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Air quality in the Danube macro-region

Towards a coordinated science-based approach in support of policy development

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Quantifying the causes of air pollution to support the development of abatement strategies
A study on selected EU cities in the Danube macro-region concludes that energy production/industry, agriculture, residential heating and transportation are the main sources of pollution. The long –range transport of pollutants from within and outside the EU-28 has a considerable impact in certain cities while in others local emissions are the key to reducing urban pollution. Measures at different policy levels to address the issues identified are analysed and the cross-policy implications are discussed.

Contents

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Executive summary

Policy context

Air quality in the Danube macro-region is a serious problem. Exceedances of PM_{10} and precursor gases, NO_2 or SO_2, have led to infringement procedures in almost all of the EU-Danube Member States and some of them have been referred to court.

The Danube macro-region encompasses one of Europe's air pollution "hot spots" where the development of a strategy to achieve the standards laid down in EU legislation requires appropriate diagnosis with the most suitable tools.

Several pilot urban areas in EU Member States, representing different situations within this macro-region, were chosen as a case study. A detailed analysis of the causes of pollution in eight cities (Zagreb, Budapest, Sofia, Vienna, Bucharest, Munich, Prague and Bratislava) was then used to identify measures to counter the exceedances of limit values (Directives 2008/50/EC and 2004/107/EC) and to comply with national emission ceiling (NEC) obligations (Directive 2016/2284/EU).

Key conclusions

Due to the complexity of air pollution processes coordinated actions should be taken at **different levels**: local, regional, national, European and international. To improve the effectiveness of measures, it is essential to involve all the relevant actors and assess possible **interactions between sectorial policies**.

At the local level, measures are required to control diffuse emission sources from **domestic heating** and **traffic**. In these sectors the impact of technological measures (substitution of fleet vehicles and the use of efficient stoves) is uncertain. Such measures are likely to be insufficient to bring emissions to acceptable levels and should, therefore, be accompanied by **structural and behavioural changes**. Reducing ammonia emissions in the **agriculture** sector would be an efficient way to abate secondary PM_{10} and $PM_{2.5}$.

To reduce the impact of the long-range transport of pollutants in the eastern Danube macro-region, reinforcing international cooperation within the framework of the Convention on Long-range Transboundary Air Pollution (CLRTAP) and the United Nations Framework Convention on Climate Change (UNFCCC) would help to advance the implementation of air quality and climate change policies in **non-EU Eastern European countries**.

Based on the outcome of this study, better integration of sectorial policies (**EUSDR priority areas**) in the Danube macro-region would improve the effectiveness of the measures. Since the impact of air pollution is greater in urban areas, where the majority of the population resides, initiatives like the **Partnership on Air Quality** in the EU Urban Agenda, could help to involve relevant actors, access funding and achieve consensus for future actions. In this context, the PA6 Task Force on Air Quality could play a catalysing role for policy implementation.

Main findings

An analysis was carried out to quantify the contribution made by sources to $PM_{2.5}$ and the geographic areas from where the pollution originates. The SHERPA tool developed by the JRC was used to model $PM_{2.5}$ concentrations in the main cities in the Danube macro-region: Bratislava, Budapest, Bucharest, Munich, Prague, Sofia, Vienna and Zagreb. The information was then integrated with the outcome of a previous source apportionment study.

Contributions by the main emission sources are as follows:

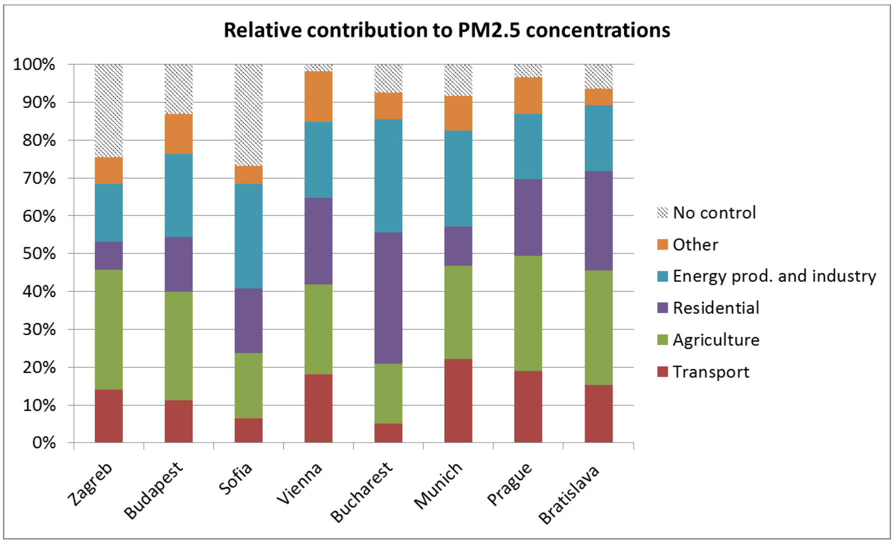
Agriculture accounts for a considerable share of $PM_{2.5}$ concentrations in cities: between

16 % and 32 % of urban $PM_{2.5}$ concentrations originates from agricultural activities.

Energy production and industry also play an important role, with contributions ranging from 15 % to 30 % of the urban $PM_{2.5}$ concentrations.

Residential heating makes variable contributions throughout the Danube macro-region ranging from 10 % to 35 %. Finally, transport contributes between 10 % and 25 % playing a smaller but substantial role compared to the other sectors.

Reductions in the yearly $PM_{2.5}$ concentrations by reducing the emissions from different sources



Source: JRC analysis

About one-quarter of the $PM_{2.5}$ fraction in Sofia and Zagreb originates from beyond the EU-28 boundaries or is of natural origin. Thus, action across a broader area is required to abate concentrations in these cities. On the contrary, reductions in local emissions could lead to sizeable improvements in Munich and Vienna with the main efforts focused on transport, energy/industry and residential heating.

Related and future JRC work

This work contributes to the EUSDR PA6 Task Force on Air Quality (WPK ENVIRONMENT-3575, project MARREF-348). In addition, source apportionment and integrated assessment tools to support air quality management are developed and tested within the framework of FAIRMODE (WPK IAM-SUL 2002, project SUL 705).

Quick guide

- The number of premature deaths due to air pollution in the EU is ten times higher than those caused by traffic accidents.
- Directives 2008/50/EC and 2004/107/EC define limit and target values for legislated pollutants.
- When air pollution exceeds the established thresholds Member States and local authorities draft air quality plans to abate pollution levels within a given term.
- In case of non-compliance, an infringement procedure is launched by the Commission and when the Member State fails to make appropriate commitments it may be referred to the Court of Justice of the European Union.
- The tools developed by JRC provide valuable support to designing pollution abatement strategies at local and regional levels.
- The approach adopted in this study could be extended to other macro-regions.

1 Introduction

1.1 The Danube macro-region

The EU Strategy for the Danube Region (EUSDR), launched in 2010 (European Commission, 2010) and approved by the Council in 2011, encompasses nine EU Member States: Germany, Austria, the Slovak Republic, the Czech Republic, Hungary, Slovenia, Croatia, Romania and Bulgaria, and 5 non-EU countries: Serbia, Bosnia and Herzegovina, Montenegro, the Republic of Moldova and Ukraine (Figure 1).

The EUSDR aims at promoting the sustainable development of a macro-region that counts 115 million inhabitants by tackling key topics that require working across borders and national interests. The identified key issues are mobility, energy, water, biodiversity, socio-economic development, education, culture and safety. The strategy is structured in four pillars: "Connecting the region", "Protecting the environment", "Building prosperity" and "Strengthening the region" subdivided in 11 priority areas (PA). Environmental protection of natural resources such as biodiversity, air quality and soil is allocated under the sixth thematic PA.

Figure 1: Countries and regions that compose the Danube macro-region

Source: EUSDR website http://www.danube-region.eu/about

The Joint Research Centre (JRC) provides scientific support to the EUSDR both by supporting decision-makers and other stakeholders to identify the policy needs and actions for the implementation of the strategy and by promoting cooperation across the scientific communities of the Danube Region. The Scientific Support to the Danube Strategy initiative is sub-divided into different flagship clusters and activities.

The Danube Air Nexus (DAN) is one of the flagship projects of the EUSDR coordinated by the JRC aiming at protecting human health, ecosystems and climate from the impacts of atmospheric pollution.

1.2 Outline of the study

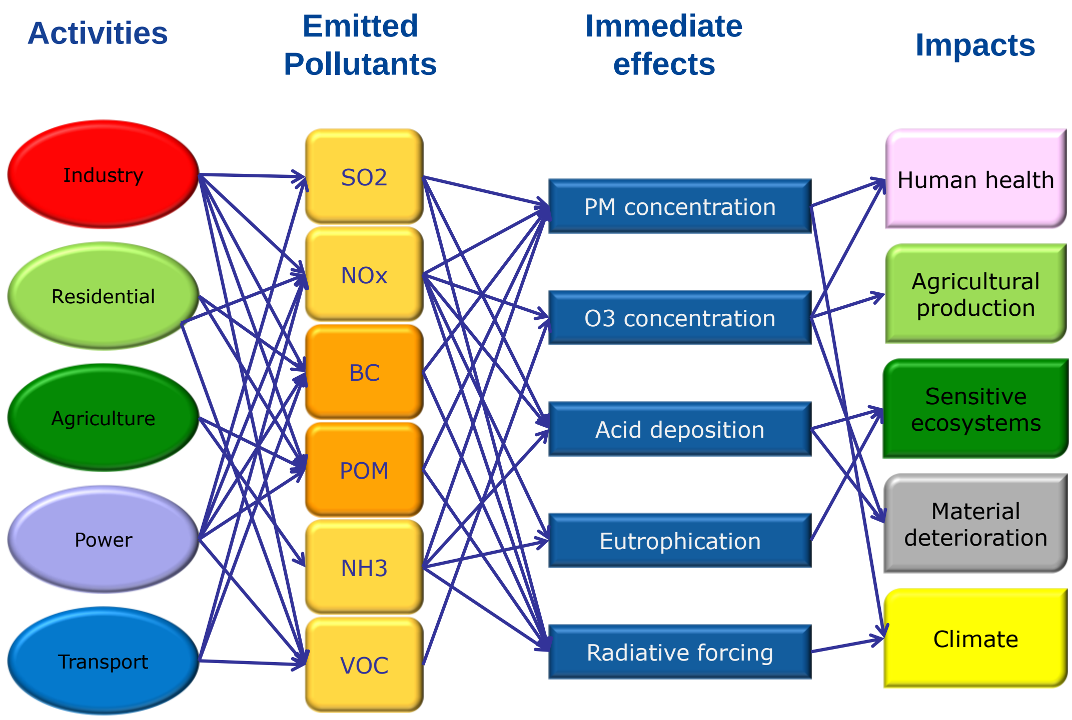
The Danube region encompasses one of the air pollution "hot spots" in Europe and is also influenced by another one located in southern Poland. Supporting the development of a strategy to achieve the standards laid down in the EU legislation and the PA6 objectives requires appropriate diagnosis with the most suitable tools to support the definition of the strategies. From the river sources to the outlet, the Danube macro-region spreads out through countries with different levels of emissions, due to the different kind of technologies and fuels used and to different levels of implementation of environmental policies. In addition, within each sub-basin, gradients from rural–mountainous areas to flat populated areas impacted by different type of sources are present.

Particulate matter (PM) has been chosen for this study because it impacts on both health and climate and is the regulated pollutant with the highest number of exceedances in the area. For a comprehensive understanding of the PM pollution causes it is also necessary to assess its precursor gases (NO_2, SO_2 and NH_3). In order to capture the variability across the macro-region, some cities in EU Member States were chosen as case studies. A thorough evaluation of the sources of PM and its precursors has already been made for three of these cities using source apportionment and Lagrangian models. In the present study, the SHERPA integrated assessment tool is used to make a detailed analysis of the causes of pollution in eight EU cities, providing the basis for the identification of measures at the local, regional, European and international level to improve urban air quality.

1.3 Air pollution has serious consequences for health and the economy

The concentration of pollutants in the atmosphere is the consequence of emissions from human activities and natural processes and their interaction with the meteorological variables.

Figure 2: Understanding the complexity: sources, pollutants and impacts of air pollution.



Source: JRC

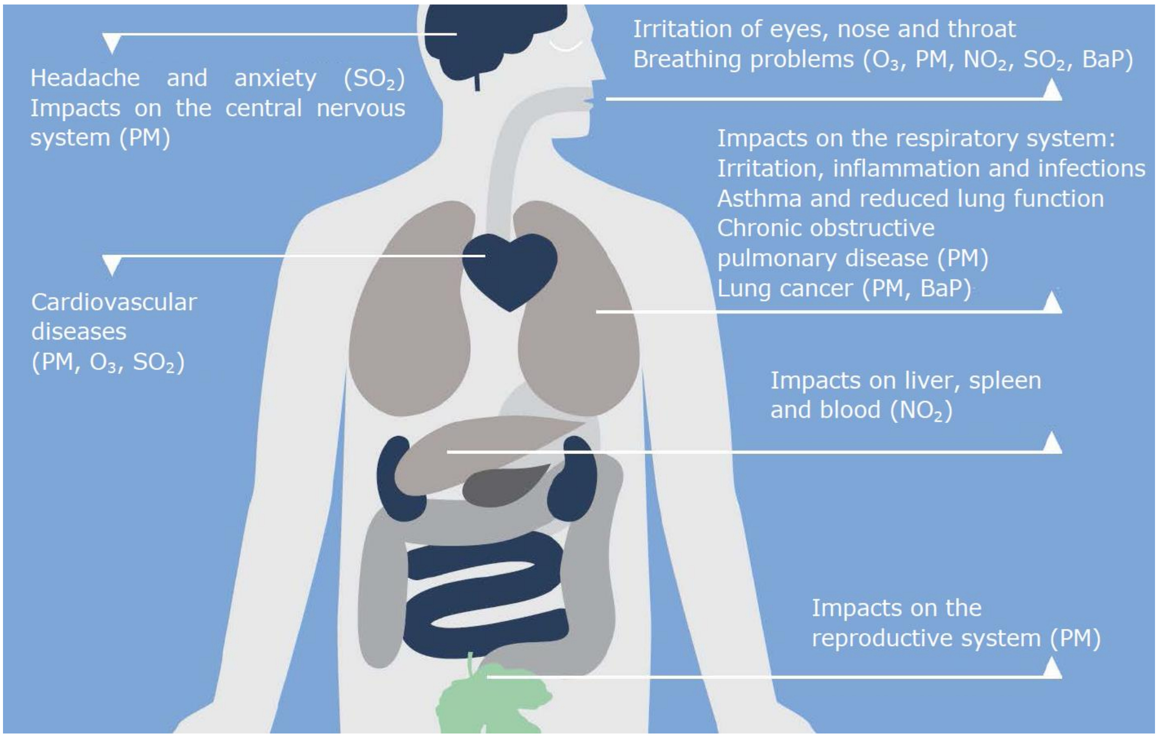
Substances maintaining their chemical composition after being emitted in the atmosphere are referred to as primary pollutants, while pollutants that undergo chemical transformations are called secondary. In general, primary pollutants are more likely to be found near their sources. Pollutants transported by air masses have time to react (depending on the type of pollutant and the atmospheric conditions). For that reason, long-range transport of pollutants is often associated with secondary pollution. Air pollution sources contribute to varying extents to secondary aerosol formation: biomass burning and residential heating, road and off-road traffic, industry, and agriculture. Inorganic aerosol formation processes (which lead to production of ammonium nitrate or ammonium sulphate) are generally better known than organic aerosols that involve a large number of partly unknown chemical species.

Atmospheric pollution impacts on different receptors ranging from human health and economic activities (agriculture, materials) to ecosystems (acidification, eutrophication) and eventually long-term global processes such as those governing climate (Figure 2).

1.3.1 What is the relevance of air pollution for the protection of human health and the ecosystems?

It is well documented that high levels of atmospheric pollutants have a negative impact on human health and the environment through ecosystem acidification and eutrophication (Figure 3, Table 1). Studies reviewed by the World Health Organization (WHO) provide evidence proving that particulate matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and ozone (O_3) cause considerable adverse health impacts (WHO 2013a, 2013b).

Figure 3: Health impacts of air pollution



Source: EEA, 2013.

$PM_{2.5}$ and PM_{10} affect the respiratory and cardiovascular system of large groups of the general population, leading to an increased risk of premature mortality and thus a reduced life expectancy. O_3 affects respiratory and cardiorespiratory mortality. Adverse effects of O_3 on asthma incidence and lung-function growth have also been reported. Short-term exposure has been shown to have adverse effects on all-cause, cardiovascular and respiratory mortality. Effects on mortality and morbidity due to NO_2 exposure have been observed even in areas where concentrations were at or below the current standard values (European Commission, 2013a; US EPA, 2011).

Premature deaths attributed to outdoor air pollution in the United Nations Economic Commission for Europe (UNECE) region in 2012 (including North America) totalled 576,000. The number of premature deaths due to air pollution in the EU is ten times higher than those caused by traffic accidents. (Eurostat, http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm)

In 2010 ambient PM air pollution was the ninth cause of disease burden globally while in Europe and North America was rated between the 11th and 14th cause of death and disease (Lim et al., 2012). Such impact of PM pollution has been associated with the high share (ca. 75 %) of the European urban population exposed to annual PM_{10} concentrations that exceed the World Health Organization (WHO) air quality guideline concentrations (WHO, 2006; EEA, 2015a).

In Eastern Europe, the Caucasus and Central Asia (EECCA), there are many areas where the available monitoring data are insufficient to properly quantify the impact of air pollution on health (Maas and Grennfelt, 2016).

1.3.2 What are the costs associated with air pollution?

The economic costs due to premature deaths caused by air pollution in Europe (UNECE region) have been estimated to be EUR 1,000 billion, while those due to illness caused by air pollution, add up to EUR 100 billion. For half the UNECE countries, the total health costs of air pollution represent more than 10 % of GDP (WHO, 2015).

Table 1: Main outdoor air pollution impact categories

Impact category	Impact description	Market impacts	Non-market impacts
Health	Mortality from lung cancer, cardiovascular and respiratory diseases due to high concentrations of PM2.5 and ozone		Premature deaths
	Morbidity from lung cancer, cardiovascular and respiratory diseases due to high concentrations of PM2.5 and ozone	Increased health expenditure Changes in labour productivity due to absence from work for illness	Disutility (e.g. pain and suffering) due to illness
	Other health impacts, from e.g. low birth weight, pregnancy Direct health impacts from NO2		
Agriculture	Damages to crop yields due to high concentrations of ozone	Changes in crop yields	
Tourism, leisure	Changes in tourism and leisure due to e.g. reduced visibility, damages to cultural heritage and health risks		
Ecosystems, biodiversity, forestry	Degraded air and water quality, reduced ecosystem health		

Source: OECD, 2016

In the EU, health-related costs associated with air pollution are expected to decline under a business-as-usual scenario (baseline projection) to EUR 200–730 billion in 2030 (2005 prices) (European Commission, 2013). The corresponding economic benefits of the proposed national emission ceilings of the EU air policy package can be monetised, corresponding to about EUR 40–140 billion, with the costs of pollution abatement to implement the package estimated at EUR 3.4 billion (per year in 2030). The monetised benefits will therefore be about 12 to 40 times greater than the costs incurred (European Commission, 2013).

Cost-benefit analyses of abatement policies show that overall societal benefits in the medium-long term are higher than the costs for some sectors in the short-term. Certain positive effects on economy can already be observed in the short-term, for example, the reduction in absence from work due to the improvement of the population's health. In the long term, environmental policy boosts the economy as a consequence of a more efficient use of resources (Bollen et al., 2011; European Commission, 2013).

If the existing policies were to be fully implemented, the number of life-years lost due to PM in the EU would fall by 40 % between 2005 and 2030. By implementing best available technologies it would be possible to achieve a further 20 % reduction at an additional cost of EUR 50 billion, equivalent to 0.3 % of GDP (Amann, 2014).

1.4 The legislative framework

Different levels of legislation on air quality, from international conventions to national laws, including regional or city authorities' ordinances, coexist within the Danube macro-region.

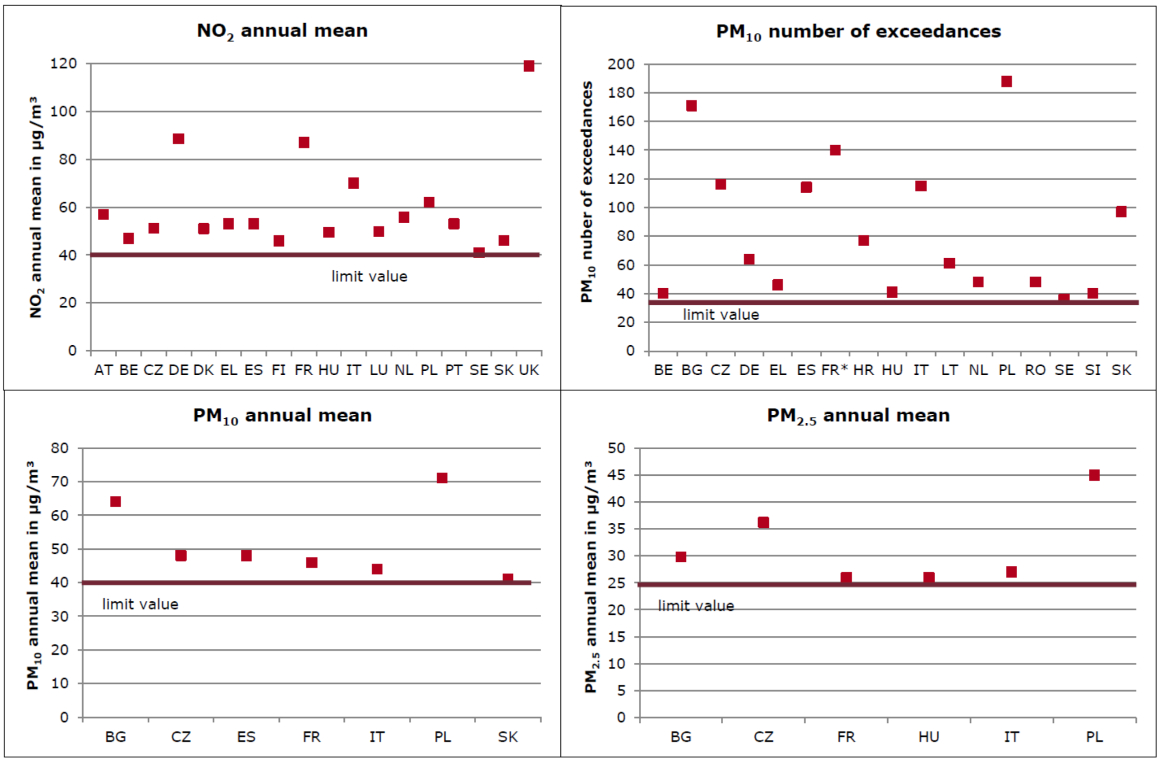
The European air quality policy encompasses: the Air Quality Directives (AQD, Directives 2008/50/EC and 2004/107/EC), the National Emission Ceilings Directive (NECD, Directive 2016/2284/EU) and more specific instruments oriented to particular pollution sources such as the Industrial Emissions Directive 2010/75/EU (IED), the Medium Combustion Plant Directive 2015/2193/EU (MCPD) and directives for specific products e.g. the Directive on sulphur content of liquid fuels 1999/32/EC, the Directive on the quality of liquid fuels 2003/17/EC, Commission Regulation (EC) No 692/2008 on Euro 5 and Euro 6 standards of light vehicles and Regulation (EC) No 595/2009 on the Euro VI standard for heavy duty vehicles. As regards international agreements, the most important in Europe and the Northern Hemisphere is the Convention on Long-range Transboundary Air Pollution (CLRTAP) and globally the Framework Convention on Climate Change (UNFCCC), which, in addition to greenhouse gasses (GHG), covers emissions of certain pollutants. More details about these legislative instruments are given in Annex 1.

2 Current status of air quality in the Danube macro-region

In this chapter the levels and exceedances of PM (PM_{10} and $PM_{2.5}$) and two gaseous precursors (NO_2 and SO_2) in Europe and in the Danube macro-region are discussed on the basis of the data reported to the European Commission and the European Environment Agency (EEA) (e-reporting).

At the European level, PM_{10} and NO_2 are the most critical pollutants among those regulated by the AQD (Figure 4).

Figure 4: Maximum levels of PM and NO_2 in the EU Member States with exceedances in 2014 (country alpha-2 codes ISO 3166-1).



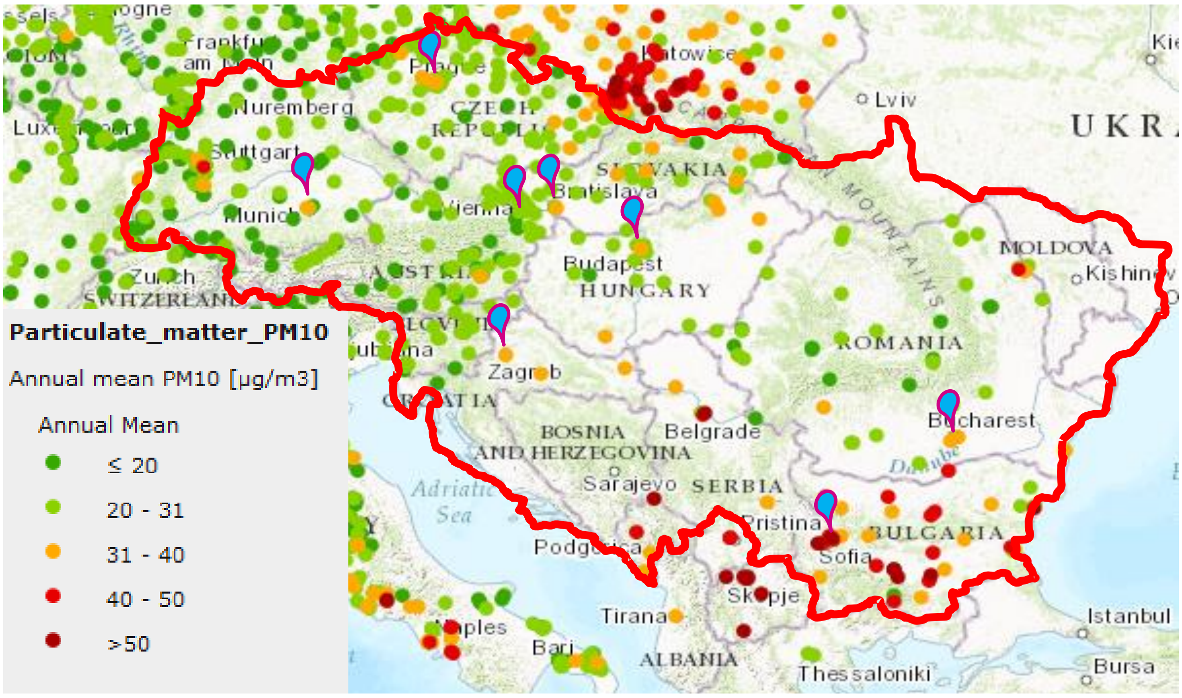
Source: Nagl et al., 2016

There are PM_{10} hotspots in Eastern European countries, parts of Italy and the Benelux. In the Danube macro-region the highest levels are observed in the south-east while the northern area is adjacent to the southern Poland hot spot (Figure 5). While PM levels have fallen in western European countries, no significant changes are observed in Eastern Europe.

NO_2 levels are high throughout Europe, particularly in urban areas. The same pattern, with the highest levels occurring in the main cities, is observed in the Danube macro-region (Figure 6), where exceedances are more frequent in the western sector (from Tyrol to Baden-Württemberg). In addition, NO_2 shows a general decreasing trend in certain areas while in others it remains stable at high levels.

In 2014, limit values of these two pollutants were exceeded in about two thirds of the EU Member States. Thus, the European Commission launched infringement procedures against 23 of the 28 Member States. In addition, 10 Member States have been referred to the Court of Justice for exceeding the PM_{10} limit values.

Figure 5: PM_{10} annual mean in Danube Macro-region (outlined in red) in 2013; the cities included in this study are marked with map pins.

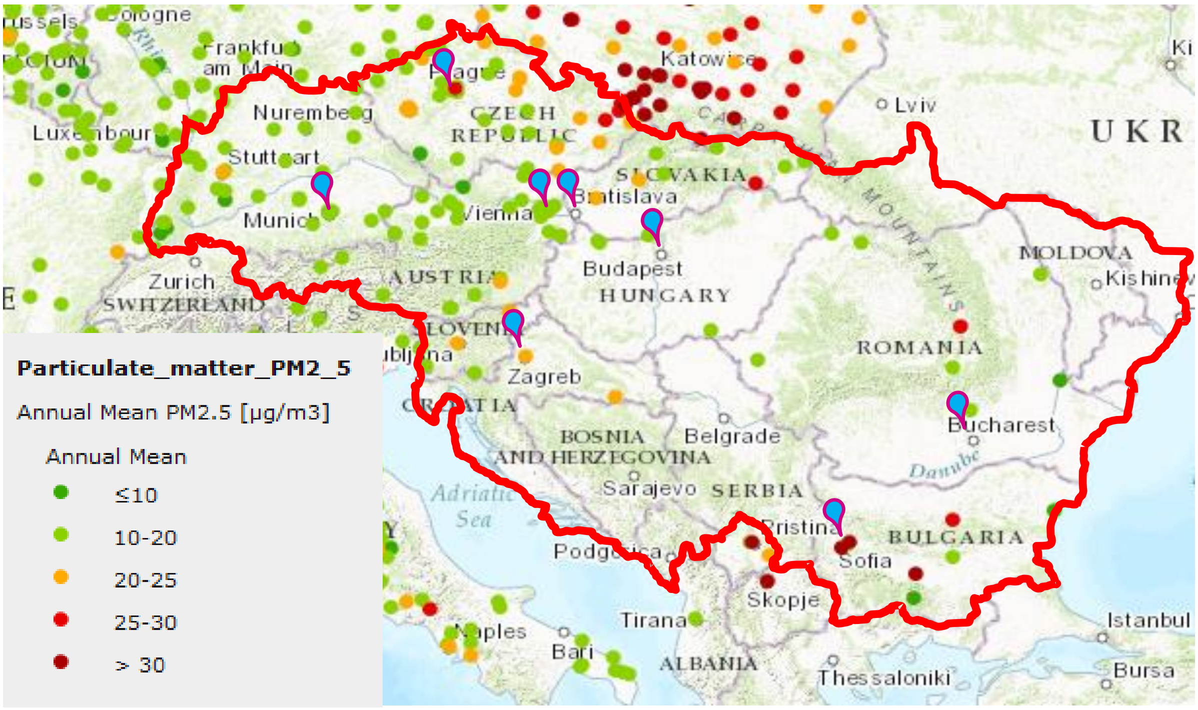


Source: EEA modified by JRC; http://www.eea.europa.eu/themes/air/interactive/

Figure 6: NO_2 annual mean in Danube Macro-region (outlined in red) in 2013; the cities included in this study are marked with map pins.

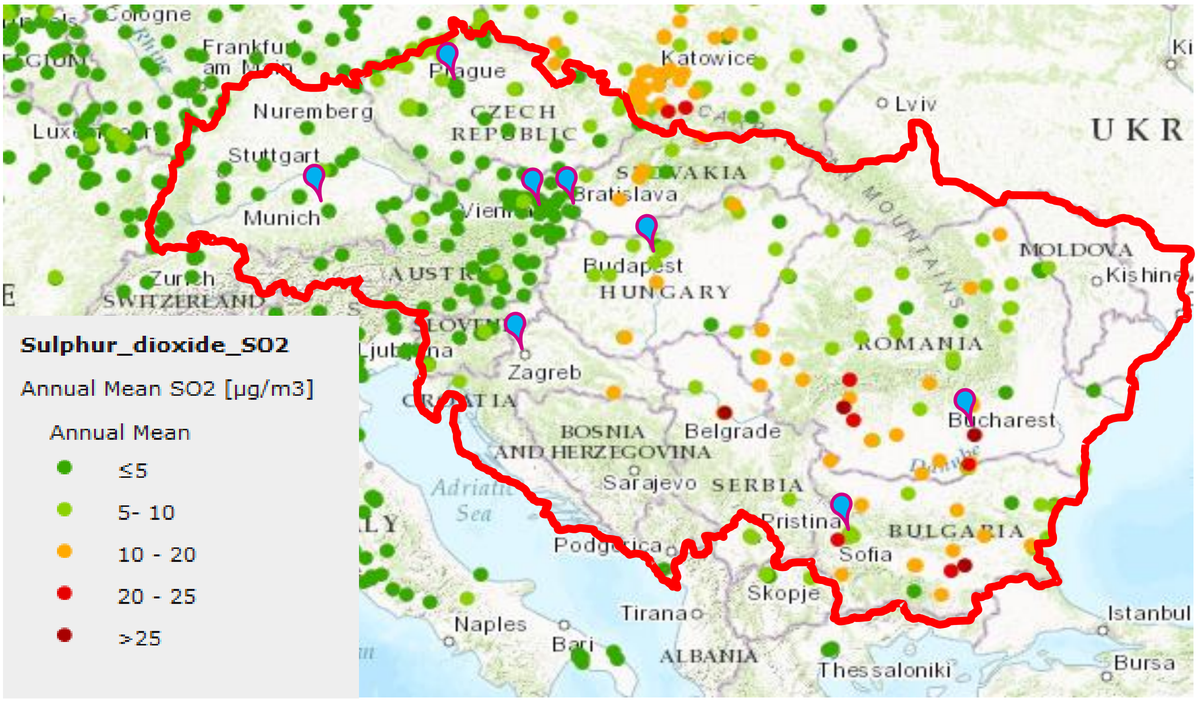
Source: EEA modified by JRC; http://www.eea.europa.eu/themes/air/interactive/

Figure 7: $PM_{2.5}$ annual mean in Danube Macro-region (outlined in red) in 2013; the cities included in this study are marked with map pins.



Source: EEA modified by JRC; http://www.eea.europa.eu/themes/air/interactive/

Figure 8: SO_2 annual mean in Danube Macro-region (outlined in red) in 2013; the cities included in this study are marked with map pins.



Source: EEA modified by JRC; http://www.eea.europa.eu/themes/air/interactive/

Box1: Infringement procedures

In case of non-compliance with the AQD, an infringement procedure is launched by the Commission; if the Member State fails to make the appropriate commitments it may be referred to the Court of Justice of the European Union.

— Danube macro-region Member States for which infringement procedures have been launched: AT (NO_2), BG (SO_2), CZ (PM_{10}), DE (NO_2), HU (PM_{10}), RO (PM_{10}), SK (PM_{10}), SI (PM_{10});

— Danube macro-region Member States that have been referred to the court: BG (PM_{10}) and SI (PM_{10}).

Source: Nagl et al., 2016

Even though the number of $PM_{2.5}$ monitoring sites is much lower than those for PM_{10} and there is little or no coverage in many areas, $PM_{2.5}$ in the Danube macro-region presents a similar geographic pattern to that of PM_{10} (Figure 7).

In 2014, the $PM_{2.5}$ target value was exceeded in six Member States, three of which are part of the Danube macro-region: BG, CZ and HU. The highest levels are observed in Poland along the Danube macro-region border.

SO_2 is the pollutant with the greatest decline in recent decades and current levels in Europe are well below the limit values. The only hot spots are located in southern Poland and in the southern Balkan Peninsula. In the Danube macro-region there is a clear NW-SE gradient of SO_2 concentrations (Figure 8). At present, BG is the only country with an infringement procedure for SO_2 exceedance.

3 Sources of pollution in the Danube and the role of extra EU areas

In 2015, a comparative analysis of the contribution of sources and geographic areas to particulate matter was conducted in three cities in the Danube macro-region: Budapest, Sofia and Zagreb (Belis et al., 2015). In that pilot study the sources were estimated using source apportionment receptor models combined with Lagrangian models for the analysis of trajectories. Receptor models computed the contribution from each source on the basis of the measured chemical composition of PM. Such results were complemented by Lagrangian trajectory model runs to determine the geographical origin of specific sources. In this section a complementary study covering a wider group of cities and by means of the SHERPA tool is presented. The information gathered in the two studies is then summarised and discussed.

3.1 The SHERPA tool

The SHERPA (Screening for High Emission Reduction Potential on Air, (Thunis et al., 2016) tool has been developed to identify the most efficient scale to act in a European context where a multi-level governance approach is needed. SHERPA allows for a rapid exploration of potential improvements in air quality resulting from national/regional/local emission reduction measures.

The tool has been developed by the JRC with the aim of supporting national, regional and local authorities in the design and assessment of their air quality plans. The tool is based on simplified relationships between emissions and concentration levels, which can be used to answer the following questions:

— What is the potential for local action in my region?

— What are the priority activities, sectors and pollutants on which to take action? and,

— At what scale (national, regional, local, etc.) should I act to be more efficient?

The SHERPA tool is distributed with default EU-wide data for emissions and source-receptor relationships at 7x7 km^2 spatial resolution. Current data refer to 2010, and are related to a specific air quality model and emission inventory (Menut et al., 2013). It is important to mention that the SHERPA results closely reflect the set of input data used, both in terms of emissions and the underlying air quality model (in this case CHIMERE).

In this study, SHERPA has been used to analyse the main sources of pollution contributing to air quality in a set of the major cities in the Danube macro-region (Table 2).

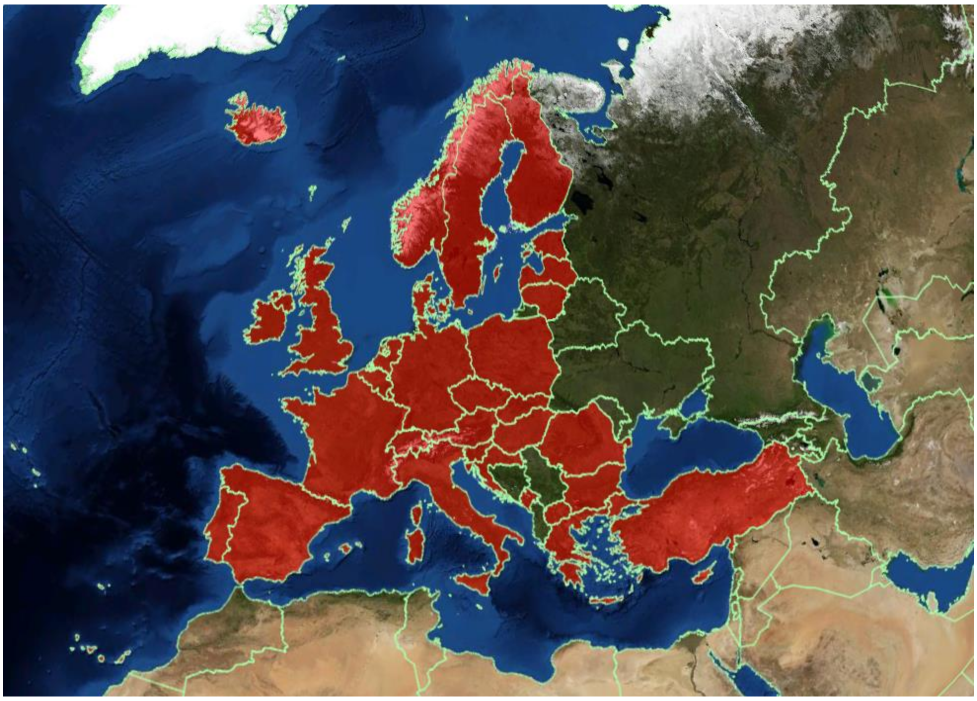
3.2 SHERPA assumptions

As illustrated in Figure 9, the current SHERPA domain only encompasses EU28 Member States plus some additional neighbour countries (red highlighted areas). Therefore, in this study, the Danube macro-region is represented by the EU member states within it, as indicated in Figure 10. Only the contributions from the red area in this figure are considered when assessing the impact of the Danube macro-region on each city.

The SHERPA analysis is performed on eight cities within the Danube macro-region, as listed in Table 2. Only cities in EU Member States were selected for the study because of the SHERPA domain constraints. The urban areas are defined according to the NUTS3 classification standard, which may result in urban areas differering in size from country to country (Figure 11).

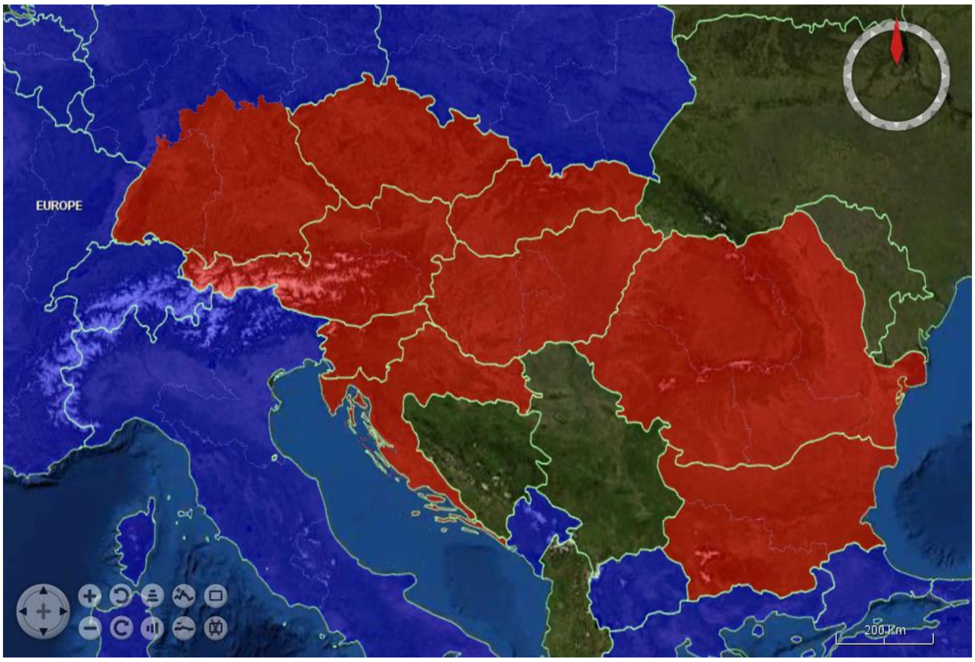
To compute the contribution from different geographical areas and from different activity sectors, the cities' annual $PM_{2.5}$ concentrations are modelled with SHERPA, taking into account a range of geographical areas and activity sectors as explained below.

Figure 9: SHERPA areas in which emission reductions are applied to quantify the Danube region impacts.



Source: JRC analysis

Figure 10: SHERPA areas in which emission reductions are applied for EU wide impacts.



Source: JRC analysis

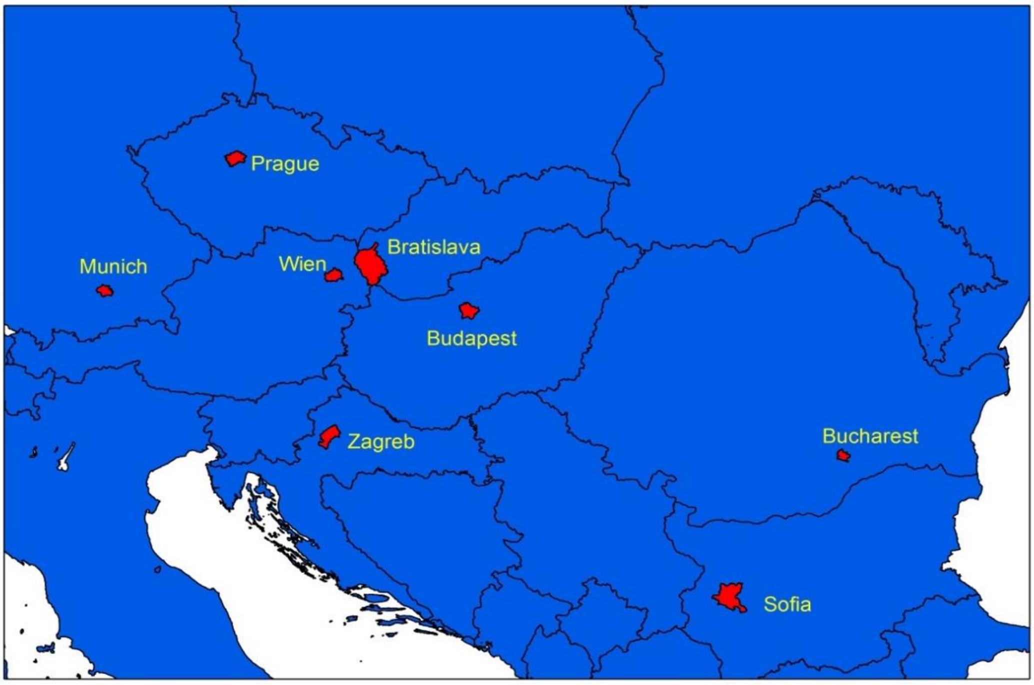
— **Geographical areas**: spatial areas with reduced emission scenarios of increasing dimensions (city, region, Danube area, country, EU28) are selected to quantify their impacts on the $PM_{2.5}$ concentrations in every studied city.

— **Activity sectors**: specific emission reductions are applied to the transport, agriculture, residential, energy production and industry sectors.

Table 2: List of cities considered for the SHERPA analysis with their coordinates

	LAT	LON
Zagreb	45.8	15.9
Budapest	47.4	19.1
Sofia	42.6	23.3
Vienna	48.2	16.3
Bucharest	44.4	26.1
Munich	48.1	11.5
Prague	50.0	14.4
Bratislava	48.1	17.1

Figure 11: Geographical location of cities considered in the SHERPA analysis (NUTS 3).

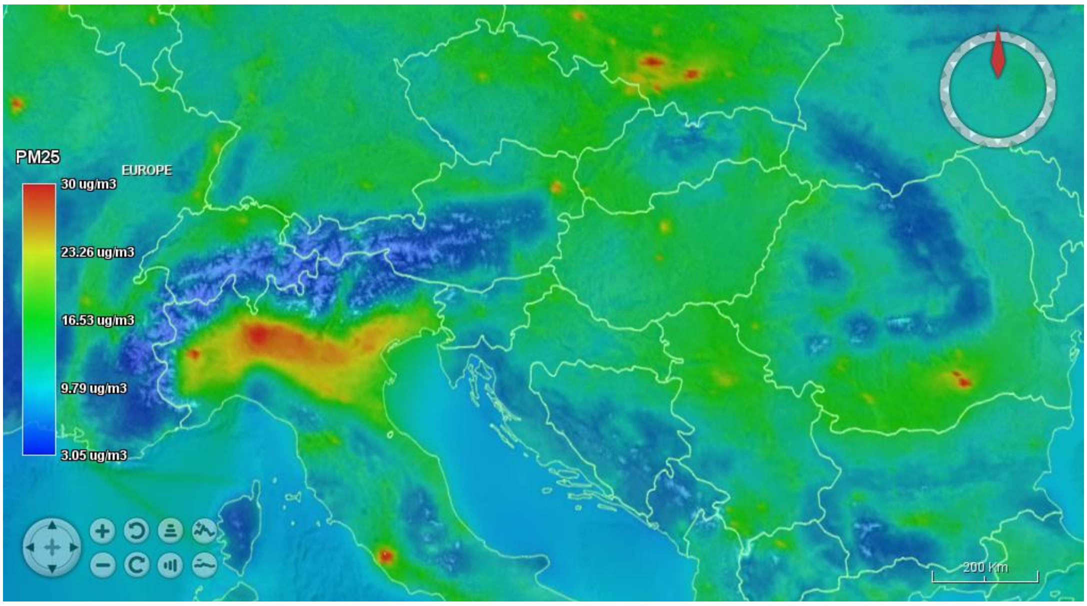


Source: JRC analysis

3.3 Results

Figure 12 shows the annual $PM_{2.5}$ concentrations ($\mu g/m^3$) as modelled using SHERPA. The percentages discussed in this section refer to these modelled concentrations.

Figure 12: Modelled $PM_{2.5}$ yearly average concentrations for the considered domain.

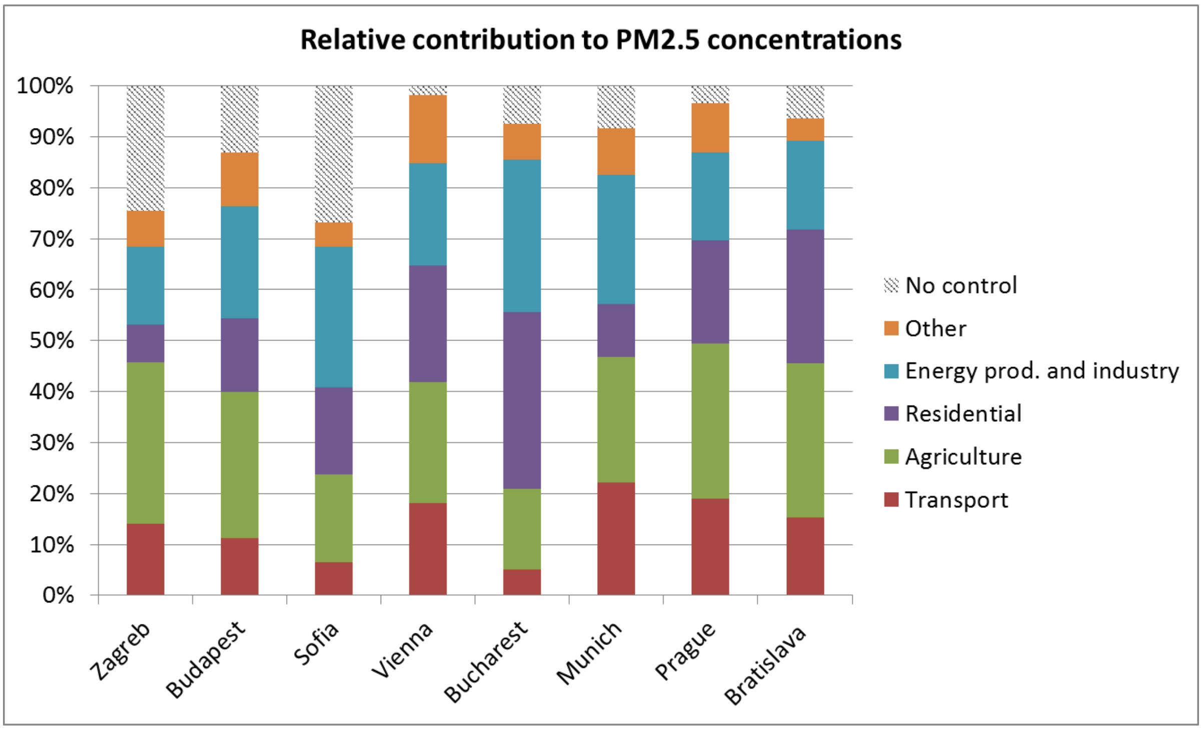


Source: JRC analysis

An overview of the impact on $PM_{2.5}$ concentrations in the selected cities within the Danube macro-region, resulting from emissions reductions in different sectors and geographical areas is shown in Figure 13. The main points to highlight are:

- **Agriculture** accounts for a considerable share of $PM_{2.5}$ concentrations. Between 16 % and 32 % of urban $PM_{2.5}$ concentrations originates from agricultural activities. NH_3, a gaseous $PM_{2.5}$ precursor, is emitted from agricultural activities outside cities and only contributes to urban $PM_{2.5}$ concentrations after transportation and reacting in the atmosphere with other gaseous precursors (NO_2, SO_2) derived from other sources, to produce secondary $PM_{2.5}$. Measures to address agricultural emissions must be coordinated at regional or national level or even on a larger scale. In addition, to be effective those measures should also take into account emissions of precursors from transport, energy production and industry (see section 4).
- **Energy production and industry** also play an important role, with a contribution ranging between 15 % and 30 % of the urban $PM_{2.5}$ concentrations.
- **Residential heating** contributes from 10 % to 35 % while, unlike in western EU cities, **transport** plays a smaller role, between 10 % and 25 %.
- The "**no control**" fraction is that resulting from natural emissions or from emissions originating in areas not highlighted in Figure 9 while **"other"** includes the following sectors: waste management, extraction of fossil fuels and solvents. This remaining fraction ranges between 2 % and 27 %, with very high values in Zagreb and Sofia. This could mean that long-range trans-boundary pollution, (also from outside the EU-28) could be very important for these cities.

Figure 13: Reductions in the yearly average $PM_{2.5}$ concentrations resulting from emission reductions for different sources



Source: JRC analysis

Given the relevance of secondary pollutants, which are often transported over long distances, it is important to analyse the contribution to air pollution in terms of geographical origin.

The analysis has been carried out separately for each city, considering emissions from areas which are growing progressively (from the city to the region, Member State, Danube area, EU-28). The contribution of local emissions to local concentrations is then estimated. Using this approach it is possible to highlight when coordination with neighbouring regions or Member States is necessary to abate local pollution.

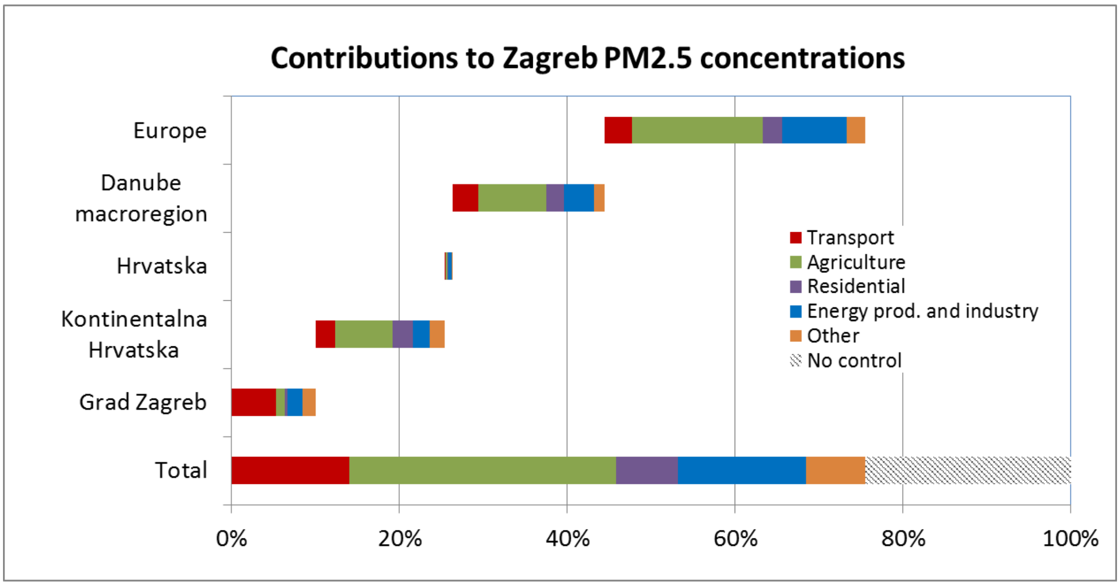
In the following sections, cities are grouped on the basis of the impact of local emissions on local $PM_{2.5}$ concentrations.

Zagreb and Sofia: reductions in local emissions show a limited impact on concentrations

Figures 14 and 15 show the potential $PM_{2.5}$ abatement in relative terms, arranged by activity sectors and by geographical entities, in Zagreb and Sofia, respectively.

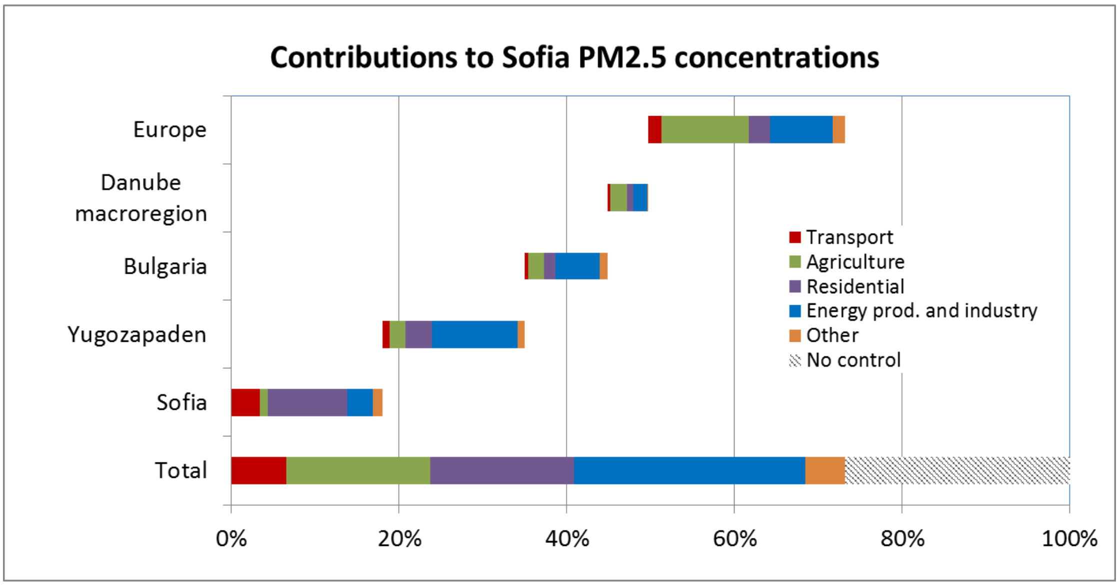
In both cities, strategies limited to local emission reductions alone would not be sufficient to substantially improve air quality. Cutting local emissions only improves air quality by 10 % in Zagreb and by less than 20 % in Sofia. According to the present study, local emission strategies should mostly focus on traffic in Zagreb, and on residential heating in Sofia. Strategies extending over the whole Danube basin would be required to significantly curb the current $PM_{2.5}$ concentrations in Zagreb while national strategies are sufficient in the case of Sofia. However, for both cities, it is worthwhile noting that the "no control" contribution is high, indicating sizeable contributions from areas outside the EU-28 that are not analysed by SHERPA).

Figure 14: Contributions to $PM_{2.5}$ concentrations in Zagreb



Source: JRC analysis

Figure 15. Contributions to $PM_{2.5}$ concentrations in Sofia

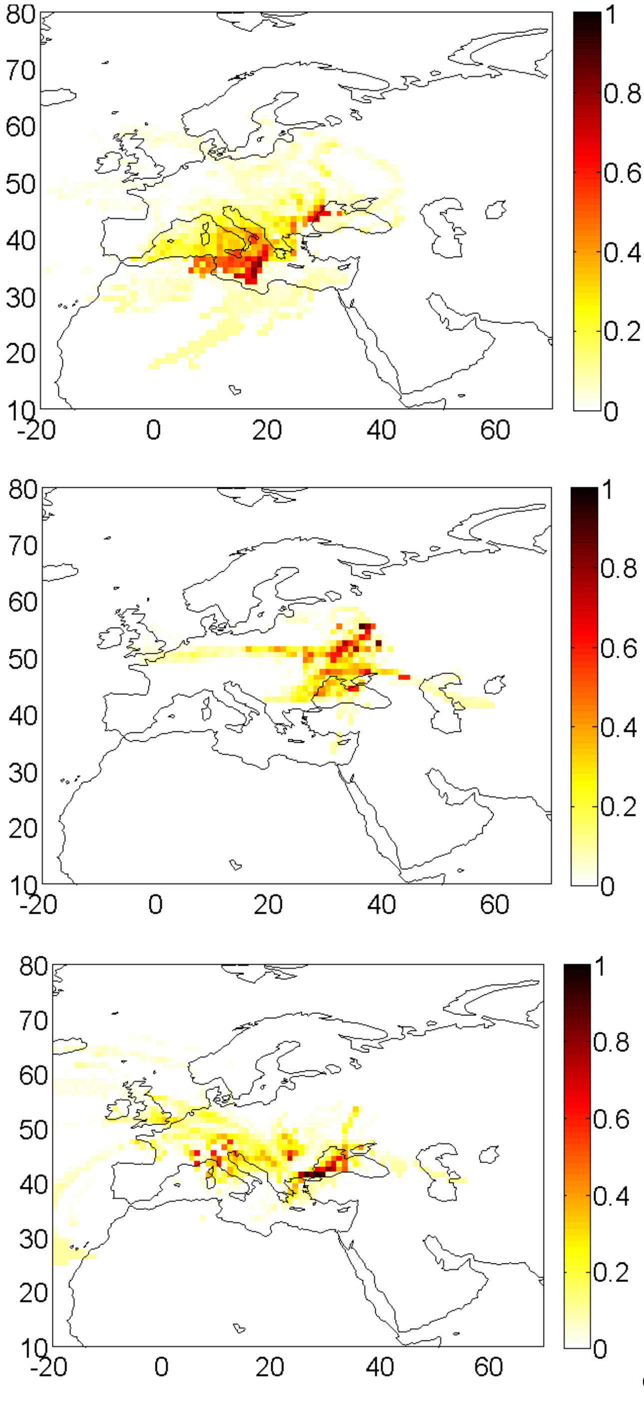


Source: JRC analysis

The estimated contributions of transportation and biomass burning to $PM_{2.5}$ in Sofia determined by a source apportionment study (Belis et al., 2015) are comparable to those in this study (Figure 8). However, in Zagreb, significant $PM_{2.5}$ fractions deriving from wood burning (28 %) and traffic (22 %) for year 2013 are reported in the above mentioned study. The differences with the present study may be due to the poor representation of wood burning in the emission inventories (Piazzalunga et al., 2011) or to differences in the meteorology between the years of the two studies (2010 & 2013).

As mentioned above, the contribution from non-controllable sources is high for both cities. According to the source apportionment study, in Zagreb the long-range transport of PM is mainly associated with Saharan dust events (Figure 16a). In Sofia, a considerable trans-boundary contribution of secondary pollutants from the area surrounding the Marmara Sea and of dust from the area to the north of Black and Caspian Seas has been identified (Figure 16b and 16c). The contribution observed from areas outside the SHERPA domain, (which is restricted to the EU member states of the Danube macro-region), used in the present study explains the relatively high contribution from no control areas in Zagreb and Sofia.

Figure 16: Long-range transport of pollutants contributing to $PM_{2.5}$ and PM_{10} in Zagreb (a: dust) and Sofia (b: dust; c: secondary) using the Potential Source Contribution Function. Colour scale: contribution probability.



a

b

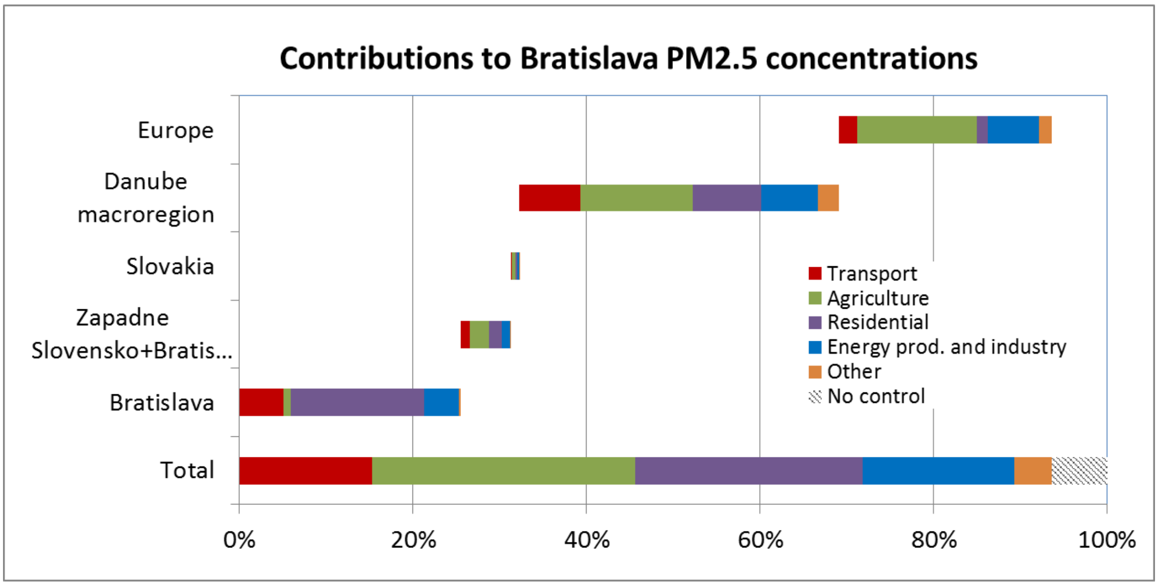
c

Source: Belis et al., 2015

Bratislava, Bucharest, Budapest and Prague: reductions in local emissions have a moderate effect on local concentrations

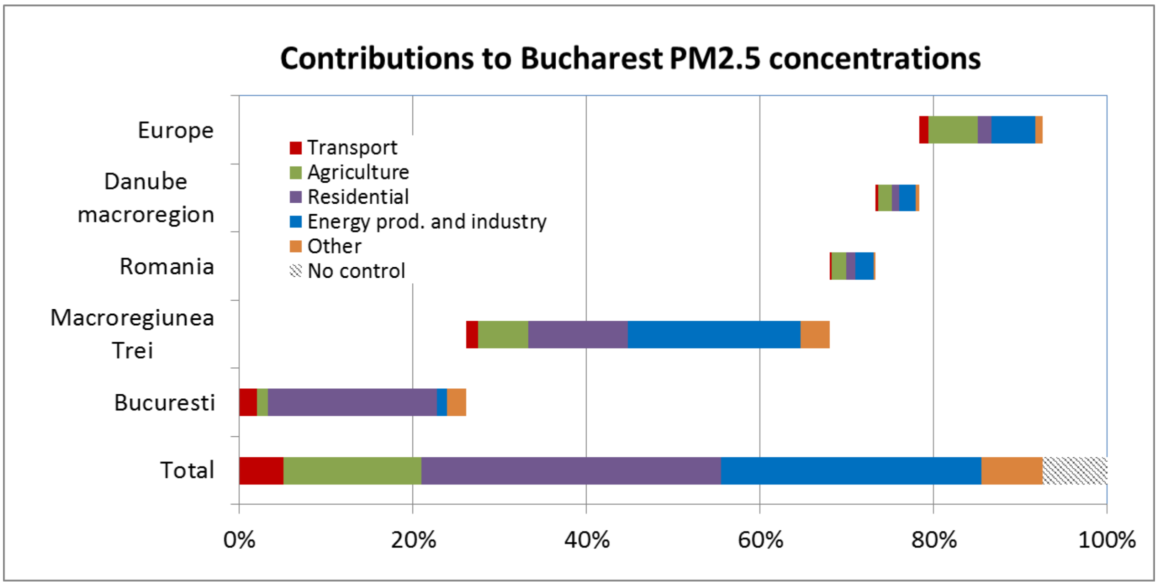
In these cities, local strategies can improve air quality by around 20 % to 30 % relative to the 2010 baseline levels (Figures 17 to 20).

Figure 17: Contributions to $PM_{2.5}$ concentrations in Bratislava



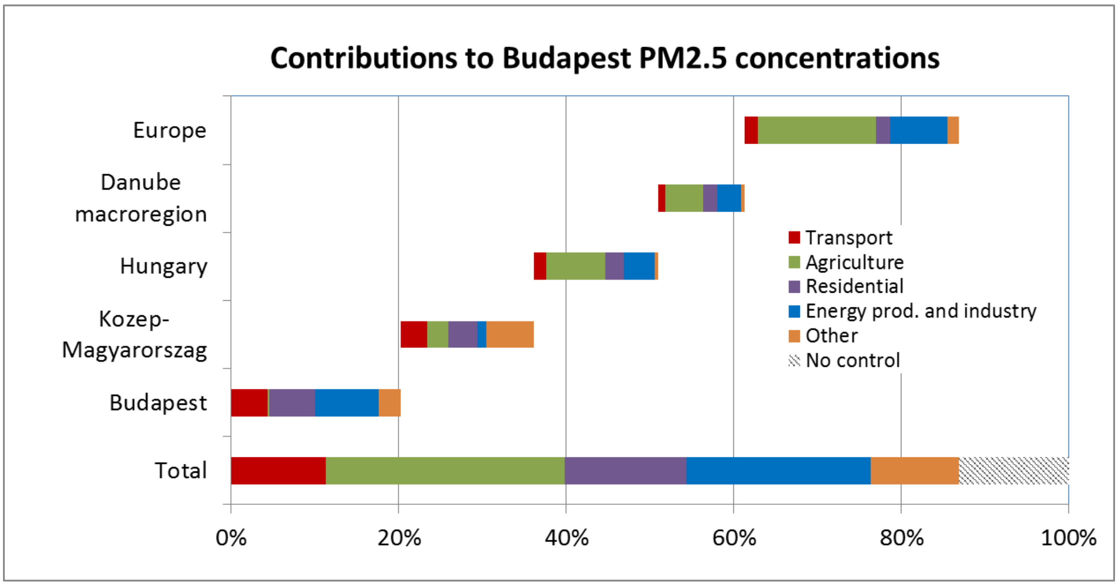
Source: JRC analysis

Figure 18: Contributions to $PM_{2.5}$ concentrations in Bucharest



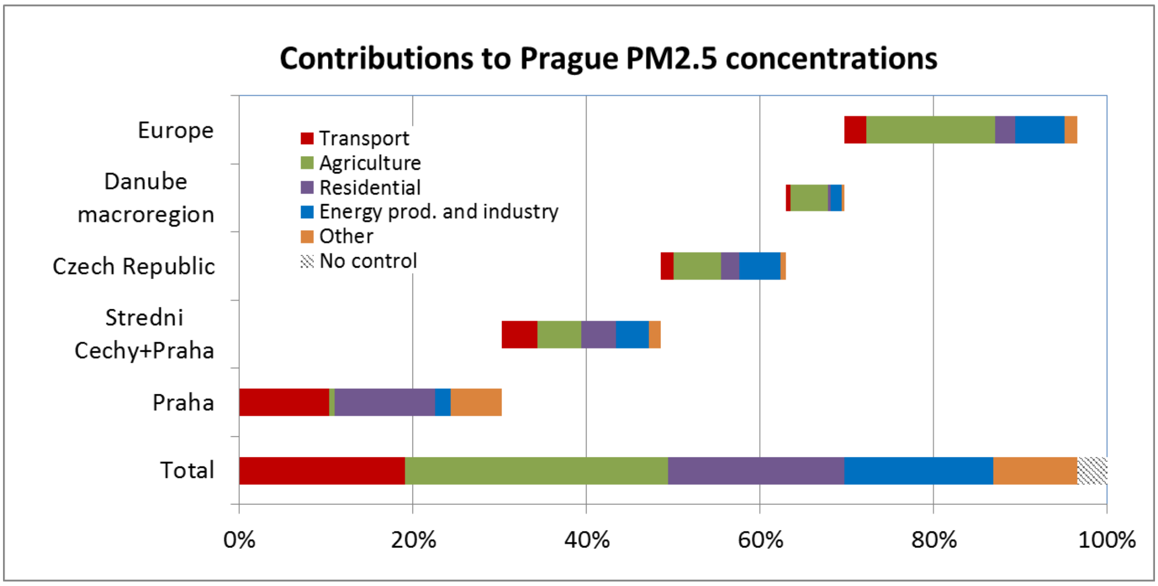
Source: JRC analysis

Figure 19: Contributions to $PM_{2.5}$ concentrations in Budapest



Source: JRC analysis

Figure 20: Contributions to $PM_{2.5}$ concentrations in Prague



Source: JRC analysis

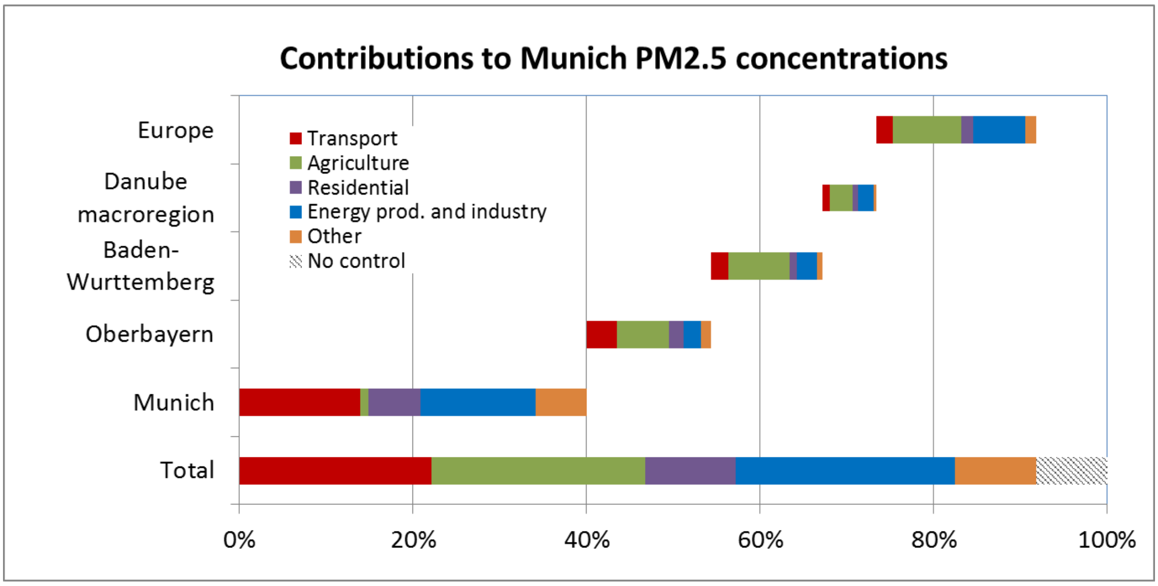
Local strategies should focus mainly on the residential sector in Bratislava and Bucharest, while the focus should be on these plus the traffic and energy production/industry sectors in Budapest and Prague. Strategies applied at the "Danube macro-region" scale would improve air quality up to 60 % - 80 %. Nevertheless, with the exception of Bratislava, regional/national policies could also lead to appreciable reductions. Bucharest is the city with the highest contribution from the surrounding region, mainly from the energy/industry and residential heating sectors.

The abovementioned source apportionment study (Belis et al., 2015) indicated primary contributions of 18 % from traffic and 23 % from wood burning for the city of Budapest. These estimates are 30 % to 40 % higher than those reported by the present study. As already mentioned, these differences could be due to the different reference years (different temperatures or dispersive conditions) or due to limitations in the emission inventories.

Munich and Vienna: reductions in local emissions would contribute significantly to an improvement in air quality

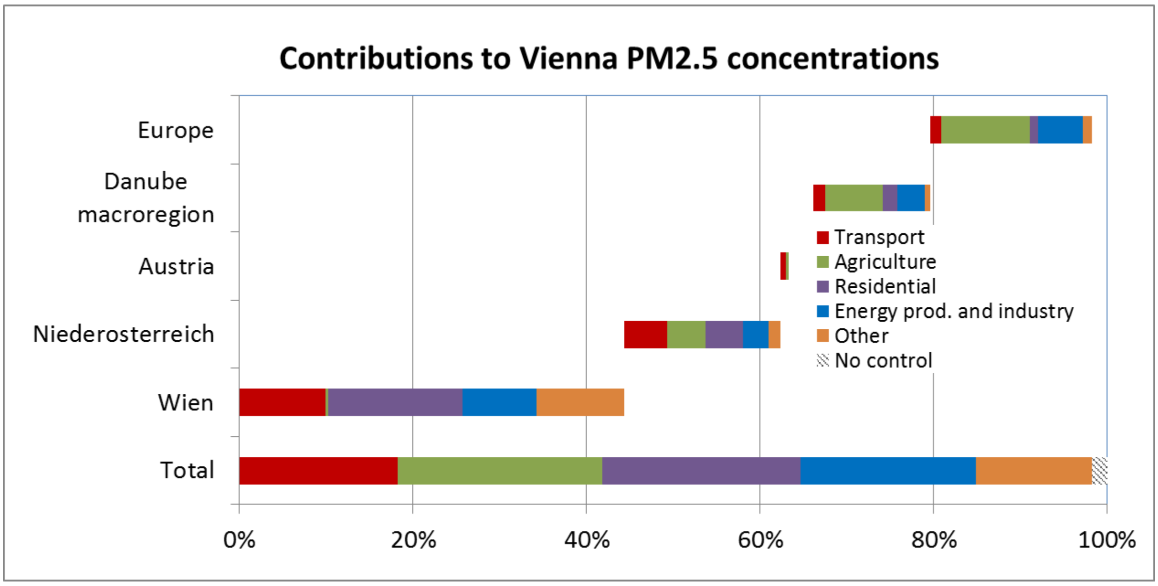
The results suggest that Munich and Vienna present a quite different pattern compared to the other cities (Figures 21 and 22).

Figure 21: Contributions to $PM_{2.5}$ concentrations in Munich



Source: JRC analysis

Figure 22: Contributions to $PM_{2.5}$ concentrations in Vienna



Source: JRC analysis

In both cities, local emission reductions would lead to improvements in the $PM_{2.5}$ concentrations of about 40 %, with the main effort to be focused on transport, energy/industry and residential heating. For both cities larger scale policies (regional/national/macro-regional) also show beneficial impacts, although less important than the local measures.

4 Air pollution abatement measures

The results of this study demonstrate that sources within the cities studied may make a considerable contribution to $PM_{2.5}$ (i.e. traffic, domestic heating). Other pollutants are often transported from distant source areas (e.g. secondary ammonium sulphate and nitrate). In addition, some pollutants are of mixed origin (e.g. biomass burning, natural dust). This outcome suggests that reducing atmospheric pollution in cities requires action at different levels: local, national, European and international.

Understanding the processes leading to the formation of $PM_{2.5}$ provides useful hints for designing abatement strategies. The long-range transport associated with **secondary pollution** typically also involves multiple sources located in different geographical regions. Tackling the resulting pollution requires coordination between regions and countries and involves different human activities (e.g. agriculture, energy production and transportation). For the eastern EU Member States the implementation of EU policies may not be sufficient to achieve compliance, so international commitments are needed to involve non-EU Eastern European countries. In addition, more effort is needed to address pollutants and sources that were neglected in previous strategies.

In the past, the CLRTAP protocols have mainly focused on emissions from the power sector, industry and transport. In future, to reduce exceedances, this initial focus would must be expanded to include agriculture and small stationary combustion sources in the residential and commercial sectors.

In the atmosphere, NH_3 (mainly emitted by agriculture) reacts with NO_2 and SO_2 to produce secondary $PM_{2.5}$. In the **agricultural sector** the most effective strategy to reduce the emissions of NH_3 is to reduce the livestock densities, particularly in sensitive natural areas like the Danube protected biodiversity areas. It would be also beneficial to change feeding habits to reduce food waste. Moreover, changes in dietary habits leading to a reduction in meat consumption would also reduce the amount of manure produced and lower ammonia emissions from meat production (Maas & Grennfelt, 2016).

There is scientific evidence about the impact of **residential heating** on PM in Europe and in Eastern Europe, with particular reference to wood burning and other solid fuels (Mira-Salama et al., 2008, Vossler et al., 2015). This sector is of particular concern when considering that it is associated with emissions of carcinogenic compounds (i.e. polycyclic aromatic hydrocarbons, PAHs) and black carbon (Belis et al., 2011). Despite the relevance of this source, estimations of its contributions need further improvement due to the considerable uncertainties in the emission factors and limited knowledge of the behaviour of the emitted organic compounds and how they condense or react with other pollutants (e.g. O_3) (Piazzalunga et al., 2011).

Domestic heating is a main source of PM and black carbon emissions in the EU. Emissions from new boilers and stoves are in part addressed by the Eco-design Directive. However, the directive is expected to have a limited impact in the short-term because of the long transition periods and long lifespan of the appliances set out in the Eco-design Commission Regulations (EU; Nos. 813/2013, 814/2013, 2015/1185, 2015/1188, and 2015/1189).

The **vehicle emission** regulations in force were designed to achieve a significant reduction of NO_x and PM emissions. Nevertheless, unrealistic NO_x emission estimates from type approval tests have led to a significant underestimation of real world emissions, with a consequent increase in NO_2 emissions in urban areas (Degraeuwe, 2016). Even though the regulation has been successful in lowering exhaust emissions due to the application of diesel particle filters, this technical measure has no impact on the non-exhaust emissions. This source, which encompasses particles deriving from abrasion of vehicle and road surfaces and re-suspension of particles deposited onto the road, can be controlled most efficiently by non-technical measures to reduce the traffic vehicle fleet.

4.1 Measures at the local and regional levels

Heating and traffic are typically diffuse sources in cities. In particular, the use of solid fuels such as coal and wood for heating could contribute significantly to air pollution in cities and their outskirts.

In the short term, banning the use of fireplaces or wood stoves on days that pollutant concentrations are expected to be very high might help to deal with high pollution episodes.

The practice of burning agricultural waste should also be regulated to reduce PM levels at the suburban and regional scales. This measure should be accompanied by efficient waste collection.

In the long-term, the substitution of low efficiency stoves with improved ones could contribute to reducing emissions of PM and PAHs. Nevertheless, the fact that the emission factors from solid fuels are higher than those from efficient appliances using liquid and gaseous fuels must be taken into account. Therefore, it is unlikely that solid-fuelled appliances will achieve the same PM emission levels as those fuelled with natural gas or gasoil.

Limiting the circulation of the most-polluting vehicles (e.g. EURO 1 to 4) when high concentrations of transported pollutants are expected may help in the short term. In particular, limitations to the circulation of diesel powered vehicles may contribute to reduce PM and NO_2 levels.

In the longer term, the substitution of the vehicle fleet has local effects, but it is an expensive measure that has to be promoted by scrapping schemes at national or regional levels. However, recent research on the impact of diesel vehicle emissions show that the latest standard EURO 6 might not be efficient enough to abate NO_2 to levels below the AQD thresholds in city centres.

Examples of additional measures to reduce NO_2 are the introduction of low emission zones that ban diesel vehicles from inner-city areas, or progressively increasing taxation on diesel fuel .

To limit the emissions from road transport it is also necessary to reduce the number of vehicles circulating at any one time. This has the advantage of tackling both exhaust and non-exhaust emissions. To this end, incentives to use public transport, increase the number of passenger per vehicle (car-pooling), and the use of low impact vehicles (e.g. bicycles, electric cars) should be implemented through Sustainable Urban Mobility Plans.

Non-exhaust emissions may have high concentration of heavy metals. Measures to contain these sources are:

Systematically cleaning streets and pavements after intense pollution events, in order to immobilise and partially remove the heavy load of dust present for re-suspension;

Increasing urban vegetation and reducing the free surfaces where particles may accumulate and easily re-suspend; for instance, trees settle out, trap and hold particles, while grass terrains prevent further re-suspension of local soil dust.

Catalogue of air quality measures

In addition to the end-of-pipe measures discussed in Annex 2, structural improvements and behavioural changes should be also considered. A database with approximately 70 measures that were implemented at local level in EU Member States to control atmospheric pollution is available online at http://fairmode.jrc.ec.europa.eu/measure-catalogue/. These measures have been selected to be representative of different situations in the EU. The database is intended to support the implementation of the Air

Quality Directive in EU Member States by providing examples of both successful (best practices) and unsuccessful measures.

Measures are flagged as successful when the goals (emission reduction, air quality improvements, changes in indicators) set beforehand by the responsible authority have been achieved. Unsuccessful measures are those that either did not have the expected effect or where reduction effects are disputed or effects are lower due to improper implementation. Nevertheless, it should be noted that what are unsuccessful measures in a given situation, might be successful under different circumstances.

The following measures were flagged up as successful:

- Reducing traffic emissions: bike rental, extension of cycle paths, car sharing, introduction of cleaner vehicles (private and public), ban on heavy-duty vehicles, city spatial planning, inter-modality, central logistics, reduction in the prices for public transport, increase of extension and velocity, congestion charges, low-emissions zones, and reducing speed limits;
- Controlling biomass and wood burning: prohibition of open-field burning of agricultural waste, banning the use of bituminous fuels and fuel oil for heating, extending the district heating and the control of emissions, increasing the energy efficiency of residential biomass combustion, limiting emission values for domestic heating, and tackling fuel poverty.

4.2 Measures at the national and international level

The present study clearly indicates the importance of gas-to-particle conversion processes in the atmospheric pollution in cities. The transformation of gaseous pollutants such as SO_2, NO_x and NH_3, and subsequent formation of secondary aerosols contribute to PM_{10} and $PM_{2.5}$ levels. These aged pollutants may travel over medium to long distances and could therefore represent emissions from other areas within the same country or from abroad. While SO_2 and NO_x derive mainly from combustion processes, NH_3 is emitted by agriculture. In many areas, the secondary fraction of regional background PM concentrations are most efficiently reduced by cutting agricultural NH_3 emissions (ETC/ACM, 2013a, 2013b). Tackling NH_3 emissions efficiently would however require

Box 2. Measures to abate PM at the national level:

— Drafting and implementation of National Programmes to fulfil NECD obligations;

— Implementing permit schemes and control mechanisms for industrial plants (IED) and for medium combustion plants (MCPD). In areas not complying with the AQD limit values, Members States can apply stricter emission limit values than those set out in the MCPD for individual combustion plants;

— Introducing industrial sources permits that go beyond best available techniques (BAT) levels and carrying out regular inspections;

— Enforcing effective controls on maintenance schemes for vehicles;

— Introduce scrapping schemes for old vehicles and motorcycles;

— Assessing the feasibility of more stringent emission standards for stoves in specific regions for environmental or health-related reasons. This could be applied in areas in the Danube macro-region where studies demonstrate that this source significantly contributes to exceedances.

addressing the whole nitrogen cycle through integrated nitrogen management, low emission manure application techniques, low-emission manure storage systems, livestock feeding strategies, and to limit ammonia emissions from the use of mineral fertilizers (UNECE, 2015).

The results obtained with the GAINS model for the Clean Air Policy Package include cost-efficient optimisation of measures, which can be used as guidance for choosing and implementing measures at the national level.

At the European level the emission of the abovementioned pollutants are regulated under the NECD. This legislation sets upper limits for each Member State from 2010 for the total national emissions of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution: SO_2, NO_x, NMVOC and NH_3 ($PM_{2.5}$ was added in 2016). Member States decide on the measures they will use to achieve compliance.

Implementing the NECD would contribute to the abatement of primary PM and gaseous PM precursors responsible for secondary PM.

Box 3. Measures to abate PM at the European and international level:

- Implementing CLRTAP protocols and relevant EU legislation.
- Implementing climate and energy targets.
- Improving the vehicle standards on the basis of realistic testing cycles.
- Developing emissions standards for non-road mobile machinery and domestic stoves.
- Developing emission standards for farming and promotion of best practices.
- Enforcing emission standards for farms and domestic stoves.
- Agreeing with industry on environmentally stringent standards in the framework of the Eco-design Directive by promoting voluntary agreements for the domestic heating sector.

The results obtained with the GAINS model for the Clean Air Policy Package include cost efficient optimisation of measures, which can be used as guidance for choosing and implementing measures at the national level. To support national authorities in the design of optimised abatement plans, it is useful to account for the abatement potentials of the measures with regard to the specificity of each country. As mentioned in Belis et al. (2015), there is a considerable potential for abatement of emissions from power plants and industrial combustion processes at the national level, particularly in Hungary and Bulgaria, by applying end-of-pipe technological measures. Considerations about the cost-benefit analysis of such measures are beyond the scope of this study. Techincal measures for pollution abatement evaluated by the GAINS model for selected countries of the Danube macro-region are provided in Annex 2.

5 Interaction between air quality, climate change, energy and urban policies

Air quality and climate change policies

The combustion of fossil fuels for energetic purposes is the main source of major greenhouse gases and one of the most important sources of air pollutants. Therefore, a coordinated abatement strategy is required to take advantage of synergies and address both policy areas more effectively. Such a strategy should prioritise those CO_2 mitigation measures which also reduce air pollutant emissions, and complement these measures through balanced reductions in cooling and warming short-lived climate-forcing components (SLCFs) (European Commission, 2013b).

An integrated approach to climate change and air pollution could lead to significant co-benefits. Reduction in the emissions of methane, and of absorbing aerosols, in particular black carbon, should help to improve air quality by reducing ozone concentrations.

Making climate change policy which does not consider the effects on air pollution could be detrimental to air quality. For example, an isolated focus on reducing carbon dioxide emissions by encouraging the use of wood stoves, diesel cars or biofuels, could result in co-damage to air quality by increasing exposure to fine particles. Vice versa, air quality policies may hamper climate policy. For instance, reductions in SO_2 emissions can be expected to increase global warming. This implies that neither ambitious climate change policy nor air quality abatement policy will automatically yield co-benefits unless there is an integrated approach. Unfortunately, in many countries, climate mitigation policies are separate from air quality policies, which means there is a risk of conflicting measures (European Commission, 2013b).

Air pollution policy could focus on the abatement of air pollutants that have both a warming effect and cause risks to human health and ecosystems: black carbon and O_3 precursors. On the other hand, climate policy focusing on reducing CO_2 emission reduction from fossil fuel may also be beneficial for the emissions of SO_2, NO_X, NMVOC and PM.

Air quality and energy policies

Air pollutant emissions due to human activity derive from energy production and use, mainly the combustion of fossil fuels and biomass. Coal use dominates SO_2 emissions, emitting the highest level of SO_2 per unit. For NO_x, oil derivatives lead the emissions followed by coal. For PM, bioenergy dominates as the consequence of high emissions from domestic wood burning in low-efficiency stoves. Since energy production is the predominant source of air pollution, improving air quality implies action by this sector (IEA, 2016).

In the most recent energy and climate package for 2030 (New Energy Outlook, New Policies Scenario), the EU is committed to a combined decrease in greenhouse-gas emissions of at least 40 % by 2030 compared to 1990 and an increase of the share of renewables in the energy mix to at least 27 %. Energy demand in the EU in the New Policies Scenario is projected to fall by 15 % within 2040, with the share of renewables in primary energy demand more than doubling. NO_x emissions would decline by 55 % as the regulations to combat air pollution becomes more stringent, in particular in road transport, and energy efficiency increases. A continued fall in SO_2 emissions (47 %) by 2040 are due to a reduction in coal use for power generation, energy efficiency measures in buildings and the lower emission intensity of coal-fired power stations. Only a 20 % decrease in $PM_{2.5}$ is projected for 2040 due to the fall in the use of fossil fuels, being partially balanced by a higher use of biomass for household heating and in power generation.

However, to achieve the WHO recommended air quality levels, more ambitious measures are required: stricter pollution-control standards, further improvements in energy efficiency in buildings and a higher penetration of renewables in power generation. A more ambitious but feasible reduction scenario would reduce the number of people exposed to $PM_{2.5}$ levels above the WHO guideline to below 10 %. With such a package of measures the number of premature deaths in the EU in 2040 would fall more than 20 % below the level expected to result from the current New Policies Scenario. Important co-benefits include the reduction of the EU fossil-fuel import bill by around $120 billion and a reduction of CO_2 emissions by 260 Mt (or 13 %) in 2040 (IEA, 2016).

In the eastern Danube macro-region action should focus on the substitution of coal for energy production or the installation of the best available technologies (BAT) in existing plants that simultaneously abate SO_2, black carbon and PM. A greater effort to reduce the impact of diesel vehicles on NO_2 levels is required in the main cities throughout the macro-region. The dissemination of BAT in the domestic heating sector should be carefully monitored to take advantage of potential CO_2 reductions without impacting negatively on the emissions of PM and associated black carbon and PAHs. Reinforcing the international cooperation in the framework of the CLRTAP and UNFCCC is important to marking progress in the implementation of air quality and climate change policies in the non-EU Eastern European countries, reducing the impact of long-range transportation of pollutants in the eastern Danube macro-region.

Air quality and the EU Urban Agenda

Even though the EU has no formal mandate to deal with local policies, it is recognised that most of the policy issues can be more efficiently tackled at the local level. The EU's Urban Agenda is a new working method to improve the dialogue across policy levels by promoting cooperation between Member States, cities, the European Commission and other stakeholders. The scheme promotes European partnerships with the objective of involving cities in EU policy and legislation process, facilitating their access to European funds, and stimulating horizontal cooperation among them.

The **Partnership on Air Quality** involves four Member States, five cities and a number of stakeholders. It aims to improve air quality in cities. The main tasks required to achieve its objectives are: identification of gaps and conflicting regulations, exploitation of funding opportunities and exchange of knowledge and best practices. The activity of the partnership is structured in four actions: urban modelling, mapping regulatory and funding instruments, best practices and guidelines for air quality action plans (https://ec.europa.eu/info/eu-regional-and-urban-development/cities_en).

When it comes to energy and climate policy at the urban level, the **Covenant of Mayors for Climate and Energy** is an important instrument. This initiative involves thousands of local and regional authorities which voluntarily take action to implement the EU climate and energy 2020 targets and more recently the 2030 ones. Signatories submit a Sustainable Energy and Climate Action Plan, which is evaluated and then monitored. Like the Urban Agenda, this instrument gives local authorities the flexibility to select and implement the measures according to their particular context.

Integration of Air quality in the Danube Priority Areas

Air quality involves many aspects of human activities. On the one hand, the drivers (emission sources) depend on a wide range of factors, from economic activities to simple individual activities such as domestic heating or driving private vehicles. On the other hand, the impacts of air quality affect human health, ecosystems and, in the longer term, climate. It follows that air quality management is a cross-cutting issue in which all relevant actors must be involved for it to be effective. Transposing this concept into the Danube strategy, would imply better coordination among the relevant priority areas (PA) on this topic taking advantage of the more interdisciplinary working approach that is already planned for the next three-year framework. According to the outcome of this study, it will be important to promote coordinated work, at least, between: PA 6 "Biodiversity, landscapes, quality of air and soils" which is in charge for this thematic area, PA 1B "Mobility Rail-Road-Air" and PA 2 "Energy". Involvement of other PA would

help to better identify and monitor possible positive or negative consequences of their work plans on air quality (e.g. PA8 Competitiveness). In addition, strengthening links with PA10 Institutional capacity and cooperation would help to raise awareness of this topic among public and private managers.
In this context, the PA6 Task Force on Air Quality may play a catalysing role in the implementation of the EUSDR objectives in this field. In addition to scientific support and capacity building, the Task Force would be in the position to promote the dialogue and collaboration between different actors such as experts, authorities, health professionals and non-governmental organisations.

6 Conclusions

Air quality in the Danube area is a serious problem. Exceedances of PM_{10} and precursor gases, NO_2 and SO_2, have led to infringement procedures in all the Danube EU Member States (with the exception of Croatia) and some of which have been referred to the court.

The geographical distribution differs according to pollutant. PM_{10} and $PM_{2.5}$ have hot-spots in the south-east of the Danube macro-region, while a second hot-spot in southern Poland influences the northern border of the Danube macro-region. SO_2 is present in higher levels in east of the Danube region, while NO_2 occurs in urban areas throughout the Danube basin.

The combination of modelling tools (source apportionment and SHERPA) used in this and previous studies have identified and quantified the causes of air pollution in a range of urban areas in the macro-region, in order to provide valuable technical advice for science-based air quality policies. Dissemination of such tools would help to raise the level of capacity in the field of air quality in the institutions of the macro-region.

Energy production/industry, agriculture, residential heating and transport are the main sources for the most important cities in the macro-region. However, the extent to which local emissions influence the concentration of pollutants varies. According to the present study, long-range transport influences local concentrations in Sofia and Zagreb while in Munich and Vienna, emissions from within the cities themselves have considerable impact on local concentrations. Intermediate situations are observed in the other cities of the macro-region.

Long-range transportation has been identified from Eastern European areas beyond the EU's borders and from Northern Africa. Due to the complexity of air pollution processes coordinated actions at different levels: local, regional, national, European and international are needed. It is essential to involve all the relevant actors to assess possible interactions between sectorial policies in order to improve the effectiveness of the measures.

In the eastern Danube macro-region action should focus on end-of-pipe technical measures (high-efficiency dedusters and electrostatic precipitators) in coal-fuelled energy plants to simultaneously abate SO_2, black carbon and PM. More efforts are required to reduce the impact of diesel vehicles on NO_2 in the macro-region's main cities. To take advantage of potential CO_2 reductions without impacting negatively on the emissions of PM and associated black carbon and PAHs, the dissemination of BAT or even higher standards in the domestic heating sector for biomass-fuelled appliances should be promoted and carefully monitored. Opportunities within the framework of the Eco-design Directives should be explored to promote improvement in the heating appliances' sector.

To reduce the impact of the long-range transportion of pollutants in the eastern Danube macro-region, reinforcing the international cooperation within the framework of the CLRTAP and the UNFCCC would help the implementation of air quality and climate change policies in non-EU Eastern European countries. More effort is needed for the integrated implementation of air quality, climate and energy policies.

Considering the outcome of this study, a better integration of sectorial policies (e.g. the EUSDR priority areas covering energy, transportation, competitiveness and institutional capacity would be beneficial to the effectiveness of measures in the Danube macro-region. Since the impacts of air pollution are greater in urban areas, where the majority of the population resides, initiatives like the Partnership on Air quality of the EU Urban Agenda, could help to involve relevant actors, access funding and achieve consensus for future actions.

The PA6 Task Force on Air Quality could trigger action by providing scientific support, contributing to capacity-building and coordinating cross-sectorial activities in this thematic area within the macro-region.

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List of abbreviations and definitions

AQD: Ambient Air Quality Directive

BAT: best available technology

CH_4: methane

CLRTAP: Convention on Long-range Transboundary Air Pollution

CO_2: carbon dioxide

DAN: Danube Air Nexus

EC: European Commission

EEA: European Environmental Agency

EECCA: Eastern Europe Caucasus and Central Asia

EU: European Union

EUSDR: European Union Strategy for the Danube Region

GHG: greenhouse gasses

JRC: Joint Research Centre

IED: Industrial Emissions Directive

MCPD: Medium Combustion Plants Directive

$\mu g/m^3$: micrograms per cubic meter

NECD: National Emission Ceilings Directive

NH_3: ammonia

NMVOC: non-methane volatile organic compounds

NO_x: nitrogen oxides

NO_2: nitric oxide, nitrogen dioxide

NRMM: non road mobile machinery

O_3: ozone

PM_{10}: particulate matter with aerodynamic diameter below 10 micrometres

$PM_{2.5}$: particulate matter with aerodynamic diameter below 2.5 micrometres

SLCF: short-lived climate-forcing component

SO_2: sulphurous anhydride

UNECE: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

US EPA: United States Environmental Protection Agency

WHO: World Health Organization

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Annexes

Annex 1. The legislative instruments

Air Quality Directives (AQD)

To protect human health and the ecosystems, Member States take action in order to comply with limit values and critical levels, and where possible, to attain the target values and long-term objectives set by the AQDs (Directives 2008/50/EC and 2004/107/EC). When the levels of pollution exceed the limit values or target values Member States, and subsequently local authorities, shall establish air quality plans where measures are implemented to tackle the pollution sources and bring the air quality levels below those thresholds within a given term. Moreover, according to the Commission Implementing Decision of 12 December 2011, information about the contribution of sources and scenarios that supports these air quality plans must be reported by Member States to the Commission through the so-called e-reporting scheme.

National Emission Ceiling Directive (NECD)

The recently approved Directive 2016/228/EU in replacement of 2001/81/EC (NECD) implements the EU commitments under the Gothenburg Protocol after the 2012 revision (see below). It limits the total emissions in each Member State of SO_2, NO_2, non-methane volatile organic compounds (NMVOC), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$), because of their contribution to the acidification and eutrophication of the ecosystems and the development of ozone pollution near the ground-level (not to be confused with the stratospheric ozone layer that protects the earth from UV radiation). To fulfil the obligations set under this Directive, Member States draft National Programmes and report emissions and projections to the Commission and the European Environment Agency (EEA). The EEA regularly publish the NEC Directive status report based on the reporting by Member States.

Emissions from Industrial and Medium Combustion Plants (IED, MCPD)

Emissions from industrial installations are limited under the IED in particular through application of best available techniques. The MCPD covers combustion plants between 1 and 50 MW, which are an important source of emissions of SO_2, NO_2 and PM in the EU.

Eco-design Directive

Directive 2009/125/EC (Eco-design Directive) provides consistent EU-wide rules for improving the environmental performance of products, such as household appliances, information and communication technologies or engineering. The Directive sets out minimum mandatory requirements for the energy efficiency of these products. In the EU domestic heating devices, like boilers and ovens are a main source of PM and black carbon emissions and are partly addressed by this Directive. However, to avoid distortions of the EU market, more stringent national limits or additional parameters for conformity testing and operation cannot be defined by the Member States. Opting-out for environmental and health reasons is possible in specific regions, on a case-by-case basis.

Vehicle emissions regulations (EURO 5, 6, VI)

Minimum requirements for air pollutant emissions from vehicles are laid down by Commission Regulation (EC) No 692/2008 on Euro 5 and Euro 6 standards of light vehicles and Regulation (EC) No 595/2009 on the Euro VI standard for heavy-duty vehicles. The implementation of these regulations is expected to significantly reduce NO_x and PM emissions from vehicles. The use of diesel particle filters has considerably reduced PM exhaust emissions from vehicles. However, differences in NO_x emission levels between type approval tests and real world vehicle emissions have led to exceedances of NO_2 limit values in European cities.

The Non-Road Mobile Machinery (NRMM) Directive 97/68/EC is currently under revision.

Convention on Long-range Transboundary Air Pollution (CLRTAP)

The Convention on Long-range Transboundary Air Pollution was adopted in 1979 and entered into force in 1983. It recognises that air pollution is a major environmental problem that needs international collaboration to be solved. The convention is complemented by eight protocols on specific pollutants SO_2, NO_2, NMVOC, heavy metals (HM), and persistent organic pollutants (POP) among others. UNECE is the convention secretariat and the EMEP is the implementing body.

Provisions for fulfilling EU obligations under this convention are included in the AQD and NECD (paragraphs 1.1 and 1.2, respectively).

United Nations Framework Convention on Climate Change (UNFCCC)

The UN Framework Convention on Climate Change, Rio de Janeiro, 1992, including the Kyoto Protocol, 1997, and the Paris Agreement, 2015 are intergovernmental treaties to for the global stabilisation of the levels of gases that absorb solar radiation and emit infra-red radiation, the so-called GHG (mainly CO_2, CH_4, N2O, O_3 and CFC). In addition, particulate black carbon contributes to global warming both directly (radiative forcing) and indirectly (darkening of ice surfaces and influencing cloud formation).

Annex 2. Technical measures in selected Danube cities

Emission control measures can be classified into three groups: behavioural, structural, and technical (Amann et al., 2011). The first two categories are more relevant at the global and national level, while the third one refers to 'end-of-pipe' measures.

This section discusses the potential for PM emission abatement of a set of technical measures evaluated by means of the GAINS model (http://gains.iiasa.ac.at/gains/EUN/) using the scenario PRIMES 2013 REF-CLE for the reference year 2010.

The "abatement potential" was calculated on the basis of the actual primary emissions of a given sector, the removal efficiency of the selected measure and the controlled capacities, i.e. the proportion of the actual emissions that could actually be subjected to the selected abatement measure.

Figures 23 to 25 report measures arranged on the basis of their decreasing abatement potentials down to 0.8 kilotonnes (kt). In certain cases, measures with different abatement potentials are evaluated for the same kind of emissions.

In Croatia (Figure 23), the highest abatement potentials for PM at the national level are those in the sectors of fertilizer production, coal-fired power and district heat plants, and cement plants. Considerable emission reductions could be also achieved in the domestic wood burning, lime production and coal-fuelled industrial boilers. For point sources the most effective measures are high efficiency dedusters followed by two-field electrostatic precipitators. For the domestic and commercial wood-burning sector the most effective choice is the introduction of improved stoves. The abatement in the road traffic sector, modest at the country level, is important at the local scale. The best technological option is the introduction of EURO 4 for light- and heavy-duty diesel road vehicles.

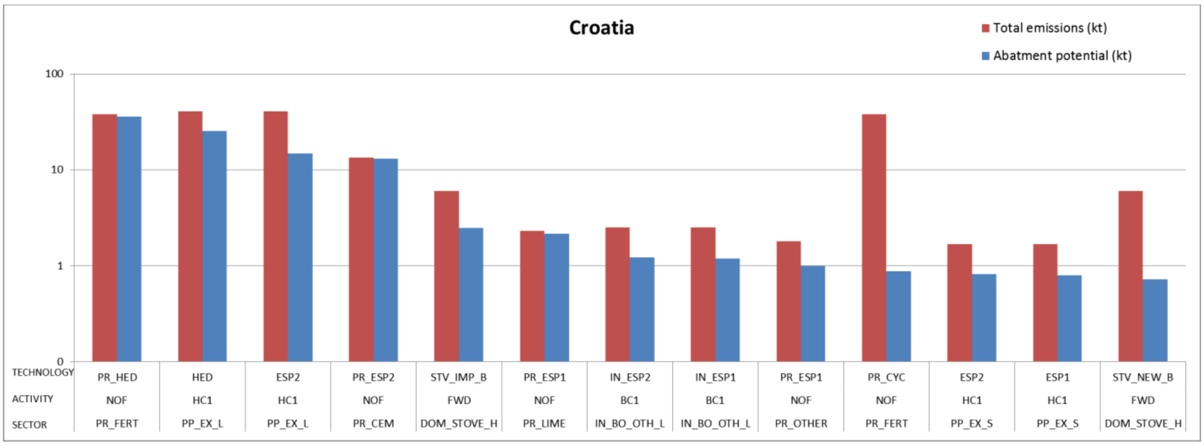
Table 3: Abbreviations for GAINS terminology

Abbreviation	SECTOR
PP_EX_L	Power & district heat plants, existing; brown coal/lignite and hard coal fired (> 50 MW el)
PP_EX_S	Power & district heat plants, existing; coal/lignite fired, small units (< 50 MW el)
PR_CEM	Ind. Process: cement production
IN_BO_OTH_L	Industry: other sectors; combustion of brown coal/lignite and hard coal in large boilers (> 20 MW th)
PR_EARC	Ind. Process: electric arc furnace
PR_OT_NFME	Ind. Process: other non-ferrous metals prod. - primary and secondary
IN_BO_CHEM	Industry: chemical industry (combustion in boilers)
PR_GLASS	Ind. Process: glass production (flat, blown, container glass)
PP_NEW	Power heat plants: New
PR_COKE	Ind. Process: coke oven
DOM_STOVE_H	Residential-commercial: heating stoves
TRA_RD_LD4T	Light-duty vehicles: light commercial trucks with 4-stroke engines
TRA_RD_HDT	Heavy-duty vehicles - trucks

Abbreviation	ACTIVITY
NOF	No fuel use
HC1	Hard coal, grade 1
BC1	Brown coal/lignite, grade 1
FWD	Fuel wood direct
OS1	Biomass fuels

Abbreviation	TECHNOLOGY
HED	High efficiency deduster
ESP1	Electrostatic precipitator: 1 field
ESP2	Electrostatic precipitator: 2 fields
PR_CYC	Cyclone - industrial process
STV_IMP_B	Improved biomass stove

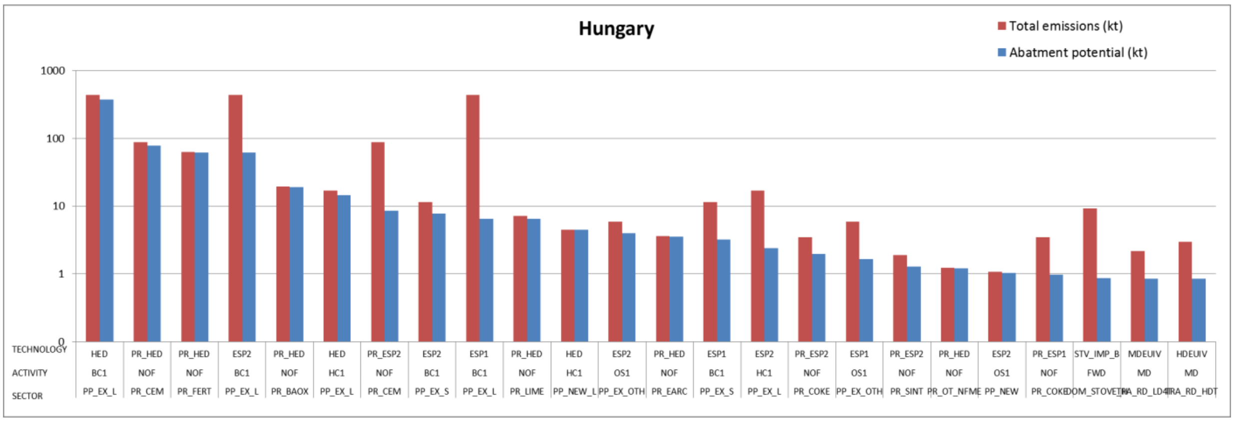
Figure 23: Total primary PM emissions and emission abatement potential of technical measures for Croatia; abbreviations in Table 3.



Source: GAINS model data elaborated by JRC

According to the analysed scenario the main PM abatement at the national level in Hungary would result from the application of technical measures to power plants and industrial combustion processes using coal as fuel (Figure 24). Significant reductions could also be achieved by treating non-combustion emissions from plants for the production of cement, fertilisers, lime, coke and metallurgic industries. For the domestic wood-burning emissions and the road traffic sectors, which are more relevant for the urban areas, the most suitable measures are similar to those already discussed for Zagreb: improved stoves and the introduction of the EURO 4 standard for diesel vehicles.

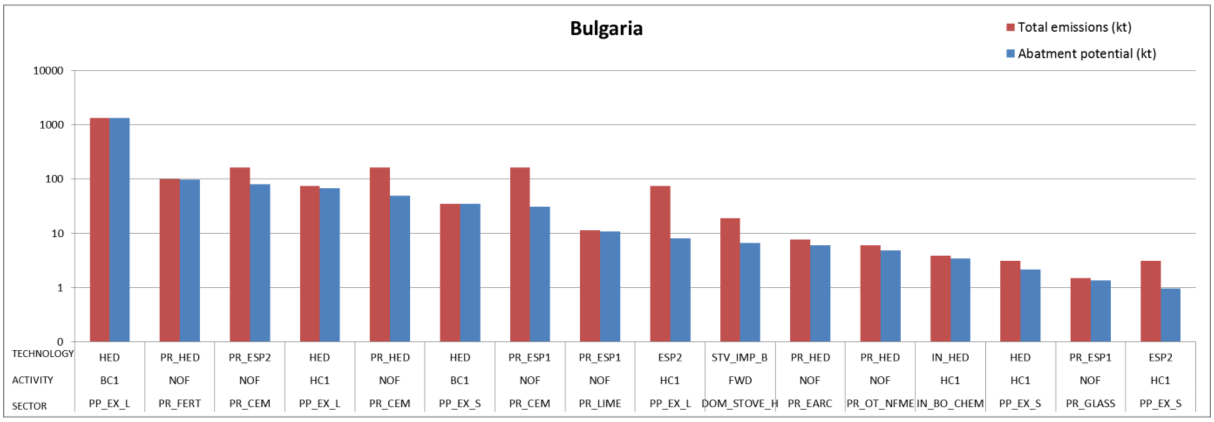
Figure 24: Total primary PM emissions and emission abatement potential of technical measures for Hungary; abbreviations in Table 3.



Source: GAINS model data elaborated by JRC

At the national level, the situation in Bulgaria resembles that described in Hungary with the measures to abate emissions from the combustion of coal in power plants being the most significant (Figure 25). Most of the emissions in this sector derive from a group of power plants located in the eastern part of the country. In addition, industrial processes for the production of fertilisers, cement, lime, glass and metallurgic plants have sizeable abatement potential. The introduction of improved stoves for the abatement of wood burning emissions from the domestic sector is among the ten most potentially effective measures. The introduction of EURO standards 3 and 4 have similar abatement potential.

Figure 25: Total primary PM emissions and emission abatement potential of technical measures for Bulgaria; abbreviations in Table 3.



Source: GAINS model data elaborated by JRC

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