An evaluation of the influential factors on energy performance: A case study of a shopping mall by Maryam Rabitabar

Popular science summary of a master thesis

To reduce emissions caused by human activities, the European Commission set some directives and targets regarding energy production and consumption and the reduction of emission of greenhouse gases. The building industry is one of the biggest responsible for energy consumption and C02 emission. The main legislative instrument in the past decade, a considerable number of studies have been conducted to evaluate the performance of buildings. Quantifying building energy performance through the development and use of key performance indicators (KPIs) is essential in identifying the whole picture of operational performance of both new and existing buildings. Research on energy conservation has been widely pursued, but studies focusing on identifying appropriate KPIs for a holistic evaluation of building performance remain limited. Energy performance and energy saving are two common KPIs for measuring the benefits of building energy performance. Normalized annual energy consumption by floor area is commonly used as an indicator of benchmarking metrics in rating and certification systems.

However, total energy consumption and normalized annual energy consumption provide limited insight into why a building performs well or poorly at a more detailed level. Moreover, it does not take into account the type of activity carried out, geometry, outdoor climate, or operating time of the building. Literature review shows that efficiency indicators based on building type are not explored comprehensively. Therefore, it is crucial to determine influential parameters on energy use to identify indicators. Shopping malls are using energy tremendously and becoming more prevalent. The number of shopping centers in Sweden has doubled in the last five years. This study aims to determine the influential factors on the energy performance of shopping malls in Sweden.

Two approaches could evaluate a building's energy performance: data-driven analysis and simulation modeling. As simulation modeling is based on causal relationships, data-driven analysis has been used to determine the relationships between a set of inputs and corresponding outputs. In addition, growing installation of sensors and meters in buildings makes investigations and evaluations of energy performance applicable on different levels of a building, systems, and equipment through improved data collection. The studied shopping mall was a complex building that included several sections connected to various air handling units, district heating heat exchangers, cooling units, and chillers. The building is connected to a local district heating network for heating demand and an electricity network for cooling, lighting, and equipment energy use. Consequently, energy performance should be evaluated separately for electricity and heating due to the various energy carriers. A control system records all energy uses and operational and functional settings. Exploring available data on the control system showed that energy use is recorded on the whole building level while operational data are on the equipment level. As inconsistency in the data metering system hindered assessing the equipment level, measured data from equipment and system levels were aggregated to convert all measurements into a similar level. Moreover, an analysis of one building would not provide a comprehensive perspective of the influential factors on shopping malls' energy performance; therefore, different periods of the years are examined as case studies to simulate distinct conditions. Two groups of dependent and independent variables were chosen to be investigated in relationship analysis over the entire year, cold months, warm months, coldest week, and warmest week of the studied periods. Dependent variables are cooling, property electricity, and district heating flow, influenced by independent variables such as outdoor temperature, cooling degree hour, heating degree hour, supply airflow, occupied and unoccupied mode, time of day, and day of week.

The assessment showed that influential factors of each energy carrier are specifically related to its usage for cooling, heating, or appliances. In addition, assessments of more extreme conditions of the studied periods indicate that a higher number of factors influence a building's energy performance in warmer than colder conditions and colder conditions rather than the entire year. District heating flow is strongly related to heating degree hour, while in colder conditions, influential factors are occupied/unoccupied mode, time of day and supply airflow. The results indicated that each energy carrier depends on its application and has different influential parameters. Moreover, changing condition affects the strength of correlations. The number of influential parameters is higher in warm conditions than in cold ones. According to annual assessments, district heating is primarily impacted by heating degree hours, while in cold conditions, it depends primarily on working hours, time of day, and supply airflow.

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Similarly, cooling electricity strongly relates to cooling degree hour and supply airflow, while under warm conditions, it is additionally related to occupied/unoccupied mode, property and tenant electricity. Property electricity is dependent on working hours, tenant electricity, and supply airflow. It is suggested to install energy meters on equipments' level to make a comparison between strength of other influential factors and floor area as an accepted factor to normalized energy use. The result of the study can be used as a guide for further study of identifying an energy performance indicator.