M3a.2 Quantification of anthropogenic heat for each pixel for future development scenarios

Determination of anthropogenic heat generated by transport, industry, and energy supply:
The data used for the analysis is broken down in Annex 8. Depending on the source, there are different time stamps and regional breakdowns.

First, the flow chart for the capital of Austria is depicted for August 2015 in Fig. 5. A flow chart is a representation of the energy quantity flow within a system under consideration, in this case Vienna, in a specific time period, in this case the August 2015. The data comes from a mix of published data from E-Control, Statistics Austria, Wiener Netze and Wien Energie. The energy flow diagram shows how much energy is needed to supply the city of Vienna, how this amount of energy is subsequently converted or distributed and in which areas it is ultimately used. The diagram is read from left to right. At the beginning, every primary energy is found either in free or in bound form (Pehnt 2010). The colors each represent an energy source that was either imported or produced locally in Vienna. Every energy source has its own color: oil is orange, electrical energy blue, district heating in purple, gas is pink, biogenic fuels and combustible red, combustible waste is grey, and renewables are green.
The imported and domestically produced energy sources are shown on the far left. On the upper left side, the imported fractions are depicted; they consist of oil, a part of the electrical energy and district heating, gas, and a part of the biogenic fuels and combustibles. On the lower left side, domestic production consists of biogenic fuels and combustibles, combustible waste and renewables.
Electrical energy and district heating belong to secondary energy. They arise from lossy conversion steps such as burning and refineries (Pehnt 2010). In 2015, the conversion input consisted of gas, biogenic fuels and combustibles, combustible waste and renewables. More than half of the imported gas was converted to be able to be used in the form of electrical energy and district heating. The efficiency of gas conversion is around 60%. Usually, gas is burnt either in gas turbines or in gas-steam power plants (Pehnt 2010). The biomass caloric plants are normally decentralized nearby the place where big amounts of biomass accumulate. Thereby, biomass is burnt in steam generators with downstream steam cycle and is technically mature. Furthermore, it has been on the market for decades (Lechner et al. 2003).
Electrical energy can also be generated from renewable energy sources. The hydroelectric power plant in Freudenau is the highest producer of renewable energy in Vienna with a nominal power of 172 MW and a production of electricity of 1,035 GWh in 2015 (Verbund 2017).
In August, the distribution and the use of individual energy sources differs fundamentally from the distribution in 2015. Fig. 5 depicts the distribution of energy sources considering the final energy consumption in August 2015. What is noticeable at first glance is that gas consumption is greatly reduced and now accounts for only 16% of Vienna's total final energy demand. This is not surprising, however, as gas is mainly used for heating in Vienna, which is omitted in summer. The main share for which gas is used in August is for heating water.
Furthermore, the elevation level of the emissions can be determined. The heat from oil is assumed to be only on the road level for the sake of simplicity, since traffic accounts for 89% of oil consumption. The elevation level for gas emissions is split up between the façade and the roof. However, most of the waste heat that is required for hot water and heating is located at façade level. Only the loss which accumulates the consumer circulates upwards is attributable. to the chimney level. Therefore, the combustion efficiency of gas boilers is needed. It amounts to 80% (Durkin 2006; Qu et al. 2014).
As a result, 80% of the heat is emitted at façade level and around 20% at chimney level. Both the heat from electricity and district heating take place mainly at façade level. This results from the fact that there are no longer any large losses at the end consumer and that district heating is mainly used for hot water preparation and heat. District heating is therefore only assumed to emit at façade level, as it is almost exclusively used in houses.
Electricity is mainly used for the operation of electrical appliances and light. For electricity consumption, it is assumed that 5% results at street level, since electricity is of course also used for street lighting and various other needs at road level. For example, this is the case for charging electric cars. The rest, i.e. 95% of the consumption, is emitted at façade level.

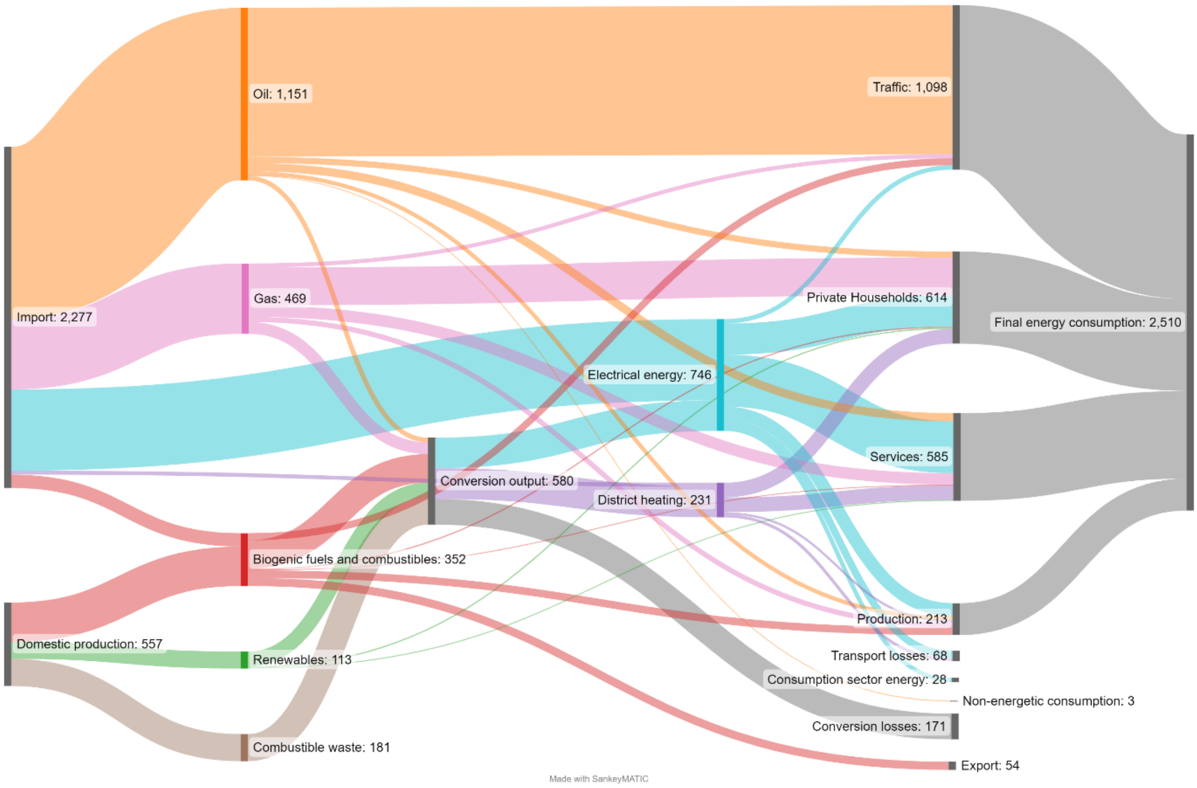

Figure 5. Sankey flow chart for Vienna for August 2015 in GWh

The sum of domestic production and import equals the heat which arises. This amounts to roughly 3,003 GWh in August. Divided by the area of Vienna, this corresponds to an energy input of around 10.04 W/m². To be able to classify this amount of energy somewhat, it is compared with the energy generated by global radiation. The mean global radiation measured in August 2015 was around 224 W/m2 in Vienna (Universität für Bodenkultur Wien 2022). Accordingly, the anthropogenic energy input amounts to about 5% of the global radiation in August 2015.

Time-series of heat emission

The use of standard load profiles was identified as a method for reducing the time resolution of the data. Using these, each energy source can be broken down in time, usually in 15-minute or 1-hour increments. There are different procedures to ensure spatial division. Regarding traffic, noise maps or NO_2 emission concentration measurements can be used. For private households, the spatial distribution can be approximated by the inhabitants of each of the 23 districts. For private and public services and production, the energy consumption of each district is used to obtain a district-by-district breakdown. An example of the heat emissions during June 1-7, 2022, can been seen in Annex 9.

Future scenarios

The future scenario used here is a mixture of those that have been published. Three major changes to the energy balance of August 2015 in Vienna were made: the complete electrification of transport, the replacement of gas with heat pumps and the expansion of renewable energies, especially photovoltaics.

According to the scenario, the energy consumption will amount to 2.089 GWh in August 2040 (Fig. 6). This corresponds to a heat input of around 7 W/m². Comparing the energy consumption of August 2015 with that of August 2040, a reduction to 69% might therefore be possible.

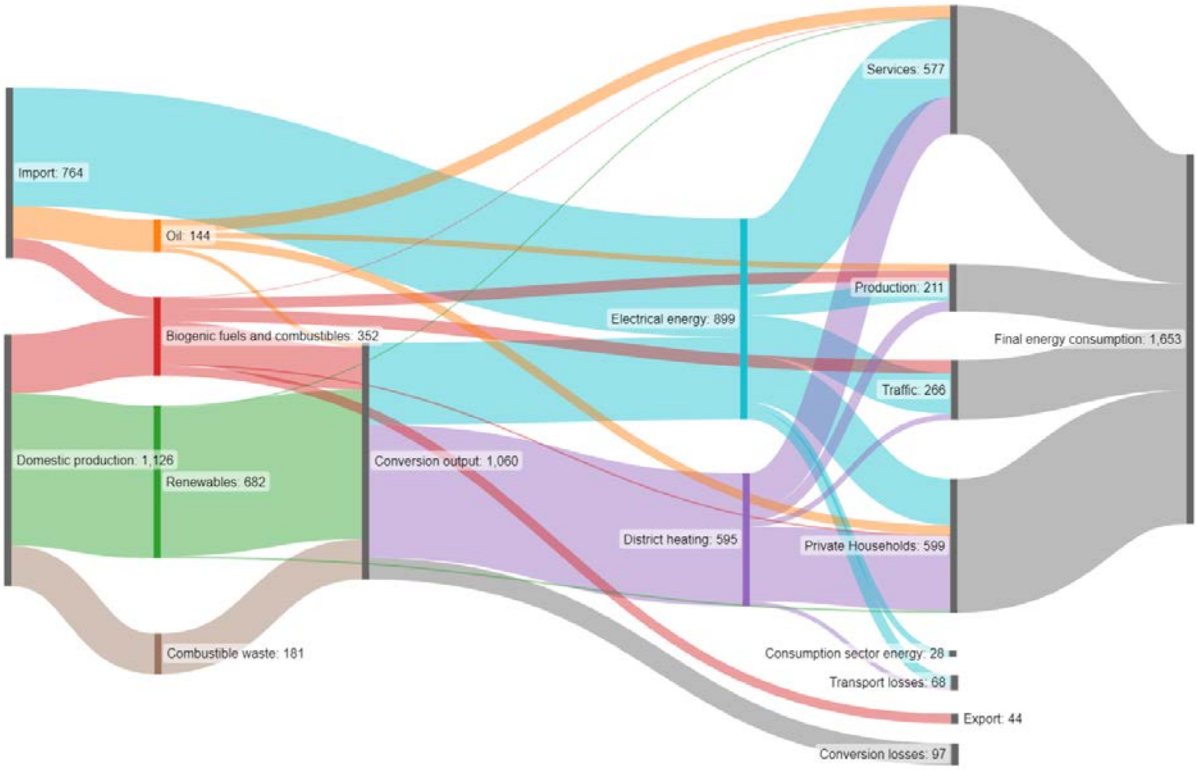

Figure 6. Sankey flow chart for Vienna for August 2040 in GWh

Localization of heat emissions:

Annex A10 and A11 provide a detailed representation of the monthly average values for both summer and winter episodes across the specified scenarios. The summer values are derived from the average of the months June, July, and August, ensuring a comprehensive overview of the summer period. For the winter episodes, the averages from December, January, and February were calculated, capturing the essence of the winter season. These tables serve as a crucial tool for accurately assigning the values to the respective designated zones, facilitating a clear and organized analysis of the data. By examining these tables, one can gain a deeper understanding of the seasonal variations and their implications within the different scenarios.