Conference Proceedings

EuroSun 2016

Palma de Mallorca (Spain), 11 – 14 October 2016

ISES EuroSun 2016

MONITORING AND PROCESS OPTIMIZATION- THE WILLIBALD-GLUCK-GYMNASIUM IN NEUMARKT (i.d.OPF)

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Abstract

The newly constructed building of the Willibald-Gluck-Gymnasium in Neumarkt i.d. OPf. is a great example for integral planning of school buildings and enables the study of future-oriented technical and energy concepts.

Within the scope of this Federal Ministry for Economic Affairs and Energy-funded research project and the participation in the accompanying research "Energieeffiziente Schulen" (EnEff:Schule), the building's performance is being monitored and optimized to obtain and document verified insights about the system's performance. Innovative operation strategies for educational buildings are developed and evaluated with respect to high energy efficiency and increasing consumption of self-produced electricity. Accordingly geothermics as a low temperature heat source combined with heat pumps are used for heating the school building and gym.

The integral building concept unifies architectural ideas of alignment and shape of the building, a high quality and air-tight building shell with small heat transfer coefficients, and energy efficient building technology for heat and electric supply. Furthermore the available space is used optimally as an area collector is installed below the sports ground.

Keywords: School, energy concept, heat pump, low temperature heat source, monitoring, optimization

doi:10.18086/eurosun.2016.01.06 Available at http://proceedings.ises.org

1. Introduction

In the town of Neumarkt i.d. OPf. the Landkreis Neumarkt erected the new building of the Willibald-Gluck-Gymnasium (WGG) for approximately 1400 students including a gym. The four-story-building with inner atria and a net floor area (NFA) of about 11500 m² started operation in the winter term of 2015/2016. The sports hall with three fields and a NFA of 2900 m² was built at the same time (Fig. 1).

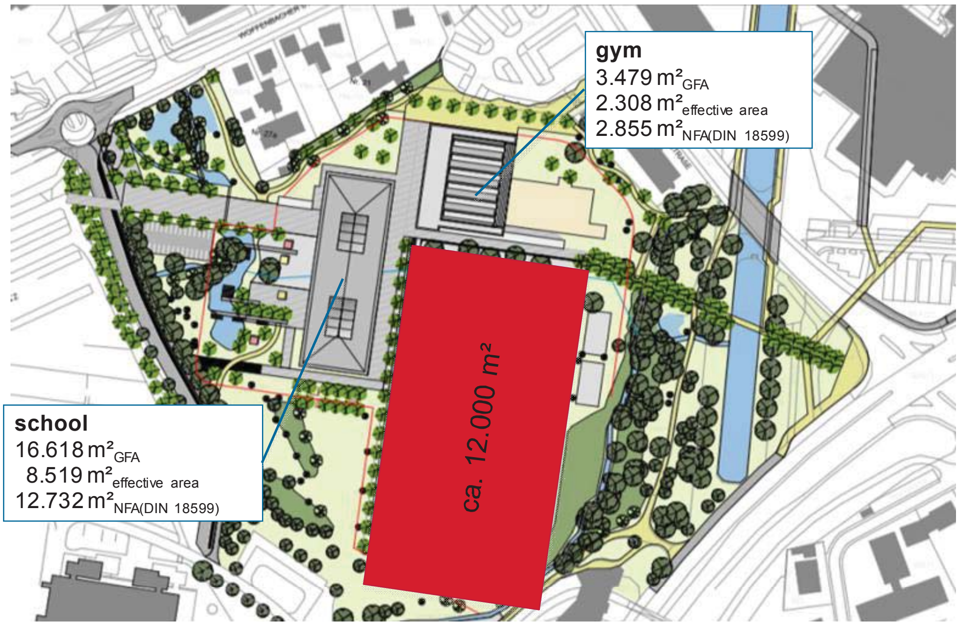

Fig. 1: Site plan of the school and gym

Prospective to the EU directive regarding the overall energy efficiency of buildings, the complex was to be realised as an "EnergyPLUS-School". It thereby implements the standard of "nearly zero energy buildings" as a demonstration project. The integral and innovative energy concept is based on energy optimised, sustainable, functional, comfortable, and architecturally valuable design. The necessary technology has been implemented and evaluated. The project demonstrates these conceptual aspects visibly and takes a role model function for public educational buildings.

The realised, innovative technologies are taken into operation using the new method of the "Performance Test Bench (PTB)" and monitored throughout their operation. The built-in measurement and monitoring infrastructure allows the sophisticated analysis of operation variables, building performance and air quality in the rooms.

A learning platform for teachers and students benefits the transparency and acceptance of this future-oriented project. To this purpose, the "Active Functional Specification (AFS)" is implemented in the PTB, a web-based platform for specifying building services' functions, validating their implementation, and detecting errors. It was developed by the IGS and Synavision. Energy performance and comfort in school buildings are to be visualised for the students and teachers. The treatment and analysis of the processes will take place during an energy laboratory lesson in the school's schedule.

2. Architecture

Light, transparency, open communication, and clear alignments are just some of the self-stated quality factors for interior architecture and the architecture of the new school. The main goal is creating an optimal learning and teaching climate for both students and teachers. Coloured windows, weather protection for wings of the windows, create cheerful atmosphere. Noise reducers are integrated as formative elements (Fig. 3).

Students and teachers experience open and bright rooms in the entire building, e.g. through apertures in the rooms' walls. Light and visibility are enhancing an open and communicative school. Two great atria are sending daylight into the building's core. Lucid corridors connect all areas. Dark hallways are nowhere to be found. The halls are more like open streets with open spaces for free communication and calm alcoves for resting (Fig. 2 and Fig. 3).

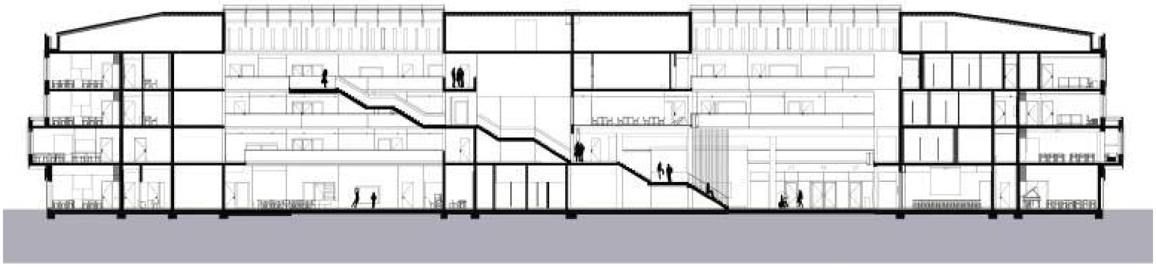

Fig. 2: Longitudinal section of the school

Entrance area

Class room

Inner courtyard

Gym

Fig. 3: Photographs of the WGG's new building and the gym
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3. Energy concept

As a lighthouse project for the new building type EnergyPLUS-School, the WGG utilises photovoltaics, heat pump and the new vanadium redox battery (VR-battery). With these components the building works as a decentralised energy producer. The concept's main medium is electricity, causing an economic and energetic interest to use the photovoltaic power in the building.

Geothermal energy is used as both source and sink. It works as a thermal storage with its more than 99 foundation piles (piles) and its area collector (ground-heat exchanger "Agrothermiefeld") below the sports ground. The geothermal heat pumps cover the heat demand of the floor heating system, the concrete core activation, and the ventilation system.

All class rooms are ventilated manually to ensure the room air quality (CO_2-concentration lower than 1500 ppm) that is essential for educational buildings (Fig. 4). The ventilation system has an integrated heat recovery to reduce heat losses and an adiabatic air humidification for cooling in summer. The supply air reaching corridors, halls, and resting areas is taken in through the class rooms. The exhaust ventilation is accomplished by a central suction system stored in the roof area in each of the two atria. A night time ventilation assists the school's cooling. For rapid heating of the class rooms during the heating period, the rooms are preheated before the beginning of the classes in the morning. The ventilation system can deliver variable amounts of supply air based on demand signalled by the CO_2-concentration ($\leq$ 1.500 ppm). The maximum flow rate is limited to 4.4 1/h.

The cooling of the class rooms and the IT/electrical installation rooms is realised passively (recirculation) in connection with the foundation piles and the area collector. The heat generation is adapted to the heat sources and provides heat with low temperature. This improves the integration and usage of renewable energy and serves as a foundation for energy efficient operation of the building and especially the heat pumps. The renewably generated electricity from the photovoltaics is primarily used in the building. Surplus power is fed into the electricity grid. The energy concept estimates that approximately 70 % of the heat demand will be covered by the heat pumps. Peak load (30 %) will be covered by a gas condensing boiler.

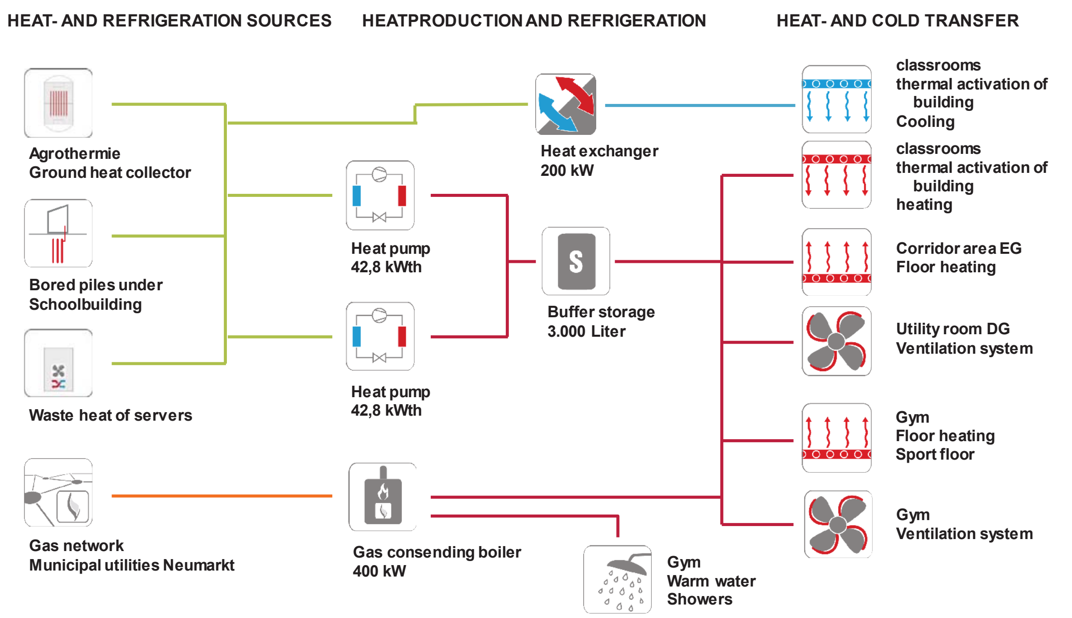

Fig. 4: Energy concept- heating and cooling

With a power capacity of approximately 290 kW_p the rooftop mounted PV-installation on the school building and the gym (Fig. 5) produces the greater part of the electrical power demand in the year's theoretical balance. For reaching the state of the EnergyPLUS building and later a negative primary energy consumption, the power capacity would need to be increased to approximately 500 kW_p. An enlargement of the system up to 600 kW_p has already been taken into consideration during the planning of the building and the structure is suitable. The enlargement of the installation will be implemented at a later time by the building owner.

The concept includes a usable fraction of the electric energy of 65 % by including a VR-battery. The other 35 % will be fed to the electrical grid. The combination of the PV-system and the VR-battery facilitates a solar coverage of 40 % according to the design (Fig. 6).

Fig. 5: Aerial photos of the PV-installation on the school building (left) and the gym (right)

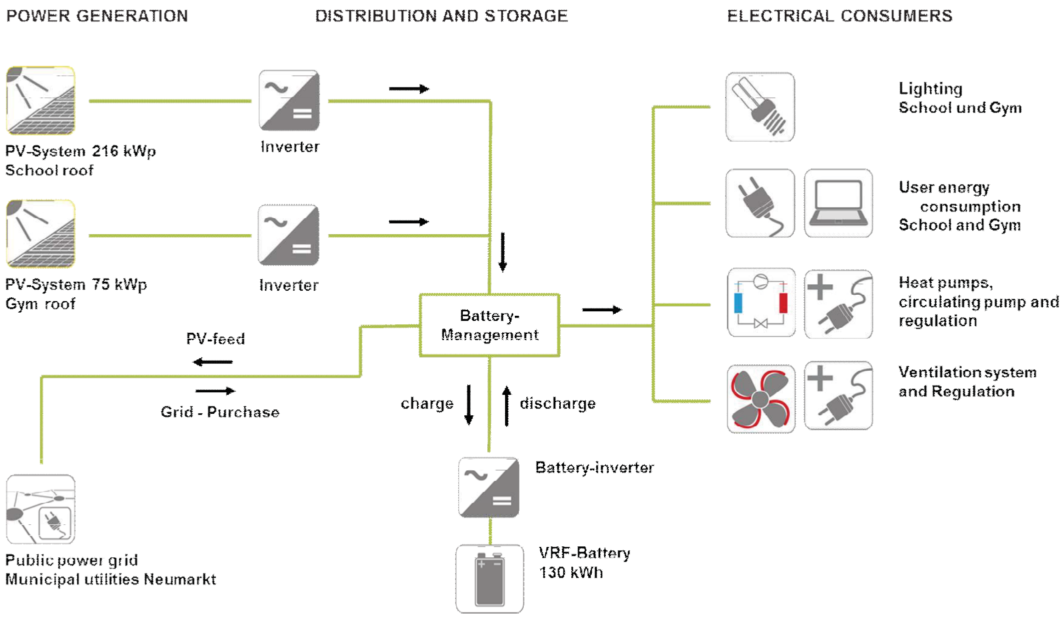

Fig. 6: Energy concept- electricity

3.1 Ground-heat exchanger "Agrothermiefeld"

Below the sports grounds next to the school an "Agrothermiefeld" has been realised. The field, an area collector, has been installed using an innovative technique in the field of geothermics. The piping system is brought two meters into the ground by specially designed plough. An active area of up to 4400 m² has been installed in total (Tab. 1). The installation process has been completed in August, 2015, without any major complications (Fig. 7).

Tab. 1: Information „Agrothermiefeld“

Number of pipes	47 pipes à 93,5 m
Dimensions of pipes	D_a 40 x 3,7
Installation depth	ca. 2,26 m (ploughing)
Collector area	ca. 4.400 m²

Fig. 7: Ploughing with pipe installation and completed sports field including the pipes

3.2 VR-battery

The installation and start-up of the vanadium redox battery manufactured by Gildemeister took place between September and October, 2015. In December the battery took up full operation. In January and February, 2016, minor changes in the internal control system were implemented. Since March 2016 the battery is being charged, discharged, and controlled as designed. Already in August, 2016, an optimisation of the internal controlling parameters has been executed. The overview information about the battery is listed in Tab. 2. Photos of delivery and installation are shown in Fig. 8.

Tab. 2: Overview vanadium redox battery

Manufacturer	Gildemeister
Type	CellCube FB 30-130
Electrical storage capacity	130 kWh
Utilisable capacity	100 %
Max. charge power	30 kW_p
Max. discharge power	30 kW_p
Weight of the filled system	14.000 kg

Fig. 8: Delivery and installed VR-battery

3.3 Energy balance

The energy consumption has been certificated based on the current “Energieeinsparverordnung” (EnEV 2009 / DIN V 18599-1:2007-02). Furthermore, the user electricity consumption is to be supplied sustainably. The heating power consumption takes less than one third of the annual energy demand. Two thirds belong to electricity consumption for ventilation, lighting, and other purposes (Fig. 9).

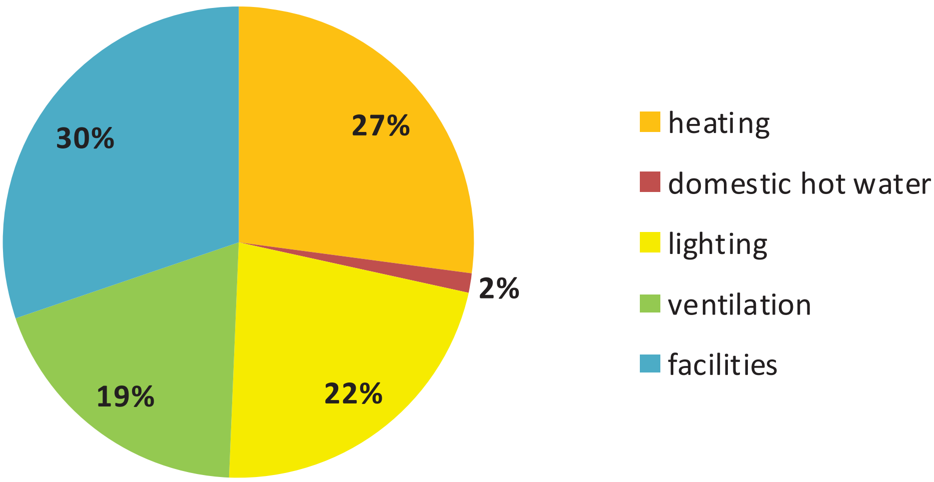

Fig. 9: Overall energy distribution

The quality of the implemented edificial standard and building technology undercuts the legally defined specifications of the EnEV 2009 (EnEV 2014) to the primary energy consumption by approximately 50 %. The characteristics for the EnEV-calculation are summed up in Tab. 3. In addition to the values contained in the balance of the EnEV, the equipment’s power consumption is being included. The school complex is supposed produce a net surplus in primary and overall energy. The demand values are calculated based on DIN V 18599 (Fig. 10).

Tab. 3 Characteristics of the WGG-building

	School	Gym
Year of construction	2015	2015
Net floor area (NFA based on DIN V 18599)	12.732 m²	2.855 m²
Heated edifice volume V_e	63.056 m³	17.264 m³
Annual heating energy demand	25 kWh/(m²$_{NFA}$a)	
Annual cooling energy demand	10 kWh/(m²$_{NFA}$a)	
Overall electricity demand incl. equipments	40 kWh/(m²$_{NFA}$a)	

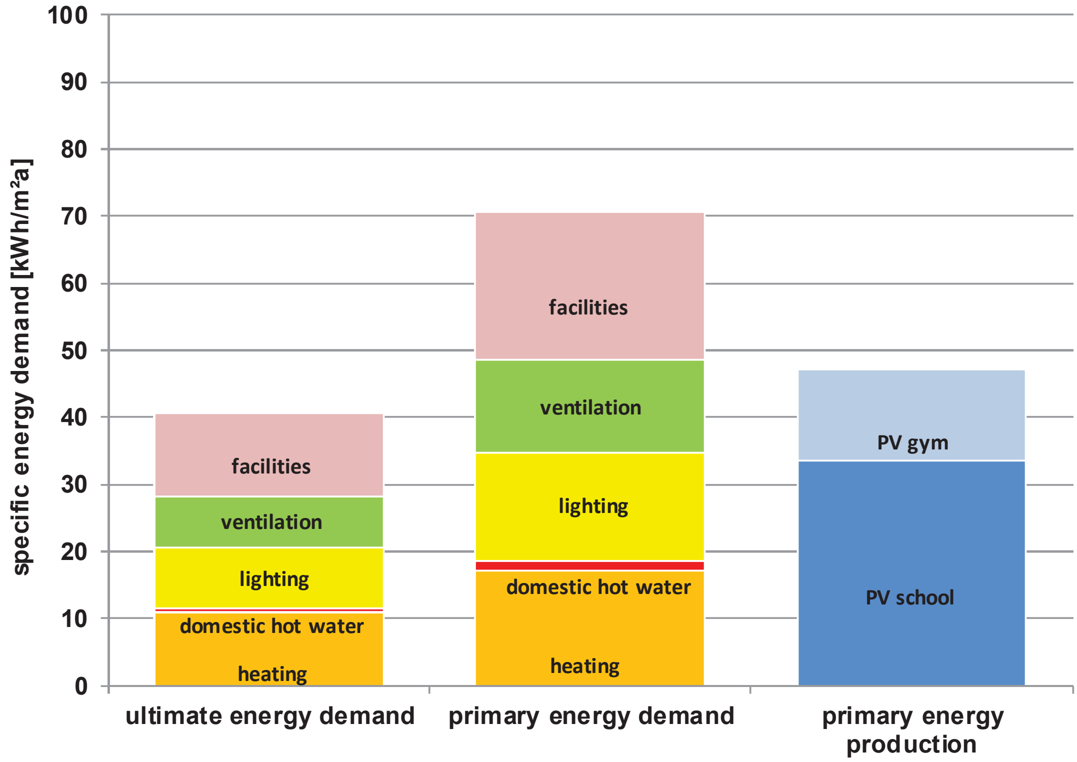

Fig. 10: Energy balance demand vs. production (DIN V 18599)

4. Monitoring

A concept containing a set of indicators for the system and building performance has been developed. It enables the analysis and assessment of the energy efficiency and different modes of operation. Based on the definition of aims, a measuring and monitoring concept has been realised. Respective specification for process measuring and control technology / building automation have been formulated.

Due to delay in construction and the installation of the process measuring and control technology, the recording of data started in May / June 2015.

4.1 Comfort monitoring

Fig. 11 shows the results of the comfort monitoring in the rooms 115, 216, and 230 in July 2016. The results show that the room air quality is mostly held within an acceptable or good state. Room 230 temporarily reaches temperatures >26 °C. The room is an IT room in the inside of the building causing greater thermal loads. By tendency, the room temperatures lie within the warmer comfort zone. The night time ventilation (01:00 to 06:00) achieves a temperature drop of 1 or 2 Kelvin. The average room temperature of the three rooms lies between 24 and 25 °C.

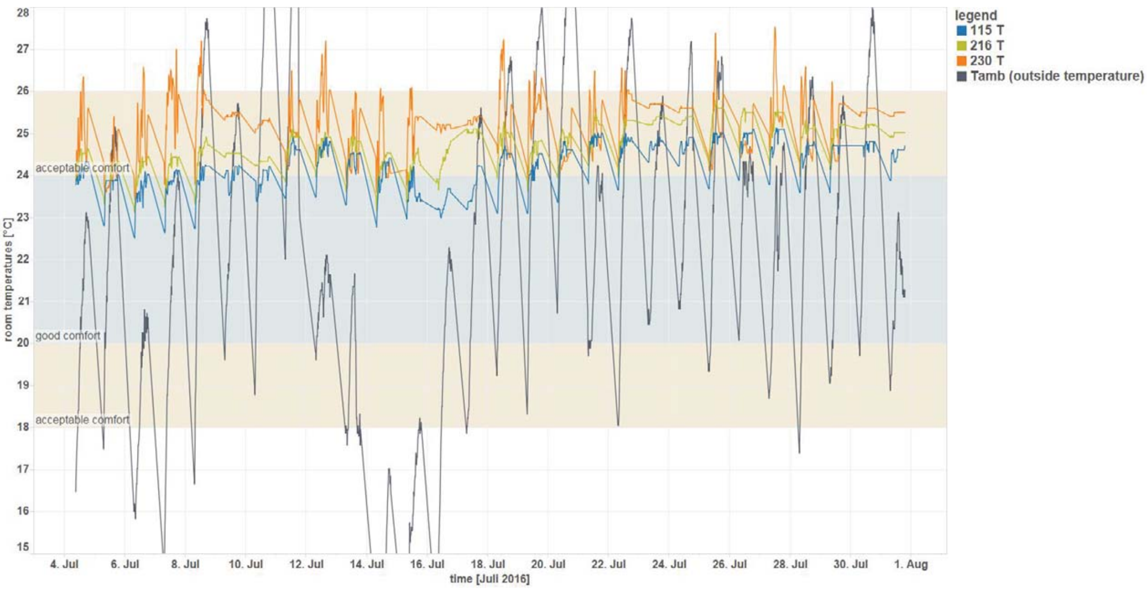

Fig. 11: Room temperatures in July 2016 between 07:00 and 18:00

The maximum CO_2-concentration of 1500 ppm is satisfied on most occasions in all of the three rooms (Fig. 12). Temporarily the limit is succeeded. On average, the concentration during the classes (07:00 – 18:00) moves between 515 and 730 ppm. This corresponds with good comfort.

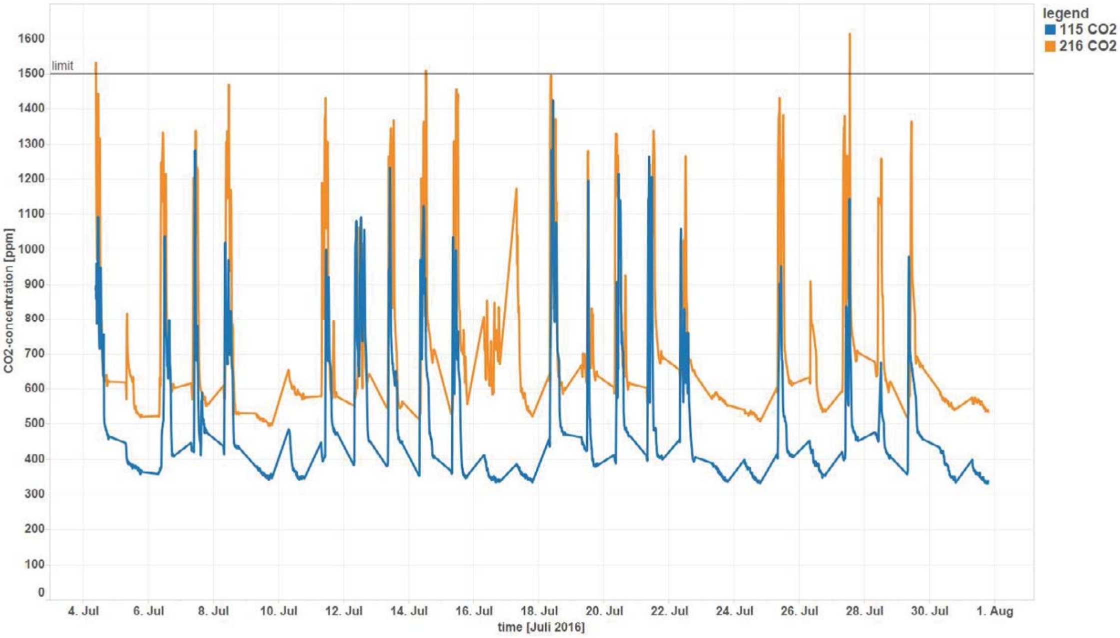

Fig. 12: CO_2-concentration in the rooms R115 und R216 July 2016 between 07:00 and 18:00

4.2 PV-production

Fig. 13 shows the electricity production of the PV-plant, the overall electricity consumption, and the resulting amount of coverage in the week of 11.-17.07.2016. Depending on the PV-power, the electricity demand of school and sports hall can temporarily be covered entirely by the plant (coverage = 100 %). The weekly average is approximately 40 %.

The photovoltaic electricity production in the time between 01.01. and 31.07.2016 amounts to 116,3 MWh (400 kWh/kW$_p$). Of this amount, 60,6 MWh are being consumed in the school and sports hall, corresponding to an ad-hoc-consumption of about 52 %.

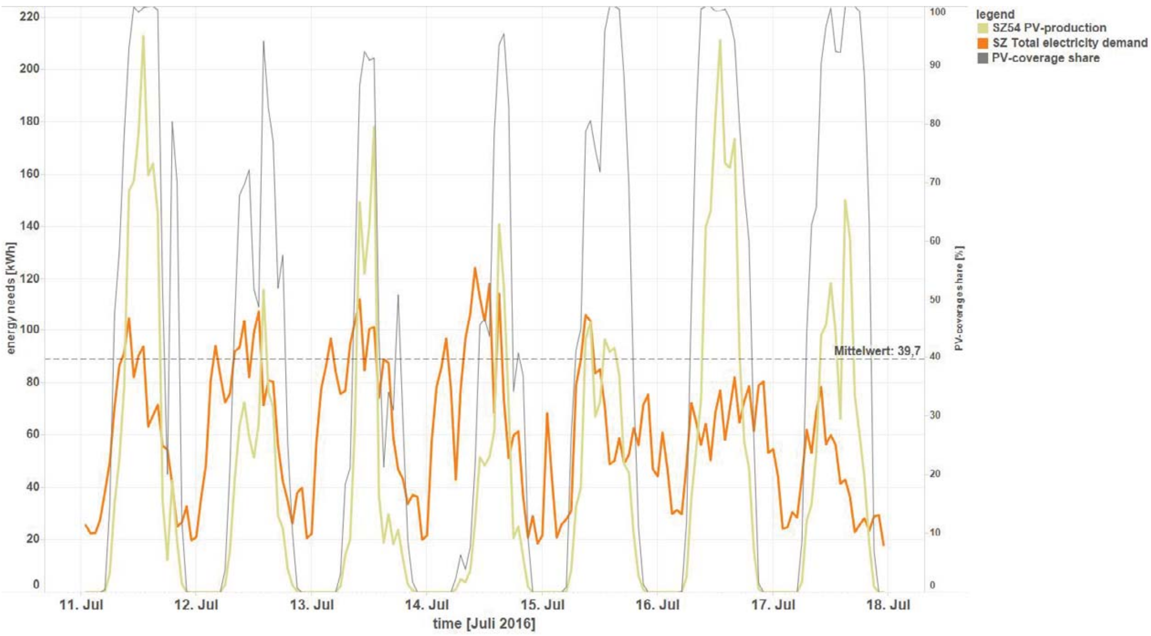

Fig. 13: PV-production, electricity consumption and amount of coverage (11.-17.07.2016)

4.3 VR-battery

After initial difficulties with the control system, the VR-battery is in orderly operation since 18.08.2016. During the day, the battery is being charged (up to battery level 100 %). During the night time, the battery is discharged down to a level of 5 %. Fig. 14 shows the battery level in the time 19.-26.08.2016.

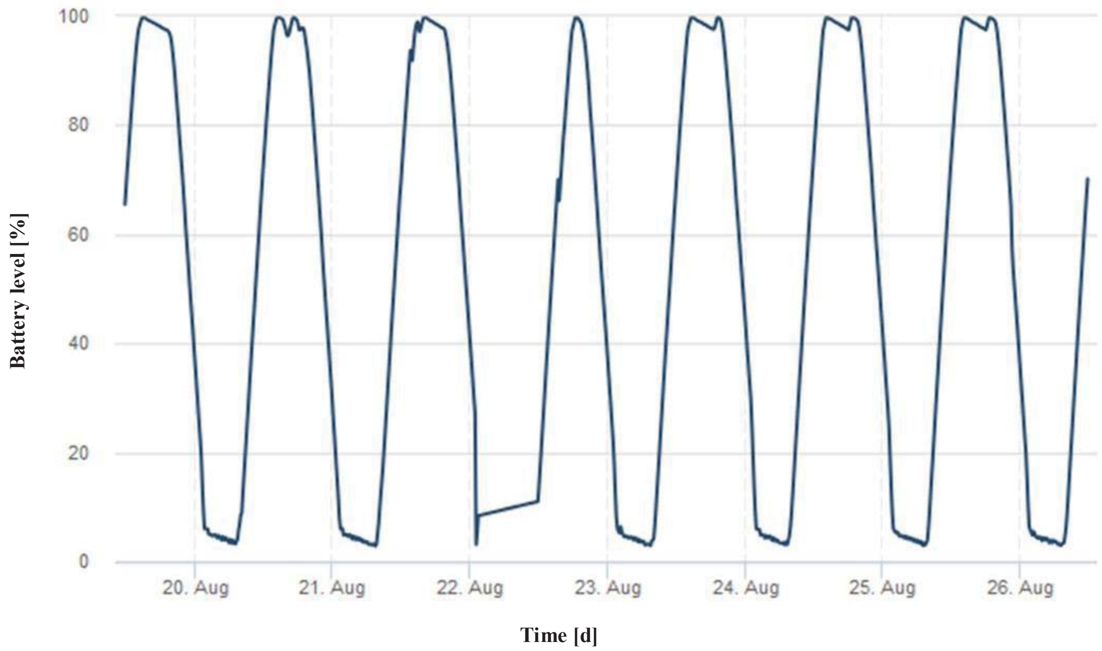

Fig. 14: Battery level in the time 19.-26.08.2016

5. Conclusion

The pilot project gives a great example of future building standards. It reveals the frame for the development and evaluation of necessary methods and tools for educational building and public edifices.

The scheduled completion of the technical system at the beginning of the school year in August 2015 was tenable. The school's operation started in the winter term 2015/16, though with limited and unplanned operation of heating and ventilation. The heat pumps were activated in February 2016. From August 2015 to February 2016 the school and sports hall were solely heated by the condensation boiler which was intended as a peak-load unit. The concrete core activation was started up in January 2016. Before that, the heat was transferred solely by ventilation air and floor heating.

The notable optimisation potential of the building system became visible in the course of the first months of operation. The results and insights uncovered in this research project help avoiding these problems and optimising operation in future construction projects. The new buildings serve as role models and are, due to their typical use and characteristics, suitable to be multiplied.

Only in practical application, singular technologies can be observed in their effective behaviour and integrated into the construction process. The operator's and user's ability to work and maintain the systems in a suitable manner can also only be assessed after the installation and start-up of the actual machinery. The necessity of early planning, documentation, and intensive surveillance for the successful implementation of an energy concept containing low-ex-heat sources has been proven within this project. The final realisation of the project is only possible in interdisciplinary cooperation of all parties involved.

6. Expression of thanks

The research project „EnOB: Monitoring und Betriebsoptimierung des Willibald-Gluck-Gymnasiums in Neumarkt (i.d.OPf.)" is funded by the Federal Ministry for Econimic Affairs and Energy under the reference number 03ET1308B.

Federal Ministry
for Economic Affairs
and Energy