Concepts for Net Zero Energy Buildings in refurbishment projects

Florian Kagerer[*] and Sebastian Herkel

Fraunhofer Institut for Solar Energy Systems ISE, Heidenhofstrasse 2, 79110 Freiburg, Germany

Introduction

Regarding the proposed objectives to reduce CO_2- emissions significantly it is highly relevant to optimize the energy consumption in the building sector. For that purpose the development of Net Zero Energy Buildings (NZEB) which produce as much energy as they consume within a year is a promising approach. On basis of a highly energy efficient building standard it could be proved for new buildings that net zero energy concepts can be realized with today's available techniques. From 2019 on the new EU building directive claims Net Zero Energy Buildings as an obligatory standard for new buildings. As the current rate for newly built houses in many European countries is below or about 1% the impact on the CO_2 balance will be very low, even if all new buildings are realized as NZEBs. Therefore the energy optimization of the existing building stock is a core target for the future. Zero Energy Concepts have to adopted to the specific requirements and characteristics of refurbishment projects and have to be developed to an affordable solution to supply new and existing buildings.

Motivation

Within the IEA Task 37 "Advanced housing renovation by solar and conservation" many best practice examples for multi-family houses as refurbishment projects all over Europe could be shown. On basis of detailed measurements the energy performance of the following buildings were analysed.

Table 1. Overview of part of buildings analysed in Task 37.

	Freiburg, Rislerstrasse ~ 40/60 kWh/m²a primary energy demand Condensing boiler with solar thermal collectors
	Heidelberg, Blaue Heimat ~ 34 kWh/m²a primary energy demand natural gas chp unit
	Freiburg, Roter Block ~100 kWh/m²a primary energy demand (10 kWh/m²a considering biomass) biomass chp unit (rapeseed methyl ester)

Compared to new buildings one of the main characteristics of refurbishment projects is that due to technical or economical reasons not all known and established measures for energy efficiency can be realized. On this account the energy building standards vary from buildings with nearly no improvements on the building envelope like buildings under historical preservation protection to buildings according to the Passivhaus standard. In any way high efficiency is the basic requirement to get to a Net Zero Energy Building. In this regard especially heat pumps and chp-units offer the most potential to improve the energy supply of buildings for the time being. Additional both systems offer the possibility of energy management measures by generating or respectively consuming electricity in connection to the electrical grid.

Objectives

Taking into account the results of IEA Task 37 the following issues will be discussed in this paper:

- Analysis of different kind of building standards as state of the art in refurbishment projects
- evaluation of chp-units and heat pumps as electricity based supply systems
- estimation of potential for NZE concepts and interaction with the electrical grid

Methodolgy

The measurement results from the projects mentioned above are used to build up a validated and calibrated basic simulation model for the building and supply system. Thereon the simulation model is varied according to different building standards and additional supply systems are implemented. All measures for a NZEB are limited to the potential on site. The over all performance of the buildings are analysed and evaluated as well as the interaction between supply system and public grid. The calculations for the energy balances are drawn out for site energy and primary energy. For evaluation two approaches for NZEBs are considered:

- total energy demand including energy for heating, domestic hot water, auxiliary energy and all household appliances.
- supply energy demand, including energy for heating, domestic hot water and auxiliary energy.

The primary energy evaluation takes into account the German primary energy factors of 2.6 for electricity and 1.1 for natural gas.

Building description and boundary conditions for simulation

The simulated building is a 3 storey multi family house with 18 dwelling units (Rislerstrasse, Freiburg). The net heated floor area sums up to 1550 m² and the ratio of the building envelope to the heated volume is 0.46. The building is orientated to the south/ south-west and provides good conditions for solar appliances like photovoltaic and solar thermal.

Fig. 1. ground floor and facades of simulated building.

As shown in table 1 the energy building standards are varied with different qualities of the building envelope. In all cases a mechanical ventilation system is implemented in combination with and without heat recovery. The air change rate is considered for infiltration, mechanical ventilation and user behaviour. Internal loads are taken into account with 2.1 W/m².

Table 2. Different alternatives for building standards.

ACH-Rates	ACH-mechanical	ACH-user	ACH-inf	Total U-value
A_1	0.50	0.20	0.10	0.42
A_2	0.30	0.20	0.10	0.30
A_3	0.30 – HRC 85%	0.30	0.10	0.30
A_4	0.50 – HRC 85%	0.20	0.10	0.42
A_5	0.30 – HRC 85%	0.20	0.10	0.30
A_6	0.30 – HRC 85%	0.15	0.05	0.30
A_7	0.30 – HRC 85%	0.10	0.05	0.30

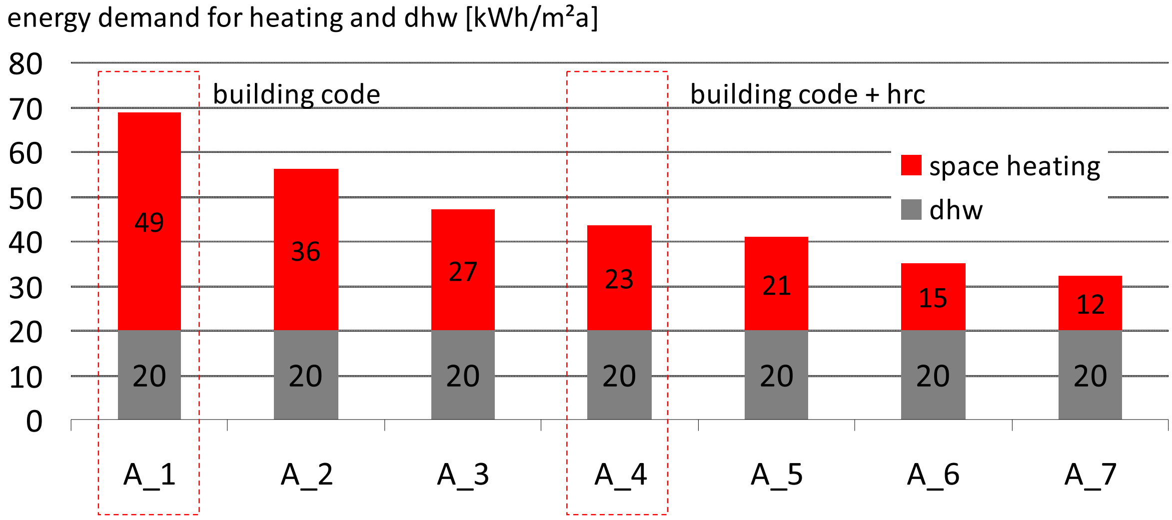

Fig. 2. energy demand for heating and domestic hot water for different building standards.

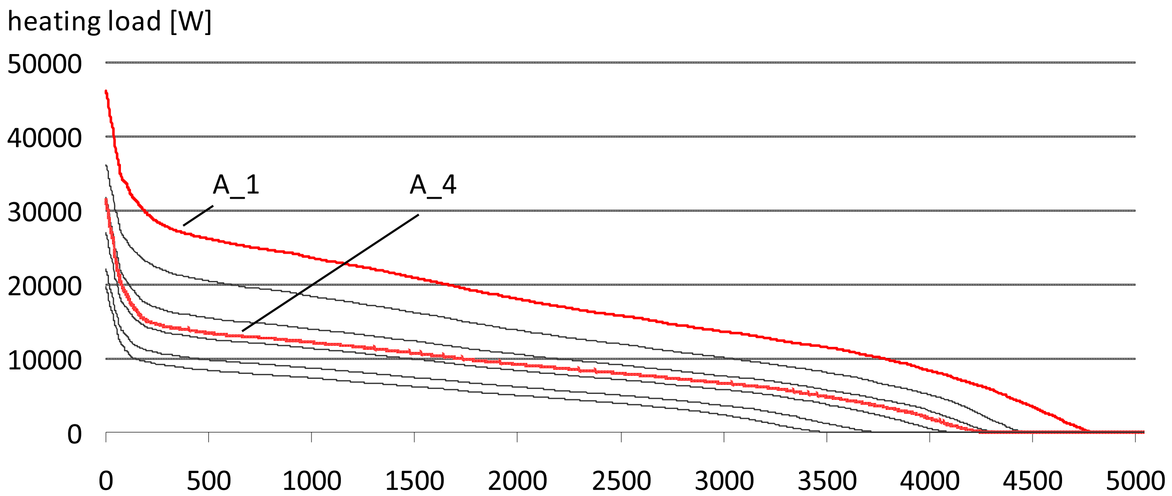

Fig. 3. heat load of different building standards.

Out of a variety of supply systems the focus in this analysis is made on heat pumps and chp- units. Both systems offer the possibility to increase the energy efficiency of the heating supply for the building and additionally to contribute to a load management strategy by interaction with the electrical grid. The systems are combined with a 3500 litre buffers storage and 50 m² solar thermal collectors for domestic hot water and heating. For generating electricity photovoltaic is applied on the available roof area of 250 m².

Table 3. Supply systems for heating and electricity.

Supply system	PV	Solar thermal	tank
HP 25kWel	250m²	50m²	3,5m³
CHP 50kWth 35kWel	250m²	50m²	3.5m²

Results

The simulation results show that a balanced energy consumption and production considering the total energy demand including household appliances is not possible with the analysed systems. In comparison to single family houses the available areas for solar thermal or photovoltaic is limited, especially if related to the net heated floor area. The chp- unit enables with both buildings standards an energy balance close to net zero just for the supply system. Beside the photovoltaic the benefits for the electricity production by the chp unit are essential. The heat pump supply system does not reach a zero energy balance for both standards and for both approaches (total energy / supply energy demand). The main requirements for zero energy buildings are to further improve the over all efficiency of the supply systems and to increase the fraction of renewable energy for heat generation on site. Whereas for single family houses net zero energy concepts are already available in different alternatives for multi family houses, the most promising concept is limited to a supply system based on chp units at the moment. Only a combination with the use of biomass enables a net zero energy balance for all energy appliances on site.

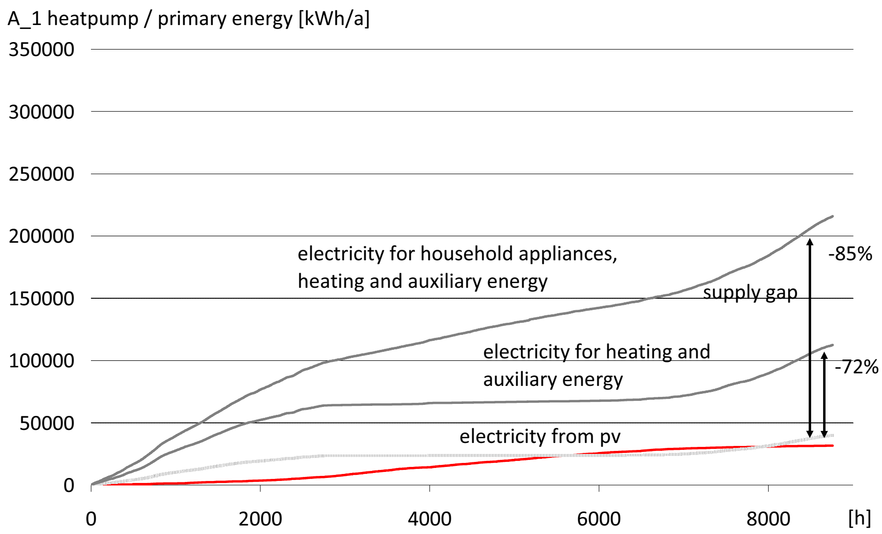

Fig. 4. building standard A_1: pv production provides only 15% of the total primary energy demand and 28% of the electricity demand for heating, dhw and auxiliary energy.

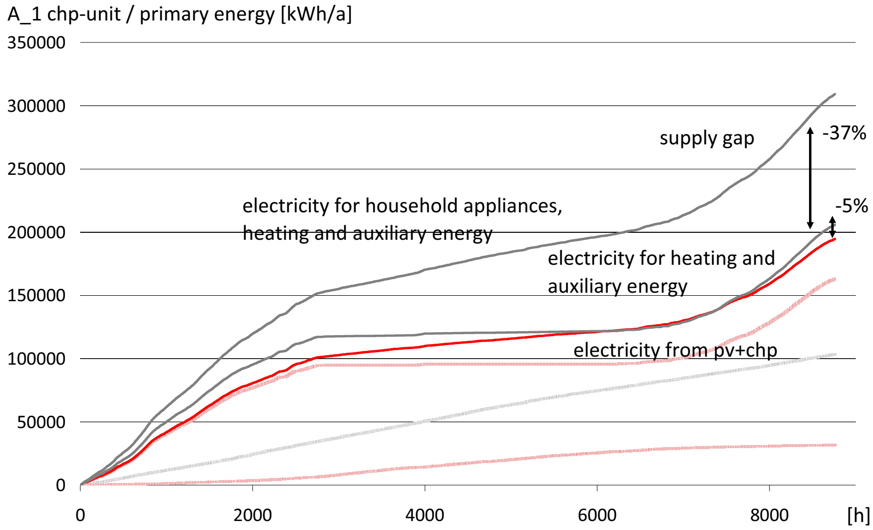

Fig. 5. building standard A_1: pv and chp production provides 63% of the total primary energy demand and nearly 95% of the electricity demand for heating, dhw and auxiliary energy.

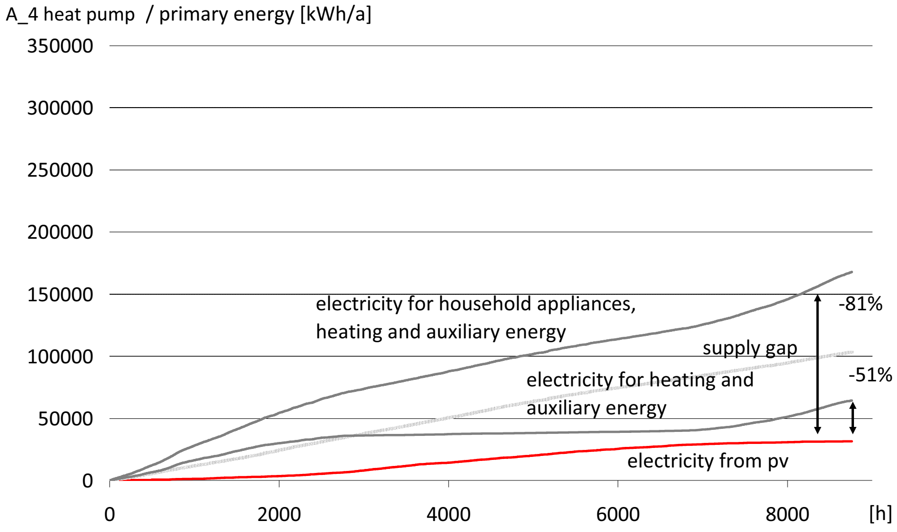

Fig. 6. building standard A_4: pv production provides only 19% of the total primary energy demand and at least 49% of the electricity demand for heating, dhw and auxiliary energy.

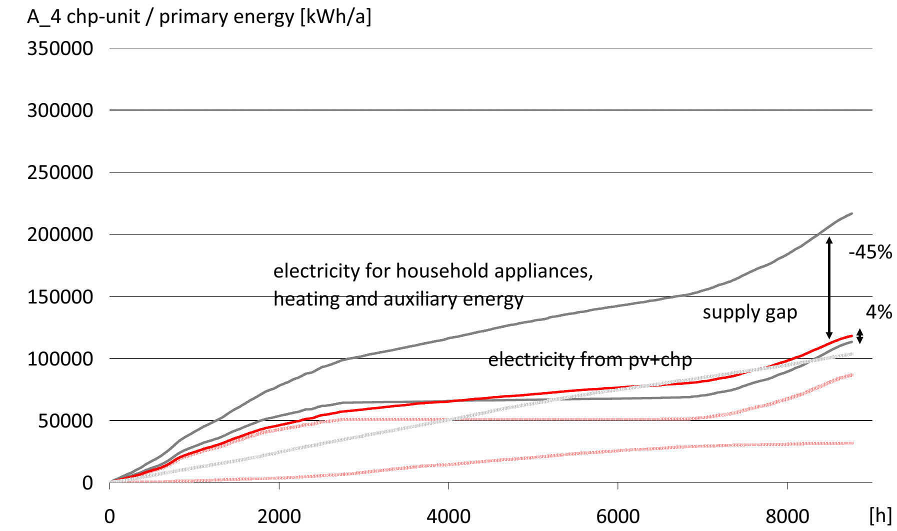

Fig. 7. building standard A_4: pv and chp production provides 55% of the total primary energy demand and generates a small surplus of 4% regarding the electricity demand for heating, dhw and auxiliary energy.

Conclusion

The simulation study shows that Net Zero Energy Concepts for multi-family houses are still a challenge. Depending on the definition of Net Zero Energy Buildings especially the total energy approach with a consideration of the household electricity demand is difficult to realize on site. Following the main results and topics are summarized

- energy efficiency of existing building stock can be improved significantly with known and established measures.
- due to limited roof and façade areas for photovoltaic the NZE approach for multi family houses considering the total energy demand can be realized for the presented buildings only with heat supply systems which are based on renewable energy.
- the most promising approach for supply systems are chp-units. A combination with solar thermal is possible and mainly a matter of economics.
- due to higher supply temperatures the efficiency potential of heat pumps is limited for multi family houses. Strategies and Solutions for low temperature emitters have to be implemented or developed.
- a Net Zero Energy concept totally based on electricity (combination of heat pump and photovoltaic) based on existing technologies is not yet available for the total energy approach as well as for the supply energy approach.
- further analysis of potential for interaction between building and electricity grid or district heating has to be done in order to reduce grid mismatch and grid stress.
- with better building performance the influence of household electricity increases significantly. Therefore measures on electrical efficiency have a higher impact on the total energy balance.

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