

EXPLORING THE IMPACT OF ELECTRIC RETAIL RATES AND NETWORK TARIFFS ON DECARBONISING RESIDENTIAL ENERGY DEMAND

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Overview

The transition to carbon-free energy sources, that is envisioned in the European Green Deal [1], requires significant transformations in every sector. Energy usage in cities and particularly in the residential sector account for over 25% of the total primary energy demand, making it one of the highest emitting sectors. Currently, much of residential energy usage still strongly relies on carbon-based sources: heating, hot water and cooking are often based on natural gas, private transportation is based on diesel or gasoline and electricity is, to a large part, supplied by coal and gas-based power plants.

In order to decarbonize this sector, two main strategies can be identified:

1. Directly switching the energy source to a carbon-free source. Examples are: self-generating electricity with PV cells, using solar thermal collectors for hot water (and to a limited extent also space heating).
2. Electrifying end-uses and simultaneously increasing the amount of carbon-free generation and storage options in the electric grid. Examples of electrified residential end-uses are: electric vehicles for transportation, heat pumps for space heating and hot water, electric boilers for hot water and electric or induction stoves for cooking.

These two strategies are not mutually exclusive, in some cases there can be synergies between them: a heat pump can be made more efficient when it is coupled with a thermal reservoir that is heated by solar thermal collectors, an electric vehicle can be charged at lower cost and with fewer emissions with rooftop PV cells.

However, these options require financial investments, which can be burdensome for households. If the expected cost-savings from lower energy prices cannot largely compensate for the investment costs, most households will not make these investments. And even when the cost savings are larger than investment costs over the lifetime of the asset, many households may require subsidies or financial assistance to overcome the high upfront costs.

Currently, most households have electricity retail contracts with a constant price per kWh, or perhaps a day-and-night rate with lower prices during the night. These rates may not be conducive to making investments in high-power electrified end-uses such as EVs and heat pumps, as they do not allow to make use of lower electricity prices during times of high availability of cheap renewable energy from wind and solar. Retail rates that more closely mirror this availability of cheap power may induce more investments in electrified end-uses.

However, widespread electrification of personal transport and heating may lead to another problem: it can cause overloading of the electric network that is used to transport electric power from large generation centers and distribute it to end-users. This is especially true with the retail rates described above, as many of these new high-power devices may simultaneously react to low retail prices and create large peaks for which the network was not designed. Currently, network charges typically do not give an incentive to lower these peaks and protect the network against overloading.

In this contribution, we investigate the impact of alternative electricity retail rates, network charges and the interplay between them. The main objectives are encouraging investments in fossil-free technologies and protecting the network against overloading from an increase in electrified end-uses.

Methods

We use the Calliope modeling framework [2] to build an energy system model of a typical residential neighborhood in the Netherlands. The model includes five different energy end-use demand types: electricity, heating, transportation, hot water and cooking. The initial configuration is based on technologies that are currently in use: gas boilers for heating and hot water, gas fired stoves and diesel or gasoline cars for private transportation.

For decarbonization options, we allow for investments in the following electrified end-uses and carbon-free energy end-uses: heat pumps, electric boilers and stoves, PV cells, batteries, solar thermal collectors with thermal storage and electric vehicles. We also model a network constraint at a low-voltage neighborhood-level transformer. In case of strong increase of electric peaks, we require the network to be upgraded and split the resulting costs among all customers in the neighborhood. The inputs for prices and carbon-content of electricity from the national grid is based on results from the Euro-Calliope model for a possible low-carbon generation mix by 2030.

To investigate the impact of retail rates and network charges, we change the model inputs for electricity prices and network constraints. Modeled retail rates are: flat, Time-of-Use (ToU) and Real Time Pricing (RTP). Modeled network tariffs are: fixed, flat volumetric, two-segment tariff with a low and high-power rate and a hypothetical smart tariff that enforces the network constraint at the LV level while minimizing the dispatch cost of flexible resources. For each combination of retail rates and tariffs, we study the optimal investments in the possible decarbonization options and required network upgrades.

(Expected) Results

The profitability of investments is impacted by the type of retail rate and network tariff that a residential customer is subscribed to. Flat volumetric retail rates give limited incentive to invest in electrification of flexible end-uses such as heating and transportation, as they do not allow the inherent flexibility potentials of these end-uses to be utilized. ToU rates give stronger incentives, they allow EV chargers and heat pumps to make use of lower energy prices to a limited degree. Retail rates based on real-time market prices give the strongest incentives for electrification, as they allow flexible end-uses to make use of the lowest available prices.

Electrification of energy end-uses leads to increasing demand and feed-in peaks. This will be particularly pronounced for retail rates based on real-time market prices, as these give both the strongest incentives for investing in electrification, as well as concentrating power demand in peaks centered around low prices. Thus, intelligently designed tariffs need to be a vital complement to these rates.

Fixed and purely volumetric tariffs, which are currently still common in many countries [3], do not give incentives to reduce peaks and therefore require costly network upgrades for electrification of end-uses. A static capacity subscription tariff [4] delays the need for grid upgrades but also reduce the benefits of market based prices slightly. The hypothetical tariff that enforces network limits while optimizing dispatch cost naturally gives the strongest incentives for investing in electrification. It can serve as a benchmark against which other tariffs can be measured.

Conclusions

Residential retail rates can have a strong impact on investment incentives for low-carbon end-uses in electric grids. Smart network tariffs may be vital in order to protect network infrastructure and avoid costly network upgrades that are driven by excessive peak loads. In combination, these two measures can have a strong impact in accelerating the transition to carbon-free energy sources.

References

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