USING HEAT MAPS TO ASSESS THE ENERGY EFFICIENCY OF INDUSTRIAL COMPANIES

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Abstract

New solutions are required to reduce the CO_2 emissions of industrial companies, as currently most of the heat is generated by burning fossil fuels. Here, not only more efficient technologies, but technologies which incorporate renewable heat sources are required. Industrial heat consumption makes up a large portion of the overall heat consumption. Before individual decarbonisation roadmaps can be developed it is imperative to assess the current heat consumption of an industrial plant. This presents a major problem, as industrial complexes can be large and consist of many individual buildings. Thus, it is often unclear where to begin. The heat map in this work is used to visualise key figures of each individual building in an industrial site allowing the comparison between the buildings with respect to different aspects. It displays the heat consumption of each individual building in an industrial complex visually. For example, this makes it possible to compare the specific heat consumption, and to identify which buildings possibly represent the largest potential for energy efficiency measures. The specific heat consumption on building level also makes it possible to compare the buildings with those of other plants, with similar usage. The heat map can also be used to analyse the local distribution of waste heat and heat sinks.

Keywords: heat map, specific heat consumption, heat consumption, process heat

1. Introduction

Considering the current climate crisis, countries all over the globe are aiming to reduce their CO_2 emissions. Although heat represents the largest share of energy end usage with almost 50 %, a lot of the focus has been placed on renewable electricity generation in the past, which makes up a share of 20 %, transport makes up the remaining 30 % of energy end usage. Of this heat consumption industrial processes make up about 51 % and 46 % are consumed for space and hot water heating in buildings. Currently, this heat is mainly generated by burning fossil fuels (IEA, 2021). To reduce greenhouse gas emissions, energy efficiency measures must be taken to reduce the heat consumption, while at the same time increasing the share of renewable heat. However, before respective roadmaps for the transition of industrial companies can be developed, the current heat consumption needs to be determined based on available data. Here, large urban industrial complexes present a challenge, as these mostly consist of a great number of individual buildings. The question arises which buildings should be analysed first and how this can be illustrated clearly. The heat map presented in this paper provides various building specific data, which makes it possible to compare the buildings to one another using key figures of the buildings. In this paper, two key figures are defined regarding the specific heat consumption, the heat consumption divided by the floor space and heat consumption divided by the building volume. Moreover, the resolution of the heat consumption on building level makes it possible to include the usage of the buildings and the types of heat consumers inside. Based on the comparison of building parameters, energy efficiency potentials can be identified, and the different buildings can be prioritised. The resolution of the heat consumption on building level also makes it possible to not only assess the energy efficiency of the respective buildings but also identify the reasons for this higher specific heat consumption. Furthermore, best practise examples can be identified and adapted to other buildings. Another way of reducing the overall heat consumption of an industrial plant is the identification and utilisation of waste heat potentials. Again, large industrial plants present the problem of consisting of many different buildings. Here, the heat map can be used to show the location of the waste heat sources and the heat consumption on the map. The heat map is then used to identify suitable heat sinks for nearby waste heat sources. This is invaluable as the economic viability for the utilisation of waste heat decreases with greater distances between sinks and sources, as additional piping and systems are needed. In this study, the heat map will show the heat consumption of an automotive manufacturing plant.

2. Methodology - Developing the Heat Map

For the creation of a heat map sufficient data on the objects, which are to be mapped, is required. In this case study the data is supplied by various sources. The operator of the automotive manufacturing plant supplied heat flow meter data for some individual buildings, building complexes, and supply lines. Furthermore, data on the installed heat consumers, such as the installed heating capacity, and their location in the plant is given. To supplement this data, heat flow measurements are performed with ultrasonic flow meters. As the heat consumption of most of the buildings is not measured individually, it is necessary to estimate the heat consumption of these buildings based on the knowledge of the heat consumers, the available flow meters, and own measurements. It is then possible to estimate the individual heat consumption of the buildings. This standardised annual heat consumption is shown in Figure 1. At this point, the specific values are calculated, but not shown here, as they include third party data. Thus, the heat consumption of the buildings is normalised, to show the buildings heat consumption in relation to each other. The map itself is created with the OpenStreetMap data bank (OpenStreetMap contributors, 2022). Even though the absolute value of the heat consumption of individual buildings in industrial companies is needed for the design of the required heat generation units or the local district heating grid, it is of little use when comparing the buildings within the industrial site or even with similar buildings in other sites. Because the various buildings differ greatly in size (Figure 1). For this comparison and further evaluation of the heat consumption, specific values are required. For this purpose, the building parameters, such as inside air volume and floor space are needed. This data is supplied by the operator of the automotive manufacturing plant. For some buildings this data is not available, so it is calculated based on the blueprints provided by the plant operator.

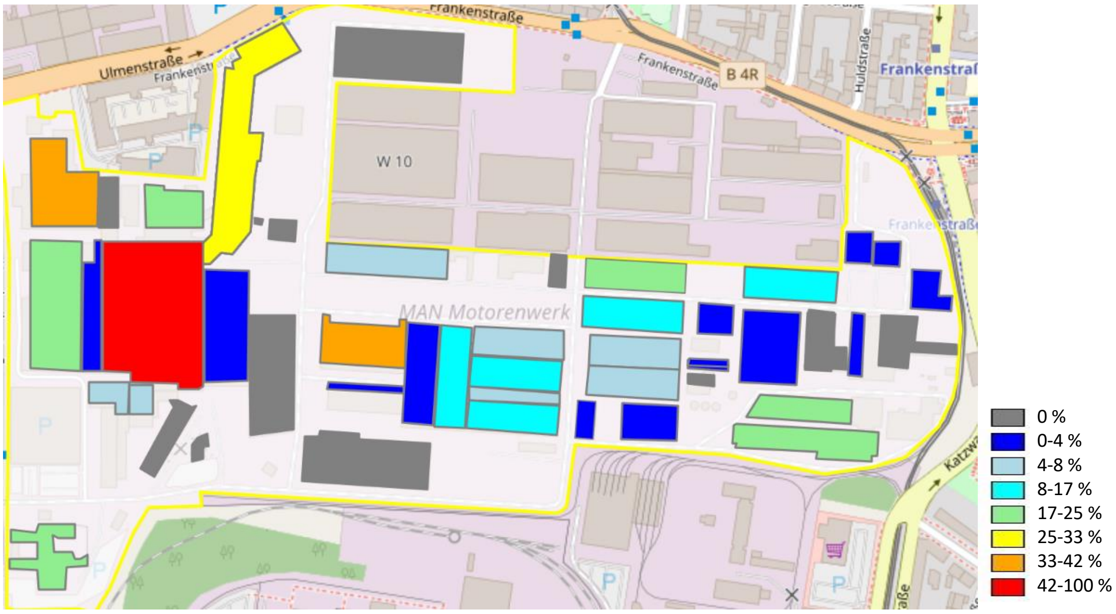

Figure 1: Standardised annual heat consumption of the different buildings in an automotive manufacturing plant

3. Results - Utilising the heat map

In this example, the heat consumption of the production site is dominated by space heating through ventilation and recirculation systems which are used to ensure fresh air and space heating in the big manufacturing halls. Typical process heat systems such as washing machines, heated baths, or drying processes play a minor role in the heat consumption of the manufacturing plant, as they amount to about 18 % of the heat consumption. Thus, the specific heat consumption can be used to pre-evaluate the thermal efficiency of the buildings. Nevertheless, it must be kept in mind, that some buildings have a significant process heat consumption and thus show a higher specific heat consumption, even if they have a higher thermal efficiency. One example of a building with a high process heat demand is the yellow building in Figure 1 which houses the paint shop with various drying processes. The two key figures for the annual specific heat consumption are shown in Figure 2 with the heat consumption divided by the floor space and in Figure 3 with the heat consumption divided by the gross building volume. Figure 2 shows two buildings in orange with a high area-specific heat consumption and identifies these as buildings with a potential for increasing the energy efficiency. Thus, these buildings are analysed more closely to find the reasons for this high specific heat consumption. Contradictory to this, Figure 3 shows that, the right of the two orange buildings has a low volume-specific heat consumption. Consequently, in this case the specific heat consumption, regarding the buildings floor space is not sufficient to compare the energy efficiency of the buildings, as the volume of the buildings also has a great influence on the heat consumption. Therefore, the specific heat consumption regarding the buildings inside air volume represents a better key figure than the specific heat consumption based on the floor space, as the heat consumption for space heating increases with the buildings volume: The air flow is mostly dependent on the buildings inside air volume because the ventilation units are designed to provide certain air exchange ratios. As the inlets of the ventilation units are mostly situated directly under the roof the whole building volume is exchanged. However, additional factors influence the buildings heat consumption, these include the control of the ventilation and recirculation systems as well as the utilisation of heat recovery systems.

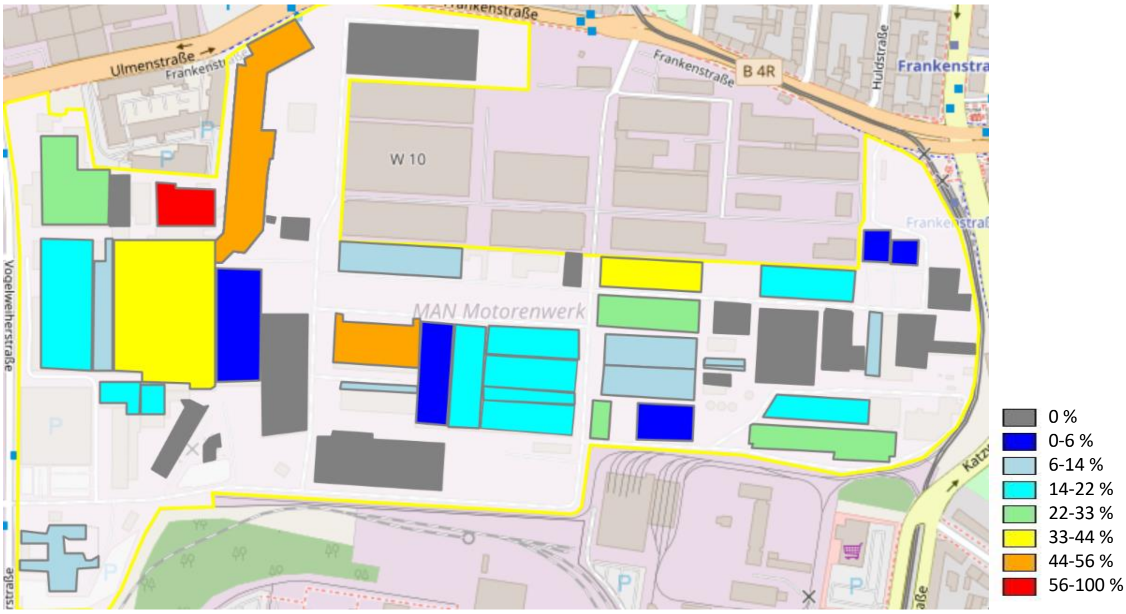

Figure 2: Standardised specific annual heat consumption of the different buildings in an automotive manufacturing plant (floor space)

Figure 3: Standardised specific annual heat consumption of the different buildings in an automotive manufacturing plant (gross building volume)

In residential buildings the heat losses are dominated by transmission, as the walls, buildings and windows are badly insulated, and these buildings commonly are not fitted with air ventilation units. After energetic renovations the transmission heat losses and the air permeability are reduced, and air ventilation units are required. Here, the buildings volume becomes more important, as the ventilation units then provide certain air ventilation ratios. However, as the ceiling height of most buildings is similar the volume correlates with the floor space. In this automotive manufacturing plant, the heat losses are dominated by ventilation heat losses, as the installed ventilation units provide high air exchange ratios. Consequently, in this case the gross building volume is of interest, as a higher building volume results in higher volume flows.

A multitude of production processes take part in an industrial manufacturing plant e.g., washing, drying, tempering, and the generation of compressed air. With some exceptions, such as washing machines radiating waste heat directly into the halls, the waste heat generated in these processes, is rejected to the environment with cooling units or compression chillers. The utilisation of this waste heat presents a large potential to reduce the heat consumption within an industrial site. At this point, not only the amount of waste heat but also the location of the waste heat sources in the industrial site, in relation to the location of heat consumers, is of interest. The standardised waste heat potential of the automotive manufacturing plant is presented in Figure 4. The waste heat potential was standardised to the same value as the heat consumption in Figure 1, to be able to compare them to each other. These potentials include waste heat from compression chillers, various production processes, server cooling, and engine tests. The manufacturing plant includes test stands for the serial tests of engines (yellow building) and test stands for research and development (red building), in Figure 4. The waste heat potentials of the air compression units (green and light blue building) are estimated based on the electricity demand, provided by the plant operator. For the engine tests, the energy content of the consumed diesel was used to estimate the waste heat potential, from which the electricity generation is subtracted. Further data is obtained by own heat flow measurements with ultrasonic flow meters. The overlay of the two maps in Figure 1 and 4 makes it possible to assess if the waste heat can be used locally in the same building, buildings close by, or if the heat must be transported to other buildings of the plant. The Figures 1 and 4 show, that in the west of the plant the waste heat potential could be utilised to also meet the high heat consumption in the west of the plant. The building on the bottom left of Figures 1 and 4 also shows a sufficient heat sink for its own waste heat. On the other hand, the red building (Figure 4) on the bottom right shows a higher waste heat potential than heat consumption. Thus, this waste heat must be distributed to other nearby buildings. In this case, the heat map can supply a first indication to the relation and position of waste heat potentials and heat consumption within the plant. This makes it possible to prioritise the utilisation of waste heat sources, depending on absolute amount of waste heat and the availability of nearby heat sinks. This information also allows to identify which heat sinks and waste heat sources need to be examined more closely, regarding the simultaneity of heat consumption and waste heat potential.

Figure 4: Standardised annual waste heat potential of the different buildings in an automotive manufacturing plant

4. Conclusion and outlook

When developing different energy efficiency and decentralised renewable heat generation roadmaps for a large industrial site, it is imperative to first estimate the current heat consumption. The developed heat map allows a graphical comparison of key figures of different buildings within a plant and gives the opportunity to compare them to similar buildings of other plants. This enables the users to quickly identify buildings with a higher specific heat consumption. Based on this, an assessment can be made which buildings already consume less heat and which buildings should be the focus of potential energy efficiency measures. Moreover, estimating the heat consumption on building level makes it possible to examine the different buildings individually and account for their usage and the different heat consumers within. This is necessary as they directly impact the heat consumption of the building. Furthermore, the heat map offers the opportunity to show the location of waste heat sources and heat sinks, making it possible to prioritise the utilisation of waste heat potentials in the vicinity of heat sinks and identify which heat sinks should be supplied by which waste heat source.

This heat map shows the heat consumption and waste heat potential as annual values and therefore cannot be used to assess the simultaneity of the heat consumption and the waste heat potential. In consequence, the individual heat sources and sinks need to be examined more closely, than done in this study. This also means, that it cannot be used to calculate the maximum heat load of the system. The creation of a heat map requires a lot of data on the buildings, which are to be mapped. The bigger the industrial complex and the more numerous the data the more a heat map can help to get a better overview of the specific buildings in a plant. This heat map is used to identify buildings with a lower energetic efficiency, within the automotive manufacturing plant. From this base, the different buildings were prioritised for the implementation of energy efficiency measures. The heat map is then also used to identify possible heat sinks for waste heat sources. In the next step the heat map shall show how the heat consumption of the buildings changes when implementing different energy efficiency measures and the integration of waste heat. This will make it possible to quantify the remaining heat consumption, which is to be decarbonised.

5. Acknowledgments

The authors thank the Federal Ministry for Economic Affairs and Climate Action for the funding of the project (03EN3023A) as well as the project partners for the good cooperation and the supply of data.

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