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ANALYSIS OF THE POTENTIAL TO LEVERAGE PRICE VOLATILITY THROUGH FLEXIBILITY OPTIONS IN A LOCAL ENERGY SYSTEM

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Overview

The ramp-up of decentral renewable energy plants on the generation side and the accelerated market penetration of new loads such as heat pumps and battery electric vehicles on the demand side lead to a dynamic grid behavior. This results in the increased need for flexible control of technical plants in distribution grids. In residential districts, the decentralized units can be coordinated via a common control system to respond to price signals on the electricity markets and offer flexibility. Through the adapted mode of operation, it contributes to grid stability, energy supply security and, last but not least, to cost advantages. In some cases, energy suppliers already have to offer at least one flexible tariff in addition to the fixed tariff by passing on the exchange prices, which fluctuate greatly over the course of a day. This encourages consumers to adjust their electricity consumption. In addition, the increased integration of controllable consumer devices and grid connections into the electricity grids is planned for the future. Thus, grid operators will be able to control heat pumps and wallboxes for battery electric vehicles in such a way that electricity consumption can be distributed evenly. In return, consumers benefit from cost advantages, e.g. reduced grid charges.

Methods

Using an in-house developed techno-economic energy system model, behavioral patterns, interactions between individual agents as well as the influence of a regulatory framework are investigated in a residential district in Germany as a use case (Figure 1 shows the structure and components of the model). The model optimizes the residential energy system from a macro perspective and subsequently performs separate analyses from the energy supplier and consumer perspectives. The macro view is the starting point for the analysis and represents the reference scenario. In this scenario, the residential district is centrally optimized and welfare optimum is achieved. In the next step, the energy supplier and consumers are optimized bi-level. Due to its pricing power, the energy supplier offers energy prices based on its procurement strategy to which the consumers respond. Depending on the level of energy prices, consumers decide to purchase energy or to invest in self-generation in order to supply themselves and / or to market the self-generated energy. Based on this result, the energy supplier adjusts the offered prices to optimize revenues. The sum of producer and consumer surplus represents the new welfare of the residential district. By adjusting parameters, such as changes in electricity prices, the introduction of regulatory policies is simulated. Depending on the regulation, revenue and cost flow change, resulting in new producer and consumer rents and thus in new welfare on the district level. Hence, it is possible to determine, on the one hand, how beneficial a regulation is for the individual agents and, on the other hand, to what extent the regulation has led to an increase in welfare loss. From this, recommendations for regulatory action can be derived.

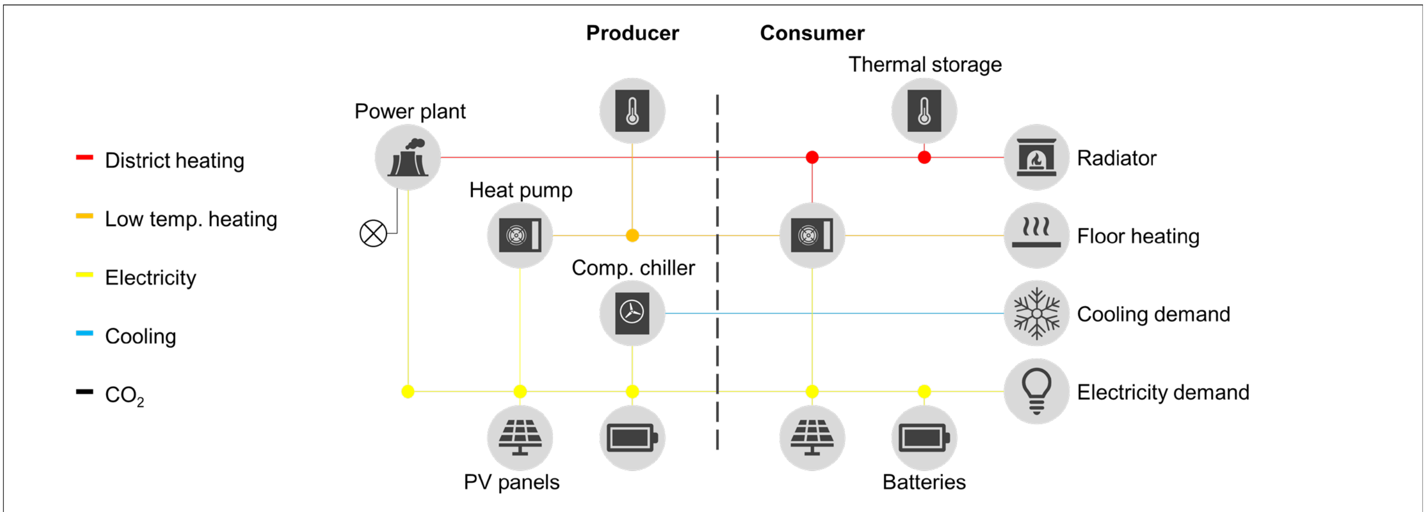

Figure 1: Techno-economic energy system model of a residential district

Results

The preliminary results show that optimizing the residential district as a whole always leads to higher welfare than the bi-level optimization of the energy supplier and consumers. Optimizing the agents' objective functions (profit maximization on the producer's side and cost minimization of consumers) results in welfare losses, with the result that the welfare optimum is not achievable. In addition, consumers react to different price signals in the form of changing electricity prices or reduced grid charges. The behavioral patterns differ depending on the type of consumer (single-family house, multi-family house, etc.). The reduction or elimination of grid charges, and thus the reduction of the electricity price, leads to increased consumer demand for electricity from the grid. This results in positive effects on consumers' annuity costs. Consumers reduce their self-supply rate as capital-intensive batteries do not appear attractive. Multi-family houses reduce their local heat demand by 87 % and district heat demand by 100 %, opting to operate their own heat pumps. The energy supplier increases its electricity supply by 67 %. Due to the reduced demand for heat and the lower prices, its annuity costs increase.

Conclusions

Consumers do respond to price signals for energy, which are passed on through both changed grid charges and flexible tariffs. As expected, electricity demand increases when electricity prices decrease and vice versa. Therefore, regulatory policies are suitable to impact the behavior of consumers (and indirectly producers). By setting targeted price signals, the demand for electricity can be controlled with the objective of stabilizing the grids. Due to the effects on revenue and cost flows, it should be noted that distribution effects occur and should be considered, when designing regulations.

References

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