European Commission

Increasing policy coherence between bioenergy and clean air policies and measures

Toolkit for developing air quality mitigation measures for solid biomass use

Written by Logika Group, TNO and Ineris
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1 Introduction

1.1 What is this toolkit for?

The purpose of this toolkit is to provide advice and support for EU Member States, their regions or cities in the development of measures to mitigate the potential adverse impacts of bioenergy on air quality. As noted below, bioenergy use accounts for around 50% of the emissions of fine particulate matter ($PM_{2.5}$) across the EU. This presents a challenge for the achievement of clean air in Europe[1]. However, bioenergy is an important source of renewable heat and energy in many Member States. This, as well as the often informal market for wood fuel at the domestic-scale, makes the development of mitigation measures complex. This toolkit is intended to help navigate through that complexity, presenting the rationale for mitigation measures, the key considerations in developing such measures and examples of measures that have been successfully implemented elsewhere. It also provides links for further resources which will aid the planning, implementation and evaluation of measures at the national, regional or local scale. The main focus of this toolkit is on the impact and potential control of emissions from small, domestic bioenergy combustion, through the use of logs, pellets or other woody solid fuels, for water or space heating.

1.2 What do we mean by bioenergy?

The term "bioenergy" can have a wide variety of definitions. For the purposes of this project, biofuels used in transport and biogas are excluded from the definition, which leaves solid biomass as the main source of air pollution emissions. This still leaves a wide range in the potential scale of installations producing bioenergy, and thus the nature of the issues associated with them. Larger installations in the EU, from major power stations operating on biomass fuel to smaller, local heat and power plants (i.e. medium combustion plant), operate under the rules set by the Industrial Emissions Directive, Medium Combustion Plant Directive, etc. While smaller, domestic-scale heaters, stoves and boilers also have emission limits applied, through the Ecodesign Directive (2009/125/EC), these are fuel specific, i.e. wood fuelled boilers have a different standard to, say, gas fired boilers, and only apply to new units.

Emissions inventories from many countries now show domestic combustion, mainly of solid fuels, to be the largest or one of the largest sources of particulate matter emissions. Across the EU, bioenergy use in small combustion is responsible for half the total $PM_{2.5}$ emissions in the EU27, and the use of bioenergy in other sectors only makes a small contribution[2]. Hence, it can be concluded that when it comes to air pollution related to the use of bioenergy and its impacts, the main issue is the use of bioenergy in the small combustion sector, which mostly consists of wood used for heating purposes. Overall, $PM_{2.5}$ emissions have decreased over the last 2-3 decades in the EU27, by almost 40% between 2000 and 2021[3]. However, this decrease is mostly attributed to sectors other than small combustion, in particular transport and industry, because of the abatement measures that were implemented in these sectors. Hence, the relative importance of small combustion in total $PM_{2.5}$ emissions in EU27, which are primarily related to bioenergy use, has increased in the last decades.

1.3 The role of bioenergy

Bioenergy is the main source of renewables in the EU in terms of gross final energy consumption, representing almost 60% of renewable energy sources[4]. Its main use is for heating and cooling (around 75%). In the EU, the use of solid bioenergy increased by 33.5% between 2008 and 2021, however in recent years the growth seems to be levelling out because of uncertainties in policies and debates about sustainability of bioenergy[5]. Germany, France, Italy and Sweden are the EU27 Member States with the highest bioenergy consumption in absolute terms.

[1] See main report: https://data.europa.eu/doi/10.2779/94296.
[2] 3rd Clean Air Outlook: https://environment.ec.europa.eu/publications/third-clean-air-outlook_en
[3] https://www.eea.europa.eu/data-and-maps/dashboards/air-pollutant-emissions-data-viewer-5
[4] https://energy.ec.europa.eu/document/download/68e51bbf-aa4f-4570-9497-0af7c19c153c_en?filename=COM_2023_650_1_EN_annexe_autre_acte_part1_v7.pdf
[5] Ibid.

The largest part of bioenergy is used in transformation input (mostly for electricity and heat generation) as well as in other sectors (mostly for small-scale heat generation). Around 65% of this solid and gaseous bioenergy is used in combined heat and power (CHP) plants, whereas electricity and heat-only plants use 18% and 17% of the bioenergy in EU27 in 2021, respectively. Industry is a smaller but not negligible user of bioenergy, and within the industrial sector the main users are the pulp and paper industry and the wood and wood products industry (20%). In terms of the type of bioenergy used, industry and other sectors primarily use it in solid form (wood or similar), while the electricity and heat generation sector also utilises significant amounts of bioenergy in liquid and gaseous form.

However, over and above the energy statistics, bioenergy, in the form of wood fuel, plays an important social and cultural role in many countries. This is especially so in rural and traditionally forested areas, where fuel is often locally or self-sourced and provides a cultural link to the natural environment. In many counties, the use of wood fuel is seen as being part of the traditional culture and the emission of smoke is seen in a different context to those associated with, for example, old diesel engines. The aesthetic appeal of wood combustion has led to a trend in many parts of Europe, mainly in wealthier areas, for the installation of wood stoves as supplementary heating sources, often at great expense. These factors combine to make controlling the use or installation of wood fired heating appliances through pricing measures challenging.

In addition, solid fuel is the primary heating fuel for many households. The numbers vary by country, ranging from a minority of relatively isolated, rural households to larger numbers of urban households, especially in Eastern Europe. Dependence on log wood fuel (and coal) is often associated with economically deprived households, and thus those least able to upgrade their heating systems to more modern, cleaner alternatives. During fuel price shocks, such as affected much of the EU following the invasion of Ukraine by Russia, there is anecdotal evidence of an increased use of fireplaces and stoves as single room heaters, using waste products as fuel, to avoid the use of conventional, metered energy. However, as a recent study in the UK has found, wood fuel may not be the most economically advantageous option for home heating[6] and thus continued reliance on it may trap households in fuel poverty.

Measures to address the air pollutant emissions associated with bioenergy use need to take these cultural and socio-economic factors into account if they are to be successful. The different drivers for domestic solid fuel and bioenergy use – price, access to other heating fuels, aesthetics, cultural values, the costs of upgrading, etc. – mean that different measures will be needed, and these are discussed in the following sections.

1.4 Future prospects for bioenergy

The baseline scenario of the European Commission's Third Clean Air Outlook[7], which was derived from the PRIMES energy system baseline, includes different bioenergy sources in all sectors of the economy. It estimates the air quality impacts of future energy developments, hence including bioenergy use.

Currently solid bioenergy is used primarily (45%) in the small combustion sector which comprises the residential, commercial/institutional and agricultural stationary combustion. Combustion of biomass in the energy transformation sector[8] and in industry comprises 22% and 20%, respectively. The consumption in industry includes both consumption in onsite boilers or combined heat and power (CHP) units, as well as in furnaces. In future projections, derived using the PRIMES model and considering a 2050 net-zero carbon scenario, the amount of bioenergy use increases and the split between sectors changes:

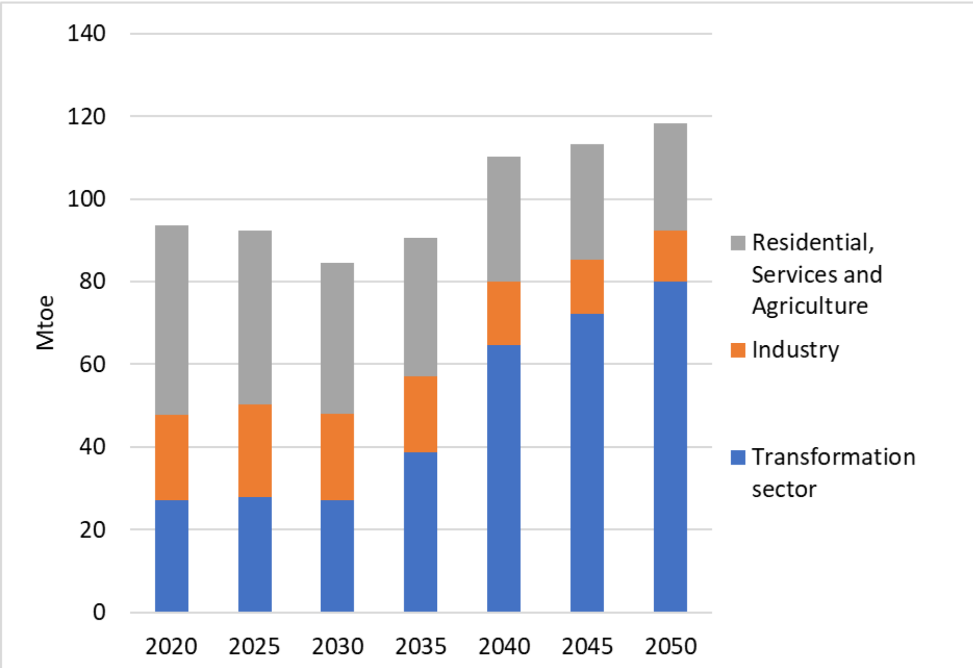
- Solid bioenergy use in the small combustion sector is projected to reduce and then almost stabilise. This is the result of renovation in European buildings incl. change of equipment to higher efficiency, as well as a shift towards electrification through heat pumps

[6] https://urbanhealth.org.uk/wp-content/uploads/2023/11/Relight-my-fire-investigating-the-true-cost-of-woodburning-stoves-impact-on-urban-health.pdf
[7] https://environment.ec.europa.eu/publications/third-clean-air-outlook_en
[8] The energy transformation sector includes power, steam/heat generation as well as other elements of the transformation sector such as Blast Furnaces (based on the EUROSTAT energy balance split).

- Similarly in the industrial sector: the solid bioenergy consumption reduces and then almost stabilises. This is also due to efficiency in equipment and processes (incl. heat recovery), electrification and the shift to new process types using e.g. hydrogen
- The energy transformation sector is the sector where the use of solid bioenergy consumption is increasing, which is due to a shift towards biomass in power and steam/heat generation, which represents a form of dispatchable power generation in a system otherwise dominated by variable renewable energy sources

Figure 1-1 shows these trends for bioenergy consumption in EU27 up to 2050. It should be noted that projected bioenergy consumption across the EU27 is dependent on the assumptions taken in the scenario, for instance regarding the potential of available biomass (and related products), biomass prices (and subsidies) and also regarding the (level of) deployment of the specific CO_2 reduction options like Carbon Capture and Storage (CCS). The actual development of these factors in future years will also impact the bioenergy use and hence its environmental impact.

Figure 1-1: Consumption of solid bioenergy by sector in the stationary demand (source: PRIMES scenario that meets the Fit for 55 targets for 2030 and climate neutrality in 2050)



1.5 Health effects

Wood or bioenergy combustion is known to emit particulate matter ($PM_{2.5}$, PM_{10}, ultrafine particles), NMVOCs, but also NO_x, SO_x and NH_3, as well as polycyclic aromatic hydrocarbons (PAHs) and dioxins. PM emissions from combustion sources contain a large fraction of carbonaceous aerosol, predominantly present in the sub-micron size fraction (<1µm). Amongst these pollutants, $PM_{2.5}$ (primary and secondary), as well as PAHs and dioxins are of specific health concern[9][10].

$PM_{2.5}$ has long been linked to mortality, to inflammation and oxidative stress, which compromises pulmonary immunity and increases the susceptibility to infection. The illnesses associated with the presence of $PM_{2.5}$ range from lung cancer, bronchitis and other respiratory infections to cardiovascular diseases, strokes, dementia,

[9] Denier van der Gon, H. A. C et al., Particulate emissions from residential wood combustion in Europe – revised estimates and an evaluation, Atmos. Chem. Phys., 15, 6503–6519, https://doi.org/10.5194/acp-15-6503-2015, 2015
[10] UK Air Quality Expert Group for Defra, 2017, The Potential air quality impacts from biomass combustion, Report: The Potential Air Quality Impacts from Biomass Combustion - Defra, UK.

Parkinson's disease and low birth weight. Effects are particularly pronounced for children, pregnant women, and the elderly[11][12]. PAHs can reduce the immune function and are known for their carcinogenic and mutagenic effects[13], and dioxins are also carcinogenic[14]. Both families of substances are known to be persistent and to accumulate. PAHs emitted to the atmosphere can be deposited onto soil, water and vegetation. In water they can accumulate in aquatic organisms, in soil they can enter the groundwater and be transported within an aquifer[15]. When accumulated in soil and water, they can enter the food chain also through their uptake by vegetation and plant materials, and through the use of contaminated vegetation to feed livestock[16]. Dioxins bind to sediment and organic matter in the environment, they are absorbed in animal and human fatty tissue and bio-accumulate in the food chain[17].

Epidemiological studies document that short- and long-term exposure to smoke from biomass combustion are responsible for chronic obstructive pulmonary disease (COPD)[18], acute respiratory and cardiovascular disease[19], pneumonia, tuberculosis, asthma and cancer[20]. A strong relationship between PM from biomass combustion and health impacts such as hospitalisations, cardiovascular and respiratory problems and premature mortality has been found[21].

The World Health Organisation (WHO) notes that short-term exposure to particles from wood combustion appears to be as harmful to health as exposure to particles from the combustion of fossil fuels[22]. Other studies indicate that emissions from wood burning might be specifically dangerous for health: Danish Ecological Council (2016) suggests that soot particles, emitted amongst others from wood burning, might be more harmful than inorganic particles formed from the precursors NO_x, NH_3 and sulphates. And a study in Athens found that the fraction of PAHs associated with biomass burning was linked to increased health risk compared to other sources, accounting for 43% of the annual PAH carcinogenic potential[23].

[11] Chakraborty, R.et al., Indoor Air Pollution from Residential Stoves: Examining the Flooding of Particulate Matter into Homes during Real-World Use. Atmosphere 2020, 11, 1326. https://doi.org/10.3390/atmos11121326
[12] Sigsgaard, T. et. al., Health Impacts of Anthropogenic Biomass Burning in the Developed World, European Respiratory Journal 46: 1577-1588, https://doi.org/10.1183/13993003.01865-2014, 2015
[13] Tsiodra et al., Annual exposure to polycyclic aromatic hydrocarbons in urban environments linked to wintertime wood-burning episodes, Atmos. Chem. Phys., 21, 17865–17883, https://doi.org/10.5194/acp-21-17865-2021, 2021.
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[15] EFSA, 2008, Polycyclic Aromatic Hydrocarbons in Food, Scientific Opinion of the Panel on Contaminants in the Food Chain, (Question N° EFSA-Q-2007-136), Adopted on 9 June 2008, The EFSA Journal (2008) 724, 1-114, https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/j.efsa.2008.724
[16] Sampaio et al., 2021, Polycyclic Aromatic Hydrocarbons in Foods: Biological Effects, Legislation, Occurrence, Analytical Methods, and Strategies to Reduce Their Formation. Int. J. Mol. Sci. 2021, 22, 6010. https://doi.org/10.3390/ijms22116010.
[17] MEMO/01/270, 2001, Fact Sheet on dioxin in feed and food, European Commission, Brussels, 20 July 2001, https://ec.europa.eu/commission/presscorner/detail/en/MEMO_01_270
[18] Salvi, S.S. & Barnes, P.J., 2009, Chronic obstructive pulmonary disease in non-smokers, Lancet 2009, 374: 733–743
[19] Ibid.
[20] Patel et al., 2013, Indoor Air Pollution from Burning Biomass & Child Health, International Journal of Science and Research (IJSR), Volume 2 Issue 1, January 2013
[21] Kukkonen et al., 2020, The influence of residential wood combustion on the concentrations of PM2.5 in four Nordic cities, Atmos. Chem. Phys., 20, 4333–4365, https://doi.org/10.5194/acp-20-4333-2020, 2020
[22] WHO, 2015, Residential heating with wood and coal: health impacts and policy options in Europe and North America, https://apps.who.int/iris/bitstream/handle/10665/153671/9789289050760-eng.pdf?sequence=3&isAllowed=y
[23] Ibid.

2 Case studies

The following subsections provide examples of bioenergy policies implemented in EU Member States, at various governance levels. They provide an illustration of the different policy measures that can be applied to address the potential problems associated with bioenergy, as well as the scales (national, regional, local, etc.) of implementation.

A key observation from the case studies is that policy measures are implemented as part of a package of measures, and not in isolation, as indicated in the case studies below. A full description of the case studies is available in the main project report for this project[24].

2.1 Case Study 1: Denmark

Operational measures	Stock renewal	Use restrictions	Public information campaigns
✓	✓	✓	✓

Three quarters of Denmark's renewable energy comes from bioenergy[25]. Whilst its predominant application is in district heating, according to the Danish Technological Institute, as of 2021, there were around 130,000 biomass-fuelled boilers typically in regions with no or limited access to district heating. Furthermore, it is estimated that Denmark has one of the highest amounts of wood stoves and fireplaces, with around 700,000 estimated.

The Emission Control Air Act sets emissions limits for PM and CO in domestic woodburning appliances, as well as requiring stoves to be compliant with DIN EN standards. As of 2010, this meant that wood stoves emitting beyond the limit values had a finite amount of time based on the average life of the installation to comply, and if this failed, they were either retrofitted with a dust filter or replaced. From 2015, the same process applied for any appliance fitted later than 2010. Denmark's Wood Stove Order empowers municipalities to increase restrictions and enforcements on wood burning and impose additional regulations on wood use in their jurisdiction. The Order also empowers citizens to reach out to their municipal representatives to complain about smoke from wood burning. Furthermore, it allows municipalities to place a ban the use of wood-burning stoves and fireplaces produced before June 2008 in areas with district heating or natural gas from 1 January 2023.

Public information campaigns have been run at national levels by both public authorities and industry. For example, the Danish association of suppliers of fireplaces and woodstoves (DAPO) provides information online setting out best practice on avoiding emissions when using wood fuels.

2.2 Case Study 2: Germany (federal level measures)

Operational measures	Stock renewal	Use restrictions	Public information campaigns
✓	✓		✓

Bioenergy is highly regarded as a sustainable source of energy in Germany, and dependence on the fuel is quite high with over half (55%) of renewable energy in the country being biomass[26]. The German Environment

[24] See main report: https://data.europa.eu/doi/10.2779/94296
[25] https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Denmark_final.pdf
[26] https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Germany_final.pdf

Agency estimates that there are currently more than 11 million wood-burning stoves in Germany[27]. Furthermore, it is estimated that over 27% of households in Germany have a stove as a supplementary heating appliance[28].

The German Ordinance on Small and Medium Firing Installations (1. BImSchV) is the main piece of operational legislation in Germany[29]. It first entered into force in 2010 and sets out permissible fuels, monitoring requirements and the standards to which these should be met.

The German Energy Act for Buildings and the VDI-Standard 4207-2 implement the requirements of the 1. BImSchV. There are also regional financial support schemes to enable compliance with 1. BImSchV and there are further incentives to encourage technological improvements and innovation for ultra-low emission stoves. There is a national user training programme designed to raise public awareness of efficient wood burning practices.

In addition, chimney sweeps in Germany must go through an intensive, three-year training programme to become qualified. They are obliged to test fuels, something which is not within the scope of chimney sweeps in other Member States, such as France. All data kept by the chimney sweep is entered into a harmonised database of chimney sweeps nationwide, which works to generate data on national fuel statistics and numbers of appliances.

2.3 Case Study 3: Bavaria (Germany)

Operational measures	Stock renewal	Use restrictions	Public information campaigns
✓	✓	✓	

As noted above, Germany is one of the main consumers of woody biomass for heating in the residential sector, and Bavaria probably accounts for the largest share of wood fuel use in Germany.

There was a utilisation ban on appliances non-compliant with emissions limits in Munich as of the 31st of December 2018, which implements the Federal Emission Control Act of 1974. The State Capital Munich Department for Climate and Environmental Protection implements the 1. BImSchV through requiring the declaration on the decommissioning of a single-room combustion system for solid fuels in the state capital Munich[30]. Between 2014 and 2017, a timebound subsidy scheme was implemented to shorten the transition period from older to new stoves[31].

There is also a Bavarian-specific version of the wood stove operation training course, which has been shortened and streamlined to better reflect the local desires of users.

[27] https://doi.org/10.3390/pr10030545
[28] https://www.umweltbundesamt.de/en/topics/health/environmental-impact-on-people/special-exposure-situations/emissions-from-wood-coal-burning-stoves-in#use-of-wood-and-coal-stoves-in-residential-areas
[29] https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Gesetze/1_bimschv_en_bf.pdf
[30] Municipality of Munich (2021) "Merkblatt und Erklärung zur Stilllegung einer Einzelraumfeuerungsanlage für feste Brennstoffe auf dem Gebiet der Landeshauptstadt München". Online. Available at: https://www.muenchen.de/rathaus/dam/jcr:fa244625-fd16-41a1-a9b2ec2d101bf5ea/merkbl_stillegung.pdf. [Accessed: 19/12/2023].
[31] Municipality of Munich (2017) Incentive programme of the city of Munich for log wood stove replacement. Online. Available at: https://docplayer.org/59137101-Richtlinie-staedtisches-foerderprogrammem-2017-fuer-den-austausch-alterfestbrennstoffbefeuerter-oefen.html. [Accessed: 19/12/2023].

2.4 Case Study 4: Sweden

Operational measures	Stock renewal	Use restrictions	Public information campaigns
✓			✓

In Sweden, bioenergy is not relied on to a great extent. The small-scale market of biomass use for heating in single-family houses reached historically low levels of around 8 TWh in 2020[32]. However, use of wood as a secondary heating source has increased in the last 15 years. In Sweden, wood combustion is the largest source of emissions of Black Carbon (BC) and accounts for ca. 30% of $PM_{2.5}$ emissions [33].

There are many municipalities that do not have restrictions on wood burning, but do have recommendations based on, for example, neighbourly complaints. The strictest measure was found related to the city of Malmo, where there are restrictions on solid fuel firing where special zones have been established. There is also the regulation by the Swedish National Board of Housing Building and Planning that limits the boilers and stoves that can be installed for residential heating in new buildings. Information campaigns are relatively infrequent, with the last major national campaign occurring in 2017, although there are annual social media information campaigns, and there may also be regional or local campaigns.

Since the scale of the problem is relatively unknown in Sweden, and most domestic heating is district-based, there are only a handful of national or local measures in Sweden. Most of these are used to implement EU policy to adhere to Ecodesign regulations. The usage ban in Malmö, however, which is the most prescriptive of the municipal policies identified, only allows 'cosy' firing to take place for half of the year (October to March), and on top of this, the municipal authorities recommend that fires in tiled chimneys are also lit no more than twice per week.

2.5 Case Study 5: Sofia (Bulgaria)

Operational measures	Stock renewal	Use restrictions	Public information campaigns
	✓	✓	

While the use of wood fuel in Sofia is lower than the national average, it still accounts for a very large proportion of heating. The national census in 2011 indicated that around 50,000 households across the city are reliant on solid fuel heating, with wood logs being the most common fuel. In addition, it has been indicated that domestic solid fuel (though this also includes coal) use for heating make up around 56% of all PM_{10} emissions[34] in the city.

Two key measures are applied in Sofia: a Low Emission Zone (LEZ) for transport and household heating, and an appliance replacement scheme. The LEZ for household heating is expected to be in action as of 1 January 2023[35]. This covers mostly central areas of Sofia, and entails a ban on solid fuel heating (wood and coal, but not wood pellets). The appliance replacement scheme is linked to a LIFE IP Clean Air Programme project which

[32] https://energimyndigheten.a-w2m.se/FolderContents.mvc/Download?ResourceId=208766
33 Bodin, S. (2017) "Evaluation of the Swedish Communication Campaign "Lighting in the Top," 2017-18 Woodburning Season Summary and Conclusions," International Cryosphere Climate Initiative. Online. Provided through Email contact with stakeholder.
[34] https://csd.bg/fileadmin/user_upload/publications_library/files/2023_03/Reversing_the_trend_Smart_Enforcement_of_the_LEZ_in_Sofia_WEB.pdf
[35] Ibid.

aims to facilitate a transition from heating with wood and coal towards pellets, gas, or use of the central heating network.

2.6 Case Study 6: France

Operational measures	Stock renewal	Use restrictions	Public information campaigns
✓	✓	✓	✓

According to the IEA[36], around 60% of renewable energy in France is from biomass. In domestic heating, 6,725,000 domestic wood-burning appliances produced 75,700 GWh of renewable heat in 2020[36]. The Ministerial Decree of 2 April 2016 authorises prefectures to temporarily suspend the use of inefficient biomass combustion devices. There are further geographical bans under the Atmosphere Protection Plan applicable in agglomerations greater than 250,000 inhabitants where air quality standards are not complied with.

The efficient domestic wood heating action plan[37] is a systematic approach to reducing particulate matter across the country, by speeding up the replacement of old stoves and fireplaces with efficient equipment. It covers multiple integrated approaches to abating air quality impacts of residential woodburning. These are raising public awareness of the impact on air quality of using inefficient appliances and fuels; strengthening, and simplifying support schemes to speed up the replacement of inefficient appliances; extension of the Green Flame label beyond a 7-star threshold to showcase best available technology and appliances; and to develop a label indicating high quality fuels regarding their moisture content and origin. The approach will be tailored to each region to reflect public awareness and potential reception of air quality measures. Additionally, Decree No. 2023-641 introduced mandatory chimney sweeping as well as inspections of the maintenance of appliances.

The local plans required under the Atmosphere Protection Plan must be evaluated every two years, meaning the first will take place in 2025. Therefore, there will be estimates of effectiveness going forward, and thus should be regarded as best practice given the lack of evaluation generally evident for such measures.

[36] https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_France_final.pdf
[37] https://www.ecologie.gouv.fr/gouvernement-presente-plan-daction-developper-chauffage-au-bois-domestique-plus-performant-et

3 Designing interventions

This section sets out an approach to developing policy measures to help mitigate the air quality impacts of mainly small-scale bioenergy use. Section 3.1 outlines the overall framework for designing interventions. Section 3.2 provides details on the key problem drivers and trends to be considered in a structured analysis of the problem; this first step is key in determining the specificities of the problem for a given context, and subsequently informing the choice of interventions. Section 3.3 gives an overview of the key types of policy measures to consider, and how they relate to specific problem drivers. Parameters and indicators to consider in monitoring the performance and success of policy measures are listed in Section 3.4.

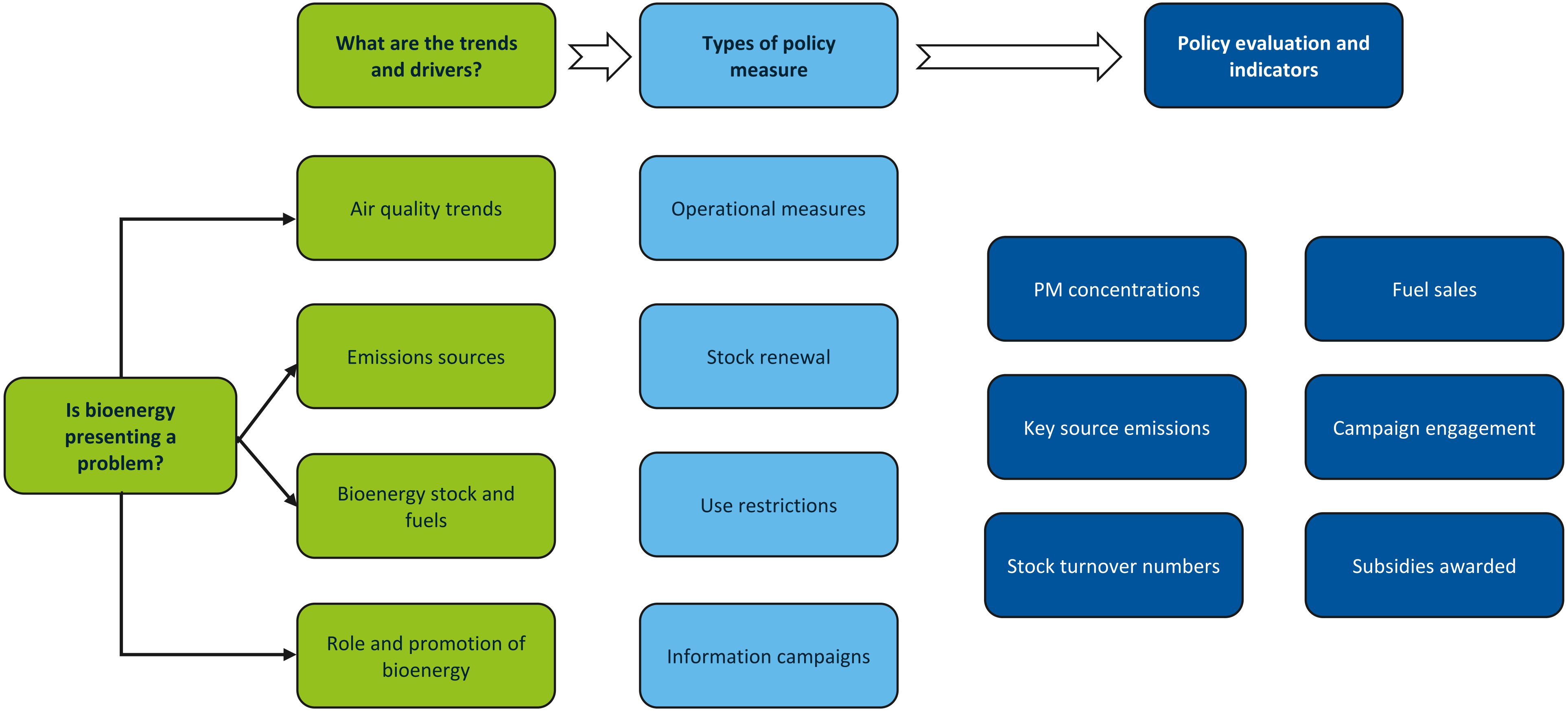
3.1 Developing policy to reduce the negative impacts of bioenergy

As discussed in Section 1.5, use of bioenergy can present problems with respect to emissions of air pollutants, specifically $PM_{2.5}$, with subsequent implications for public health. In seeking to develop policies to address these issues arising from bioenergy use, a number of factors need to be taken into account:

- **What are the trends and drivers of the potential problem?** The first step should consider the scale of and trends in air quality and emissions in order to understand whether bioenergy is presenting problems with respect to these issues. Other key drivers to understand in order to inform the selection of policies are the characteristics of the existing bioenergy appliance stock and the fuels used, as well as how bioenergy is positioned in the market and by existing policies and initiatives (e.g. as an environmentally benign source of energy)
- **What type of policy measures should be considered?** A number of different policy measures should be considered based on the specificities of the trends and drivers of the problem. Different measures are better suited to different scales of implementation (e.g. national vs local implementation), and a package of measures deploying multiple policy measures can more completely address the problems than single measures adopted in isolation
- **Policy evaluation and indicators.** When designing interventions, it is important to consider the indicators and metrics that can be monitored periodically to assess the extent to which interventions are achieving their intended outcomes

Figure 3-1 provides an overview of the underlying trends and drivers to explore when analysing problems relating to bioenergy, as well as the types of policy measures to consider, and potential evaluation indicators. Further details on the aspects presented in the figure are provided in subsequent sections.

Figure 3-1 Design process for interventions addressing bioenergy



3.2 Problem trends and drivers

The following sections elaborate on each of the trends and drivers of the potential problem, setting out specific questions to consider when analysing problems. The aim of exploring the trends and drivers is to better understand the specificities of the air pollution problem as regards bioenergy, and to clarify the causal links between bioenergy and the resulting problems in order to identify more targeted policy measures. Specific driver characteristics and trends that may be better addressed by particular policy measures are identified for each area.

Tool #13 of the European Commission's Better Regulation Toolbox[38] sets out a series of questions to consider in seeking to define problems to be addressed by policy interventions. These include:

- Establishing what the problem is, and why it is problematic
- Assessing the magnitude of the problem
- Establishing the causes ('drivers') and assessing their relative importance
- Identifying relevant stakeholders, and
- Assessing the likelihood that the problem will persist

The questions set out under the following areas of trends and drivers have been developed to support the definition of problems pertaining bioenergy, in line with the Better Regulation Toolbox framework.

3.2.1 Air quality

A key first step in designing interventions to address bioenergy is to establish the existence and nature of problems in air quality. Subsequently, a methodical review of key drivers linked to bioenergy use can establish whether there is a causal link between the air quality problem and bioenergy, and inform the development of interventions.

Questions to inform the analysis of air quality trends and problem definition are outlined below. The key metric to explore when defining the problem in terms of air quality is particulate matter (including PM_{10} and $PM_{2.5}$). The questions seek to understand how PM concentrations have evolved, including examining any temporal trends, such as seasonal PM peaks or spikes in concentrations during cold weather episodes, which could be largely or partly a result of bioenergy use. The questions also seek to understand the magnitude and scale of the problem by analysis of geographical trends, for example, whether there is evidence of urban PM hotspots that could be linked to a high level of bioenergy use.

- What are the long-term trends in PM_{10} and $PM_{2.5}$ concentrations, at a given geographical level?
- Are there seasonal trends in PM_{10} and/or $PM_{2.5}$?
  - Have PM_{10} / $PM_{2.5}$ peaks been observed in winter and cold weather episodes?
- What geographical trends have been observed in PM_{10} and $PM_{2.5}$ levels?
  - Are PM_{10} / $PM_{2.5}$ levels ubiquitously elevated? Are peaks observed across a broader area?
  - Are there localised PM_{10} / $PM_{2.5}$ hotspots?

[38] https://commission.europa.eu/system/files/2023-09/BRT-2023-Chapter%202-How%20to%20carry%20out%20an%20impact%20assessment_0.pdf

The principal output of these questions is an understanding of the nature of the problem with respect to air quality. Specifically, an understanding of finer temporal and geographical trends can strengthen the causal linkages between air quality issues and drivers in bioenergy use. Furthermore, an understanding of these trends can inform the design of interventions once the other problem drivers have been established. Some aspects of air quality trends to consider when designing interventions are outlined below.

Considerations in choosing policy measures

- **Localised air quality issues**: Localised use restrictions, information campaigns
- **Broader air quality issues**: Depending on bioenergy stock, regional / national operational measures, stock renewal initiatives

3.2.2 Emissions sources

The next step in ascertaining the causal link between air quality issues and bioenergy use is an examination of the role of bioenergy within the broader suite of PM emissions sources. National and local information on the extent of bioenergy use in domestic heating can be matched with geographical trends in air quality. Data on emissions sources can provide an indication of the relative contribution of bioenergy in domestic heating to overall PM emissions compared to other sources, which can be indicative of the extent of air quality issues attributable to bioenergy use. Key questions to consider when examining trends in emissions sources are set out below. Outcomes from the questions that should be considered in designing interventions are also provided. An index of potential data sources can be found in Section 4.1.2.

- To what extent is bioenergy used in domestic heating?
- Is bioenergy in domestic heating a dominant source of PM emissions?
- How do emissions from bioenergy in domestic heating compare with other emissions sources?

Considerations in choosing policy measures

- **Broad use of bioenergy, which is a significant emissions source**: Consider a package of multiple policy measures informed by other drivers
- **Bioenergy is a smaller source of emissions**: Consider localised policies, informed by other drivers, along with measures to address other source sectors

3.2.3 Bioenergy stock and fuels

The causal link between bioenergy and air quality issues can be clarified through analysis of air quality trends and emissions data. Further consideration of underlying drivers, including the specifics of the bioenergy stock and fuels used, can highlight important aspects to consider when determining the policy measures to be applied. Ascertaining the prevalence of bioenergy use among particular communities (for example, rural communities) can provide further evidence of the localised or more ubiquitous nature of the problem, and inform the development of localised or broader interventions. This information can also steer public information campaigns. Furthermore, clarifying the composition of bioenergy appliances used and the fuels typically used can provide a starting point for the development of technical operational interventions, and a baseline for the implementation of stock renewal measures. Questions to consider under this problem driver are set out below, along with outcomes from the questions to consider in intervention design.

- To what extent is bioenergy used in domestic heating?

- Is bioenergy a traditional single source of heat?
  - Are there particular communities (e.g. rural communities) that are particularly reliant on bioenergy?
- What bioenergy fuels are typically used?
- Where do bioenergy users obtain their fuel?

Considerations in choosing policy measures

- **Bioenergy widely used**: National-level operational measures, stock renewal initiatives
- **Localised bioenergy use**: Local stock renewal initiatives, information campaigns
- **Where certain fuels are dominant**: Operational measures (e.g. fuel quality standards), stock renewal initiatives

3.2.4 Role of bioenergy

In designing interventions, it is important to ensure their consistency and coherence with existing legislation and broader environmental priorities. Bioenergy is often promoted as an environmentally sustainable solution via public information drives, and policies, grants, or subsidies, or indirectly promoted through regulations. The existing role and presentation of bioenergy in society can be a driver of the overall challenge, and can inform potential public information campaigns to change how bioenergy is promoted and perceived socially. Questions to explore for this driver, along with considerations in developing interventions, are provided below.

- Is bioenergy currently promoted via other policies, grants or subsidies, public information campaigns, etc.?
- Is bioenergy currently presented as a sustainable or environmentally sound solution?

Considerations in choosing policy measures

- **Where bioenergy is currently promoted**: Review whether current support could better differentiate between more and less polluting forms of bioenergy, to avoid environmentally harmful subsidies
- **Bioenergy presented as a sustainable solution**: National public information campaigns to communicate and clarify environmental trade-offs
- Important to ensure coherence both in legislation and in environmental priorities, as well as coherence across policy fields

3.3 Policy measures

Further information on the four main policy measures to address problems relating to bioenergy is provided in Sections 3.3.1 to 3.3.4. It is important to highlight that wherever possible, a package of suitable measures deploying multiple approaches should be considered over application of individual measures, in order to facilitate greater positive impacts. In addition to the examples shown in the case studies, a database of measures implemented in EU Member States and other European countries has been assembled, and can be found here. Further information resources can be found in section 4, below.

3.3.1 Operational measures

Description These measures focus on how bioenergy appliances are used, and relate to operational aspects such as maintenance procedures applied and the quality of fuel used. Such measures can include operational training for users (mandatory or voluntary), maintenance requirements (such as the need to use registered chimney sweeps, and the frequency of inspections), and the regulation of fuel either sold or used, such as a requirement to only sell seasoned wood.	
Intended positive impacts Application of 'better practice' in the use of existing bioenergy stock. Compared to other policy measures, changes to the use of existing bioenergy appliances could represent low-cost 'easy wins' in addressing the problems. Subsequent reductions in PM emissions, and resulting improvements in ambient air quality, and associated health benefits.	**Potential adverse impacts** Without accompanying funding initiatives, compliance with maintenance, registration and/or fuel quality requirements could place additional financial burdens on bioenergy users, particularly problematic among disadvantaged sectors of society. Could be seen to legitimise bioenergy use, even where it is inappropriate or unnecessary.
Dependencies Determining the exact operational measures to be applied may require coordination of working groups or fora to generate technical evidence.	**Examples** Denmark, Germany, Bavaria, Sweden, France
Levels of implementation Can be implemented at national or local scale. National (ie more centralised) implementation can support the generation of technical evidence needed to identify operational measures.	

3.3.2 Stock renewal

Description Initiatives to replace older, more polluting bioenergy appliances with cleaner bioenergy technologies or alternative technologies. Such measures include incentivising the sale of cleaner operating stock, stove or boiler swap-out schemes (voluntary or mandatory), or incentives for other heating technologies, such as air-source heat pumps or solar PV.

Intended positive impacts	**Potential adverse impacts**
Uptake of cleaner bioenergy stock or non-bioenergy alternatives. Subsequent reductions in PM emissions, and resulting improvements in ambient air quality, and associated health benefits.	Potential transition to technologies or fuels (e.g. natural gas) that raise other (non-air quality) challenges, e.g. CO_2 emissions.
Dependencies Initiatives often rely on subsidies / grants to facilitate stock replacement.	**Examples** Denmark, Germany, Bavaria, Sofia, France
Levels of implementation Can be implemented at national or local scale, although centralised implementation can harness greater investment for grants and scrappage schemes.	

3.3.3 Use restrictions

Description	
Measures aiming to prevent the use of bioenergy appliances altogether. These are typically limited in geographical or temporal scope (or both).	
Intended positive impacts Complete prevention of emissions by removing bioenergy emissions sources. Reductions in PM emissions, and resulting improvements in ambient air quality, and associated health benefits.	**Potential adverse impacts** Without accompanying measures to support (and fund) uptake of non-restricted energy technologies, restrictions could present financial barriers to bioenergy users unable to fund transition themselves, particularly among disadvantaged sectors of society.
Dependencies Restrictions will typically only be feasible where alternative energy sources are accessible. However, this is highly likely to be the case in almost all urban and suburban areas. In addition, support may be needed to assist transition, e.g. capital and installation costs.	**Examples** Denmark, Bavaria, Sofia, France

Levels of implementation Typically applied locally with exceptions and exemptions, either for type of equipment or times at which restrictions apply.

3.3.4 Public information campaigns

Description Initiatives to encourage beneficial behaviours as regards bioenergy use or use of non-bioenergy alternatives. Campaigns could be aimed at the general public but they could also be sector specific, such as the hospitality trade or fuel retailers.	
Intended positive impacts Campaigns may not, in themselves, reduce emissions, but can support implementation of other policy measures and enable greater reductions via a combination of measures.	**Potential adverse impacts** Potential for conflicting messaging generating confusion where bioenergy has previously been promoted as an environmentally sound solution.
Dependencies Potentially limited impact when implemented in isolation. Largely dependent on other accompanying measures to leverage greater emissions reductions.	**Examples** Denmark, Germany, Sweden, France
Levels of implementation Multiple levels of implementation possible. At a geographical level, campaigns can be adopted nationally or locally. Specific sectors using bioenergy could be targeted, or campaigns could be more universal.	

3.4 Evaluation

A key aspect of intervention design is considering how to assess the performance of measures in delivering their intended outcomes. A number of evaluation indicators relevant to measures addressing bioenergy have been identified. While the ultimate aim of measures addressing bioenergy is the reduction of air pollution (specifically, reductions in PM concentrations), it is often difficult to link this environmental performance metric back to specific interventions. This is because in most cases, interventions will lead to environmental improvements through a series of intermediate impacts, and the environmental improvements are likely to be realised over an extended period of time. As such, in evaluating interventions, it is important to consider a number of indicators to complement the environmental parameters:

- **PM emissions**: how have emissions from sources using bioenergy (and, in particular, those sources targeted by the intervention(s)) changed since adoption of the intervention(s)?

- **PM concentrations**: how have PM levels changed in the targeted geographies over the course of the implementation of the intervention(s)?
- **Stock turnover**: how has the use of bioenergy appliances changed over the course of the implementation of the intervention(s)? This is particularly relevant for interventions aiming to replace older appliances or bioenergy altogether
- **Fuel sales**: how have sales of different bioenergy and non-bioenergy fuels evolved since adoption of the intervention(s)?
- **Campaign engagement**: to what extent have targeted sectors and/or the general public engaged with information campaigns? This will likely rely on a set of sub-indicators, such as (where relevant) information on survey responses received, number of website visits, etc.
- **Subsidies awarded**: what amounts have been awarded in subsidies, and for what purpose? This information is relevant to policies seeking to renew or replace bioenergy appliances where subsidies and grants have been awarded

Further guidance on monitoring the application of interventions can be found in Chapter 5[39] of the European Commission's 'Better Regulation' toolbox

[39] https://commission.europa.eu/system/files/2023-09/BRT-2023-Chapter%205-Monitoring%20the%20application%20of%20interventions_0.pdf

4 Resources

The following sections provide direction to useful sources to support the design of interventions. Section 4.1.1 signposts to key pieces of EU legislation and policy which would form the backdrop of any further intervention design. Sources of data and information to be considered in analysing problem drivers and trends, particularly with respect to air quality and emissions, are identified in Section 4.1.3. Links to guidance on specific pieces of EU legislation can be found in Section 4.1.4, while relevant studies and reports on bioenergy in the EU are listed in Section 4.1.5.

4.1.1 EU legislation and policy

- European Green Deal
- Zero Pollution Action Plan
- Ecodesign Directive (2009/125/EC)
- Ecodesign regulation for solid fuel boilers (EU) 2015/1189
- Energy labelling regulation for solid fuel boilers (EU) 2015/1187

4.1.2 Data and information

4.1.3 Air quality and emissions data

- EEA national air pollutant emissions data viewer 2005-2021
- National Emission reductions Commitments (NEC) Directive emission inventory data
- EEA European city air quality viewer
- JRC Urban $PM_{2.5}$ Atlas
- EEA Air Quality e-Reporting
- EEA Air quality statistics

4.1.4 Policy guidance

- Frequently asked questions on the Ecodesign measures for manufacturers and importers (2023)
- Frequently asked questions on the energy labelling measures for suppliers and dealers (2023)
- European Commission guidelines: Ecodesign requirements for heaters, and solid fuel boilers (2018)

4.1.5 EU studies and reports

- The use of woody biomass for energy production in the EU (2021)
- Sustainable and optimal use of biomass for energy in the EU beyond 2020 (2017)
- EU Clean Air Technology Hub: Final clean air tech report on development and greater uptake of cleaner solid fuel household heating solutions (2023)

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