Transforming a residential building cluster into electricity prosumers in Sweden

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Buildings as electricity prosumers are growing in energy space as they not only produce energy from distributed energy resources, but also consume the generated energy locally, through heating, ventilation and air conditioning (HVAC) systems, appliances and electric vehicles (EV) etc. These have profound impacts on the smart grid value chain. It is also a harbinger of another transformation – the shift of "power", from being concentrated in the hands of utilities as the sole owners/distributors of electricity, to electricity prosumers on a vastly distributed and decentralized basis.

With the intensive growth in photovoltaic (PV) panels, EVs, home batteries, distributed heat pumps (HP), thermal energy storage (TES) and direct-current (DC) grid, buildings offer great potentials for consumers and building owners to re-evaluate their energy practices. As the electricity prosumers are increasing at urban or district scale, the building integrated or added PV installations are boosting with very large capacity in recent years, which bring many unknowns about the integration of smart gird infrastructure that need to be optimized. To develop strategies for the future, policymakers and planners need knowledge of how many and where PV systems could be integrated effectively and efficiently into local energy infrastructure and markets.

The Energy-Matching consortium has published a research paper by using the main energy concepts from the project. They reported a case study of transforming an existing residential building cluster in Sweden into electricity prosumers. The building cluster is located in Sunnansjö, Ludvika, Dalarna region, Sweden. This demo site is a multifamily dwelling unit with three buildings built in 1970/1973, as shown in Fig. 1. The cluster (three buildings) includes 48 apartments over three floors, and most of the apartments have one or two bedrooms. The total façade surface gross area of the complex is 2,146 m^2, the total roof surface gross area is 1,750 m^2, and the total heated area is 3861 m^2. The energy consumption of the cluster is 165 kW·h/(m^2·year), including operational electricity but not including electricity used in the flats for appliances and lighting.

Fig. 1: Three buildings in the cluster for renovation in Ludivika, Sweden.

These buildings will be improved by a series of renovation plans, including installation of PV, thermal energy storage, DC micro grid, EVs and heat pump systems, as presented in Fig. 2. First, a centralized heat pump using exhaust air and ground as heat sources will be used for supplying the heating and hot water for all the three buildings. All the exhaust air in each building will be ducted to a heat exchanger unit, in which the waste heat will be recovered and then delivered to the centralized heat pump via a brine loop.

A back-up pellet boiler will be utilized to accommodate the peak heating needs. The PV can be installed on the roof and façades of the buildings. The PV energy will first be used to power the electrical facilities in the buildings (e.g. fans, pumps, lighting, EV demands). After this part of electrical load is met, the remaining PV energy will be considered as excess PV energy. A hot water storage is planned to store the excess PV energy in the form of heat, where the excess PV electricity power is transmitted to the heat pump to produce heating energy, and the produced heat is stored as the hot water. All electricity in the buildings, including that in the flats, as well as that supplied to the EV's is managed by one Energy Hub (see Fig. 3) in each building, connected together via a DC micro grid. The DC sources (i.e. PV panels) and sinks (i.e. EVs and variable speed heat pump compressor), as well as batteries if present, are connected directly to the DC micro grid.

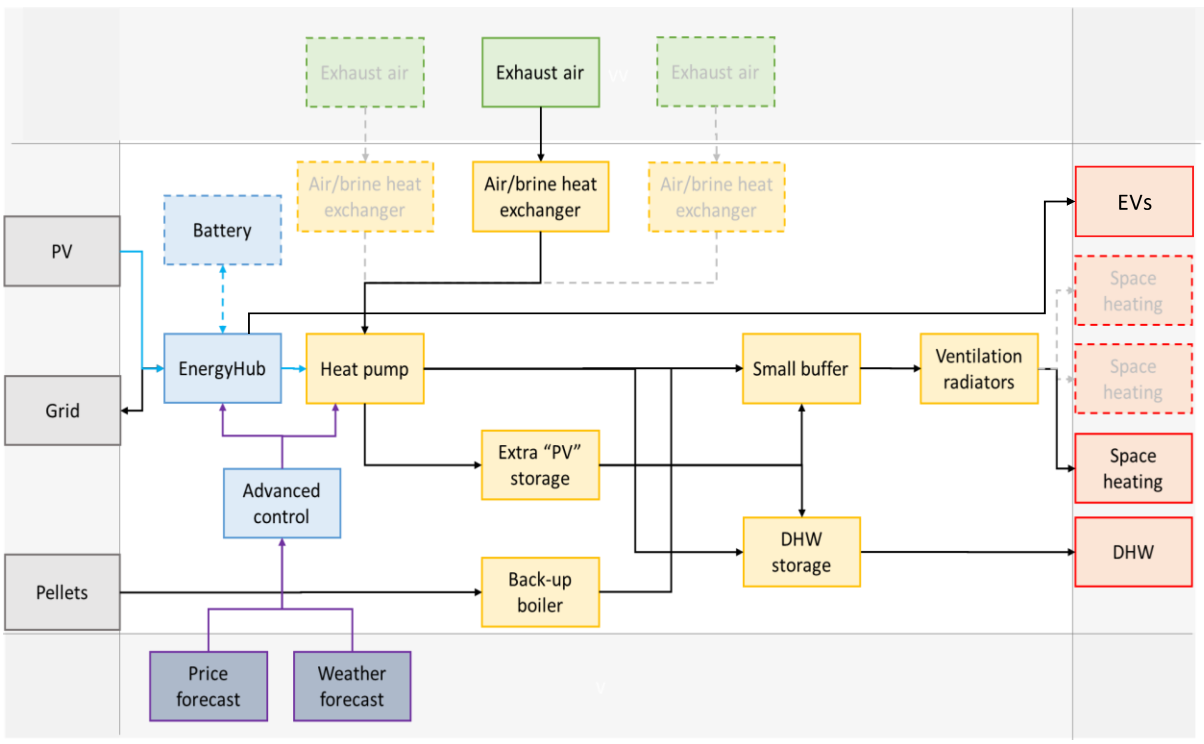

Fig. 2: Overall energy concepts for the building cluster.

Fig. 3: Schematics of the Energy Hub micro DC grid from project partner - Ferroamp Elektronik AB

An optimization tool has been developed to design the capacity and positions of PV modules on each building, which aims at maximizing the self-consumed electricity under the constraint that the system has a positive lifetime net present value (and thus it is profitable). This tool will be further open to public to use in different scenarios. Results indicate that the coupled system can effectively improve the district-level PV electricity self-consumption rate to about 77% in the baseline case, see Fig. 4. The research results reveal how electric vehicle penetrations, thermal storage, and energy sharing affect PV system sizing/positions and the performance indicators, and thus help promote the PV deployment. More importantly, this study has demonstrated the feasibility for transferring the existing Swedish building cluster into smart electricity prosumers with higher self-consumption rates and energy efficiency with more intelligence, which offers good solutions for EU to achieving the '32% share of renewable energy source' target.

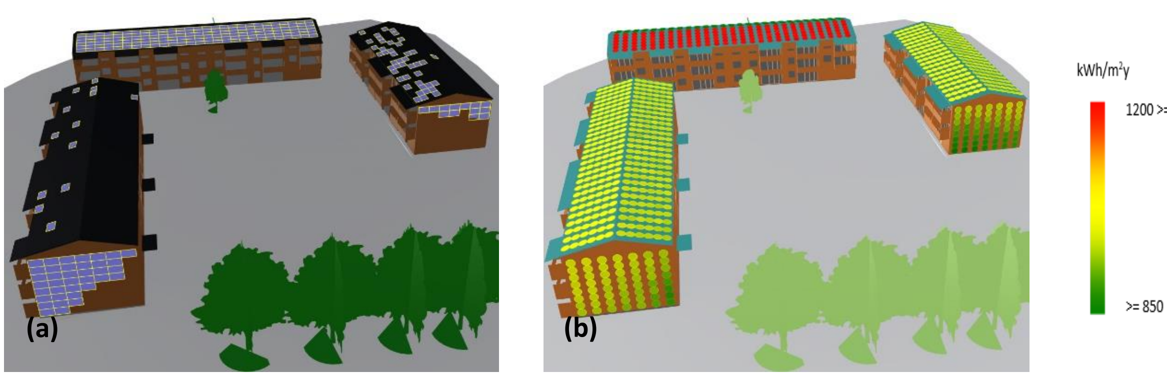

Fig. 4: The optimized results in the baseline case: (a) The optimal configuration for the baseline case: most of the system is installed in the southern slope of the roof and on the southern façade; (b) Color-coded depiction of the annual cumulative irradiation: despite the higher area installed, the façade is less irradiated overall.

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