InventAir: Methodological framework for mapping energy poverty and assessing its climate impacts

InventAir project

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Consortium

Co-financed by:

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1. Welcome to InventAir

Although energy poverty theme is rapidly spreading over EU, it has distinct specificities in Eastern European Countries (EEC): low-income households cannot afford to change the old inefficient heating equipment or replace the poor quality heating fuels. Thus, they become primary cause for dramatic seasonal increase in air pollution in their communities. The lack of precise data on the quantities and quality of the fuels used makes estimation of environmental, climate and health impacts difficult.

The link between energy poverty and poor air quality has not gained EU-wide recognition by the current policies and measures: in the EEC existing energy efficiency programmes and schemes aimed at alleviating energy poverty allocate grants that allow vulnerable households to directly purchase and utilize humid wood and low-quality coal and burn them in highly inefficient stoves. Major obstacle to utilising these grants in an economically viable and environmentally and climate friendly way is the lack of comprehensive energy poverty criteria and indicators that would facilitate the proper identification and precise segmentation of energy poor households.

The undesired and negative effect of the low deployment of new and efficient heating technologies is the households' continuous use of inefficient heating equipment that produces excessive polluting emissions which threaten and deteriorate the population's health. It is necessary to carefully assess different woodstove changeout options towards cleaner heating for energy poor households that will both reduce air pollution and supress the GHG pollutants increase. Major obstacles are the lack of coherent methodology to identify and make an inventory of the energy poor households, variety of facultative fuel-to-energy conversion methodologies and country-specific emissions factors. These are the basis for poor sustainable energy planning on local and national level which hinders the rapid reduction of the polluting emissions and reaching the EU-wide targets for low-carbon development.

The current document "InventAir: Methodological framework for mapping energy poverty and assessing its climate impacts" has been inspired by the specific demand to address the cross-cutting issue of poor heating practices and increased air pollution in urban and rural areas in the EEC. Its major aim is to support the local policy makers in exploring the multiple environmental and climate impacts of energy poverty by focusing on the development and implementation of joint clean air and energy poverty policies. It has been primarily developed for energy and environmental experts, social experts, decision- and policy- makers, local authorities, national authorities and institutions.

Co-created by EEC and German experts, the InventAir methodology supports the process of developing joint local, national and EU policies and actions for tackling energy poverty and air pollution by bringing forwards and raising the public awareness on the link between the inefficient heating practices among energy poor households and the rapid air pollution in their communities. It facilitates the long-term planning of woodstove changeout programmes to boost the sustainable, resilient and low-carbon development for the local communities.

2. The Eastern European countries target region

The InventAir project targets the Eastern European countries as regions in energy and social transition that undergo significant structural changes to align them with the overall EU28 targets and objectives. Despite their constant efforts, statistics shows they are hot spots of energy poverty and poor air quality, a theme that is less recognised on EU level, yet strongly affecting the local communities.

Photo 1 Eastern European Countries region addressed by the InventAir project

There are number of major differences in the energy, environmental and social aspects in those EEC that underlie the challenges they experience. These communities have a long history of old building stock, old and inefficient heating systems, traditional use of wood and coal, and evolving social support systems. The joint design and enforcement of policies to alleviate energy poverty and air quality may be highly beneficial for the sustainable, resilient and low-carbon development of these communities.

Energy demand

In 2015, the Eastern European Countries have higher shares of energy consumption in the residential sector (28%) compared to the other European countries (22%) and most of them are above the EU average (25%). Even though the statistics covers the energy demands for all domestic activities, usually the share for heating and/or cooling is the greatest.

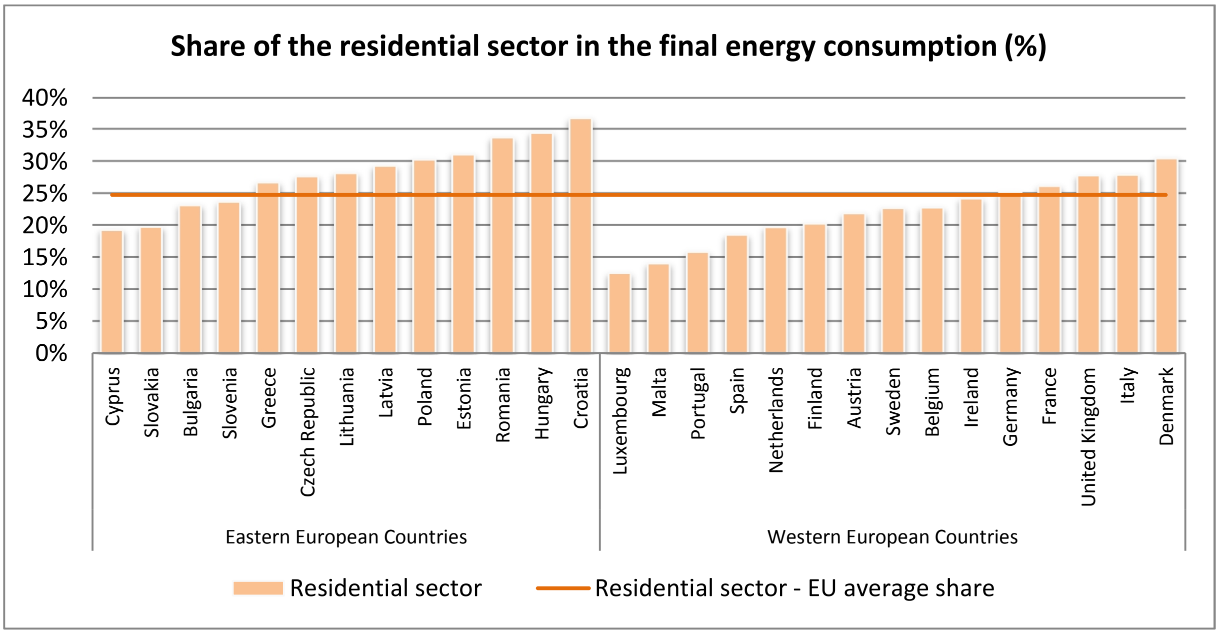

Figure 1 Share of the residential sector in the final energy consumption (Modified from: EU Energy in figures 2017)

The Eastern European countries have a higher demand for residential space heating as estimated by the Odyssee-Mure project (2012) – the EU average is 525.136 (MJ/m2) whereas the EEC average is 586.232 (MJ/m2); the average of the other MS is below the EU average – 506.666 (MJ/m2).

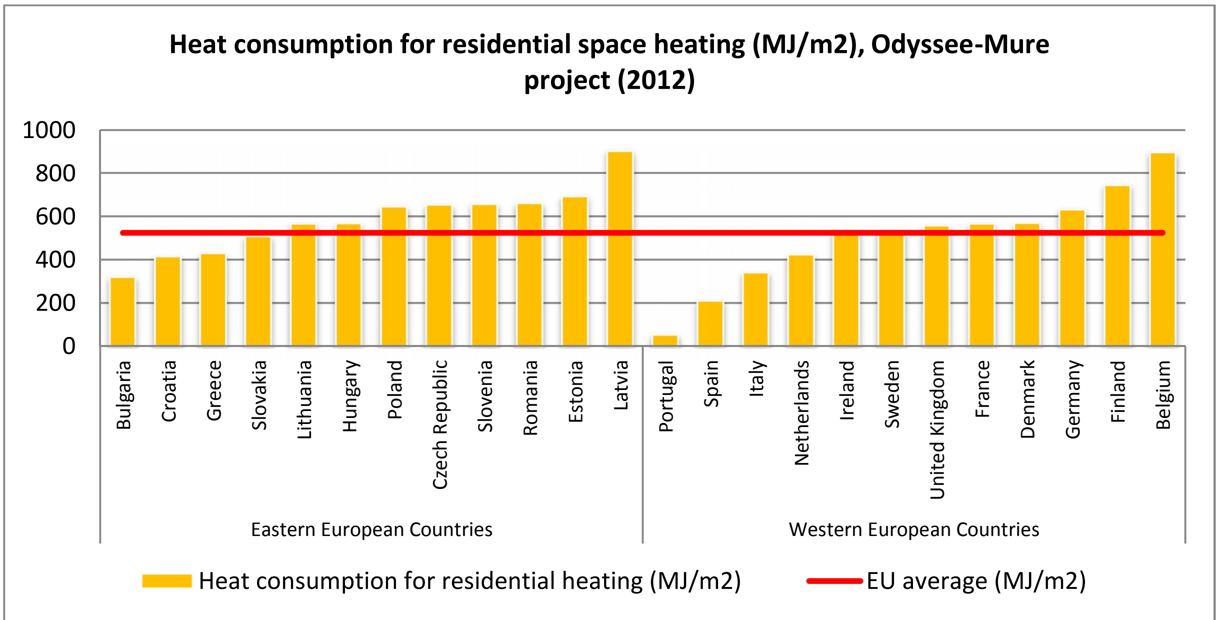

Figure 2 Heat consumption for residential space heating (MJ/m2), Odyssee-Mure project (2012), modified from EMEP/EEA air pollutant emission inventory guidebook 2016

In 2015, the shares of solid fuels and biomass and renewable wastes of the Eastern European Countries is higher than this of the other European member states – the average share for solid fuels is 5% compared to 3% and EU average 4% and the average share for the biomass and renewable wastes is 13% compared to 7% and EU average 10%. Even though statistics is general for all types of solid fuels and biomass and renewable wastes, it is clear that there are significant differences between the member states.

According to the statistics provided by EMEP/EEA air pollutant emission inventory guidebook 2016 (based on Denier van der Gon et al., 2015), the average consumption of wood per capita for the Eastern European member states is around 6.61 GJ and that for the non-member states is 5.14 GJ, whereas the wood consumption in the Western European member states is 4.09 GJ.

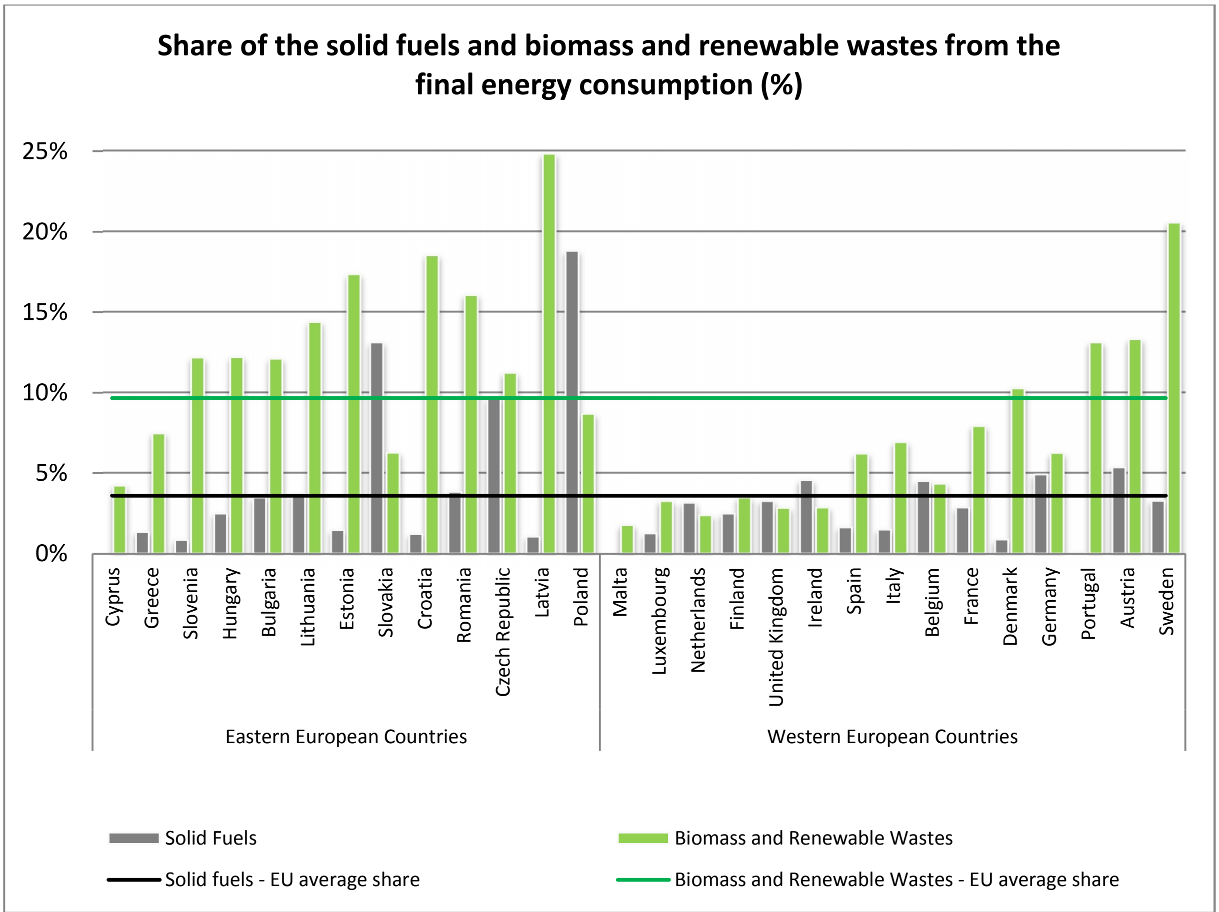

Figure 3 Share of the solid fuels and biomass and renewable wastes from the final energy consumption (Modified from EU Energy in figures 2017)

The deployment of old and inefficient stoves in the Eastern European countries is rather high (Figure 4). The use of heating stoves and boilers is typical for the areas that are not supplied with another infrastructure (central heating, gas infrastructure), have easy access to wood and coal, and are socially segregate. There is a long-standing tradition in these communities to use wood and coal for heating and households have been using the same heating device for many years back. Thus, even though regulations on the quality of the stoves are enforced, they will be applied to the newly produced equipment and the old stoves will not be affected; also, the penetration of the eco-labelled stoves would be slow due to the persistent use of the old stoves and the inability of energy poor households to invest in woodstove change.

Based on estimations by IIASA GAINS model for EMEP/EEA air pollutant emission inventory guidebook 2016, the share of stoves across the EU is the most significant one – 59% in the Eastern European and 49% in the Western European member states; the rate of stoves in the Eastern European countries that are not member states is much higher - 92%. The difference though is related to the types and certification of stoves – most of the stoves in Eastern Europe are old and not certified and thus no technical or emission specifications may be applicable.

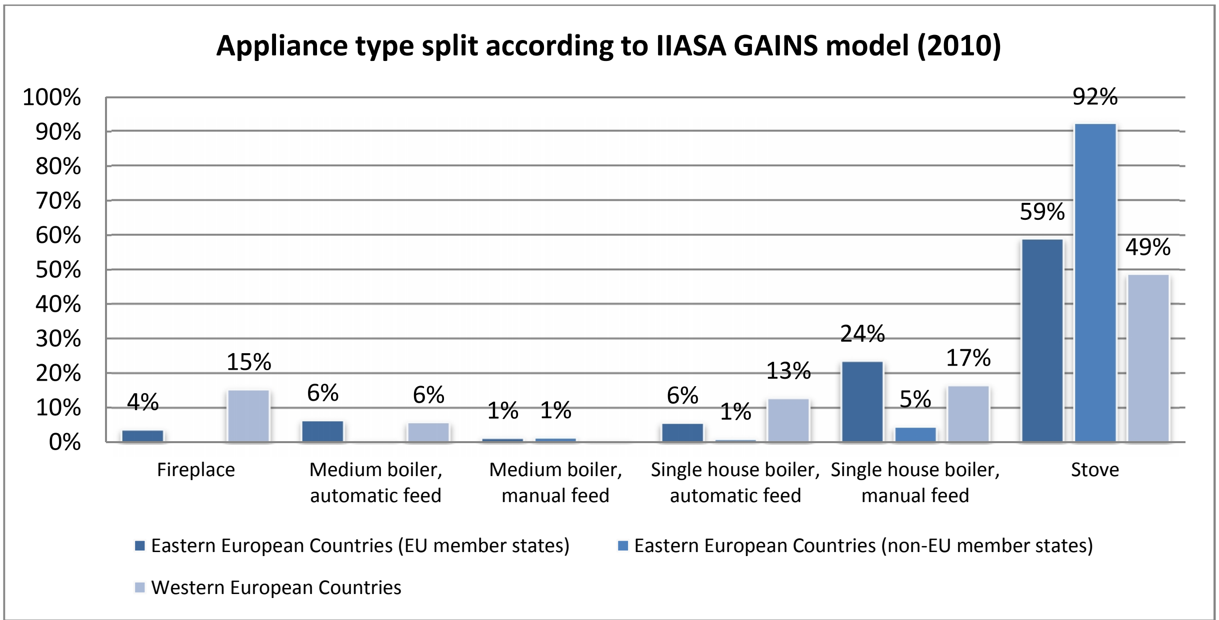

Figure 4 Average use of heating appliances (Modified from EMEP/EEA air pollutant emission inventory guidebook 2016)

Energy poverty

Energy poverty is a widespread problem across Europe, as between 50 and 125 million people are unable to afford proper indoor thermal comfort. A common European definition does not exist, but many Member States (MS) acknowledge the scale of this socio-economic situation and its negative impact translated into severe health issues and social isolation. Different terms are used to describe affected persons: fuel poor, energy poor, vulnerable energy consumers or, to a larger sense, at-risk-of-poverty or low-income people.

Energy poverty can be correlated with low household income, high energy costs and energy inefficient homes and can be tackled by income increase, fuel prices regulation and energy efficiency improvements in buildings.

Even though there are no energy poverty definitions across the EU and only segregated indicators and criteria may be applied, the most relevant aspect for the Eastern European countries is the ability to keep home adequately warm. The statistics provided by the EU Energy poverty observatory suggests that Eastern European households struggle with that.

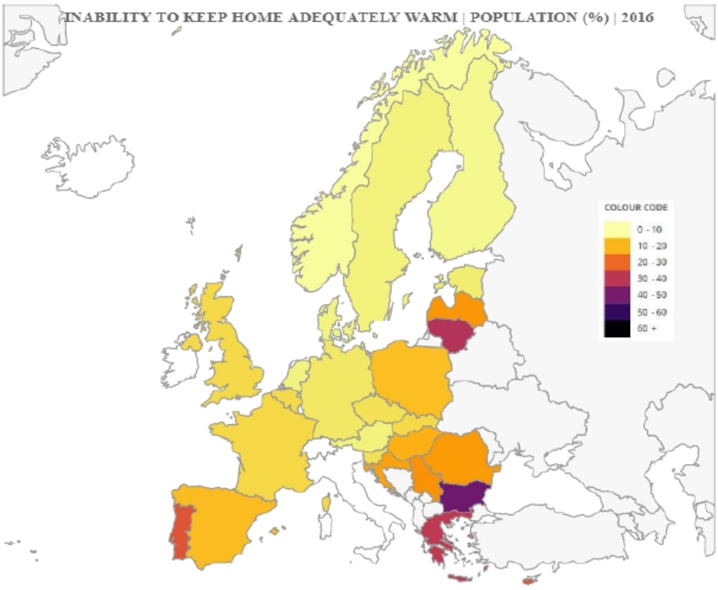

Figure 5 Inability to keep home warm (Source: Thomson and Bouzarovski, 2018)

The housing stock in EEC is in relatively poor state as compared to the rest of Europe. Poor construction materials, poor insulation and poor maintenance contribute to the inadequate state and high inefficiency of many dwellings. This, combined with the old, inefficient and poorly maintained heating systems and domestic appliances, contributes to the bigger depth of the energy poverty in EEC as compared to the Western Europe.

In EEC countries there is very limited social or other support for energy poor households, as compared to the rest of EU. While some minor positive cases appear (e.g. 100% subsidy for insulation of energy poor households in Slovenia), these cases are almost negligible in comparison with the support programs that exist in Germany or the UK. Unlike in other parts of EU, some of the currently existing funding programs for abating energy poverty in EEC function in a way that majority of funds are granted for the direct purchase and utilization of low-quality coal and briquettes with high humidity content burned in inefficient heaters. The undesired and negative effect of existing assistance mechanisms is the excessive pollution with PM10 produced from household heating which threatens and deteriorates the population's health.

In EEC, no clear division between social housing and non-social housing buildings or areas can be detected. This means that measures for eradicating energy poverty cannot be targeted to specific areas or neighbourhoods, which complicates both the identification of the most vulnerable areas and the actions that need to be taken.

Photo 2 Typical mountainous rural stove use for heating and cooking (Credits: EAP)

Citizens of EEC had to make a switch from subsidized energy prices to market based prices, which resulted in continuous and significant increase in energy bills. Behaviour and habits of the people, arising from subsidized energy prices, represent a significant barrier to abating energy poverty in EEC. Whereas in some Western European countries it makes sense to shape measures for stimulating landlords to invest in increasing the energy efficiency of their building stock, this makes poor or no sense in EEC. Namely, the EEC have a significantly higher share of home ownership than in rest of Europe. While landlords might have funds to invest in improvement, this is not the case with the poorer owners of their flats; hence different approaches must be taken, such as providing subsidies for energy efficiency of the energy poor households.

Last, but not the least, in EEC households can benefit from installation of 'low-tech' devices, such as draft proofing or efficient light bulbs, while this is often not the case in Western European countries (e.g. in Germany double glazing is a standard, so installed devices tended to be 'high-tech', for example wireless switchers).

Air Quality

The constant monitoring of the air quality stations across the EU has been indicating heavy PM10 and PM2.5 pollution in the Eastern European countries along with Northern Italy. The major source of particulate matter pollution is the heating in public, residential and commercial buildings.

While particulate matter levels have fallen in western European countries, no significant changes are observed in Eastern Europe (Belis et al., 2016). Exceedances of the PM10 and PM2.5 values are detected in all EEC where small combustions installation are predominant and contribute to the pollution with 20-25%. Moreover, the seasonal use of the old, inefficient stoves contributes to the overall air pollution, because during the winter the dispersion of the particles is supressed and they tend to stay above their origin source locations.

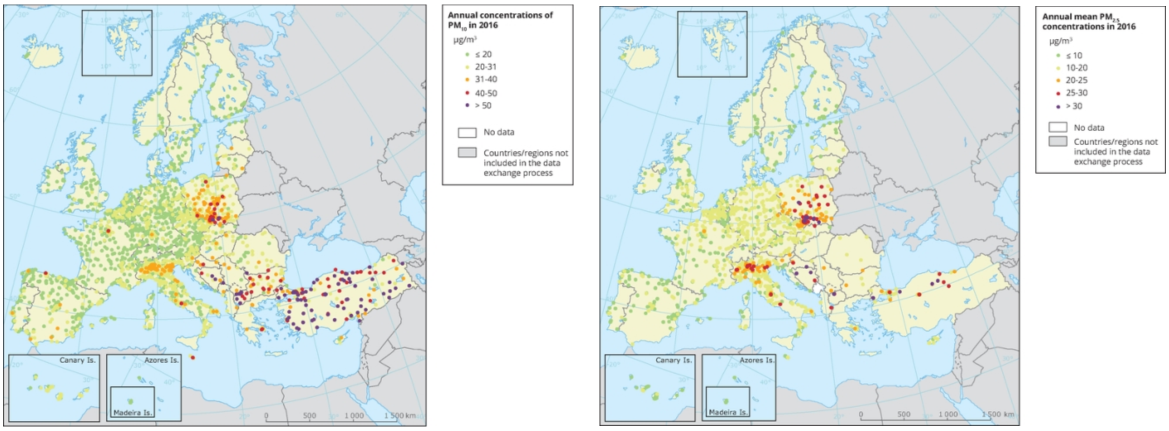

Figure 6 Annual concentrations of PM2.5 and PM10 in 2016

The annual concentration for the PM10 (2016) values across the border between Poland and the Czech Republic is around 31-40 µg/m3 and across the Western Balkans is above 50 µg/m3; for Bulgaria, data shows concentrations around 40-50 µg/m3. Thus, annual concentrations for PM10 in the targeted region proves to be higher than suggested by the EU and WHO regulations and immediate actions to alleviate it are needed. The annual PM10 threshold under the Air Quality Directive is 40 µg/m3.

The annual concentration for the PM2.5 (2016) is observed to be above the 30 µg/m3 for the border region between Poland and the Czech Republic and the Western Balkans. The annual PM2.5 threshold under the Air Quality Directive is 25 µg/m3 and thus these regions have significantly higher concentrations than allowed by the legislation.

Very high levels of particulate matter were observed in recent years in most of the Western Balkans areas where this parameter is monitored. Bosnia and Herzegovina, Macedonia and Montenegro are those with the highest exposure levels (Belis et al., 2017). From the EU member states, Bulgaria has excessive PM2.5 values, together with Poland, Slovakia and Hungary. Only Estonia, Latvia, and Lithuania have annual means of PM2.5 below the EU average.

Photo 3 A-B Wood stored for the winter in the city of Smolyan, Bulgaria (Credits: EAP)

The air pollution with particulate matter in the urban and rural areas in the EEC is predominantly caused by residential burning. The estimation of the impact of wood and coal used for domestic heating is difficult due to lack of comprehensive data. The emission inventories on national level poorly represent the amounts of wood and coal used for domestic heating and such inventories on local level are difficult to obtain, structure and keep up-to-date. The data collection and procession for wood and coal are a challenge for a few reasons:

- wood and coal data needs to cover amounts as well as other specific features – humidity for wood and calorific value for coal; these are tightly specific, and crucial for calculation of emission factors;
- data needs to be collected bottom-up, i.e. from the households or the retailers; the households may know the quantities they use, but cannot know the humidity or calorific value, whereas the retailers may speculate on the specific features of the wood and coal sold, but will have difficulty determining the quantities per household used; also, energy poor households may use other materials to burn as well – oil, cloth, paper, etc. that additionally contribute to the air pollution;
- data on the stoves used in the households needs to be collected bottom-up, i.e. from the households in the area. Data from stove producers may not be complete or reflecting the situation in the area observed. Also, old stoves do not have any technical specifications, so their efficiency needs to be empirically inspected.

Even though biomass and wood use are important renewable sources in the final energy mix of the EU, their promotion should be careful. According to Eurostat reports[1] that over 90% of the total roundwood production in Slovakia is fuelwood, in Greece (2014) over half of the roundwood is fuelwood, and for Hungary, Bulgaria, Croatia, Romania and Estonia the share of fuelwood varied between 32 % and 47 % of the roundwood production. The utilisation of this fuelwood in old and inefficient stoves contributes to the air pollution in the respective communities which peak in the winter season.

2.1. Interconnections between poor heating and air pollution in the EEC

Keeping a home warm or cool, lighting and the energy to power appliances are crucial foundations of a decent standard of living and human health. As 65% of the total energy used by European households is required for heating, heat supply is the main field of action when tackling the issue of Energy poverty. The problem is particularly relevant in Eastern European countries: due to the liberalization of the energy markets, many households moved from a situation with subsidized energy into a situation with (higher) market based energy prices.

Policies and measures in the field of energy poverty need to consider the multidimensional nature of the problem: solving energy poverty issue contributes to decrease in general poverty, improvement of health, energy security and contributes to fighting climate change by decreasing climate-damaging pollutants.

Climate and energy aspects

- Housing stock is often in a bad state (due to construction materials, inadequate insulation and poor maintenance) with poor building efficiency.
- Use of old, inefficient and poorly maintained heating systems.
- Use of low-quality fuel (wood, coal and briquettes; e.g. with high humidity or sulfur content) or even waste burning. State support is often granted for the direct purchase of these low quality fuels.
- Residential burning leads to substantial emissions of short-lived climate pollutants (SLCPs). Especially black carbon – as part of particulate matter – contributes to global warming.

Social and economic aspects

- Affects low income-households (retired people, unemployed or poorly paid, dependent on social benefits and single parent households) which are often socially isolated.
- Energy poor people cannot afford to change heating systems and suffer from high energy prices. The latter leads to the use of cheaper, low-quality fuels.
- Households often do not know how to use energy in a sensible way. They are often not informed about pollution levels and related health impacts.
- Social welfare systems often not provide enough support and social worker have not sufficient capacities to address the problem of energy poverty.
- Lack of trust towards energy suppliers (district heating).

Health aspects

- Persons affected by EP often live in poor conditions, including mold, moisture, and dust due to poor heating options and practices.
- They tend to be subject to physical (e.g. respiratory and cardiac illnesses) as well as mental health risks (i.e. due to low temperatures and stress associated with unaffordable energy bills).
- Increased (premature) mortality and morbidity due to exposure to high indoor and outdoor concentrations of particulate matter ($PM_{2.5}$) and other health-damaging pollutants such as beno(a)pyrene. These effects are even more dramatic for vulnerable groups such as elderly or disabled persons.

Energy poverty and poor air quality are both long standing issues in the EEC, but have yet not gained sufficient EU-wide recognition. Unfortunately, the multidimensional nature is often neglected in the political perception of energy poverty – especially the link between EP and air quality is not considered by the current policies and measures. As a result, policies for energy, environment and climate issues are not integrated in most cases. In addition, there is a lack of ambitious targets for energy efficiency and reduction of climate and air pollutants.

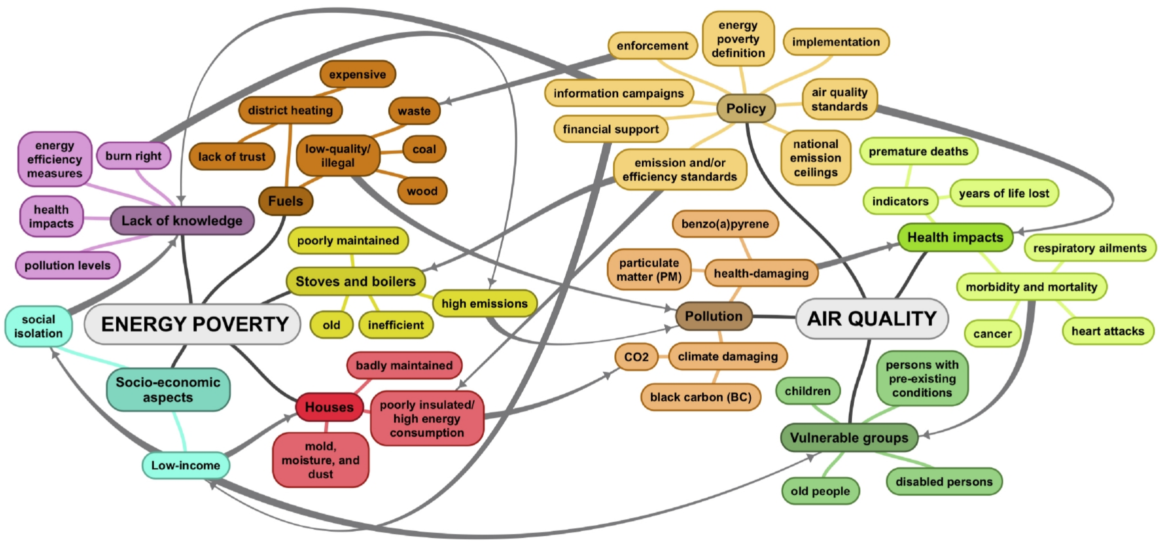

Figure 7 Interconnections of energy poverty and air pollution

2.2. Cross-cutting challenges in the EEC

As shown in the mind-map, there are numerous synergies between energy poverty and air quality. Thus, it is crucial to look at the central issues in the EEC and identify the gaps to policies and regulations in forerunners such as Germany (and other European countries). In the following section, main problems in many EEC and good examples in the relevant area are depicted:

Table 1 Challenges in the EEC and positive German experience

	Challenges in the EEC	Positive German experience
Emission and efficiency standards	Lack or weak emission and efficiency standards for stoves and boilers.	In Germany, there are already emission limits (PM, CO) for new stoves and boilers that are at least on a par with the upcoming eco-design standards for these appliances. Old stoves and boilers that does not meet the limit values for old appliances (installed before 2010) have to be shut down or retrofitted with a filter. In addition, the national legislation also includes provisions for minimum efficiency of appliances. While stoves only have to meet the requirements in the type approval, boilers are subject to recurring measurements on site, which are done by the chimney sweeps.
Fuel standards/restrictions	There are no or weak standards for solid fuels used in residential burning.	In Germany, only specific fuels are allowed to be used in appliances. Both in Germany and Slovenia, it is only allowed to use firewood with a maximum humidity of 25% (fuel storage is regularly checked in the course of the fireplace inspection by the chimney sweeps). While coal use is still possible in Germany (with specific fuel requirements such as sulfur content), coal burning is completely forbidden in households in Slovenia. Pellets and woodchips in Germany are subject to certification schemes (ENplus, Blue Angel).
Enforcement on site/role of chimney sweeps	Lack of registration, monitoring and maintenance of residential burning appliances. Weak enforcement of legislation and insufficient competences/ measures to address illegal burning.	Before putting into operation, all appliances have to be checked and registered by a chimney sweep in Germany. They also investigate the appliance at least two times in seven years (in addition to regular visits for maintenance/usually once a year). The duties and the role of chimney sweeps is defined by law (SchfHwG). Enforcement is done by local authorities/public order offices and chimney sweeps together. Fines for illegal burning are high (up to 50.000€) but rarely executed in Germany (because proof of illegal burning is often difficult in reality). In the Switzerland, chimney sweeps conduct a large number of ash tests based on x-ray fluorescence to prove illegal burning (about 3000 tests annually). In Poland, authorities monitor illegal burning with measuring devices mounted on drones.
Local policies	There is lack of concrete, obligatory measures with regard to energy and air quality planning (and residential burning in particular); no strict deadlines and sanctions if target values are not reached within the period set.	Temporary ban for specific appliances in Stuttgart (Germany)/Graz (Austria); permanent bans for solid fuels in Krakow (Poland)/Berlin (Germany; only solid fuel boilers in new construction plans in the city centre); minimum requirements for wood burning appliances based on labelling (France/Flamme verte and Lombardy region in Italy). Quicker replacement or shutdown of old appliances (as foreseen on national level) and/or stricter emission limits for old stoves in several German cities like Munich/Aachen. Information and alerts about high exceedances of PM concentrations in several European cities (e.g. Paris, Stuttgart).

Funding for renewables/building efficiency	Weak requirements for building efficiency; not sufficient funding for heating systems with very few emissions.	Comparatively strict efficiency standards for new homes in Germany. The market incentive program (MAP) provides funding for solar/geo-thermal heat as well as biomass appliances (pellet, wood chip or logwood boilers as well as specific pellet stoves). Besides, the program includes extra financial support for particle separators.

Apart from these legislative gaps, there are further challenges that are strongly connected to energy poverty and air quality. The following table includes potential solution approaches that were discussed with experts from Germany and Eastern European countries.

Table 2 Further challenges in EEC and solution approaches

	Challenges in the EEC	**Solution approaches**
Knowledge	Lack of knowledge with regard to energy efficiency measures, health impacts, pollution levels and how to operate appliances properly.	• "Burn Right" campaigns that are combined with (low-level) energy consulting and awareness raising. • Educational campaigns for low-income households are needed (incl. schools and presence at public spaces, in TV and Social Media)
Socio-economic aspects	High poverty rate and social inequality/isolation; current social programmes to reduce energy poverty are not effective.	• Subsidies/financial schemes for energy poor households, based on holistic approach (i.a. building efficiency) and economic assessment of viable heating exchange options. • Costs for fuel and maintenance should also be eligible across financial programmes.
Data	Lack of reliable data that is needed to draft measures and to evaluate them (e.g. on energy use/definition and monitoring of energy poverty). Insufficient data on emissions, air quality and health impacts.	• More monitoring stations and PM measurements (indoor/outdoor) on site. • Real-life emission factors by investigating and monitoring of real-life burning practices in energy poor households and their change.
Additional issues	No functioning energy market; heating with electricity and waste burning. Insufficient European legislation.	• Long-term strategy for decentralized energy supply. • Affordable waste disposal system and financial incentives to give residue wood/garden waste a value; effective structures to control and issue sanctions in case of waste burning. • Best practices on implementation of European legislation and adoption of WHO recommendations for air quality in the EU in the medium term.

3. Multiple impact assessment of energy poverty and air quality

3.1. Interaction between energy poverty and air quality

The InventAir project puts a strong focus on the interaction and synergies between energy poverty and air quality and investigates not only the links, but also the impacts between them. As already simply explained, households in the Eastern European countries that do not have access to sustainable energy, live in poor housing conditions, and suffer social segregation should be considered at high risk of energy poverty. The specific aspect of such households in the addressed regions is that they quite often use wood and coal for heating thus becoming a primary cause for dramatic seasonal increase in the air pollution. The lack of policies to address adequately the energy poverty issues along with weak control over the fuels and heating devices is detrimental to the overall energy, climate and environmental status of these communities.

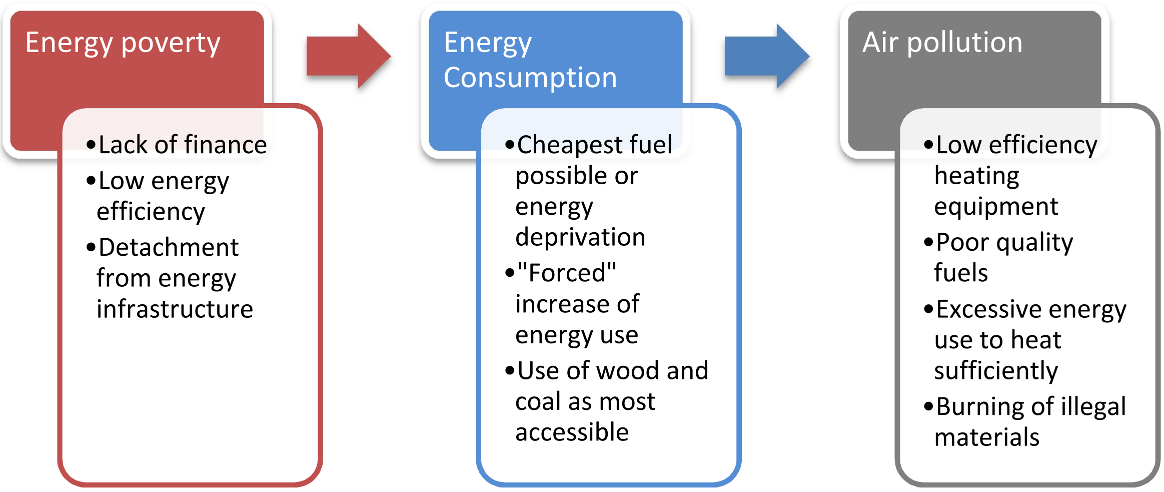

Figure 8 Resonating challenges of energy poverty, energy consumption and air pollution

3.2. Multiple approach assessment

The project promotes a "multiple impacts" assessment method that pays attention to an array of aspects – financial and energy savings, saved emissions, increased comfort, reduced morbidity and mortality, etc. There are a number of specific approaches to multiple impact assessment – for example, multi-criteria analysis (MCA), life-cycle assessment (LCA), cost-benefit analysis (CBA), etc., that could be used separately or combined. They have different features and specifics and sometimes choosing between which approach to undertake is a difficult task. Still, most of them follow a structure containing a segregate estimation of different impacts and then aggregating the end results in a single evaluation statement.

The InventAir methodology is mostly based on the multi-criteria approach as the most flexible one. It is useful for evaluation of non-market benefits and does not provide monetisation. It could be built upon quantitative statistical data or qualitative data (interviews, opinions, etc.). The multi-criteria approach is based on a flexible step-by-step structure (modified from Dodgson, Spackman, Pearman, & Phillips, 2009 in Literature review on Multiple Impact quantification methodologies, COMBI project, 2015):

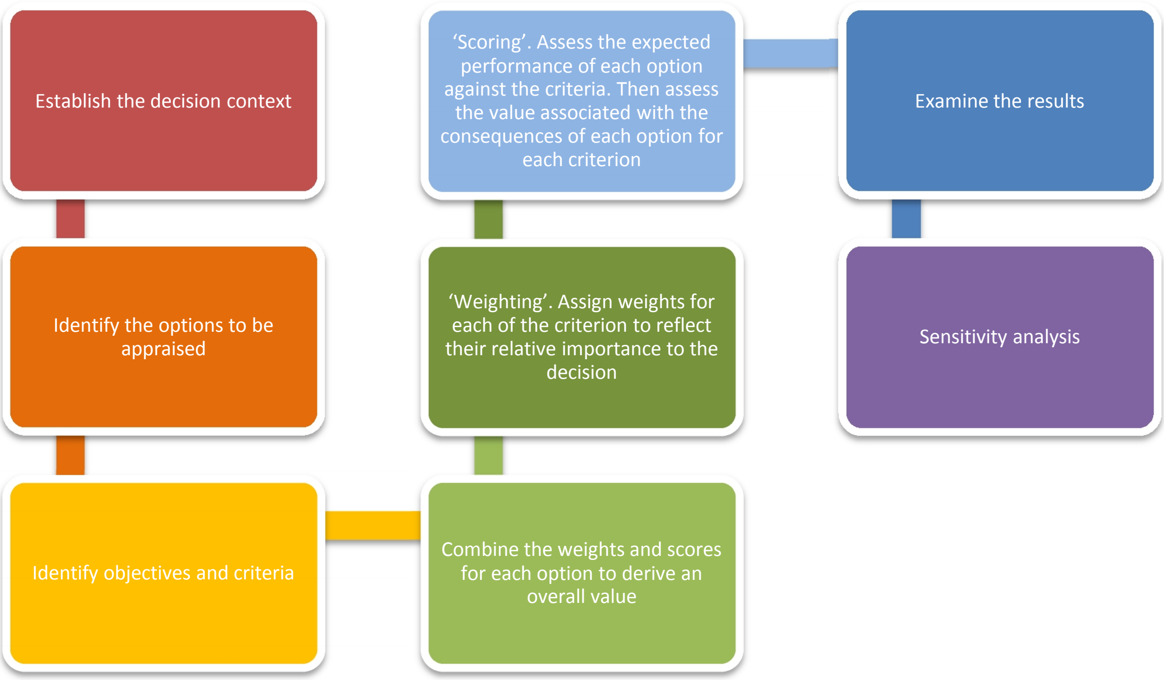

Figure 9 Multi-criteria approach for multiple impacts assessment

The trickiest steps from the multi-criteria analysis are the choice of criteria and their weighting, because they are the essence of the current status upon which positive changes need to be triggered.

For the purposes of alleviating energy poverty, the core criteria would be "energy poverty" along with its indicators and parameters to measure it. In section 5.2.1. more information on its identification and segmentation in this respect is given. For the purposes of its impact assessment, the weighting would be based on air quality factors. In section 5.2.3. more information on the estimation and calculation of the air pollution is given.

The multi-criteria approach could be applied flexibly with a number of criteria and weighting factors that best reflect the local needs. It leans upon analytical thinking and considerations for the local situation and thus may provide excellent outputs if carefully performed. An example of the multi-criteria approach embedded in the InventAir methodology is provided:

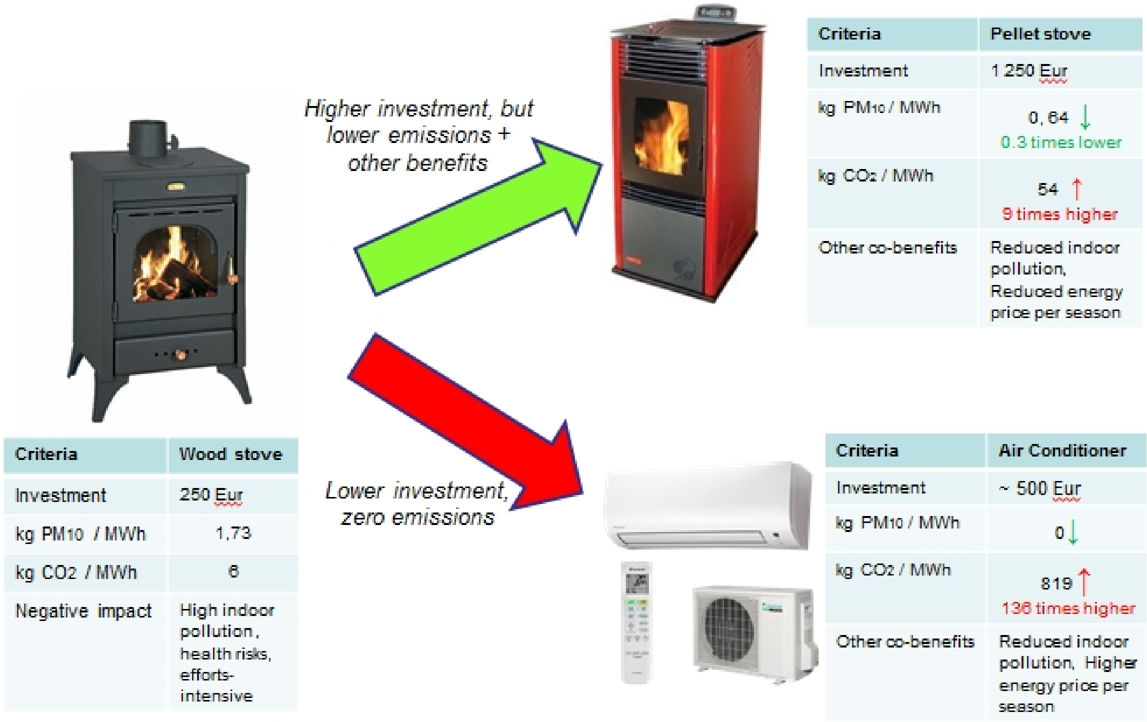

Figure 10 Example of multi-criteria approach based on the Bulgarian experience

The example based on the Bulgarian experience and data is built upon the use of old inefficient stoves as major criteria for energy poverty. Such stoves are relatively cheap and use the cheapest fuel per ton, but are highly polluting – they can emit up to 1.73 kg PM/MWh and for entire season around 24 kg PM. Still, they have low CO2 emissions – only 6 kg/MWh, compared to other energy sources. The accompanying negative impacts are related to increase in-door pollution and thus increase morbidity and mortality, higher energy costs per season, time- and effort-intensitive. If we take the energy and health aspect as leading criteria in this example, we can compare the other two options:

A. Replacement with pellet stove – the particulate matter emissions will be 3 times lower and thus will positively impact the health aspect; but the CO2 emissions may be 9 higher. The pellet stoves offer twice as higher efficiency of combustion process, so they lower the fuel demand and thus the energy bill per heating season. No supporting infrastructure is needed. Households heating on wood would be used to such combustion installations and will not have difficulty transferring from the old to the new technology. Still, the investment cost is higher, but the reimbursement period under these circumstances is rather short.
B. Replacement with air conditioner – the particulate matter emissions will be completely avoided, but the CO2 emissions may be 136 higher. The air conditioners may offer healthier indoor environment, but for higher energy cost per season. Though the initial investment is lower, additional installation procedures may be needed. It provides easy control over the energy consumption; and also provides heating and cooling combined.

From a user's perspective the air conditioner may be a desired alternative, because it provides comfort, flexibility, reduced costs and health risks; but from the local authorities perspective it is not suitable alternative due to its high CO2 emissions. When designing an woodstove exchange programme, the local authorities need to first focus on energy sources that are based on renewables and utilise local resources and revitalising existing infrastructures, so that the impact on environment is brought down to zero. On the other hand, they need to balance it with cost-effectiveness and provision of adequate quality of life parameters.

Thus, the ultimate aim of applying a multiple assessment in this case is to be sure that measures and actions implemented have a positive impact on the current and long-term status. The multiple assessments may be considered successful if it introduces joint measures and actions related to improved energy performance, better human health, job creation and productivity, improved fuel and technology market competition, energy autonomy and independence for the end-user and the entire community.

3.2.1. Identification and segmentation of energy poor households

Energy poverty indicators[2]

Energy poverty being a multi-dimensional concept, it is not easy to describe and capture it by a single indicator. This is why combination of indicators, each of them capturing a slightly different aspect of the phenomenon, should be used to measure energy poverty. EPOV proposes the following comprehensive overview of possible indicators, dividing them into primary and secondary sets.

Primary Indicators

There are four different primary indicators for energy poverty:

- Inability to keep home adequately warm: Share of (sub-) population not able to keep their home adequately warm, based on question "Can your household afford to keep its home adequately warm?"
- Arrears on utility bills: Share of (sub-) population having arrears on utility bills, based on question "In the last twelve months, has the household been in arrears, i.e. has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.) for the main dwelling?"
- Hidden energy poverty (HEP): The HEP indicator presents the share of population whose absolute energy expenditure is below half the national median. HEP is a relatively new indicator to complement other expenditure and self-reported indicators.
- High share of energy expenditure in income (2M): The 2M indicator presents the proportion of population whose share of energy expenditure in income is more than twice the national median share. High variance in energy/income shares can occur due to structural differences in energy expenditure between household groups, as well as in situations where energy is often, but not exclusively, included in rent.

Secondary Indicators

Secondary indicators are relevant in the context of energy poverty, but are not directly indicators of energy poverty itself:

- Fuel oil prices: Average household prices per kWh generated from fuel oil
- Biomass prices: Average household prices per kWh generated from biomass
- Coal prices: Average household prices per kWh generated from coal
- Household electricity prices: Electricity prices for household consumers, band DC 2500-5000 kWh/yr consumption, all taxes and levies included
- District heating prices: Average household prices per kWh from district heating
- Household gas prices: Natural gas prices for household consumers, band 20-200GJ consumption, all taxes and levies included
- Dwelling comfortably cool during summer time: Share of population, based on question "Is the cooling system efficient enough to keep the dwelling cool?" and/or "Is the dwelling sufficiently insulated against the warm?"
- Number of rooms per person, owners: Average number of rooms per person in owned dwellings
- Dwelling comfortably warm during winter time: Share of population, based on question "Is the heating system efficient enough to keep the dwelling warm?" and "Is the dwelling sufficiently insulated against the cold?"
- Number of rooms per person, renters: Average number of rooms per person in rented dwellings
- Dwellings in densely populated areas: Share of dwellings located in densely populated areas (at least 500 inhabitants/km2)
- Number of rooms per person, total: Average number of rooms per person in all dwellings
- Dwellings in intermediately populated areas: Share of dwellings located in intermediately populated areas (between 100 and 499 inhabitants/km2)
- Poverty risk: People at risk of poverty or social exclusion (% of population)
- Dwellings with energy label A: Share of dwellings with an energy label A
- Energy expenses by income quintiles: Consumption expenditure for electricity, gas and other fuels as a share of income for the different income quintiles
- Equipped with air conditioning: Share of population living in a dwelling equipped with air conditioning facilities
- Equipped with heating: Share of population living in a dwelling equipped with heating facilities
- Excess winter mortality/deaths: Share of excess winter mortality/deaths
- Presence of leak, damp, rot: Share of population with leak, damp or rot in their dwelling, based on question "Do you have any of the following problems with your dwelling / accommodation?
- a leaking roof, damp walls/floors/foundation, rot in window frames or floor

Approaches to define, identify, and segment energy poverty

Discovering and assessing energy poverty is challenging. Energy poverty is confined to the privacy of homes, it can vary over time and by place, and it is a multidimensional problem that is culturally sensitive (Thomson and Snell, 2016). Defining and identifying of energy poverty cannot follow a simply prescribed path, but is subject to making decisions on what needs to be achieved. Apart from that, availability of data and resources can be important factors influencing the process. Bearing all that in mind, Thomson and Snell (2016) propose three main methods of measurement:

- Direct measurement, where the level of energy services (such as heating) achieved in the home is compared to a set standard. The key challenges of this method are insufficient studies of energy services at home, plus a specific obstacle for EEC: in many EEC countries, in homes that are served by district heating systems people cannot control their heat consumption, so the temperatures in homes are not a good indicator of energy poverty.
- Expenditure approach, which explores the ratio of household income to energy expenditure, in comparison to certain absolute and relative thresholds. This approach is one of the most commonly used energy poverty measures for national assessments. However, this approach is complex and requires strong technical and scientific capacity within this field. There are a few deliberations to be made if using this approach:
    - Absolute versus relative measures: In the case of an absolute measure of energy poverty, a household is considered to be energy poor if they spend more than a fixed X per cent of their income on energy. In the case of relative threshold, energy costs are calculated on a median cost to income ratio. This measure is subject to fluctuations because energy prices and incomes change, making it a 'moving target', but with the strength that is represents the difficulties of the households more accurately.
    - Energy needs and spending: to measure energy poverty based on expenditure, quantification of energy costs is needed. It is possible to estimate theoretical spend or actual spend. Especially in EEC region, where it is common that people reduce use of energy or even disconnect, the required energy expenditure is considered to be more meaningful than actual spend. However, energy cost modelling is rare in the EU, hence this approach faces the challenge of lack of available data.
    - Household Income: The last deliberation is how to accurately assess household income: to use a before housing costs or after housing costs measure, what welfare payments or benefits should be included within this calculation, should income be equalized to reflect household size?
- Subjective or consensual approach, which is based on self-reported assessments of individuals or households of ability to cover certain basic needs. So far this approach has mostly been used to measure pan- European rather than national energy poverty. One of the strengths of the consensual approach are that it can be less complex to collect consensual data than expenditure data, hence it can be used as an interim measure of energy poverty where comprehensive data is lacking. Consensual approach also shows potential to cover more aspects of energy poverty, such as social exclusion. However, one pitfall of the approach is that households may not identify themselves as energy poor

even though they could be characterized to be energy poor. Also because there is no standard on what goods or services households should be able to afford, a person may classify as poor due to their consumption preferences rather than lacking resources.

Table 3 Summary of available subjective indicators (Thompson and Snell, 2016)

Indicator	Data sources
Ability to pay to keep home adequately warm	EU-SILC main survey; Eurobarometer 72.1 (2009) and 74.1 (2010); European Quality of Life Survey 2007 and 2012
Arrears on utility bills within the last 12 months	EU-SILC main survey; European Quality of Life Survey 2007 and 2012
Risk of falling behind on paying utility bills over next 12 months	Eurobarometer 72.1 (2009) and 74.1 (2010)
Leaking roof, damp walls/floors/foundation, or rot in window frames or floor	EU-SILC main survey; Eurobarometer 73.2 + 73.3 (2010); European Quality of Life Survey 2007 and 2012
Dwelling comfortably warm during winter time	EU-SILC ad-hoc housing conditions module 2007 and 2012
Dwelling equipped with heating facilities	EU-SILC ad-hoc housing conditions module 2007 and 2012
Dwelling comfortably cool during summer time	EU-SILC ad-hoc housing conditions module 2007 and 2012
Dwelling equipped with air conditioning facilities	EU-SILC ad-hoc housing conditions module 2007

Thomson and Snell (2016) also propose that for specific policy delivery at the local level, the listed approaches are also supplemented by indicators for household identification. Most often used indicators to target households affected by energy poverty are:

- ‘Passport’ benefits, such as receiving various forms of welfare payments;
- Area based approaches that draw on local statistics around housing conditions and poverty (this approach is rarely suitable for EEC, however);
- Or base support on demographic criteria such as age.
- If certain groups are estimated to be especially vulnerable (e.g. elderly women or unemployed single mothers), a combination of the upper criteria can be used to target the group.

It must be, however, emphasized that targeting households can prove to be very problematic. Many indicators oversimplify the complexity of the problem or in the case of self-assessment the energy poor may not categorize themselves as such. This is why many practical measures, targeted at energy poor households face challenges when trying to identify the target households. Bearing this in mind, it is advisable to include local actors, such as social services or local associations, into the designing of set of indicators to be used for identifying the target households.

One approach to estimate a threshold for energy poverty is to make reverse calculation: take into consideration the amount of energy needed to heat properly a flat/house for one winter and then calculate the energy bill for the seasons. For example, in Slovenia the heat consumption for residential space heating is 658.428 MJ/m2 (Odyssee-Mure project) and the average area of a dwelling of an energy poor household (REACH project) is 87 m2. So, the heat demand would be around 16 MWh per season (October to March). The price of the wood for heating is around 4 EUR/MWh, so for one month of heating season the energy bill would be around 106 EUR; if the energy poverty threshold is 15% of the income, then the household needs to have an income of 707 EUR at least to be considered outside the energy poverty scope. Any income below that would put them in energy poverty risk.

3.2.2. Air quality definition and segmentation[3]

The levels of air pollution in the residential are defined through the human energy use patterns, the technology and fuels deployed the availability of controls, and the enforced regulatory policies. Overall, the high shares of particulate matter pollution across the EEC are due to the extensive use of old, inefficient heating appliances along with poor quality fuels, inadequate heating practices and low energy efficiency.

The assessment of the air quality status in the residential sector has to pay attention to the collection and procession of specific data that may not be available in the local authorities and national institutions. The major data sets that may be required are:

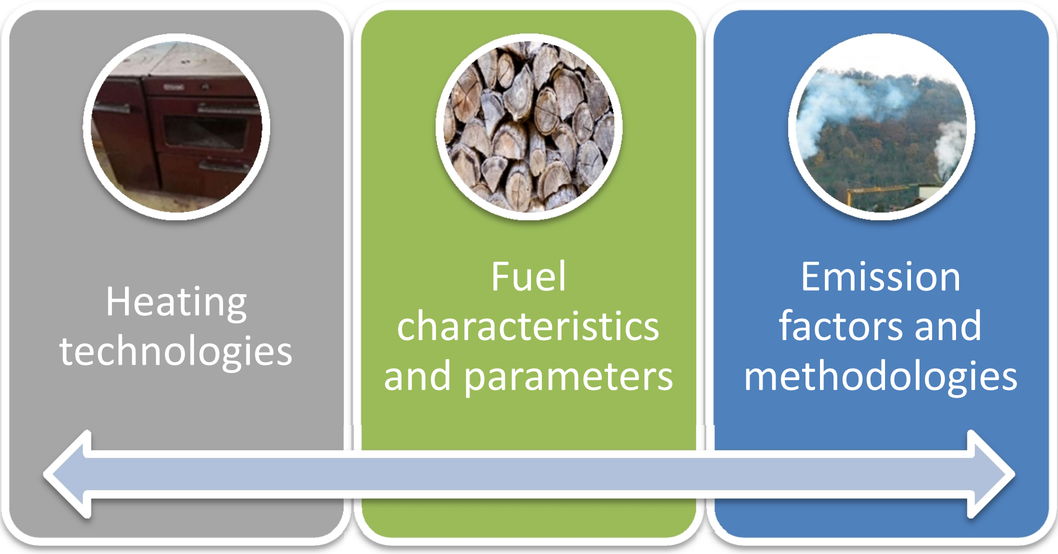

Figure 11 Major data needed for air quality estimations

The heating installations and devices

The emissions from small combustion installations are significant due to the varying burning techniques, efficiency and features of the fuels used. These installations do not have strict burning or emissions control systems and are quite often fire-hazardous and threatening the human health. In the residential sector, the households use a variety of such heating appliances with diverse specifications, lifespan, fuel feed, and supplementary infrastructure. Manually fed heating and poorly controlled appliances are of particular concern due to their primitive design and operation. For this reason, inventorying the small combustion installations may be an impossible task.

Photo 4 Open fireplace, wood stove and a pellets stove

Each of these heating appliances can be characterised in terms of its major features and characteristics, its efficiency and emissions, and its correspondence to a certain standard. The whole combustion process in such devices is difficult to manage and constant control is needed. Even though, there is certain laboratory tests of the emissions produced during burning, these tests reflect the “perfect” condition that is usually far from the everyday practices of the households. Moreover, the households quite often *misuse* the heating appliance by putting wood and coal combined to improve burning, paper and cloth, sometimes machine oil and residue materials. Such practices are basically impossible to detect in real life due to regulatory restrictions and inability to foresee such events. Thus, indoor and outdoor emissions in real life are far greater than the ones detected by laboratory setting and so are their environmental and health impacts.

Between 1990 and 2003, total emissions of particulate matter decreased by 86% in German mainly due to technical measures in the course the German reunification. In the residential sector, many home owners replaced coal stoves with modern gas or oil boilers, that emit very few PM. This general development was accompanied by local regulations: Already in the 1990s in Berlin, for instance, it was only possible to install new heating systems if particle emissions were on a par with oil or gas boilers (excluding solid fuels like coal and wood).

Nonetheless, the pollutants emitted are highly dependent on the combustion process – the more complete it is, the fewer pollutants are emitted; other factors are the oxygen levels, temperature, residence times, and radical concentrations. The efficiency of the heating device is crucial for the emissions – the higher its efficiency, the less pollutants will be emitted:

- Fireplaces: 50-80%
- Solid fuel stoves: radiating stove - 40-50%, mansory stoves: 60%-80%
- High-efficiency conventional stoves : 55%-75%
- Advanced combustion stoves: nearly 70% at full load
- Pellets stoves: 80-90%

The energy carriers and sources

When estimating the impacts of the energy use for residential heating on the air pollution, the quantities and qualities of the fuel used is data that is crucial for the estimation. Often, disaggregated data is not available on local or national level and should be collected bottom-up; top-down approach is not advised. Information may be available from the fuel suppliers and utility companies, local and national authorities, executive agencies, energy agencies and energy observatories. It is possible to use local or national studies and analysis that use informed estimations and energy modelling.

One of the most reliable approaches to acquiring specific data on residential heating is through surveying or applying questionnaires. Even though, it is time-consuming and effort-intensive activity, it could give the best results possible. Moreover, the survey may include open or closed questions that provide additional information and insight into the energy behaviour and practices of the community.

There are sample questionnaires provided by the WHO, EPA, the World Bank, etc. Still, it is essential to know what data you will need for your own survey and what information you need to extract and utilise for the purposes of your won survey.

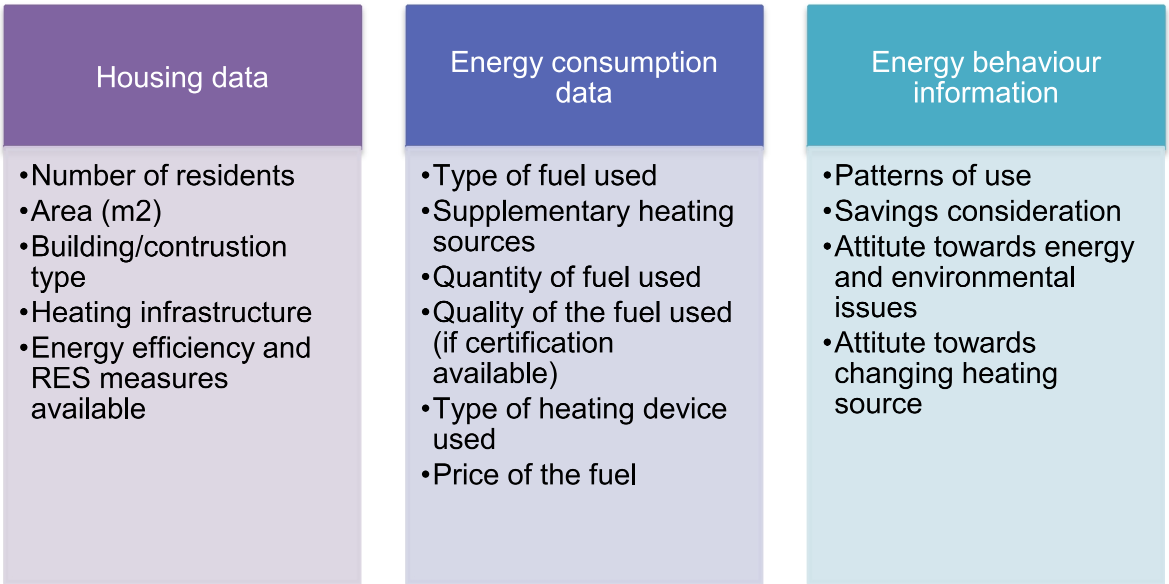

Figure 12 Basic energy data for the purposes of air quality estimations

For converting natural units (tons, kilograms, litres, etc) one can use approved conversion factors and/ or online calculators.

> ***The Observatory for Energy, Environment and Climate at the Energy Agency of Plovdiv provides a suitable calculator:***
> http://observatory.eap-save.eu/index.php/documentation/article-showcase

The emissions

The air pollutants may be primary and secondary. The primary pollutants maintain their chemical composition when they are emitted in the atmosphere and the secondary pollutants undergo changes.

The pollutants that are of particular interest when it comes to residential heating, because of their impact on health and environment, are the particulate matter (PM10, PM2.5), nitrogen oxides (NO_x), sulphur oxides (SO_x), non-methane volatile organic compounds (NMVOC) and often polycyclic aromatic hydrocarbon (PaH) and carbon monoxide (CO).

When replacing the old stoves with alternative equipment (electrical heaters, gas boilers, etc.), it is needed to know the emission factors of the old and new stoves for all air pollutants and CO2 emissions alike.

The estimation methods

Guidance on the calculation of the CO2 emissions may be found in the "Covenant of Mayors for Climate and Energy Reporting Guidelines (2016)". Some of the major emission factors may be summarised:

Table 4 Emission factors for fossil and RES fuels (outtake)

	Energy carriers		IPCC		LCA	
		Standard denomination	*t CO2/MWh*	*t CO2 eq./MWh*	*t CO2/MWh*	*t CO2 eq./MWh*
Emission factors for fossil fuel combustion	**Lignite**	**Lignite**	0.365	0.365	0.368	0.375
	Coal	**Anthracite**	0.354	0.356	0.379	0.393
		Other Bituminous Coal	0.341	0.342	0.366	0.38
		Sub-bitominious Coal	0.346	0.348	0.366	0.38
Emission factors for renewable energy sources	**Other biomass**	**Municipal waste (biomass fraction)**	0	0.007	0.107	0.106
		Wood*	0	0.007	0.006	0.013
			0.403	0.41	0.409	0.416
		Wood waste	0.403	0.41	0.193	0.184
		Other primary solid biomass	0.360	0.367	-	-

** Upper line – sustainable RES, lower line – non-sustainable RES*

Guidance on the calculation of the air pollutants may be found in the "EMEP/EEA air pollution inventory guidebook (2016).

Table 5 Air pollutants from non-biomass fuels (Tier 2 method; g/GJ)

Type of combustion device	Particulate matter (PM10)	Particulate matter (PM2.5)	Black carbon (% of PM2.5)	Sulphur oxides (SOx)	Nitrogen oxides (NOx)	NMVOC
Partly closed fireplaces	330	330	9.839	500	60	600
Closed fireplaces	450	450	6.4	900	100	600
Solid fuel stoves radiating	450	450	6.4	900	1000	600
Solid fuel stoves convection	450	450	6.4	900	100	600
Advanced combustion stoves	240	220	6.4	450	150	300
Conventional over-fire boilers	225	201	6.4	900	158	174

Conventional under-fire boilers	225	201	6.4	900	158	174
Advanced combustion under-fire boilers	240	220	6.4	450	150	300
Stocker coal burners	240	220	6.4	450	150	300

Table 6 Air pollutants from biomass fuels (Tier 2 method; g/GJ)

Type of combustion device	Particulate matter (PM10)	Particulate matter (PM2.5)	Black carbon (% of PM2.5)	Sulphur oxides (SOx)	Nitrogen oxides (NOx)	NMVOC
Partly closed fireplaces	840	820	7	11	50	600
Closed fireplaces	760	740	10	11	50	600
Solid fuel stoves radiating	760	740	10	11	50	600
Solid fuel stoves convection	760	740	10	11	50	600
High-efficiency conventional stoves	380	370	16	11	80	350
Advanced combustion stoves	95	93	28	11	95	250
Pellets stoves	60	60	15	11	80	10
Conventional over-fire boilers	480	470	16	11	80	350
Conventional under-fire boilers	480	470	16	11	80	350
Downdraught wood boilers	95	93	28	11	95	250
Wood boilers	60	60	15	11	80	10

It is visible that burning non-biomass fuels has strong impacts on sulphur oxides and NMVOC and in some cases nitrogen oxides, whereas burning biomass fuels has strong impacts on the particulate matter pollution and NMVOC.

The successful preparation of woodstove changeout roadmap as explained in the "Step-by-step Guidelines" will require precise datasets and inventories, specific information on the heating equipment/technologies deployed, and quality and quantity of fuels used. It could be useful to apply air quality modelling and source apportionment. If there is lack of reliable data and poor expertise to produce such an analysis, the overall quality and usefulness of the roadmap could be questioned, and may lead to inadequate measures and action planning.

3.2.3. Multiple assessment in practice

Quantifying the emission reductions from replacing old stoves with new heating equipment is challenge. There are uncertainties all the way the process and even though a complete example is given in this section, the real-life calculation may be even more complex. So, the purpose of this section is to provide **methodological approach** towards calculating the multiple impacts of the woodstove changeout. Based on it, you can develop your own approach suitable for the local circumstances.

In general, the emission reductions from a Woodstove changeout programme are based on initial number of operating stoves minus the number of stove replaced with other heating equipment – electrical devices, gas heaters, pellets stoves, etc.

There are a number of variables that need to be available for you to start with the calculation:

- Number of households heating on wood and coal (incl. number of households members)
- Energy-for-heating per household
- Quantity and quality of the wood and coal used
- Type of heating device
- Emission factors
- Alternative heating options

Step. 1. Determine the number of households

In the current methodological guidelines, we assume that each household heating on wood and coal and living in poor housing conditions may be considered energy poor.

Data on the number of households heating on wood and coal may be found in the statistical offices, the local authorities' databases, the local energy providers, etc. In the cases, when you do not know the exact number of households, you may try to acquire data for the wood and coal consumption for the community and then divide it by the general energy-for-heating per household. Mind that energy poor households usually have more than average energy consumption.

For more segmentation approaches, you may refer to section 3.2.2.

Step 2. Determine the fuel used

There are two ways of determining the fuel used – by acquiring data on the overall quantities used through survey or from an energy provider, or acquiring data on the energy-for-heating use per household which could be found in local energy statistics. Mind that energy poor households may use a mixture of wood and coal and other inflammable materials (paper, plastic, oil, etc.) which is not subject to statistics. The best way to collect such data is to conduct your own survey.

Step 3. Determine the type of heating device

In section 3.2.2. a number of heating devices along with their efficiency were presented. Still, in order to know the exact type of devices used, one may assume that all of them are solid fuel stoves with efficiency of around 50%. Usually, there is no statistical data on the devices used, and thus the advisable approach to acquire such data is to conduct a survey among the households.

Step 4. Produce activity data

The activity data refers to the energy consumption of wood and coal in households based on input from Steps 1-3. For example,

Activity data = (number of targeted households) x (energy consumption per household)

or

Activity data = (overall consumption of wood and coal in the targeted community) x (fuel-to-energy conversion rate)

Step 5. Consider the emission factors

The emission factors represent the quality of pollutants emitted in the atmosphere. They could be specific for the fuel used and for the heating device. There could be specific emission factors for your country, so you can address the local or national environmental agencies to provide you with concise data; if this is not the case, it is advisable to use the EMEP/EEA guidebook data. To reflect the specifities of the local situation, one may have to adjust the emission factors. If you are unsure of what emission factor to use, then address experts on air quality or energy to support you with that.

Step 6. Calculating the emissions

The calculation of emissions refers to Step 4-5 and could be expressed as the product of the activity data (energy use) and the suitable emission factor for each pollutant. For example,

Emissions = (activity data) x (emission factor)

The most important emissions to consider are CO2, PM, BC, NOx, SO2, NMVOC and so they need to be calculated.

Step 7. Calculate the health impacts

The health impacts calculation may be based upon an estimation of the 'premature mortality rate' (PMR) or 'years of potential life loss' (YPLL). Also, the population that is exposed to the pollution may be considered as the entire population of the community and the population exposed to extreme pollution and considered at great risk – all the households heating on wood and coal.

The premature mortality rate is calculated by multiplying the number of deaths occurring at each age by the number of remaining years of life up to a selected age limit. For example,

PMR = (deaths occurring at each age) x (remaining years of life)

The premature mortality rate is then determined by adding up the potential lost years of individuals in each country.

The 'years of potential life lost' (YPLL) estimates the average years a person would have lived if he or she had not died prematurely and could be calculated for the entire population. For example,

YPLL = [(reference age) – (age of death)] x (population)

Both indicators may be calculated for a certain disease or for all diseases of the entire population affected.

Step 8. Consider the alternative options

Within the Woodstove changeout programme some households may decide to change to non-wood and non-coal based options or to advanced combustion devices. In all other devices emissions are considered to be lower and non-existent, but the other options may have other significant environmental or health impacts that need to be considered.

Each alternative option will have improved efficiency and thus reduced energy consumption.

Step 9. Post-change emissions

For each of the alternative options calculate the Steps 1-7 and subtract each alternative post-changeout emissions from the pre-changeout emissions to see the final net emission reduction.

Step 10. Post change health impacts

Based on the number of devices to be installed re-calculate Step 7.

Step 11. Financial savings calculation

For each alternative heating device, investment and the average price of the device needs to be calculated along with the reduction of the energy bill. The reduction of the energy bill is the subtract of the pre-change energy bill minus the post-change energy bill.

You can estimate the average simple buy-back period by dividing the finance saved by the investment.

Step 12. Summarise the results

The pre- and post-changeout data needs to be summarised and compared. This is best done in a table or graphic format.

Step-by-step matrix

The current matrix summarises the flow of the input data:

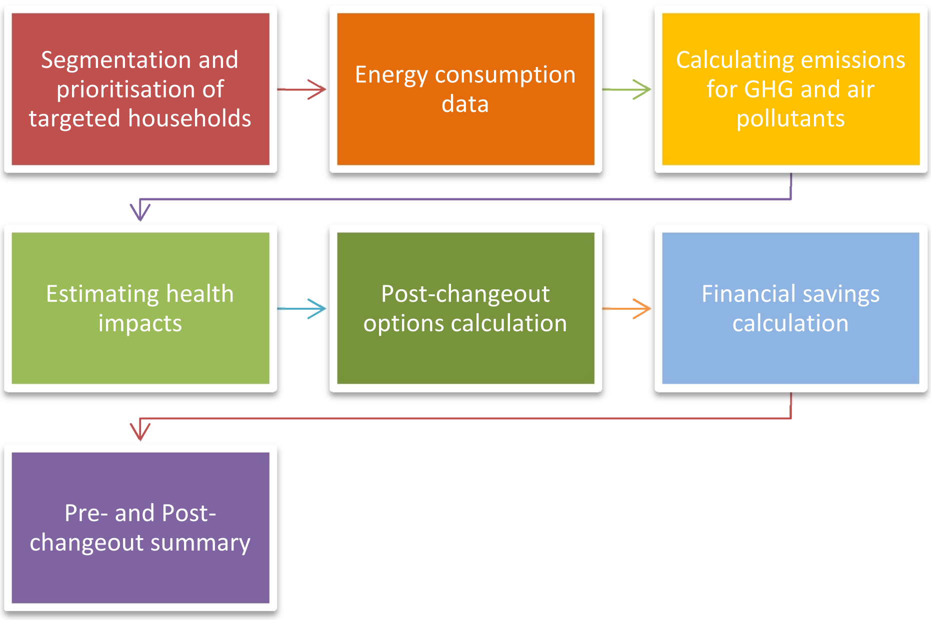

Figure 13 Flow of input data

Example in Practice

Mind this is close-to-reality example, but may not be the best one for your situation. Go through it carefully and consider it from the point of view of the steps describes above.

Step 1:

In the city of Z there are 17 000 households and based on national statistics around 9 000 households (53%) heat on wood and coal. Out of these 9 000 households, 9 out of 10 report (in the media or through a survey) they struggle with keeping their homes warm; so the estimation is that 8 100 households suffer risk of energy poverty.

Step 2:

Based on data from the local energy provider of wood and coal, the households in the city of Z buy around 34 th. m3 wood and 386 t coal. So, each household uses 4.2 m3 wood and 0.05 t coal which through a conversion calculator is around 8.2 MWh wood and 0.2 MWh coal.

Step 3:

Unfortunately, the city of Z does not keep statistics on the devices used by its population. Based on the empirical evidence and experts experience, we could assume that all households use old, solid fuel stoves with an efficiency of up to 50%. Even though there may be some bigger boilers or else, we will prefer to neglect them.

Step 4:

The activity data for targeted households in the city of Z may be derived through the second approach:

Activity data = (overall consumption of wood and coal in the targeted community) x (fuel-to-energy conversion rate)

But as there are two types of fuels, it needs to be calculate for each one of them. In our case, we use an online calculator that says:

- 34 th. m3 = 66 500 MWh total energy from wood
- 386 t = 1 430 MWh from coal

So, the total energy consumption of the households addressed is 67 930 MWh, and each household has an average consumption of 8.4 MWh.

Step 5:

The emissions that are of interest for the city of Z, because it exceeds their limits are CO2, PM, NOx, and SO2. Their emission coefficients are taken from the national environmental office and are also checked in the EMEP/EEA guidebook. The only exception is the CO2 emission facto which is taken from the Covenant of Mayors guidebook.

Step 6:

In this step, the energy for each fuel (wood and coal) is multiplied by the respective emission factor to arrive at the total number of pollutants in Table 1.

Table 1 Impact of energy poverty on air quality

	Energy use (MWh)	CO2 (t MWh)	PM (t/y)	Nox (t/y)	SO2 (t/y)
Wood	66 500	26 800	167.4	16.7	1.4
Coal	1 430	522	2.4	0.5	4.6
Total	67 930	27 321	169.9	17.2	6.1

Step 7:

The population exposed to air pollution is the entire population of the city of Z – 17 000, and the population exposed to extreme risk is all the households heating on wood and coal – 8 100 households or 32 400 people (based on average statistics for number of family members).

According to the local health statistics, the average life expectancy is 75 years. Thus, the calculation of the premature mortality would be (Table 2):

Table 2 Premature mortality rate

Age	Nm of deaths due to air-associated disease	Remaining years of life	Premature mortality rate
10s	100	60	6000
20s	100	55	5500
30s	100	45	4500
40s	150	35	5250
50s	150	25	3750
60s	250	15	3750
70s	300	5	1500
Total potential lost years (PMR)			30 250

Based on the local health statistics, the average life of people with a certain pollution-induced disease would be around 60 years. So, the YPLL would be: (75 – 60)*8 100 = 121 500 years.

Step 8:

The authorities in the city of Z have decided to fund 2 500 pellet stoves, 1 500 air conditioners and 700 gas-fuelled heating devices.

Step 9:

For the post-change emissions we assume that there will be no reduction in the energy use despite the improved efficiency of the device, i.e. the comfort will increase.

Table 3 Post-change emissions

	Nm devices	MWh/ household	MWh	CO2 (t MWh)	PM (t/y)	Nox (t/y)	SO2 (t/y)
Pellet stoves	2 500	8.4	21 000	1 260	9.065	5.288	0.453
Air conditioners	1 500	8.4	12 600	10 319.4	0 (-31.46)*	0 (-3.19)*	0 (-1.12)*
Gas-fuelled devices	700	8.4	5 880	11 87.76	0 (-14.68)*	0.888	0.042
Total	4 700		39 480	12 767	55.205	9.366	1.615

** avoided*

Mind that even though air conditioners and gas-fuelled device do not have certain emissions, they basically replace the emissions of the wood and coal-based devices, and thus ‘avoided’ emissions are formed.

Step 10:

The number of households with new heating device will be 4 700 which means that severely affected by air pollution will be 3 400 households who did not replace their heating equipment. Thus, the affected people will be with 18 800 less (or 58%). It could be expected that the premature deaths along with the years of potential life loss will be reduced by the same percentage, i.e. PMR = 12 705 and YPLL = 51 030.

Step 11:

To calculate the financial savings per type of heating device, we use the average data from the local energy providers for EUR per MWh.

Table 4 Pre- and Post-changeout energy bills

Woodstove changeout	Households	Energy used	MWh/ household	EUR/ MWh	Total (EUR)
Pre-changeout	8 100	Wood and coal	8.4	45	3061800
Post-changeout	3 400	Wood and coal	8.4	45	1285200

	2 500	Pellets	8.4	41	861000
	1 500	Electricity	8.4	106	1335600
	700	Natural gas	8.4	39	229320

The reduction of the energy bills will increase by 649 320 EUR or 21% where the heating comfort is increased, i.e. there is no reduction of the MWh/household used.

The investment needed for the new appliances is:

Table 5 Investment in new devices

	Device	Nm devices	Price/device (EUR)	Total (EUR)
Post-changeout	Pellet stove	2 500	1 250	3 125 000
	Air conditioner	1 500	650	975 000
	Gas-fuelled device	700	600	420 000

Step 12:

The pre- and post-changeout situation is presented in the current table:

	House-holds	Energy carrier	Energy use (MWh)	CO2 (t MWh)	PM (t/y)	Nox (t/y)	SO2 (t/y)	Highly exposed population	PMR	YPLL	Energy bills
Pre-changeout	8 100	Wood and coal	67 930	27 321	169.9	17.2	6.1	32 400	30 250	121 500	3 061 800
Post-changeout	3 400	Wood and coal	28 514	11 468	71.3	7.2	2.5	13 600	12 705	51 030	1 285 200
	4 700	Pellets, electricity, gas	39 480	12 767	55.2	9.4	1.6	0.0	0.0	0.0	2 425 920
			diff	*3 086*	*43*	*0.6*	*1.9*	*18 800*	*17 545*	*70 470*	*-649 320*
			% reduction	*11%*	*26%*	*4%*	*32%*	*58%*	*58%*	*58%*	*-21%*

In summary, it can be noted that by exchanging 58% of the solid fuel stoves, 4 700 households may be supported and taken out of energy poverty risk as the new heating devices will potential reduce their energy bills and will allow better control over the energy consumption. Also, all these households will have improved internal living environment and the risk from premature death and pollution-related disease will be eliminated.

The impact on the local community will be a significant reduction of the polluting emissions along with a decrease of the CO2 emissions – in total there will be 11% reduction of the CO2 emissions, 26% reduction in the PM emissions, 4% in the NOx and 32% in the SO2. The population that is at high risk of the air pollution will be reduced by 58% and so will decrease the premature deaths expectancy and the years of life loss.

The investment needed for the changeout will be around 4 520 000 EUR.

Concluding remarks:

The current step-by-step calculation method is further explained and extended in the document "Step-by-step woodstove changeout roadmap development" prepared by the InventAir project. It describes in depth the approaches towards segmentation and prioritisation of households, splitting energy and environmental targets over a period of time, and estimating all these impacts in a wider manner. The document presents templates and sample tables that further clarify the process of setting up and implementing a roadmap.

4. Conclusions

The current document "InventAir: Methodological framework for mapping energy poverty and assessing its climate impacts" encompasses the challenges of energy poverty and air pollution faced by the Eastern European countries.

The available information and data on these issues suggests that the Eastern European communities struggle with the implementation of join policies to tackle them. There is a strong need to design and implement joint policies on local and national level that are targeted to the introduction of measures and actions that address the cross-cutting issues.

Despite the overall demand for action, there are other significant demands:

- Definition of energy poverty based on clear and concise indicators
- Improved local and national emission inventories, esp. for fuelwood and coal
- Reliable emission factors based on real-life measurements
- In-depth understanding of the energy behaviour associated with wood and coal use and the housing conditions

Resolving these challenges will trigger the policy development and will thus support the long-term energy planning to replace the old heating equipment. Thus, the adequate actions to be taken would be to:

- Enforcement of strict regulations and control over the heating devices and fuels used (incl. Ecodesign Directive)
- Start immediate replacement of old and inefficient heating equipment with new, highly efficient stoves on modern biomass
- Design adequate financial support schemes for energy poor households
- Promotion of energy efficiency measures and RES deployment
- Strong awareness campaigns on energy poverty and air quality impacts on environment, economy, and health

The document proposes an easy step-by-step process to calculate the impacts of the air pollution on environment, health and economic environment. It is a prelude to the development of comprehensive woodstove changeout programmes.

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