Multi-family Passive House units with energy gains

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1 Introduction

These days, completed Plus Energy buildings tend to be single-family houses that produce so much energy in the summer with photovoltaic systems that they achieve an energy surplus when calculated over the whole year. But how can a surplus be created when conditions are different – when a multi-family dwelling has limited space for photovoltaics and a suboptimal orientation, or when homemade power's share of consumption increases and the power grid can't be used for seasonal storage? Solutions for these issues are being developed in the "Passivhaus mit Energiegewinn" (Passive House with energy gains) research project at Cordierstrasse 2-6 in Frankfurt, Germany; this paper presents a new build with 1,190 m² of treated floor area divided among 17 residential units as an example. The multi-family dwelling is being built by ABG Frankfurt Holding and planned and implemented by the faktor10 architecture firm.

2 Efficiency concept

In order to achieve an overall annual balance between production and demand in multi-family dwellings, energy efficiency must first be increased in all areas. Starting with the Passive House Standard, improvements in the efficiency of hot water supply and domestic power use are particularly important. A holistic efficiency concept was therefore developed for the new build at Cordierstrasse 2-6 in Frankfurt that can significantly reduce the building's energy demand. The main points of the concept are as follows:

- A reduction in heating demand due to Passive House architecture
- A reduction in energy demand for hot water from lower hot water temperature, minimized distribution losses, and fixtures that reduce water consumption
- A reduction in auxiliary power due to especially energy-efficient building services
- A reduction in private household power consumption due to kitchen appliances with the highest possible efficiency, energy-efficient lighting, and a simplified switch for standby consumption

3 Technology concept

The remaining energy demand is covered with solar thermal, photovoltaics, and a biomethane-fired cogeneration unit (see Figure 1).

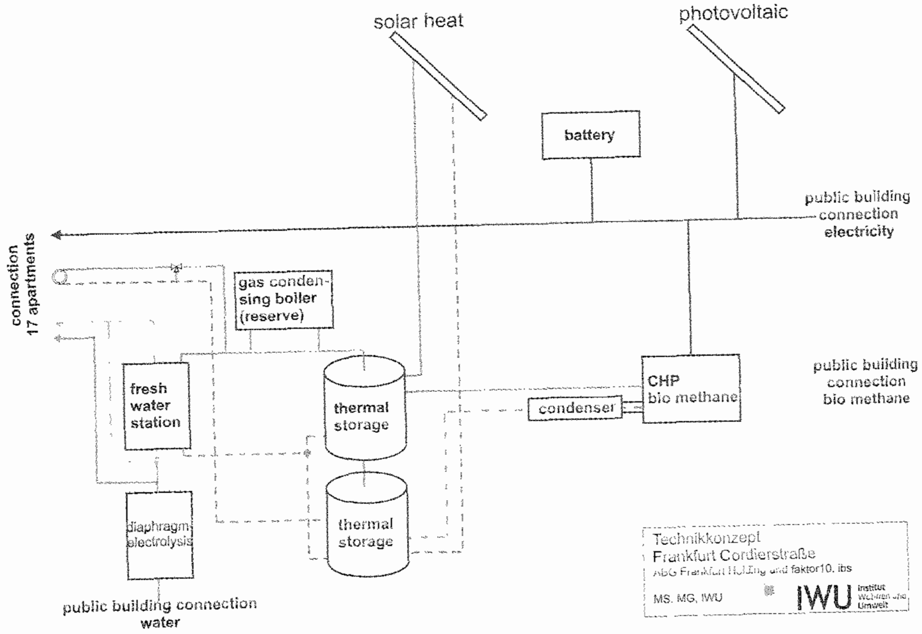


Figure 1: Simplified installation scheme, Cordierstrasse 2-6

The solar thermal system with a 40 m² evacuated tube collector produces about 60 %of the heat needed for hot water, while the cogen unit (5 kWel, 12.3 kWth, another 2.3 kWth via a condenser) supplies the rest of the heat for the heating system and hot water. The gas-condensing boiler (25 kW) is included as a reserve system and only used during maintenance or if the cogen unit fails. Diaphragm electrolysis is used to clean the water, making thermal disinfection unnecessary, which in turn means that the hot water temperature can be reduced to 48°C and distribution losses can be significantly reduced (see [Grossklos 2011]). The photovoltaic array (37 kW in total) provides electricity along with the cogen unit. A system for storing electricity ensures that primarily energy produced by the building is also consumed in the building.

As with single-family homes built to produce a surplus of energy, photovoltaics is also the deciding factor for a positive energy balance for multi-family dwellings. Achieving this goal is much more difficult for the latter, however, since less (roof) space is available for solar energy production per m² of living area. At the same time, electricity demand is typically higher per m² of living area in a multi-family dwelling because of the smaller apartments

and, usually, higher density of residents. Other unfavorable conditions on a particular site may also come into play. The project on Cordierstrasse, for example, has to deal with a suboptimal building orientation, shading from neighboring buildings, and requirements from the building authorities regarding the building's appearance.

Reducing demand for household and auxiliary power is therefore key to achieving an energy surplus in multi-family dwellings. Positive results from taking steps to reduce power consumption have already been seen in the Rotlintstrasse project (see [Grossklos et al. 2013]). Those steps included pre-installation of efficient lighting, standby switches, and drying closets in some units. Several components were added to the concept for the building in this project, with the owner equipping the apartments with high-efficiency kitchen appliances, standby switches, and efficient lighting in all rooms.

By combining such measures with the use of highly efficient solar panels – which are now available with efficiencies of up to 19 % – on the roof and suitable areas of the façade, an energy surplus can now be achieved. Any additional commercial or agricultural buildings or other structures on the site should also be used for photovoltaics. In the case of the Cordierstrasse building, the carport roof on the site is also used to produce solar power, in part to reduce the amount of less efficient, significantly more expensive photovoltaics on the façade.

4 Energy balance

Figure 2 depicts the energy balance for this multi-family dwelling with 17 residential units. The calculations are based on energy values from PHPP with regard to treated floor area. Primary energy factors, including power from photovoltaics, calculated using Gemis 4.7 were used for the primary energy assessment (see Table 1).

	Gemis 4.7	DIN V 18599-1
Biomethane	0.30 kWh/kWh	0.5 kWh/kWh
Photovoltaics	0.39 kWh/kWh	0.0 kWh/kWh
General power mix	2.34 kWh/kWh	2.4 kWh/kWh
Power offset	2.34 kWh/kWh	2.8 kWh/kWh

Table 1: A comparison of primary energy factors

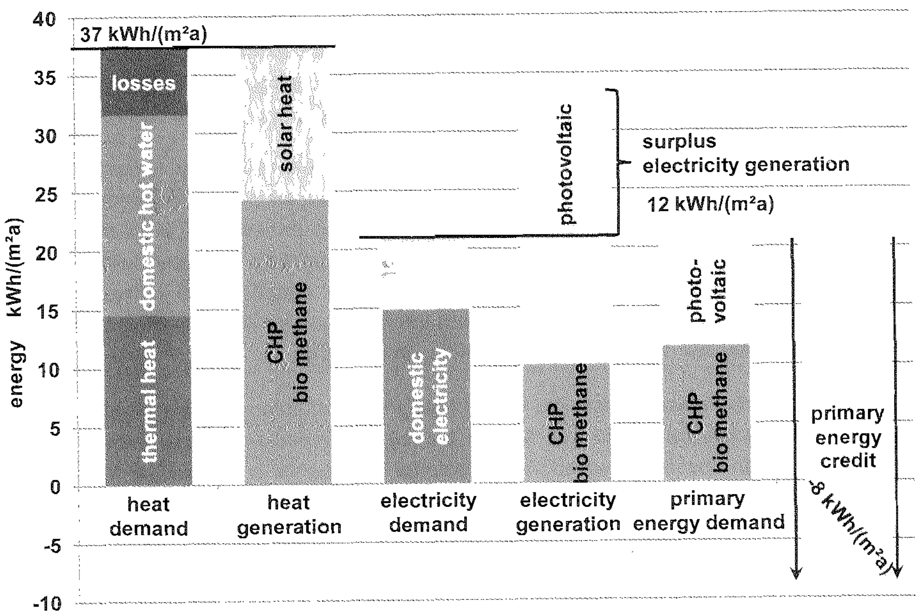
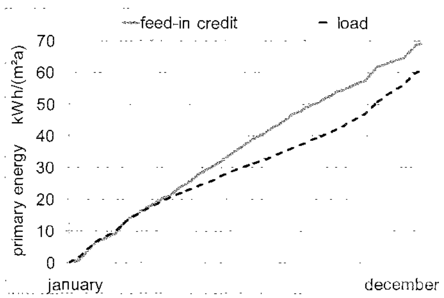


Figure 2: Energy balance

The energy balance demonstrates that the combination of a solar thermal system and a cogen unit can limit demand for biomethane, a renewable fuel, to about 25 kWh/(m²a), which is significantly lower than the amount of biomass that can sustainably be used in Germany ([Diefenbach 2002]) of about 35 kWh/(m²a). Primary energy credit for PV power sent to the grid leads to a surplus of 8 kWh/(m²a) in the annual balance, even though the orientation of both the building and its photovoltaic surfaces is not optimal. Under the BMVBS's conditions for model projects built to the "Effizienzhaus Plus" standard, calculated based on A_N according to EnEV2009 / DIN V 18599, the building still achieves a primary energy surplus that is just a little lower (6 kWh/(m²A_N a)).

The solar thermal array provides a large portion of the heat needed in the summer and transitional periods, while the cogen unit is mostly used in the winter, with heat demand only increasing when photovoltaic yields are low. When it comes to producing electricity, the cogen unit and the photovoltaic array complement each other so well that a large share of power consumption is covered by the building's own systems, even in the winter. The grid is therefore not used for seasonal storage. Primary energy figures are also balanced over the course of a year (see Figure 3).



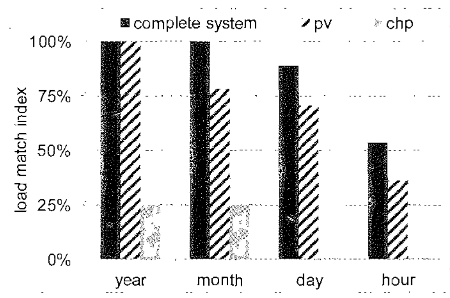


Figure 3: Feed-in tariffs and loads over the course of a year

Figure 4: Load match index

The "load match index" is another indicator that demand and production are well coordinated in terms of time. This term is used by [Voss et al. 2011] to describe the effect of net zero-energy buildings on the power grid, with the following calculation:

$$f_{load,i} = \min\left[1, \frac{on-site\_electricity\_generation}{electricity\_consumption}\right] * 100 \quad [\%]$$

i = time interval (hour, day, month, year)

Load match indexes for the multi-family dwelling in this project are depicted in Figure 4 as average load match index values for each time period within a year. The calculation does not include energy storage. Power from the cogen unit was calculated with the same method as solar power. The graph makes it clear that the combination of photovoltaics and cogeneration significantly increases the hourly, daily, and monthly load match index. Adding electricity storage, which in this case would be designed to balance production and consumption between the daytime and nighttime, can increase the hourly load match index even further.

5 Conclusion

By reducing energy demand in all areas and very efficiently using renewable energy, multi-family dwellings, too, can achieve overall energy surpluses. Along with using the Passive House Standard, which by now has proven its worth many times over, to decrease the amount of heating energy needed, it is also important to significantly reduce energy demand for hot water and focus particularly on reducing electricity demand. The project at Cordierstrasse 2-6 demonstrates that highly efficient buildings equipped with especially efficient building services for producing renewable power and heat can achieve an energy surplus over the course of a year. Using biomass in a cogeneration unit increases the balance between energy demand and production over the course of a year as well as the load match index for self-produced power compared to overall power consumption, thereby reducing load on the power grid, which will be an important issue in the future.

Nevertheless, the use of biomass should be kept to a minimum in light of the limited amount available.

6 Acknowledgements

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7 References

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