



## High-resolution direct GHG emission estimation and simulation from residential space heating using open data

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Residential space heating remains a major source of greenhouse gas emissions in the building sector. In Germany, space heating accounts for the largest share of residential energy consumption, and accurate quantification of associated emissions is essential to meet national climate mitigation targets.

Most research on residential heating emissions focuses on the regional or national levels, while estimates at finer spatial scales remain limited. Data availability further constrains the transferability and usability of current models. Consequently, approaches that deliver spatially and temporally detailed emission estimates and interactive tools to support analysis and decision-making by stakeholders are urgently needed.

We introduce the Climate Action Navigator (CAN), a dashboard for the analysis and visualization of climate mitigation and adaptation spatial data, based entirely on open science principles. One of the tools available in the CAN estimates carbon dioxide emissions from residential heating at fine spatial at temporal scales. The tool applies a bottom-up accounting methodology at 100 m spatial resolution based on publicly available census and building characteristics data in Germany, including building age and dominant energy carriers. The resulting emission estimates are consistent with official city- and national-level inventories, confirming methodological reliability. Germany-wide analyses reveal strong spatial heterogeneity in energy consumption and emissions that correlate with urban morphological characteristics.

Temporal dynamics are captured through an hourly simulation using the Demand Ninja model based on local weather data. The resulting temporal emission patterns can support inverse emission modelling applications as well as aid energy management by, for example, revealing peak heating demand times and locations.

Results are delivered via the CAN interface as intuitive, interactive maps and charts that allow users to compare across neighborhoods, explore temporal emission dynamics, and assess potential mitigation actions. By integrating open-source data with high-resolution modeling and visualization, the Climate Action Navigator bridges the gap between scientific emission quantification and practical decision making. The approach supports transparent attribution and tracking of residential space-heating emissions, thereby advancing evidence-based climate mitigation planning.

