2025

The Indoor Air Pollutants Inventory Tool (InAPI) v1.0

USER GUIDE
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Contents

1. Introduction

The InAPI tool was developed within Work Package 1 (WP1) of the IAQ-EMS project to create a comprehensive inventory of indoor air pollutants in the UK. Based on a literature review and field measurements, the tool catalogues data across four key areas of the IAQ-EMS framework—organizing information by pollutant, environment, and activity. InAPI also identified chemical and biological emission sources, surveyed occupant behaviour and environmental parameters, and built a flexible database representing indoor environments commonly experienced by the UK population.

The main goal of the InAPI tool is to provide a clear overview of indoor air pollution levels in the UK, highlighting average pollutant concentrations in key public and private indoor spaces. It also quantifies major indoor emission sources for the first time using a chemical mass balance approach. InAPI aims to make relevant literature easily accessible, offering a valuable resource for model developers, researchers, and policymakers working to understand and manage indoor air quality.

2. Methodological Approach

InAPI is a visualization tool based on the IAQ-EMS indoor air pollutant inventory (Mazzeo et al., 2023), designed to display activity-based concentrations and emission rates of indoor pollutants. It organizes data into four general indoor environments here after called Built Environments (Benv)—Residential, Occupational, Recreational, and Transport—further detailed by micro-environments, activities, and fuel types. The inventory includes data on gases (e.g., NO, NO_2, CO, O_3), aerosols (PM_{10}, $PM_{2.5}$, $PM_{1.0}$, UFPs), biological agents (bacteria, fungi), and around 40 VOCs, collected from UK literature between 1996 and 2023. Reporting varies: some studies focus on long-term averages, while others capture short-term activity-specific exposures.

Activity-related data in the Residential category are especially detailed, including fuel-specific cooking methods, heating types (e.g., wood, coal), and activities like smoking or cleaning. Transport environment sampling covers vehicles such as cars, buses, trains, and the London Underground, mainly focusing on aerosol levels. Occupational environments include offices, hospitals, and schools, with a broader pollutant range. InAPI also provides contextual data such as sampling site size and ventilation rates when reported by the original sources.

Measurement techniques used to measure indoor air pollutants concentrations are grouped by pollutant into four main categories: active sampling (e.g., air pumps, canisters), passive sampling (e.g., sorbent tubes), gravimetric methods (e.g., particle filters), and optical methods (e.g., sensors, UV/IR detectors). Passive methods were commonly used for large-scale, multi-pollutant monitoring across dwellings, while optical techniques offered high-resolution data in individual environments. Active and gravimetric methods were more targeted, often used for source-specific studies or particle analysis.
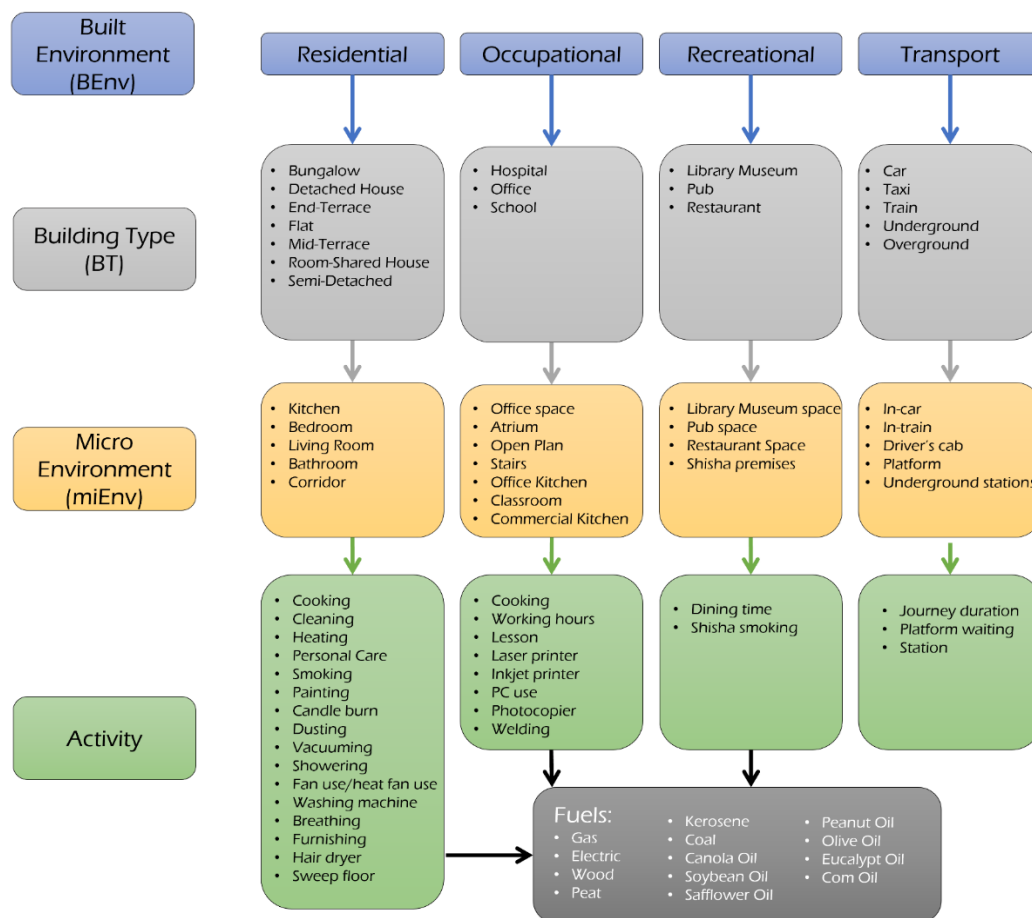
Figure 1 Macro and micro categories of division of data in the IAQ-EMS indoor pollution inventory reflected in the InAPI tool. In Blue the four largest areas of division of the data (namely Built Environments). In Grey and Yellow the first and second level of subdivision of the environments across the four Built Environments. In Green are reported the individual activity types for which measurements done in the UK are available and are visualisable in InAPI Tool. For some of these activities are also provided information about the fuel (Dark Grey).

3. Modules, options, and functions of the InAPI tool

The flowchart in Figure 2 summarises the main features of the InAPI. The tool is divided in two main areas, relating to (i) measurements of indoor pollutants and (ii) indoor emission rates by activity.

Both areas provide a consistent set of tools: A) a **dashboard** where information from the original IAQ-EMS indoor air pollutant database can be extrapolated in the form of a table filtering by pollutant, environment, and activity. B) a **visualisation** page where bar-chart graphs provide the user with a quantitative comparison of the activity-based measurements and/or emission rates.

A third area of the tool permits visualising emission rates obtained from chemical mass balance (hereafter, **cmb**) calculations and comparing them with emissions from literature (hereafter, **lit**). The emissions from cmb and lit are visible as hourly averaged emission rates by pollutant for individual or combined activities/environments (see sections 4.3 and 5.3 for additional information).

Particular focus is given to the Residential Built Environments. Hourly emissions have been grouped by pollutant and by activity to allow the user to visualise the total hourly emissions produced by one pollutant belonging to one or more activities occurring simultaneously. Alternatively, the user can visualise how many pollutants are emitted simultaneously during a single activity.
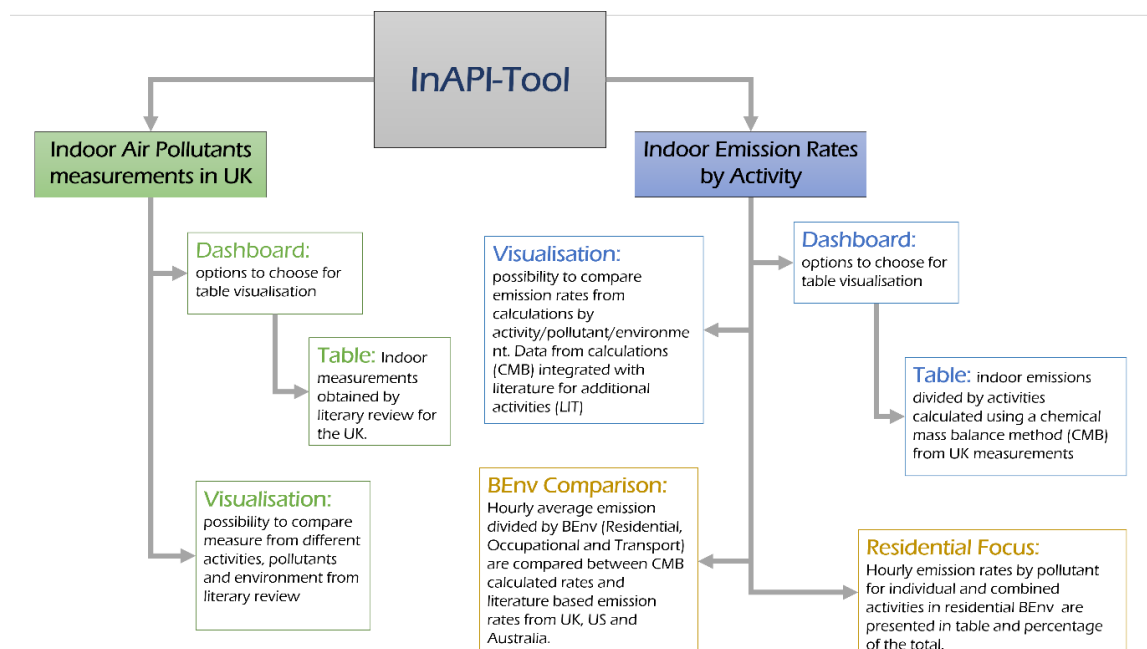

Figure 2: Flowchart showing the individual pages of the InAPI tool. The tool is divided into two main areas, measurements (green) and emissions (blue), both providing section for table numbers, dashboard of selection of a large range of parameters, visualisation and comparison of values. Emissions from literature (lit) and calculations (cmb) are also shown in a more detailed format in the BEnv Conmparison, and Residential Focus sections (yellow).

Within the InAPI tool, a number of parameters and acronyms are used with particular definitions. Information for each parameter/acronym used in the InAPI tool is provided in the table below.

Definition	Description
Built Environments (BEnv)	Indoor measurements and emissions have been divided within four main Built Environments. These are RESIDENTIAL - relative to private buildings of different type (see Building type), OCCUPATIONAL - that groups all working, commercial, educational, and service environments, RECREATIONAL - relative to public places of enjoyment and TRANSPORT - that group the available information about private and public transport vehicles.
Building type (BT)	Each B Env has been divided in a variable number of Building types representative of different dwellings for each BEnv I.e., BTs relative to the RESIDENTIAL BEnv are Flats, Bungalows, Houses (divided between rural houses, end- mid-terrace, detached and semi-detached). BTs relative to the OCCUPATIONAL BEnv are Office, School, Hospital. BTs represented in RECREATIONAL BEnv are pubs, restaurants and museums. Finally BTs for the TRANSPORT BEnv are taxis/car, trains/underground and buses.

Micro-Environment (miEnv)	For Particular BTs included in the RESIDENTIAL and OCCUPATIONAL BEnv the enclosed space where the activity has been monitored or the emissions have been calculated is provided. Micro-Environments for RESIDENTIAL MaEnv are Kitchen, Bathroom, Living Room and BedRoom, while for OCCUPATIONAL are Office Space, Shop Space, Classroom
Activity	Measures and emissions have been categorised based on human activities by pollutant, BEnv, BT and miEnv.
Micro-Activity	For particular activities has been possible to arrive to the level of detail of individual micro-activity. If a general activity is COOKING, this can be divided according to different type of micro-activities: roasting, frying, baking. If the activity is CLEANING different type of micro-activities can be: mopping, vacuuming, dusting etc.
Fuel Type	Some activities/micro-activities can be fuelled in different way. This is evident for the RESIDENTIAL and OCCUPATIONAL BEnv for what concern the COOKING and HEATING activities that can be fuelled by gas/electricity, peat/coal/wood
Sampling method	Indoor measurements have been obtained according to different techniques. The measures reported in the tool are divided by 4 macro categories of sampling: Active and Passive. Detailed information of sampling method used in individual works can be found in the table below in this page.
Ref.	For each individual number relative to measures/emissions the original reference where to find additional information is reported. More detailed information and the individual database used for the creation of the tool can be found in the database (Mazzeo et al., 2023)

4. How to use InAPI tool

In this section the individual areas of the InAPI tool will be presented to help the user to navigate the available options.

4.1 General options for measurements and emissions visualization

The InAPI tool is an excel based program, and it is based on an intuitive system point and click that allows the user to navigate through the different sections of the tools simply clicking on the individual rectangles in the menu on the left side of the screen.

Each section of the tool (with exception of Residential Focus, see section 4.3 and 5.3) use the same system to visualise and/or filter the data. The way to navigate this filtering option is the same between the different areas and will be explained in a general way.

Data are divided into groups shown in the coloured-mini windows, in green for measurements and in blue for emissions. Each window has on the top left the title that explain the type of data that can be selected by the user (e.g., Built Environment "**BEnv**" windows will provide the four main categories Residential, Occupational, Recreational and Transport). On the top right of each window there are two icons: one picturing a list of ticked elements, and another picturing a fennel (Figure 3, a). The first icon once clicked (activated) will allow the multiple selection or deselection of the items included in the window.

The second icon will activate a filter of the variables included into the window while the fennel will allow the multiple selection of more than one parameter included in the window. If the user wants to select one variable from each window, the only operation to do will be to select the

desired variable that will be highlighted with the colour of the window (green for measurements and blue for emissions) while all the others will become white (Figure 3, b). Once selected a variable, the fennel icon in the top right of each window will become coloured (Figure 3, b). Clicking on the coloured fennel the user will be able to reset the applied filter, and all the variable of the window will be again coloured.

Finally, when the icon picturing a list of ticked elements is selected, the simultaneous selection or deselection of more than one variable for each window will be allowed to the user (Figure 3, c). In this case more than one variable will be coloured in the window where the list of ticked elements icon will be activated and the multiple selection will be reflected in the corresponding table or bar chart.
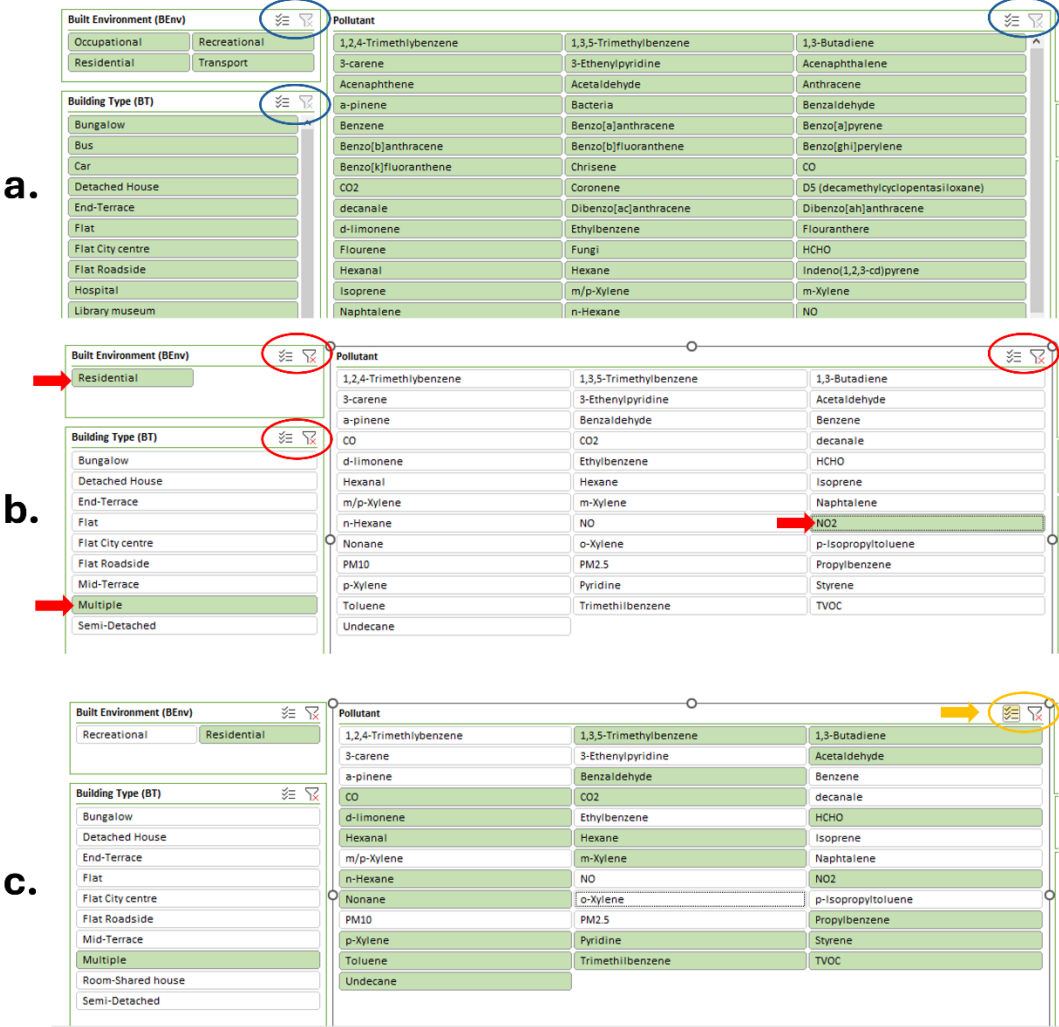

Figure 3: Screenshot of the measurement's dashboard of InAPI tool with filters button deactivated (in blue) and activated (in red). Once activated, the only options that are still coloured in the individual windows will be visualised in the table.

4.3 Options of Residential focus area

This section focusses on the most heterogeneous indoor environment, the **RESIDENTIAL** Built Environment (**BEnv**). This environment is the most highly variable one in terms of the number of pollutants, types of activities (taking place individually or in combination) and Building Types (**BT**).

The emission rates provided in this section have been calculated from the measurements made in the UK using the chemical mass balance method (**cmb**) and emission rates taken directly from the literature (**lit**). The latter include emissions calculated within the National Atmospheric Emission Inventory for the UK for 2020 (NAEI, 2021), and emission rates from the literature from other countries (US and Australia). Emissions are presented as hourly totals by pollutant for individual or combined activities/environments.

Hourly average emission rates calculated for individual pollutants have been summarised showing individual activities (Option A in the InAPI tool Residential Focus page) or the combination of the hourly emissions from different activities for the same pollutant (Option B in the InAPI tool Residential Focus page). The values can be visualised as a total of the emissions in one hour from one or more activities, individual hourly activity emissions and percentages of the total (Figure 4).
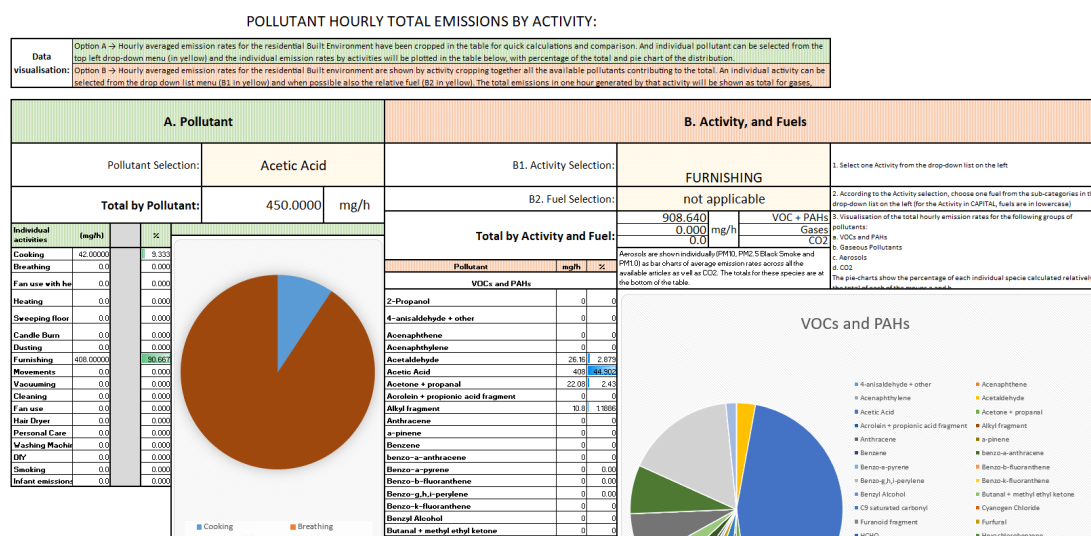

Figure 4: Snapshot of the Residential Focus dashboard of the InAPI tool. The dashboard has two main sections: A. selection of a chemical specie from the Pollutant Selection panel. The average hourly emissions of the selected pollutant across all the available activities will be shown as pie chart and as table of percentages. B. Here a particular activity and related fuel can be selected, and the dashboard will show all the chemical species contributing to it with the relative percentages.

In the Residential Focus area of the tool is available a different option for the selection of the variable. Both in section A (Pollutant) and in the section B (Activity, and Fuels) there is the possibility to open a drop-down menu in correspondence of the "Pollutant Selection", "Activity Selection" and "Fuel Selection" areas (Figure 5).

A list of possible species will appear from the section A and the user will be able to directly see the total amount of emissions in the rectangle below the drop-down menu area and the specific information by activity in mg/h and as percentage of the total in the columns below.

The same criteria are applied for section 2 where the user is asked to choose both the activity selection and fuel selection. The choice of fuels is allowed only for the following activities: COOKING and HEATING. For all the other activities in the section B2. Fuel Selection it will be necessary to select "not applicable" to visualise the results. Additionally, this section provides information for VOCs, Gases and Aerosols but not all these parameters are always available for all the species. For those combinations of selections for which data are unavailable the tool will show "#REF!".

Figure 5 Screenshot showing the drop-down menu icons in the section A and B of the Residential focus area of InAPI tool.

4.2 Built Environment emission rate comparison

Hourly averaged emission rates for three main Built Environments (Residential, Occupational and Transport) are summarised in this section of the InAPI tool. The information provided in this section allow the comparison between emission rates obtained from the chemical mass balance method (**cmb**) on UK measurements, and emission rates from literature, reports, and the national emission inventory (**lit**). The emissions are all expressed in mg/h for all species except for bioaerosols which are expressed in Colony-forming unit (CFU) per cubic metre (CFU/m^3). More detail on the three Built Environments is outlined below.

A. Residential: the user can choose from different types of Micro-environments and/or Building Types where a particular Activity takes place. Some Activities are divided according to micro-activities. This option permits to highlight an Activity (e.g., cooking) a particular micro-activity (e.g., frying bacon) and evaluate the individual contribution.

B. Occupational: in this section the user can choose from different occupational Micro-Environments (e.g., offices, schools, hospitals commercial kitchens etc.) and related Activities. The Activity of commercial cooking (Kitchen) is the only one providing information on different type of oils used for frying.

C. Transport: this section provides emissions rates related to four type of transport type (car, van, SUV and train) and allows to select different fuel types. For the case of cars and vans the user can choose between a number of car/van model and particular ventilation filter to visualise too. The information of this section is limited to aerosols (PM_{10}, $PM_{2.5}$, $PM_{1.0}$) and nitrogen dioxide (NO_2).

5. Examples of InAPI tool applications

In this section we outline how to use the individual sections of the inAPI tool incl. example applications. Specifically, we explore how to visualise the indoor measurements for a single

pollutant in a particular environment, how to compare two studies providing information for the same pollutant in the same environment and how to navigate the Residential Focus section.

5.1 Visualising indoor measurements and emissions

The present section shows how to visualise indoor measurements from the InAPI tool. The same approach can be used for the visualisation of the emissions.

a. On the left side menu, click on "Visualisation" under the section "Indoor Measurement". The page will display a graph at the top and nine windows where it is possible to select individual options (e.g., pollutant, environment, activity, reference etc.).

b. To start, deselect all the filters that could be applied to the individual nine windows. All the mini funnels in the top left corners of the windows should appear grey. If any display a red cross, it indicates that a filter is currently applied to that window. Click on the red flag to turn the mini funnel grey again (see Figure 5).
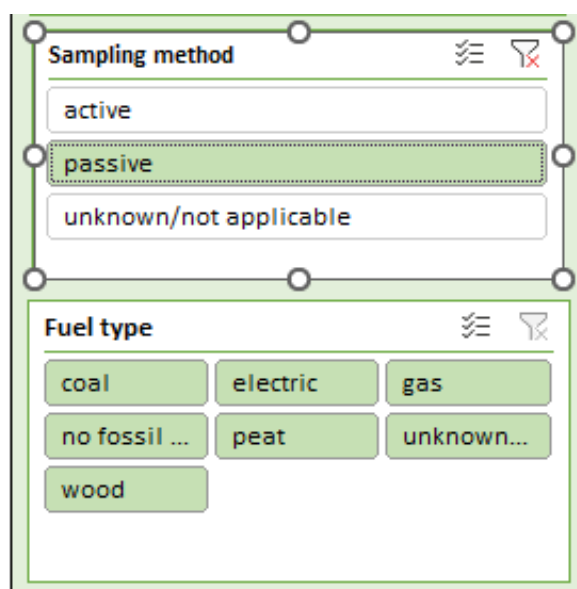

Figure 5: Example application of the filtering windows of sampling method (top) and fuel type (bottom) from the visualisation area of the InAPI tool. The sampling method filter is active, showing only passive sampling, while the fuel type filter is inactive, displaying all possible fuel types. The mini funnel with the red cross in the top right indicates the presence of an active filter in a particular window.

c. Once all the filters are deselected the user can choose the combination of information to visualise or select a specific filter to view all available options.

d. For instance, to visualise information regarding NO2 from cooking, select "NO2" in the "Pollutants" filter window, then choose "COOKING" from the "Activity" window, and finally select "KITCHEN" from the "Micro Environment" window. The tool will then display all relevant references, providing information on fuel type, sampling method, and the units used for visualising the results in a bar chart (see Figure 6).
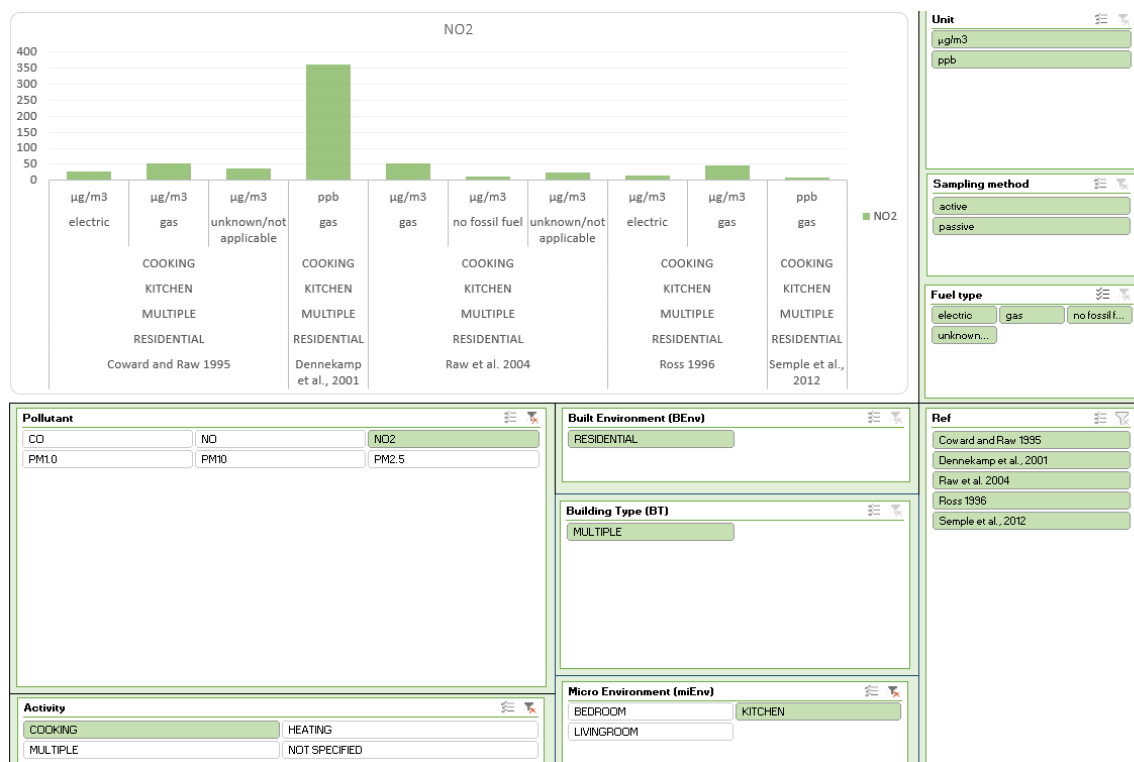
Figure 6: Example of visualisation of NO₂ from COOKING activity in KITCHEN environment.

5.2 Visualising reference papers

The individual articles used in the InAPI tool can be easily accessed from the "References" section in the left menu. Once in the References area, use the filter window at the top to select one or more references from the list. The information will then be displayed in the table below the filtering window (Figure 7). To select multiple filters, click on the icon to the left of the mini funnel at the top right of the filtering window before you start. This option allows you to select all the articles that interest you. The table that appears below the filtering window will provide information about the papers, including relevant DOI links to access them directly online (Figure 7).
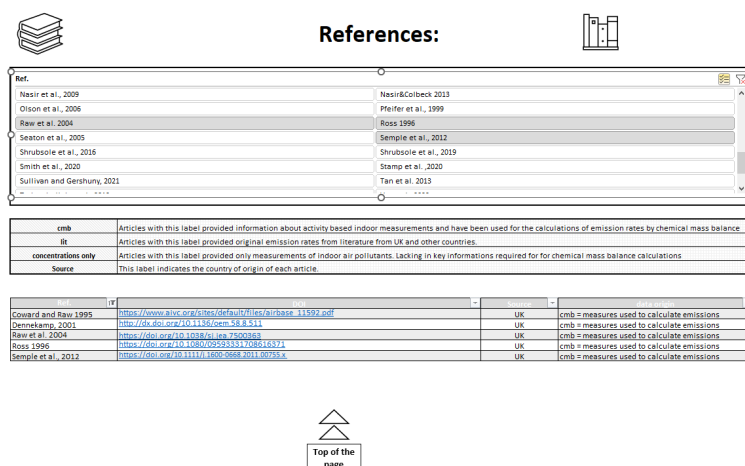

Figure 7: Illustration of the filtered selection for the articles obtained from the example in Figure 6.

5.3 Visualising residential focus information

The residential environment is the one that provides detailed information about the emissions calculated within the InAPI tool. In this section, we will outline how to visualize all available emissions by pollutants, as well as how to view emissions by activity and fuel for all available pollutants.

By navigating through the page, it is possible to select the total hourly emissions by activity for an individual pollutant. The section offers two options:

Option A → A table displaying hourly averaged emission rates for the residential built environment is provided to facilitate quick comparisons and calculations. Users can select specific pollutants using the drop-down menu in the top left corner (marked in light yellow). Once selected, the table below will show the emission rates associated with different activities, including their percentage contribution to the total and a pie chart visualizing the distribution.

For example, in the "Pollutant Selection" area (highlighted in light yellow), find the drop-down menu and select "Acetic Acid". By scrolling through the list on the left, you will find individual activities for which information about Acetic Acid is available, expressed in mg/h and as a percentage of the total. The pie chart on the right provides a graphical representation of these percentages.

Option B → Hourly averaged emission rates within the residential built environment are presented by activity, combining all relevant pollutants that contribute to the overall total. Users can select a specific activity from the drop-down menu in the top right corner (highlighted in light yellow), and, where applicable, choose the associated fuel type (also highlighted). The resulting display will show the total emissions produced by that activity over the course of one hour, including values for gases, CO_2, and the combined total of VOCs and PAHs. Detailed emission rates for individual compounds—including aerosols—are listed in the table below, accompanied by both pie and bar charts (see Figure 4).

For example, in the "Activity Selection" area (highlighted in light yellow), find the drop-down menu and select "FURNISHING." In the "Fuel Selection" area (highlighted in light yellow), choose "not applicable," as there is no fuel involved in this activity. The total by activity will be displayed below in three categories: VOCs and PAHs, gases (NO, NO_2, NH_3, SO_2, and CO), and aerosols (PM_{10}, $PM_{2.5}$, $PM_{1.0}$, and Black Carbon). The list on the left and the pie/bar charts on the right will summarize the selected information.

5.4 Visualising Build env. Comparison

In this section the InAPI tool allows the user to investigate three particular Build Environments (Residential, Occupational and Transport) in more detail. The area of the tool is organised in three sections, one per **Benv**. In each of these sections the user can choose through the filter windows between a range of variables:

1. Pollutants
2. Micro-activities
3. Fuel Types
4. Building types
5. Data origin (literature or calculated by chemical mass balance)
6. Micro-environments

7. Literature references

To visualise the variables in the correct way it is important to choose the variables according to the order provided in each section and numbered from 1 to 3. Due to the limited availability of data in certain cases not all the combination of filters are always allowed and generate results.

Example of visualisation:

a. From the residential section of the **Benv** Comparison select the activity "COOKING"
b. From the Micro-activity section select "Frying"
c. From the fuel Type area select "gas"

Arrived at this point the tool will provide a filtered selection of emissions all from literature (in the section data origin will appear only the option "li"), from multiple environments (in the section Building Type will appear only the option "MULTIPLE") and from KITCHEN micro-environments. In the window 3 will appear only the the available pollutants for which this subset of data is present in the tool: PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ with the relative reference papers from where these values have been taken (Figure 8).
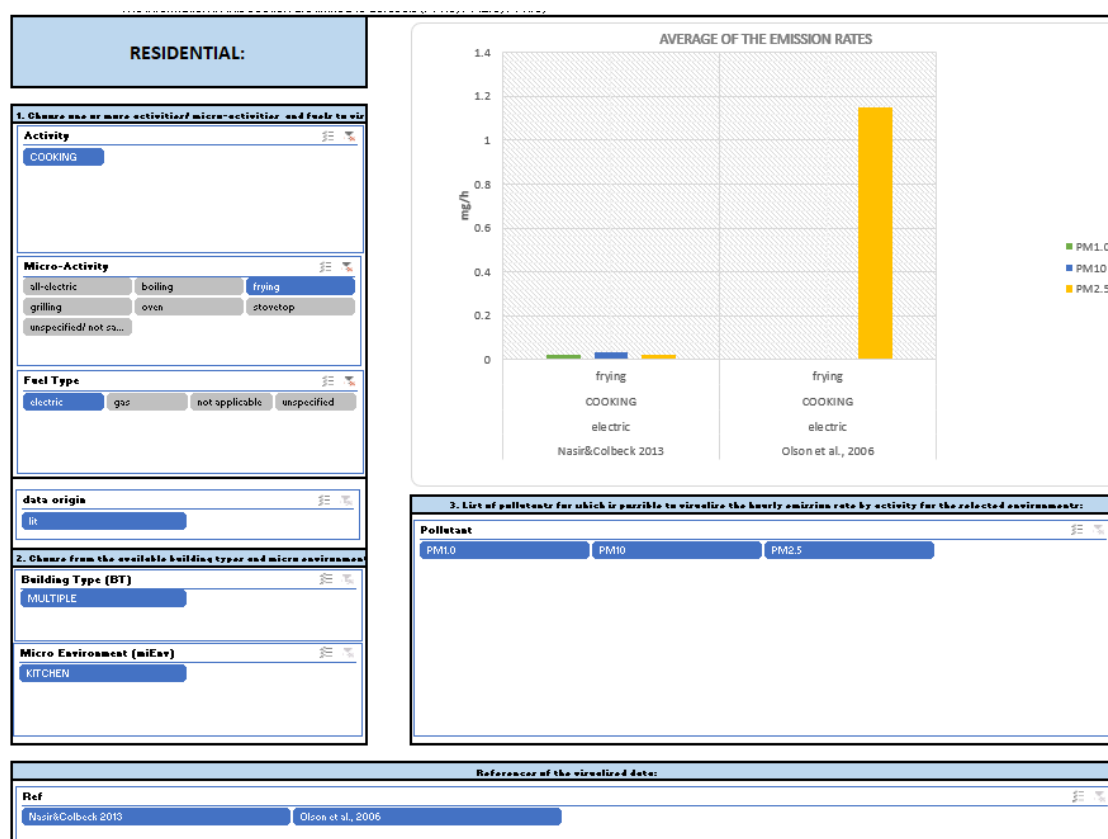

Figure 8: Screenshot of the Benv comparison visualisation obtained from the example showed in section 5.4

5.5 Caveats in the visualisation options

The InAPI tool has been developed based on the currently available information on indoor measurements and emissions published in peer-reviewed literature. Additionally, in some cases, measurements obtained from literature have been converted into emission rates using the Chemical Mass Balance method (see Section 2.2 of the original manuscript for more details). Despite this, there are still gaps and a lack of information on indoor air pollution research and

therefore not all the possible options in the different areas of the tool are currently active. Some pollutants/activities/environments are not included in this version of the InAPI tool.

6. References

Mazzeo, A., Nasir, Z. A., & Pfrang, C. (2023). *Indoor Air Quality Emissions & Modelling System (IAQ-EMS) - Indoor Air pollutants database* (https://doi.org/https://doi.org/10.5281/zenodo.15630355

NAEI, N. A. E. I. (2021). *National Atmospheric Emission Inventory for UK*. Retrieved May 2021 from https://naei.beis.gov.uk/