DIRECTION

DEMONSTRATION OF VERY LOW ENERGY NEW BUILDINGS

DIRECTION

Demonstration at European Level of Innovative and Replicable Effective Solutions for very Low Energy new Buildings

D3.6: Metering project for demonstrator III

WP3, Task 3.2

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SEVENTH FRAMEWORK PROGRAMME

Technical References

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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services).

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CO = Confidential, only for members of the consortium (including the Commission Services).

Table of Content

List of Figures

List of Tables

0 Abstract

This document describes the energy metering system, following the premises of task 3.2 found in annex I "Description of work" of Grant agreement no: 285443, to have energy consumption measures.

1 Introduction

The metering system is integrated into the monitoring project therefore all general specifications and information have been compiled in deliverable 3.3 "Monitoring project system for demonstrator III", and you can obtain more information in this document.

The main goal is to obtain **energy saving measures**. To evaluate the energy consumption it is necessary to gather information about the insulated measurements and in the whole building.

This document defines an overview of the energy consumption in the building, the position of the sensors and the identification of the meters in its particular position.

The aim is to define the counters that are necessary to achieve the measures of these consumptions and their position. The treatment of these collected data is defined in the Deliverable D3.3 Monitoring System Project of Demonstrator III in the section 3.3 "Data treatment and storing" with the aim to obtain the building performance.

2 Systems overview

Thermal Energy in NuOffice is used for heating the thermally activated slab systems (TABS) and for preheating supply air via heating coils. During wintertime an absorption heat pump (AHP) is used in addition to the district heat for a more efficient initialization of heating energy.

NuOffice will be delivered with cooling power by using renewable energy. Therefor cool water coming from a groundwater well will be used for cooling purposes in the building (via TABS). Furthermore the whole year needed cooling capacity for IT-devices like servers is mostly covered by this. In wintertime, the groundwater is also used as heat source for the heat pump An electrical driven compression chiller is installed for backup purposes.

Electrical energy is used for the air handling units (AHU), lighting and as auxilliary energy for plants and other building services. Figures 1 and 2 give a schematic overview of installed devices at NuOffice building and their energy fluxes.

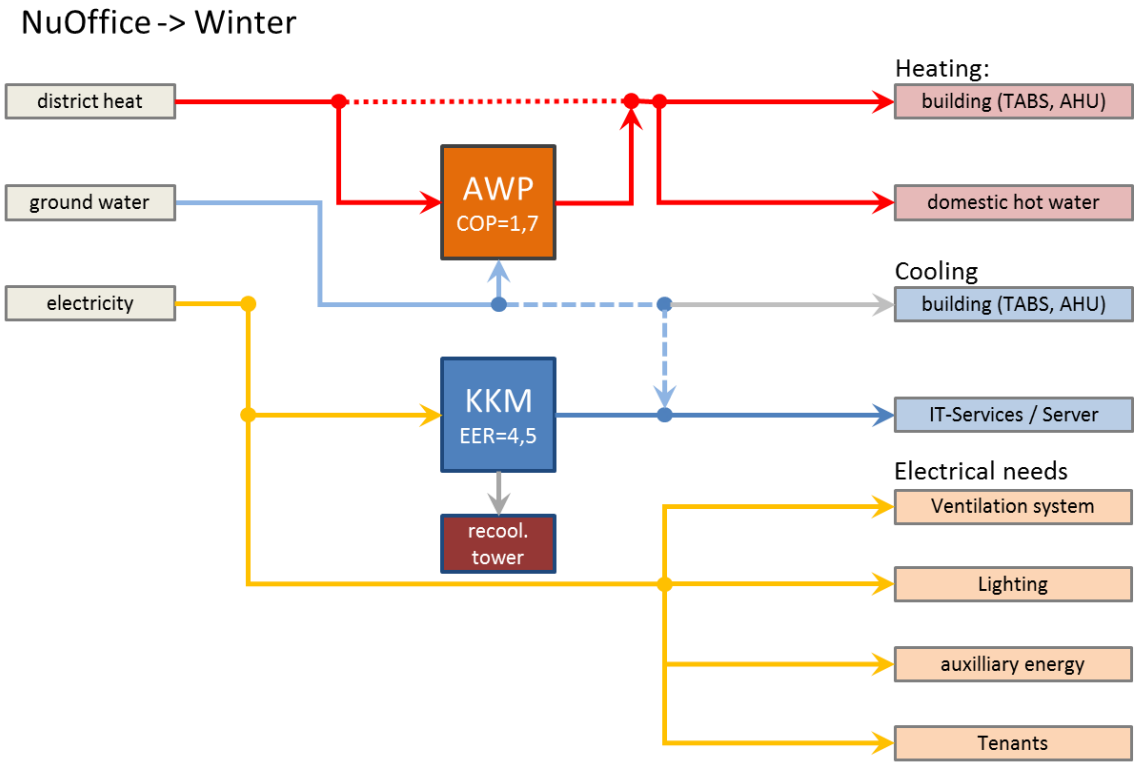


Figure 1: Overview of the installed technical devices and their energy fluxes in wintertime.

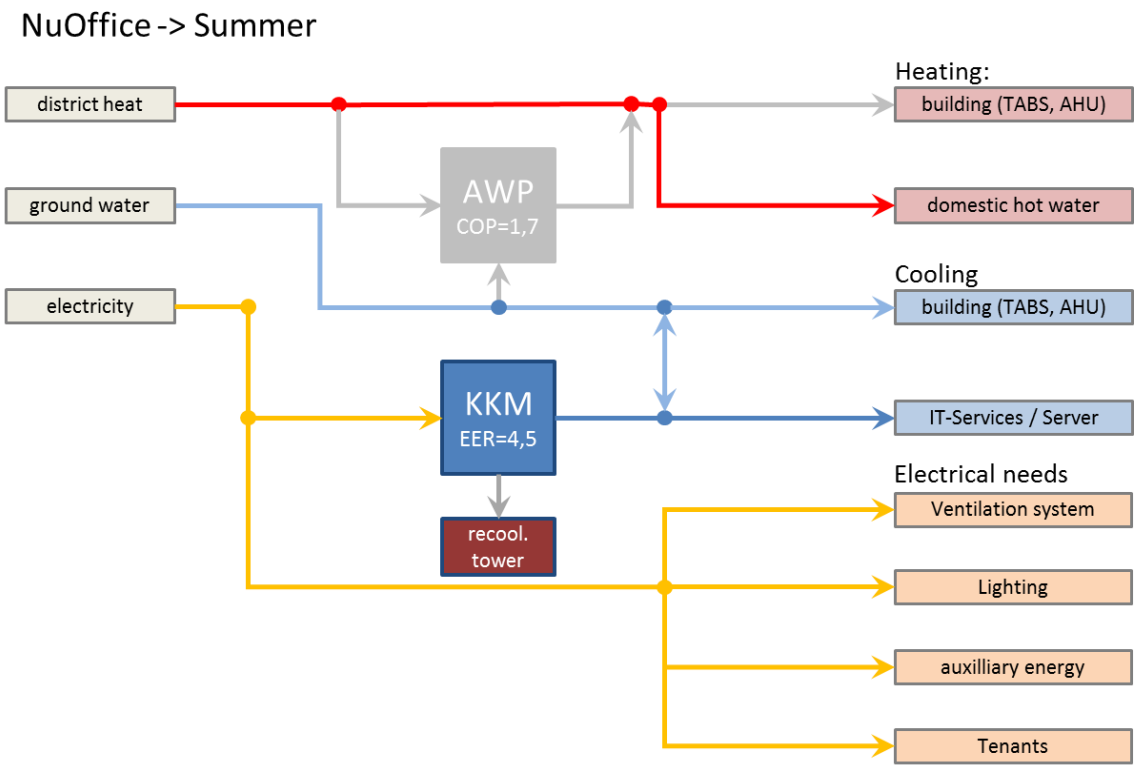


Figure 2: Overview of the installed technical devices and their energy fluxes in case of summer.

Basing on these schemes the positioning of needed meters and counters has to be defined in order to provide the building with a complete balance of energy, which can be later compared with calculated values.

3 Energy metering sensors selection

All the sensors and devices to measure are described in this section such as the thermal energy consumption for heating and cooling as electrical consumption for auxiliary energy for plants, pumps and ventilation and electrical lighting.

These sensors are directly implemented into the DDC (BA-System), as it is explained in the derivable 3.3 the BEMS is performed with a DDC where both monitoring and metering are including. To develop the comunication in the metering system the MBus meters are connected over an MBus-Master to the DDC, ModBus-Sensors via Modbus-Gateway.

According to the energy scheme as described in D4.1 Evaluation planning, Figure 3 shows the scheme of energy production and use in NuOffice with the placement of needed energy measurements.

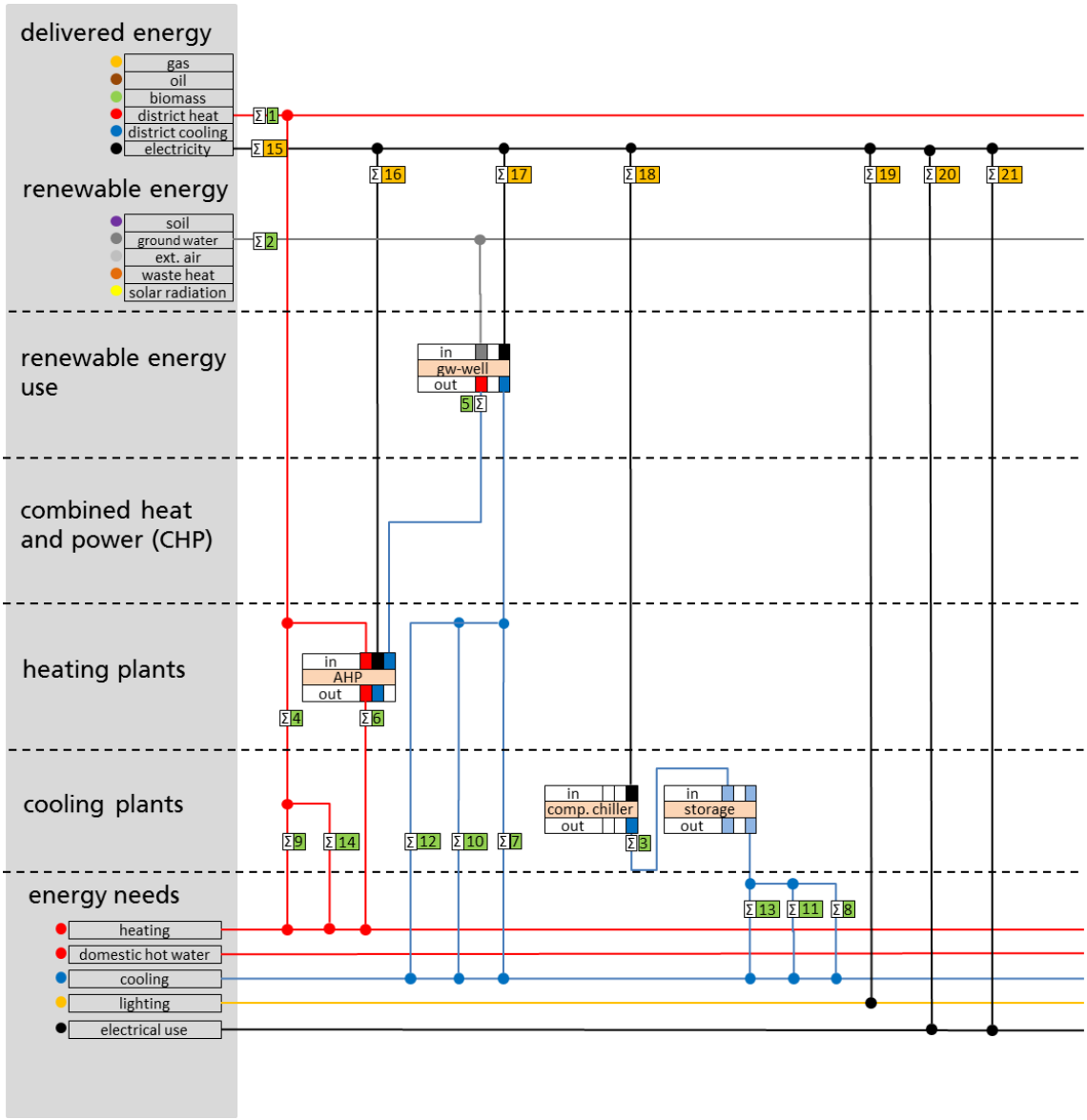


Figure 3: Energy scheme of NuOffice with placed heat and cold meters (green) plus electric meters (orange)

The following installations are required to account the energy performance of the building:

A. **Fourteen calorimetric counters** in the pipes that connect the building to the grid and count renewable energy use plus metering the energy needs, composed by two temperature sensors measuring the thermal level of the flow entering and outing the system. Additionally the physical properties of the thermal fluid as specific heat and density have to be defined or evaluated.

The Energy provider must give the clients the numbers corresponding to the primary energy factor and the tons of CO_2 emitted to the ambient when the energy delivered was produced.

B. **twentyfive electrical measurer** which counts the electrical energy consumed by the building from the electrical grid. This electricity measurement includes the need to drive computers, lights, ventilation fans, pumps etc. It could be done separately. The needed counters for building services are shown in Figure 3, for a detailed set-up for all monitored electrical meters see Figure 4 Figure 5.

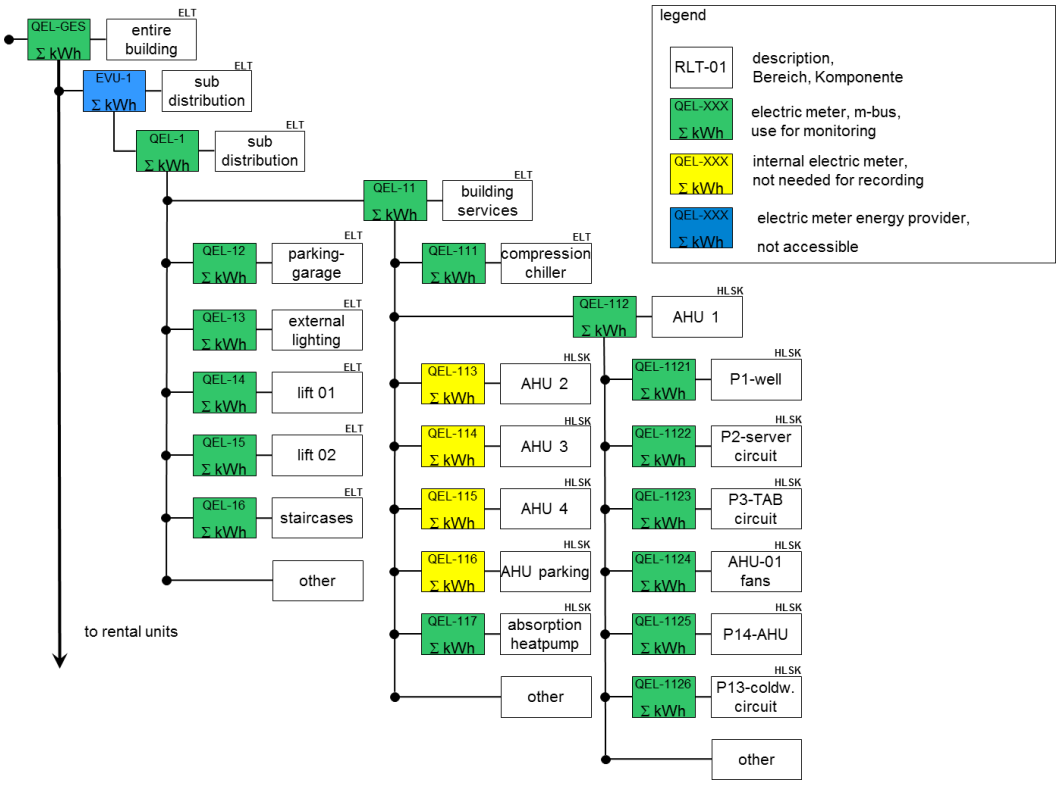


Figure 4: Set-up of all needed electrical counters for building services

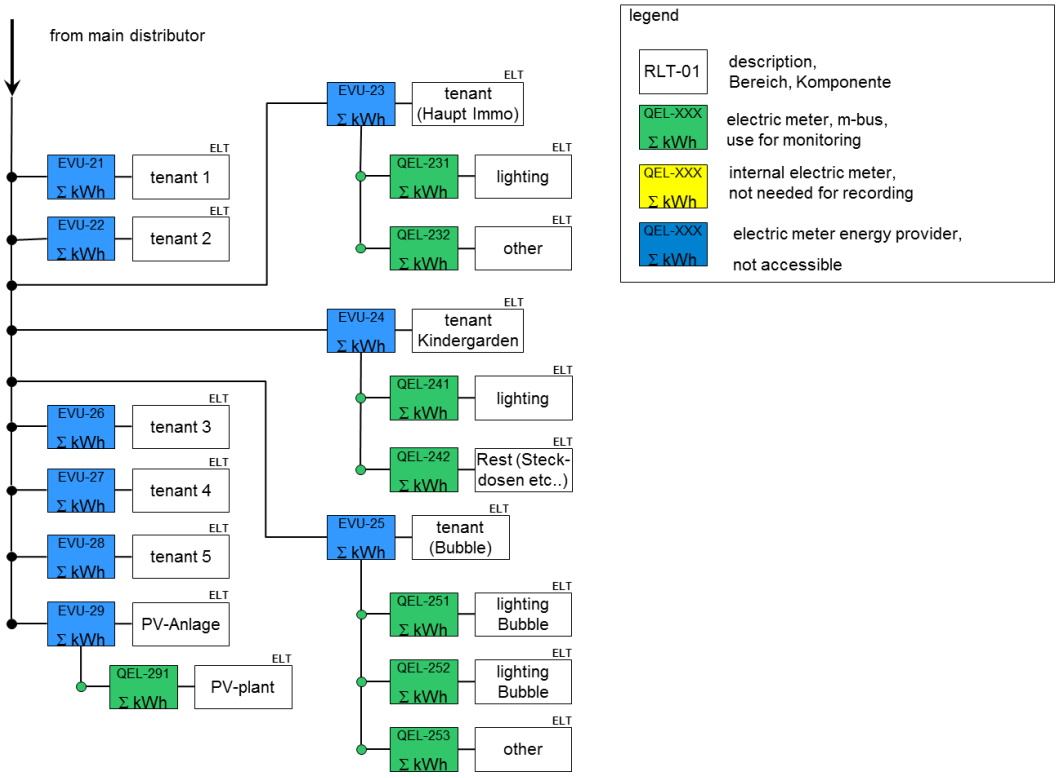


Figure 5: Detailed plan of needed counters within tenant areas

C. An **electrical counter** that measures the energy produced by the photovoltaic system. The factors associated to the PV production will be considered equal to the ones defined in point B. The renewable production "saves" primary energy and contamination corresponding to the nonrenewable case. The concept of the building was based on the no-need of a cooling system (mainly electrical). The electricity produced by the PV system will mainly cover the demands from the electrical equipment installed inside the building as copiers, computers and screens. Lighting systems will not be considered in spring, autumn and summer due to the fact, that the times of occupancy and the artificial light demand do not correspond.

D. Measurements of **enthalpy** must be done inside the duct that distributes the air flow in the building after it has been treated in the AHU. It must be evaluated only in the cases of lower enthalpy of the air current than the existing one in the zone that must be acclimatized during the summer or when the air enthalpies are higher than the internal ones in the heating season. The evaluation will compare the incoming enthalpies against the set points inside the building zones. In the case of a single air current and different zones demanding, the final value is the sum of the single values.

The following lines add information about the tree counter structure of the electric meters in order to have a specific knowledge about the use of the counters.

There is a general electrical meter, "entire building" with the measurement of total building consumption.

The meter "sub distribution" gives the measurement of the common zones and HVAC equipment.

In order to gather information about the common zones there are the following meters:

- Parking-garage.
- External lighting.
- Lift 01.
- Lift 02.
- Staircases.

The counter "building services" gives a measurement of the all HVAC systems into the building.

A specific counter for each climate machine, so that there are the following meters:

- Compression chiller": To measure the electrical consumption for cooling with the electrical compression machine.

- Absorption heatpump: To measure the electrical consumption.

Furthermore we can obtain the consumption of the AHU units by the sum of the counter for AHU 2-4 plus AHU parking plus the sum of AHU-01 fans. In addition the counter "AHU 1" gives the consumption of the one specific AHU (AHU 1) and of the whole distribution system.

The following meters give the consumption of the distribution system:

- P1-well: Measures the electrical consumption of the geothermal pumps.

- P2 server circuit: Measures the electrical consumption of the pumps to distribute the cooling for the servers.

- P3-TAB circuit: Measures the electrical consumption of the pumps to distribute the energy into the concrete core activation.

- P14-AHU: Measures the electrical consumption of the pumps to distribute the energy from the AHUs.

- P13-coldw.circuit: Measures the electrical consumption of the pumps to distribute the cooling from the compression chiller.

There is a focused measurement within tenant areas. The consumption of lighting and another one are in different counters.

The PV-plant counter records electrical production of the PV plan.

The bubble has two electrical counters for lighting in order to compare the consumption in the different floors, one floor with normal glazing and external blinds and the another floor with electrochrome glazing.

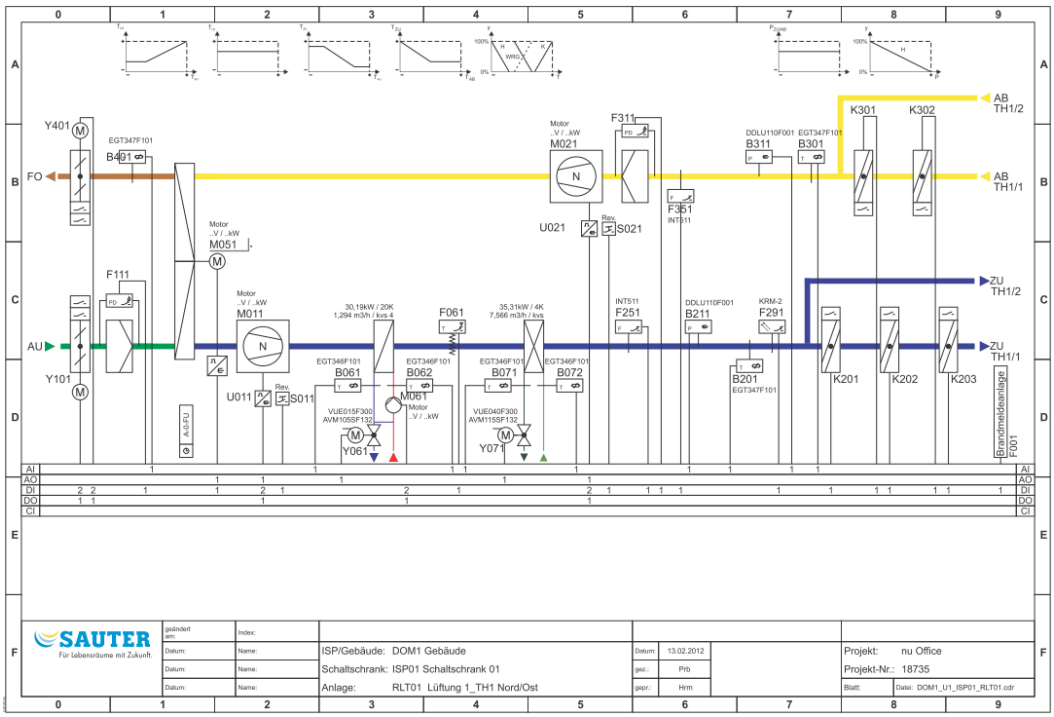


Figure 6: Scheme for one AHU as visualized in the control unit.

German	English
Anlage	system
Brandmeldeanlage	fire alarm system
Etagenverteiler	floor distributor
Geändert am	date of change
Gebäude	building
Lüftung	ventilation
Schaltschrank	control cabinet

The system consists of the following components:

- Outside air damper
- Outside air filter
- Heat recovery using heat recovery wheel
- Fresh air fan (speed-controlled by frequency changer)
- Fresh air ventilator isolation switch
- Air heater with heater valve, heater pump and flow/return temperature sensor
- Frost protection monitor
- Air cooling unit with cooling valve and flow/return temperature sensor
- Fresh air flow monitor
- Fresh air pressure sensor
- Fresh air temperature sensor
- Fresh air smoke detector

- Fresh air fire dampers (end switch monitoring)
- Fire alarm shutdown (connected to fire alarm system)
- Exhaust air fire dampers (end switch monitoring)
- Exhaust air temperature sensor
- Exhaust air pressure sensor
- Exhaust air flow monitor
- Exhaust air ventilator (speed-controlled by FC)
- Exhaust air isolation switch
- Heat recovery frost protection
- Exhaust air damper

The table below shows a summary of the energy measuring points as needed for calculating the entire building performance.

Table 1: Overview of heat/cold meters and electrical counters for building services

supply area	Sensor identifier	Sensor type	Sensor position
cooling	hm_02	flow counter	primary circuit groundwater well
Absorption heat pump	hm_01	heat/cold meter	primary circuit district heat to AHP
heating	hm_04	heat/cold meter	primary circuit district heat to heating-system
comp. chiller	hm_03	heat/cold meter	primary circuit comp. chiller
Absorption heat pump	hm_05	heat/cold meter	recooling system AHP (used as source)
Absorption heat pump	hm_06	heat/cold meter	primary circuit AHP-TABS
TABS	hm_07	heat/cold meter	primary circuit TABS cooling
TABS	hm_08	heat/cold meter	primary circuit TABS backup-cooling
TABS	hm_09	heat/cold meter	primary circuit TABS backup-heating
IT-Services	hm_10	heat/cold meter	primary circuit IT-cooling
IT-Services	hm_11	heat/cold meter	primary circuit IT-backup-cooling
AHU	hm_12	heat/cold meter	primary circuit AHU cooling
AHU	hm_13	heat/cold meter	primary circuit AHU backup-cooling
AHU	hm_14	heat/cold meter	primary circuit AHU-heating
Building	ec_15	elec. counter	main counter entire building
AHP	ec_16	elec. counter	el. consumption AHP
Gw-well	ec_17	elec. counter	el. consumption pump
chiller	ec_18	elec. counter	el. consumption comp. chiller
light	ec_19	elec. counter	el. consumption lighting
BEMS	ec_20	elec. counter	el. consumption building services, including building automation
PV	ec_21	elec. counter	delivered energy photovoltaic system

With this configuration of measurements it's possible to calculate the efficiency of the installed AHU and the compression chiller as well as to determine the fraction of renewable energy at whole energy consumption.

4 Building energy consumption and subsystems performance

This section shows the methodology to obtain the overall energy consumption in the building and how to calculate the performance of the most important subsystems.

In order to evaluate the energy consumption it considers the following consumptions in the building:

- Thermal energy consumption for heating and cooling.

- Electrical consumption for building services (auxiliary energy for plants, pumps and ventilation, electrical lighting)

4.1 Building performance

The energy performance is obtained by comparing measured data with calculated values coming from simulations and calculations per EPBD. The objective is to compare the energy based parameters as described in the deliverable D3.3 Monitoring System Project of Demonstrator III in the section 3.3 “Data treatment and storing” with simulated and calculated values The following lines show how to of gather the energy data from the building in order to obtain complete information to evaluate its performance.

Figure 7 and 8 shows the location of the electrical and energy counters:

- Heat counters in red.

- Refrigeration measurements in blue.

- Electrical consumption in green. In this case it shows the main measurements. Take into account that the remaining pumps, valves, flaps and any additional service devices are measured within meter QEL-112.

This figure represents the different sources of energy on the left (district heat, ground water and electricity) and how the different counters follow the energy used by the equipments.

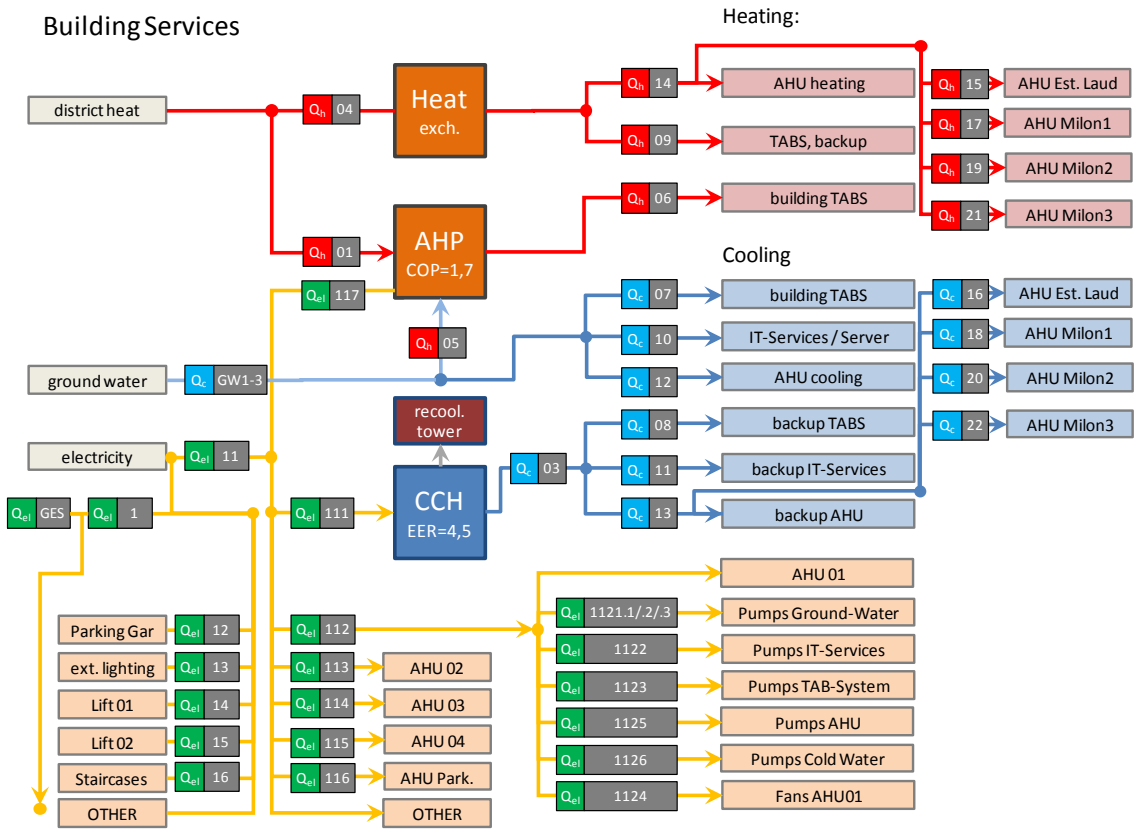


Figure 7, Location of the counters into de building services 1.

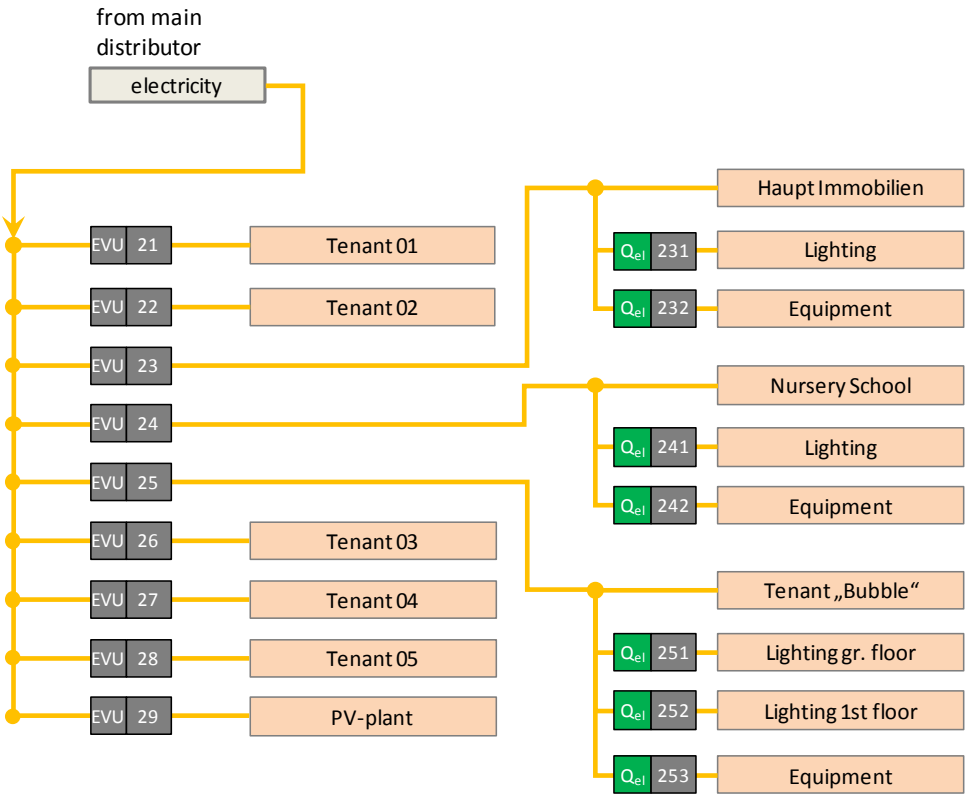


Figure 8, Location of the counters into de building services 2.

4.1.1 NEC, Net Energy Consumed

Section 3.3.2 shows the formula used to evaluate the building's performance, which requires the NEC. The following table shows how to gather the NEC from each area and the interval of time used.

Table 2: Net Energy Performance in NuOffice.

	Area	energy type	Device	counter as per scheme	unit	measurement interval
NEC Net Energy Consumed	Heating	thermal	district heat for direct use and absorption heat pump	$Q_h01 + Q_h04$	kWh	15 min
	Cooling	electrical	Compression chiller	$Q_{el}111$	kWh	15 min
	Cooling	thermal, renewable	Ground Water well	$Q_c07 + Q_c10 + Q_c12$	kWh	15 min
	aux. energy	electrical	Pumps, Valves etc..	$Q_{el}111 + Qel112 - Q1124 + Q_{el}117$	kWh	15 min
	Ventilation	electrical	AHU (01,02,03,04 and parking)	$Q_{el}1124 + Q_{el}113 + Q_{el}114 + Q_{el}115 + Q_{el}116$	kWh	15 min
	Ren. Energy	electrical	PV-Plant	$Q_{el}291$	kWh	15 min
	Artificial[1] Light	Electrical	Lighting Systems	$Q_{el}13 + Q_{el}231 + Q_{el}241 + Q_{el}251 + Q_{el}252$	kWh	15 min

The method of calculating the whole consumption of the lighting is to use the measurements of the lighting of three tenants, Haupt Immobilien, Kindergarten and Bubble (you can see this in Figure 5: Detailed plan of needed counters within tenant areas) which have the electrical consumption separated from the rest. With this information the building has the reference values for the offices, nursery school and the show room. By dividing these values with the utilisation area it gets characteristic values for the most common zones with which it is possible to extrapolate to the entire building in order to obtain the whole lighting consumption.

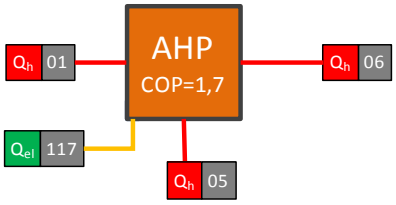
4.2 Energy efficiency of HVAC systems

For the overview of the subsystems see figure 7. The following figures depict how to obtain the energy efficiency of heating and cooling systems. It takes into account the following:

- **AHP:** The energy from ground water is not considered to be consumption because it is a renewable source of energy (heat counter 05).

The counters used are the follows:

- Electrical counter 1121.2.3 measures the consumption of the ground water pumps.
- Electrical counter 117 measures the consumption of the AHP.
- Heat counter 01 measures the heat consumption from district heating.



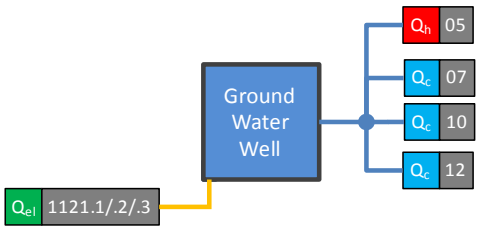
$$COP_{AHP} = \frac{Q_{h,06}}{(Q_{el,117} + Q_{el,1121.2.3} + Q_{h,01})}$$

Figure 9, Performance of the Absorption Heat Pump.

- Ground water well: This is a renewable energy source. This subsystem has two modes of operation, heating and cooling, each one with a different performance.

The counters used are as follows:

- Heating operation:
- Electrical counter 1121.2.3 measures the consumption of the ground water pumps.
- Heat counter 05 measures the heat contribution from the ground water to the AHP.
- Cooling operation:
- Cooling counter 07 measures the consumption of the TABS.
- Cooling counter 10 measures the consumption of the IT server.
- Cooling counter 12 measures the consumption of the AHU.



$$\eta_{GW,heating} = \frac{Q_{h,05}}{Q_{el,1121.1.2.3}}$$

$$\eta_{GW,cooling} = \frac{Q_{c,07} + Q_{c,10} + Q_{c,12}}{Q_{el,1121.1.2.3}}$$

Figure 10, Performance of the Groundwater Well.

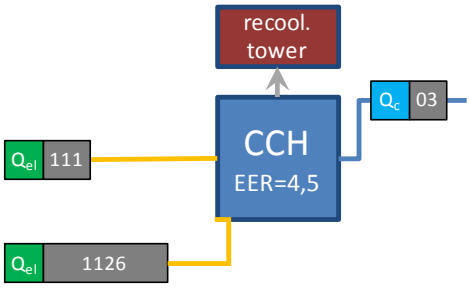
- CCH: In this case there are two different formulations for calculating the performance of the chiller:

EER1: performance of the cooling machine

EER2: performance of the overall cooling equipment, taking into account the consumption of the pumps. This calculation is more realistic.

The counters used are as follows:

- Electrical counter 111 measures the electrical consumption of the chiller.
- Electrical counter 1126 measures the electrical consumption of the pumps to carry the cooling.
- Cooling counter 03 measures the cooling produced.



$$EER1_{CCH} = \frac{Q_{c,03}}{(Q_{el,111})}$$

$$EER2_{CCH} = \frac{Q_{c,03}}{(Q_{el,111} + Q_{el,111})}$$

Figure 11, Performance of the Chiller.