

**AN EMISSION INVENTORY FOR THE CENTRAL
EUROPEAN INITIATIVE 1988**

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Preface

Reliable knowledge of the sources and magnitudes of emissions of air pollutants is an absolute requirement for any assessment of air pollution for research and policy purposes.

A few years ago, accessible information on pollution in many eastern European countries was sparse. Nevertheless, using IIASA's position as an East–West institute, IIASA's Transboundary Air Pollution Project developed the RAINS model for the integrated assessment of international strategies to reduce transboundary air pollution in Europe. With the help of many collaborators in IIASA's member countries, the databases have been filled with the best information available at that time.

Now the situation has changed and environmental information is abundant. However, serious questions remain as to the quality and the international consistency of national data. Again, IIASA has used its scientific network to establish the first harmonized inventory of air pollutants' emissions in the region of the Central European Initiative. The task was facilitated by the fact that most countries participating in this new initiative are also members of IIASA.

Providing detailed information on emissions in the heart of Europe this inventory will serve as a valuable basis for the design of effective strategies to reduce air pollution in Europe.

Peter E. de Jánosi
Director



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Abstract—This paper presents the first consistent inventory of emission of sulphur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter (PM), and carbon dioxide (CO₂), for the countries co-operating in the Central European Initiative: Austria, Croatia, Czechoslovakia, Hungary, Italy, Poland and Slovenia. The inventory is based on national and regional statistics as well as on information received from collaborating institutions. National data has been verified and converted into a common format, consistent with the database used by the European Environmental Agency and the European Community (the "CORINAIR" system). The inventory describes emissions in the year 1988, before the restructuring process began in former socialist economies. Data has been collected on the national level, for administrative units and for large point sources. The database on point sources contains specific information on 400 large plants in the region (e.g. capacity, commissioning year, fuel use, production, etc.).

Total emissions of SO₂ in the CEI region in 1988 were 10.3 million tons, which accounts for 25% of total European SO₂ emissions. The highest emission densities (more than 100 t km⁻²) are found in Northern Bohemia (Czech Republic) and Upper Silesia (Poland). The overwhelming majority of SO₂ emissions (70%) originates from combustion of domestic (brown and hard) coal. Across the region, 60% of SO₂ is emitted from the large point sources identified in the study and over 50% of SO₂ emissions from public power plants in the CEI region is produced in plants older than 20 years.

Key word index: Inventory, central Europe, emissions, air pollution, point sources.

INTRODUCTION

Central Europe maintains a central position on the continent not only in a geographical sense—various circumstances have also given it a central role in releasing harmful substances into the atmosphere. Reliable information on emission quantities is, however, still rare. Before the political changes of 1989/1990 environmental data was often considered confidential, providing room for vast speculations. After that time, access to information became possible; the quality and reliability of statistical material, however, are in many cases still reasons for concern, and the international consistency, and consequently the comparability, of the environmental data of this region has still to be established.

Several estimates of the emission levels of various air pollutants in East European countries on national level (Veldt, 1991; Pacyna, 1989; Pacyna *et al.*, 1989) as well as for point sources (Pacyna, 1988) have already been performed. Although those studies covered generally all East European countries, the estimates were mainly based on western European experience and literature studies, and did not make use of the existing national inventory systems and expert know-

ledge available at many environmental institutes and agencies in the region.

The study described in this paper was carried out as part of the international activities of the Central European Initiative (CEI) which includes Austria, Croatia, Czechoslovakia, Hungary, Italy, Poland and Slovenia. National experts representing various institutions in concerned countries were actively involved in the process of collecting data as well as in verifying the final report. This paper summarizes the results of this work, i.e. an inventory of the emissions of sulfur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter (PM) and carbon dioxide (CO₂) for the year 1988 (Klimont *et al.*, 1993).

METHODOLOGY

The CORINAIR* data-reporting format (CEC, 1988) has been adopted as the common standard for all European countries to fulfil their obligations within the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UN/ECE). Recognizing this, a decision has been taken by all country experts involved in this study to establish a common CEI inventory in line with the CORINAIR standards. This decision will fully apply to the upcoming CEI inventory for the year 1990, for which data collection is currently being performed.

However, existing national emission databases (e.g. for the year 1988) in most of the CEI countries are not fully compatible with the CORINAIR standards. Analysis has shown that an exact transformation of the existing databases

*CORINAIR is part of a comprehensive Programme CORINE (COoRdination of INformation on the Environment), providing a sound basis for all kinds of environmental information (land use, air pollution, waste, water pollution, etc.) in Europe (CEC, 1991).

into the CORINAIR format would create major difficulties in some countries. Consequently, a procedure has been developed to establish a common data structure, as far as possible consistent with the envisaged CORINAIR'90 system, into which all existing national databases could be converted.

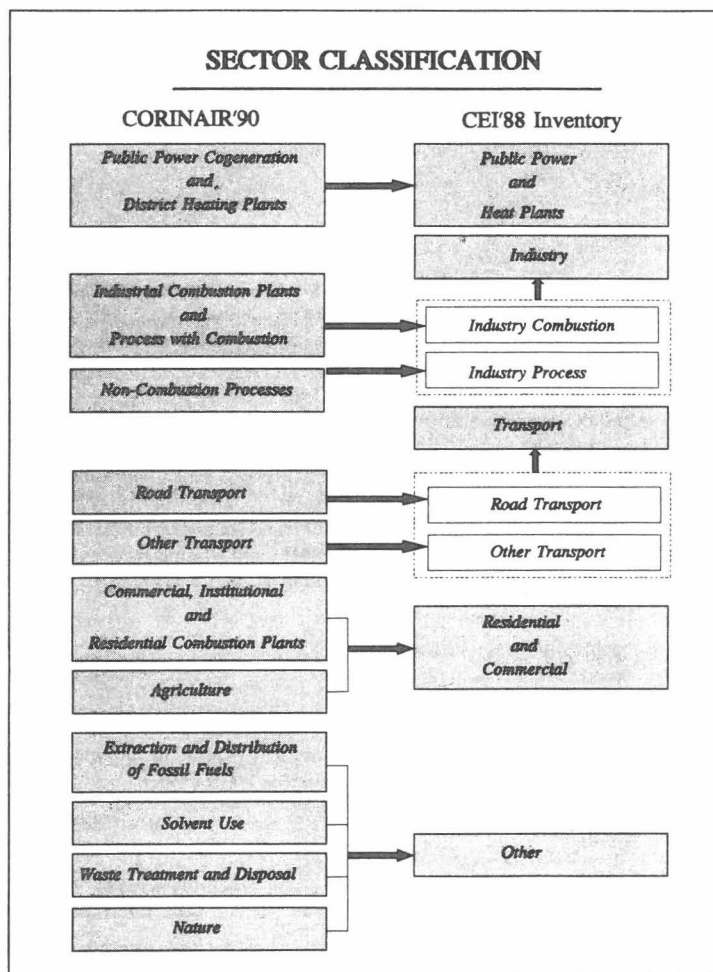
The CEI'88 inventory makes a distinction between emissions from large point sources (LPS) and from dispersed area sources. In order to identify the largest single polluters in the region and subsequently to design cost-effective strategies to reduce emissions, the emissions from large point sources are collected on a plant basis together with a number of techno-economic features of the emission sources. Large point sources (identified in this study) include emitters fulfilling at least one of the following criteria:

- power plants with a capacity of more than 50 MW_{therm.},
- oil refineries,
- plants in which sulfuric acid or nitric acid is produced,
- plants which discharge into the atmosphere more than 1000 tons of SO₂ or NO_x or particulate matter per year.

For each of these sources a set of basic information is stored in the CEI'88 database. For the largest emitters, depending on the availability of information, a variety of additional characteristics are contained (e.g. location, construction year, type and number of boilers, installed capacity and its utilization, fuel use and its quality, production, and emissions of air pollutants). Unfortunately, this in-depth information is not yet available for all large point sources across the CEI region.

Area sources, covering all remaining emissions not counted under the large point sources category, should provide important information on the total amount of emissions in a certain region, information that is relevant to analyse the environmental impacts of air pollution. The data are stored as national totals, i.e. describing emissions from the individual countries of the CEI region, as well as for regional levels (according to the NUTS—Nomenclature des unités territoriales statistiques—levels as defined by the Statistical Office of the European Communities EUROSTAT (EUROSTAT, 1991, 1992)).

On a national level, emissions are aggregated into major activity groups (economic sectors), as far as possible com-



Scheme 1. Sector classification of the CORINAIR'90 and CEI'88 inventories.

patible with the CORINAIR'90 inventory (Scheme 1). Unfortunately, lack of information did not allow a consistent sectoral disaggregation on a regional level. Only a few of the countries considered could provide appropriate data.

RESULTS AND DISCUSSION

Analysis of national and regional emissions

The aggregated results of the emission account performed in this study are displayed in Table 1. On a national level, emission densities vary for SO₂ by as much as a factor of 19, and for NO_x and particulates

by a factor of 4 and 21, respectively. In terms of population, the largest differences occur for SO₂ emissions, ranging from about 200 kg per capita in the Czech Republic to 15 kg per capita in Austria. Similarly, a difference in GDP-related SO₂ and PM emissions exists between, e.g. the Czech Republic or Poland and Austria by a factor of around 20. On the other hand, NO_x emissions per unit of GDP vary only by a factor of five.

Carbon intensity (ton CO₂ per PJ energy input) in the former CMEA (Council of Mutual Economic Assistance) economies is 3–5-times higher than in Austria, Italy and Slovenia. It has to be noted that the high numbers of NO_x emissions in the Czech Republic and the Slovak Republic are subject to serious doubts because of the emission coefficients used to calculate NO_x emissions from power plants in these countries.

Within the CEI region the contribution of individual countries to overall emissions is strongly dependent on the pollutant (Fig. 1). For example, whereas the market economies of Austria and Italy contribute some 10–20% of the total CEI emissions of particulate matter and SO₂, they release about 40% of the NO_x and CO₂ emissions in this region.

The CEI'88 inventory allows for a structural in-depth analysis of national emissions. Important conclusions can be drawn from disaggregating national data according to the fuel types causing the emissions. As shown in Fig. 2, the overwhelming majority of SO₂ emissions in the CEI region (70%) originates from combustion of domestic (brown and hard) coal. In the Czech and Slovak Republics, Hungary and Slovenia, the burning of these fuels creates more than 75% of the total national SO₂, in Poland as much as 90% of SO₂

Table 1. National total emissions for the countries of the CEI region in 1988

| Country | SO ₂ (kt) | NO _x (kt) | PM (kt) | CO ₂ (mlnt) |
|-----------------|-------------------------|-------------------------|------------|---------------------------|
| Austria | 116 | 225 | 44 | 55 |
| Croatia* | 70 | 10 | 2 | — |
| ČSFR | 2672 | 1109 | 1144 | 244 |
| Czech Republic | 2066 | 858 | 840 | 180 |
| Slovak Republic | 606 | 251 | 304 | 64 |
| Hungary | 1171 | 231 | 222 | 84 |
| Italy | 2216 | 1982 | 492 | 443 |
| Poland | 3827 | 1363 | 2145 | 454 |
| Slovenia | 210 | 50 | 25 | 14 |
| CEI | 10,282 | 4970 | 4074 | 1295 |
| Europe† | 40,644 | 20,546 | — | 7250‡ |

* Emission data for Croatia includes only public power plants (Jelavic *et al.*, 1992).

† Total European emissions of SO₂ and NO_x are estimated on the basis of the UN Economic Commission for Europe (ECE) data as of 1 Oct. 1992 (UNECE, 1992).

‡ Total European CO₂ emission estimation is based on information stored in the database of the Environmentally Compatible Energy Strategies Project at IIASA.

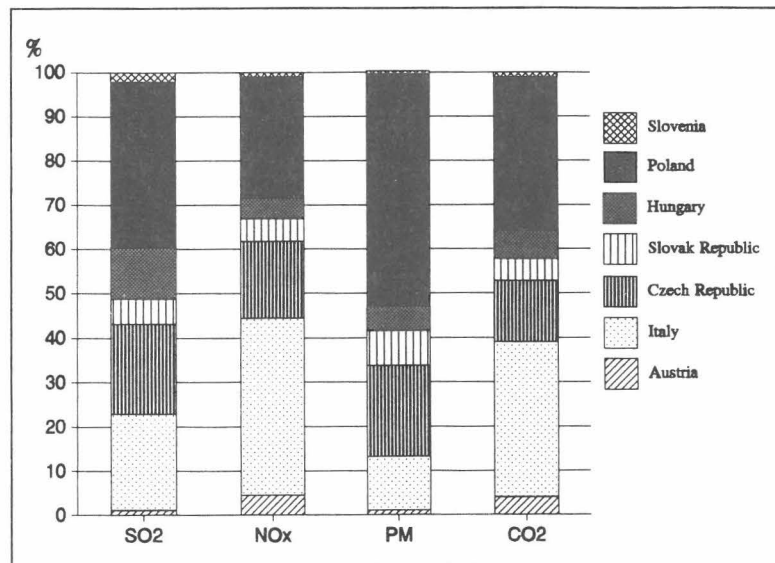
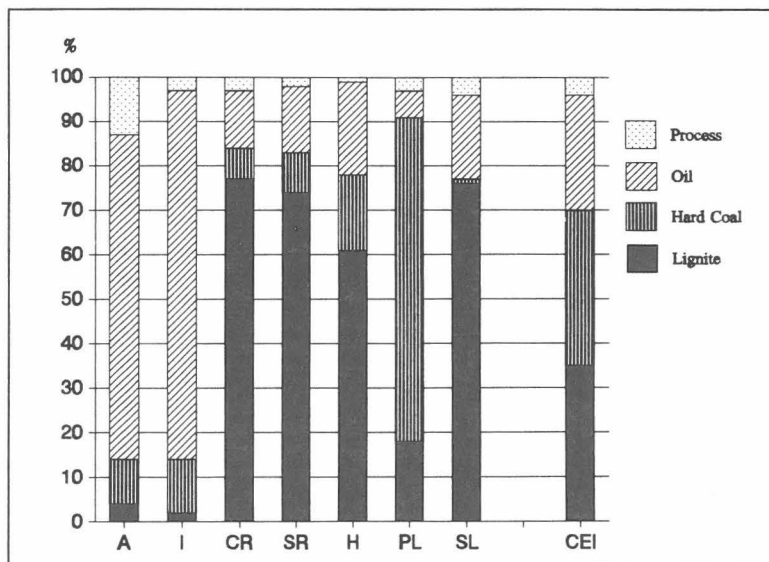
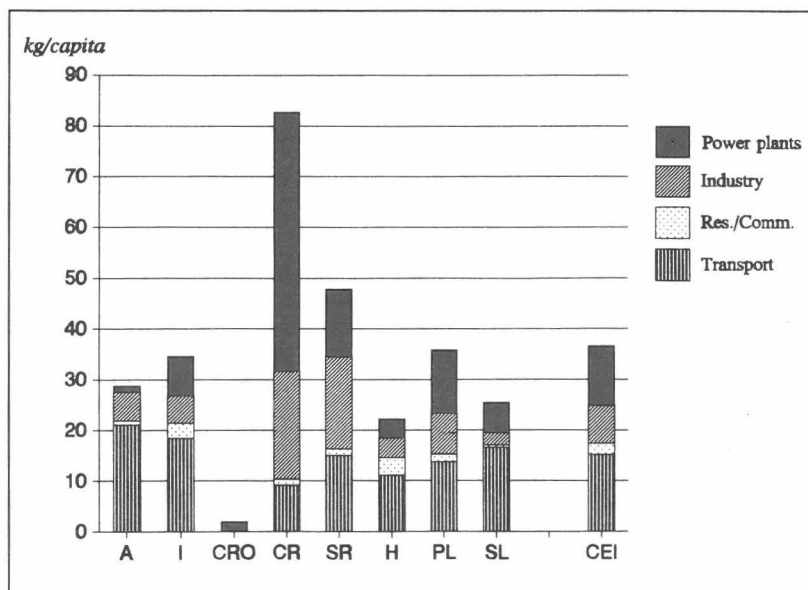


Fig. 1. National contributions to total CEI emissions.

Fig. 2. SO₂ emissions by fuels in the CEI region.Fig. 3. Sectoral per capita emissions of NO_x in the CEI region.

emissions result from combustion of (domestic) solid fuels. On the other hand, in countries where solid fuels are to a large extent imported, i.e. in Austria and Italy, related SO₂ emissions account for less than 20% of their national totals. As a consequence, it may be concluded that a simple fuel substitution policy in order to decrease emissions, i.e. replacing high-sul-

phur hard coal by other forms of (imported) energy, would have significant economic effects on the domestic coal-mining activities in eastern European countries.

A similar situation exists for emissions of particulate matter. The high emissions specific to solid fuels are aggravated by the fact that, in contrast to western

European standards, many power stations in the former CMEA countries are still operated without adequate equipment to capture particulates.

The contribution of western countries to total NO_x and CO_2 emissions in the CEI region is substantially higher than their contribution to SO_2 and PM emissions. Higher traffic density in Austria and Italy results in higher NO_x emissions (see Fig. 3). A similar situation is also present for carbon dioxide emissions. Higher CO_2 emissions due to the energy intensity in the former CMEA countries are partly counterbalanced by higher transport emissions in western market economies.

SO_2 , NO_x and PM emission densities

The CEI'88 inventory also contains a database with SO_2 , NO_x and particulate matter emissions allocated to the territorial units. This section presents maps of the CEI region. The maps display the emission densities of the considered pollutants.

Figure 4 displays the emission densities of SO_2 in the individual administrative regions throughout the CEI region. Area-related emissions range from below one ton of SO_2 per km^2 per year ($\text{SO}_2 \text{ km}^{-2} \text{ yr}^{-1}$) in Austria, northern Poland, and many regions in Italy to above 100 tons $\text{SO}_2 \text{ km}^{-2} \text{ yr}^{-1}$ in Northern Bohemia and Upper Silesia. The major reason for this wide range can be derived from a comparison of the emission densities of area sources with those of point sources. Area source emissions show relatively little variations, with peaks in densely populated areas (e.g. in Prague, Warsaw, Budapest and Milan), and in districts around coal mines, where local coal is burned in small appliances (e.g. Northern Bohemia and eastern Hungary). Large point sources, however, can dominate total emissions in a region. The absolute peak occurs in Northern Bohemia (with more than 100 tons $\text{SO}_2 \text{ km}^{-2} \text{ yr}^{-1}$ from LPS); many areas, however, have low or even no LPS emissions.

Regional densities of NO_x emissions show less variation than regional densities of SO_2 emissions (Fig. 5). High emissions occur in many regions of Italy and in the industrialized areas of Poland and Czechoslovakia. The major source of NO_x emissions in most Italian regions is from area sources, only in a few regions (e.g. Gorizia, La Spezia) do point sources contribute substantially. In Czechoslovakia and Poland, point source emissions have higher shares in total regional emissions than in other CEI countries. The main reason for this is the higher motorization in western countries and the fact that in Czechoslovakia and Poland the number of large point sources identified (in this inventory) is larger than, for example, in Hungary, where individual data on industrial sources is missing.

Figure 6 shows the regional distribution of particulate matter emissions. The strong reliance on low-quality coal combustion without appropriate control technologies in the former CMEA (Council of Mutual

Economic Assistance) countries causes considerable emissions in this region, whereas in countries where high-efficiency electrostatic precipitators are standard equipment of coal-fired boilers, emission densities are significantly lower.

Characterization of large point sources in the CEI region

The CEI'88 emission inventory comprises a database with detailed techno-economic information on the large pollution sources in the region. Currently, this database identifies 402 individual sources. The locations and the emission levels of the individual large point sources of SO_2 are displayed in Fig. 7.

Across the CEI region, 60% of SO_2 is emitted from the large point sources. On the other hand, only about one-third of NO_x originates from these large emitters. The contributions of large point sources to total national emissions are shown in Fig. 8. In the majority of the CEI countries LPS contribute more than 60% to national sulphur dioxide emissions. The only exception is Austria, where a rigorous desulphurization program applied to large boilers lowered the contribution to about 25%.

Out of the 402 large point sources identified in the CEI'88 inventory, 204 units belong to the category of public power plants. Thereby, the generation of electricity in those plants causes almost half (46.3%) of the total SO_2 emissions of the region. Consequently, power plants are major candidates for reducing SO_2 emissions in the region. However, any effective emission reduction strategy should not only focus on environmental aspects alone, but also consider the broader economic context, in particular the energy efficiency of national economies, the age and technical performance of the equipment, and changes in energy demand caused by structural changes in the economy.

With the information collected during the study for the large point sources important conclusions for potential restructuring processes can be drawn. As an example, Fig. 9 displays national SO_2 emissions in public power stations according to the age classes of the boilers, i.e. differentiated according to the commissioning year of the source. Over 50% of SO_2 emissions from public power plants within the CEI region is produced in plants older than 20 years. An important exception is Austria where power stations older than 20 years, using sulphur-containing fuels, operate only in peak mode contributing only 5% to the SO_2 emission. In Hungary, on the other hand, more than 80% of the SO_2 was produced in boilers older than 20 years.

In general, boilers usually reach the end of a technical lifetime within 20–40 years. Consequently, it does not seem promising to promote strategies for retrofitting plants older than 20 years with desulphurization equipment, but, if economically feasible, it might be preferable to replace the entire plant by new installations. Such new installations will also have a

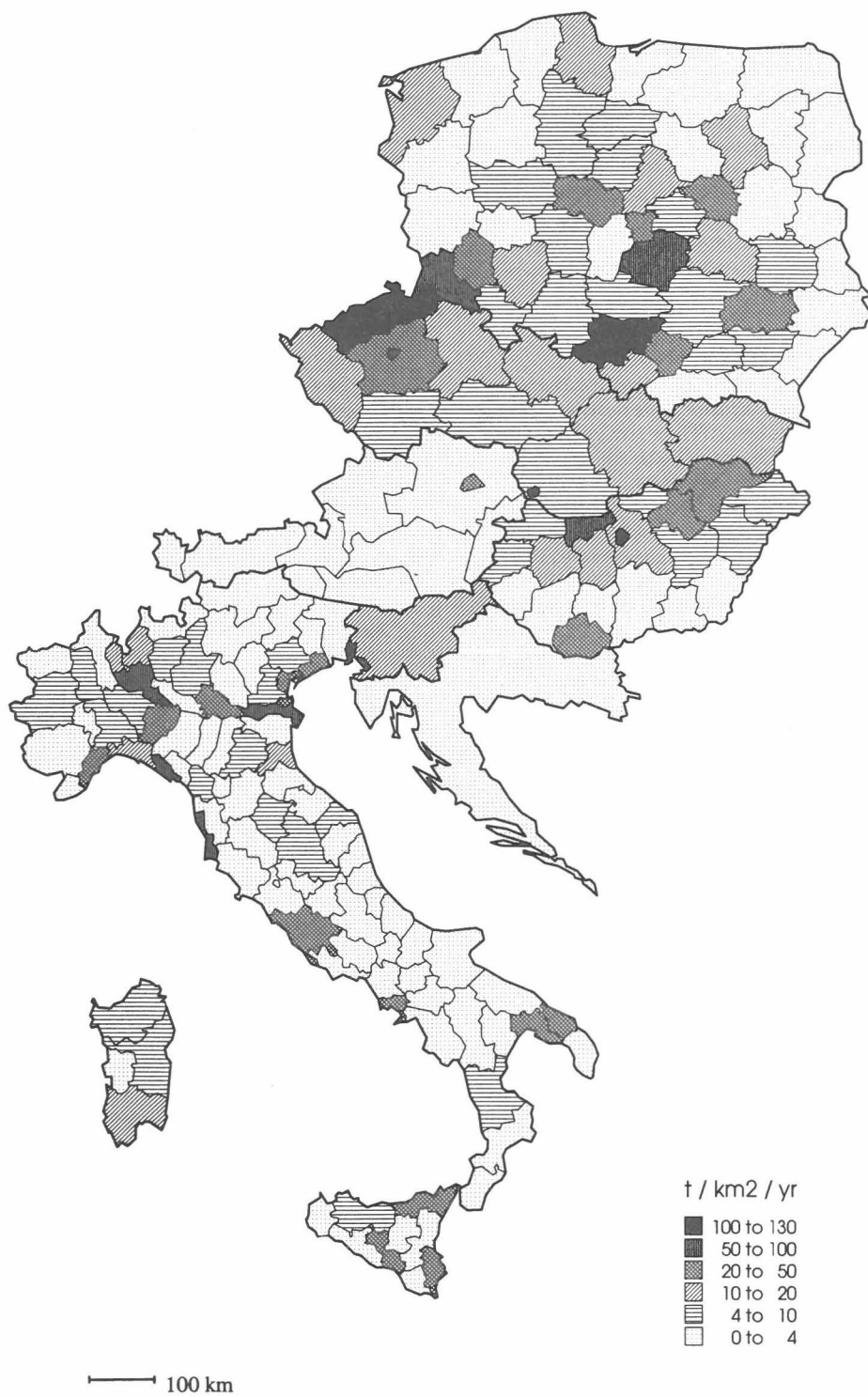


Fig. 4. Regional SO₂ emissions from all sources in the CEI region.

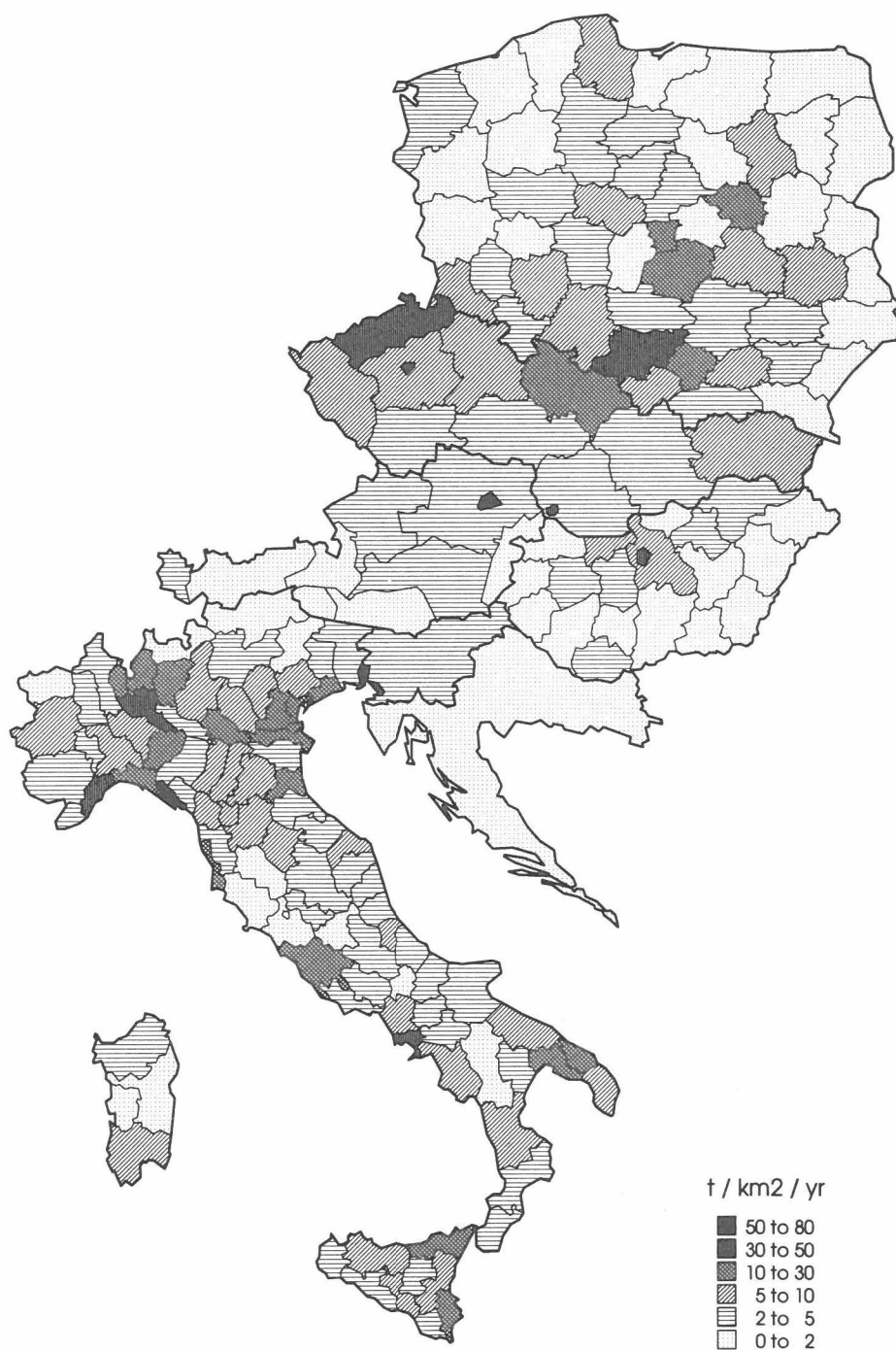


Fig. 5. Regional NO_x emissions from all sources in the CEI region.

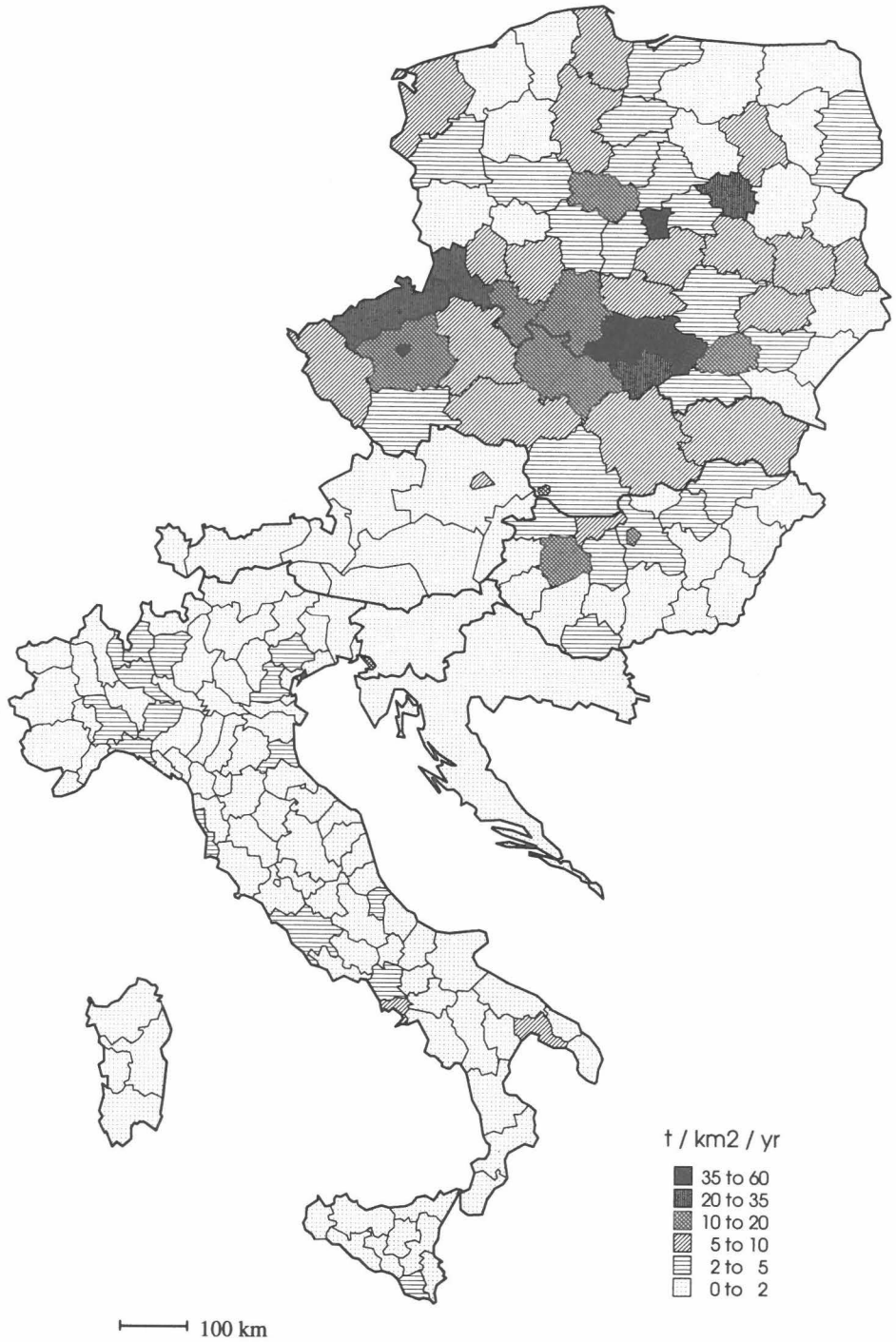


Fig. 6. Regional PM emissions from all sources in the CEI region.

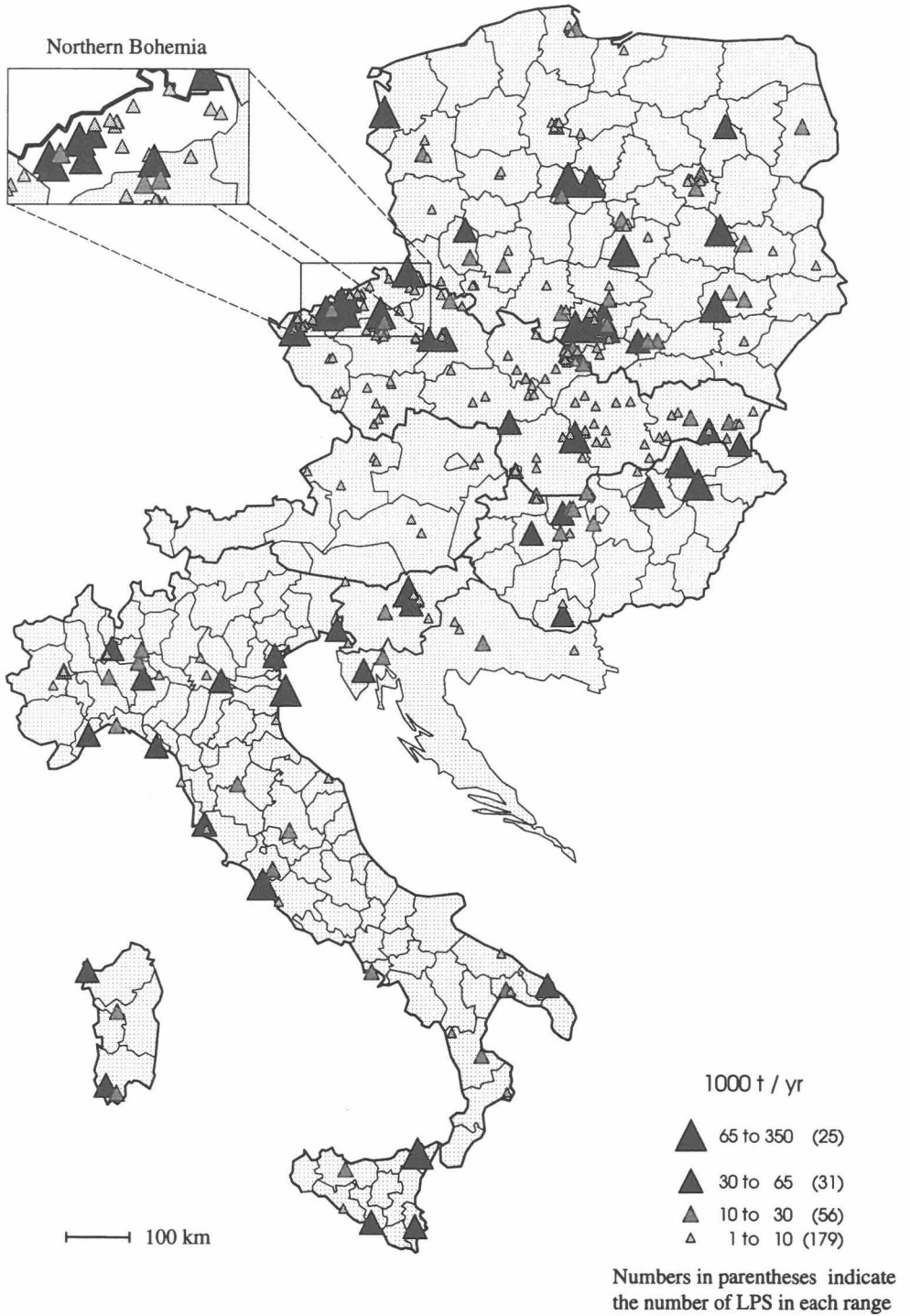


Fig. 7. Locations of large point sources of SO₂ emissions in the CEI region.

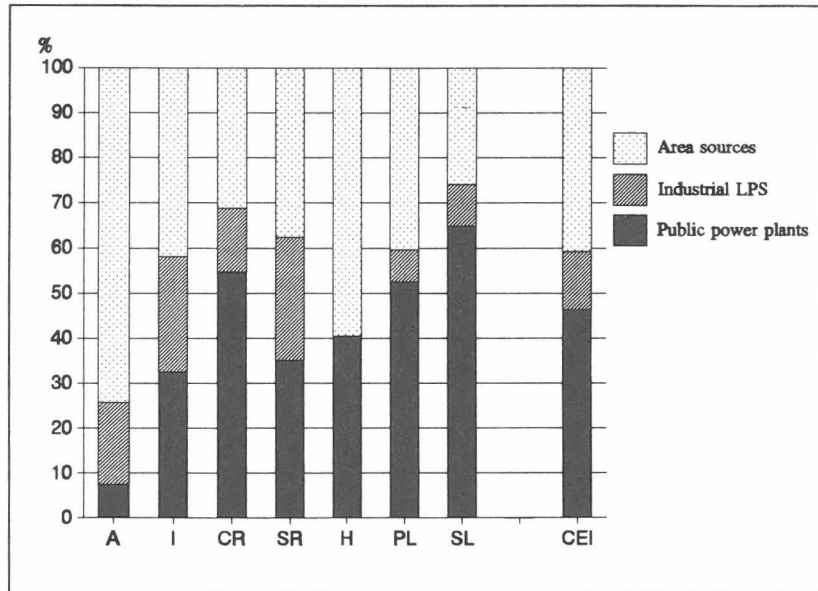


Fig. 8. Share of large point sources in national SO₂ emissions.

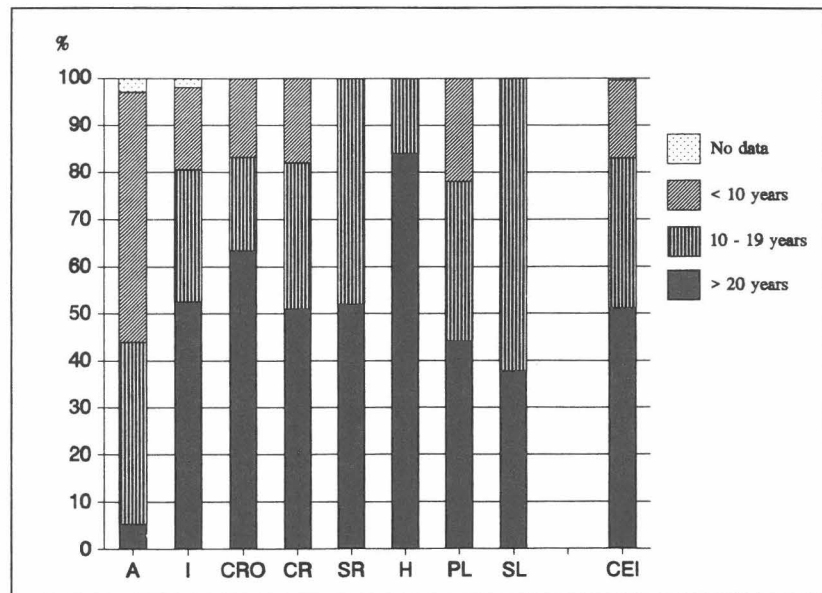


Fig. 9. SO₂ emissions according to the age of boilers (public power plants only).

higher energy efficiency than the old boilers, thereby reducing the required volume of fuel input (e.g. coal) to produce the same amount of electricity. According to the CEI'88 database most of the power plants in the former CMEA countries older than 20 years are

operating with an efficiency of between 28 and 32%. For new conventional plants, however, efficiencies range between 40 and 43%. This means that when electricity demand is constant, just replacing old obsolete equipment with new installations (without

| | Name of the Plant | Country | Region | SO ₂ Emission (kt/year) |
|-------|-------------------|-------------|----------------------|------------------------------------|
| 1 | PPP Belchatow | Poland | Piotrkow Trybunalski | 341.6 |
| 2 | PPP Prunerov | Czech Rep. | Northern Bohemia | 273.5 |
| 3 | PPP Turov | Poland | Jelenia Gora | 205.4 |
| 4 | PPP Tusimice | Czech Rep. | Northern Bohemia | 196.3 |
| 5 | PPP Polaniec | Poland | Tarnobrzeg | 149.8 |
| 6 | PPP Jaworzno III | Poland | Katowice | 131.4 |
| 7 | PPP Pocerady | Czech Rep. | Northern Bohemia | 126.9 |
| 8 | PPP | Italy | Roma | 123.9 |
| 9 | PPP Kozenice | Poland | Radom | 116.2 |
| 10 | PPP Kostolany | Slovak Rep. | Central Slovakia | 114.7 |
| 11 | PPP Siersza | Poland | Katowice | 111.5 |
| 12 | PPP Rybnik | Poland | Katowice | 97.1 |
| 13 | PPP Gagarin | Hungary | Heves | 94.6 |
| 14 | PPP Tisova | Czech Rep. | Western Bohemia | 86.2 |
| 15 | Refinery | Italy | Messina | 85.1 |
| 16 | PPP Sostanj | Slovenia | Slovenia | 84.7 |
| 17 | PPP Patnow-Konin | Poland | Konin | 84.0 |
| 18 | PPP | Italy | Rovigo | 80.3 |
| 19 | PPP Melnik | Czech Rep. | Central Bohemia | 79.1 |
| 20 | PPP Dolna Odra | Poland | Szczecin | 78.3 |
| 21 | PPP Laziska | Poland | Katowice | 77.6 |
| 22 | PPP Borsod | Hungary | Borsod-Abauj-Zemlen | 68.9 |
| 23 | PPP Tisza | Hungary | Borsod-Abauj-Zemlen | 67.4 |
| 24 | Refinery Plock | Poland | Plock | 67.3 |
| 25 | Chemopetrol | Czech Rep. | Northern Bohemia | 65.7 |
| Total | | | | 3007.5 |

PPP - Public Power Plant

Scheme 2. The 25 largest emitters of SO₂ in the CEI region in 1988.

applying any emission control) could reduce SO₂ emissions by 30–40%. The application of standard emission control technologies (such as flue gas desulfurization) or fuel substitution could reduce emissions even further.

Particularly high emissions occur at many power plants in eastern Europe. The largest emitter, the power plant in Belchatow (Poland), emits 342 kt of SO₂, which is almost three times higher than all Austrian sources together (116 kt SO₂). This is not an exception; there are nine additional plants identified in the inventory whose emissions surpass those of all of Austria. In total, 25 largest plants (out of the 402 LPS identified in the CEI'88 inventory) are responsible for about 30% of total SO₂ emissions in the CEI region (Scheme 2).

Reliability and accuracy of the emission inventory

The question of reliability of emission estimates is often cause for concern. Major factors influencing the accuracy of emission estimates are:

- quality of energy and emission data,
- data on fuel quality (sulphur content, calorific value, etc.),
- emission factors.

The quality of statistical material available varies from country to country. In some of the CEI countries, energy and emission statistics were incomplete for 1988. Therefore, appropriate statistics for other years were used. The margin of error, however, is expected

to be small due to the fact that at that time economic changes were relatively slow. A more important source of inaccuracy is related to differences in classification of sectors in data provided by the national experts.

Fuel quality data, especially sulphur content and calorific value, are of great importance for all emission estimates. Data on the national level are usually consistent and reliable. However, calculations on the regional level, especially for the residential/commercial sector, are often based on incomplete data. This applies mainly to those countries where domestically produced solid fuels are used extensively in this sector, e.g. Poland, the Czech Republic and the Slovak Republic.

In this paper, NO_x emissions are based on data provided by the national experts. The underlying NO_x emission factors are generally in accordance with internationally accepted coefficients (Bouscaren, 1991). There are, however, some exceptions. In case of the Czech Republic and the Slovak Republic, emission factors applied in the national system for estimation of emissions of air pollutants (REZZO—Register of Emissions and Sources of Atmospheric Pollutants) (Jilek, 1992) result in emissions, in some cases, even 100% higher than emissions calculated using international emission factors.

For particulate matter emission, the values obtained for power plants are generally reliable. However, PM emissions for other sectors, especially estimates on the regional level, rely strongly on the avail-

ability and the accuracy of fuel quality data as well as on estimates of efficiency of particulate control equipment. Again, this is a major concern in countries where solid fuels play a dominant role.

CONCLUSIONS

The emission inventory of the Central European Initiative (the CEI'88 inventory) described in this paper provides the first consistent overview of emissions of sulphur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter (PM) and carbon dioxide (CO₂) of the region. The inventory describes the situation in the year 1988 for Austria, Croatia, Czechoslovakia (separated into the Czech and Slovak Republics), Hungary, Italy, Poland and Slovenia. The collected database provides the following:

- an estimate of the overall quantity of emissions (regionally disaggregated into 187 administrative units),
- a description of the most important techno-economic parameters of the main individual emission sources in the region (402 sources are considered).

The study shows that central Europe contributes substantially to total European emissions of air pollutants. The reasons for this dominant role are the high population density and the high level of economic activities occurring in the region. Even more important, however, are the high energy intensities of the former centrally planned economies, where energy is mainly supplied by the combustion of domestic solid fuels without appropriate emission control equipment.

The CEI'88 inventory provides important information for in-depth analysis of air pollution, not only for central Europe, but, due to the long-range transport of pollutants, also for the whole of Europe. The information contained in the database is an essential element for designing of cost-effective strategies to reduce air pollution.

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