Power sector:
Emissions from Heat Plants

Jeremy Freeman[1,2], Lekha Sridhar[1,2], and Madison Alvara[1,2]
1) WattTime, 2) Climate TRACE

1. Introduction

Heat plants combust fuel to generate heat that is then distributed for thermal comfort or industrial usage via a pipe network to multiple buildings/ units. This is also referred to as "district heating", which is differentiated from other forms of thermal heating such as onsite fuel usage (the combustion of fuels to produce heat within a single building or residence).

Heat plants are widely used to provide thermal comfort in many countries including Iceland (largest percentage of residents served), China (largest district heating capacity), and several other European countries (Solar Thermal World, 2018). Heat plants can be an effective solution for small towns and college campuses, reducing the necessity of each building installing its own boilers. However, over 90% of the heating supplied by heat plants is currently generated using fossil fuels, making heat plants a globally significant source of greenhouse gas (GHG) emissions (IEA, 2023). In some cases, heat plants can contribute ~0.12% to global emissions which, although a small share globally, represent a significant portion of national totals in some regions, particularly Central Asia and Eastern Europe. That said, there are many opportunities for reducing emissions from heat plants including the use of combined heat and power plants (these are currently included in the Climate TRACE inventory under electricity-production), use of renewable energy to heat (International District Energy Association, n.d.).

This methodology aims to close coverage gaps by estimating country-level heat plants' emissions. Furthermore, beginning November 2025, Climate TRACE is providing potential emission reduction solutions (ERSs) to understand how this sector's emissions can be reduced through specific mitigation strategies.

2. Materials and Methods

Heat plant emissions were estimated by applying the Intergovernmental Panel on Climate Change (IPCC) National GHG Inventory Guidelines Tier 1 approach,

$$\text{Emissions}_{\text{GHG,fuel}} = \text{Emission Factor}_{\text{fuel}} \times \text{Fuel Consumption}_{\text{GHG,fuel}}$$

Where:

$\text{Emissions}_{\text{GHG,fuel}}$ = emissions of a given GHG by type of fuel (t GHG)
$\text{Emission Factor}_{\text{fuel}}$ = default emission factor of a given GHG by type of fuel (t gas/TJ). For CO2, it includes the carbon oxidation factor, assumed to be 1.

Fuel Consumption$_{GHG,fuel}$ = amount of fuel combusted (TJ)

2.1 Datasets employed

Data on fuel consumption in heat plants for the years 2015-2022 (the years for which Climate TRACE calculates emissions) were obtained from the International Energy Agency's (IEA) World Energy Balances dataset (2024) which provided energy consumption by fuel type for heat plants. For the purpose of this dataset, the IEA defines heat plants as plants (including heat pumps and electric boilers) designed to produce heat only and who sell heat to a third party (e.g. residential, commercial or industrial consumers) under the provisions of a contract. Main activity producers generate heat for sale to third parties, as their primary activity. They may be privately or publicly owned. Note that the sale need not take place through the public grid (IEA, 2024).

Tier 1 default emission factors were obtained from the IPCC Emission Factors Database which provides default emission factors for Fuel Combustion (1.A) by fuel type (IPCC n.d.). Where multiple emission factors were available, an average was used.

Emissions were calculated at country level annually and then were spatially and temporally disaggregated at the county/district level and monthly scale, respectively. In addition, emissions up to 2025 were projected using 2023 emission estimates. To understand the methodology for the spatial and temporal disaggregation, refer to the following documents hosted in the Climate TRACE *Post Processing for Global Emissions and Metadata Completeness* folder in the GitHub methodology repository:

- Gary Collins, April Nellis, Krsna Raniga, Nicole Brown, Michael Pekala, Zoheyr Doctor, Dan Moore, Elizabeth Reilly, Marisa Hughes, Gavin McCormick (2024), *Spatial Disaggregation of Remainder Emissions*; and
- Krsna Raniga, Dan Moore, Zoheyr Doctor, Peter Thomas, Ishan Saraswat, Gary Collins, April Nellis, Nicole Brown, Michael Pekala, Justin Rokisky, Christy Lewis, Elizabeth Reilly, Marisa Hughes, Gavin McCormick (2024), *Temporal Allocation of Emissions Estimates*.

3. Result Highlights

The global emission total from heat plants for 2024 is 91.4 million tonnes CO_2e (only CO_2 emissions were estimated) from 37 countries.

3.1 Validation

Only 14 Annex 1 countries reported heat plant emissions in their official GHG inventories to the United Nations Framework Convention on Climate Change (UNFCCC) against which Climate TRACE estimates emissions were compared (Figure 1).

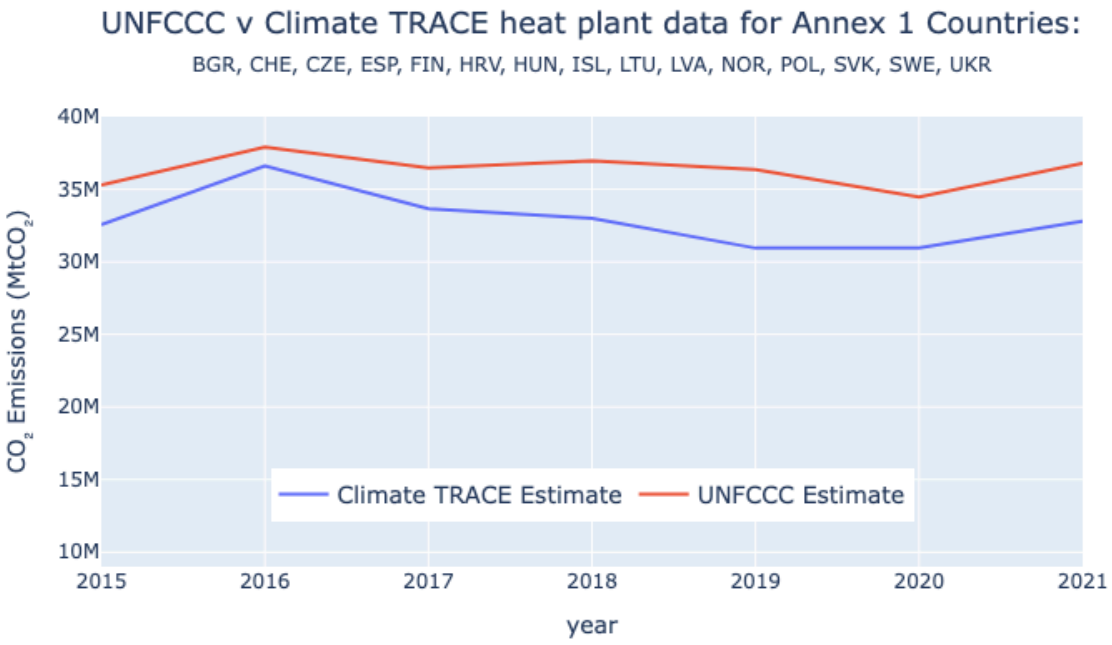

Figure 1: Comparison of emissions from heat plants for 14 Annex 1 countries for which data was available from Climate TRACE and the UNFCCC.

As seen in the Figure 1 comparison, both datasets are largely in agreement on year-on-year emissions trends and magnitude of emissions, where UNFCCC estimates emissions closer to 35 million tonnes versus Climate TRACE estimates ranging between 30 to 34 million tonnes. This could also be seen at the country level, with the exception of a few countries like Switzerland, where Climate TRACE's emissions were less than half of what had been officially reported. This may be due to system boundary differences or due to errors in the underlying data.

3.2 Data issues

The underlying IEA activity dataset used to produce emissions estimates have some possible data issues, namely:

1. The world total for heat plant energy consumption is greater than the sum of the countries (a difference of around 5-8%). While this is a small difference in global terms, it points to possible issues such as under or non-reporting in some countries.
2. There is a large increase in energy consumption in 2021 – it is unclear if this is due to a change in reporting guidelines, a correction of under-reporting in previous years, or an actual increase in heating-based energy consumption in 2021.
3. One conspicuous absence, both in the UNFCCC reporting and the IEA data is Russia, as the IEA does not provide heat only emissions for the country. In Russia's official GHG inventory, all emissions under "1.A.1.a. Public electricity and Heat Production" have been attributed to "1.A.1.a.ii. Combined Heat and Power Generation" even though heat

plants are known to exist in the country (Power Engineering International, 2009; Reuters, 2024).

4. Conclusion

Climate TRACE aims to address these underlying issues in the data in future iterations by gathering plant level information and other sources of data on energy consumption at heat plants.

5. Emission Reduction Solutions

Emissions Reduction Solutions (ERSs) for this sector is one strategy: renewable power to heat. *s. Note: Only rank 1 strategies are provided for assets on the Climate TRACE website and additional strategies will be made available in future releases.*

Renewable power to heat

Current heat technologies include boilers, which are mainly gas-fired and dominate low- to mid-temperature operations up to 500ºC for steam or thermal oil production, and process heaters or furnaces, which produce higher temperatures either directly or indirectly. The solution of using renewable power for heat involves deploying technologies such as solar thermal, geothermal, and industrial waste heat to replace fossil fuel use in these systems.

By substituting conventional fuels with renewable heat sources, emissions from district heating can be reduced by over 30% for natural gas systems, with lower or higher reductions depending on the fuel type; 30% has been used as an average estimate. Renewable heat projects have been successfully implemented in several countries, including solar heating in Austria and Germany and geothermal installations in Italy and Germany, demonstrating practical feasibility and supporting wider adoption of these technologies (ScienceDirect, 2025; IRENA, 2017).

6. Supplementary materials metadata

Country-level emissions estimates for heat plants are available for download at ClimateTRACE.org, and the following table summarizes this data.

Table S1 General dataset information for "country-climate-trace_heat-plants_xxxx24.csv"**.**

General Description	Definition
Sector definition	*Heat Plants*
UNFCCC sector equivalent	*1.A.1.a.iii*
Temporal Coverage	*January 1, 2015 – current year (2 month lag)*
Temporal Resolution	*Monthly*
Data format(s)	*CSV*
Coordinate Reference System	*Not applicable*

General Description	Definition
Number of sources available for download and percent of global emissions	*Country level only, 100% of known emissions, disaggregated to GADM level 2 regions.*
Total global emissions for 2024	*92.9 Mt CO_2*
Ownership	*Not applicable*
What emission factors were used?	*IPCC Tier 1 emission factors*
What is the difference between a "NULL / none / nan" versus "0" data field?	*"0" values are for true non-existent emissions. If we know that the sector has emissions for that specific gas, but the gas was not modeled, this is represented by "NULL/none/nan"*
total_CO2e_100yrGWP and total_CO2e_20yrGWP conversions	*Climate TRACE uses IPCC AR6 CO_2e global warming potentials (GWPs). CO_2e conversion guidelines are here: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport_small.pdf.*
Do the estimates include emissions from biomass fuels?	*No, due to concerns of overcounting since biomass is accounted for by the Climate TRACE forestry and land use sector.*

Data citation format: Freeman, J., Sridhar, L., and Alvara, M. (2024). *Power sector-Emissions from Heat Plants.* WattTime, USA, Climate TRACE Emissions Inventory. https://climatetrace.org [Accessed date]

Geographic boundaries and names (iso3_country data attribute): The depiction and use of boundaries, geographic names and related data shown on maps and included in lists, tables, documents, and databases on Climate TRACE are generated from the Global Administrative Areas (GADM) project (Version 4.1 released on 16 July 2022) along with their corresponding ISO3 codes, and with the following adaptations:

- HKG (China, Hong Kong Special Administrative Region) and MAC (China, Macao Special Administrative Region) are reported at GADM level 0 (country/national);
- Kosovo has been assigned the ISO3 code 'XKX';
- XCA (Caspian Sea) has been removed from GADM level 0 and the area assigned to countries based on the extent of their territorial waters;
- XAD (Akrotiri and Dhekelia), XCL (Clipperton Island), XPI (Paracel Islands) and XSP (Spratly Islands) are not included in the Climate TRACE dataset;
- ZNC name changed to 'Turkish Republic of Northern Cyprus' at GADM level 0;
- The borders between India, Pakistan and China have been assigned to these countries based on GADM codes Z01 to Z09.

The above usage is not warranted to be error free and does not imply the expression of any opinion whatsoever on the part of Climate TRACE Coalition and its partners concerning the legal status of any country, area or territory or of its authorities, or concerning the delimitation of its borders.

Disclaimer: The emissions provided for this sector are our current best estimates of emissions, and we are committed to continually increasing the accuracy of the models on all levels. Please review our terms of use and the sector-specific methodology documentation before using the data. If you identify an error or would like to participate in our data validation process, please contact us.

References

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