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Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Building Automation and Smart Control

ENGLISH VERSION

JULY 2024

中华人民共和国
住房和城乡建设部
Schweizerische Eidgenossenschaft
Confédération suisse
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Building a climate-neutral future together

This report has been produced within the framework Sino-Swiss Zero Emissions Building Project; an international collaboration funded by the Swiss Agency for Development and Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development.

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Cite as:

Szostek, K., Althaus, S., Stamms, D. (2024). Building Automation and Smart Control. Sino-Swiss Zero Emissions Building Project Technical Report. Intep-Skat: Zurich

The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

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China Academy of Building Research

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Contents

Image: ZEB China Demonstration project. Training building, Long Shan Shu Yuan Middle School, Shoaxing, Zheijiang Province. Courtesy of Shaoxing Future Community Development and Construction Co.

1. Introduction

This booklet offers a comprehensive understanding of Building Automation Systems (BAS) or Building Management Systems (BMS), emphasizing their critical role in achieving zero-emission buildings by optimizing energy consumption and improving operational efficiency. The energy-saving potential of BMS is significant, with systems capable of reducing energy consumption by up to 30% in commercial buildings, according to a study by the U.S. Department of Energy (DOE). The demonstration projects in Beijing and Shaoxing, highlighted in this booklet, showcase both the challenges and potential of implementing advanced BMS. These projects underscore the need for integrated systems and continuous innovation to fully realize the benefits of smart building technologies, paving the way for more sustainable and energy-efficient building operations in the future.

A building automation system is crucial for controlling and monitoring various subsystems within a building, including HVAC, lighting, shading, energy consumption, security, and fire safety. This booklet explains how these systems operate at three levels: management, control, and field. Additionally, it delves into the Swiss standard SIA 386.110 (equivalent to the European standard EN 15232:2012), which classifies BMS efficiency into four classes (A-D), with A being the most efficient. These classifications guide the potential energy savings achievable by a BMS, varying based on building type and specific implementations. Furthermore, the importance of using standardized communication protocols like BACnet IP and OPC UA is emphasized to ensure seamless interaction between different systems, thereby enhancing overall building efficiency. The booklet also explores next-generation technologies like AI, Cloud, and IoT devices, showcasing their potential to further enhance BMS capabilities.

The Sino-Swiss Zero Emission Building (ZEB) demonstration projects in Beijing and Shaoxing detailed in this booklet illustrate the practical application and potential of advanced BMS. It is noted that these systems currently operate standalone, which reduces efficiency. Recommendations for improvement include integrating air quality measurements, automating heat recovery, equipping windows with sensors, and enhancing energy monitoring. By addressing these aspects, the potential of achieving zero emission buildings through advanced BMS can be more fully realized.

Image: Freepik

2. Building automation and smart control

Basis

In general, a building automation system (BAS) or building management system (BMS) is understood as an overall system, that controls and monitors all relevant systems in a building. Such as HVAC, lighting, shading, energy consumption but also security and fire safety functions.

Systems are commonly divided in different levels which are:

- Management level: consists mainly of the BMS-Software which visualizes all systems and measured data on specific graphics. It's also the main interfaces for building operators and end-users if access is granted. Further Data is recorded and archived by the system. But also, all IT infrastructure which is
- needed to operate the system.
- Control level：consists of a programmable logic controller (plc) which is the interface for all sensors and actors of the systems. The control logic is executed on the controller. It processes the incoming data according to the programmed logic and executes the necessary actions through its in- and outputs.
- Field level: consists of sensors and actors which measure data and execute commands. This may be a temperature sensor or a valve. All field devices are connected to a plc. This may be through a cable or even trough wireless radio signals. The variety is large.

In Switzerland a BMS classically controls all systems concerning heating, cooling, ventilation, lighting, shading as can be seen in the Figure 1. The BMS as central element connects all systems, operates them in highly efficient way and minimizes energy consumption.

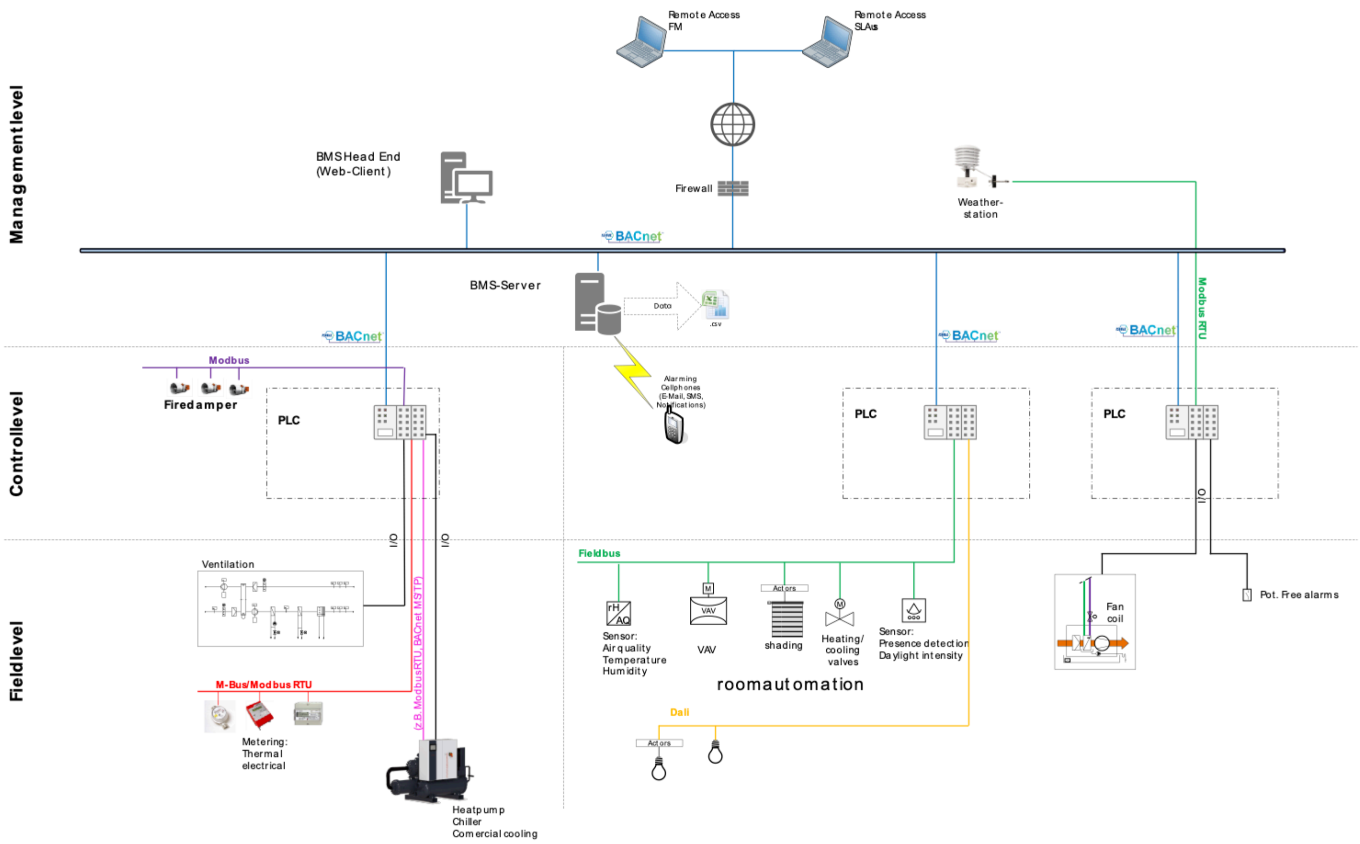

Figure 1. Typical BMS system architecture. Source: Willers

How much energy savings a BMS can achieve differs from building to building. The Swiss standard SIA 386.110 which is identical to the European standard EN 15232:2012 gives some indication about the energy efficiency in buildings depending to the realized BMS. The standard names four efficiency classes A-D for BMS' s:

Class	Description
A	High efficient BMS ▪ Connected room automation control with automated demand control ▪ Regularly maintained systems ▪ Energy Monitoring established ▪ Optimizing of energy consumption
B	Advanced BMS ▪ Connected room automation control ▪ Energy Monitoring established
C	Standard BMS ▪ Connected primary systems ▪ No room automation control ▪ No Energy Monitoring established
D	No BMS ▪ No connected systems ▪ No room automation control ▪ No Energy Monitoring established

Table 1. Four efficiency classes A-D for BMS.
Source: SIA 386.110

Further the standard defines according to the efficiency class energy efficiency factors for thermal and electrical energy for some building types. The factors are shown in the following tables. In the tables it is assumed that a class C BMS is the standard which is built in all buildings. This may be the case for Switzerland but differ for Chinese buildings. The gain in efficiency with a more efficient BMS is a fact none the less.

Class Building type	D	C	B	A
Office Building	1.51	1	0.80	0.70
Lecture Hall	1.24	1	0.75	0.5
Schools	1.2	1	0.88	0.80
Hospitals	1.31	1	0.91	0.86
Hotels	1.31	1	0.85	0.68
Restaurants	1.23	1	0.77	0.68
Commercial Buildings	1.56	1	0.73	0.60
Residential Buildings	1.1	1	0.88	0.81

Table 2. Efficiency factors for thermal energy.
Source: SIA 386.110

Class Building type	D	C	B	A
Office Building	1.10	1	0.93	0.87
Lecture Hall	1.06	1	0.94	0.89
Schools	1.07	1	0.93	0.86
Hospitals	1.05	1	0.98	0.96
Hotels	1.07	1	0.95	0.90
Restaurants	1.04	1	0.96	0.92
Commercial Buildings	1.08	1	0.95	0.91
Residential Buildings	1.08	1	0.30	0.92

Table 3. Efficiency factors for electrical energy.
Source: SIA 386.110

Image: Freepik

Connection of systems

As is shown in the previous chapter a BMS is mainly a connection of various systems in a building. How many systems are connected differs from building to building. Mainly it' s the following systems:

- Ventilation
- Cooling
- Commercial Cooling
- Heating
- Sanitary
- Domestic hot water
- Electrical distribution units
- Shading
- Curtains
- Lighting
- Metering
- Leak detection
- Door/Window detection

Further a BMS can have the following superordinate functions which enhance it to fulfil its purpose:

- Alarming
- Monitoring
- Scheduling
- Calendars
- Visualization
- Centralized Commands

The connection between the systems has multiple benefits. For example, it can be prevented that the same space is cooled and heated simultaneously, cooling and shading can be harmonized, mechanical and natural ventilation can be synchronized, central switching of lighting, etc. All those and further functions can be implemented trough control loops which are located on the PLC controllers.

Standardization

The connection of various systems requires a standardization of communication between the systems. The simplest way of data exchange between a system and a PLC is based on hardware signals such as 0-10 V, 0-20mA or pot. Free contacts. However, it already needs to be harmonized on which side a signal is generated and where it is received. If the depth of information exchange needs to be increased other communication protocols which use serial buses or IP can be used. In such cases it is vital to rely on standardized protocols. These can for example be the following:

- BACnet IP
- OPC UA
- Modbus TCP
- LoRa WAN
- MQTT
- Modbus RTU
- BACnet MS/TP
- KNX
- DALI
- ASI-Bus
- MP-Bus
- M-Bus

The list is not exhaustive, it is rather a sample of commonly used standardized, open communication protocols often used in Switzerland. Additionally, there are a lot of proprietary protocols of the numerous suppliers. It is however strongly recommended to use open protocols in order to enhance the communication between the systems. For further information about the specific standards refer to the respective official webpages linked above.

Once chosen, it is recommended that a Concept about the technical communication is written and established in each project. Each supplier has then to fulfil the defined standards so it is guaranteed that the systems can be connected to the BMS.

Smart controls

In the following chapter possible functions of a connected system are listed and some examples for specific functions are shown.

Presence detection of lighting control can be used:

- to adjust the air volume flow of the dedicated VAV' s.
- to adjust the setpoint of the room temperature (lower setpoint if the room is unoccupied for a longer time period i.e. weekends and nights).

Room measures (temperature, humidity, CO2) can be used:

- to adjust heating or cooling power
- to adjust supply temperature of cold water in order to prevent water condensation on pipes in the rooms
- to generate demand signals for heat or cold-water supply and adjust the production or optimize storage management

Shading status can be used:

- to allow or prevent cooling (in summer) or heating (in winter)
- optimize daylight harvesting and reduce lighting intensity

Status of VAV' s can be used:

- to optimize fan speed in the AHU and reduce pressure loss in the overall system.

Outdoor conditions can be used:

- to optimize fan speed in the AHU and reduce pressure loss in the overall system.

Outdoor conditions can be used:

- to prevent unnecessary cooling or heating in seasonal transition periods
- to prevent cooling or heating according to outside temperature
- to adjust room and supply temperature setpoints according to

Central Commands can be used:

- to switch off lighting in the whole building
- to close blinds during nighttime in winter in order to save energy
- to prevent simultaneous cooling or heating

Example 1: Room temperature control heating and cooling

The current room temperature is measured by the room sensor which wall mounted. The room temperature is controlled by a control loop which continuously controls valves of the heating/cooling. It is operated in eco or normal mode, which depends on time schedule and presence detection per room.

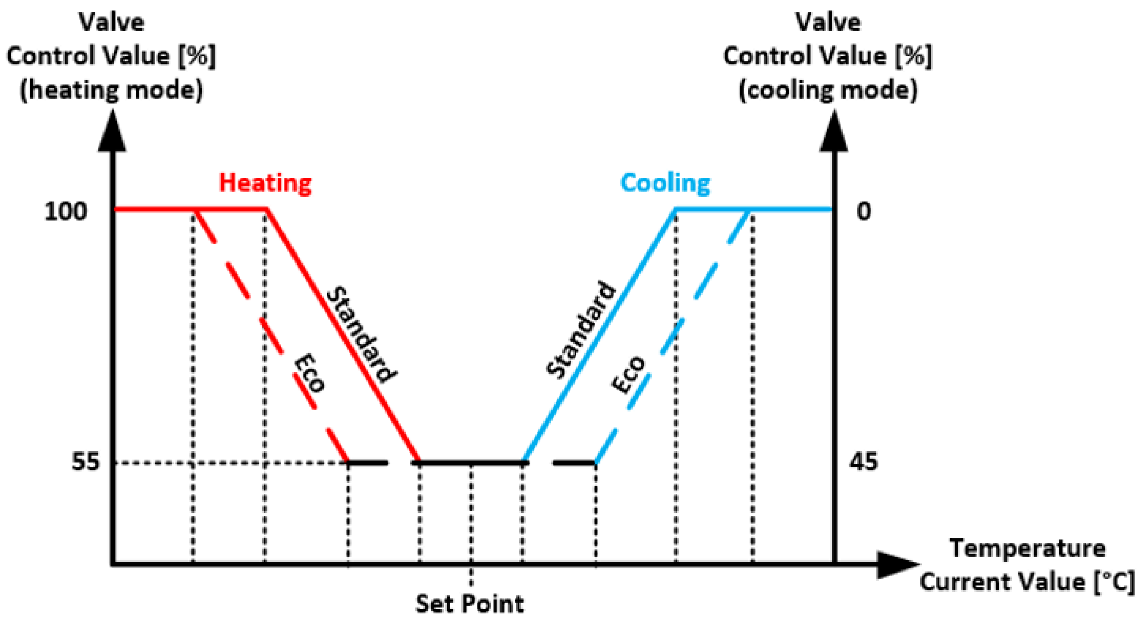

Figure 2. Valve control of the heating and cooling. Source: Willers.

Valve control: the valves have one single control signal which is 0-100% percent:

Control Value	Function
100%	Max. heating
55%	Min. heating
45%	Min. cooling
0%	Max. cooling

Table 4. Valve control value and its functionality of Figure 2.

The functionality for heating is enabled only if the outside air temperature is below or above the defined limits.

In order to prevent the formation of moisture, the cooling valves are switched off at a relative humidity of >75% in the room and activated again at a relative humidity of <65%.

Value name	Value
Setpoint Winter	21°C
Setpoint Summer	26°C
Zero Energy Band Standard	1K (+/- 0.5K)
Zero Energy Band Eco	2K (+/- 1K)
Enable heating	Outdoor temperature < 16°C
Enable cooling	Outdoor temperature > 18°C

Table 5. Parameter names and value

Example 2: Indoor air quality control

The current air quality is measured with the VOC sensor which is wall mounted. The CO2 value is derived from the VOC value, which is therefore a calculated value and is called the eCO2 value. The air quality is controlled by a controller which continuously controls the supply air VAV.

The exhaust air is discharged for several rooms by one or more centralized exhaust air VAVs. The setpoint of this VAV results from the sum of the supplied air from the supply air VAVs so that the exhaust air - supply air balance is correct. All exhaust air VAV per floor and per ventilation system belong together and are controlled simultaneously.

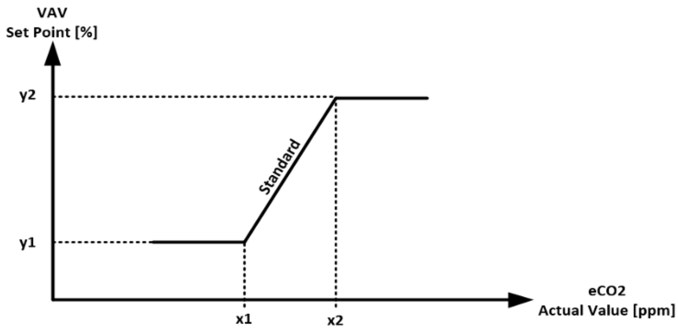

Figure 3. VAV and air quality in calculated eCO2 value. Source: Willers

Value name	Value
x1	750ppm
x2	1200ppm
y1	Minimal value (ca. 20% / Vnen)
y2	100%

Table 6. Parameter explanation for Figure 3

Example 3: Blinds operation

Cleaning mode

The cleaning function for the windows is operated from the building management system per floor/facade. When the window cleaning function is activated, the shading in the selected area is cancelled and automatic and local operation are disabled.

Manual operation by push button

The local manual control (pushbutton or multimedia touch panel) overrides the automatic mode, safety functions are still active. If the room has not been occupied for 30 minutes, the system switches back to automatic mode. If a function of a higher priority is active the pushbutton is deactivated which must be signaled to people (e.g. a red LED on the push button).

Energy control (cooling)

If the corresponding facade is exposed to sunlight, the blinds are controlled based on the cooling demand in the room. In cooling mode, shading is initiated from global radiation values of >250 W/m2 to prevent excessive heat input.

The following hysteresis must be followed

- If >=4 rooms of a facade side are in cooling mode, shading of this facade side is initiated
- If <=2 rooms of a facade side are in cooling mode, shading of this facade side is canceled

Time schedule

The timer programs can be used to move the blinds to a predefined position for each building, facade or floor on a time-dependent basis. The automatic mode is overridden, whereby the safety functions and manual operation are still active. The following switching functions are possible:

- Cancel shading
- Initiate shading

The program timer has the following setting options:

- Daily and weekly program (validity range can be restricted with calendar)
- Flexible calendar function over several years
- Automatic summer/wintertime changeover
- Special days (fixed days) and holidays
- Switching on and off of shading programs
- Automatic switching time adjustment to sunrise and sunset (astro function)

Automatic functions:

- The automatic functions are only enabled if no safety or timer commands are active, and no manual interventions have been made from the BMS or from local.
- If the set global radiation value (specified via interface) is exceeded, shading is initiated according to the shading image.

General functions:

Restart blocking time: After an automatic blind movement (initiate or cancel shading), at least 20 min. must have elapsed to minimize running before the next automatic movement command is executed.

Example 4: Fan optimizer

In order to control the supply air VAV always in an optimal range, the pressure can be increased or decreased with the supply air fan of the air handling unit. The VAV which has the largest opening angle of its flaps is always decisive.

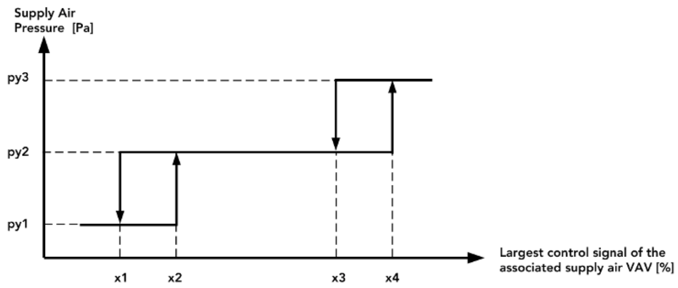

Figure 4. Supply air pressure and VAV. Source: Willers

Value name	Value
x1	30% (or minimal value)
x2	35%
x3	75%
x4	80%
py1	tbd
py2	tbd
py3	tbd

Table 7. Parameter explanation of Figure 4

Example 5: Supply air temperature control with heat recovery damper

The supply air temperature is measured via duct mounted temperature sensor. The temperature control loop controls the supply air temperature according the setpoint with the heat recovery (bypass damper), air heater and air cooler.

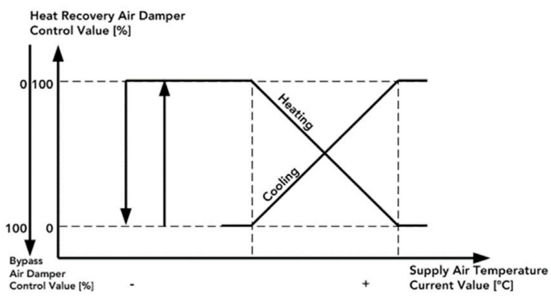

Figure 5. Supply air temperature control with heat recovery damper. Source: Willers.

Value name	Value
V1	5%
Time delay	10 min.

Table 8. Parameter explanation of Figure 5.

Smart building use cases

Next level technologies such as AI, Cloud or IoT Devices open up a new potential for further improvement of building operation. The use cases are case studies rather than often proofed solutions. However, the potential for even more energy efficiency is proven.

Data Predictive Control

Through the combination of AI, weather forecast and historical data of the BMS the application can predict the necessary amount of energy input to a room in order to reach its temperature setpoint in time as it considers the future (weather forecast) and the past (historical data).

Predictive Maintenance

Through surveillance of operating hours combined with other indicators and product information for certain parts such as pumps or valves maintenance can be planed. Lifecycle of those parts can be extended through this.

Predictive Room Conditioning

If existing systems, such as a room reservation tool and a BMS can be connected new potential is unlocked. i.e. heating can be reduced in a room as long as it is not booked and then the temperature can be raised if a booking is upcoming. Also, can a booking become cancelled if no presence is detected in the room.

3. Demonstration project case studies

Beijing Demonstration Project

In March 2022, the "Beijing Fangshan China Construction First Building (Group) · Xuefu Yinyue Zero Carbon House Project" was selected as one of the 1st batch Demonstration Projects of Sino-Swiss ZEB Project. The project commenced in May 2021 and after more than two years of joint efforts by Sino-Swiss teams, was officially completed with its construction on September 27th, 2023, and achievement of ZEB goal. The building serves as a community center with a multifunctional exhibition hall and several senior apartments.

Project initial data

- Investor: C-Land Real Estate
- Leading planning team: SUP Atelier of THAD(Architect) + CABR (Energy Consulting) EE
- Location: Fangshan District, Beijing / China (climate zone: Cold; Solar resource area II)
- Climate zone: cold area
- Area: gross building area 1,557m2 (reduce to 1,200m2 in the end), consisting of 3 aboveground floors and 1 below-ground floor. Energy reference area is 1,262m2 (reduce to 838m2 in the end)

Highlights of energy concept

- Building-integrated photovoltaics (BIPV) on Façade and PV on the roof
- Air heat pump / air cooled chiller for space heating and cooling
- Mechanical ventilation with heat recovery (optional with natural ventilation through roof windows)
- High-performance doors and windows
- Free cooling through natural ventilation openings
- Idea of recycled building material without concrete design

In general, there seems to be no connection between the various systems in this Demo project. The following systems operate all standalone:

- Air handling unit (ventilation)
- Heating and cooling for each room
- Shading
- Windows
- Lighting
- Metering (electrical)

This leads to a less efficient way of operating the building. The following functions were recommended if a BMS will be implemented.

- Connect the indoor air quality measurement with the AHU' s in order to adjust air volume flow according to the air quality.
- Automate the heat recovery function of the AHU' s and add it to the air heating control loop (see Chapter 3.4.5). Therefore, also the heat pumps and the dedicated room temperature measurements need to be connected.
- Equip the windows with contacts that enable the surveillance of the status (open/closed) and connect them to the AHU' s in order to reduce air volume flow when windows are opened.
- Automate rooftop windows opening for more efficient natural ventilation manual operation is usually the least efficient way.
- Add further energy meters and connect them to the BMS in order to establish an energy monitoring system within the BMS.

Figure 6. Image of the project. Source: Project presentation 17.11.2022 ©SUP Atelier.

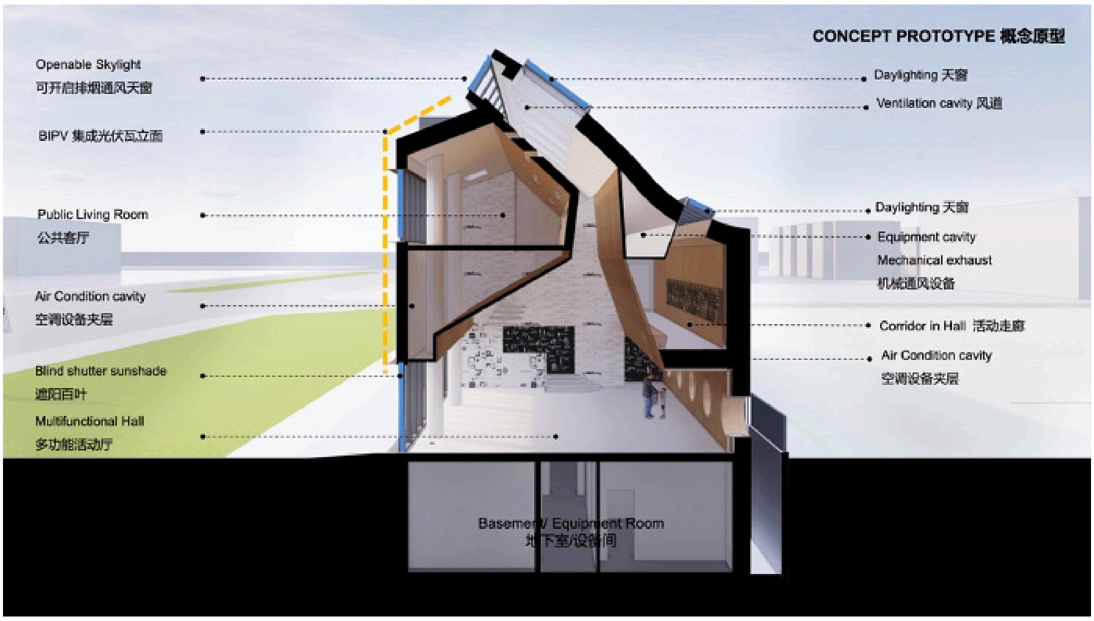

Figure 7. Highlights of Energy concept. Source: Project presentation 17.11.2022 ©SUP Atelier.

Shaoxing Demonstration Project

In March 2022, the "Training Building (4#) of Long Shan Shu Yuan Middle School in Shaoxing, Zhejiang" was selected as one of the 1st batch demonstration projects of Sino-Swiss ZEB Project. The project commenced in May 2021 and, after more than two years of joint efforts by Sino-Swiss teams, is expected officially completed with its construction in June 2024. The building serves as a training center with classrooms, labs and offices.

Project initial data

- Investor: Shaoxing Future Community Development and Construction Co.
- Planning team: CABR
- Local near zero energy consultant: Centre for Science, Technology and Industrial Development, Ministry of Housing and Construction, Beijing Kangju Certification Centre Co.
- Location: Shaoxing, Zhejiang Province (Southeastern China)
- Climate zone: hot summer and cold winter area
- Area: demonstration Building: 4# Training Centre, building Size: 5,299.68m2, building Height: 19.8m (4 floors above ground)

Highlights of energy concept

- Air source variable refrigerant flow (VRF) multi-connector units for space heating and cooling
- Mechanical ventilation with heat recovery, variable frequency fan with air volume adjustment
- No domestic hot water systems
- Lighting with efficient LED light sources, automatically adjust function
- Roof mounted photovoltaic systems (BIPV)

In general, there seems to be no connection between the various systems in this Demo project. The following systems operate all standalone.

- Air handling unit (ventilation)
- Heating and cooling for each room
- Shading
- Windows
- Lighting
- Metering (electrical)

This leads to a less efficient way of operating the building. The following functions were recommended if a BMS will be implemented, similar to Demo project Beijing:

- Connect the indoor air quality measurement with the AHU' s in order to adjust air volume flow according to the air quality.
- Automate the heat recovery function of the AHU' s and add it to the air heating control loop (see Chapter 3.4.5). Therefore, also the heat pumps and the dedicated room temperature measurements need to be connected.
- Equip the windows with contacts that enable the surveillance of the status (open/closed) and connect them to the AHU' s in order to reduce air volume flow when windows are opened.
- Connect shading and cooling to only enable cooling if shading is active in a room. Shading reduces solar heat gain to the room and consequently reduces cooling demand in summer.
- Connect shading and heating to enhance solar heat gain in winter and as a consequence reduce heating demand.
- Automate lighting with presence detection in rooms and corridors. Also connect to the BMS in order to implement central commands and schedules.
- Add further energy meters and connect them to the BMS in order to establish an energy monitoring system within the BMS.

Figure 8. Rendering of the project. Source: Project presentation 22.06.2022 ©CABR.

Figure 9. Image of the project. Source: Project presentation 22.06.2022 ©CABR.

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