CRC Report No. A-102

Source-Sector Contributions to European Ozone and Fine PM in 2010 Using AQMEII Modeling Data

Executive Summary

October 2016

COORDINATING RESEARCH COUNCIL, INC.

5755 NORTH POINT PARKWAY·SUITE 265·ALPHARETTA, GA 30022

The Coordinating Research Council, Inc. (CRC) is a non-profit corporation supported by the petroleum and automotive equipment industries. CRC operates through the committees made up of technical experts from industry and government who voluntarily participate. The four main areas of research within CRC are: air pollution (atmospheric and engineering studies); aviation fuels, lubricants, and equipment performance, heavy-duty vehicle fuels, lubricants, and equipment performance (e.g., diesel trucks); and light-duty vehicle fuels, lubricants, and equipment performance (e.g., passenger cars). CRC's function is to provide the mechanism for joint research conducted by the two industries that will help in determining the optimum combination of petroleum products and automotive equipment. CRC's work is limited to research that is mutually beneficial to the two industries involved, and all information is available to the public.

Source-Sector Contributions to European Ozone and Fine PM in 2010 Using AQMEII Modeling Data

CRC A-102
Executive Summary

Prepared for:
Coordinating Research Council, Inc.
5755 North Point Parkway, Suite 265
Alpharetta, GA 30022

Prepared by:
Ramboll Environ
773 San Marin Drive, Suite 2115
Novato, California, 94998
www.ramboll-environ.com
P-415-899-0700
F-415-899-0707

October 26, 2016

06-35893C

RAMBOLL ENVIRON

EXECUTIVE SUMMARY

The objective of this collaborative study was to use the source apportionment tools in CAMx for ozone and PM (OSAT and PSAT) with a recent European modeling database developed for Phase 3 of the Air Quality Model Evaluation International Initiative (AQMEII) to compare the contribution of on-road mobile sources to other source sectors in Europe. In CRC Project A-75, Ramboll Environ collaborated with RSE (Research on Energy Systems) to model O_3 and $PM_{2.5}$ over a European modeling domain for calendar year 2006 in Phase 1 of AQMEII. AQMEII Phases 2 and 3 developed more current modeling databases for 2010. None of the previous or ongoing studies for AQMEII have examined source sector contributions to O_3 or $PM_{2.5}$ in Europe. CRC Project A-102 fills this gap by quantifying the contributions of several source sectors, including on-road mobile sources, in Europe.

Ramboll Environ's collaborators (Dr. Alessandra Balzarini and Dr. Guido Pirovano at RSE) on CRC Project A-102 developed the European CAMx modeling database for 2010 in the framework of the AQMEII Phase 3. RSE conducted a model performance evaluation using the database and provided the database for the source attribution studies described here. The emissions data for the modeling were segregated by source sector, including natural emissions (biogenic, sea-salt) and 9 anthropogenic source sectors, referred to as Selected Nomenclature for Air Pollution (SNAP) sectors. Table ES-1 provides a description of the SNAP sectors.

The modeling domain for the study covered Europe and a portion of Africa. CAMx version 6.1 with CB05 gas phase chemistry and the Coarse-Fine (CF) aerosol scheme was used in the study. Meteorological inputs and wind-blown dust emissions for 2010 were obtained from WRF-Chem 3.4.1. Biogenic emissions for 2010 were developed using MEGAN v2.04, while anthropogenic emissions for the SNAP sectors were derived from the TNO-MACC_II emission inventory. Sea salt emissions were estimated using published algorithms and chemical boundary conditions were derived from the Monitoring Atmospheric Composition and Climate (MACC) project using the Composition–Integrated Forecast System (C-IFS) model.

The OSAT and PSAT simulations were conducted for a summer month (August 2010) and a winter month (February 2010) with a 1 week spin-up period preceding each month. In addition to the SNAP sector emission categories, the contributions of biogenic emissions, dust and sea salt emissions (for PM), and boundary conditions were explicitly tracked in the source apportionment simulations for the two months. Secondary organic aerosol (SOA) was not apportioned in the PSAT simulation due to computer memory constraints.

Sixteen cities, representing the Nordic countries, countries in western, central, and eastern Europe, and countries near the Mediterranean were selected for the source attribution analysis. The source attribution results for summertime ozone, summertime $PM_{2.5}$, and wintertime $PM_{2.5}$ are shown in Tables ES-2 through ES-4 for the top source sectors with contributions greater than 5%. Results for wintertime ozone are not shown because of the low ozone concentrations and because wintertime ozone levels are dominated by boundary conditions.

The results show that long-range transport of ozone and/or its precursors has a strong influence on summertime ozone in August 2010 over most of Europe. The boundary condition (BC) contributions are about 26% to 34% in southern Europe and 20% to 30% in central and eastern Europe. The boundary condition contributions in western Europe are larger, ranging from about 30% to 60%. In the Nordic cities, BC contributions range from about 20% in Stockholm to 40% in Oslo. For many cities, boundary conditions are the largest contributors. These results are in qualitative agreement with a number of studies that have examined the role of intercontinental transport of ozone and its precursors to the European continent.

Contributions from biogenic emissions to summertime ozone levels in Europe are also important in many cities, ranging from a low of 8% in London to a high of 33% in Kiev. The transport sector is an important anthropogenic contributor for summertime ozone with combined on-road and non-road contributions ranging from 20 to 40%. Other important contributing sectors are the energy sector and the industry sector. The largest contributions of the energy sector are in central and Eastern Europe (9% to 17%) and in the Nordic cities (5% to 13%). Industry contributions to summertime ozone are important for the Mediterranean cities and cities in central and eastern Europe, with contributions ranging from 5% to 9%. In two of the 16 cities selected for analysis, solvent and product use also contributed more than 5% to summertime ozone.

Boundary conditions also have a large impact on summer $PM_{2.5}$ levels and are the largest contributors for the Mediterranean cities (40% to 50%). These results are consistent with studies showing the role of transport of Saharan dust from North Africa on PM concentrations in the Mediterranean region. Secondary organic aerosols (SOA) are also important contributors to summer PM (ranging from 8 to 15% in the Mediterranean cities to 23 to 31% in the Nordic cities). The important anthropogenic source sectors for summer $PM_{2.5}$ concentrations in Europe are the energy sector, the transport sector, industry, and agriculture. Energy sector contributions are particularly important in central and eastern Europe, with the largest contributions (over 20%) in Warsaw and Budapest. Non-road transport contributions (6 to 28%) are generally larger than on-road contributions (5 to 13%). The largest non-road contributions are in Amsterdam (28%), London (23%), and the Nordic cities (15 to 26%). Industry sector contributions to summertime $PM_{2.5}$ concentrations range from 5 to 11%. Agriculture contributions range from 6 to 14%, with the largest contributions in central and eastern Europe (12 to 14%) and in Paris (14%). In the Nordic cities, agriculture contributions are less than 10%, except in Copenhagen (7%).

The contributions from boundary conditions to wintertime $PM_{2.5}$ are much smaller than the summertime contributions. SOA contributions are less than 5% in central and eastern Europe but are higher (6 to 47%) in the other three regions, with the largest contribution of 47% in Lisbon and the second largest contribution (23%) in London. Residential wood combustion is an important anthropogenic sector in winter for $PM_{2.5}$ over most of Europe, with the largest contributions in central and eastern Europe (29 to 37%) and in the Nordic cities (19 to 47%). Other anthropogenic sectors with large contributions to wintertime $PM_{2.5}$ include the transport sector (7 to 22% for road transport and 7 to 23% for non-road transport), the energy sector (6 to 17%), and agriculture (7 to 16%). Industry sector contributions to wintertime $PM_{2.5}$ are less than 10%.

Table ES-1. SNAP sector classification of anthropogenic emissions.

Sector Number	Description
1	Energy industries (e.g., power generation and refineries
2	Non-industrial (residential) combustion
34	Industry*
5	Extraction and distribution of fossil fuels
6	Solvent and other product use
7	Road transport (includes exhaust, evaporative, tire/brake/road wear)
8	Non-road transport (includes rail, aircraft, shipping, construction equipment)
9	Waste treatment
10	Agriculture

***Sector 34 combines "industrial combustion" (SNAP 3) with "industrial processes" (SNAP 4) to mitigate inconsistent classification of sources to sector 3 or 4 (see Kuenen et al., 2014).**

Table ES-2. Sectors contributing 5% or more to summertime H1MDA8 ozone concentrations.

City (ppb)	Sector* Contributions (%)					
Barcelona (58)	BC (28)	SNAP 7 (21)	SNAP 8 (18)	Biogenic (15)	SNAP 34 (7)	SNAP 1 (5)
Lisbon (61)	BC (34)	SNAP 7 (20)	Biogenic (19)	SNAP 8 (11)	SNAP 34 (6)	SNAP 1 (6)
Athens (69)	BC (26)	SNAP 7 (24)	SNAP 8 (16)	Biogenic (15)	SNAP 1 (8)	SNAP 34 (6)
Istanbul (73)	BC (26)	Biogenic (24)	SNAP 7 (15)	SNAP 8 (13)	SNAP 34 (9)	SNAP 1 (8)
Minsk (58)	BC (25)	Biogenic (23)	SNAP 7 (19)	SNAP 1 (15)	SNAP 8 (10)	--
Budapest (63)	SNAP 7 (35)	BC (29)	SNAP 1 (11)	Biogenic (10)	SNAP 8 (7)	SNAP 34 (5)
Warsaw (66)	BC (28)	SNAP 7 (24)	SNAP 1 (17)	Biogenic (14)	SNAP 8 (7)	SNAP 34 (7)
Kiev (70)	Biogenic (33)	BC (21)	SNAP 7 (18)	SNAP 8 (10)	SNAP 1 (9)	SNAP 34 (6)
London (41)	BC (56)	SNAP 8 (12)	SNAP 7 (11)	Biogenic (8)	--	--
Paris (44)	BC (59)	SNAP 7 (13)	Biogenic (10)	SNAP 8 (6)	SNAP 6 (6)	--
Amsterdam (51)	BC (29)	Biogenic (21)	SNAP 7 (19)	SNAP 6 (10)	SNAP 8 (8)	SNAP 1 (6)
Berlin (56)	BC (46)	SNAP 7 (17)	SNAP 1 (13)	Biogenic (11)	SNAP 8 (6)	--
Copenhagen (44)	BC (29)	SNAP 7 (23)	SNAP 8 (14)	SNAP 1 (13)	Biogenic (12)	SNAP 34 (5)
Oslo (50)	BC (41)	Biogenic (20)	SNAP 8 (14)	SNAP 7 (12)	--	--
Helsinki (50)	BC (31)	SNAP 8 (21)	SNAP 7 (17)	SNAP 1 (13)	Biogenic (13)	--
Stockholm (57)	SNAP 7 (24)	BC (21)	SNAP 8 (18)	Biogenic (18)	SNAP 1 (12)	--

*See Table ES-1 for anthropogenic (SNAP) sector descriptions

Table ES-3. Sectors contributing 5% or more to summertime monthly mean $PM_{2.5}$ concentrations.

City (µg/m³)	Sector* Contributions (%)					
Lisbon (11)	BC (45)	SNAP 8 (18)	SOA (15)	SNAP 34 (6)	SNAP 7 (5)	--	--
Barcelona (12)	BC (40)	SNAP 8 (19)	SOA (11)	SNAP 7 (10)	SNAP 34 (5)	--	--
Athens (16)	BC (38)	SNAP 1 (15)	SNAP 8 (10)	SOA (9)	SNAP 10 (8)	SNAP 7 (7)	SNAP 34 (6)
Istanbul (17)	BC (49)	SNAP 34 (11)	SOA (8)	SNAP 1 (8)	SNAP 10 (7)	SNAP 8 (6)	--
Budapest (10)	SNAP 1 (23)	BC (23)	SNAP 10 (13)	SOA (13)	SNAP 34 (9)	SNAP 7 (8)	SNAP 8 (5)
Warsaw (13)	SNAP 1 (24)	BC (21)	SOA (13)	SNAP 10 (12)	SNAP 7 (10)	SNAP 8 (8)	SNAP 34 (8)
Minsk (13)	BC (27)	SOA (18)	SNAP 10 (14)	SNAP 1 (14)	SNAP 7 (8)	SNAP 8 (7)	SNAP 34 (7)
Kiev (13)	BC (37)	SOA (17)	SNAP 10 (12)	SNAP 1 (9)	SNAP 8 (9)	SNAP 34 (6)	--
Berlin (8)	SOA (19)	SNAP 1 (15)	SNAP 8 (14)	BC (14)	SNAP 7 (12)	SNAP 34 (10)	SNAP 10 (8)
London (10)	SOA (32)	SNAP 8 (23)	SNAP 7 (13)	BC (12)	SNAP 1 (7)	SNAP 34 (5)	--
Paris (11)	SOA (18)	SNAP 8 (16)	SNAP 10 (14)	BC (14)	SNAP 7 (13)	SNAP 34 (8)	SNAP 1 (8)
Amsterdam (13)	SNAP 8 (28)	SOA (23)	SNAP 7 (13)	SNAP 1 (9)	BC (9)	SNAP 34 (6)	SNAP 10 (6)
Oslo (8)	SNAP 8 (25)	SOA (25)	SNAP 2 (11)	BC (10)	SNAP 7 (9)	SNAP 1 (7)	SNAP 34 (6)
Stockholm (8)	SOA (31)	SNAP 8 (15)	BC (15)	SNAP 1 (12)	SNAP 7 (10)	SNAP 34 (7)	--
Helsinki (8)	SOA (31)	BC (15)	SNAP 8 (15)	SNAP 7 (13)	SNAP 1 (10)	SNAP 34 (5)	--
Copenhagen (11)	SNAP 8 (26)	SOA (23)	BC (11)	SNAP 7 (10)	SNAP 1 (10)	SNAP 10 (7)	SNAP 34 (6)

*See Table ES-1 for anthropogenic (SNAP) sector descriptions

Table ES-4. Sectors contributing 5% or more to wintertime monthly mean $PM_{2.5}$ concentrations.

City (µg/m³)	Sector* Contributions (%)							
Lisbon (13)	SOA (47)	SNAP 2 (15)	SNAP 8 (13)	SNAP 7 (7)	SNAP 34 (6)	--	--	--
Barcelona (13)	SNAP 8 (21)	SOA (18)	SNAP 7 (18)	SNAP 2 (17)	SNAP 10 (7)	SNAP 1 (7)	SNAP 34 (7)	--
Athens (15)	SNAP 2 (20)	SNAP 8 (17)	SOA (13)	BC (12)	Dust (10)	SNAP 7 (10)	SNAP 1 (9)	--
Istanbul (26)	SNAP 2 (25)	SNAP 7 (11)	BC (11)	SNAP 34 (11)	SNAP 1 (10)	SNAP 8 (10)	SNAP 10 (9)	SOA (6)
Budapest (30)	SNAP 2 (29)	SNAP 7 (18)	SNAP 1 (17)	SNAP 10 (15)	SNAP 8 (7)	SNAP 34 (7)	--	--
Minsk (30)	SNAP 2 (33)	SNAP 10 (16)	SNAP 1 (13)	SNAP 7 (12)	SNAP 8 (10)	SNAP 34 (7)	--	--
Kiev (31)	SNAP 2 (37)	SNAP 10 (12)	SNAP 1 (11)	SNAP 8 (10)	SNAP 7 (10)	SNAP 34 (9)	--	--
Warsaw (38)	SNAP 2 (34)	SNAP 7 (17)	SNAP 10 (16)	SNAP 1 (12)	SNAP 8 (7)	SNAP 34 (6)	--	--
London (21)	SNAP 8 (23)	SOA (23)	SNAP 7 (19)	SNAP 2 (11)	SNAP 10 (7)	SNAP 1 (6)	--	--
Paris (25)	SNAP 2 (30)	SOA (16)	SNAP 7 (16)	SNAP 8 (13)	SNAP 10 (8)	SNAP 1 (6)	SNAP 34 (6)	--
Amsterdam (26)	SNAP 7 (19)	SNAP 8 (18)	SNAP 2 (16)	SNAP 10 (13)	SOA (12)	SNAP 1 (10)	SNAP 34 (7)	--
Berlin (32)	SNAP 2 (24)	SNAP 7 (18)	SNAP 10 (15)	SNAP 1 (12)	SNAP 8 (11)	SNAP 34 (7)	SOA (6)	--
Stockholm (17)	SNAP 7 (22)	SNAP 2 (19)	SNAP 8 (16)	SOA (14)	SNAP 1 (10)	SNAP 10 (7)	SNAP 34 (6)	--
Oslo (19)	SNAP 2 (47)	SNAP 8 (16)	SNAP 7 (11)	SOA (7)	SNAP 1 (6)	SNAP 10 (5)	--	--
Helsinki (21)	SNAP 2 (33)	SNAP 7 (18)	SNAP 8 (14)	SNAP 1 (9)	SOA (9)	SNAP 10 (7)	SNAP 34 (5)	--
Copenhagen (24)	SNAP 2 (20)	SNAP 8 (19)	SNAP 7 (14)	SNAP 10 (12)	SNAP 1 (12)	SOA (11)	SNAP 34 (6)	--

*See Table ES-1 for anthropogenic (SNAP) sector descriptions