Heat Pump System Analysis

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A Data Science Approach

Masterarbeit

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ABSTRACT

The aim of this paper is to identify factors influencing the performance coefficient of heat pumps. The performance coefficient refers to the ratio of electricity used to heat generated and thus describes their efficiency. The research question is answered, which variables have an influence on the efficiency of a heat pump. For this purpose, data from two different websites are merged into one database using web scraping with python. To answer the research question, the functionality and reasons for installing a heat pump are first explained. Then the data collection and pre-processing using the web scraping method is explained in detail. The focus of the paper is then on the data analysis and the evaluation of the results. Finally, the limitations of the analysis are discussed, and a conclusion is drawn that can be used for further research and development of heat pump technology.

The efficiency of a heat pump is influenced significantly by its construction type, the maximum flow temperature and its output. It was also found that the efficiency of the heat pump has developed very positively over the last 15 years. The aims of further research could be to investigate the temperature dependence of the performance coefficient of different construction types and to make a distinction between new buildings and existing buildings that is not based on the primary energy demand.

Keywords:

Heat Pump, Efficiency, Data Science, Web Scraping, OLS Regression

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1 INTRODUCTION

As a result of the expansion of renewable energies and Russia’s attack on the Ukraine, energy prices have been rising sharply since 2021. The need for a climate-friendly alternative to heat generation that is independent of fossil resources and supply chains is becoming increasingly urgent. In addition to rising prices, supply chain disruptions are causing major problems for the German energy market. A possible interruption of all deliveries of energy sources, such as gas from Russia, poses a considerable risk. In addition to the German economy, private individuals using gas and oil for heating are particularly affected. The German transition from fossil to renewable energy sources is also processing slower than expected. Climate protection is the central challenge of our time, alongside inflation and supply chain disruptions.

Heating and cooling applications account for almost 60% of Germany's total energy demand, while the share of renewable energies in the heating sector is just over 15%. One technology that meets the current difficult challenges and growing demands for climate protection is the heat pump technology, which is an extremely efficient and clean solution for heat and cold generation that has been available and proven for many years. However, an international and European comparison shows that Germany is lagging in terms of the growth rate of installed heat pumps. (see Breising et al. 2020: 9-10)

The paper “Renewable energy and climate change” published by Volker Quaschning in 2020 already addressed the opportunities of using heat pumps to accelerate the achievement of energy transition goals to counteract climate change.
Furthermore, extensive research is available on the government's need for action in the heating sector and how economically viable and feasible it is to implement more heat pumps in Germany. (see Breising et al. 2020)

The goal of this work is to analyse factors which determine the heat pump technology’s efficiency. Efficiency refers to the ratio of the electricity used to the heat generated from it, also known as the performance coefficient. The research question is to be answered, which factors influence the efficiency of a heat pump. Therefore, factors that influence the performance coefficient will be identified. From this, it will be assessed which variables should be in focus should be on for newly installed pumps and in which areas further research could be done.

Data from two different databases are used, a heat pump consumption database and a climate map. These data are collected, pre-processed and then merged into a comprehensive database for subsequent regressions. This database is then used to investigate isolated variable influence on the performance coefficient and to run regressions across all variables to determine the absolute and relative impact on heat pump efficiency.

To answer the research question, the functionality and reasons for installing a heat pump are explained. This is followed by a detailed explanation of the data collection and pre-processing using the web scraping method. The work then focuses on the data analyses and results evaluation. Finally, the limitations of the analysis are discussed, and a conclusion is drawn which can be used for further research and regarding the further expansion of heat pump technology.

9 SUMMARY

Heat pumps are the most important driver in the heating sector for replacing fossil fuels and reducing greenhouse gases and particulate matter. The technology is also the most efficient way to produce heat.
In this work, data science methods have been used to investigate which factors influence the efficiency of this important technology. Using the method of web scraping, a consumption database with over 1,200 individual consumption datasets of heat pumps and a climate map for collecting temperature data were merged into a regression database.
Using this, seven potential factors were analysed in isolation regarding their influence on the performance coefficient of the heat pumps, the ratio of electricity used to generate heat. Subsequently, four OLS regressions were drawn across all variables to highlight the absolute and relative influence on heat pump efficiency.
The biggest influence on heat pump efficiency is its construction type. In this paper, air-to-water and brine-to-water pumps were investigated. In the course of this work it has been determined, that brine-to-water pumps have the greatest absolute influence on the efficiency and generate significantly more heat than air-to-water pumps with the same amount of electricity used. If this design is feasible and reasonable for the building in concern, this construction type of pump should be installed in any case.

Further it was observed that the continuous variable with the highest effect on heat pump efficiency is the maximum flow temperature. The higher the pump heats the water, the more its efficiency decreases. It is therefore highly relevant to determine the maximum flow temperature in terms of the individual requirements.
The output of the heat pump was also identified as a significant factor that reduces its efficiency. This makes heat pumps in residential buildings even more lucrative, as they require pumps with lower power.
Further the monovalent use of a pump has a positive effect on its efficiency compared to the bivalent use. The difference is significant but not particularly large.

Finally, the year of installation is also a major factor. It has been found that the efficiency of heat pumps has developed significantly over the past 15 years. Newer pumps run much more efficiently than older ones. If we consider a period of more than 10 years, the effect is greater than that of the type of construction.

With reference to the research question formulated in the introduction, it can be concluded, that the efficiency of a heat pump is influenced significantly by its

construction type, the maximum flow temperature and its output. It was also found that the efficiency of the heat pump has developed very positively over the last 15 years.

The aims of further research could be to investigate the temperature dependence of the performance coefficient of different construction types and to make a distinction between new buildings and existing buildings that is not based on the primary energy demand.