MANAGING PHOTOVOLTAIC ELECTRICITY SURPLUSES IN MULTI-APARTMENT BUILDING IN NORTHERN EUROPE: BATTERY STORAGE VS. DOMESTIC HOT WATER HEATING

Summary

This study investigates strategies for managing photovoltaic (PV) electricity surpluses in multi-apartment buildings in Northern Europe by comparing battery storage and domestic hot water (DHW) heating using an electric heater in a storage tank as flexibility solutions. The analysis is based on dynamic simulations performed in TRNSYS 18 software. The model integrates household electricity consumption data, DHW demand profiles, the maximum potential solar energy production from rooftop PV installations, and spot electricity prices. Various storage capacities were evaluated for both cases to determine their technical performance and economic viability. The findings indicate that the temporal mismatch between solar generation and building demand significantly influences overall feasibility. Properly dimensioned storage can increase on-site energy utilization; however, cost-effectiveness is highly sensitive to storage size and electricity price dynamics.

Keywords: PV panels, solar energy, multi-apartment building, storage capacity, domestic hot water

Field of application for the findings: Sustainable Energy Infrastructure and Electrification

Addressed audience: researchers, investors, apartment owners, policymakers

1. Introduction

Building operations account for 30 % of global final energy consumption and 26 % of energy-related emissions. Of these emissions, 8 % are directly attributable to buildings, while 18 % result from the production of electricity and heat used in buildings (IEA, 2023). The residential sector is responsible for approximately 40 % of global energy consumption, with 90 % of this energy coming from fossil fuels (Magrini et al., 2020).

The use of photovoltaic (PV) panels in multi-apartment buildings has gradually increased in recent years, reflecting growing investor interest in renewable energy solutions for urban residential environments. However, large-scale deployment remains limited due to several barriers, including limited roof area, the complexity of negotiating with building owners, challenges in fairly allocating generated electricity, and the temporal mismatch between PV electricity production and building demand. Consequently, the penetration of PV systems in multi-apartment buildings remains relatively low. Despite these limitations, there is a potential for PV systems. A theoretical study by (Zajecs & Lebedeva, 2026) demonstrated that PV system on a five-story multi-apartment building in Latvia could cover up to 57 % of the building's annual electricity demand.

Approximately 76% of the solar irradiation in Riga, Latvia, occurs between April and September, which corresponds to the non-heating period (data analysis based on PVGIS-SARAH3, (European Commission, 2024)). During this time, there are two primary ways to utilize solar energy: either as electricity for the building's consumption or for heating domestic hot water (DHW) via electric heaters or heat pumps. Since heat pump solutions involve significant investments, this paper focuses on the use of electric heaters.

PV systems often produce more electricity during peak solar hours than the building can immediately consume. This surplus can be stored in batteries, exported to the grid, or used for DHW production. Maximizing on-site utilization is generally preferred but requires effective surplus management due to variable energy generation, with daily-scale storage playing a key role in improving self-consumption and system integration.

The aim of this study is to compare battery storage and DHW heating with a storage tank as strategies for managing PV electricity surpluses in multi-apartment buildings in Northern Europe, evaluating their technical performance and economic feasibility to determine their potential for wider adoption in Latvia and similar climates. This research contributes to the knowledge base on PV integration in urban multi-apartment buildings, providing insights relevant for technical implementation and policy development.

2. Methods

The reference building used in this study is a five-story, 60-apartment building with a flat roof area measuring 10 m by 64 m (see Fig.1). PV panels are installed with the longer side oriented horizontally to optimize roof space utilization. To maximize the roof's utility while minimizing the mechanical stress from wind, the panels are set at a 15° slope, with a 2-meter gap between rows (see Fig.2). This configuration allows for four rows of panels, totaling 80 panels (192 m²), all oriented due south. Roof utilization ratio 30 %.

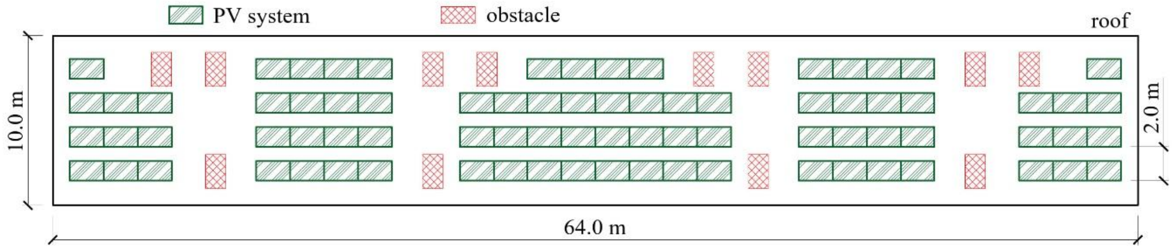

Fig. 1: Roof area of a reference building with possible installed PV panels

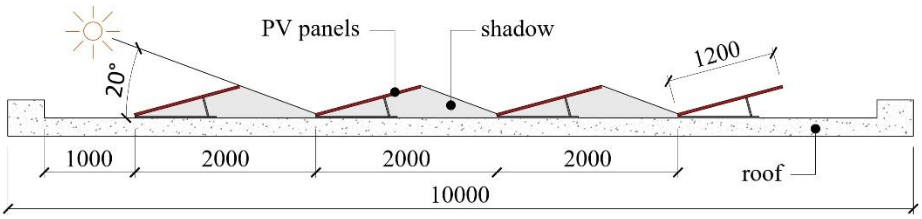

Fig. 2: Section drawing of PV panels installation and shading on December 21 at 12:00 in Riga

The analysis was performed using dynamic system simulations in TRNSYS 18 (Solar Energy Laboratory, 2017) with a one-minute timestep for one-year period. The base scenario assumes no battery or water tank storage, meaning all produced electricity by PV panels is either consumed on-site or sold to the grid.

Two TRNSYS 18 models were created:

- PV-generated electricity is used to meet the building's electricity consumption, with varying sizes of local battery storage. Excess electricity is sold to the grid, and any shortfall is purchased from the grid.
- PV-generated electricity is used for electric heating of the domestic hot water tank, with varying sizes of local storage tank. Excess electricity is sold to the grid, and any deficiency in DHW heating energy is supplied by the town's district heating system.

Input values for all scenarios:

- The photovoltaic electricity production was modeled using the TRNSYS 18 dynamic simulation software. Climate data for Riga was obtained from the Meteonorm v5.0.13 database, in TMY2 format. For the sensitivity analysis, different PV panel parameters identified through market analysis were used.
- Hourly grid electricity spot prices for Latvia were obtained from Nord Pool with a one-hour timestep. A four-year period (2022–2025) was used for the sensitivity analysis.
- The annual electricity consumption profile, also with a one-hour timestep, was derived from measured average hourly consumption data for 31 apartments over a three-year period (Borodiņecs et al., 2024). These apartments are located in a typical five-story multi-apartment buildings in Riga, Latvia. The data includes load profiles for different apartment types with varying household sizes, averaging approximately two occupants per apartment.
- Domestic hot water consumption data taken from (Grasmanis et al., 2015), based on over 5,000 residential buildings in Riga, indicate that hot water systems consume, on average, 50.9 kWh/m² per year (equivalent to 0.139 kWh/m² per day). This figure aligns with measurements from multi-apartment buildings in Oslo, Norway, where daily hot water consumption ranges from 0.079 kWh/m² to 0.189 kWh/m², with an average of 0.127 kWh/m² (Walnum et al., 2021). For this study, a daily consumption value of 0.139 kWh/m² was applied. The daily hot water consumption profile was based on the dataset provided by (Fuentes et al., 2018), with a one-hour timestep for residential buildings.

3. Results

To evaluate and compare the cases, the following key performance indicators (KPIs) will be used:

- the share of PV-generated electricity consumed on-site;
- the economic performance of the system, considering initial investment costs and savings from reduced grid electricity or district heating consumption.

The results will present a comparative analysis of the two surplus management strategies – battery storage and DHW tank storage – by evaluating changes in KPIs as storage capacity increases. The analysis will quantify the impact of storage size on on-site energy utilization, grid interaction, and economic performance.

As storage capacity increases, the initial investment cost of the system also rises. Therefore, the study aims to identify economically feasible storage configurations under real-world electricity price conditions.

A sensitivity analysis will be conducted to evaluate the impact of electricity price variability, PV panel performance, and system costs on overall technical performance and economic viability.

4. References

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