GLOBAL SENSITIVITY ANALYSIS OF A TECHNO-SOCIO-ECONOMIC BUILDING STOCK ENERGY MODEL

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Overview

For various planning and policy issues the estimation of future development of heating and cooling demand is of great importance. However, techno-socio-economic building stock energy models used for energy and emission development projections and policy assessment involve considerable uncertainty.

In this paper we assess the building stock model Invert/EE-Lab [1, 2, 3], using the Elementary Effects Method, a method appropriate for the degree of complexity of the model. We provide exemplary results for selected parameters for selected countries that have been acquired in the IEA EBC Annex 70 – Building Energy Epidemiology project. Invert/EE-Lab is a dynamic bottom-up model that evaluates the effects of economic and regulatory conditions on future development of total energy demand, energy carrier mix, CO2 emission reduction and costs. The model contains a variety of detailed input data including a highly disaggregated building stock database on country level, heating and hot water technologies, exogenous development presets for building stocks, regional climate, energy prices and energy carrier potentials as well as behavioral aspects and investment decision criteria.

Within this article, we focus on the analysis of the influence of relevant indicators such as interest rates, costs, energy prices, selected technical parameters and behavioral aspects on the final energy demand, respectively related energy carrier shares or installed capacities.

Methods

The Elementary Effects method introduced by Morris (1991) and further developed by Campolongo et al. (2007) and others can be seen as a randomized "One-At-a-Time" design. Elementary effects for each input are computed from different points in the input space, leading to to mean and standard deviation that can be taken as a measure of importance of a specific input variable and its interactions with other inputs. The EE method combines the global focus of more advanced variance-based methods like the Sobol method, which is planned to be also taken into account on a smaller model scale with the lower computational cost of OAT techniques. This method is applied to the building stock model Invert/EE-Lab.

The key approach of the model Invert/EE-Lab is to describe the building stock, heating, cooling and hot water systems on highly disaggregated level, calculate related energy needs and delivered energy, determine reinvestment cycles and new investment of building components and technologies and simulate the decisions of various agents (i.e. owner types) in case that an investment decision is due for a specific building segment. The core of the tool is a myopical, multinomial logit approach, which optimizes objectives of "agents" under imperfect information conditions and by that represents the decisions maker concerning building related decisions. Invert/EE-Lab has been implemented and validated for all EU-28 countries (+IS, NO, CH). For this exercise, we select three exemplary countries.

For the application of the EE-method to the Invert/EE-Lab model we use the SAFE toolbox implemented by Pianosi et al. (2014) (www.safetoolbox.info) to generate the input samples used for the model iterations as well as for analysis and visualization. The great variety of input parameters was broken down to 11 parameters, comprising of interest rates applied to heating system change and renovation measures, economic weight and subsidy awareness amongst other investment decision parameters, heating system and renovation costs, energy prices, lifetime of buildings and heat pump coefficient of performance, as well as service factors representing user behavior. The chosen parameter set was used to to calculate 20 elementary effects per variable. This setting leads to around 720 model runs carried

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out for a simulation period from 2012-2030, including redundant runs per sample to reduce the impact of stochastic model effects.

Results

The analysis was carried out with respect to the output variables *installed capacity of heat pumps* and *share of final energy demand related to heat pumps and natural gas heating systems*. The results for installed *heat pump capacity* show different levels of importance and interconnections for the evaluated input variables. Whereas the parameter *economic weight* can be considered to be of significant influence and great interconnection with other variables, others like *interest rates*, *costs* and *service factors* can be considered as non-influential on the observed output variable. It has to be mentioned tough, that the results are highly dependent on the selected value ranges for the input parameters, as well as on country specific datasets and pre-sets. The results also provide confidence bounds and convergence investigations, which lead to differentiated analysis of the parameter impacts. These is explained in more detail in the paper.

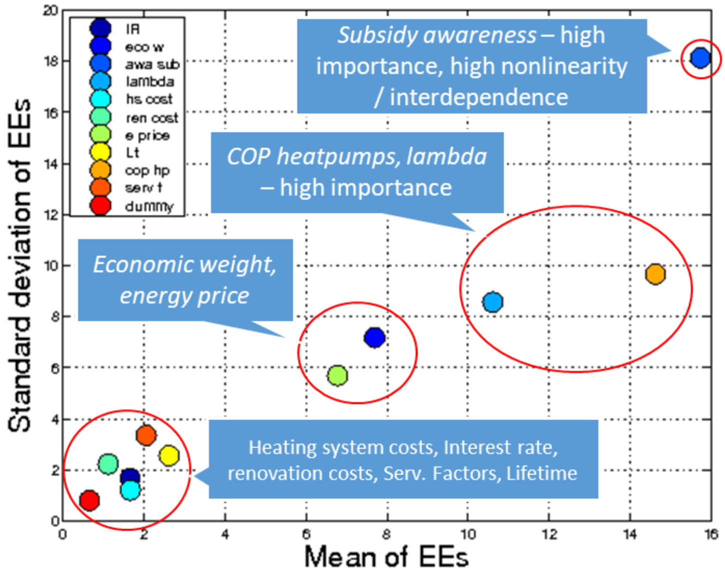

Figure 1. Mean and Standard deviation of Elementary Effects of different input variables on the installed capacity of heat pumps in France 2030

Conclusions

The sensitivity analysis carried out through the Elementary effects method provides valuable insights for the influence of various input parameters. The insights gained can be used for improved scenario development as well as deeper result interpretation trough better model understanding. Whereas the analysis shows partly controversial results the input variables and ranges has to be selected carefully and increased sample sized as well as additional method evaluations with variance-based methods can be beneficially.

Referenzen

[1] Müller, A., 2015. Energy Demand Assessment for Space Conditioning and Domestic Hot Water: A Case Study for the Austrian Building Stock (PhD-Thesis). Technische Universität Wien, Wien.

[2] Kranzl, L., Hummel, M., Müller, A., Steinbach, J., 2013. Renewable heating: Perspectives and the impact of policy instruments. Energy Policy. https://doi.org/10.1016/j.enpol.2013.03.050

[3] Invert/EE-Lab [Model website], URL http://invert.at/ (accessed 30.11.19).