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Energy Sustainable Living – Deep Renovation of Residential Building – PAVE

J Včelák and E Novák

Czech Technical university in Prague, University centre for energy efficient buildings
Třinecká 1024, Buštěhrad, 273 43, Czech Republic

jan.vcelak@cvut.cz

Abstract. There are not many energy plus building projects in Czech Republic. Project described in this paper aims even higher because the goal is to renovate older building to energy plus standard and not build it from the scratch. This article describes concept of energy active building which will be renovated in Litoměřice. Older military building from 1980 will be renovated into energy active standard with a high share of renewables. The purpose of the building is to provide low area – starting flats for young families. The concept is unique in terms of complexity since it counts with direct use of the energy from PV, battery energy storage as well as electromobility charging stations. The results of simulations and estimations are shown in this publication as well as comparison of various simulated options.

1. Introduction

The concepts of a low-energy building or a passive house are known by almost everyone today. However, fewer people would be able to define what would be the criterion to put the building into these categories. Other terms, such as the Near Energy Efficiency Building (nZEB) or energy-efficient building, are still not clearly defined in Czech legislation. More precise definitions are embedded in the legislation of neighbouring countries in Austria or Germany[3]. An illustrative picture of the requirements can be seen from the graph in Figure 1 [2].

One of the parameters by which category buildings are assessed is the specific consumption of non-renewable primary energy in a building or house. Residential buildings use about 20% of the total energy consumed. While new homes have a number of realizations in a passive or nZEB standard, apartment buildings in this category are very rare not only in Czech Republic but also in neighbouring countries. For most of the projects implemented in the passive or nZEB standard, the basic rule is it is a new building. The ambition to become the first energetically active public building in the Czech Republic is the reason why the renovation of older object in town Litoměřice is that interesting.

2. Project description

The subject of the PAVE project is the realization of the first energy active public building in the Czech Republic, which will not be a newly built from the scratch but it will be based on a reconstructed building. The project will be supported by the State Environmental Fund program. One of the critical condition of the program is the requirement for local consumption of energy produced from renewable energy sources in the range of 60–70%. As we will show later, this condition is not a matter of course. Within the framework of the project, the abandoned former military building (four-storey hostel with



a boiler room), which is located in the grounds of the Jiřího z Poděbrad barracks, owned by the city, will be reconstructed. The building consists of two blocks – wing A and wing B with a total occupied area of 1268 m². The present state is shown in Figures 2a and 2b. The building will be reconstructed into a residential building with 52 starting flats (18x 1 + kk, 28x 2 + kk, 6x 3 + kk) for a total of 156 people. The visualization of the reconstructed building is shown in Fig. 3. In the reconstruction, the boiler room will be cancelled and the wing B will be lifted by another two residential floors. This will create a three-story block B with a flat roof suitable for PV installations.

Consumption of primary energy in buildings – Heating (kWh/m²a)

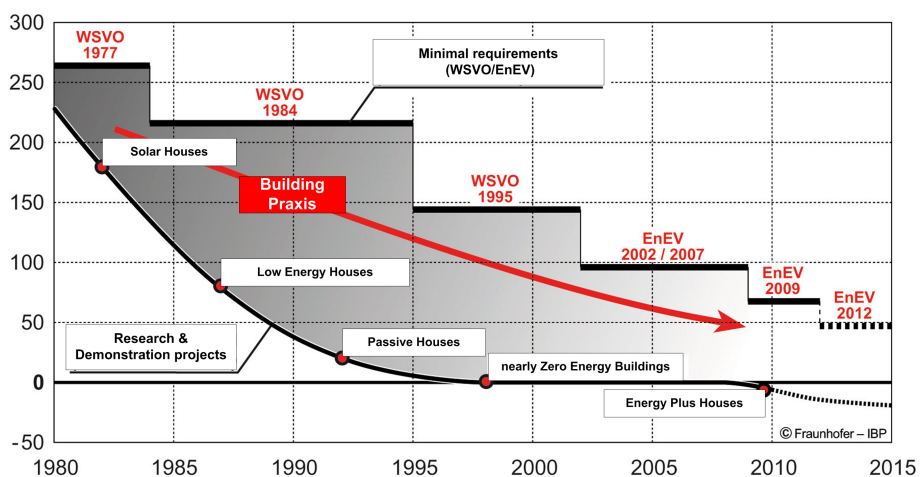


Figure 1. Primary energy use in family houses [2].

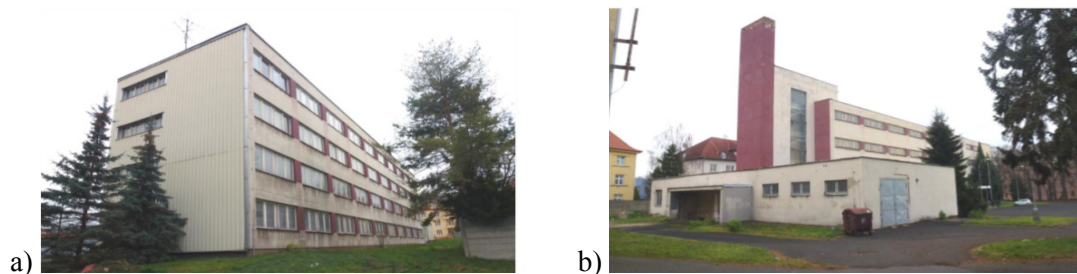


Figure 2. Current state of the building



Figure 3. Visualization of the building after the deep renovation [1]

An energy performance study has been done for the facility and the results are shown in Table 1. The building envelope is designed in passive standard, which significantly reduces the energy demand for heating. Active cooling is not planned for the building. The energy demand for heating will be covered by the district heating as well as the energy consumption for the preparation of the HWP. Thus, the energy consumption needed for lighting, the energy needed to run an air-handling units, and the energy for normal household electrical appliances can be included in the electricity consumption. Neither of these energies has the character of a flexible load, therefore, the total consumption of the building is estimated at 77.4 MWh with the daily consumption profile estimated and shown in Figure 5 and the seasonal variation shown in Figure 4.

Table 1. Energy consumption within the building

Energy type	Absolute (kWh/rok)	Scaled (kWh/m ² .a)	Primary non-renewable energy (kWh/year)
Heating	59 800	14	59 800
Hot water	73 000	17	73 000
Lightning	10 800	3	32 400
Air Handling	9 400	2	28 200
Appliances	57 200	13	171 600
Total (without appliances)	153 000	36	193 400
Total (including appliances)	210 200	49	365 000

Taking into consideration the local conditions and the current state, where the district heating exchange station is located on the ground floor, and supplies other buildings in the area, the municipality decided to keep the existing connection to district heating for the heating of the building and for the hot water preparation. Unfortunately, this reduces the flexibility of the load to the photovoltaic system. In order to meet the condition of an energy-efficient building (a building that replaces / saves more primary non-renewable energy than the use of the building), it is necessary to produce 75 MWh of electricity from the renewable energy sources – photovoltaic installation.

The building is ideally suited for the realization of RES energy supply by direct supply, where the energy utilization of the local renewable energy source is maximized. The object then appears to be a single end user for the distribution system. The total energy bill from DS is then shared by the individual apartment units using secondary electricity meters. The energy invoicing is then done based on a contract with the PV operator and the tenant.

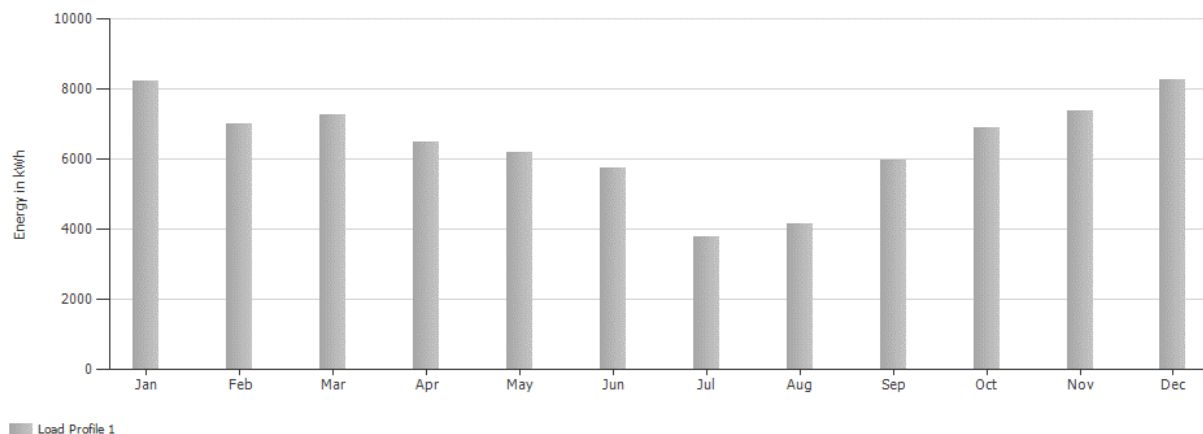


Figure 4. Building consumption profile on monthly basis (common appliances, AHU, lightning)

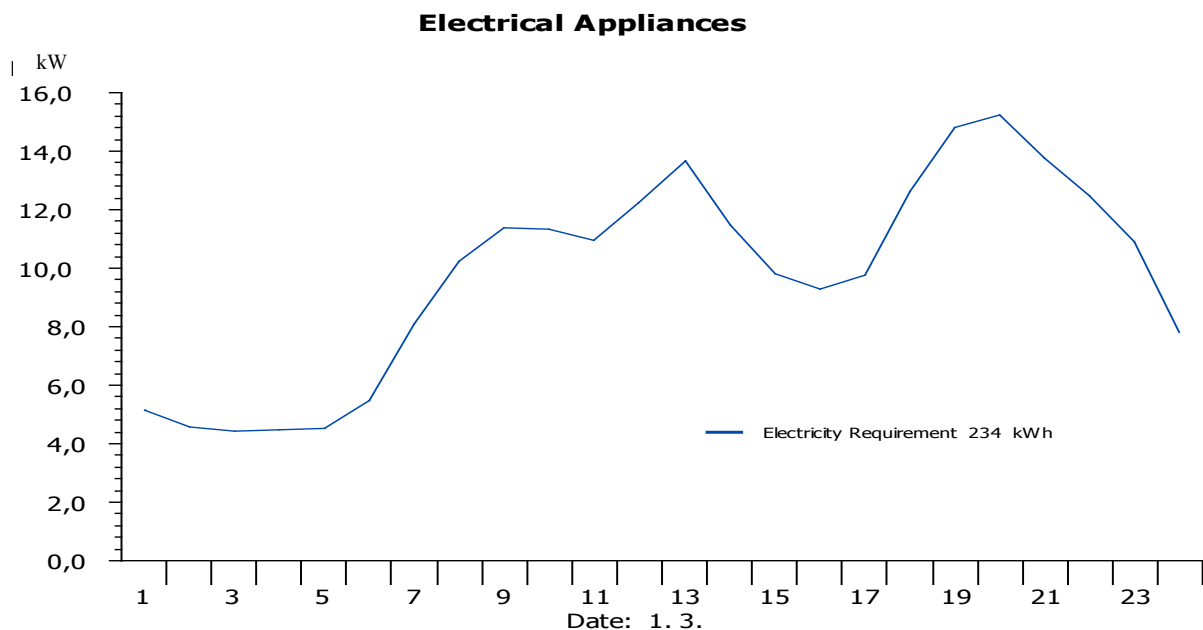


Figure 5. Estimated daily PAVE building consumption profile (common appliances, AHU, lightning)

3. Photovoltaic energy

Photovoltaic panels were installed for the required energy harvest. As suitable space not only the flat roofs of the building but also vertical south façade of the building were selected. In total, the facility has three photovoltaic power plants PV1,2 and 3 with a total output of 95.4 kWp.

Annual simulation of combined PV on the object, including shading analysis, is performed in the PV Sol Premium 2018 software. The annual PV energy production is shown in the graph in Figure 6. The combined system of three photovoltaic power plants on the building generates a total of 88.4 MWh. PV Sol simulation takes into account both shadows from the building parts and shielding between individual PV modules.

Table 2. PV installation on the building

PV parameters	PV1 Block A roof	PV2 Block B roof	PV3 southern facade
Panel	300 Wp	300 Wp	300 Wp
Number of panels	178	56	84
Angle (°)	15	15	90
Configuration	6x31-8	7x8	7x12
Total power (kWp)	53.4	16.8	25.2
Total annual energy (MWh)	55.25	13.9	18.34

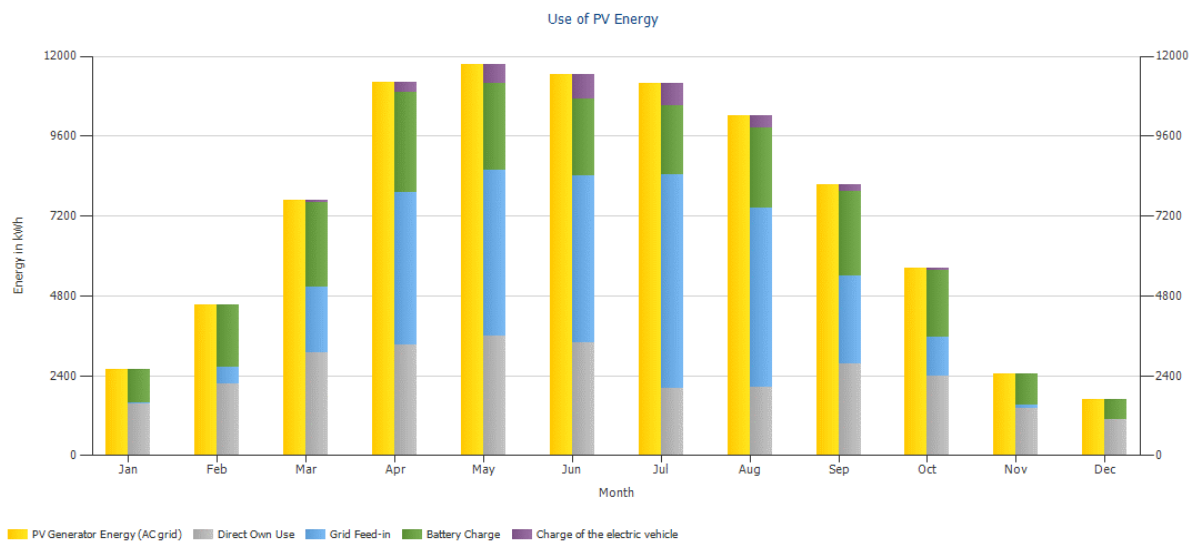


Figure 6. Simulation of combined PV production with distribution of its use for battery charging, direct consumption, electric vehicle charging and feeding into grid, 318 PV panels, 88.35 MWh / year, 95.2kWh battery, 12x electric vehicles

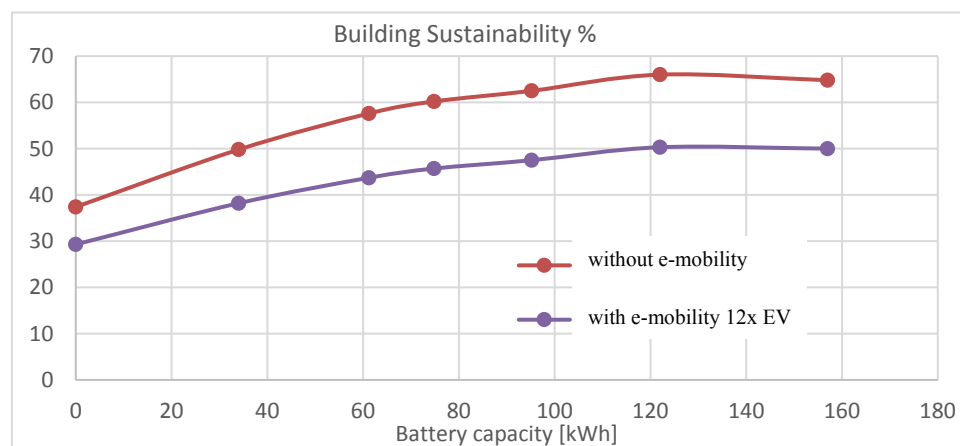
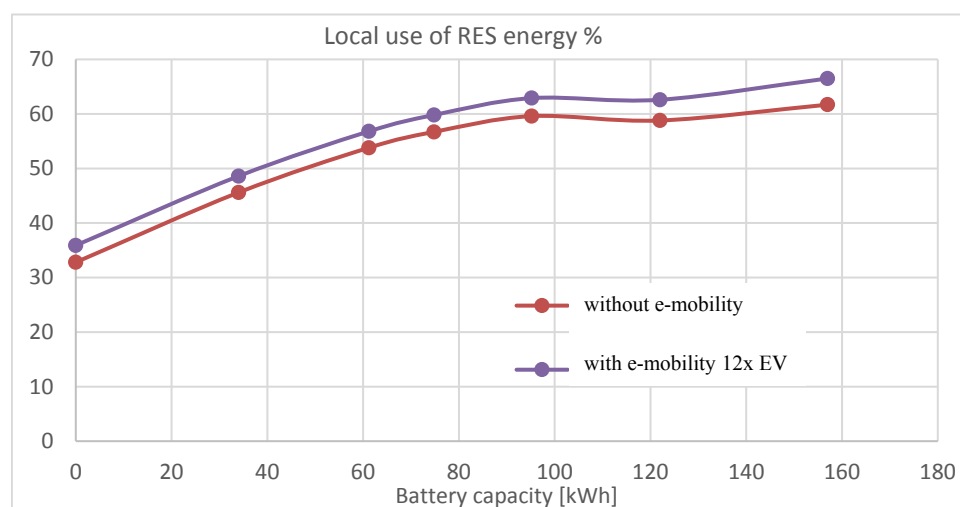
4. Battery storage and electromobility

Although in the case of a 52-apartments, it would have made more sense to use surplus energy for hot water production, thanks to the fact that district heating is kept as a source of heat, this option was relinquished. On the other hand, the contracting authority decided to use the possibility of installing a battery storage for common consumption of the building, electricity consumption of residential units or also charging of electric vehicles. Battery storage will help to increase the share of locally consumed energy from RES. The operation of the facility was simulated using a battery storage facility with 6 options of battery capacity (without battery, 34 kWh, 61.2 kWh, 74.8 kWh, 95.2 kWh, 122 kWh, 157 kWh). For each option, energy self-sufficiency of the building was calculated from the point of view of electricity and the share of locally consumed energy from RES (Table 3, Figures 7a and 7b).

Energy load with which we need to consider for the future is the evolving electromobility. Electromobility becomes an integral part of the building's energy system and will have a significant impact, which should be taken into consideration when designing the capacity of the connection of the building to the distribution grid. PAVE project counts on the development of electromobility, so there are 12 charging racks 22kW in the project. The energy balance of the building was made with and without the influence of energy consumption for the operation of 12 electric vehicles. Although the mode of operation can hardly be estimated accurately, a suitable model of EV use must be selected for simulation. 12x Renault Fluence Z (22kWh battery, AC charging 22kW) was selected as a type electric car. The electromobile mode of operation is chosen as a daily commuter car for about 45km / day, with a night charge enabled from 18am to 7pm. It can be seen from the graphs below, Fig. 7a, b and Fig. 8, the energy for charging electric vehicles is in this particular case mainly covered with energy from the grid, only about 10% of the energy to be charged is used for the production of RES (see Figure 8). The plots in Figures 7a and 7b show also a case, where the energy self-sufficiency of the building is reduced and only a small increase in the local energy use from RES is included in the inclusion of electromobility (numbers in brackets).

Table 3. Simulated annual energy behaviour of the building

Battery type	0 kWh	34.0 kWh	61.2 kWh	74.8 kWh	95.2 kWh	122 kWh	157 kWh
Direct own consumption from PV (MWh)	28.8 (31.7)	28.8 (31.7)	28.8 (31.7)	28.8 (31.7)	28.8 (31.7)	28.8 (31.7)	28.8 (31.7)
Feeding into grid (MWh)	59.5 (56.7)	48.1 (45.4)	40.9 (38.2)	38.3 (35.6)	35.7 (32.8)	36.8 (33.1)	33.8 (29.6)
Energy from the grid (MWh)	48.6 (76.5)	38.9 (66.9)	32.8 (60.9)	30.9 (58.8)	29.0 (56.7)	26.3 (53.7)	27.2 (54.2)
Sustainability ratio (%)	37.4 (29.3)	49.8 (38.2)	57.6 (43.7)	60.2 (45.7)	62.5 (47.5)	66 (50.3)	64. (50)
Local RES consumption (%)	32.8 (35.9)	45.6 (48.6)	53.8 (56.8)	56.7 (59.8)	59.6 (62.9)	58.8 (62.6)	61.7 (66.5)

**Figure 7a.** Self-sufficiency level of the PAVE object depending on the size of the battery storage (only electrical energy considered)**Figure 7b.** Level of local use of energy from renewable sources depending on the size of the Battery storage

Energy Flow Graph

Project: 15 st největší počet panelů a bateriové úložiště

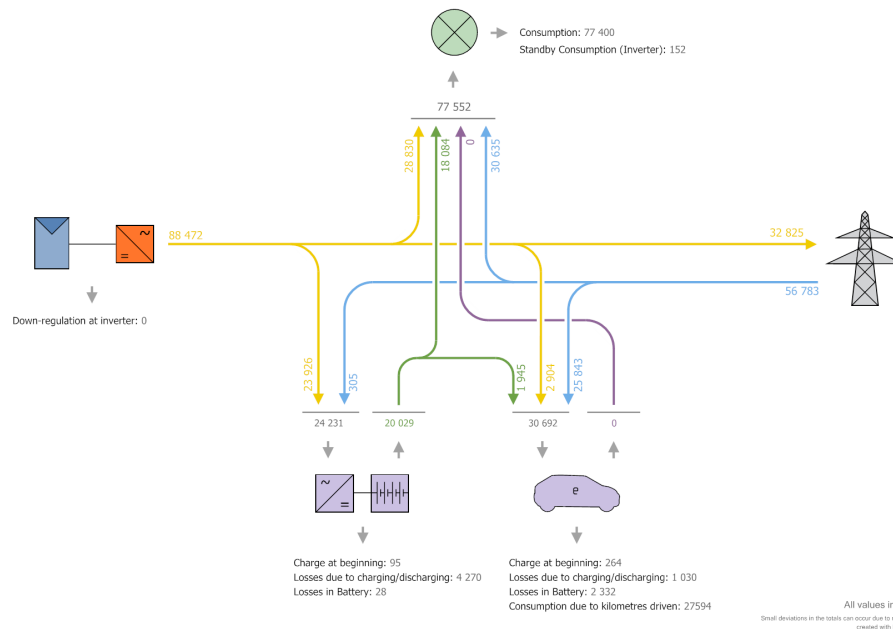


Figure 8. Annual energy flows in Building (12xEV, FVE 95.4 kWp, 95.2kWh battery, annual predicted consumption profile of 77.4 MWh / year)

5. Conclusion

This publication demonstrates that energy-saving housing doesn't have to be only the case of new buildings only, but we can also implement it at the level of residential buildings undergoing reconstruction. The PAVE object is a complex solution to the building's energy system, where the main focus is on using renewable energy sources, saving energy, but not forgetting the integration of electromobility as another appliance that will have to be counted in the future. It should be remembered that in the case of the PAVE project, the economic aspect of the proposed solutions is not the primary criterion. The most important factor in decision making is the share of primary non-renewable energy used and local production / consumption of energy from renewable sources.

The simulations confirm that the size of the optimum battery storage for the use of renewable energy in an object is around 80–100 kWh. Another increase in capacity does not affect the self-sufficiency of the building or the local use of energy from renewable sources, and further increases in the storage capacity increase only the investment costs.

The simulations point to a problems with the integration of electromobility, when the time for charging is different then the time of PV production, and therefore this load only increases the consumption from distribution grid. This leads to implementation of intelligent charging driven by a building automation system with a preference of charging at the moment of RES production or low energy demand fro distribution grid (if such moments occur) or charging in a so-called low tariff.

In conclusion, PAVE will be a pioneer in energy-efficient construction because it is a building reconstruction and not a new building. Even the degree of self-sufficiency of an object in the order of 50–60% is not at all a bad result. The aim of this reconstruction is also to become an exemplary pilot project that should open the way to further realizations of a similar type.

Acknowledgement

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