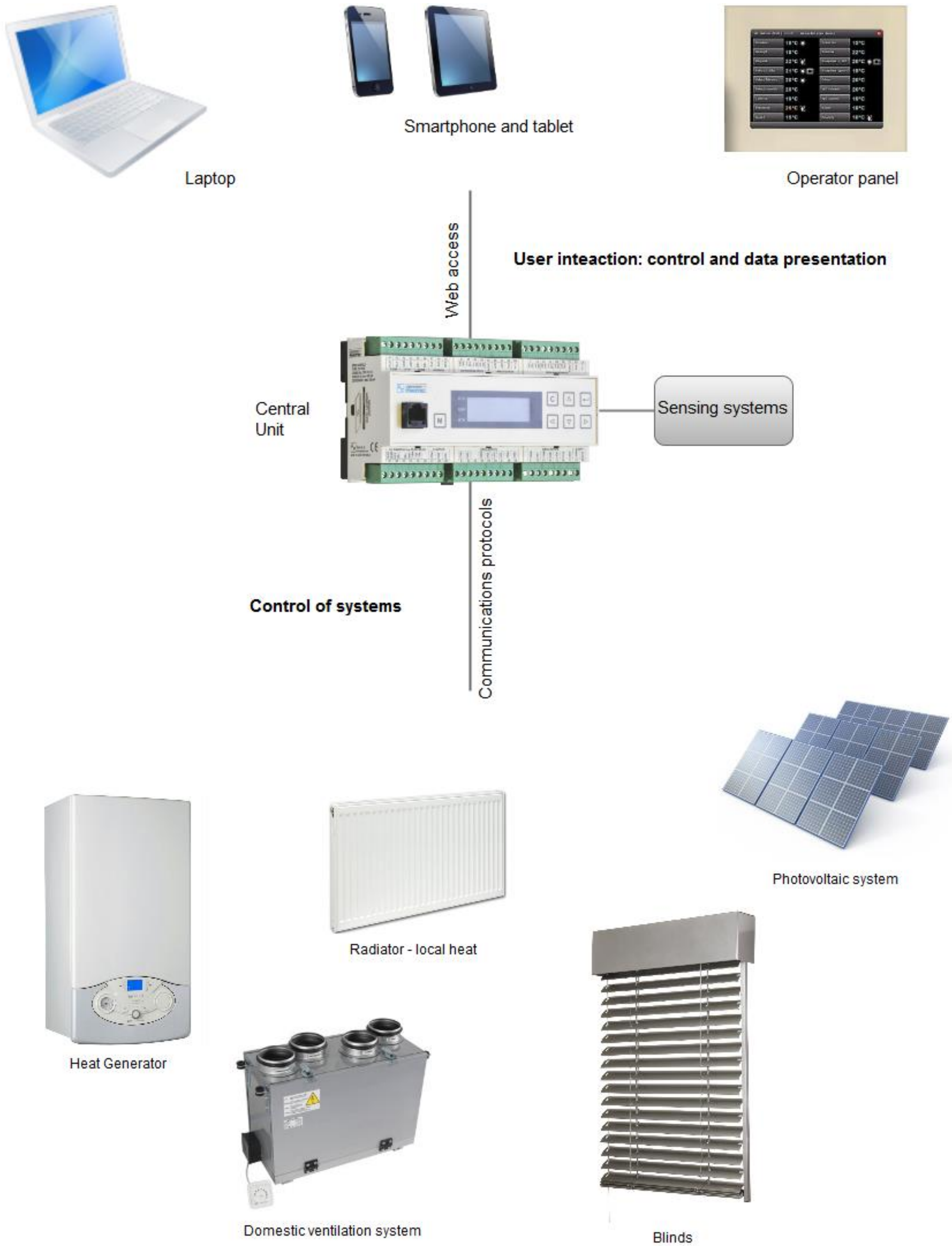


Figure 2 - Web access illustrative diagram for user control of diverse systems

Wireless sensor systems

RFox network

RFox network is a Teco a. s. wireless radio network operated in accordance with the Czech Telecommunication Office's General Authorization No. VO-R/10/05.2014-3 on the use of radio frequencies and the operation of short-range equipment. It operates in the unlicensed 868 MHz radio band; no other permission is required to operate it in the country.

RFox Parameters

Communication model	**Master-slave (up to 64 slaves per bus (master))**
Transmission power	**3.5mW (standard); 25mW (max.)**
Duty cycle	**1% max. (standard configuration)**
Frequency band	**868.35 MHz (license free ISM band)** **CEPT ERC/REC 70-03 General License**
Channels (Frequency range)	**8 (from 868.05 to 868.75 MHz)**
RF modulation	**FSK (frequency-shift-keyed)**
Type of communication	**Two-way (with confirmation packet)**
Baud rate	**19.2 kb/s**
Topology	**Star or Mesh**
Mode of operation	**Permanent or intermittent (sleep mode)**
Routing	**Max. 4 routers per bus (master)**
Range	**100m outside – 30m inside**

The communication between the RF master and RF peripheral module is supported for star (direct communication) and mesh topologies (direct and routing communication), see figures 3 and 4. The router (repeater) is a device that receives incoming RF packet, amplifies it and sends it further. By using routers, it is possible to increase the master's basic communication range. A maximum of four routers can be used in one RFox mesh network. The transmitted RF packet must reach its recipient after making no more than five hops.

It is important to highlight that each hop represents an increase in the time lag between sending and delivering of the packet and that either a dedicated RF router or any RF module in continuous operation can be selected for the function of the router (this function is assigned to the module during its configuration to the RFox network).

In terms of operation, the modules with continuous operation are always able to respond to commands from the master (they are mostly permanently powered modules), while the ones with intermittent operation go into the "sleep mode", during which they do not respond to master's commands (they are usually battery-powered modules).

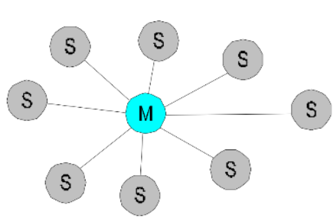


Figure 3 - Example of star topology

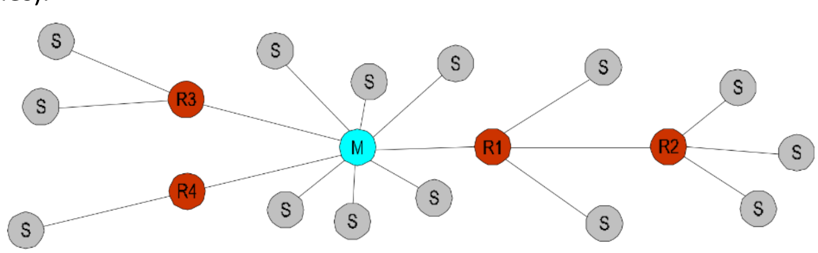


Figure 4 - Example of mesh topology

RFox connected devices

The following Teco a. s. devices will provide wireless solutions to the controlling problematics inside the building retrofitted with MORE-CONNECT panels.

R-HC-0101F - proportional head of radiator valve

DI		
DO		
AI	**2**	1x internal temperature sensor 1x external temperature sensor or window contact
AO	**1**	Valve position 0-100%
COM		RFox slave
DESIGN		For assembly to radiator valve, M30x 1,5 mm
CONNECTION		Integrated antenna, Power supply from battery

Basic features
- Motor control of head of radiator valve.
- Contains internal sensor of room temperature.

Connection
- Head mount on radiator valve only.
- It has no wire connections.
- Module is connected to RFox network by bonding process.

Use
- Regulation of hot water heating in rooms – radiator or floor heating.
- Direct fixing on radiator valve M30 × 1.5 or via reduction.

R-RT-2305W: RFox router

DI		
DO		
AI		
AO		
COM		1x RFox- wireless 869MHz
DESIGN		Socket adapter
CONNECTION		Into socket 230V AC

Description
The R-RT-2305W dedicated router is a network component of the R-Fox platform intended for delivering packets to devices out of range, especially where there is no other RFox module in range that could be used as a non-dedicated router.

RF-1131: RFox master

DI		
DO		
AI		
AO		
COM		1x RFox- wireless, 1x TCL2
DESIGN		1 module for DIN rail
CONNECTION		Fixed screw type terminals

Basic features

• The module is the gateway of Foxtrot system into the wireless data network RFox. It is the master of bidirectional communication (with confirmation of each data transmission) with slaves, and operates in the license free frequency band of 868 MHz.

• As coordinator/master of data network, this RFox module enables to connect up to 64 wireless modules with inputs and outputs to Foxtrot system.

• Module RF-1131 is not included in the limit of max. 10 modules on TCL2 bus.

• Module is operated on low power up to 10mW.

• Master module continuously monitors the network to keep the actual status of all slaves. This status image is available for central module anytime. Vice-versa the master module sends commands from the central module and writes new statuses to slave modules.

Connection

• Module is designed as a standard communication module at TCL2 bus.

• Mechanical design is suitable for installation on DIN rail.

• Antenna or cable can be connected on module directly with SMA connector.

Use

• Creation of wireless control system with centralized processing of signals and commands.

• Creation of wireless and wire system combination.

• Suitable for reconstruction of buildings in places, where we cannot install the electrical installation bus.

• For any application, where digital or analog values needs to be wireless transferred.

RC-RC-OO1R - Room Control Manager

DI		Rotation + press button
DO		
AI	**2**	internal temperature measurement NTC, external NTC
AO		
COM		RFox slave, internal antenna; LCD display
DESIGN		Plastic box on the wall with rotation button and feedback
CONNECTION		screw terminals for power supply

Basic features

• Wireless module for interior design in offices or residential facilities. Module is designed for visualization of status and setting required values (Room Control Manager).
• LCD displays the values (temperature, time, humidity, speed, heating, cooling) and many other graphic icons often used in HVAC field.
• Rotational element with pushbutton for confirmation is available to program individual needs over the menu.
• Built-in temperature sensor. Also possibility to connect external NTC sensor to choose suitable place of measuring, independent of device position.
• Module is freely programmable by user. Any icon or number can be controlled as a digital output. The operations of rotational element and its pushbutton are accessible to the programmer.

Connection

• Module is designed as standard device of radio network RFox. Power supply comes from battery.

Use

• Use as Room Control Manager in each room or space, where we require individual control of temperature and ventilation.

R-OR-001B - Output module for wireless network RFox

DI		rotation + press button
DO	**1**	Relay, switching contact 16A
AI		internal temperature measurement NTC, external NTC
AO		
COM		RFox slave, internal antenna;
DESIGN		Built-in module into installation box
CONNECTION		Integrated antenna Outputs embarrassed with CY 3x 1,5 mm2 Power supply 230 V AC

Basic features

• Module with one switching relay contact for power loads at 230 V AC.
• Power supply from 230 V AC. Wireless communication.
• Modules are designed for switching independent loads/devices by relay output.
• Relay is independently addressed and wirelessly controlled by central module via sending commands with confirmation.

Connection

• Module is designed as standard device of radio network RFox.
• Mechanical design suitable into standard installation box.
• Recommended installation position vertical, according to sign on the cover.

Use

• Used for switching the loads at 230 V AC, where we need to replace wire bus communication by wireless connection.
• During the project, contact load and its protection type should be taken into account.

BIPV façade, roof system key elements and options for both M-C experimental panel and M-C experimental house

M-C experimental house BIPV Facade

1) **PV cladding technology**
- Thin-film
- Monocrystalline
- Polycrystalline

2) **Façade system**
- Ventilated
- Non-ventilated

3) **Fitting Anchor methods**
- Mullion –transform
- Point-fixing such as clamp or undercut system
- Structural sealant glazing (SSG)

Each of these options has some advantages and disadvantages. Our pre-selected criteria for PV façade which would fit our needs are based on some specific aspects:

- Due to an issue with façade space restrictions our solution requires the use of monocrystalline/polycrystalline PV panels. They produce a greater amount of electricity than thin-film solar panels for the same amount of space (figure 5).
- We would consider PV modules specifically developed for the façade applications has considerably darker glass, black frame with the black backing lamination (in the case of frame modules) , or almost black panels with frameless construction. They have also small distance gaps with visually pleasant and clean uniform look.

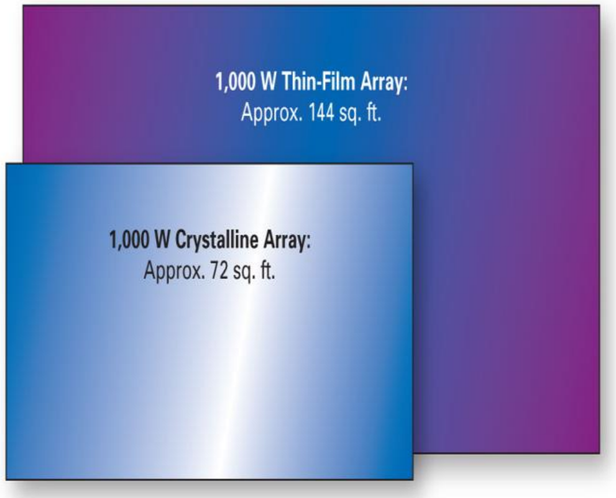


Figure 5 – Solar technologies. Source: http://www.homepower.com/articles/solar-electricity/equipment-products/solar-electric-options-crystaline-vs-thin-film

- Ventilated façade system was pre-selected due to the better aesthetic possibilities, elimination of the thermal bridges and condensation problems. Very important aspect of pre-selection criteria was the impact of so-called “chimney effect action” on thermal properties of BIPV panels.
  The ventilated façade system is creating the specific thermal conditions well suited for BIPV system.
  Firstly it is breaking the direct contact between the externally irradiated surface of PV panels and the thermal insulation thus greatly reduce direct heat transfer.
  Secondly, the airflow created by chimney effect in ventilation cavity would subtract the irradiation heat from the back of the PV panels (figure 6).
  There will be temperature sensors placed on the back of the PV module in predefined positions

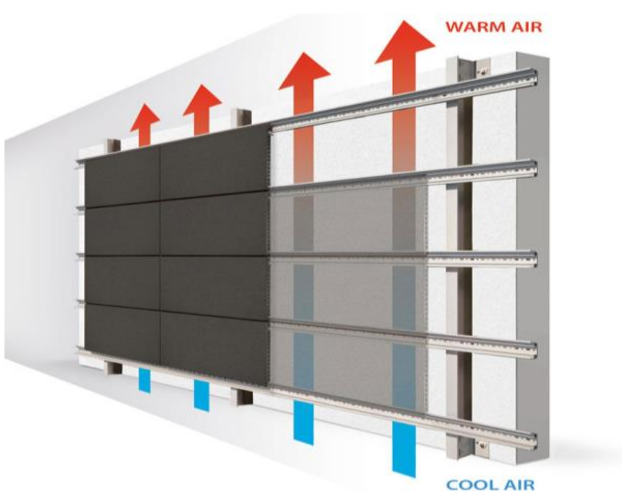


Figure 6 – Ventilated facades. Source: http://www.tempio.es/en/ventilated-facades.php

- Each of the fitting anchor methods has a different aesthetic impact on BIPV façade. In our case, we try to achieve the highest possible level of aesthetics of BIPV M-C façade.

Thus the clamp fixing or SSG anchor system would be more suitable for our project (figure 7).

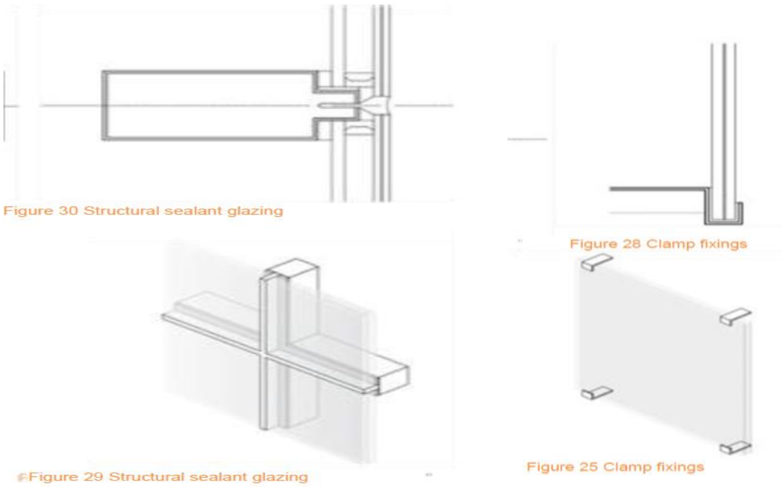


Figure 7 – Fitting methods. Source: http://www.polysolar.co.uk/_literature_138380/2015_Guide_to_BIPV

M-C experimental house BIPV Roof:

- Pitched roof east-west orientation with slope of 20°
- The PV system with east-west orientation
- PV modules based on monocrystalline or polycrystalline technology with high efficiency
- Solar insolation sensors and PV module temperature sensors

Position	Number of PV modules	Size of the PV system [kW]	Output 1 kW/Year (PVGIS estimate*) [kWh]	Total system output / Year [kWh]
Roof slope 20°/ Azimuth-90° east	8	2,16	794	1715
Roof slope 20° /Azimuth 90° west	8	2,16	790	1706
South façade 90° slope/ Azimut 0°south	6	1,62	633	1025
All surface areas-Total	22	5,94	2 217	4 446

Table 1 - Specifications of façade/roof PV system on M-C experimental house. Based on PV modules 270Wp. Different PV modules could be chosen during the design process

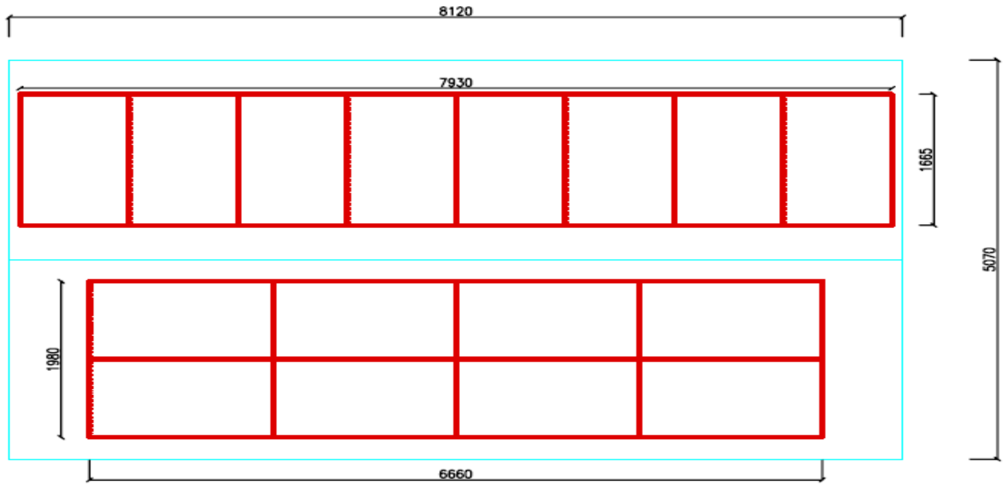


Figure 8 - M-C experimental house PV roof configuration (landscape or portrait orientation of the PV modules)

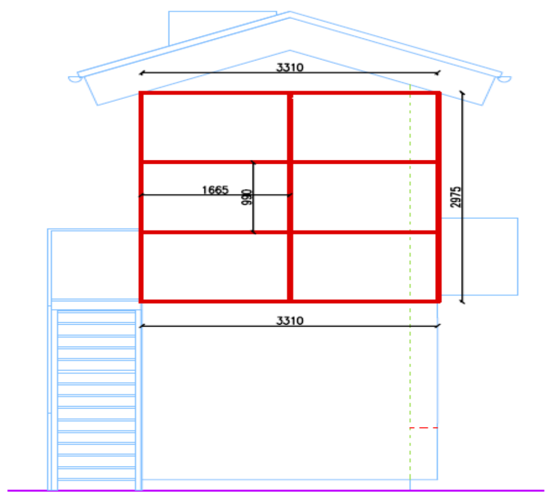


Figure 9 - M-C experimental house PV south facade configuration (landscape orientation of the PV modules)

There are two types of connection topology related to a solar hybrid system investigated in M-C experimental house. The connection is usually called AC coupling and DC coupling (Figure 10).

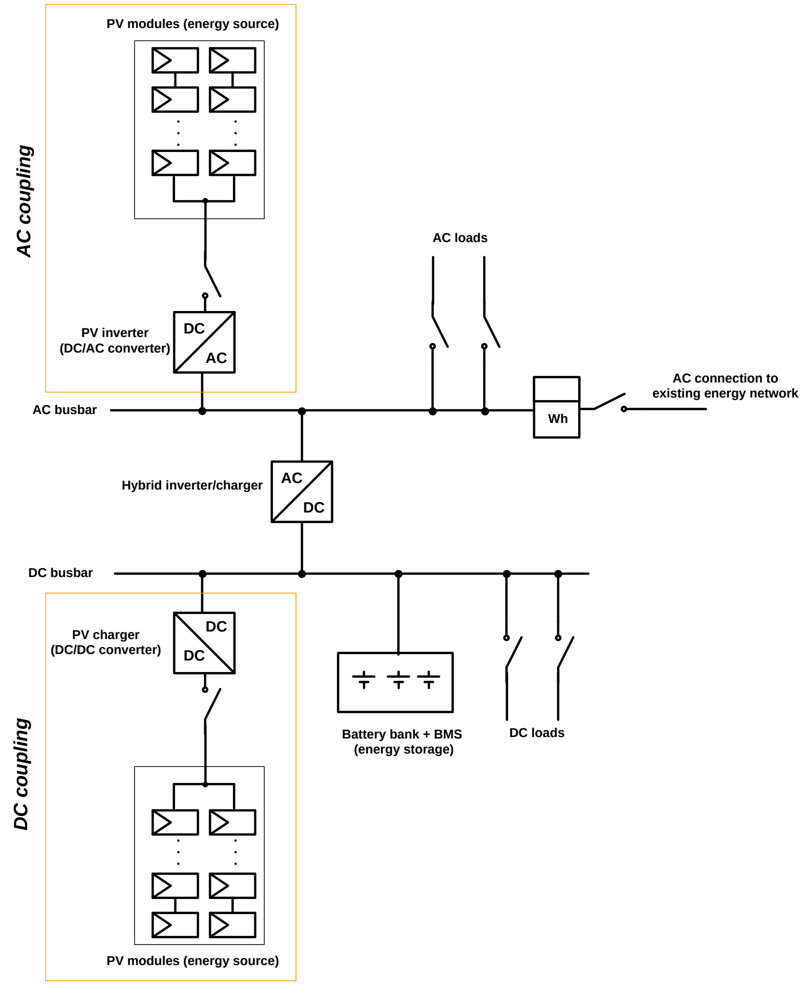


Figure 10 - Block diagram of the DC and AC coupling

The Hybrid roof and façade PV system supply energy for the loads – directly using AC coupling and indirectly using DC coupling (Figure 10). Both principles have their pros and cons, a mixed concept is in some cases recommended as well [1].

The system is precisely monitored and data evaluated. This will enable to specify and present the pros and cons of both principles (AC and DC coupling), to find optimal control procedure and methodology for optimal system design and control.

Also, several types of operation will be tested – hybrid operation with a distribution network, stand- alone system, micro-grid system cooperating with main UCEEB building and technology which is installed nearby (e.g. CHP unit). The control is based on innovative approaches to PV forecasting, demand response techniques, model predictive control, and intraday tariff.

Brief description of electrical concept (Figure 10):

A mixed concept of AC and DC coupling was implemented. This will enable for testing purposes to run the system in all three states (AC, DC, AC+DC coupling). AC coupling shows usually better performance if energy is directly consumed when generated (during the day), on the other hand, DC coupling is suitable for loads running most time when there is no PV source present (during the night). Hybrid inverter/charger will be the main unit to transfer the energy between the DC and AC bus bar; it will enable an autonomous operation as well (switching off the grid and running the local grid in autonomous mode).

The whole system is electrically connected to existing energy network of UCEEB research center, the energy control system will enable both – fully autonomous control and operating the UCEEB building and technology together to support each other.

[1] New Trends in Hybrid Systems with Battery Inverter. Pierre-Olivier MOIX. Proceedings of Small PV-Application 2009. Ulm, Germany.

Energy Storage System

M-C experimental house has PV system with battery storage implemented. The battery storage system consists of a series of characteristic components. For each of these components, there are several basic types according to the materials used, production technologies, technical design or topology. Yet the most important component of all is the battery technology itself.

Battery storage system combined with the photovoltaic system allows storing the excess power produced by the PV system. It can be then used to offset peak load or nighttime use. Another possible use of the battery storage system is to buy the energy at the time of its low cost (low tariff, off-peak) and use it at a time when the electricity from the grid has a high price typically during the peak load time (figure 11)

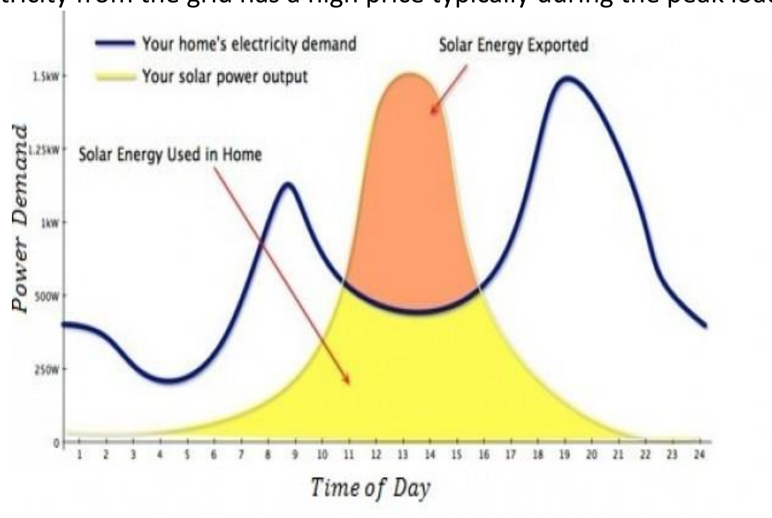


Figure 11 – Power demand. Source: http: //www.goingsolar.com.au/what-we-do/solar-electricity-hybrid

Batteries

The market with battery technology is evolving dramatically. Focus is on improving main battery characteristics like the high number of cycles (life), the possibility of charging / discharging with high currents, the possibility of cycling with deep discharge, low self-discharge rate, and low maintenance.

The newest types of the batteries on the energy market are Lithium Iron Phosphate ($LiFePO4$) and Lithium Titanium Oxide (LTO), which are characterized by a very high number of cycles, high safety, charge / discharge rate and resistance to temperature fluctuations. Their main disadvantage is the high purchase price.

The new types are also so-called „flow batteries“. Vanadium Redox (VRB) and Zinc Bromide (ZNRB) are the most common. The flow technology is based on the electrochemical reaction of reduction-oxidation, which is used for energy storage and subsequent retrieval of electricity. There is an electrolyte divided into two separate containers and the special membrane that allows the passage of ions (figure 12).

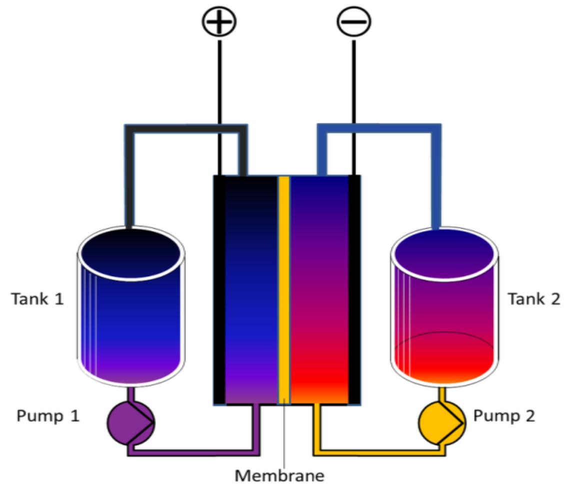


Figure 12 - Flow battery. Source: https://en.wikipedia.org/wiki/Flow_battery#/media/File:Redox_Flow_Battery_English.png

The main advantages of the flow technology are theoretically an unlimited number of cycles, in practice, approximately 15,000 (membrane as one of the few elements of the system that must be changed over the time), no degradation of the electrolyte.
The main disadvantage of this technology is the low energy density (about 20 kWh/m3 or 25Wh/kg). This means that it is quite a large and heavy battery more suitable for industrial applications. Some companies start to introduce smaller units for residential market applications as well.

The main parameters of the batteries:

- Voltage [V]-The batteries are composed of a number of cells. The batteries are usually assembled into a battery bank with a voltage of 12V, 24V or 48V.
- Battery capacity [Ah]- is the discharge current a battery that can be delivered within certain time.
- C-Rate [C] is a measure of the rate at which a battery is discharged / charged relative to its maximum capacity
- The Depth of Discharge (DOD) [%] - is expressed as a percentage and determines the percentage of operational discharge of the battery providing the desired service life.

Parameters	NiCd	Ni-MH	Li-ion	LiFePO4	LTO	Pb
Specific energy density [Wh/kg]	45-80	60-120	90-120	90-120	50-70	30-50
Cycle life (80% discharge)	1500	300-500	>1500	2000+	10000+	400-500
Lifespan [year]	5 years	3-4 years	10 years	10 +years	25 years	10 years
Self-discharge [%]	20 %	30 %	5-10 %	3-5%	1,5-2,5%	5 %
Cell nominal voltage [V]	1,2 V	1,2 V	3,3 V	3,2 V	2,4 V	2 V
Price [EUR/Wh]	0,33	0,65	0,33	0,60	1,5	0,11

Table 2 - Key battery parameters for different chemistry types

Producer	Chemistry	Parameters	Sale Price (CZK)	CZK/kWh
Fronius Solar Battery 12.0 Li-ion	Li-ion	12 kWh, 8000 cycles 80% DoD	292 240,- (2)	24 353,-
Hoppecke, OPzV bloc solar power 180 Pb	Pb	12V, 2,16 kWh, 2700 cycles 50% DoD	17 010,- (1)	7 875,-
Hoppecke sun powerpack classic Li-ion	Li-ion	48V, 11,0 kWh, 2500 cycles 50% DoD	65 715,- (6)	5 974,-
Victron Energy, Lithium Battery-BMS Li-ion	Li-ion	12,8V, 2,56 kWh, 5000 cycles 50% DoD	60 166,- (4)	23 502,-
Winston 12V90AH LiFeYPO4	LiFEYPO4	12V, 1,08 kWh, 6000 cycles 50% DoD	14 008,- (3)	12 970,-
GWL/EV-Power LiFePO4	LiFePO4	12V, 1,092 kWh 2000+cycles 80% DoD	12 933,- (5)	11 843,-
GWL/EV Power LTO	LTO	2,4V 0,096 kWh 10000+cycles 80% DoD	2 080,- (5)	21 666,-

Table 3 - Examples of batteries and prices (the Czech Republic market)

Producer	Chemistry	Parametres	Sale Price [CZK]	CZK/kWh
Tesla PowerWall Li(NiMnCo)/Li(NiCoAlO2)	Li(NiMNCo) Li(NiCoAlO2)	7 kWh/10 kWh 5000 cycles 100% DoD	72 360,-/105 000,- (8)	10 337,-/ 10 500,-
Sonnenbaterrie ECO4/PRO LiFePO4	LiFePO4	4-16 kWh/24-96 kWh	Od 145 000,- (including inverter) (8)	36 250,-
SafeBOX Home SBH 2,6-4,5-2,3/2,6-7,5-3,5 LiFePO4	LiFePO4	4,5 kWh/7,5 kWh 4000 cycles 95% DoD	*149 000,-/*194 000,- (7)	33 111,-/ 25 866,-
ElectroIQ Power All in One	Li-ion	10kWh 8000+ cycles 80% DoD	384 720,- (11)	38 472,-
ABB React REACT-3.6/4.6-TL (jen baterie)	Li-ion	2kWh 4500 cycles 94% DoD	85 003,- (14)	9 775,-/ 8 238
Bosch BPT-S 5 Hybrid	Li-ion	4,4-13,2kWh 6500 cycles 50% DoD	590 012,-/ 1 111 930,-(13)	134 093,- / 84 237,-
Varta Engion Family	LiFePO	3,7-13,8 kWh. 6000 cycles 80% DoD	351 842,-/ 541 296,- (12)	95 092,-/ 39 224,-

*Table 4 - Examples of residential battery storage systems so-called home batteries (*prices without VAT)*

Technical Specifications	Total price [CZK]	Technical Specifications	Total price [CZK]	Technical Specifications	Total price [CZK]
3 kWp Set ,10x Sharp 285W,1x3,0 kW hybrid měnič Solax, baterie Pro Solax LiFePO4 4,8 kWh (6)	171,380,-	5 kWp Set ,20x Omsun 250 W 1x5 kW hybrid měnič Solax,baterie Pro Solax LiFePO4 7,2 kWh (6)	229 455,-	8,67 kWp, 34xAmerisolar 255W, Kostal Piko BA 8, Wattrouter ECO+SSR relé,baterie Li-ion 12kWh (1)	718 000,-
3,18 kWp, 12xPolySol 265 W,1x 1 x Fronius Symo Hybrid 3.0-3-S, Fronius Solar Battery LiFeYPO 4,5 kWh (9)	*304,900,-	5,22 kWp, 36xNexPower NT145AX,1x Studer Xtender XTM 4000-48,regulátor, Studer,16xWB-LYP300AHALiFeYPO4 15,36 kWh (9)	*425,800,-	7,50 kWp, 30xWinaico WST-250P6, 3 x Studer Xtender XTM 2400-24, 2 x Studer VarioTrack VT-80´+MPP, Batterie 24 x MOLL OPzV solar 2 V / 710 Ah 34,00kWh (9)	*555 900,-
3,18 kWp, 12xKyocera KT 265 6MCA, Fronius Symo Hybrid 3.0 - 3-S, Fronius Solar Battery LiFeYPO4 7,5 kWh	*352,865,-	5,3 kW,20xKyocera KT 265 6MCA, Fronius Symo Hybrid 5.0 - 5-S, Fronius Solar Battery LiFeYPO4 9 kWh	*465 580,-		

Table 5 - Examples of complete sets of PV and battery bank (price without VAT)*

Sources:
(1) Frankensolar Eastern Europe s.r.o., Kostelecká 59/879, 196 00 Praha 9, Česká republika
(2) Silektro s.r.o., Perunova 17, 130 00, Praha 3
(3) Ing. Martin Kolařík, ostrovni-elektrarny.cz, Náves 112, Vlkoš, 751 19
(4) Neosolar spol. s r.o., Stavbařů 4334/41, 586 01, Jihlava
(5) i4wifi a.s., GWL/EV-Power, Průmyslová 11, 102 19 Praha 10
(6) Nanosun s.r.o,, Křižíkova 36a, Praha 8
(7) Fotovoltaické systémy, Slunečná 342,751 11 Radslavice
(8) http://oenergetice.cz/technologie/elektroenergetika/souboj-domacich-baterii-sonnenbatterie-vs-tesla/
(9) SOLARENVI a.s., Dukelská 145, 379 82 Třeboň
(10) Sun Pi s.r.o. Sedláčkova 472/6, 397 01 Písek
(11) electriqpower.com
(12) Swonia Tržiště 372/1,Praha 1, 118 00
(13) http://www.enter-shop.com.au/catalogue/c3/c44/c261/p1254
(14) ABB s.r.o., BB Centrum budova Delta II, Vyskočilova 1561/4a ,140 00 Praha 4

PV-battery systems development in relation to EU SET-plan

Despite the fact that the market for hybrid systems combined with battery storage in the Czech Republic is influenced by many specific factors, in the long term is to assume an inevitable upward trend following the trend in the EU energy market as a whole. Here are some examples of trend prediction:
In figure 13 the market volume is displayed with the PV energy storage for the private sector in the size up to 10kWh net capacity. Here is clearly shown a rapid increase in the market volume of the storage for the whole European market.

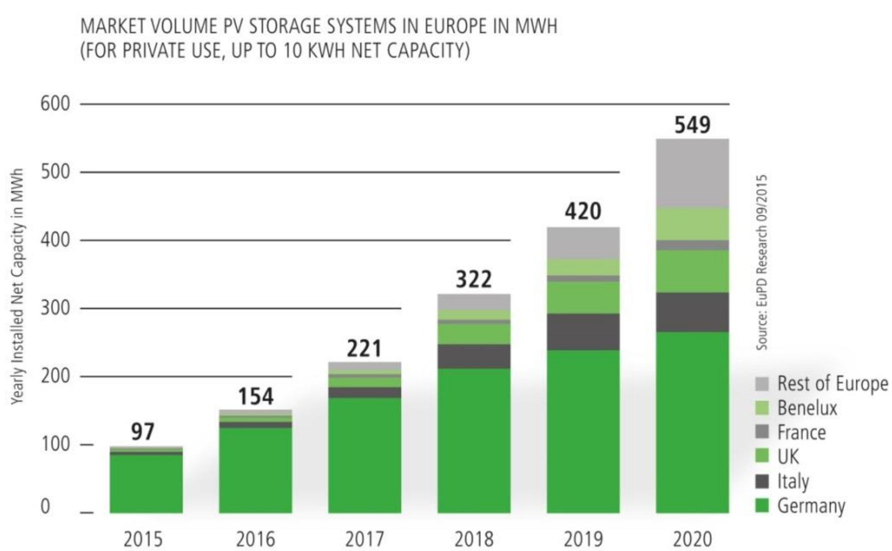


Figure 13 - Expected development of the capacity of residential PV systems to store energy in Europe. Source: http://www.ees-europe.com/en/news-press/press-material/market-information.html

The next figure 14 shows the price index development for battery storage system costs according to technology used in the previous years.

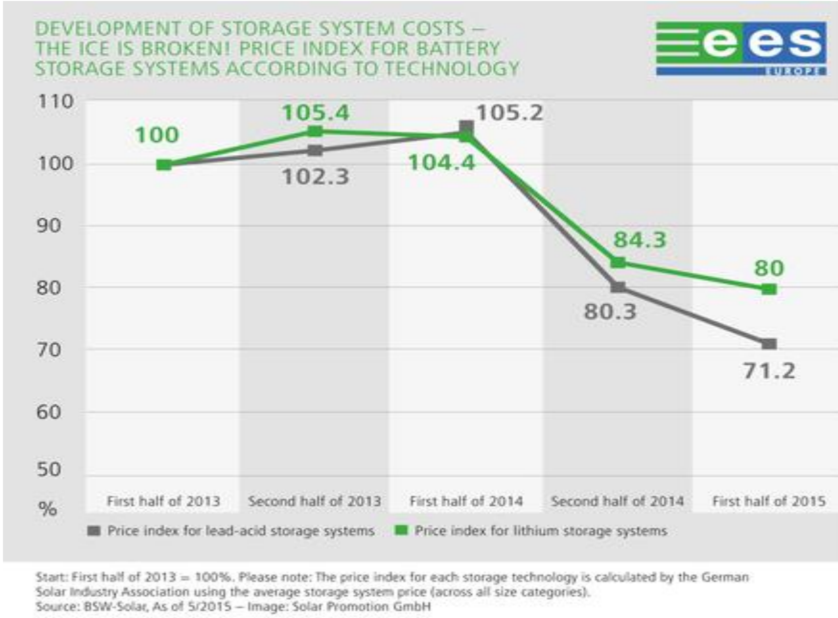


Figure 14 - The expected price development of energy storage system. Source: http://www.ees-europe.com/en/news-press/press-material/market-information.html

Below is the forecast information from another source with the clear uptrend displayed. There is an interesting detail about new storage systems installation projections outside German market (Figure 15).

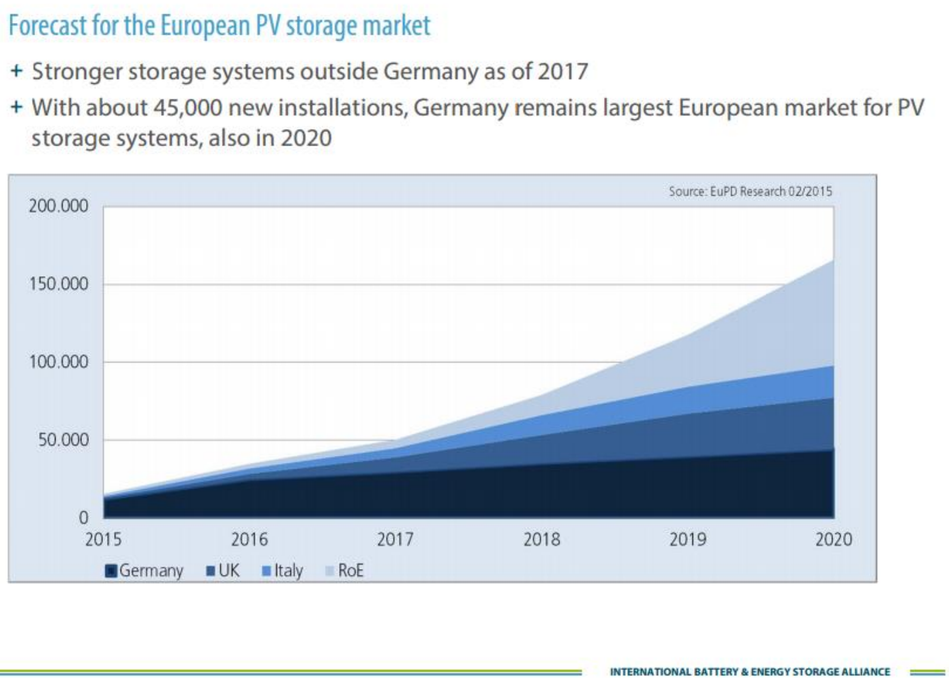


Figure 15 - Estimated market with PV systems, energy storage Number of new systems. Source: http://ibesalliance.org/fileadmin/content/download/presentation/Markus_AW_Hoehner_Smart_Cities_Renewable_Energy_Storage.pdf

Other factors that greatly speeds up the number and size of the installed battery storage on the European market are:

1. The EU's stabilization and balancing electricity system in connection with the need to integrate an increasing amount of RES

2. The pressure to reduce expenses on maintaining the balance of power in the EU distribution electricity network closely related to so-called the emergency disconnection of RES (such as solar or wind power).

3. Falling prices of hybrid PV systems and battery storage speeds up the number of installations for both the private sector and for industrial applications as well.

4. European energy reform in progress as an Energy Technology Plan (EU SET-plan)which would focus more on power generation, transmission, and smart grids.

5. The increasing demands on the energy security of transmission and distribution systems across the EU in the event of major and unexpected outages and disruptions.

PV forecast service to control PV hybrid system

As shown in figure 22 the main energy demand peaks in residential segment happen in periods where the PV production is generally low. Hybrid system containing batteries is able to store the energy generated by PV and use it in later time when the demand exceeds actual PV power. The batteries enable building to switch to tariff supply only and to minimize the energy supplied from the grid. The batteries the charge only during night low tariff (Dual tariff structure Czech Republic) and discharge during the day in high tariff periods. Therefore, the supply from the grid is minimized and energy bills reduced.

The night tariff charging can be improved by knowledge of forecasted PV energy for the next day. When the advanced energy management system knows the predicted amount of energy generated in the coming day (or two, depending on the total battery capacity), it can set the charging level only to a desired point to cover the night and morning demand and to use fully the day PV energy for charging as well as for covering the actual day demand of the building. Such a control mechanism will eliminated situations where the PV energy during the day exceeds the day consumption and the batteries are fully charged (e.g. from night charging). Such situations are not efficient because the system cannot generate as much energy as is available.

More connect advanced energy management system will use the PV forecast service to get the information of the predicted PV power to eliminate situations mentioned in previous paragraph and to increase the energy efficiency of the whole system. The main parameters of the service are summarized in following points:

- Irradiance forecasting for next 24/48 hours with one hour step
- Uses multiple forecasting sources to improve reliability and accuracy
- Standardized requesting commands using http
- Selectable format of the responding forecast data
- Easy to implement in PLCs and automated control systems

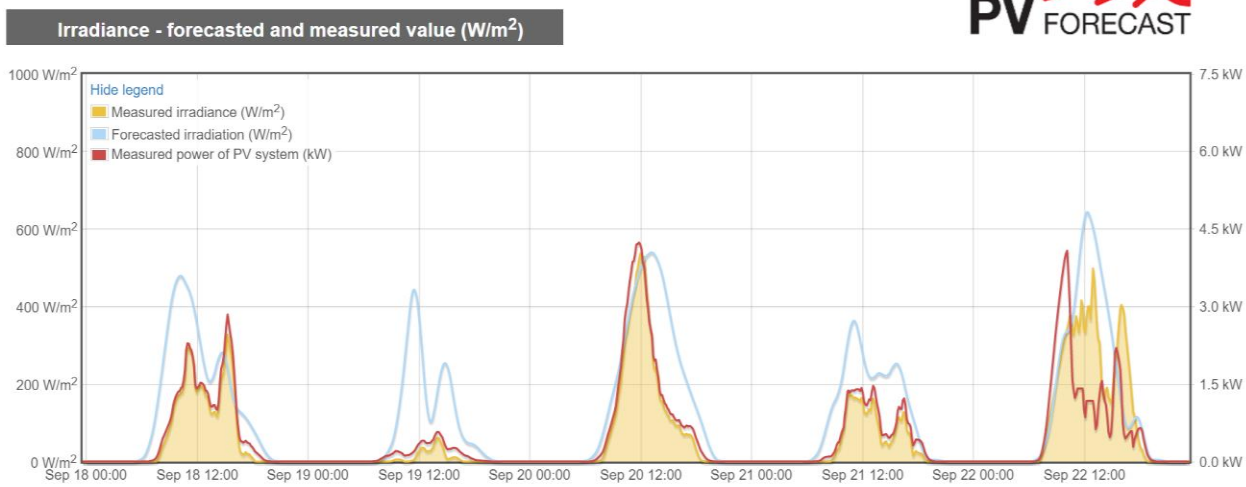


Figure 16 – PV Forecast

Micro Grid

The M-C experimental house is incorporated as an integral part of UCEEB Microgrid (figure 17). It will play an important role in energy demand management, storage and generation.

In the first step, we demonstrate the advantages of micro grid on the inner grid of our research center where we already operate different energy sources (gas boilers, CHP unit, PV, Lithium battery, among others) and collect data on energy production, operating data (indoor and outdoor temperatures, solar irradiance, and possibly other data as well). The research center composes of administrative rooms and laboratories that can be separately measured and evaluated.

As part of the M-C experimental house, we would measure and analyze the new energy data. Based on the data collection process we will create an efficient control algorithm which will be based on model predictive control strategy (MPC).

Next step would be the utilization of the algorithm to fully control the M-C experimental house related to UCEEB microgrid as a whole and evaluate the results in order to see the benefits, issues, and areas of possible improvements.

The research would focus on optimization of M-C experimental house with a hybrid photovoltaic system connected to energy storage system within the concept of the smart grid.

Another important focus area would be the short term weather prediction so-called “nowcasting”. Within the M-C experimental house project, the research team would adapt our PV Forecast service to new requirements for the intraday energy trading platforms and use new equipment (RaZON+ ALL-IN-ONE Solar Monitoring System with pyranometer and PH1 pyrheliometer) to refine short-term PV-forecast service.

The main aim would be to precisely predict and control energy fluctuations, the microgrid balancing, peak-load shifting, improvement of electric power quality(voltage / frequency) and demand – response control. These elements are now critical for the concept of the smart grid in the whole EU electricity distribution network.

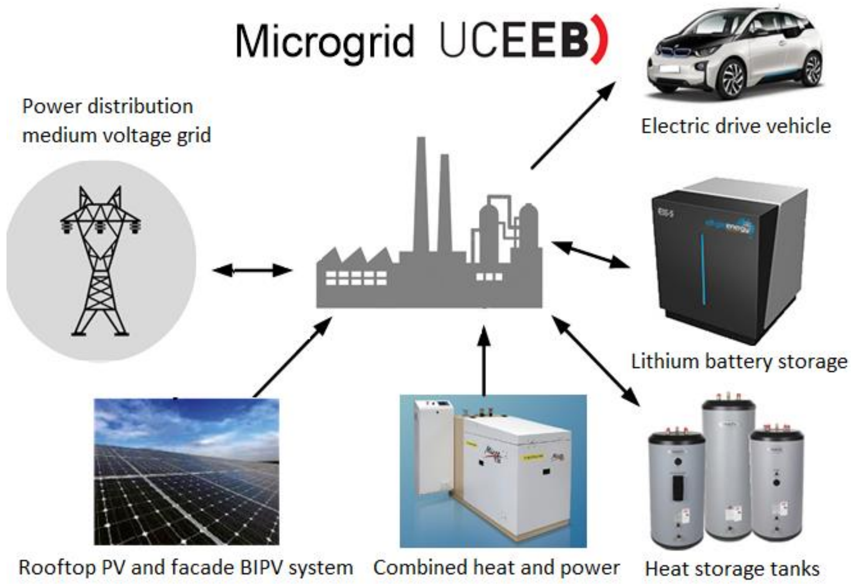


Figure 17 – Micro grid UCEEB providing heat and electrical energy for laboratories and administrative rooms

Wood moisture monitoring – MoistureGuard

MoistureGuard is a unique system for continual monitoring of moisture content within the wood and was developed to be integrated directly in the MORE-CONNECT wooden façade structure. System is able to detect the health of the wooden parts continuously and to detect problem related to vapor condensing, leaks or high levels of moisture in the structure that are not easily discoverable in the interior. The sensors are integrated in the façade elements during the manufacturing process and are connected via RS-485 to the control and monitoring system. Except the pin wood moisture measurement, the system also detects the air humidity and temperature in façade elements cavities or insulation material.

Technical parameters

Measurement:	Moisture content in building materials, air humidity, temperature
Power:	5 to 16 V DC, < 3 mA at 5 V
Working environment:	−40 to +85 °C (−40 to +176 °F), 0 to 80 %RH noncondensing
Communication interface:	RS-485 & Modbus RTU (configurable)
Mounting:	2 stainless screws (serves also as measuring electrodes)
Dimensions:	42 x 28 x 18 mm

Wood resistance measurement:	range 0 to 50 GΩ resolution 2 kΩ
Moisture measurement:	range approx. 7 to 30 % (depends on material) resolution 0.01 % accuracy ±2 %
Relative air humidity measurement:	range 0 to 100 %RH

resolution 0.04 %RH
accuracy ±2 %RH (typical)
repeatability ±0.1 %RH
hysteresis ±1 %RH
nonlinearity <0.1 %RH

Absolute air humidity measurement conversion from relative humidity: resolution 0.01 g/m^3 (0.01·10^{-4} lbs/ft^3)

Figure 18 – MoistureGuard sensors

Indoor air quality sensor

Combined indoor air quality sensor was developed within MORE-CONNECT project to control air ventilation system. The system is equipped with most important sensors covering temperature, air humidity, CO2 sensor and volatile organic compound sensor. These four variables were selected as the most important for healthy indoor environment and are used for direct control of the ventilation system and heating in the building.

Technical parameters
Measures: CO2 concentration, VOC concentration, temperature, relative humidity
Power: 7 - 24 V DC, 140 mA
Working range: 400 – 3000 ppm CO2, 0 – 30 ppm VOC
−40 to +85 °C (−40 to +176 °F), 0 to 80 %RH non-condensing
Communication interface: RS-485 & Modbus RTU (configurable), IQRF

Figure 19 – Environmental sensor UCEEB

Irradiance sensor

Irradiance sensor will be also part of the control system to measure instant irradiance and thus enabling the energy management control of the building components. The irradiance sensors will be used to control and verify the PV production and all adjustable loads within the building.

Technical parameters

Measurement:	Irradiance, temperature of sensing element, inside box and up to 4 additional temperatures
Power:	6 to 35 V DC, < 3 mA at 5 V
Working environment:	−40 to +85 °C (−40 to +176 °F), 0 to 80 %RH noncondensing
Communication interface:	RS-485 & Modbus RTU (configurable)
Mounting:	4 holes for screws (ø4 mm, 98 x 36 mm)
Dimensions:	110 x 57 x 29 mm
Ingress protection:	IP54

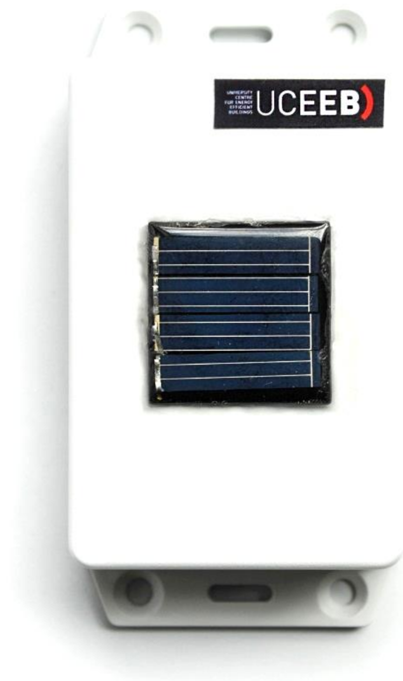


Figure 20 – Irradiance sensor UCEEB

- Temperature sensors on back of the PV panels on M-C experimental house facade and roof
- Solar insolation sensors on M-C experimental house facade and roof
- RaZON+ ALL-IN-ONE Solar Monitoring System with pyranometer and PH1 pyrheliometer

Building elements inspecting

Thermographic camera

A thermographic camera is a device that forms an image using infrared radiation, typically operating in wavelengths in the range of 2-15 um, and comprises a valuable tool for inspecting and performing non-destructive testing of building elements.

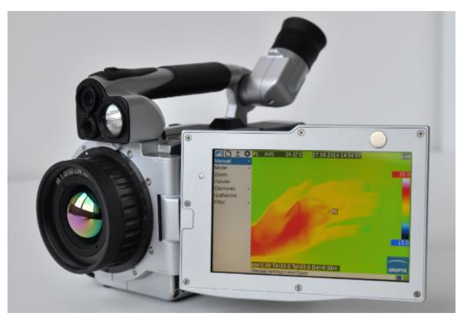


Figure 22 - thermographic camera

Use in the construction sector:

- Detecting where and how energy is leaking from a building's envelope
- Collecting data for clarifying the operating conditions of hard to reach heating
- Diagnostics of energy systems for buildings, Ventilating and air-conditioning (HVAC) installations and air handling units (AHU)
- Identifying problems with the electrical and mechanical installations under full-load operating conditions.
- Inspection of claddings
- Thermal bridges, leaks, condensing spots finding
- Sensing the layout of inaccessible heating elements
- Photovoltaics - detecting "hot spot" disorders; complex diagnostics PVP
- Inspection thermal stress on components
- Fire tests (prefabricated wooden panels, glass panel)
- Inspection of the building envelope and building elements
- Visibility floor heating system / leak detection media

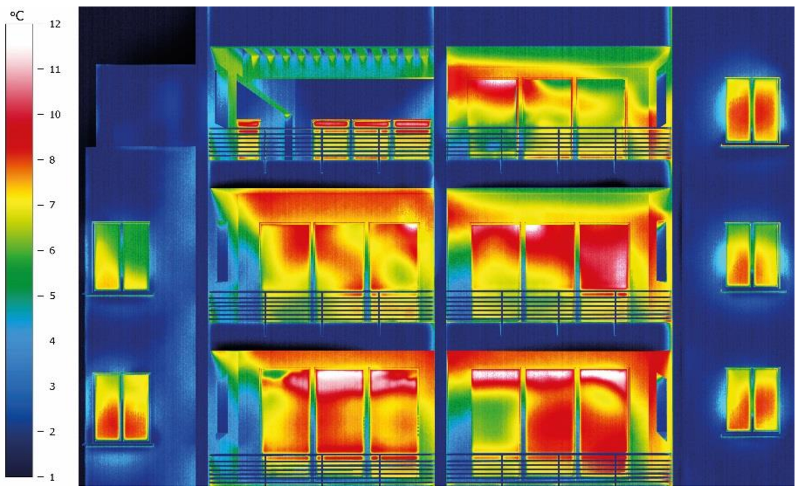


Figure 21 - IR imaging of a building

Possible interpretations for observed temperature differences (ΔT) from anticipated values in electrical inspections

ΔT (K)	Interpretation
1-10	Minor problem. There is a small possibility of physical damage. It is recommended to fix the problem during the next regular maintenance.
10-30	Average problem. There is a small possibility that there may be damages to nearby components. It is recommended to fix the problem in the near future; check load breakdown and adjust them accordingly; inspect for possible physical damage; check neighboring components for other possible damages.
30-70	Serious problem. It is recommended to fix the problem as soon as possible; replace the inspected component; carefully inspect all neighboring components for physical damage.
>70	Critical problem - danger exists. Needs immediate repair; if possible; replace the inspected component; carefully inspect all neighboring components; perform a follow-up IR inspection after the repairs to ensure that no damages have been overlooked.

Table 6 - C.A. Balaras, A.A. Argiriou. 2002. Infrared thermography for building diagnostics.

The inspection via thermal imaging camera consists in the detection of emitted radiation of an object. During a building energy assessment, for example, such inspection helps to quickly survey the entire building, spot heat losses or gains through the entire envelope. Based on the image analysis it is possible to identify potential problems or energy savings, schedule interventions and set priorities for preventive/predictive maintenance or the need for immediate service. Additionally, costly refurbishment can be avoided this way through the precise and detailed information of where an issue is present, enabling local repairs. Examples: missing, improperly installed or damaged insulation, thermal bridges, air leakages, moisture damages and detection of cracks in concrete structures.

Heat flux sensor

A heat flux sensor is a transducer that according to an electrical signal determines the heat rate applied to its surface. By dividing the heat rate by the sensor surface area the heat flux is determined. The heat flux can in principle be totally composed by convective, radiative as well as conductive heat, and all be measured. Their use comprises several applications, being the main interest here the study of building envelope thermal resistance.

In such application, it is important to highlight two facts: - wall generally do not change its thermal properties (provided its moisture content does not change); - the interior of a wall is not always acessible, so that the sensor has to be mounted on its inner or outer surface. Additionally, if the heat flux sensor is mounted on a surface of the wall, added thermal resistance cannot be too large and the spectral properties should be matching those of the wall as closely as possible. If there's solar radiation present in the measurement, painting the sensor in the same color as the wall can be an option.

Figure 3 - HFP01 manufactured by Hukseflux

HFP01 from Hukseflux is probably the most popular sensor for walls and building envelopes. The total thermal resistance is kept small by using a ceramics-plastic composite body. The sensor is very robust and stable. It is suitable for long term use on one location as well as repeated installation when a measuring system is used at multiple locations. HFP01 measures heat flux through the object in which it is incorporated or on which it is mounted, in W/m2. The sensor in HFP01 is a thermopile. This thermopile measures the temperature difference across the ceramics-plastic composite body of HFP01. A thermopile *is a passive sensor; it does not require power. Using HFP01 is easy. It can be connected directly to commonly used data logging systems. The heat flux in W/m2 is calculated by dividing the HFP01 output, a small voltage, by the sensitivity. The sensitivity is provided with HFP01 on its calibration certificate. A typical measurement location is equipped with 2 or more sensors. HFP01 is the world's most popular sensor for heat flux measurement in the soil as well as through walls and building envelopes.*

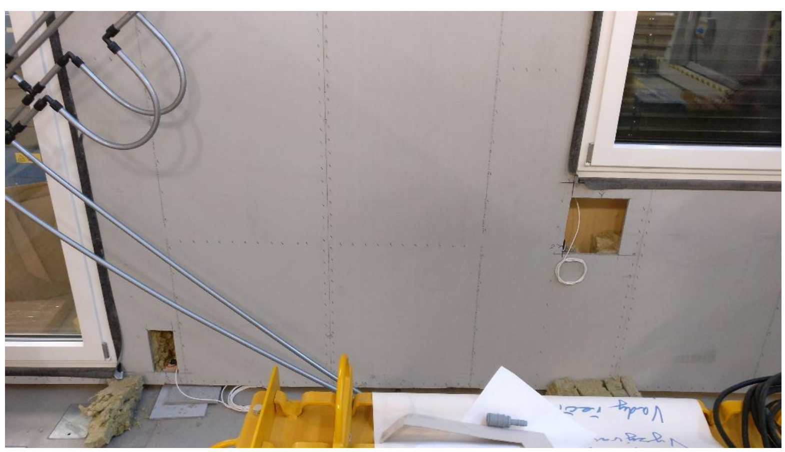
Prototype Panel

Cable guiding

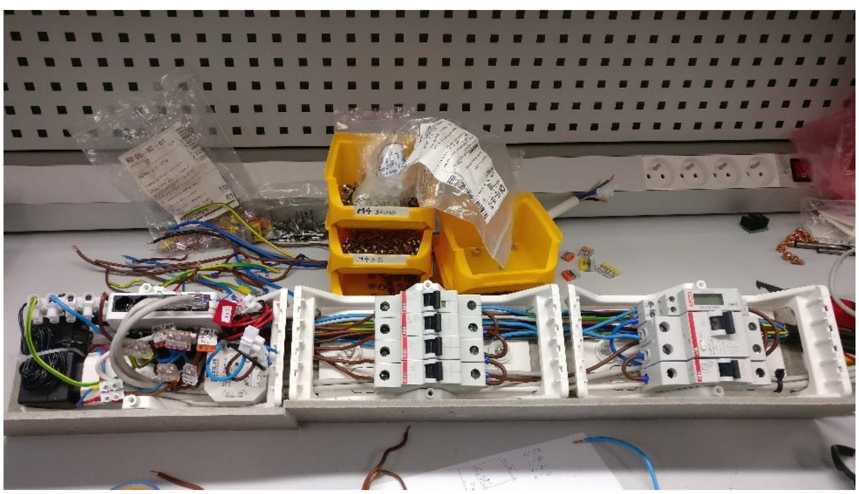

Air tightness around electrical box



Moisture Guard

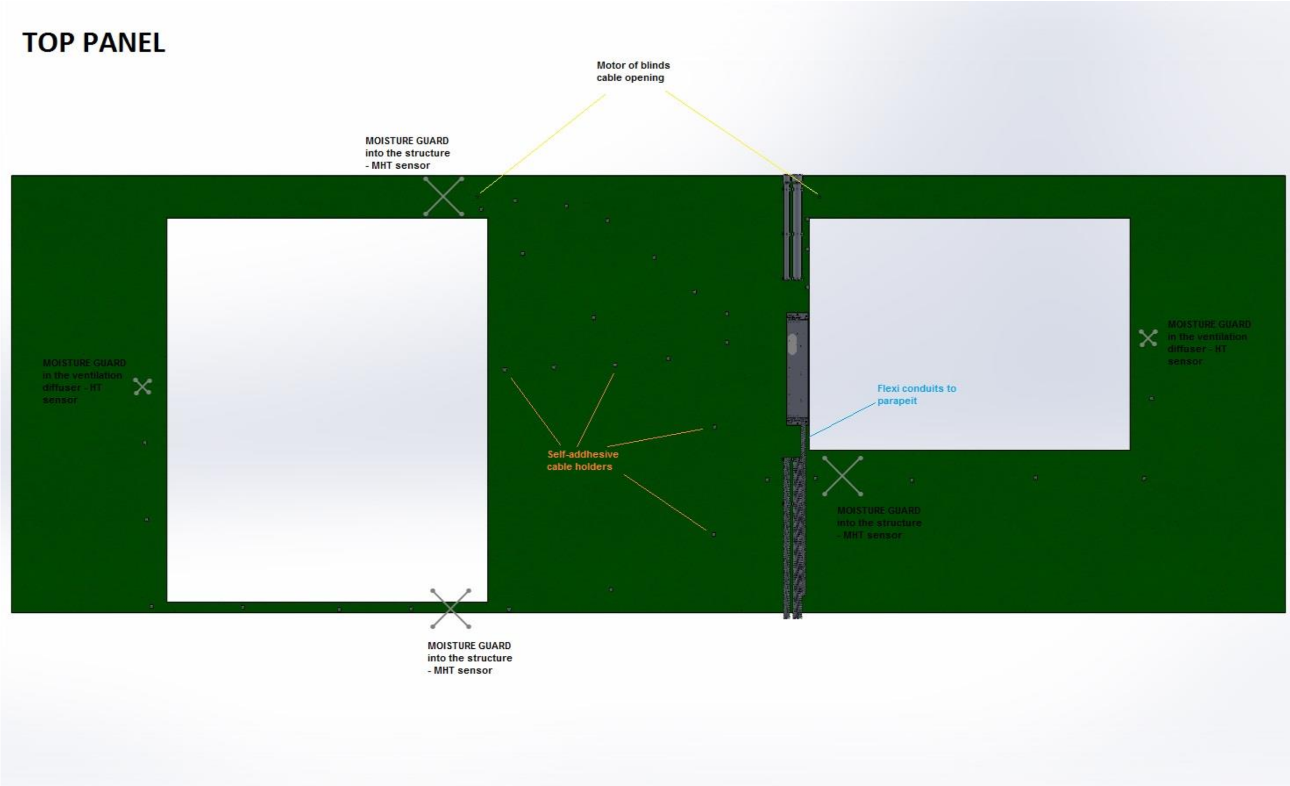


Distribution box



Overview

Pilot House


TOP PANEL
Motor of blinds cable opening
MOISTURE GUARD into the structure - MHT sensor
MOISTURE GUARD in the ventilation diffuser - HT sensor
Self-addhesive cable holders
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MOISTURE GUARD in the ventilation diffuser - HT sensor
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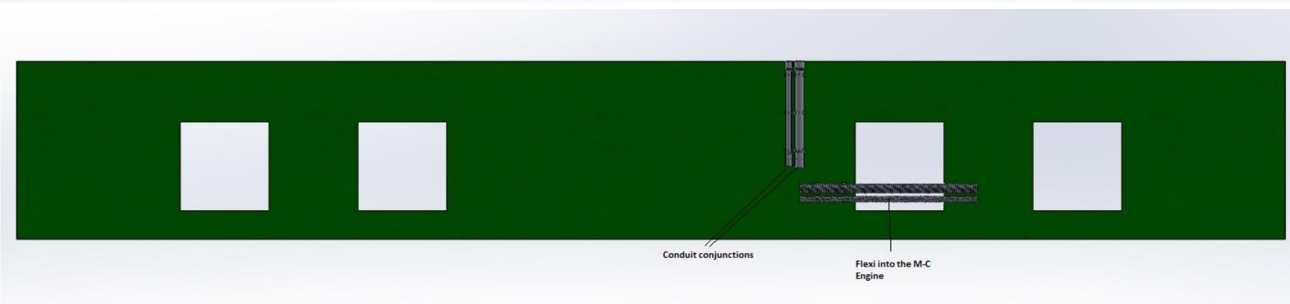
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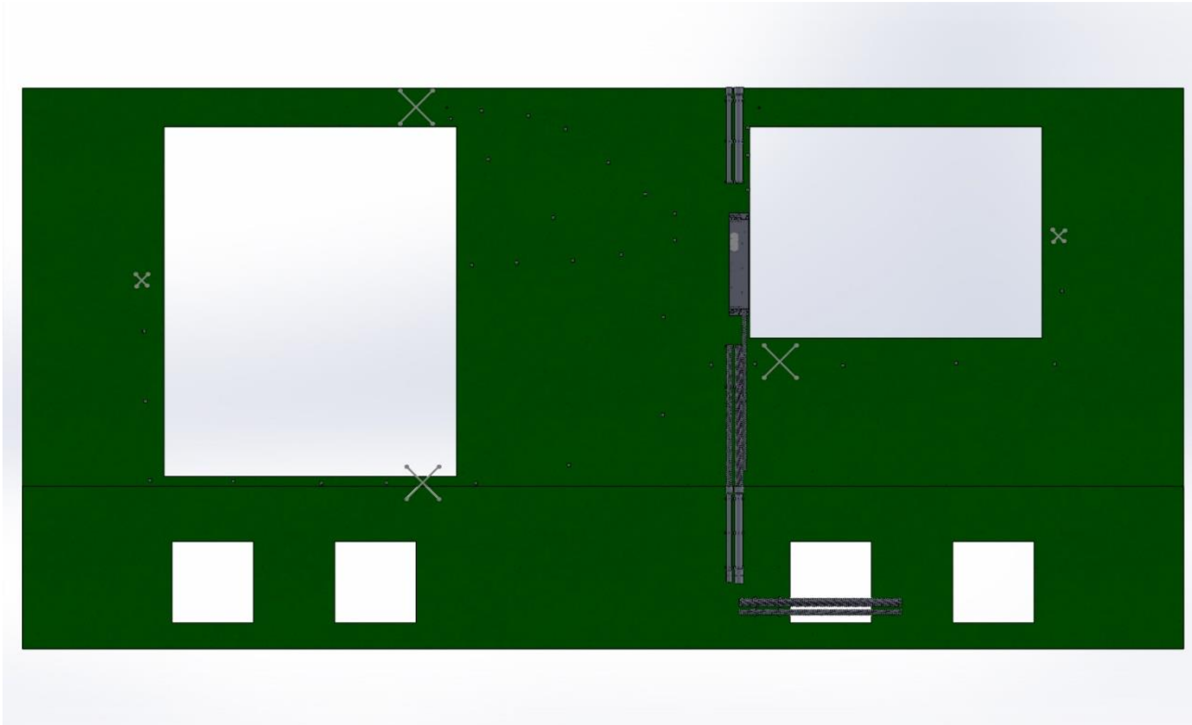
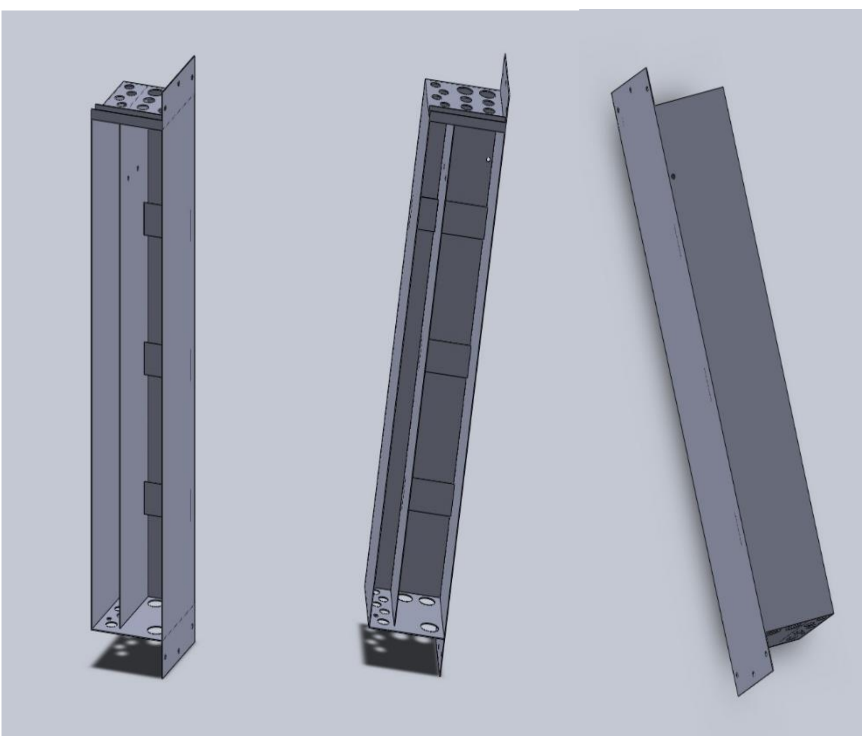
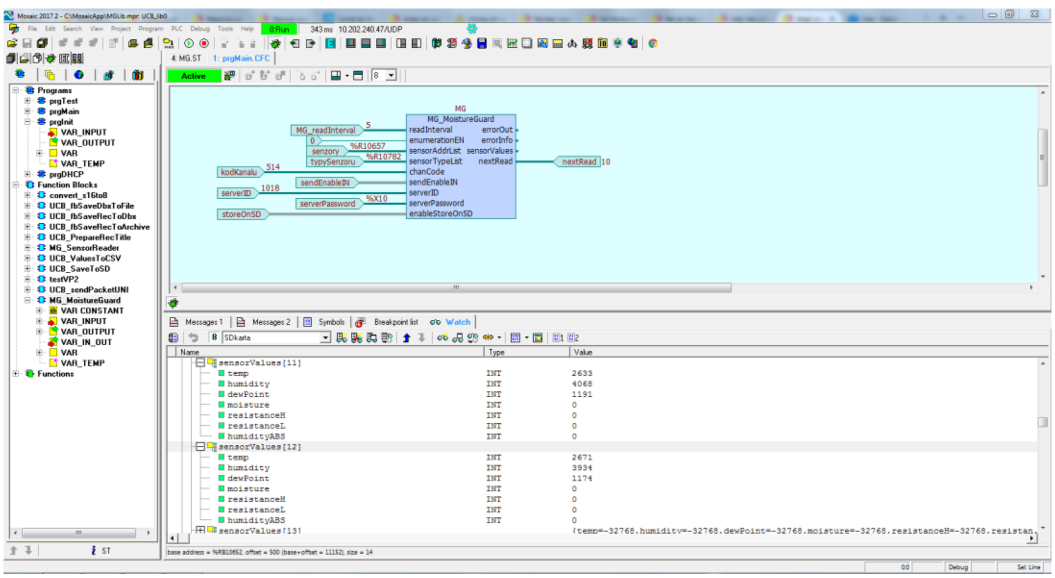


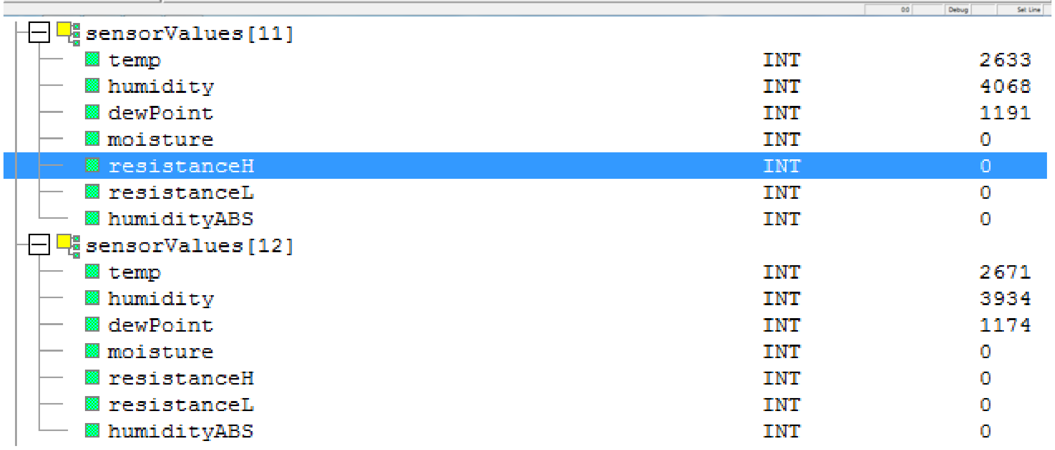
Customized box



Annex 1: Monitoring outputs

The data will be inserted here in M48.





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