Financial incentives of time-variable electricity pricing in sector-coupled local urban energy systems under German regulations (EnWG14a)

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Overview

The transition towards decentralized renewable electricity generation and the electrification of heating and mobility sectors is resulting in increased peak loads on the electricity grid, necessitating significant investments in grid infrastructure. Dynamic electricity tariffs and variable grid fees present an opportunity to shift loads to periods of high renewable generation and off-peak hours [1, 2]. In Germany, the recent amendment to the Energy Industry Act (EnWG14a) sets a framework for controllable loads, enabling grid operators to manage load fluctuations and implement time-variable grid fees. Controllable loads primarily include charging infrastructure for electric vehicles, heat pumps but also electrical storage units. This study explores the financial incentives of dynamic electricity tariffs and the remuneration schemes for controllable loads including variable grid fees under the German regulatory framework within local urban energy systems, specifically focusing on electrical heating systems.

Three distinct local energy systems in Germany are compared: the Glückaufpark district in Gelsenkirchen, featuring single-family homes (SFH) and multi-family homes (MFH) supplied by a cold distribution network (2 - 15°C) and decentralized heat pumps; Seestadt district in Mönchengladbach, a residential neighborhood composed solely of MFH with a low-temperature distribution network (39°C) utilizing central sewage water, central ground source heat pumps, and gas boilers for peak load; and the Shamrockpark district in Herne, which is characterized by a mixed area with a significant proportion of commercial buildings and multi-storey apartments utilizing a low-temperature grid (22°C) that incorporates low temperature industrial and internal waste heat sources used by decentral heat pumps, a small combined heat and power (CHP) unit, and a connection to district heating. The role of storage capacities in providing flexibility is investigated, analyzing both battery storage and central/decentral thermal storage facilities. In the Glückaufpark District, extended thermal capacities by increasing temperatures in decentralized buffer storages and leveraging the thermal inertia of buildings are considered as additional flexibility options.

Methods

This study employs the KomMod optimization tool [3], a bottom-up techno-economic model for local energy systems that enables sector-coupled representation. Input data encompass cost data, demands for space heating, hot water, and electricity, alongside the available potential of renewable energy sources such as solar and geothermal energy or waste heat. The model is formulated as an linear programming optimization problem with the target of minimizing total energy system costs, calculating full-year operation profiles at an hourly resolution and performing calculations based on energy balances.

For studying the impact of variable electricity pricing three different pricing schemes are developed. Using a dynamic electricity tariff (dynSP), variable grid fees (varNNE) and both combined (dynSP-varNNE). The dynamic electricity tariff is based on 2023 market prices and comprise procurement costs given by the day-ahead prices, grid fees (10ct/kWh), electricity tax and other charges (5ct/kWh) as well as 19% VAT, which is applied to all price components.

Under current German regulations variable grid fees are only applicable for controllable loads. Three different remuneration schemes exist according to the current regulation, one of them enabling the application of variable grid fees [4]. The study investigates those three applicable modules of EnWG14a in combination with static and dynamic procurement tariffs. In addition, also a fictional scenario with only variable grid fees without load control is considered, which is not possible under current regulations. The variable grid fee pricing scheme is derived based on typical load profiles in districts including solar generation, with lower fees during peak production hours and higher fees at other times (see Figure 1). The load reduction control signals are modelled with an assumed 50% probability and 60% load reduction factor, i.e. the load is reduced to 40% of the installed capacity of a controllable load if a control signal is received. As load reduction probability and the load reduction factor might vary depending on the considered location and energy system specifications, in addition a sensitivity analyses w.r.t these parameters is conducted.

Results

The analysis reveals that dynamic procurement tariffs (dynSP) as well variable grid fees (varNNE) often lead to higher overall energy system costs. In typical residential neighborhoods with a relatively high share of installed PV systems like Glückaufpark and Seestadt district shifting a substantial portion of the load under the considered price schemes is generally not economically viable; in their cases total energy costs rise by 2-8% with time-variable tariffs. This can be seen in Figure 2, which depicts the relative costs of selected scenarios compared to the base scenario. These increased costs due to variable pricing primarily stem from investments in battery storage (up to 73% additional investment costs in Shamrockpark district), which cannot always be offset by the modest reductions in electricity import costs. Additionally, forced load reductions necessitate increased thermal storage (up to 12% of additional investment costs in Glückaufpark district) as well as heat generation capacities gaps (up to 13% of additional investment costs in Glückaufpark district) to address supply. Conversely, in Shamrockpark district, characterized by a high constant electrical load, the application of dynamic electricity tariffs and variable grid fees yields notable cost savings, amounting to 5% of total energy system costs and 18% of electricity import costs. Sensitivity analyses indicate a strong requirement for substantial decentralized storage capacities as the probability and depth of load reductions increase, rasing total energy system costs up to 6% in Glückaufpark district for a load reduction factor as high as 80%.

When considering the different EnWG14a modules, it can be stated that their application is mostly not economically attractive, as the increased system costs are often higher than the received remuneration. However, in Shamrockpark district, the application of Module 1+3 including variable grid fees enables cost savings of up to 3% of total energy system costs in combination with a dynamic procurement tariff, as can be seen in Figure 2. The savings, however, are smaller than if only variable grid fees are applied without remuneration for controllable loads. For Glückaufpark district also cost savings of 2% can be achieved applying EnWG14a Module 2 by using raised flexibility of thermal inertia, if a tolerance of indoor temperature of 2°C is accepted (this scenario is not contained in Figure 2).

Conclusions

The findings suggest that there are limited financial incentives for dynamic electricity tariffs or variable grid fees in the analyzed local urban energy systems. However, utilizing variable tariffs does incentivize the development of battery storage, with decreasing battery costs variable tariffs become more attractive. Furthermore, though the full potential for load shifting remains untapped under the current pricing structures, with higher dynamics expected in the future financial incentives for load-shifting increase. In systems with a significant share of self-generated solar energy, time-variable tariffs tend to be less attractive, as low prices coincide with peak generation periods. Finally, the remuneration schemes for controllable loads do not always compensate for higher energy system costs caused by the need for higher heat generation or storage capacities, making them economically inattractive.

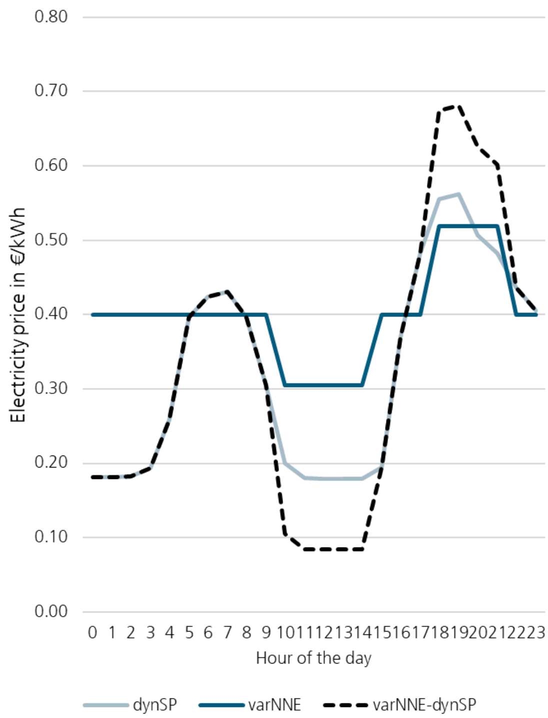

Figure 1: Electricity prices for the variable pricing schemes dynamic electricity tariff (dynSP), variable grid fees (varNNE) and both combined (varNNE-dynSP)

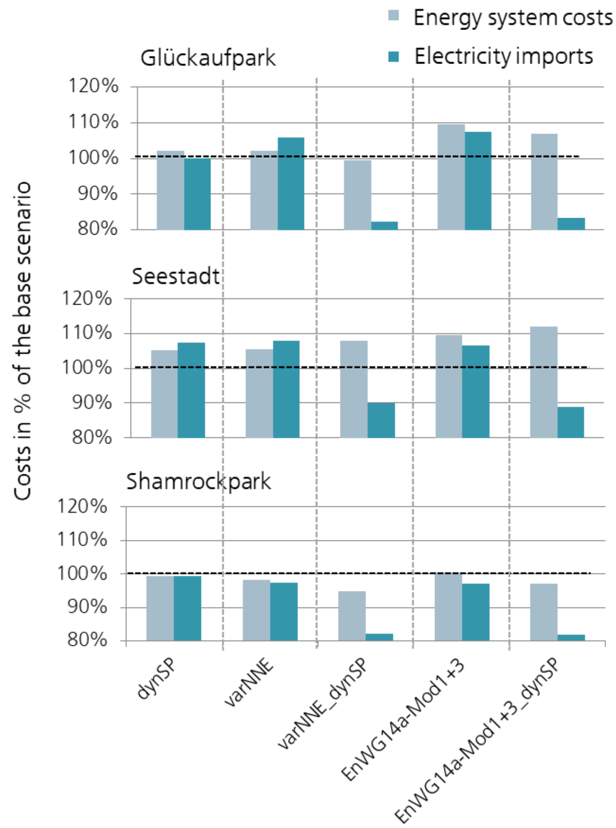

Figure 2: Possible cost savings using dynamic elctricity tariffs (dynSP) and variable grid fees (varNNE) in or without combination with remuneration for controllable loads (EnWG 14a Mod1+3).

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