Scenario Analysis Heating Markets - Effects to Future Energy Grids

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ABSTRACT

The model of the „Scenario Analysis Distribution System Operator (DSO) grid development for the heating market" allows to evaluate and to better understand the drivers and effects of customer's choices with regard to new heating technologies and heating systems. The drivers are e.g. political interventions to achieve COP 21 targets or rising energy prices and subsidies.

INTRODUCTION

Customer Orientation

Westnetz is Germany's largest Distribution System Operator. Westnetz distributes electricity with 4.9 Mio. grid access points and Natural Gas with 0.5 Mio. grid access points to his costumers. The total length of its energy distribution grid is about 213,000 km. As a service provider Westnetz GmbH's strategic and planning decisions are strongly based on their customer's choices.
The ability to react to diverging customers' demands, as flexible as possible, is thus a key business factor.

Making predictions about customers' choices is an ability which allows in principle to be better prepared and to follow customers' demands in a more timely manner, than via a crude readjustment after customers' actions had been taking place. Predicting may thus further flexibility. Predictions can be done via mathematical modelling and simulation.

However customers' choices are influenced by a wide variety of drivers, which makes prediction of choices challenging.
It is thus important to identify key drivers of customer choices and to carve out their main dynamics. In the model this process will be carried out for the private sector.

One main driver for costumers' decisions is price and hence assuming a mainly price-based choice is a priori a sensible option to investigate the main possible outcomes of customer decisions. This will be detailed in the following.

Customer Decisions and Prices

A customer's choice for a heating and thus for a corresponding energy carrier depends firstly on factors, which are due to the customers personal situation. Whether the customer lives in an unrefurbished old detached house or is the landlord of a newly constructed apartment building makes a big difference in the time span and scale for which decisions for a new heating system are to be made. Personal preferences like environmental friendliness etc. may also play a role.

A second major factor is the availability of options. In case of the Westnetz gas distribution grid it is crucial for a customer's choice whether there exists an access to the gas distribution grid or not, as the gas grid in Germany is not ubiquitously available.

A third major factor are the price of heating units, price of heating refurbishments, hook-up fees and the current and future prices of the corresponding energy carrier.
In the present work the price-based choices are implemented via a certain discrete choice model as detailed in the "Modelling approach and Methods" section.

Factors which influence prices

Prices of heating systems are not only dependent on market demand but also on regulatory interventions. So in particular - due to the German "Energiewende" (energy transition) there exist subsidies and constraints for certain heating types, as well as for certain energy carriers. There are also considerations about regulatory interventions such as CO_2 fees which influence the overall price of heating systems.

In the turn the hook-up costs for e.g. gas heating units are to a great extend under the control of the gas grid provider. This opportunity will be commented on in the section "Outlook: hook-up fees and other parameters as grid investment".

All these factors can be seen as "fine-tuning parameters" whose variation will change the possible outcome of a customer's decision.

Outline of the article

The article is organized as follows: Section "Modelling Approach and Methods – Model Outline" gives an overview of the mathematical structure of the model, and in particular of its main influencing parameters. Section "Modelling Approach and Methods – Vesta DSS" describes the technical solution which was chosen as a fluid approach to modelling and simulation. "Modelling Approach and Methods – Data Resources" provides a list of all used data resources of relevance, which were used in the simulation. Section "Conclusions and Outlook" provides a wrap-up of some major conclusions which were drawn from the simulation, as well as a collection of open questions.

MODELLING APPROACH AND METHODS

Model Outline

Classification of heating systems

Customers and potential customers of Westnetz are identified via their heating systems. Socio-economic as well as structural heating system data was collected and implemented into the model in order to provide a realistic background.

Heating systems are classified according to the following classes and class properties: Building type: single family house or apartment building; Building age class: I, II, III, IV ; Building condition: refurbished or not; Gas distribution grid: available or not; Energy carrier/Heating medium: Natural Gas, Oil, Electricity and Wood; Heating unit types: Boiler, CHP, CHP fuel cell, geothermal heat pump, air heat pump, electricity storage heating, stove.

The German Census 2011 provided concrete information about the number of buildings within a small construction time interval and size range on the territory of Westnetz. The European Tabula/Episcope study [L1] classified residential buildings into typology classes. Each building type represents a certain construction period and a specific building size to which characteristic energy related properties are assigned to. A basic classification scheme for German buildings were building type: single family house or apartment building; Building Age class: I, II, III; The Building class IV is not in the Tabula classification – it refers to newly built buildings in the model. The assignment of energy related properties to the building types facilitated estimation of energy carrier demands on the territory of Westnetz. Westnetz data like number of access points, grid capacity, supply density etc. enabled to identify grid access as well as to quality check the estimation of demand for the energy carrier gas, as determined from the above building and census data. The percental assignment of heating systems to the respective building classes was also provided by Tabula. This knowledge is to a great extent based on surveys conducted by the Institut Wohnen und Umwelt (IWU) with the assistance of chimney sweeps [2]. Using a mathematical distribution model, percental heating system data was combined with geographical building data.

Heating system changes as actions

A change in the distribution of heating systems in buildings can a priori be seen as parameter and function dependent action (“flow”) on the set of heating systems (“stock”). This view allows thus to implement methods of system dynamics. The parameters which invoke and guide a change from one specific heating system to another are triggered by a choice model, which is based on price.

That is the action “change of heating system” depends on the (representative) utility connected with that action. The utility itself depends on prices. Concretely, as an example, the utility for a refurbishment decision of a heating is in the model given by the following quantities (abbreviation in brackets): utility (*utility*), operating costs after refurbishment (*opcosts*), costs of refurbishment (*refurbcosts*), length of service life after refurbishment (*servicelength*), sensitivity parameter (*sensitivity*). The following formula holds:

$$utility = \frac{opcosts + \frac{refurbcosts}{servicelength}}{sensitivity}$$

Those quantities may again be dependent on other functions and parameters. For example, the operating costs after refurbishment depend on (time dependent) prices of CO_2 fees. Similarly legislative constraints as for example imposed by the German Energy Saving Ordinance EnEV (Energieeinsparverordnung) or subsidies (see section Data resources) are entering indirectly into costs via the concrete costs for the respective systems.

Discrete choice method

The probability distribution which models a choice is a so-called logit choice probability P [1]:

$$P = \frac{\exp(utility)}{\sum_{refurbishment\ choices} \exp(utility)}$$

Here *utility* is the representative utility a respective customer (heating system) expects upon change (or non-change) to respective alternatives of heating systems. exp(*utility*) is the exponential function applied to utility, it is summed over all refurbishment choices in the denominator. The logit choice probability is a discrete choice model in which it is assumed that the unknown part of a utility has no correlation to unknown parts of alternatives. In the above form, i.e. where a “customer” may function as its own alternative it has strong connections to statistical mechanics (see Boltzmann distribution [3]).

In other words in the model an action takes place with a probability which is proportional to its corresponding logit choice probability.

Simulation

Given a starting distribution of heating systems, a time series can be generated by annually updating the new distribution according to the logit choice probability, i.e. by this approach future distributions of heating systems are «simulated». Derived quantities like the energy consumptions associated to the respective heating systems (classified with respect to specific building types) can thus accordingly be summed up from this time dependent distribution and used for decision making.

The Vesta DSS

Basic description

The Vesta Decision Support System is a software suite for self-service asset-management in the domain of utility grids. It allows for easy handling of data, as well as for enhanced modelling and simulation operations.

The suite provides GUIs (Graphical User Interfaces) for the processing and cleansing of data as well as for its segmentation according to user-defined classifications. There are GUI's which enable the easy application of system dynamics operations.

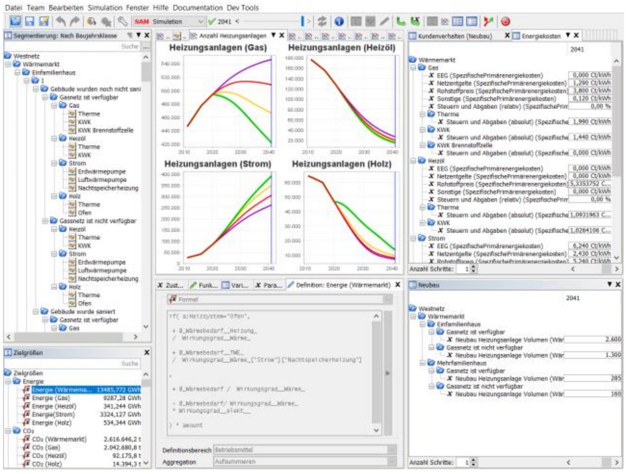

Figure 1. Screenshot of the model in Vesta DSS

Purpose

The Vesta DSS main application area has so far been in the domain of self-service asset management for utility grid providers. Due to its modular form and the general mathematical approach it is however well suited for other modelling tasks including the here, in this article, described model. The all-over set-up is optimized for quick data and model-structural updates without any lengthy rewriting of code. This is important for models like the present, since finally there are constantly new updates of prices and of regulatory interventions as well as updates on the base data for heating systems.

Data Resources

The following main data resources were used in the model:

Geographical Building data

The German census 2011 [L7] provides data which links building data like construction date, number of occupants etc. in an anonymized way to geographical regions.

Building data from the perspective of typology related to heating systems

Energy related data for the buildings as classified by the IWU [L8] (basic classification) were partially taken from the full Episcope dataset (TABULA.xlsm), as well as from the national study dataset: (DE_EPISCOPE_EPI-Tables_NationalCaseStudy_IWU.xlsx).

Prices for heating systems and CO2 emissions

The prices for heating systems, as well as the price sub-classification scheme are taken from regular listings from the Interessenvertretung der deutschen Energie- und Wasserwirtschaft (BDEW)[L2]. The most recent data was from BDEW-Heizkostenvergleich Altbau 2013 and Neubau 2016, respectively. The listing contains also the CO_2 emissions for the given heating systems.

The results of the study “Wie heizt Deutschland” 2015 (How Germany Heats Up) [L3] provided information for a plausibility check for the proportions of different heating technologies and provided values for the qualitative estimation of missing parameters.

Subsidies for heating systems

National subsidies for energy efficient heating units, in particular solar PV, heat pumps, wood pellets from the Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, abbreviated: BAFA) [L4]

Energy carrier prices

The prices for Electricity and Natural Gas were taken from the Monitoring reports of the German federal network agency (Bundesnetzagentur). The last update was from Monitoring report 2015 [L5]. The prices of other relevant energy carriers were taken from well-known German internet sources or comparison portals. Price developments are varied in the simulation via future scenarios, e.g. also assumed CO2 fee, which are currently being discussed in Germany as a control instrument.

Average Service life of heating

The average service lives of heating units were taken from various well-known German internet sources, which are run by private specialists in the construction business. Main sources are listed in [L6].

CONCLUSIONS AND OUTLOOK

The exploratory analysis of the model revealed possible impacts of key influencing factors and it was possible to draw conclusions about the necessary future performance of electricity and natural gas distribution grids on the territory of Westnetz. Some key influencing factors like the price of CO_2 fees will be discussed in the sequel.

Prices of CO_2 certificates

The following diagram shows the output in tons of CO_2 depending on certificate price over the years according to the simulation:

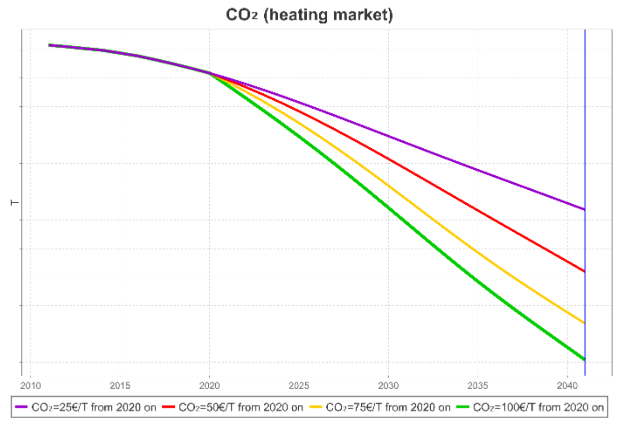

Figure 2. CO_2 output in tons over time for different certificate prices

The price assumptions for CO_2 fees are based on a current price of around 20 Euro/t.

The CO_2 output depends on customer choices for heating systems. The following development of the distribution of heating systems on Westnetz territory is obtained from the simulation:

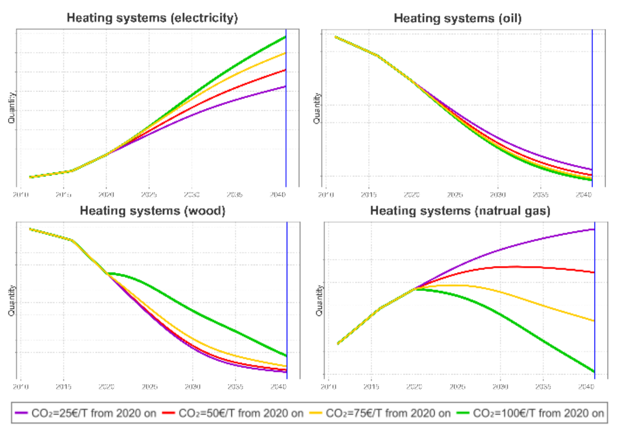

Figure 3. Amount of heating systems over time for different certificate prices for different energy carriers

Outlook: Hook-up fees and other parameters as grid investment

Westnetz GmbH decided to reduce the hook-up fees for gas heating units from 2018 on. Since the present modelling project was terminated before this price reduction could be evaluated, it would be interesting to study the impact of this business intervention within the model.

A rapid decline in the number of gas-grid customers usually results in extra costs which are e.g. due to grid imbalances, restructuring etc. It is thus important to identify counter measures which may mitigate these extra costs. A follow-up project is thus now under consideration.

REFERENCES

[1] K. Train, 2002, *Discrete Choice Methods with Simulation*, University of California, Berkeley,USA,p. 44

[2] N. Diefenbach, T. Loga, B. Stein, 2015, "Szenarienanalysen und Monitoringkonzepte im Hinblick auf die langfristigen Klimaschutzziele im deutschen Wohngebäudebestand ", *Report EPISCOPE Deliverable D 3.2-de*, 1-72.

[3] Landau, Lev Davidovich & Lifshitz, Evgeny Mikhailovich (1980) [1976]. Statistical Physics. Course of Theoretical Physics. 5 (3 ed.). Oxford: Pergamon Press. ISBN 0-7506-3372-7. Translated by J.B. Sykes and M.J. Kearsley. See section 28

URL Links

[L1] www.building-typology.eu
[L2] www.bdew.de
[L3] www.bdew.de/energie/bdew-studie-wie-heizt-deutschland/
[L4] www.bafa.de
[L5] www.bundesnetzagentur.de
[L6] www.baunetzwissen.de, www.bauen.de, www.haustechnik.de, www.energieheld.de
[L7] www.zensus2011.de
[L8] www.iwu.de

ACKNOWLEDGEMENTS

The authors would like to thank Tobias Loga of IWU for his patient assistance in navigating the building data landscape and Tobias Schmid from FFE for helpful tips about relevant data sets. Furthermore the authors would like to thank Nadja Kutz for valuable assistance with the retrieval of data resources and with the assembly of this article.