IMPACT OF ELECTRIFICATION AND SMART ENERGY MANAGEMENT ON GRID INFRASTRUCTURE

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Abstract

Increased electrification of heating systems in the residential sector will lead to an increase in electricity demand, which will most likely necessitate additional investments into grid infrastructure. In this work, a case study of an urban area is conducted where the energy demand of each building is modeled. By developing scenarios on the uptake of electrified heating systems, PV installations, battery storage, and smart energy management systems, potential necessary investments into the grid infrastructure are calculated. This is done by a two-stage modeling approach. First, the heating, cooling, and electricity demand of all residential buildings in the respective area are calculated. Then, the electricity demand is provided to a second model, calculating the necessary distribution grid infrastructure to support this demand on a granular spatial level. Results will show how the increase of heat pumps and PV systems can put additional stress on the electric grid and how smart energy management devices at the single household level could help alleviate some of this stress.

Method

First the information of buildings and the grid layout in the area is collected using Open Street Maps (OSM) and open building Databases (eg. URBAN3R[3] and 3Dbag[4]). The information of building location and adjacent wall area and ground floor area is calculated using the shapefiles from OSM while information on building age and height is obtained open building Databases. Industrial buildings, Sport centres and other large buildings not marked as such in either of the datasets are manually removed from the dataset. Sheds and other non-residential very small buildings are excluded by excluding buildings with a ground floor area less than 45m^2.This value was derived by trial and error. For the remaining buildings data on the building properties is mapped from a national building database underlying in Invert/EE-Lab[5] building stock model. This is done using the building age and classification such as single-family building, row house or apartment block.

In a next step, the electricity demand of all buildings is modelled with different appliances installed. Table 1 shows the different possibilities of appliances each house can have installed in different scenarios. To save computational recourses it was decided to cluster the buildings (using K-means++) within the area into representative buildings using the thermodynamic properties of each building together with its floor area. This resulted in 50-70 building clusters from which the permutation with all options according to Table 1 could be calculated. Each building is simulated and optimized once using the 5R1C approach described in the DIN ISO 13790. The objective function of the optimization is to reduce energy cost of the building, increasing possible PV self-consumption and given a variable electricity tariff, also reacting to the electricity price by using the electrified heating system and thermal storages as well as the thermal mass of the building. The use of the smart energy management system transforms normal consumers or prosumers into so called prosumagers (households that consume, produce and manage their electricity consumption).

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[3] https://urban3r.es/
[4] https://3dbag.nl/en/viewer
[5] https://invert.at/

Based on the scenario information that describes what percentage of buildings are equipped with certain technologies, each residential address is assigned with an electricity demand profile. This information is passed on to the TEPES[6] model to plan the expansion of the distribution grid and related costs.

Table 1: Different appliances that can be installed in each house in different combinations.

Appliances	**Option 1**	**Option 2**	**Option 3**
Heating system	Air source heat pump	Ground source heat pump	Gas boiler
Air conditioning	Yes	No	-
Smart energy System	Yes	No	-
PV peak power	0 kWp	7 kWp only for SFH	15 kWp only for MFH
Battery capacity	0 kWh	7 kWh only for SFH	15 kWh only for MFH
DHW storage	0 l	300 l only for SFH	700 l only for MFH
Heating buffer tank	0 l	700 l only for SFH	1500 l only for MFH

Results

Results will show how the uptake of single technologies can impact the necessary investment costs on the grid. While storage applications and PV installations will reduce demand derived from the grid, electrified heating systems will increase it. At the same time extensive uptake of PV can lead to grid congestion due to higher loads of exports from the building to the grid. Prosumagers can both increase and alleviate grid stress, depending on the detailed settings and frameworks incentivizing different investments and operational behaviour.

[6] https://www.iit.comillas.edu/technology-offer/tepes