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AGENT-BASED SIMULATION OF THE HEATING MARKET USING THE MCDA METHOD PROMETHEE

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ABSTRACT

In Germany, 80 % of the heat demand is still covered by fossil fuels. Decisions for a heating system are cost-intensive long-term investments and influence the sustainability of the market over a long time. In order to obtain deeper insights on the market dynamics for a more sustainable heating market, we developed an agent-based model and applied it to Hanover, a region in northwestern Germany. Different agents in the model represent various heating system owners and their dissimilar decision behavior. The individual decision processes are modeled as multi-criteria decisions using the outranking method PROMETHEE. With the combination of an agent-based simulation and multi-criteria decision processes of heating system owners, the possible effects of different legislations can be observed. Thus, this agent-based simulation model of the heating market could serve as a decision support tool for the industry or policy makers.

1 INTRODUCTION

As fossil fuels still dominate the heating sector, it contributes to 40 % of the energy related greenhouse gas emissions. Additionally, over 70 % of residential heating systems are older than 15 years and correspondingly outdated and inefficient. In order to improve the sustainability of the sector, we need to analyze the future development of the heating market and the impact of incentives. The aim of this research is to create a tool to support decisions and gain knowledge about potential developments on the heating market for industrial associations, companies and federal institutions. Thus, we developed an agent-based model using the software NetLogo, implementing the heating system owner as agents. Their decision for a heating system and the diffusion of early-stage renewable technologies will be analyzed.

The decision for a heating system is a cost-intensive and a long-term investment and depends on the individual preferences of an heating system owner. In order to account for different preferences, and decision criteria we implemented a multi-criteria decision of the agents using the outranking method PROMETHEE (Preference ranking organization method for enrichment evaluation), programmed as a JAVA extension. The possible effects of different incentives and legislation can be analyzed by simulating different scenarios. We applied the model exemplarily to the region of Hanover, a city and region in northwestern Germany. In the following section, the model design and the decision process will be explained briefly, in section 3 we will roughly present some results and conclude the abstract.

2 SIMULATION DESIGN

Our agent-based simulation is a time discrete model with a dynamic year-by-year simulation. Each simulation step represents one year and the simulation ends after 20 time steps. The simulation starts off in 2014 with over 60,000 agents, representing existing heating system owners in the region of Hanover. Each year new agents are added to the model, representing the heating system owners of new buildings.

The agents differ in terms of their preferences, knowledge, heat demand, the age of the heating system and their ownership structure. According to the ownership rate of the region, 54.7 % of the agents represent households owning and using a heating system (mainly one and two-family houses) and 45.3 % represent landlords (often owning a building with a central heating system). The agents can choose between four different heating system alternatives: gas heating, oil heating, wood pellet heating and heat pumps. These four systems were selected as they represent nearly 90 % of all heating systems used in Germany. The agent's decision process is depicted in the activity diagram in Figure 1.

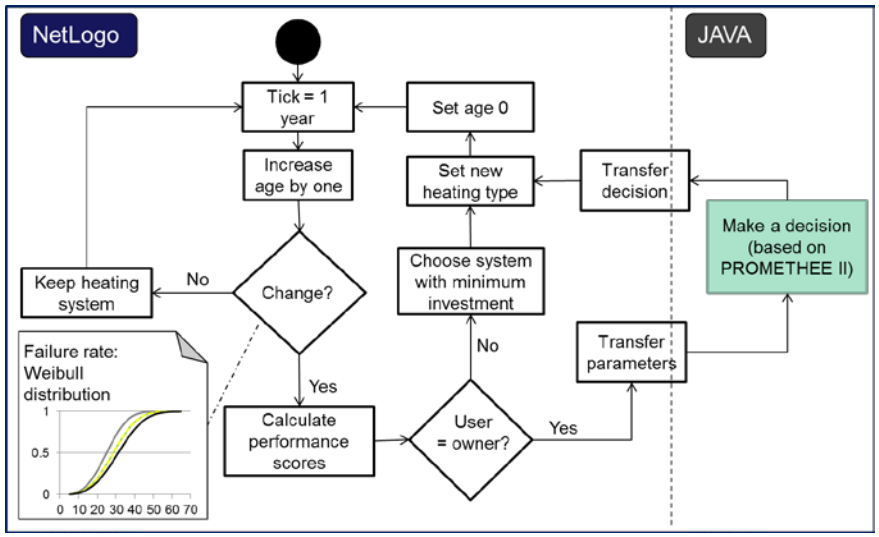

Figure 1: Activity diagram: Agent's decision process.

The probability of replacing the heating system in a given year increases according to a Weibull distribution with the age of the heating system. If an agent wants to replace its heating system, the performance scores for each criterion and alternative are calculated and transferred to the JAVA extension to calculate the decision, based on the PROMETHEE II results (comprising of the strength and weaknesses of each alternative). The PROMETHEE method is based on pairwise comparisons of alternatives. Thus, each heating system is compared to all other alternatives regarding all chosen criteria. The individual preferences are incorporated using different weightings. Economic (total costs per year and fuel price uncertainties), environmental (greenhouse gas emissions), social (knowledge and experience), and technological (comfort of use and infrastructure) criteria were used for the multi-criteria decision process. To account for the existing investor-user dilemma on the heating market, the landlord agents only consider their initial investment.

The data of the heating market characteristics were obtained from the German federal statistical office, the criteria selection and weightings are based on other research findings.

3 RESULTS AND CONCLUSION

The initial simulation results match the development of the German market over the last three years. At this present prices and legislation, we observe an increase in gas heating systems, decrease in oil heating systems and a slow adoption towards renewable technologies. Thus, we plan to further analyze the results and execute more simulations of various scenarios.

In sum, we programmed a JAVA extension for the outranking method PROMETHEE and incorporated it into our agent-based simulation model of a heating market. The model could serve as a decision support tool for the industry and legislators and could be applied to other regions and markets as well.