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Engineering & Construction

Jury Brief Report #2

solar decathlon europe 21»22
WUPPERTAL GERMANY ...goes urban!

Technische Hochschule Rosenheim

Introduction

The main topic of the project is to extend the existing building by adding storeys and at the same time refurbishing the existing building part to create an energy-efficient and climate-friendly house. For energy-efficiency retrofitting, the essential steps are reducing the heat losses and lowering the CO2 emissions of the energy supply. Using materials with a low carbon footprint should be a given nowadays, although it is not yet. The same is true for new buildings, but the cost factor for adding energy efficiency is much lower, as it means only paying the differential cost for higher quality.

The levelup team picked a building that is very common in German cities. The team's idea was to develop a concept transferable to most houses of the same type. Therefore the heating concept has to be adaptable to different supply situations and allow to reach zero CO2 emissions in the near future. From the current perspective, decarbonised heating means the usage of heat pumps, solar energy, waste heat, or emissions-free district heating. All have in common the need for low temperatures for high efficiency.

DC- Retrofit of the building envelope

Retrofit a building with a floor or panel heating means the tenants have to be billeted out for weeks which is too costly, not speaking about the acceptance by the tenants. The other significant intervention in the renovation of the existing building is the installation of a new front facade on the existing exterior wall, including the exchange of the windows. The team found a solution to incorporate all in one step with the least possible burden for the residents — a prefabricated curtain wall with integrated new windows and a facade heating system. The installation fittings for the facade PV or regular cladding panels are also premounted.

Upgrading the facade means the following steps: laser scanning of the building, fabrication of the facade elements, transport to the site, installation of the elements, installation of the facade panels, and removing the old windows from inside. The work inside the apartments is limited to removing the old windows and finishing the reveals.

The façade refurbishment comes with high air tightness making a ventilation concept mandatory. The ventilation must have heat recovery to reach a plus-energy building level. A central ventilation system for each apartment with an innovative ducting concept is planned for the best compromise between intrusion, cost, and efficiency. Ceiling-mounted ventilation units are installed in the bathrooms. They provide supply air only into the corridor of the flats. CO2-controlled room-to-room fans above the doors deliver the air into the rooms. The air flows back into the corridor through the door crack. The unit extracts air in the bathroom and via a short duct in the neighbouring kitchen. Although the airflow to the rooms needs to be higher for the same air quality, investigations at the THRO have shown that the power consumption for the complete system is lower than with standard ducting. The minimal duct length overcompensates for the higher flow rate of the rooms. For retrofitting, the ductless air distribution means only minor intervention in the apartments, plus it involves less material expense.
The planned retrofit of the building envelope reduces the heating demand for the refurbished part by about 94%.

DC- Heating system and DHW

The façade heating has two significant benefits concerning the demands for future buildings. It allows for heating temperatures as low as 25 – 28°C and thermally activates the existing wall made of imperial moulding bricks. The first renders possible the use of almost any heat source available. The latter enables hugh thermal storage, which may interact with the grid or adapt to renewable energy availability.

The façade heating consists of capillary tube mats. They are fixed at the façade elements on top of the insulation layer facing the wall. Due to their elevation, they get pressed against the old façade as the elements are mounted.

The façade heating will provide a base heating to reach a temperature of about 17 – 18°C. The existing radiators will control the individual room temperature. Since the retrofit reduced the heat load to about 10% and the façade heating covers about half of it, the flow temperature of the existing high-temperature radiators can be lowered to almost the same level as the façade heating. The exact number depends on the old design of the heaters. An additional benefit of this is lower network losses in the heat distribution of the existing building and the possibility to use lower temperature levels for heating the building.

The new storeys are equipped with underfloor heating is for heat distribution. The advantage of underfloor heating is that it provides heat to the room and can also be used for cooling in summer.

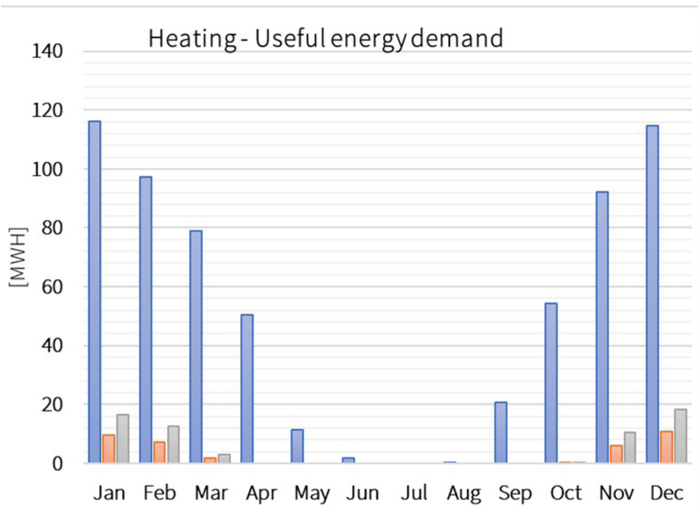

Figure 1 – Comparison of unrefurbished (blue) vs refurbished (red) vs DC total (grey)

Energy requirements can be further reduced in domestic hot water preparation (DHW). The current installations are electric flow-type water heaters. Exchanging those would mean a lot of costly construction work and cause a lot of circulation losses. Instead, the team decided on a heat recovery system for the showers, a shower channel that preheats the cold water feed. The recovery saves up to 50% of the heat demand for showering and about 40% of the total DHW demand. The assembly of the heat exchanger system is done preferably with a planned renovation of the bathroom to save costs. As most bathrooms in the house are due for remodelling, The implementation can be done within the following years.

In the extension, the energy requirement must be kept low from the beginning. For this reason, the building envelope is designed for heat transfer coefficients similar to passive house levels. The glass surfaces achieve an excellent U-value using a newly developed glass, combining a vacuum double glazing with a third layer reaching an Ug-Value of 0,5 W/K*m².

The principles of ventilation ducting are the same as in the retrofit, but the ventilation box is mounted integrated into a wall. However, the installation is placed in the apartment corridor instead of the bathroom.

The heat exchanger for the showers will be installed in the newly added building part as well. For hygienic reasons and low temperature, the hot water supply with freshwater stations on the apartment level is carried out. Since the bathrooms and kitchens of the individual residential units are always close, legionella protection is ensured by a filling quantity of the pipes of less than 3 litres and no thermal protection is required. Separate heating water risers with high-temperature levels are provided for this purpose. These will be insulated at the highest available level to keep the circulation losses low.

DC- Energy supply concept

Thermal

Since the building's concept is intended to be transferable to a wide variety of locations, a LowEx concept with a maximum heating flow temperature of approx. 25°C was developed for the building's heat supply. With a district heating supply, it offers the following innovative possibilities.

- The direct supply by a low temperature district heating with out the need of a heat pump for grid temperatures above 30°C.
- The use of an absorption heat pump when the network has a flow temperature above 85 to 90°C. The heat pump can work with groundwater or sewage as the heat source. This reduces the heating energy demand by 40%. Due to the very low heating temperatures required, return temperatures into the heating network of approx. 50°C can still be achieved with a well-dimensioned absorption heat pump.
- Instead, the heat supply can also be taken directly from the return line to create lower return temperatures for better usage and efficiency of the district heating.

Combined with an electric heat pump, the 8 to 10 K lower heating system temperature will increase the COP of the heat pump by 20 to 25%, independent of the ambient heat source. The storage capacity of the activated walls allows for shifting the running time of the heat pump to times when PV power is available and, in the case of air heat pumps, the outside temperature is higher. Even the use of gas AHPs is possible, should this prove helpful in future.

As described earlier, the thermal mass allows for grid interaction. The building can act in both ways, increasing or reducing the demand depending on the grid need. Estimations for the possible time shifts have shown that the wall loses without heat input only 1 K in about four days in the wintertime.

Since the district heating of N-ERGIE Nuremberg has a CO2 emission factor of zero certified according to FW309-1:2020 and a primary energy factor of 0.27, this is currently the most sensible external heat supply for the site. Both suitable groundwater and a suitable wastewater pipeline are available, so an AWP was planned. The use of the wastewater was investigated but does not yield better temperatures than groundwater use. The smallest commercially available plant produces a significantly higher output than required so implementation would make economic sense as part of a neighbourhood concept.

Parts of the roof PV system are designed as PVT collectors to keep the heat drawn from the grid low. These fulfil several tasks: DHW preheating, heating supply at sufficient temperatures, and, in summer, nighttime heat dissipation from the existing façade via radiant cooling.

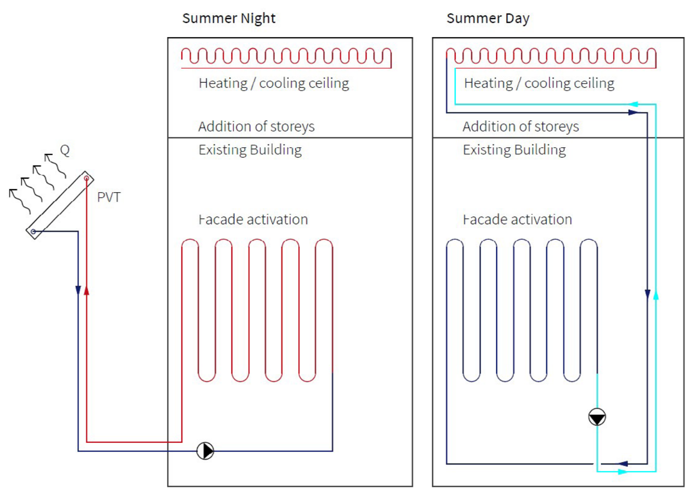

Figure 2 – Façade heating - heating and cooling mode

The thermal storage mass gained through façade activation has another advantage. The façade can be cooled down at night via the PVT. The cooled façade can then be used on hot summer days to cool the extension passively. For this purpose, a circuit is created between the façade heating circuits and the underfloor heating circuits, whereby the heat from the extension is transported into the façade. At the same time, the night cooling prevents heat built-up in the old building part over the summer and keeps it at comfortable temperatures.

A photovoltaic system is integrated into most of the building envelope to cover the electricity consumption. The roof surfaces will be equipped with high-performance PV and PVT modules, and the façades of the extension and the existing building will get a photovoltaic façade. The simulations necessary for the designs are carried out with the simulation programmes PV*SOL and Polysun.

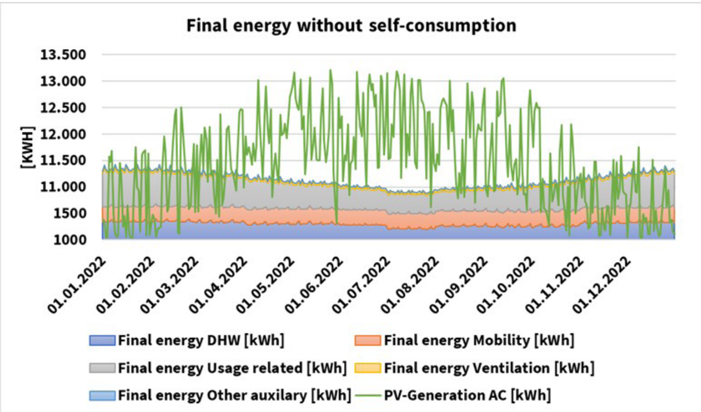

Figure 3 – Final energy without self-consumption

For a shading simulation of the façade, the surroundings of the existing building were simulated. This resulted in percentage shading values of over 20 %, especially for the façade on the ground floor, which is why no façade PV is installed on these surfaces.

Electrical wiring and building automation

The exterior walls of the dwellings serve as fire protection walls. Penetrating them requires the maintenance of the corresponding fire protection class. The installation level in the exterior walls is eliminated to circumvent this. Instead, a radio-based solution was chosen for the light switches, where the light switches are glued to the wall without needing an installation box. The sockets and network outlets are mounted on a skirting board in front of the exterior walls. With a thickness of 2 cm, it is not excessively obtrusive. This offers the additional advantage that sockets and network outlets can be repositioned later with little effort, and the position can be adapted to different user needs.

The omitted installation level impacts the room comfort as it connects the room to the thermal mass of the wooden walls and removes dynamic cooling loads.

The energy reduction measures are to be rounded off by intelligent and user-friendly building automation. This includes, among other things, adequate and demand-controlled shading in order to achieve an optimal supply of daylight throughout the year and, in addition to passive solar gains, to increase the savings of electricity for artificial lighting. Furthermore, the summer heat protection is to be ensured. By means of monitoring, conclusions are to be drawn about user presence, user behavior, heating or cooling requirements. The occupant of the apartment receives feedback on his current energy consumption as well as behavioral recommendations, for example, in order to be able to influence the load condition of the building (e.g. a recommendation for the use of the washing machine, etc.).

Basically, the individual parameters of the energy supply are to be controlled and recorded via the building automation in order to realise an energy-efficient building via energy and load management. Building automation can reach significant energy savings. However, it also comes with 24/7 energy consumption. Even when small, like 0,5 W per actor or internet connection, it will add up. Therefore it has to be used wisely and carefully to ensure the savings exceed the additional consumption. We use a 12 channel knx-actor/measuring system connected to an energy management system (EMS) with a standby consumption of a single actor. The system connects appliances and other electrical consumers to the EMS. They can be switched off to cut the standby consumption but are still available for excess PV power usage or grid demand. The built-in metering enables correct excess PV power usage with any connected device. Also, it tells the user the consumption of his devices, the state of battery charge, PV production, and finally, a house app will show rankings to engage the user in energy-saving behaviour. We calculated the smart readiness indicator (SRI) according to EPBD 2018/844 to be at least 77%. If all the predictive control algorithms in development are functional, it will be 91%.

DC-Rain- and Greywater

To irrigate the roof gardens and façade greening in a resource-saving way, the direct use of rainwater is an option. As the rainwater is used exclusively for irrigation purposes and not for sanitation, additional fine filtering is unnecessary. Short pipe runs and a low pumping capacity are ensured by installing the tanks close to the consumer in the roof area. To avoid static and constructional problems, several small tanks are interconnected to form a battery on the top floor of the extension. The rainwater is collected via a collector in the downpipe, which is flooded when the tanks are at maximum level. Thus, the excess water runs into the infiltration system during prolonged heavy rainfall. The greywater system is used as a backup during dry periods.

With only 600 mm rainfall Nurnberg is already a reasonably dry region, and climate change will reduce it further. Drinking water supply will become an important topic in large cities very soon. With a greywater treatment system, about one-third of the drinking water can be saved even during dry periods by supplying the toilet and washing machine with service water. Thus, this system is not only worthwhile from an economic point of view but also from an environmental point of view. For this purpose, the slightly polluted water from the shower and washbasin is treated. If there is a surplus of service water, the rainwater tank can be replenished due to the high quality.

Transfer to the HDU

As with the DC, both the roof surfaces and the façade of the HDU are used for solar energy generation. Due to the performance restrictions imposed by the regulations, the entire south façade is equipped with a façade photovoltaic system, but electricity is only generated via PVT collectors on the roof, which is inclined at 12° towards the southwest, while the connection for the other PV systems was merely prepared. Ten uninsulated Spring 375 Shingle Black modules from Dualsun were chosen. Each of the modules has a nominal output of 375 watts.

To not violate the rule of the maximum installed electrical power of 3 kW, only eight modules are electrically connected for the competition. Hydraulically, however, all ten modules are connected. The background to this is, on the one hand, the night cooling via the collector surfaces already mentioned at the beginning and, on the other hand, the drinking water preheating.

The electrical system of the PVT modules is completed by a Fronius Symo Gen24 3.0 Plus inverter and a BYD Battery-Box Premium HVS 5.1. The battery storage has a capacity of 5.12 kWh. To remain within the limits of the regulations, the capacity, charging and discharging power is reduced via Modbus in consultation with and with the confirmation of the manufacturer, following a 2.5 kWh storage unit.

The heating concept had to be transformed into a power only concept. The idea of the HDU heating system is the realisation of the electric heat pump option for the DC building as described earlier. An electric heat pump replaced the AHP and district heating, and a water storage tank replaced the thermal mass of the activated façade. In summer, the PVT collector is sufficient as a heat source; a geothermal basket is added for later use of the HDU in Rosenheim. The thermal storage is also used as heat storage for heating in winter, similar to façade heating.

Water hygiene and associated legionella protection require 60°C for DHW. To avoid the efficiency reduction of the heat pumps and PVT collectors due to the high temperature, constructive measures were taken instead. Using a freshwater station close to the tapping point fulfils the 3 l rule and allows for any hot water temperature.

Comprehensive Energy analysis of the DC

The refurbishment of the building envelop reduced the heating demand according to a DIN 18599 calculation with Hottgenroth Energieberater for the current building from 639 MWh/a or 185 kWh/m²a to 62 MWh/a or 10,7 kWh/m²a, a reduction of 94% (for the specific value). The end energy demand for heating is reduced further due to the thermal yield of the PVT and the AHP. The end energy for heating drawn from the district heating is for the renovated building 27,6 MWh/a or 4,8 kWh/m²a.

The heat recovery system in the shower reduces the heat demand for hot water by about 40%. Furthermore, the DHW generation in the new part gains from the PVT. The used energy is 59,7 MWh/a and the end energy needed is 28,7 MWh/a. In the building stock, the electricity for DHW is estimated to go down from 151 MWh/a to 109 MWh/a.

Regarding CO2 emissions, the reduction in heat demand from the district heating does not influence the emissions as the Nuremberg district heating has zero emissions certified. However, this is due to the calculation method, and thus it is still essential to lower the energy used from the network. It is not sensible to distribute the PV power production to the uses for the electrical power, as this will be arbitrary. Overall the hourly simulation has shown a total PV production of 541 MWh/a, total power consumption of 413 MWh/a, a self-consumption of 225 MWh/a and a grid demand of 196 MWh/a. This totals to a net power supply to the grid by the house of 315 MWh/a. This includes a car-sharing fleet of 33 cars with 20.000 km/a each.

The total end energy balance is now 56,3 MWh/a drawn from the district heating net minus 315 MWh/a supplied to the power grid resulting in a plus energy balance of 259 MWh/a. The reduction of CO2 emissions is 63 tons, not considering mobility. The cars safe 660.000 km driven with non-electric cars. Estimated at 120 g/km gives an additional reduction of 79 tons.

Rosenheim Technical University of Applied Sciences

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energy endeavour FOUNDATION

BERGISCHE UNIVERSITÄT WUPPERTAL

Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

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