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Documents
13/2013

Statistics Norway
Statistisk sentralbyrå

Kristin Aasestad

Emissions of Black carbon and Organic carbon in Norway 1990-2011

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Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger

Documents In this series, documentation, method descriptions, model descriptions and standards are published.

Published April 2013

ISBN 978-82-537-8637-7 (printed)
ISBN 978-82-537-8638-4 (electronic)
ISSN 1891-5906
Subject:

Print: Statistics Norway

Symbols in tables	**Symbol**
Category not applicable	.
Data not available	..
Data not yet available	…
Not for publication	:
Nil	-
Less than 0.5 of unit employed	0
Less than 0.05 of unit employed	0.0
Provisional or preliminary figure	*
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Preface

This report documents the methodologies used, and the results from the project **"Emission of black and organic carbon in Norway, 1990- 2011"**.

In this project, the objective has been to develop a method for calculating emissions of black carbon and organic carbon in Norway based on the methodologies used for estimatimating emissions of greenhouse gases and long-range transboundary air pollutants in Norway.

The results from the project include an applicable methodology, presented in chapter 3. Documentation of the methods used presented in chapter 4-8 and calculated emissions on black carbon and organic carbon for the period 1990-2011 for different sources are presented in chapter 9.

The report has been prepared by Statistics Norway's Division for energy and environmental statistics, and has been written by Kristin Aasestad, with contributions from Nina Holmengen and Håkon Skullerud. Marte Kittilsen has contributed in data processing.

The work was carried out with essential contributions from Vigdis Vestreng at The Climate and Pollution Agency. Lars Petter Bingh and Eilev Gjerald both at The Climate and Pollution Agency have been part of the project group and have contributed in data collection, expert judgements and other valuable contributions to the project.

The authors also thank the experts who have been consulted during the preparation of this report: Zbigniew Klimont Center for Integrated Assessment Modelling at International Institute for Applied Systems Analysis (IIASA), Austria and Kaarle Kupiainen, IIASA and Finnish Environment Institute (SYKE), Helsinki, Finland.

The project was financed by the Climate and Pollution Agency.

Statistics Norway, 5 April 2013

Hans Henrik Scheel

Abstract

Limiting anthropogenic climate change and improving air quality are two of the most important environmental challenges facing humankind. Warming effects of Black Carbon (BC) have caught the attention of climate scientists and policy makers. Scientists suggest that BC is likely to be the second most important contributor, after carbon dioxide, to global warming (UNEP 2009).

Statistics Norway was commissioned by the Norwegian Climate and Pollution agency (Klif) to develop national Black Carbon (BC) and OC (Organic Carbon) emissions inventories for the period 1990-2011.

In this project, the objective has been to develop a methodology for calculating emissions of black carbon (BC) and organic carbon (OC) for the period 1990-2011, and to describe the method used. The data employed encompass the activity date used in the Norwegian emission inventory and emission factors for particulate matter, BC and OC.

Emissions of BC and OC in Norway have been estimated based on the national emissions of $PM_{2.5}$ reported to the Convention on Long-Range Transboundary Air Pollution (CLRTAP). Emissionis of BC and OC are estimated on source and fuel basis. Source specific emission factors have been used for wood combustion in residential sector and for flaring, in order to estimate other emissions on a source and fuel basis, fractions of BC and OC of emitted PM from IIASA[1] have been used in combination with Norwegian $PM_{2.5}$ emission factors.

Estimated total emissions in Norway of BC and OC in 2011 were 5,100 tonnes and 19,900 tonnes respectively. The most important source for emission of both BC and OC is domestic wood combustion. In 2011, residential combustion was responsible for 23 and 83 per cent of the total respectively. Emissions of BC rose by 2 per cent in the period 1990-2011, whereas emissions of OC decreased by 3 per cent.

This work has been carried out with major contributions from the Climate and Pollution Agency (Klif). They have funded the work, and has provided input data and relevant literature. Most importantly, Klif has developed new emission factors for BC and OC through a separate project (Seljeskog, Goile et al. 2013).

A summary in Norwegian is available; Appendix E

[1] IIASA: International Institute for Applied Systems Analysis, Laxburg, Austria

Contents

1. Introduction

1.1. Background

Statistics Norway was commissioned by the Norwegian Climate and Pollution agency (Klif) to develop national Black Carbon (BC) and OC (Organic Carbon) emissions inventories for the period 1990-2011.

Limiting anthropogenic climate change and improving air quality are two of the most important environmental challenges facing humankind. Warming effects of Black Carbon (BC) have caught attention of climate scientists and policy makers. Scientists suggest that BC is likely to be the second most important contributor, after carbon dioxide, to global warming (UNEP 2009). This has led to increased focus on BC on a national and international level, and has revealed a need to know which sources are the most important ones also for Norway. In addition to having an impact on climate, particles are also known to have a negative impact on human health.

This report documents the new methodologies used in the Norwegian emission inventory of black carbon (BC) and organic carbon (OC). The report looks into anthropogenic emissions of BC and OC for all sources were emissions of $PM_{2.5}$ are included in the Norwegian Emission Inventory.

The structure of this documentation follows the nomenclature used for reporting to the United Nations Framework Convention on Climate Changes (UNFCCC) in the Common Reporting Format (CRF) and aggregated to Nomenclature For Reporting (NFR) used for reporting under the Convention on Long-Range Transboundary Air Pollution (CLRTAP).

Klif has funded the work, and has provided input data and relevant literature. Most importantly, Klif has developed new emission factors for EC (Elemental carbon) and OC for wood combustion in the residencial sector through a separate project (Seljeskog, Goile et al. 2013).

1.2. Purpose of the work

The aim of the study has been to make a first emission inventory (anthropogenic emissions) for BC and OC for Norway, covering the period 1990 to 2011, and to document the Norwegian emission inventory for BC and OC. It has been important to integrate the estimation of BC and OC in the Norwegian Emission Inventory for greenhouse gases and long-range transboundary air pollutants to obtain an efficient routine for annual update of the estimates. Once we know which sources are important for the emissions of BC and OC it is possible to propose efforts to reduce the emissions.

The Arctic Council has had focus on short-lived climate forces (SLCF) for some years already (Quinn, Bates et al. 2008): (Quinn, Stohl et al. 2011); (Arctic council 2011). The Norwegian Climate and Pollution Agency (Klif) is currently working on an action plan for short-lived climate forces (SLCF) to identify measures and instruments to reduce the emissions of short-lived climate forces. This document will serve as an input for policy makers, research institutes and others dealing with the climate, health and environmental impacts of emissions of BC and OC.

The Norwegian BC and OC data and documentation will be publicly available, and might also serve different international processes e.g. the assessment of the inclusion of BC in the revised Gothenburg Protocol.

1.3. Reader's guide

This report gives first an introduction to Black and Organic Carbon (chapter 2). It contains a description of the Norwegian emission inventory (Chapter 3). The structure follows the nomenclature being used for reporting to CLRTAP. The deliberations made during the work and the emission factors (EF) used for each main sector are described in chapter 4 to 8. Chapter 4: Energy combustion and Energy production, chapter 5: Industrial processes, chapter 6: Product use, chapter 7: The agricultural sector and chapter 8: The waste sector. Results are given in chapter 9, and potential improvements and further work in chapter 10.

The main focus in this report has been to describe the methodology for estimating emissions of BC and OC and give information on emission factors (EFs) used. Other central aspects have been to present the results of the inventory and to identify areas for improvement.

Klif will include the results from the inventories in their action plan for SLCF and in other relevant national and international work.

2. Definitions and formation of BC and OC

2.1. What is particulate matter?

Particulate matter (**PM**) refers to tiny pieces of solid or liquid matter suspended in the Earth's atmosphere. Sources of particulate matter can be human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes generate significant amounts of particulates. In addition particulate matter occurs naturally, originating from volcanoes, forest and grassland fires, living vegetation, and sea spray. Until now the Norwegian emission inventory has distinguished between three different fractions of particulate matter: TSP (total suspended particles), PM_{10}, with a diameter of less than 10 μm and $PM_{2.5}$, with a diameter of less than 2.5 μm.

Elemental carbon (EC) refers to all carbon in elemental form. The term EC is often used with thermal analysis to indicate the carbon that does not oxidize below a certain temperature (usually 550-650 C) or which is not extractable with, e.g., hydrogen peroxide or benzene.

Black carbon (BC), commonly known as soot, is the dark, light absorbing part of the particles. BC is measured by optical methods. BC mainly consists of EC, but may also include some light absorbing organic compounds. BC refers to the whole light absorbing fraction of carbonaceous aerosols. BC is considered as a share of $PM_{2.5}$.

Organic mass (OM) refers to the non-carbonate carbonaceous particles other than black or elemental carbon and it includes numerous organic compounds. OM is also considered as a share of $PM_{2.5}$.

Organic carbon (OC) actually refers to the content of carbon in the organic mass compounds. For estimating the organic mass (OM), OC is multiplied by a factor (F) to account for other elements than carbon in the organic molecules. The factor may vary depending on the origin and age of the OM, The factor is usually between 1.2 and 1.8, (Turpin, Saxena et al. 2000): (Bond, Doherty et al. 2013)). In this project SN, in cooperatin with Klif, has choosen to use F = 1.4.

$PM_{2.5}$ consists of black carbon, organic matter (OM) and inorganic compounds (Z) such as sodium chloride, sulphate, calcium, potassium, magnesium, sulphur, nitrogen oxides etc.

(2.1) $PM_{2.5} = BC + OM + Z$

Where OM = OC *F, where F = Factor for OC to organic mass, F = 1.4 is used in this project.
Z = inorganic compounds.

In this work it is assumed that Z is 0, and thus

$PM_{2.5} = BC + 1.4*OC$

Soot, Black Carbon (BC), Elemental Carbon (EC) and Organic carbon (OC) are all concepts of carbonaceous remains from combustion of carbonaceous material. The concepts BC and EC have emerged from the different measurement techniques that are based on the different properties of the carbonaceous remains. If the amount of carbonaceous remains is determined by optical techniques, generally using an aethalometer, which quantities particles on filter samples based on the transmission of light through a sample, the term Black Carbon, BC, is used.

If the amount of carbonaceous remains is determined by using thermal-optical analysis the term Elemental Carbon, EC, is used. A variety of thermal and thermal-optical measurement techniques have been developed to measure organic carbon (OC) and EC. While these methods generally measure the same amount of total carbon (TC), the discrimination of TC into OC and EC is operationally defined with large differences in the amount of OC and EC measured by different methods (Cavalli, Viana et al. 2010).

Thermal-optical analysis is the most used conventional method for determining the carbonaceous aerosol fraction and for classifying it into organic carbon, OC, and elemental carbon, EC. It is observed that many authors use EC and BC interchangeably in the literature, although they are actually method-specific measurements. In this project BC will be used throughout the rest of this report. For those sources where EC emission factors are applied, this will be commented.

2.2. Climate and health effects

Black carbon is not a greenhouse gas. BC has global warming properties, due to its ability to absorb heat in the atmosphere and by reducing albedo, i.e. reducing the ability to reflect sunlight, when deposited on snow and ice. In opposition, OC reflects sun light much more strongly than it absorbs, and thus has atmospheric cooling properties.

BC and OC have relatively short residence times in the atmosphere, days to weeks, and hence they are considered as short-lived climate forcers (SLCF). Given the climate properties of BC in particular, seen from a global warming perspective, the short-term climate benefits of reducing these emissions are promising.

The contribution to warming of 1 gram of BC seen over a period of 100 years has been estimated to be anything from 100 to 2 000 times higher than that of 1 gram of CO_2 (UNEP and WMO 2011).

During the recent years there has been increased focus on transport of BC and the deposition of BC in the Arctic. Only a small amount of emitted BC is deposited on the ground in the Arctic. BC has a very high albedo, even a small amount could have a relatively large effect since BC on snow and ice causes melting.

Short-term epidemiological studies provide sufficient evidence of an association of daily variations in BC concentrations with short-term adverse health effects e.g. cardiopulmonary hospital admissions. Also a long-term average BC exposure has been directly linked to cardiopulmonary and all-cause mortality. BC may not be a major directly toxic component of $PM_{2.5}$, but it may operate as a universal carrier of a wide variety of chemicals of varying toxicity to the lungs, the body's major defence cells and possibly the systemic blood circulation. Therefore, a reduction in exposure to $PM_{2.5}$ containing BC and other combustion related particulate material should lead to a reduction in the associated health effects (WHO, 2011).

2.3. Formation of Black and Organic Carbon

Combustion of fuels leads to emissions of particulate matter, BC and OC. Black carbon results from the incomplete combustion of fossil fuels, wood and other biomass.

Complete combustion would turn all carbon in the fuel into carbon dioxide (CO_2). In practice, combustion is never complete, and CO_2, carbon monoxide (CO), volatile organic compounds (VOCs), OC and BC are all formed. The ratio of OC to BC emitted per mass of particulate matter is a function of combustion conditions that depend on several factors (e.g., combustion device and the way it is operated as well as the fuel that is burned). There is a close relationship between emissions of BC and OC. They are always co-emitted, but in different proportions for different sources.

A high BC-to-OC ratio means a predominantly absorbing aerosol that will contribute to warming. A low BC-to-OC ratio means a predominantly reflecting (or scattering) aerosol that will contribute to cooling. The ratio depends on the emission source. Diesel engines emit more BC than OC and, as a result, their emissions have high BC to OC ratios. Open biomass burning typically emits more OC than BC such that biomass burning emissions have relatively low BC to OC ratios. While combustion is the primary source of BC, OC can also be produced from gaseous precursors which undergo processing in the atmosphere to form secondary organic aerosol (Bond, Doherty et al. 2013).

Emissions from the same fuel can vary by orders of magnitude, depending on the quality of the combustion. If the process or combustion fluctuates, emissions from the same source vary with time, and fluctuating conditions can result in large variations in emissions.

In this work, based on literature studies of emissions of BC and OC, emissions for non-combustion sources such as tire and break wear, as well as some industrial processes such as iron and steel foundries, secondary aluminium production and cement production have been included.

Only anthropogenic sources such as domestic heating, transport and manufacturing are included in the inventory. BC emissions from forest and grassland fires are not included.
Black carbon emissions result mainly from these source categories:

1. **Domestic combustion**. Use of wood burned in heating stoves of different technologies
2. **Land transport.** On-road and off-road diesel and gasoline vehicles and machinery
3. **Navigation**. Incomplete combustion of diesel fuel from national sea traffic and fishing
4. **Flaring** from extraction of oil and gas
5. **Energy and industrial production and waste treatment**. Use of fossil and bio fuels for power generation and process emissions from industrial production and combustion of wastes
6. **Field burning.** Anthropogenic burning of agricultural wastes (crop residues).

Measures designed to reduce BC will also have an impact on OC and $PM_{2.5}$, PM_{10} and TSP emissions. The largest BC emission reductions are obtained through measures controlling incomplete combustion of biomass and diesel particle filters.

2.4. Current Black Carbon and Organic Carbon Emissions inventories

Two BC and OC emission inventories that are widely used and referred to in the litteraure are (Bond, Streets et al. 2004) and successive updates, (e.g. in (Lamarque, Bond et al. 2010) and (Bond, Doherty et al. 2013) and International Institute for Applied Systems Analysis, IIASA,(Kupiainen and Klimont 2004) inventories. The Inventory by IIASA is estimated by the GAINS model (http://webarchive.iiasa.ac.at/gains/documentation.html) and is frequently updated. For this project, IIASA provided BC, OC and $PM_{2.5}$ emission factors (as per 28. March 2012) and emissions (6. June 2012).

(Bond, Doherty et al. 2013) defines black carbon like this: “Black carbon is a distinct type of carbonaceous material, formed only in flames during combustion of carbon-based fuels. It is distinguishable from other forms of carbon and carbon compounds contained in atmospheric aerosol because it has a unique combination of the following physical properties:

1. It strongly absorbs visible light with a mass absorption cross section of at least 5 m2g-1 at a wavelength of 550 nm.
2. It is refractory; that is, it retains its basic form at very high temperatures, with a vaporization temperature near 4000K.
3. It is insoluble in water, in organic solvents including methanol and acetone, and in other components of atmospheric aerosol,
4. It exists as an aggregate of small carbon spherules”

Bond et al. (2004) inventories
The global inventory of Bond et al. (2004) calculated global BC and OC emissions emitted from combustion. In the inventory they included emissions from fossil fuels, bio fuels, open biomass burning and burning of urban waste. They used a “bottom-up” approach by applying mass-based BC and OC emissions factors to country-level fuel use and activity data. The Bond et al. inventory takes into account regional technologies and emission controls to provide country-level emission estimates.

GAINS inventories
The GAINS (Greenhouse gas – Air pollution Interactions and Synergies) model, developed by the IIASA estimates BC and OC emissions based on national-level activity data and country and region-specific emissions factors for specific control technologies. IIASA has compiled a comprehensive material on emission factors for BC and OC for a number of stationary, mobile and process emission sources. The data by IIASA is derived from various sources in the international literature and can be seen as a compilation and harmonisation of existing information. IIASA, like Bond et al 2004, also estimated total global BC and OC emissions (Kupiainen and Klimont 2004). Data from IIASA can also be broken out by country and by sector. Kupiainen and Klimont (2004 and 2007) present measurements of specific emission factors for most combustion and some non-combustion related anthropogenic sources of BC and OC. These emission factors have been updated and adjusted, to amongst other, Norwegian conditions in the GAINS model. GAINS estimates that total Norwegian emissions of $PM_{2.5}$, BC and OC are 45, 6 and 15 ktonnes, respectively. It should be noted that BC, e.g. in Kupiainen and Klimont (2004 and 2007), has been used irrespective of the analytical method, i.e. BC has been used even though the analytical method used was thermo-optical. We have thus chosen to keep this notation in this report.

EMEP/EEA Emission Inventory Guidebook

There is an ongoing project to update the EMEP/EEA Emission Inventory Guidebook. One of the main focuses is to incorporate methodologies for estimating black carbon emissions. The goal is to incorporate emission factors of black carbon (BC) in the guidebook for all relevant sources. The updated guidebook is planned to be available by September 2013.

3. Methodology

The Norwegian estimates of the BC and OC emissions are mainly based on estimated fractions of officially reported national emissions of particulate matter, $PM_{2.5,}$ to UNECE LRTAP Convention (Sandmo et al. 2012) and work done by the International Institute for Applied Systems Analysis (IIASA). Everywhere where the Norwegian inventory estimates emissions of $PM_{2.5}$ (Finstad, Haakonsen et al. 2003), it has been considered whether there also are emissions of BC and OC.

Until now emissions of TSP, PM_{10} and $PM_{2.5}$ have been estimated. The relative size of the various particulate fractions is like this:

$TSP > PM_{10} > PM_{2.5} > BC$

Emission of TSP is larger than emissions of PM_{10} which is larger than the emissions of $PM_{2.5}$which are larger than emissions of BC.

$PM_{2.5}$ can be divided into black carbon (BC) organic matter (OM) and inorganic compounds (Z). In this work Z is assumed to be 0. This gives

$PM_{2.5} = BC + OM$

The Norwegian Emissions Inventory was developed by Statistics Norway (Daasvatn, Flugsrud et al. 1992; Daasvatn, Flugsrud et al. 1994). It was redesigned in 2003 in order to improve reporting to the UNFCCC and UNECE.
The general emission model is based on equation (3.1).

(3.1) $\quad$ *Emissions (E) = Activity level (A) · Emission Factor (EF)*

For emissions from *combustion*, the activity data concern energy use. In the Norwegian energy accounts, the use of different energy products is allocated to industries (economic sectors). In order to calculate emissions to air, energy use must also be allocated to technical sources (e.g. equipment).
The energy use data are combined with a corresponding matrix of emission factors. In principle, there should be one emission factor for each combination of fuel, industry, source, and pollutant.
Emissions of some pollutants from major manufacturing plants (point sources) are available from measurements or other plant-specific calculations. When such measured data are available it is possible to replace the estimated values by the measured ones:

(3.2) $\quad$ *Emissions (E) =* $[\,(A - A_{PS}) \cdot EF] + E_{PS}$

Where A_{PS} and E_{PS} are the activity and the measured emissions at the point sources, respectively.

Emissions from activity for which no point source estimate is available, are estimated based on activity data and emission factor, using equation 3.1.

Non-combustion emissions are generally calculated by combining appropriate activity data with emission factors according to equation 3.1. Some non-combustion emissions are available from measurements or other plant-specific calculations (equation 3.2).

BC and OC emissions are calculated using a "bottom-up" approach. Emissions are estimated as described in equation 3.1 and 3.2 by combining information on fuel use with emission characteristics of various combustion technologies.

3.1. Activity data

Combustion processes in general are major emission sources of particulate matter. Combustion sources that contribute to ambient concentrations of particles are stationary boilers and furnaces, stationary and mobile internal combustion engines, flaring in industriy, domestic burning and accidental fires. The emissions from the different installations strongly depend on the composition of the fuels and on combustion conditions.

The annual energy balance, compiled by Statistics Norway (SN), forms the framework for the calculation of emissions from energy use. The energy balances are based on a number of surveys (Sandmo 2012). Emissions from energy combustion are estimated at the sectoral level in accordance with the IPCC sectoral approach. This includes combustion emissions from energy industries, manufacturing industries and construction, transport and other combustion sources. (e.g. residential, other small scale combustion and until 2005, incineration of hospital waste.

3.1.1. Energy carrier used for calculating emissions of BC and OC

Natural gas
Most of the combustion of natural gas is related to extraction of oil and gas on the Norwegian continental shelf. The amounts of gas combusted, distributed between gas turbines and flaring, are reported annually to Statistics Norway by the Norwegian Petroleum Directorate (NPD). These figures include natural gas combusted in gas turbines on the various oil and gas fields as well as on Norway's four gas terminals on shore. Some manufacturing industries use natural gas in direct-fired furnaces; the rest is burned in boilers and, in some cases, flared.

LPG and other gases
Consumption of Liquefied petroleum gas (LPG) in manufacturing industries is reported by the plants to Statistics Norway in the annual survey on energy use. Figures on use of LPG in households are based on sales figures, collected annually from the oil companies. Use in agriculture and construction is based on non-annual surveys. Use of refinery gas is reported to Statistics Norway from the refineries. The distribution between the sources direct-fired furnaces, flaring and boilers is based on information collected from the refineries. At some industrial plants, excess gas from chemical and metallurgical industrial processes is burned, partly in direct-fired furnaces and partly in boilers. These amounts of gases are reported to Statistics Norway.

Oil products
Total use of the different oil products is based on Statistics Norway's annual statistics on deliveries (sales) of petroleum products. The calculation methodology applied is described in Sandmo (2012). Stationary use takes place in boilers and, in some manufacturing industries, in direct-fired furnaces. There is also some combustion in small ovens, mainly in private households. Mobile combustion is distributed between a numbers of different sources. The categories of fuel oil are kerosene, heavy distillate, heavy fuel oil, light fuel oil and marine gas oil. In addition to oil products included in the sales statistics, figures on use of waste oil are given in Statistics Norway's statistics on energy use in the manufacturing industries.

Coal, coke
Use of coal, coke and petrol coke in manufacturing industries is annually reported from the plants to Statistics Norway. The statistics cover all main consumers. Combustion takes place partly in direct-fired furnaces, partly in boilers. Figures on some minor quantities burned in small ovens in private households are based on sales figures. In addition, the figure on an insignificant use of coal in the agricultural sector was formerly collected from one farmer. Since 2002, there has been no use of coal in Norwegian agriculture.

Biofuels
Use of wood waste and black liquor in manufacturing industries is taken from Statistics Norway’s annual survey on energy use in these sectors. Use of wood in households for the years after 2005 is based on responses to questions relating to wood-burning in Statistics Norway’s Travel and Holiday Survey. Households are asked about the quantities of wood used, type of fireplace (open fireplace or closed stove) and age of the stove (produced before or after 1998). The survey quarterly gathers data that cover the preceding twelve months. The figure used in the emission calculations is the average of four/five quarterly surveys. For the years before 2005 figures are based on the amount of wood burned from the annual survey on consumer expenditure. Figures on some minor use in agriculture and in construction are derived from earlier surveys for these sectors. Combustion takes place in boilers and in small ovens in private households. Consumption figures for wood pellets and wood briquettes are estimates, based on annual information from producers and distributors.

Waste
District heating plants and incineration plants annually report combusted amounts of waste (boilers) to Statistics Norway and the Climate and Pollution Agency. In addition figures on use of waste oil are given in Statistics Norway’s statistics on energy use in the manufacturing industries. Statistics Norway also collects additional information directly from a few companies about the use of waste oil as a fuel source

3.1.2. Other activity data
Burning of agricultural residues: The annual amount of crop residue burned on the fields is calculated based on crop production data for cereals and rapeseed from Statistics Norway and estimates of the fraction burned made by the Norwegian Crop Research Institute and Statistics Norway. In 2012, the Norwegian Agricultural Authority has conducted a project to improve the activity data for the amounts of crop residues burnt in the fields. A questioner in 2012 showed that about 4 per cent of the crop residues were burned in 2012. It was earlier assumed that 7.5 per cent of the crop residues were burnt (based on a questioner in 2004). Activity data for 2005 – 2012 have been updated. Linear interpolation has been used for the intervening years.

Emissions from tobacco: The total consumption of tobacco in Norway is given by the net import of tobacco from Statistics Norway’s external trade statistics.

Emissions from car fires and house fires: Data on the number of car and house fires are provided annually by the Directorate for Civil Protection and Emergency Planning.

Emissions from cremations: The number of cremated bodies is gathered by the Ministry of Culture and published in Statistics Norway’s Statistical Yearbook.

3.2. Emission factors

Different approaches have been used to estimate emissions of BC/OC depending on the information available.

1. Emissions are estimated from specific BC and OC emission factors for different fuels used by different types of machines in different sectors. The emission factors are either
    a. specific emission factors based on measurments of BC and OC (see chapter 3.2.1)
    b. emission factors based on emission factors for particulate matter. Since the BC and OC emissions are sub-amounts of the PM emissions, the BC and OC emission factors are estimated as fractions of the Norwegian $PM_{2.5}$. Kupiainen and Klimont (2007) present measurements of specific emission factors for most combustion and non-combustion related anthropogenic sources of BC and OC. To ensure that the emissions of BC and OC in the Norwegian inventory do not exceed the $PM_{2.5}$ emissions, the emission factors for BC and OC are estimated as shares of the $PM_{2.5}$ emission factors based on information from IIASA, see chapter 3.2.2.
2. For point sources where emissions of TSP are reported to Klif, Emission of BC and OC are estimated based on fractions of the $PM_{2.5}$-emission, see chapter 3.2.3.
3. For the sources were emissions of BC and OC are assumed to occure, and information on BC and OC were not available in the literature, emissions are estimated by using a default method, see chapter 3.2.3.

3.2.1. Specific BC/OC emission factors for wood burning and flaring

Specific emission factors are available for two sources, namely:

1. Wood combustion in the residential sector

SINTEF Energy Research carried in 2012/2013 out a project for the Norwegian Climate and Pollution (Klif) in collaboration with SINTEF NBL (Norwegian Fire Research Laboratory) and University of Eastern Finland (UEF) where the amount of elemental carbon (EC), OC and total amount of particles (TSP) emitted from Norwegian wood stoves were measured (Seljeskog, Goile et al. 2013). Seljeskog and Goile at al (2013) presents emission factors of EC, OC and total amount of particles as grams per kilo wood burned for wood combustion, in closed stoves with old technology (produced before 1998) and new technology (produced after 1998) in the residential sector.

2. Flaring of natural gas onshore and off-shore

Flaring is a technique used in the oil and gas industry to burn unwanted flammable gases. Flaring is performed for safety reasons only in Norway. (McEwen and Johnson 2012) present measurements of specific emission factors of BC for flaring of natural gas.

3.2.2. Using PM emission estimates to estimate BC and OC emissions

When specific emission factors for BC and OC is not available or cannot be applied because they are not consistent with the Norwegian $PM_{2.5}$ inventory, the approach has been to base the BC and OC emissions factors on emission factors for particulate matter.

The BC and OC emission factors are estimated as fractions of the Norwegian $PM_{2.5}$ emission factors. The share of BC and OC depend upon fuel type, combustion conditions, sector etc. This secures that the TSP, PM_{10}, $PM_{2.5}$, BC and OC emission data are consistent, but the methodology does not necessarily imply that the resulting BC and OC emission data are more accurate than the inventory from which the shares are taken from.

The $PM_{2.5}$ emission factors used in the Norwegian inventory are either nationally derived, taken from the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA 2009) or from other literature sources considered to be relevant for Norwegian conditions. One primary condition for the emission factors used in the national emission inventory is that they should reflect the national condition as closely as possible. Particulate emissions from burning of fuels depend on combustion conditions and fuel type, e.g., the ash content of the fuel.

The BC and OC emission factors have been derived based on the work done by IIASA in the GAINS[2] (Greenhouse gas – Air pollution Interactions and Synergies) model. Kupiainen and Klimont (2004 and 2007) present measurements of specific emission factors for most combustion and some non-combustion related anthropogenic sources of BC and OC. These emission factors have been updated and adjusted to reflect Norwegian conditions in the GAINS model. Klif has provided the emission factors from GAINS for the domestic and transport sector to Statistics Norway for application in this project. SN have also had extended access to the GAINS database online. (Appendix B). SN was recommended by Klimont (personal communication 2012) to use emission factors form the scenario called “current_EU' emission vector”. This scenario is one of the scenarios used by IIASA to calculate Norwegian emissions of air pollutants in 2020.

An important part of the Norwegian emissions of BC and OC have thus been calculated based on reported national inventory data of $PM_{2.5}$ emissions, where source- and fuel specific fractions of BC and OC have been applied according to available information from IIASA. Emission factors used for estimation of emissions from energy use are given in Appendix C.

The majority of available references report values of EC. However, IIASA as well as many other authors of climate scientific papers, in several reports and articles refer to the values as BC (e.g. Kupiainen and Klimont, 2004 and 2007). Statistics Norway has used the term BC, in accordance with the notation used by IIASA.

Norwegian emission factors for BC and OC are estimated by combining the Norwegian $PM_{2.5}$ emission factor on a detailed level with estimated BC emission factor and OC emission factor shares of $PM_{2.5}$ emission factor from IIASA.
$EF\ BC_{Norway} = EF\ PM_{2.5Norway} * EF\ BC_{IIASA} / EF\ PM_{2.5IIASA}$
$EF\ OC_{Norway} = EF\ PM_{2.5Norway} * EF\ OC_{IIASA} / EF\ PM_{2.5IIASA}$

IIASA use the best available data for estimating emission for each country but it is important to bear in mind that IIASA’s objective is to use data that can be generally applicable for calculating national emissions for overall comparison between countries. For individual sources in individual countries the emission factor used by IIASA may not fully reflect the national conditions. This may be a problem even if SN has used the country specific emission factor data sheet from IIASA.

Reported emissions of TSP/$PM_{2.5}$
According to the Norwegian Pollution Control Act (The Norwegian Pollution Control Act 1981) some industrial plants and waste incineration plants have to report emission data for particulate matter to Klif or county governor. The county governor then reports this information to the Climate and Pollution Agency. If

[2] GAINS model is an integrated assessment model that explores cost-effective emission control strategies to reduce greenhouse gases and/or improve local and regional air quality. The model applies emission factors that reflect country-specific conditions such as fuel quality, combustion technologies, fleet composition, maintenance levels and the application of control technologies. http://gains.iiasa.ac.at

emissions are not reported, the general method to estimate emissions is to multiply the amount produced product or the amount of waste incinerated by emission factor. Normally a plant specific emission factor (implied emission factor) is determined for the pollutant in question. The implied emission factor is based on the ratio between previous emission figures and quantities of product produced or waste burned. To estimate missing emsissions the implied emission factor is multiplied with the amount of product produced or waste incinerated.

The emission permits do not state which particle fraction that is to be measured. It is common to measure total amount of particles (TSP). Particle size distribution for emitted particles is either reported from the plants, taken from the EMEP/EEAGuidebook or relevant literature or based on expert judgments. Some plants have only reported emissions for one or some years. For all other years emissions are then calculated by Statistics Norway, based on the reported figures and country specific emission factors and activity data (production volume).

Where emissions of TSP are reported to Klif, BC and OC emissions are calculated as a shares of the $PM_{2.5}$ emissions. The share of BC and OC is based on

1. Information from IIASA. BC/OC emissions are estimated like this:
   BC emissions =Reported emissions (TSP*share $PM_{2.5}$) * (EF BC $_{IIASA}$/ EF $PM_{2.5\ IIASA}$)
   OC emissions =Reported emissions (TSP*share $PM_{2.5}$) * (EF OC $_{IIASA}$/ EF $PM_{2.5\ IIASA}$)
2. Information from the point sources on the amount of carbon in the particulate matter from the industry. The carbon is assumed to be BC and OC. The default method is used to estimate the amount of BC and OC (3.2.3)

3.2.3. When emission factors are missing

For some sources where the emissions of particulate matter have been reported or estimated and no BC/OC shares of $PM_{2.5}$ were found in literature, shares of BC and OC have been estimated using a default method. The equation is:

(3.3) $PM_{2.5}=BC+OM+Z$

It is assumed that Z= 0. Since there is no information on the split between BC and OM, it is assumed that the amount of BC is equal the amount of OM.

Where BC = OM = 50 per cent of $PM_{2.5.}$

As mention in chapter 2.1, OM = 1.4*OC

OC is estimated using this equation:
OC = OM/1.4 or 36 per cent of $PM_{2.5}$

The following 5 chapters show in more detail how the emissions are estimated.

4. Energy

The chaper 4 Energy and the following 4 chapters are included to explain in detail how the emissions from each specific source are estimated. The emission factors used are included.

Only sources where particulate matters are emitted are included in the following description. Information on reporting codes (NFR codes) are given in Appendix D.

4.1. Energy combustion

Combustion of fuels leads to emissions of particulate matter and BC and OC. Emissions from energy combustion include contributions from all sources addressed in the UNECE Guidelines. Emissions from waste incineration at district heating plants are accounted for under the energy sector, as the energy is utilised. Emissions from flaring in the energy sectors are described in section 4.2. Energy production. Coal and coke used as reducing agents and gas used for production of ammonia (non-energy part) are accounted for under industrial processes. Flaring of natural gas and fuel gas in chemical industry is recorded in section 5.2. Other flaring outside the energy sectors is described in chapter 8 Waste. The same applies to emissions from accidental fires etc. Emissions from burning of crop residues are accounted for in chapter 7 Agriculture. Emissions from tobacco are described in chapter 6 Product use.

4.1.1. Energy industries

NFR code 1A

Energy industries include emissions from electricity and heat generation and distribution, extraction of oil and natural gas, coal production, gas terminals, gas power plants and oil refineries. Norway produces electricity mainly from hydropower, so emissions from electricity production are small compared to most other countries.

Statistics Norway carries out annual surveys on energy use in manufacturing industries. The energy use survey is assumed to cover approximately 96 per cent of the energy use in this sector. For the construction industry, the figures on use of the different energy carriers are partly taken from the annual sales statistics for petroleum products and partly projected from earlier surveys; the energy data for the construction industry are considered rather uncertain.

Emission factors used for the energy sector are given in Appendix C, table C1-C7.

Waste incineration

NFR code 1A1a

Emissions of particles from district heating plants are reported to the Climate and Pollution Agency. There is generally litle information regarding BC /OC emissions from waste incineration. Table 4.1 shows the shares of BC/$PM_{2.5}$ and OC/$PM_{2.5}$ from Kupiainen and Klimont 2004. Relating them to total particulate mass gives 0.9 percent of BC and 0.15 percent for OC.

Table 4.1 Waste incineration. Particulate matter emitted and included in the Norwegian inventory. BC/OC shares in percent of TSP

	Source	TSP[1]	BC	OC	Source for BC and OC
Municipal waste	Boilers	R	0.9 % of TSP	0.15 % of TSP	Kupiainen and Klimont 2004

[1] R means that emission figures in the national emission inventory are based on figures reported by the plants.

Special waste

For incineration of special waste the same BC/OC shares as for heavy fuel oil-Residential, commercial, services, agriculture have been used (Appendix B and Appendix C table C7.)

4.1.2. Manufacturing industries and constructions

NFR code 1A2

Most of the emission figures are calculated on the basis of activity data and emission factors. Emissions from the sector of manufacturing industries and construction include industrial emissions to a large extent originating from the production of raw materials and semi-manufactured goods (e.g. metals, petrochemicals, pulp and paper and mineral products). Emission factors used for the energy use are given in Appendix C. Table C1-C7. For some large plants (pulp, paper and print) TSP emission figures are based on reported figures from the plants.

Pulp, paper and print
NFR code 1A2d
Combustion emissions of particles are reported to the Climate and Pollution Agency. No information on BC and OC where found in the literature. Where fuel type is known, Statistics Norway (SN) has used the shares of BC/$PM_{2.5}$ and OC/$PM_{2.5}$ from IIASA (Appendix B). For the use of wood waste in the pulp, paper and print industry the emissions factors for use of fuelwood in medium sized boilers are used (Appendix B). Relating them to $PM_{2.5}$ gives 12 per cent of BC and 13 per cent for OC.

For some plants the energy carrier is unspecified, hence no information on BC and OC is available. For these emissions SN has used equation 3.3 (chapter 3.2.3), where BC is set like 50 per cent of $PM_{2.5}$, and OC is set like 36 per cent of $PM_{2.5}$.

4.1.3. Transport

Civil aviation
NFR code 1A3a
Statistics Norway annually collects data on use of fuel from the air traffic companies including specifications on domestic use and purchases of fuel in Norway and abroad. The types of fuel used in aircraft are mainly jet fuel (kerosene). Small amounts of aviation petrol are also used.

Emission factors used are given in Appendix C, table C8.

Road transport
NFR code 1A3b
Primary particle emissions from mobile sources have two entirely different origins: exhaust, i.e., due to fuel combustion, and non-exhaust emissions, i.e., tire and brake wear and road abrasion.

Exhaust emissions
For mobile combustion sources data on fuel use for each fuel type is collected on the national level by Statistics Norway. BC and OC emissions depend on vehicle type, fuel and after treatment. Typical BC emission factors for heavy duty diesel vehicle exhaust are 50 per cent of $PM_{2.5}$ without exhaust after treatment and 60-70 per cent of $PM_{2.5}$ with after treatment (Appendix B). Lowest emissions per vehicle kilometre are seen for light duty vehicles with after treatment. This variation makes it necessary to carefully consider the vehicle fleet composition when emissions of BC and OC are to be estimated.

The total consumption of each fuel is attributed to different vehicle classes based on results from the emission model of the Handbook of Emission Factors (HBEFA; (INFRAS 2009). The emission of particulate matter is estimated by the emission model of the HBEFA; (INFRAS 2009). The emissions of $PM_{2.5}$ from each vehicle class are multiplied with a corresponding BC/OC share of $PM_{2.5}$ from IIASA. The sum of emissions are then added together and divided with the corresponding fuel consumed for the vehicle class to get the emission factors for BC and OC from road transport.
The fuel activity data used in the present BC/OC emission inventory are derived from the Norwegian emission inventories. The specific fuel consumptions are aggregated from engine size (cars) and weight class (trucks and buses).

Average factors are listed in Appendix C, Table C9.

Non-exhaust emissions
Tyre wear
Tyre wear is a source for emission of particles. All rubber lost is assumed to be small particles. The emissions of particles are calculated based on emission factors and annual mileage. The BC and OC share in TSP were estimated at 1.5 and 3.6 percent, respectively (Kupiainen and Klimont 2004). Since the sum of emissions of BC and OC has to be lower than $PM_{2.5}$ emissions, the emission factors are adjusted as shown in table 4.2. The sum of BC and OC emissions are equal to the $PM_{2.5}$ emissions.

Table 4.2 Emission factors for particles from tyre wear. kg/mill. km. BC/OC in per cent of $PM_{2.5}$

	TSP	$PM_{2.5}$	BC	OC	Source for BC and OC
Passenger cars ..	69	0.96	30 % of $PM_{2.5}$	70 % of $PM_{2.5}$	Kupiainen and Klimont 2004
Light duty vehicles	90	0.9	30 % of $PM_{2.5}$	70 % of $PM_{2.5}$	Kupiainen and Klimont 2004
Heavy duty vehicles	371.25	3.71	30 % of $PM_{2.5}$	70 % of $PM_{2.5}$	Kupiainen and Klimont 2004
MC	34.5	0.35	30 % of $PM_{2.5}$	70 % of $PM_{2.5}$	Kupiainen and Klimont 2004

Source for emission factor TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Brake wear

Emissions of particles are calculated based on emission factors and annual mileage. The BC and OC share in TSP were estimated at 1 and 18 percent, respectively (Kupiainen and Klimont 2004). The emission factors are shown in table 4.3.

Table 4.3 Particle emission factors for brake wear. kg/mill. km. BC/OC in percent of TSP

	TSP	$PM_{2.5}$	BC	OC	Source for BC and OC
Passenger cars ...	6	6	1 % of TSP	18 % of TSP	Kupiainen and Klimont 2004
Light duty vehicles	7.5	7.5	1 % of TSP	18 % of TSP	Kupiainen and Klimont 2004
Heavy duty vehicles	32.25	32.25	1 % of TSP	18 % of TSP	Kupiainen and Klimont 2004
MC	3	3	1 % of TSP	18 % of TSP	Kupiainen and Klimont 2004

Source for emission factor TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Automobile road abrasion
The average annual emission of TSP from automobile road abrasion is estimated by Statistics Norway (Sandmo, Bjønness et al. 2012). The BC and OC share in TSP were estimated at one and five percent, respectively (Kupiainen and Klimont 2004). Since the sum of emissions of BC and OC has to be lower than $PM_{2.5}$ emissions, the emission factors are adjusted as shown in table 4.4 The sum of BC and OC emissions are equal to $PM_{2.5}$ emissions and the relation between the Norwegian emission factors are equal to the emission factors from IIASA.

Table 4.4 Share of BC and OC in percent of TSP

	BC	OC	Source for BC and OC
Light duty vehicles	0.83 % of TSP	4.17 % of TSP	Kupiainen and Klimont 2004
Heavy duty vehicles	0.83 % of TSP	4.17 % of TSP	Kupiainen and Klimont 2004

Railways
NFR code 1A3c
Railway traffic in Norway uses mainly electricity. Auto diesel is used at a two lines and for shunting etc. There is also a minor consumption of coal in museum railways.

Emission factors used are given in Appendix C, table C10.

Navigation
NFR code 1A3d

Navigation Emissions from movable installations used in oil and gas exploration and extraction are split between energy industries and navigation. Emissions from drilling are reported under energy industries, while emissions from transport and other activities are reported under navigation. Annual emissions are estimated from sales of fuel to domestic shipping.

Fishing: The use of marine gas fuel, heavy distillate and heavy fuel oil are identical with the registered sales to fishing in the sales statistics for petroleum products. Emission factors used for marine gas oil, marine diesel, light fuel oil, heavy distillate, and heavy fuel oil are given in Appendix C, table 12.

Natural gas: No shares for BC/OC where found in the literature for use of natural gas in navigation. For natural gas SN has used equation 3.3 (chapter 3.2.3, where the BC share is set to be 50 per cent of $PM_{2.5}$, while OC share is set to be 36 per cent of $PM_{2.5}$.

Motorized equipment
NFR code 1A3e
The category "motorized equipment" comprises all mobile combustion sources except road, sea, air, and railway transport. Farm and construction equipment are the most important categories. Other categories include mines and quarries, forestry, small boats and miscellaneous household equipment.

Emissions from motorized equipment are reported under several categories
- Agriculture/Forestry/Fishing: NFR code 1A4c
- Households: NFR code1A4
- Military: NFR code1A5b
- Other: NFR code 1A3

Activity data: See (Sandmo, Bjønness et al. 2012)

Emission factors used are given in Appendix C, table C10 and C11.

4.1.4. Other sectores
NFR code 1A4
Small combustion covers stationary combustion emissions under NFR sectors commercial and institutional, residential, agriculture and forestry and other stationary combustion. Focus in the chapter is on residential wood combustion, which is reported in NFR code 1A4b. The sectors cover combustion installations activities considered to have a thermal capacity ≤ 50 MWh.

Residential wood combustion
NFR code 1A4b
Emission factors for fuelwood are based on data for different oven technologies. Ovens made in 1998 and later have significantly improved combustion and reduced emissions. The factors are weighted based on information from the surveys of the amount of wood burned in ovens with the different technologies. The yearly weighted factors are given in Appendix C table C6.

For residential wood burning the BC and OC emission factors depend on a range of factors such as type of appliance, type of firewood, moisture content and burn rates. For studies of emissions from residential wood burning cited in Kupiainen and Klimont (2007), emission factors for BC range from 0.043 to 3.5 g BC/kg wood and 0.25 to 7.3 g OC/kg wood. These large ranges reflect the variability seen depending on type of appliance, firewood, moisture content, use, etc,. In general, the OC/BC ratio increases for less efficient burning conditions (low burn rate, high moisture contents of the firewood etc). When comparing emission factors it is important to concider the methodology used. This is particularly important for residential biomass appliances and involves both different analytical methods for

BC/EC and OC quantification, different sampling conditions (in-stack or in dilution tunnel) and different parts of the burning cycle (e.g. whether it includes the start-up phase or not).

In 2012 SINTEF has conducted a project to provide the best possible estimate of the amount of elemental (EC), OC and total amount of particles (TSP) emitted from Norwegian wood stoves.

Emission factors for these compounds where established by performing experimental measurements on two selected representative stoves, A) Closed stove - old technology (produced before 1998) and B) Closed stove – new technology (produced after 1998). The intention was to reveal emission factors for EC, OC and TSP as grams per kilo fired dry wood. In Norwegian primary households, these two types of stoves represent 96 per cent of all wood combustion.
The wood stove experiments are preformed according to the Norwegian national standard for testing and closed wood heaters and smoke emission, NORSK STANDARD NS3058/NS3059. Combustion experiments were carried out by SINTEF Energy Research AS, and the Norwegian standard for stoves was used. A themal- optical method was selected to provide results for the two components EC and OC. UEF made OC/EC analyses of the filter samples with an OC/EC analyzer manufactured by Sunset Laboratory Inc., following NIOSH 5040 analysis protocol.

The Norwegian standard for closed wood stoves has been developed with the intention to reflect a typical Norwegian household wood stove operation. This is mainly taken account for when stoves are tested at low burning rate and by diluting the flue gas before particle matter is sampled.

The Norwegian Standard requires four tests at four different burnings rates. The stoves are tested under less favorable combustion conditions with reduced burning rates lower than 1.25 g/kg. This leads to much higher emissions than what the stove is optimized for. A dilution tunnel captures condensed particles in addition to solid particles. Measurement methods in Europe are based on the measurement in hot flue gases directly in the chimney. The difference between measurements in the chimney and in the dilution tunnel can be up to 10 times depending on the burning rate (Seljeskog, Goile et al. 2013).

Emission factors for both normal firing and firing without nightfiring (smoldering fire) large cities are proposed, table 4.5. No measurements were made on open fire places. BC and OC from open fire places are estimated at shares of $PM_{2.5}$ Table 4.5 shows the shares of BC/$PM_{2.5}$ and OC/$PM_{2.5}$ taken from IIASA (Appendix B). Relating them to $PM_{2.5}$ gives 9 per cent of BC and 48 per cent for OC.

Previous work by SINTEF reveals that PM_{10} and $PM_{2.5}$ on the average will constitute about 98 per cent and 95 per cent of the particulate emissions (Seljeskog, Goile et al. 2013) PM_{10} and $PM_{2.5}$ can be estimated from the measured amount of TSP by simply multiplying this value with 0.98 and 0.95, respectively.

Table 4.5. Emission factors for fuelwood, g/kg dry matter. Normal firing and firing without nightfiring, (applied in larger cities)

Source	TSP	$PM_{2.5}$	EC/BC	OC	Source for BC and OC
Open fireplace	17.3	16.4	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B
Small stoves, old technology- with nightfiring	22.7	21.6	0.96	16.74	Seljeskog, Goile et al. 2013
Small stoves, old technology, without nightfiring	17.4	16.5	1.01	12.89	Seljeskog, Goile et al. 2013
Small stoves, new technology - with nightfiring	13.4	12.7	0.86	10.47	Seljeskog, Goile et al. 2013
Small stoves, new technology - without nightfiring ...	12.2	11.6	0.9	9.26	Seljeskog, Goile et al. 2013

Source for emission factors TSP and $PM_{2.5}$ for open fireplace; Sandmo, Bjønness et al. 2012

4.2. Energy production (fugitive emissions from fuels)

NFR code 1B
Fugitive emissions from oil and natural gas include emissions from loading and refining of oil, gasoline distribution, and fugitive emissions from gas terminals on shore. There are also fugitive emissions in connection with venting and flaring offshore.

4.2.1 Fugitive emissions from solid fuels: Solid fuel transformation

NFR code 1B1b
In 2005, a fire broke out in one of the Norwegian coal mines at Spitsbergen, causing minor emissions of particulate matter. Emissions have been calculated by multiplication of the quantity of coal combusted by standard emission factors for combustion of coal. This inventory uses the same share of BC and OC to $PM_{2.5}$ as for burning of coal (Appendix B). The share of BC in the fine fraction is 2 per cent, while the share of OC in the fine fraction is 1 per cent.

4.2.2. Oil and natural gas

Oil refineries
NFR 1B2a
Non-combustion emissions of particulates from Norway's oil refineries are reported to the Climate and Pollution Agency.The share of BC in the fine fraction was 0.16 percent, while OC was not detected (Kupiainen and Klimont 2004).

Table 4.6 Oil refineries. Particulates emitted and included in the Norwegian inventory. BC/OC shares in percent of $PM_{2.5}$

	Particles[1]	BC	OC	Source for BC and OC
Oil refineries	R	0.16 % of $PM_{2.5}$	0 % of $PM_{2.5}$	Kupiainen and Klimont 2004

[1)] R means that emission figures in the national emission inventory are based on figures reported by the plants.

Flaring of Natural gas
NFR code 1B2c
Most of the emissions in 1B2c come from flaring of natural gas offshore (during both well testing, extraction and pipeline transport) and at gas terminals and flaring of refinery gas at the refineries. This flaring causes emissions of particulates. There is also some flaring of oil in connection with well testing - amounts flared and emissions are reported to the Norwegian Petroleum Directorate (NPD) and the Climate and Pollution Agency (Klif).

Emissions from flaring of natural gas off shore are calculated by Statistics Norway on the basis of field specific gas consumption data reported to Klif and emission factors.

The emission factor for BC is based on (McEwen and Johnson 2012). This paper gives a regression formula for the emission factor as a function of the heating value (GCV) as EF = 0.0578(HV) – 2,09. For Norwegian offshore flaring a heating value of 48 MJ/Sm^3 is suggested in (Bakken, Husdal et al. 2008). This gives an emission factor of 0.684 g BC/Sm^3.

No information on OC is available. SN has used equation 3.3 (chapter 3.2.3), where OC is set like 36 per cent of $PM_{2.5}$. Table 4.7. Emission factors for flaring of refinery gas are shown in Appendix C, table C1.

Table 4.7. Emission factors for flaring of natural gas. g/Sm^3

	$PM_{2.5}$	BC	OC	Source for BC and OC
Flaring of natural gass ...	0.86	0.68	0.12	McEwen (for BC) SN (for OC)

The same factors are used for flaring of natural gas in connection with well testing. For flaring of *oil,* no information on BC or OC were found. SN has used equation 3.3 (chapter 3.2.3, where the BC share is set to be 50 per cent of $PM_{2.5}$, while OC share is set to be 36 per cent of $PM_{2.5}$.the emission factor for $PM_{2.5}$ are shown in Table 4.8.

Table 4.8. Emission factors for flaring of oil in connection with well testing tonnes/tonnes flared

	$PM_{2,5}$	BC	OC	Source for BC and OC
Flaring of oil in connection with well testing	0.014	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3

Source for emission factor $PM_{2.5}$: Sandmo, Bjønness et al. 2012

5. Industrial processes

Industrial processes are estimated to be an important contributor to the total Norwegian emissions of $PM_{2.5}$ In 2011, industrial processes contributed to around 12 per cent of the total $PM_{2.5}$ emissions in Norway. The most important sources where metallurgical industry (8 per cent), construction and building (1 per cent) and production of fertilisers (1 per cent).
The Norwegian estimates of the BC and OC emissions are mainly based on estimated fractions of officially reported national emissions of particulate matter. When it comes to process emissions it has to be considered that black carbon and organic carbon mainly are formed by incomplete combustion of organic compounds. In general, the literature mentions combustion as the main source to emissions of BC and OC. However, a number of industrial processes are mentioned as minor sources. (Kupiainen and Klimont 2004).The caracteristics of the potential BC generation processes are high temperature and availability of a carbon source. Many industrial processes emit particulate matter into the atmosphere. Emissions vary between processes because of varying process designs and different levels of abatement. The emission characteristics are highly dependent on the activity. Some may be high emitters of coarse and large particles, while the emissions in the fine size range are negligible. For industrial processes the main focus have been to investigate whether the larger $PM_{2.5}$ emission sources also emit BC and OC.

5.1. Mineral products

NFR code 2A
The sector category Mineral products in the Norwegian inventory include emissions from thirteen different products (see table 5.1). Particulate matter is emitted during the production of mineral products and included in the inventory. Table 5.1 shows for which components the emission figures in the national inventory are based on figures reported by the plants (R) and for which the figures are estimated by Statistics Norway (E).

Emissions of particles have been reported to the Climate and Pollution Agency for nine of the mineral products. For some years emission figures are based on calculations, using emission factors and production volume. It is believed that the reported figures also include emissions from combustion. Therefore emissions from combustion of coal, coke, waste oil etc are not calculated, to avoid double counting. The plants have installed particle filters. It is assumed that particles emitted during crushing of rocks and at sandpits are larger than $PM_{2.5}$.

Table 5.1 Mineral products. Particulats emitted and included in the Norwegian inventory

Mineral products	Particles[1]	BC	OC	Source for BC and OC
Cement production	R	0.25 % of PM_{10}	1.4 % of PM_{10}	Kupiainen and Klimont 2004
Lime production	R	0.2 % of TSP	1.4 % of TSP	Kupiainen and Klimont 2004
Limestone and dolomite use	R	0.2 % of TSP	1.4 % of TSP	Same EF as for lime production
Concrete pumice stone	R	37.5 % of $PM_{2.5}$	25 % of $PM_{2.5}$	Appendix B
Rock wool production	R	0.06 % of $PM_{2.5}$	0.7 % of $PM_{2.5}$	same EF as for glass and glass fibre
Glass and glass fibre	R	0.06 % of $PM_{2.5}$	0.7 % of $PM_{2.5}$	Kupiainen and Klimont 2004
Ore mines	R	NA	NA	Kupiainen and Klimont 2004
Mining and extraction of stones and minerals	R	NA	NA	Kupiainen and Klimont 2004
Production of mineral white	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3
Construction /repairing of vessels - Sandblasting	R	0	0	Sandmo 2012
Sandpit and rock-chrushing plants ...	E	0	0	Sandmo 2012
Construction and building	E	0	0	Expert judgement
Production of asphalt	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3
Leather preparing .	NA	-	-	

[1] R means that emission figures in the national emission inventory are based on figures reported by the plants.
E means that the figures are estimated by Statistics Norway (Activity data * emission factor). NA = Not Applicable.

Cement production
NFR code 2A1
Emissions of particles have been reported to the Climate and Pollution Agency (Klif). It is believed that the reported figures also include emissions from combustion. Therefore, emissions from combustion of coal, coke, waste oil etc from this industry are not calculated, to avoid double counting. The plants have installed particle filters. Table 5.1 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont (2004). Relating them to PM_{10} gives 0.25 per cent of BC and 1.4 per cent for OC.

Lime production
NFR code 2A2
For one plant, emission figures for particulate matter have been reported to Klif since 1990. Emission figures from 1990 to 1995 are based on calculations, using emission factors and production volume. Since 1996, the figures are a result of measurements at the plant. The plant has installed particle filter. Table 5.1 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont (2004). Relating them to TSP gives 0.2 per cent of BC and 1.4 per cent for OC

Limestone and dolomite use
NFR code 2A3
Emissions have been reported to Klif since 2000. Reported figures for 2000 have been used for all years 1990-1999.

Table 5.1 shows the BC and OC shares of $PM_{2.5}$ used for the calculations. SN has used the same shares as for lime production. Relating them to TSP gives 0.2 per cent of BC and 1.4 per cent for OC.

Concrete pumice stone
NFR code 2A7
The plants have reported emissions of particles to Klif since 1990. It is assumed that the reported figures include both process and combustion emissions, so emission calculations from fuel combustion are not included for this industry. The plants have installed particle filters. SN has used the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from IIASA (Appendix B) for Industrial processes, bricks production. Table 5.1 shows the BC and OC shares of $PM_{2.5}$ used. Relating them to $PM_{2.5}$ gives 37.5 per cent of BC and 25 per cent for OC.

Rock wool production
NFR code 2A7
Emission figures for particles are reported to Klif. Most of the emissions come from the spin chamber, and the particle size is assumed to be less than 1 µm. Particles emitted from the fabric filter are also assumed to be smaller than 1 µm. It is assumed that the reported figures include both non-combustion and combustion emissions. Combustion emissions of particles are therefore not included. No information on BC and OC was found in the literature. SN has used the same shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont (2004) as for glas production Table 5.1 shows the BC and OC shares used. Relating them to $PM_{2.5}$ gives 0.06 per cent of BC and 0.7 per cent for OC.

Glas production
NFR code 2A7
The two plants producing glass fibre have reported emission figures since 1990 to Klif. The one glass-producer with particle emissions has reported since 1995. Emission figures from 1990 to 1994 were therefore assumed to be the same as reported figures in 1995. This plant was however closed down in 1999. Table 5.1 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont 2004. Relating them to $PM_{2.5}$ gives 0.06 percent of BC and 0.7 percent for OC

Ore mines
NFR code 2A7
All the three ore mines report emission figures for particles to Klif. There are minor emissions of $PM_{2.5}$. No information on BC and OC where found in the literature. No emissions of BC and OC are assumed in the RAINS model. This is also used in the Norwegian inventory. This is shown in Table 5.1.

Mining and extraction of stones and minerals
NFR code 2A7
Emission figures are reported to the Climate and Pollution Agency. It is given for most plants that they use fabric filter or textile fibre to clean their particle emissions. It is assumed by the Climate and Pollution Agency that the particles emitted are larger than PM_{10}. Thus, no BC/OC emissions are calculated.

Production of mineral white (plaster)
NFR code 2A7
Emission figures are reported to the Climate and Pollution Agency. The particles are purified through a fabric filter. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3), where BC is set like 50 per cent of $PM_{2.5}$ and OC is set like 36 per cent of $PM_{2.5}$.

Construction and reparing of vessels and sandblasting
NFR code 2A7
Emission figures are reported to Klif. It is assumed by Klif that they have fabric filter and/or wet washer. At one plant particle emissions are purified in cyclones, and the size of the particles emitted is larger than PM_{10}. Thus, no BC/OC emissions are calculated.

Sandpit and rock-crushing plant
NFR code 2A7
Particles will be emitted during crushing of rocks and at sandpits. All particulates are assumed to be larger than $PM_{2.5}$ (Sandmo, Bjønness et al. 2012). Thus, no BC/OC emissions are calculated.

Construction and building
NFR code 2A7
Emission factors and activity data are used to estimate the Norwegian emissions. The activity data used is the annual area of completed buildings from the building statistics at Statistics Norway. SN assumes that none of the processes will lead to emissions of BC and OC.

Production of asphalt
NFR code 2A7
Emission figures are reported to Klif. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3, where BC is set like 50 per cent of $PM_{2.5}$, and OC is set like 36 per cent of $PM_{2.5}$.

5.2. Chemical Industry

NFR code 2B
In the Norwegian emission inventory, there are 14 different activities included under chemical industry. Emissions of particulate matter are reported from seven different activities to the Climate and Pollution Agency (table 5.2). For the other seven activities emissions of particulates are considered to be not applicable (NA). Table 5.2 shows for which components the emission figures in the national inventory are based on figures reported by the plants (R) and for which the figures are considered to be not applicable (NA)

Table 5.2 Chemical industry. Particulates emitted and included in the Norwegian inventory. BC/OC shares in percent of $PM_{2.5}$

Chemical industry	Particles[1]	BC	OC	Source for BC and OC
Production of:				
Ammonia	NA			
Nitric acid	R	0	0	Kupiainen and Klimont 2004
Other fertilisers	NA			
Silicon carbide	R	0	0	EMAP/EEA 2013
Calcium carbide	R	0	0	EMAP/EEA 2013
Methanol	NA			
Titanium dioxide	R	0	0	EMAP/EEA 2013
Sulphuric acid	NA			
Plastic	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3
Explosives	NA			
Chloralkali	NA			
Pigments	NA			
Soap	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3
Paint and varnish	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3

[1)] R = Figures reported by the plant to the Climate and Pollution Agency, NA = Not Applicable.

Production of fertilisers
NFR code 2B

Production of nitric acid
NFR code 2B2
Emissions of particles have been reported to Klif. One of the plants has also reported emissions from combustion, but since it is only 1 per cent of the non-combustion emissions, these figures are included in the figures for non-combustion emissions. No emissions of BC and OC are assumed in the RAINS model Kupiainen and Klimont (2004).This is also used in the Norwegian inventory

Silicon carbide and Calcium carbide
NFR code 2B4
Emission figures for particles are reported to Klif. No information on BC and OC where found in the literature. According to updated EMAP/EEA Guidebook (EMEP/EEA 2013), planned to be available by September 2013, no emissions of BC or OC are assumed to occour. This is also assumed in the Norwegian inventory.

Manufacture of other inorganic chemicals
NFR code 2B5

Production of methanol
One plant in Norway produces methanol. Emissions from flaring of natural gas in connection with production of methanol are reported under NFR code 2B5, even if it is not a process emission. The general emission factor for flaring of natural gass is used. Appendix C table C1.

Production of titanium dioxide
Emission figures for particles are reported to Klif. No information on BC and OC where found in the literature. According to the updated EMAP/EEA Guidebook, planned to be available by September 2013, no emissions of BC or OC are assumed to occour. This is also assumed in the Norwegian inventory

Production of plastic
Emission figures for particles are reported to Klif. No information on BC and OC where found in the literature. According to the updated EMAP/EEA Guidebook, planned to be available by September 2013, no emissions of BC or OC are assumed to occour. This is also assumed in the Norwegian inventory

Production of soap
Emission figures for particles are reported to Klif. No information on BC and OC where found in the literature. According to the updated EMAP/EEA Guidebook, planned to be available by September 2013, no emissions of BC or OC are assumed to occour. This is also assumed in the Norwegian inventory

Paint and varnish production
Emission figures for particles are reported to Klif. No information on BC and OC where found in the literature. According to the updated EMAP/EEA Guidebook, planned to be available by September 2013, no emissions of BC or OC are assumed to occour. This is also assumed in the Norwegian inventory.

5.3. Metal production

NFR code 2C
Metal production in Norway includes plants producing iron and steel, ferroalloys, aluminium, nickel and zinc and also magnesium until spring 2006 and production of anodes. As shown in table 5.3 all figures of particulate matter in the national inventory are from the plants' annual reports to the Climate and Pollution Agency. It is believed that the reported figures also include emissions from combustion, and

that the reported figures mainly consist of process emissions. Emissions from combustion of coal, coke, waste oil etc are thus not calculated for these industries, to avoid double counting.
The chemical composition of the dust from plants producing steel and ferro alloy have been investigated. The carbon content varied between 0.4 to 10 per cent of the dust content (pers. comm. Klif 2012 and 2013[3])

Table 5.3 Metal production. Particulates emitted and included in the Norwegian inventory BC/OC shares in percent of $PM_{2.5}$

Metal production	Particles[1]	BC	OC	Source for BC and OC
Production of:				
Iron and steel	R	0.05 % of TSP	0.04 % of TSP	Personal communication Klif 2012
Ferro-manganese	R	3.5 % of PM_{10}	2.5 % of PM_{10}	Personal communication Klif 2012
Ferrosilicon	R	0.23 % of PM_{10}	0.16 % of PM_{10}	Personal communication Klif 2012
Primary aluminium	R	0	0	Kupiainen and Klimont 2004
Secondary aluminium	R	0.02 % of $PM_{2.5}$	0.25 % of $PM_{2.5}$	Appendix B
Magnesium	R	0	0	Kupiainen and Klimont 2004
Nickel	R	0	0	Kupiainen and Klimont 2004
Zinc	R	0	0	Kupiainen and Klimont 2004
Anodes	R	4 % of $PM_{2.5}$	2.9 % of $PM_{2.5}$	Expert judgement

1) R = Figures reported by the plant to the Climate and Pollution Agency.

Production of iron and steel
NFR code 2C1
Emission figures for particles are reported to Klif. For iron and steel production measurements of the composition of the particiulate matter showed that between 0.4 and 3.3 per cent of the dust was carbon ((EU JRC 2013). Measurements at one steel producing plant showed that 0.1 per cent of the dust was carbon. SN uses 0.1 per cent in the inventory. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3), where BC is set like 50 per cent of $PM_{2.5}$ and OC is set like36 per cent of $PM_{2.5}$ to estimate BC and OC emissions.

Production of ferroalloys
NFR code 2C2
All plants producing ferroalloys report emission figures to Klif. The plants have installed particle filter. Two plants producing ferromanganese have measured the composition of the particulate matter. These measurements showed that 9.63 and 4.35 per cent of the particulate matter was carbon. SN has used the average of these two emissions for estimating BC and OC from ferromanganese production. One plant producing ferrosilicon has measured the composition of the particiulate matter. This measurement showed that 0.45 per cent of the particulate matter was carbon. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3), where BC is set like 50 per cent of $PM_{2.5}$ and OC is set like 36 per cent of $PM_{2.5}$ to estimate BC and OC emissions.

Production of primary aluminium
NFR code 2C3
Emission figures for particles are reported to Klif. According to Kupiainen and Klimont (2004), no studies reporting data on carbonaceous PM was found. For the time being no emissions were assumed for BC and OC.

Production of secondary aluminium
NFR code 2C3
Emission figures for particles are reported to Klif. Table 5.3 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from IIASA (Appendix B). Relating them to $PM_{2.5}$ gives 0.0229 per cent of BC and 0.252 per cent for OC.

3 E-mail from Lars Petter Bingh, Klif 28th of September 2012 and from Henrik Ness Mikkelsen 18th of February 2013)

Production of magnesium, nickel, zink, manufactore of anodes
NFR code 2C5
manufactore of anodes
There are four plants where anodes are manufactured. All four plants reports emission figures to Klif. Two plants produces anodes in combination with aluminium for this plants BC and OC are not estimated. The other two plants reports emission figures to Klif from the manufactoring of anodes. One of the plants has measured the composition of the particulate matter. These measurements showed that 8 ± 2 per cent of the particulate matter was carbon. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3), where BC is set like 50 per cent of $PM_{2.5}$ and OC is set like 36 per cent of $PM_{2.5}$ to estimate BC and OC emissions.

Emission figures for particles from production of magnesium, nickel and zink are reported to Klif. According to Kupiaine and Klimont (2004) only one study was found reporting BC and OC emissions from non-ferrous processes, antimony ore roasting (aluminum excluded).

Table 5.3 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont (2004). No emissions of BC and OC are assumed in the RAINS model. This is also used in the Norwegian inventory.

5.4. Other production

NFR code 2D

Pulp and paper
NFR code 2D1
Four plants producing pulp and paper, report non-combustion emissions of particles to Klif. Two of these plants have not reported emission figures from combustion and it is assumed that the reported non-combustion emission figures include emissions from combustion. Two of the plants state that they clean the emissions by electric filter and wet scrubbers. The other two clean their emissions using only wet scrubbers. Table 5.4 shows the BC and OC shares of TSP. Relating them to TSP gives 2 per cent of BC and 25 per cent for OC.

Table 5.4 Production of pulp and paper. Particulates emitted and included in the Norwegian inventory

	Particles[1]	BC	OC	Source for BC and OC
Production of:				
Pulp and paper	R	2 % of TSP	25 % of TSP	Kupiainen and Klimont 2004

[1)] R = Figures reported by the plant to the Climate and Pollution Agency.

6. Product use

NFR code 3
This chapter covers the emissions from the use of (chemical) products and emissions from combustion of tobacco.

Use of chemical products
NFR code 3C
Emission figures for particles are reported to Klif It is assumed that the size of the particles emitted is larger than $PM_{10.}$ Hence there is no emission of $PM_{2.5}$. Emissions of BC and OC are also set to be zero.

Other product use
NFR code 3D

Tobacco
The emission of particulate matter from the combustion of tobacco has been calculated by multiplying the annual consumption of tobacco with emission factors. Table 5.5 shows the shares of BC/$PM_{2.5}$ and OC/$PM_{2.5}$ from IIASA (Appendix B). Relating them to TSP gives 0.5 per cent of BC and 6 per cent for OC.

Table 6.1 Emission factors used for tobacco combustion. BC/OC shares in per cent of TSP

	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Tobacco	0.04	0.04	0.5% of TSP	6 % of TSP	Kupiainen and Klimont 2004

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

7. Agriculture

NFR code 4
There are some emissions of particles arising from the burning av agricultural residues and some non-combustion emissions of particles. This is for examble dust from crops that are harvested, soil dust from work with agricultural machines, wood particles from felling of trees etc. These non-combustion emissions are considered not to produce emissions of BC or OC, due to larger partiles sizes.

7.1. Emissions from agricultural residue burning (agricultural wastes)

NFR code 4F
Emissions from agricultural residue burning (agricultural wastes) give emissions of standard non-fossil combustion products, including emissions of particles. The annual amount of crop residue burned on the fields is calculated based on crop production data for cereals and rapeseed from Statistics Norway, and estimates of the fraction burned made by the Norwegian Crop Research Institute and Statistics Norway. Table 7.1 shows the BC and OC shares of $PM_{2,5}$. Relating them to $PM_{2.5}$ gives 13 per cent for BC and 42 per cent for OC. The shares of BC/$PM_{2.5}$ and OC/$PM_{2.5}$ are taken from IIASA (Appendix B).

Table 7.1 Emission factors used for agricultural residue burning kg/tonnes crop residue burned. BC/OC shares in per cent of $PM_{2.5}$

	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Agricultural residue burning	5.8	5.8	13 % of $PM_{2.5}$	42 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

8. Waste

NFR code 6
The main emissions from waste incineration are included in the energy sector (1A) since all incineration of municipal, industrial and medical waste in Norway now is done with energy recovery.

8.1. Waste incineration

NFR code 6C
The source sector 6C. Waste incineration includes emissions from flaring, except flaring from energy sectors, and emissions from cremation and until 2005 incineration of hospital waste.

Landfill gas

The total amount of landfill gas extracted each year is reported by landfill owners to the Climate and Pollution Agency. Table 8.1 shows the BC and OC shares of $PM_{2.5}$ taken from IIASA (Appendix B). Relating them to $PM_{2.5}$ gives 7 per cent of BC and 75 per cent for OC.

Table 8.1 Emission factors used for flare of landfill gas kg/tonnes burned. BC/OC shares in per cent of $PM_{2.5}$

	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Flare landfill gass kg/tonnes	0.14	0.14	7 % of $PM_{2.5}$	75 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Hospital waste

The amount of hospital waste was reported to Statistics Norway for the years 1998 and 1999. For the period 1990-1997 the average for 1998 and 1999 has been used. Since 1999, the waste amount for 1999 has been used to calculate the emissions for subsequent years. Since 2006, no hospital incinerators have been in operation. Table 8.2 shows the shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from Kupiainen and Klimont (2004). Relating them to TSP gives 18 per cent of BC and 56 per cent for OC.

Table 8.2 Waste incineration. Particualtes emitted and included in the Norwegian inventory. BC/OC shares in per cent of TSP and $PM_{2.5}$

	Particles#1	BC	OC	Source for BC and OC
Hospital waste	R	18 % of TSP	56 % of TSP	Kupiainen and Klimont 2004
Waste trade	R	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3

[1)] R = Figures reported by the plant to the Climate and Pollution Agency.

Cremation

The number of cremated bodies is gathered by the Ministry of Culture and published in Statistics Norway's Statistical Yearbook. No information on BC and OC where found in the literature. SN has used equation 3.3 (chapter 3.2.3), where BC is set to be 50 per cent of $PM_{2.5}$, and OC is set to be 36 per cent of $PM_{2.5}$. Table 8.3 shows the BC and OC shares used.

Table 8.3 Emission factor for cremation. BC/OC shares in percent of $PM_{2.5}$

	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Cremation (tonnes/body)	2.54E-08	2.54E-08	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

8.2. Other emission sources from the waste sector

NFR code 6D
The source sector Waste other covers emissions from accidental car fires and building fires, and emissions from recovering prosesses in the waste trade.

Car and house fires

Data on the number of car and house fires are provided annually by the Directorate for Civil Protection and Emergency Planning. No information on BC and OC where found in the literature on emission factors for accidental vehicle or building fires. According to updated EMAP/EEA Guidebook, planned to be available by September 2013, emissions of BC or OC recommended to be reported as not estimated (NE). This is assumed in the Norwegian inventory for car fires.

House fires
It is difficult to estimate the amount of material burned in a house fire. In Finstad *et al*. (2003) a calculation was made that has been used to scale the chosen emission factors, to reflect how much of the building that is lost in a fire. This scaling calculation is based on the amount of damage estimated in monetary value, and value on how much of the building and the furniture that is burned. The emission factors used for particles in the inventory are given by scaling the emission factors used for combustion of fuelwood in the households. Table 8.4 shows the BC and OC shares of $PM_{2,5}$. The shares of $BC/PM_{2.5}$ and $OC/PM_{2.5}$ from for wood burning in open fireplaces have been used (Appendix B).

Waste trade
Emissions from recovering processes in the waste trade include emissions particles. The emission figures are reported annually by the actual plants to the Climate and Pollution Agency. It is assumed that the size of the particles emitted is larger than $PM_{10.}$ Hence there is no emission of $PM_{2.5}$. Emissions of BC and OC are also set to be zero.

Table 8.4 Emission factors used for car and house fires. BC/OC shares in per cent of $PM_{2.5}$

	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Car (tonnes/fire) ...	0,002	0,002	NE	NE	EMAP/EEA 2013
Detached house (tonnes/fire)	0,14	0,14	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B, Fuelwood, Fireplace - uncontrolled
Undetached house (tonnes/fire)	0,06	0,06	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B, Fuelwood, Fireplace - uncontrolled
Apartment building (tonnes/fire)	0,04	0,04	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B, Fuelwood, Fireplace - uncontrolled
Industrial building (tonnes/fire)	0,03	0,03	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B, Fuelwood, Fireplace - uncontrolled

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

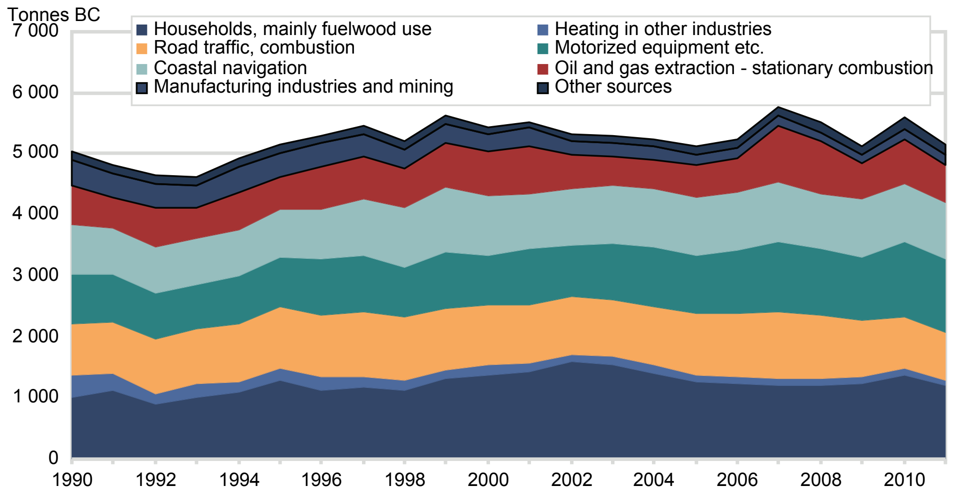
9. Results

Emissions of BC and OC in Norway have been estimated based on the national emissions inventory of $PM_{2.5}$. Emissions are estimated on a source and fuel basis. Source specific emission factors have been used for wood combustion in the residential sector and for flaring of natural gas. In order to estimate the emissions of BC and OC on a source and fuel basis, fractions of BC and OC of emitted PM from IIASA are used in combination with Norwegian $PM_{2.5}$ emission factors.

9.1. Emission of Black carbon 1990-2011

The most important sources for BC, according to the estimates are presented in figure 9.1. Estimated total emissions in Norway of BC were 5,100 tonnes in 2011. This is the same level as in 1990. The percentages of BC emissions from different sectors for 2011 are presented in figure 9.2. Heating in households is the main source and contributed to 23 per cent of total BC emissions in 2011, and 20 per cent in 1990.

Figure 9.1. Emissions of Black Carbon (BC) to air, by source in Norway, 1990-2011. Tonnes



Between 1990 and 2009 the BC emissions from the domestic sector has increased by 18 per cent. In the same period consumption of wood has increased by 26 per cent (figure 9.3). Stoves with new technology (stoves manufactured after 1998) produce fewer airborne particles and are more energy-efficient than stoves with the old technology. The BC emissions from heating in households rose by 12 per cent from 2009 to 2010. The wood consumption rose by 11 per cent. The wood comsumption increased due to both high electricity prices in 2010 and the fact that 2010 was a cold year. In 2011 the emission was at the same level as in 2009.

Figure 9.2. Distribution of BC emissions between sectors, 2011. Per cent

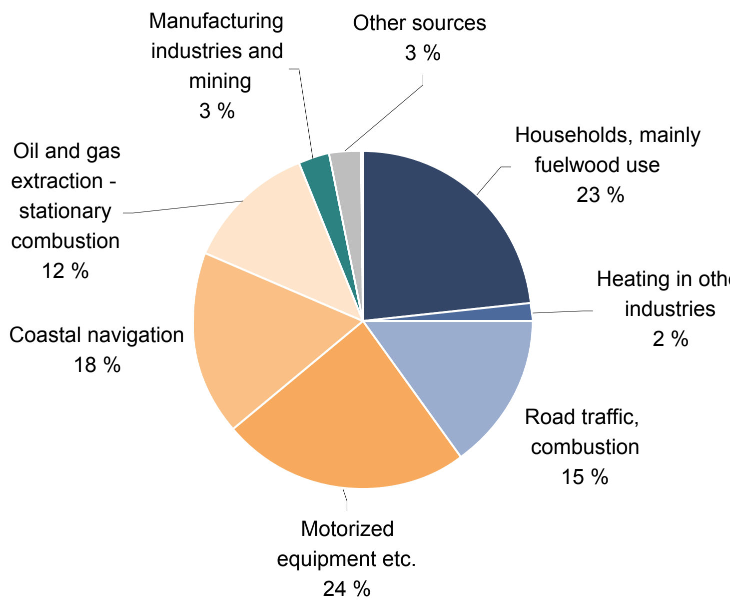
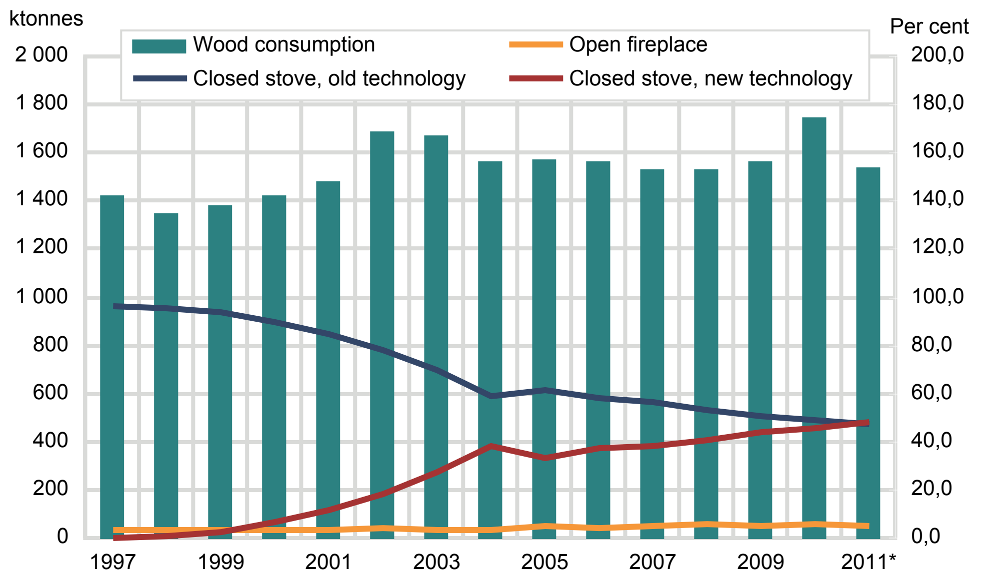


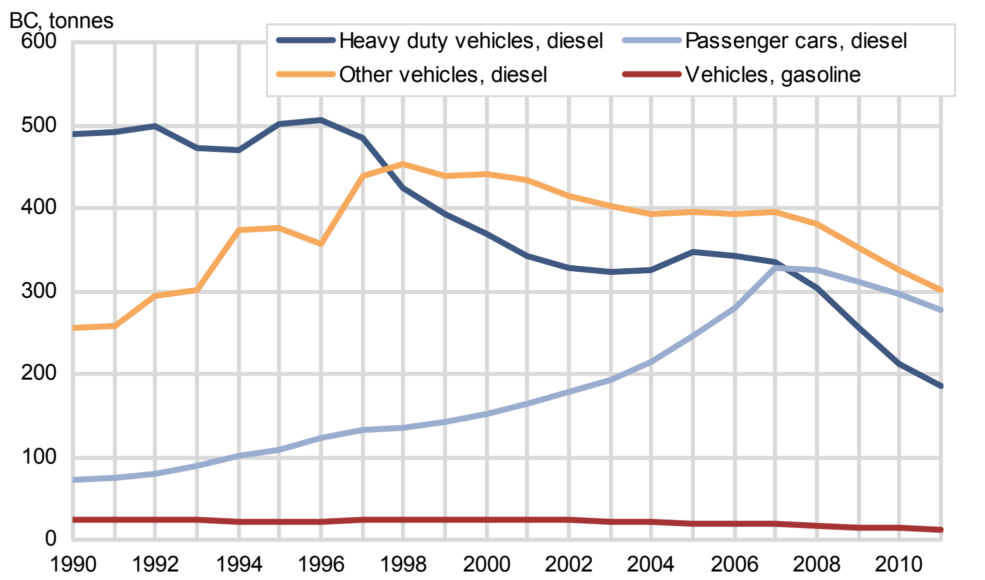
Figure 9.3. Proportion of wood consumed according to fireplace type and wood consumption 1997-2011. Per cent and ktonnes



Road traffic was responsible for 780 tonnes, or 15 per cent, of the BC emissions in 2011, compared to 17 per cent in 1990. The actual emissions decreased by 8 per cent. Emissions from diesel passenger cars were 3.8 times higher than in 1990 (figure 9.4). Emissions from heavy duty diesel vehicles have decreased by 47 per cent during the same time period. Since 1990, traffic has grown by more than 50 per cent. Factors that have contributed to lower emissions include more energy efficient vehicles and decreased emissions due to introduction of stricter exhaust emission requirements. Since 2007, the BC emissions have declined for all sources within the transport sector.

Emissions from diesel passenger cars contributed to 35 per cent of the emissions from road traffic in 2011, while emissions from heavy duty diesel vehicles, and other diesel vehicles (primarily light duty vehicles) contributed to 24 and 39 per cent, respectively (figure 9.4).

Figure 9.4. Emissions of Black Carbon (BC) from road traffic. 1990-2011. Tonnes



Domestic sea transport and fishing were responsible for 910 tonnes or 18 per cent of the BC emissions in 2011. The emissions were 11 per cent higher in 2011 than in 1990, and follow the trend in consumption of marine gasoil and marine diesel.

Oil and gas activities were responsible for 12 per cent of the BC emissions in 2011, approximately the same percentage as in 1990 (13 per cent). There are annual fluctuations in the calculated emissions. These emissions have, nevertheless, decreased somewhat in recent years, after reaching a peak in 2007 and 2008 due to increased emissions from flaring.

Emissions from manufacturing industries and mining were 60 per cent lower in 2011 than in 1990, and while these emissions constituted 8 per cent of the total in 1990, the share was reduced to 3 per cent in 2011. The decrease can be explained by plant closures and improved technology which has led to significant reductions in emissions.

Emissions from motorized equipment contributed 1,220 tonnes or 24 per cent of the emissions of black carbon in 2011. The calculations show that the emissions have increased by more than 50 per cent from 1990 to 2011. The uncertainty is particularly high for emissions from motorized equipment. This is because the activity data are distributed among the different equipment types based on fixed shares. The emission factors do not take into account the various technological changes. Klif is running a project to improve both activity data and emission factors.

9.2. Emissions of Organic carbon 1990-2011

Estimated emissions of OC were 19,900 tonnes in 2011. This is approximately the same level as in 1990. The most important sources for OC, according to the estimates, are presented in figure 9.5. The percentage breakdown of OC emissions by sector for 2011 is presented in Figure 9.6. Heating in households is the main source and contributed to 16,600 tonnes or 83 percent of total OC- emissions in 2011, compared with 79 percent in 1990. Since 1998, the OC emissions have declined due to the gradual introduction of stoves with new technology. The proportion wood burnt in stoves with new technology is increasing rapidly.

Figure 9.5. Emissions of Organic Carbon (OC) to air by source in Norway. 1990-2011. Tonnes

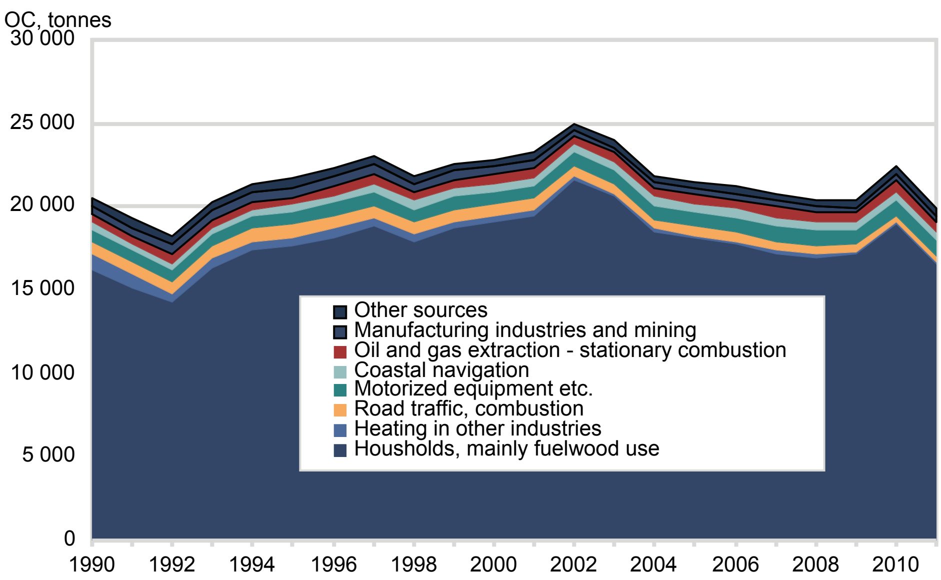
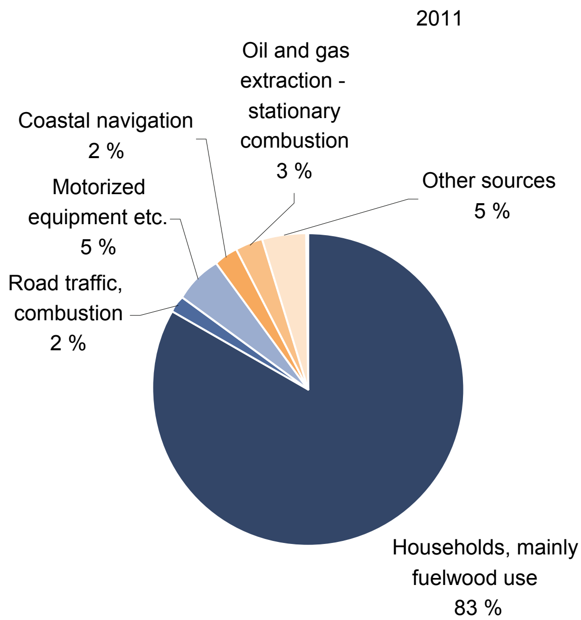


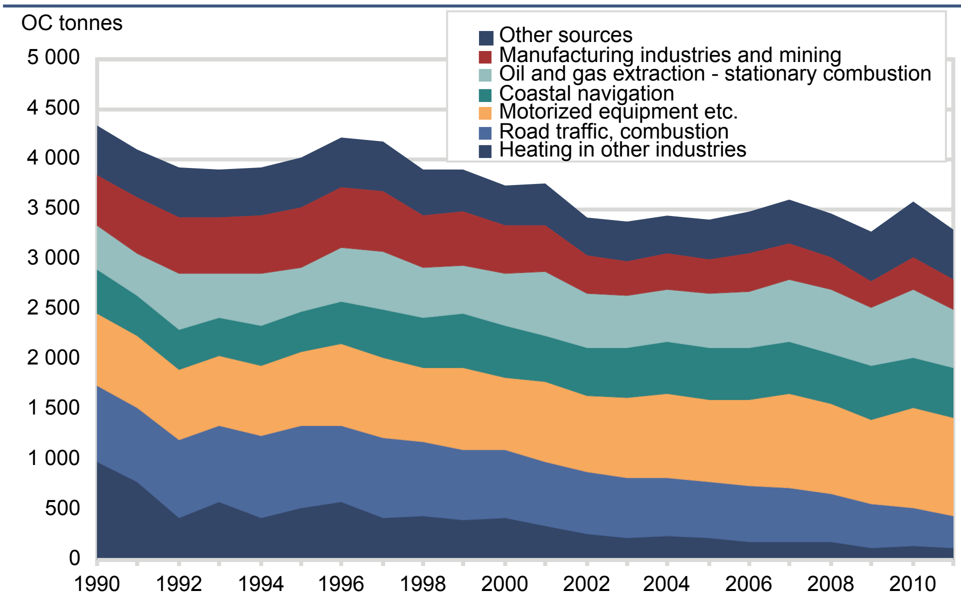
Figure 9.6. Distribution of OC sectors. 2011. Per cent



The emissions of OC for sources other than heating in households, for the period 1990-2011 are shown in figur 9.7. The ratio between the different sources has changed significantly during the period. Emissions from diesel passenger cars were almost 2 times higher in 2011 than in 1990. Since 2007, the emissions have decreased by a third. Emissions from heavy duty vehicles, diesel have decreased by 79 per cent since 1990. Emissions from other diesel vehicles (primarily light duty vehicles) have decreased by 37 per cent since 1990.

Emissions from road traffic accounted for 330 tonnes, or two per cent of total organic carbon emissions in 2011, and emissions from diesel passenger cars contributed to 30 per cent of these emissions. Emissions from heavy duty diesel vehicles, and other diesel vehicles (primarily light duty vehicles) contributed to 25 and 35 per cent respectively from road traffic in 2011.

Figure 9.7. Emissions of Organic Carbon (OC) to air by source (except heating in households) in Norway. 1990-2011. Tonnes



Navigation, oil and gas extraction, and manufacturing industries and mining were responsible for 2, 2 and 3 per cent respectively of the OC emissions in 2011. From 1990 to 2011, emissions from navigation increased by 12 per cent, emissions from oil and gas activities increased by a third whereas emissions from manufacturing industries were reduced by 40 per cent

9.3. Key categories

Key sources are in the inventory guidelines defined as the sources, ranked from largest to smallest, which sum up and contribute to 95 per cent of the total national emissions of a specific substance. The key sources contributing to 95 per cent of the emissions of BC in 2011 and the emissions from the same sources in 1990 are presented in table 9.1. In 2011 the five largest souces contributed to more than 300 tonnes of BC each. The largest sources were: Households (use of fuelwood), motorized equipment, navigation costal traffic and fishing, and light duty vehicles, diesel.

For the five largest sources the emissions of BC are higher in 2011 than in 1990. Emissions from households (use of fuelwood), motorized equipment, fishing, and light duty diesel vehicles have increased by 18, 57, 21 and 19 per cent respectively. The increases in emissions are due to increased use of energy goods.

Table 9.1. Key soures for emission of BC in Norway, 2011 and the same sources for 1990. Tonnes and per cent

	2011	Per cent	1990	Per cent
Total	**5 148**	100.0	**5 040**	100.0
Heating in households	1 205	23.4	1 021	20.3
Motorized equipment, diesel	1 176	22.8	750	14.9
Navigation - coastal traffic etc.	557	10.8	532	10.6
Navigation - fishing	354	6.9	292	5.8
Light duty vehicles - diesel	302	5.9	255	5.1
Passenger cars - diesel	277	5.4	73	1.4
Oil and gas extraction - offshore - flaring	241	4.7	380	7.5
Heavy duty vehicles - diesel etc.	187	3.6	490	9.7
Oil and gas extraction - offshore - diesel mobile installations, production	100	1.9	9	0.2
Oil and gas extraction - onshore - flaring	88	1.7	6	0.1
Energy supply	74	1.4	6	0.1
Oil and gas extraction - offshore - well testing	68	1.3	174	3.5
Oil and gas extraction - offshore - diesel fixed installations	63	1.2	27	0.5
Other industries and mining - stationary combustion	54	1.0	205	4.1
Heating in other service industries	44	0.9	33	0.7
Small boats	41	0.8	41	0.8
Road wear	38	0.7	63	1.2
Oil and gas extraction - offshore - diesel mobile installations, exploration	35	0.7	35	0.7

Table 9.2 shows the key sources for OC in 2011 and the emissions from the same sources in 1990. In 2011 there were four sources contributing more than 300 tonnes of OC, households (use of fuelwood), motorized equipment, oil and gas extraction – offshore, and navigation costal traffic. In 1990 emissions from three sources were higher 300 tonnes: residential households (use of fuelwood), motorized equipment, and road wear.

For all the larger sources the emissions of OC are higher in 2011 than in 1990. Emissions from households (use of fuelwood), motorized equipment, and oil and gas extraction - offshore have increased by 2, 56 and 65 per cent, respectively.

Table 9.2. Key sources for emission of OC in Norway 2011 and the same sources for 1990. Tonnes and per cent

	2011	Per cent	1990	Per cent
Total	**19 888**	100.0	**20 533**	100.0
Heating in households	16 579	83.4	16 188	78.8
Motorized equipment - diesel	730	3.7	468	2.3
Oil and gas extraction - offshore - natural gas in turbines etc.	322	1.6	196	1.0
Navigation - coastal traffic etc.	304	1.5	295	1.4
Small boats	243	1.2	243	1.2
Road wear	192	1.0	313	1.5
Navigation - fishing	182	0.9	139	0.7
Energy supply	130	0.7	4	0.0
Light duty vehicles - diesel	113	0.6	178	0.9
Passenger cars - diesel	96	0.5	51	0.2
Tyre and brake wear	91	0.5	61	0.3

9.4. Trends $PM_{2.5}$, BC and OC

Figure 9.8 presents emission trends for $PM_{2.5}$, BC and OC from 1990 to 2011. Emissions of particulate matter have declined due to implementation of strict air pollution control policies, especially in the transport, industry and power plant sectors. Cleaning measures, changes in production procedures and lower activity in some industries have also resulted in reduced emissions. In addition a larger share of the wood is burned in stoves with new technology. Emissions are expected to continue to decrease due to further air pollution legislation.

Figure 9.8. Emissions of $PM_{2.5}$, Black Carbon (BC) and Organic Carbon (OC), 1990-2011. Index (1990=100)

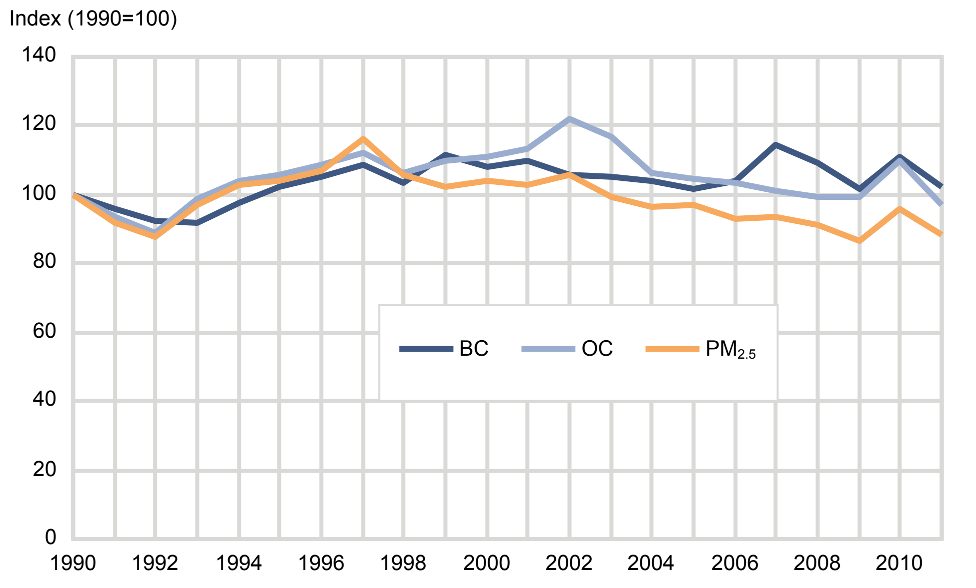
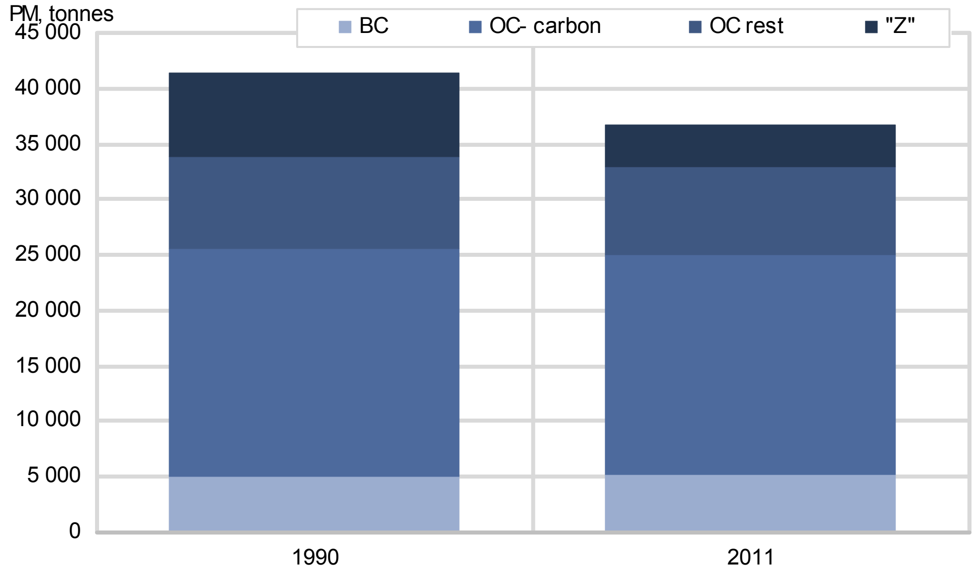


Figure 9.9 shows the composition of $PM_{2.5}$ in 1990 and 2011. In 2011, BC an OC contributed to 14 and 54 per cent of the $PM_{2.5}$ emissions, respectively. The default equation, equation 3.3 (see chapter 3.2.3), is used to estimate organic matter (OM). If the sum of BC and OM (OM= OC*1.4) exceed the emissions of $PM_{2.5}$, OM is set to be $PM_{2.5}$ minus BC. The rest of the $PM_{2.5}$ emissions are considered to be inorganic compounds "Z" ($PM_{2.5}$ minus BC and OM). In 2011, OM (without OC) and Z contributed to 13 and 19 per cent of the $PM_{2.5}$ emissions, respectively. The sum of BC and OM constituted 74 percent of the emission of $PM_{2.5}$ in 1990 and 81 per cent of the emission in 2011. The decrease in inorganic compounds is due to lower process emissions of particulate matter from production of carbides, iron steel and ferro-alloys, and aluminium. The Z is high for the production of iron and steel, ferroalloys, and anodes this is due to low carbon content in the dust.

Measurements showed that between 0.5 and 10 per cent of the particulate matter was carbon.

Figure 9.9. Emissions of $PM_{2.5}$ split into emissions of Black Carbon (BC), Organic Matter (Organic Carbon – carbon and Organic carbon –rest) and Z, 1990 and 2011. Tonnes



9.5. Comparison of Norwegian emissions with other inventories

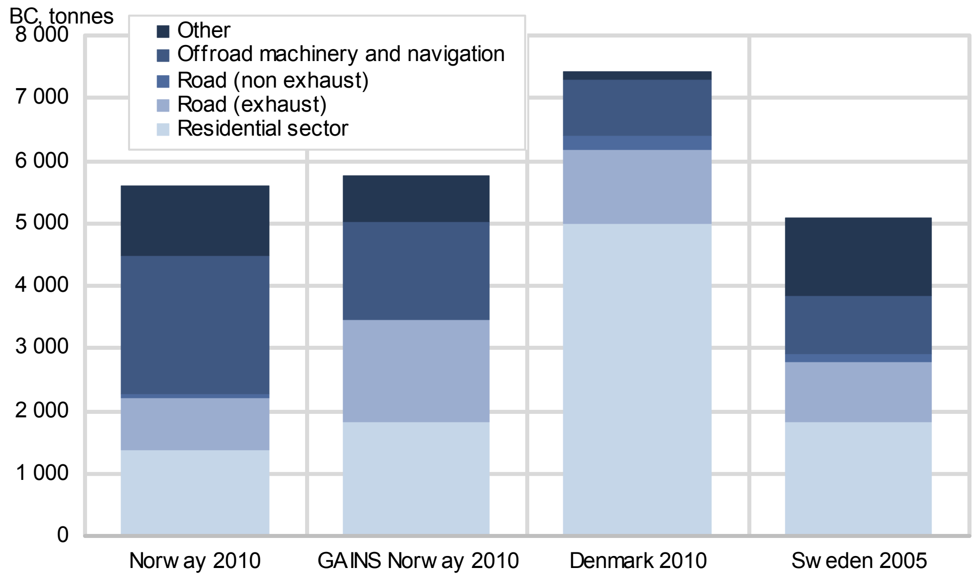
In order to provide comparability with other Nordic countries estimates we have compared the Norwegian BC emission inventory for 2010 and the BC emission calculated by IIASA, "GAINS Norway 2010", Denmark 2010 and Sweden 2005.

The emission esimates for different countries are not always directly comparable, among other factors because different standards are used in different countries to measure the emissions. For example, in Norway, emission factors for PM include the condensed OC (i.e. measure on cold smoke), whereas in Sweden PM emission measurements are made on hot smoke, excluding the condensable OC (Nielsen et al., 2010).

GAINS –inventory

The GAINS inventory (Kupiainen and Klimont 2007) is based on the PM emissions reported under the convention on long-range transboundary air pollutants (CLRTAP). Figure 9.10 shows the BC emissions data in the Norwegian inventory compared to the BC emissions calculated for Norway in the GAINS model as of July 2012. The GAINS model and the Norwegian emission inventory estimate almost the same BC emissions for 2010, but the ratio between the different sources differ. For residential wood combustion the Norwegian inventory are based on specific emission factors for EC for combustion of wood in closed storves with new and old tehnology. These emission factors are lower than the ones used in the GAINS model.

Figure 9.10. Comparison of the Norwegian emission inventory (2010) with estimated emissions GAINS-Norway 2010, Denmark 2010, and Sweden 2005. Tonnes



Source: Appendix B, (Hansson, Johansson et al. 2011; Winther and Nielsen 2011)

Denmark
The Danish draft national inventory and projections for Greenland report total emissions of BC and OC in 2010 of 7,400 and 8,700 tonnes, respectively (Winther and Nielsen 2011). The residential sector was the largest BC and OC emission source in 2010, comprising 67 and 82 per cent of the totals. In the case of BC, the residential sector was followed by road transportation (16 per cent), other mobile sources (12 per cent) and road (non exhaust) (3 per cent). The second largest OC source was shown other mobile sources, responsible for 8 per cent of emissions. Road transportation (exhaust) and road transportation (non exhaust) represents about 4 per cent each of the OC emissions (Figure 9.10). Emissions of BC have decreased by approximately 6 per cent between 1990 and 2010. There has been large reductions related to road transport emissions (48 per cent reduction) and "Other mobile sources", which is reduced by 62 per cent. Emissions related to the residential sector have increased by 71 per cent over the same period.

Sweden
The Swedish inventory report total emissions of BC and OC in 2005 of 5,100 and 6,700 tonnes, respectively (Hansson, Johansson et al. 2011). The residential sector was the largest BC and OC emission source in 2005, comprising 37 and 43 per cent of the total. In the case of BC, the residential sector was followed by road transportation (21 per cent), other mobile sources (navigation and off road machinery) and other stationary combustion (18 per cent each). The second largest OC source was shown to be road transportation (exhaust), which was responsible for 23 per cent of emissions. Other stationary and other mobile sources contributed to 14 and 11 per cent respectively.

10. Uncertainties in emission estimates and areas for improvements

Uncertainty in activity data
The uncertainty in the national emission inventory of BC and OC depends on the uncertainty in activity data and in emission factors. The activity data in the Norwegian national inventory are collected and compiled by Statistics Norway, using surveys and statistical methods to produce figures of national fuel consumption of different fuels in different sectors. Generally, the uncertainty in

activity data is assumed to be low for fuels traded on the market and the fuelwood used in households. The heat and power industry as well as the manufacturing industries have good records of their fuel use, and report this annually. Activity data under those conditions can be assumed to have a low uncertainty level, in the order of 2-5 per cent. For fuel use in the mobile sectors the national overall fuel consumption can be assumed to have a quite low uncertainty, while the uncertainty in activity data increases when this total amount is disaggregated and allocated to different end uses.

Uncertainty in emission factors

For residential small scale combustion, closed stoves, the uncertainty for the emission factors for EC and OC are estimated to 5-7 per cent (Seljeskog, Goile et al. 2013).

Actual emissions depend on several factors such as heating habits, wood consumption and types of appliances. Emission factors for PM can vary by several orders of magnitude.

For the other sectores, there are not estimated uncertainties for the emission factors for BC or OC.

For mobile sources we assume that the lowest emission factor uncertainty is found in road transport emissions, while the emission factors for off-road machinery and navigation/shipping are assumed to be in higher. Emissions from motorized equipment are concidered to have the largest uncertainty, due to uncertain usage of taxfree diesel. Improved activity data and emission factors should be included when available.

The uncertainties in the BC and OC emission factors given by IIASA, and used in the calculations of Norwegian BC/OC emissions are not known. According to Kupiainen & Klimont, 2004 there are significant uncertainties in BC and OC emission estimates. For future work they recommend that one of the main tasks in the future will be to reduce these uncertainties.

Uncertainty due to lack of completeness
As the estimated emissions of PM is the basis for calculation of BC and OC emissions, an uncertainty and possible underestimation of PM emissions also influences the estimated emissions of BC and OC.
These sources are included in the Norwegian emission inventory for at lest one pollutant, but are not included in the PM emission inventory, and hence not in the BC and OC inventory:

- Asphalt production plants
- Road traffic: Motor cycles and mopeds
- Offroad machinery: Snow scooter
- Railway contact wire abrasion
- Oil and gas extraction:
  - Cold flaring and leakage, offshore (process emissions)
  - Oil loading, offshore (process emissions)
  - Oil loading, onshore (process emissions)
  - Gas terminals, onshore (process emissions)

Process emissions from these sources are included in the Norwegian $PM_{2.5}$ emission inventory, but are not included in the BC and OC inventory:

- Petrochemistry
- Fertilizer
- Carbides
- Chemical industri, other
- Other metals
- Other mining
- Agriculture, other
- Oil refining

It is assumed that carbonaceous particulate emissions from most of the processes in petrochemistry, production of fertilizers, production of non-ferrous metal probably are small and therefore zero emissions are assumed for the time being (Kupiainen and Klimont 2004).

According to the updated EMAP/EEA Guidebook, planned to be available by September 2013, no emissions of BC and OC are assumed to occur for production of carbides.

It is assumed by the Climate and Pollution Agency that the particles emitted from the source “Other mining” are larger than PM_{10}. Thus, no BC/OC emissions are calculated.

“Agriculture other” includes various types of non-combustion emissions of particles. This is for example dust from crops that are harvested, soil dust from work with agricultural machines, wood particles from felling of trees etc. It is assumed that BC and OC does not occur in these processes.

As recommended by (Kupiainen and Klimont 2004) only BC emissions form petroleum refining are estimated. Emissions of OC are not estimated.

The following sources with relevant emission amounts are not covered in the inventory due to lack of activity data and emission factors. Emissions can be expected:

- Emissions of particulate matters from burning of bonfire, garden waste, animal carcasses and burning of waste in household stoves

Uncertainty in method

To ensure that the emissions of BC and OC in the Norwegian inventory do not exceed the $PM_{2.5}$ emissions, the emission factors for BC and OC are estimated as shares of the $PM_{2.5}$ emission factors based on information from IIASA. This may lead to underestimation for some sources if the Norwegian emission factor for PM is too low.

If the emsission factors used by IIASA do not fully reflect the Norwegian conditions, using the share of BC to $PM_{2.5}$ may in some situations be better than using the emission factor used by IIASA. If the emission factor used by IIASA reflects Norwegain conditions better than the share used in the inventory, this will make the emissions estimated more uncertain.

For sources where emission factors for BC and OC were not available, the following equation has been used if emissions of BC and OC are expected to occur (see chapter 3.2.3):

$PM_{2.5} = BC + OM + Z$

In this work it is assumed that Z is 0
For fuel-sector technologies Z varies from a few per cent of $PM_{2.5}$ to 70 per cent depending on the technology. Measurements in metal production (chapter 5.3) have shown that a large part of the PM-emission does not consist of carbon. In metal production the carbon content varied between 0.1 to 10 per cent of the dust content. This makes Z for metal production vary between 90 to 99.1 per cent of the dust content. This may also be the case for other sources.

It is assumed that BC = OM = 50 per cent of $PM_{2.5.}$
The emission factors from IIASA shows that for fuel use in domestic sector BC varies between 0.5 and 40 per cent of the $PM_{2.5}$ emission while OC varies between 5 and 51 per cent of the $PM_{2.5}$ emission. For the transport sector BC varies between 15 and 87 per cent of the $PM_{2.5}$ emission while OC varies between 11 and 45 per cent of the $PM_{2.5}$-emission depending on fueltype and tehnology.

As mentiones in chaper 2.1 it is asumed in this work that OM = F*OC, where F =1.4
F is not 1.4 for all sources (although it is assumed for several). The factor may vary depending on the origin and age of the OM. The factor is usually between 1.2 and 1.8. In the GAINS-model F is assumed to be 1.8 for burning of fuelwood, and 1.2 or 1.3 for diesel combustion (pers. comm. IIASA 2012[4])

10.1. Areas of improvement

Organic mass (OM), OC is multiplied by a factor (F) to account for other elements than carbon in the organic molecules. The factor may vary depending on the origin and age of the OM. The factor is usually between 1.2 and 1.8, where 1.4 is chosen in this work. If SN had choosen a lower figure for F, the estimamted emissions for OC would have been higher. In an updatd version it should be concidered if the factor 1.4 for calculating OC from OM should vary between different sources.

There is a scheduled update of hte EMAP/EEA emission inventory guide book. This update will include BC emission factors and calculation methodologies. In a future update of the Norwegian emission inventory for BC, the descriptions in the updated guidebook should be considered.

[4] E-mail from Zigniew Klimont IIASA 12th. of June 2012)

The uncertainties have to be kept in mind developing policy recommendations based on models relying on the emission inventories. There is a need to quantify and decrease the uncertainties in the estimated BC and OC emission as the policy implications can be affected. The most uncertainties sources are considered to be mororized equipment and navigation.

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Appendix A Abbreviations

Glossary Term	**Explanation**
BC	Black carbon
CLRTAP	Convention on Long-range Transboundary Air Pollution
CRF	Common Reporting Format, used for reporting of greenhouse gas emissions
CS	Country specific
EC	Elemental carbon
EEA	European environmental Agency
EPA	U.S Environmental protection agency
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies. An integrated assessment model and the main model used in the international air pollution negotiations with under the Convention of Long Range Transport of Atmospheric Pollutants within OECD. Developed by IIASA, extended RAINS model. Released in 2006.
IIASA	International Institute for Applied Systems Analysis
Klif	The Norwegian Climate and Pollution Agency
LPG	Liquid Petroleum Gas
NFR	Nomenclature For Reporting, used for reporting under the Cnvention of Long-Range Transboundary Air Pollutants.
OC	Organic carbon
OECD	Organisation for Economic Co-operation and Development
OM	Organic matter
PM_{10}	Particulate matter with diameter less than 10 µm
$PM_{2.5}$	Particulate matter with diameter less than 2.5 µm
RAINS	Regional Air Pollution Information and Simulation model, developed by IIASA
SINTEF	Institute of Social Research in Industry
SLCF	Short-lived Climate Forcing components, Including amongst other methane, ozone and black carbon.
Sm3	Standard cubic meters
SN	Statistics Norway
SOA	Secondary Organic Aerosols
Soot	Impure carbon particles resulting from the incomplete combustion
Total carbon, TC	Sum of EC and OC on carbon mass basis. Usually measured by same thermal method as EC.
TSP	Total Suspended Particle Mass. The diameter of the particles included in TSP is not well defined due to wind speed dependent sampling efficiency inlet, but it usually varies between 50 and 100 µm.
UNFCCC	United Nations Framework Convention on Climate Changes
UNECE	United Nations Economic Commission for Europe

Appendix B Spreadsheet IIASA

Emission factors for $PM_{2.5}$, BC, OC used in GAINS; by fuel-sector-technology, as per 28th of March 2012 "The lower calorific value (LHV) is assumed for information purposes only so that one can convert the factors to units you might want to use in your inventory."

Table B1. Domestic sector, Fuelwood [mg/MJ]

Source	BC	OC	$PM_{2.5}$	LHV wood (MJ/kg) Source code [Unit]	16 BC ef [g/kg]
Fireplace - uncontrolled	100	558	1 163	FWD-DOM_FPLACE-NOC-[PJ]	1.60
Fireplace - improved	95	273	651	FWD-DOM_FPLACE-FP_IMP-[PJ]	1.52
Fireplace - new (insert - could be catalytic if available on the market)	75	113	349	FWD-DOM_FPLACE-FP_NEW-[PJ]	1.20
Automatic medium size (>200 kW) boiler - uncontrolled	8	9	69	FWD-DOM_MB_A-NOC-[PJ]	0.13
Automatic medium size (>200 kW) boiler - cyclon	7	5	48	FWD-DOM_MB_A-MB_CYC-[PJ]	0.11
Automatic medium size (>200 kW) boiler - pellet boiler	1	1	8	FWD-DOM_MB_A-MB_PELL-[PJ]	0.01
Automatic medium size (>200 kW) boiler - high efficiency deduster	0.0	0.1	0.7	FWD-DOM_MB_A-MB_HED_F-[PJ]	0.00
Manually loaded medium size (>200 kW) boiler - uncontrolled	20	27	77	FWD-DOM_MB_M-NOC-[PJ]	0.32
Manually loaded medium size (>200 kW) boiler - cyclon	18	17	54	FWD-DOM_MB_M-MB_CYC-[PJ]	0.28
Manually loaded medium size (>200 kW) boiler - high efficiency deduster	0.0	0.1	0.8	FWD-DOM_MB_M-MB_HED_F-[PJ]	0.00
Manually loaded medium size (>200 kW) boiler - replacement with pellet boiler	2	0	8	FWD-DOM_MB_M-MB_PELL-[PJ]	0.04
Automatic single house boiler (<50 kW) - pellet boiler	3	3	23	FWD-DOM_SHB_A-NOC-[PJ]	0.05
Automatic single house boiler (<50 kW) - pellet boiler with ESP	0.3	0.3	2.3	FWD-DOM_SHB_A-SHB_HED-[PJ]	0.00
Manually loaded single house boiler (<50 kW)	75	75	233	FWD-DOM_SHB_M-NOC-[PJ]	1.20
Manually loaded single house boiler (<50 kW) - improved	38	26	93	FWD-DOM_SHB_M-SHB_IMP_B-[PJ]	0.60
Manually loaded single house boiler (<50 kW) - new (with accumulater tank)	13	12	47	FWD-DOM_SHB_M-SHB_NEW_B-[PJ]	0.21
Manually loaded single house boiler (<50 kW) - replaced with pellet boiler	4	2	23	FWD-DOM_SHB_M-SHB_PELL-[PJ]	0.06
Manually loaded single house boiler (<50 kW) - replaced with pellet boiler with ESP	0.0	0	2	FWD-DOM_SHB_M-SHB_PLESP-[PJ]	0.00
Cooking stove - uncontrolled	75	228	512	FWD-DOM_STOVE_C-NOC-[PJ]	1.20
Cooking stove - improved	71	55	189	FWD-DOM_STOVE_C-STV_IMP_B-[PJ]	1.14
Cooking stove - new	21	34	102	FWD-DOM_STOVE_C-STV_NEW_B-[PJ]	0.34
Heating stove - uncontrolled	100	1 207	2 392	FWD-DOM_STOVE_H-NOC-[PJ]	1.60
Heating stove - with ESP	6	42	102	FWD-DOM_STOVE_H-STV_IMP_B-[PJ]	0.10
Heating stove - improved	95	390	885	FWD-DOM_STOVE_H-STV_NEW_B-[PJ]	1.52
Heating stove - new	28	197	478	FWD-DOM_STOVE_H-STV_ESP_B-[PJ]	0.45
Heating stove - pellet stove	4	21	120	FWD-DOM_STOVE_H-STV_PELL-[PJ]	0.06
Heating stove - pellet stove with ESP	0.0	3	18	FWD-DOM_STOVE_H-STV_PLESP-[PJ]	0.00

Table B2. Domestic sector, Hard Coal, [mg/MJ]

Source	BC	OC	$PM_{2.5}$	LHV coal (MJ/kg) Source code [Unit]	24 BC ef [g/kg]
Automatic medium size (>200 kW) boiler - uncontrolled	4	2	199	HC1-DOM_MB_A-MB_NOC-[PJ]	0.10
Automatic medium size (>200 kW) boiler - cyclon	4	2	140	HC1-DOM_MB_A-MB_CYC-[PJ]	0.09
Automatic medium size (>200 kW) boiler - high efficiency deduster	0.0	0.0	2	HC1-DOM_MB_A-MB_HED-[PJ]	0.00
Manually loaded medium size (>200 kW) boiler - uncontrolled	4	2	199	HC1-DOM_MB_M-NOC-[PJ]	0.10
Manually loaded medium size (>200 kW) boiler - cyclon	4	44	140	HC1-DOM_MB_M-MB_CYC-[PJ]	0.09
Automatic single house boiler (<50 kW)	65	11	120	HC1-DOM_SHB_A-NOC-[PJ]	1.55
Manually loaded single house boiler (<50 kW)	120	111	222	HC1-DOM_SHB_M-NOC-[PJ]	2.87
New manually loaded single house boiler (<50 kW)	108	44	133	HC1-DOM_SHB_M-SHB_NEW_C-[PJ]	2.58
Cooking stove - uncontrolled	150	120	390	HC1-DOM_STOVE_C-NOC-[PJ]	3.60
Cooking stove - improved	147	90	273	HC1-DOM_STOVE_C-STV_IMP_C-[PJ]	3.53
Cooking stove - new	143	66	195	HC1-DOM_STOVE_C-STV_NEW_C-[PJ]	3.42
Heating stove - uncontrolled	200	160	405	HC1-DOM_STOVE_H-NOC-[PJ]	4.80
Heating stove - improved	196	120	284	HC1-DOM_STOVE_H-STV_IMP_C-[PJ]	4.70
Heating stove - new	190	88	203	HC1-DOM_STOVE_H-STV_NEW_C-[PJ]	4.56

Table B3. Transport sector - exhaust emissions, Diesel vehicles - Road [mg/MJ]

Source	BC	OC	$PM_{2.5}$	Source code [Unit]
Cars - uncontrolled	58.40	40.90	106.00	MD-TRA_RD_LD4C-NOC-[PJ]
Cars - EURO I	23.80	9.54	34.10	MD-TRA_RD_LD4C-MDEUI-[PJ]
Cars - EURO II	19.40	4.47	24.30	MD-TRA_RD_LD4C-MDEUII-[PJ]
Cars - EURO III	15.60	2.34	18.40	MD-TRA_RD_LD4C-MDEUIII-[PJ]
Cars - EURO IV	15.80	2.06	18.20	MD-TRA_RD_LD4C-MDEUIV-[PJ]
Cars - EURO V	0.19	0.39	0.97	MD-TRA_RD_LD4C-MDEUV-[PJ]
Cars - EURO VI	0.20	0.40	0.99	MD-TRA_RD_LD4C-MDEUVI-[PJ]
Light duty trucks - uncontrolled	59.00	41.30	107.00	MD-TRA_RD_LD4T-NOC-[PJ]
Light duty trucks - EURO I	24.30	9.73	34.80	MD-TRA_RD_LD4T-MDEUI-[PJ]
Light duty trucks - EURO II	27.80	6.39	34.80	MD-TRA_RD_LD4T-MDEUII-[PJ]
Light duty trucks - EURO III	21.70	3.25	25.50	MD-TRA_RD_LD4T-MDEUIII-[PJ]
Light duty trucks - EURO IV	12.00	1.56	13.80	MD-TRA_RD_LD4T-MDEUIV-[PJ]
Light duty trucks - EURO V	0.16	0.31	0.78	MD-TRA_RD_LD4T-MDEUV-[PJ]
Light duty trucks - EURO VI	0.16	0.32	0.80	MD-TRA_RD_LD4T-MDEUVI-[PJ]
Heavy duty trucks - uncontrolled	22.10	17.70	44.30	MD-TRA_RD_HDT-NOC-[PJ]
Heavy duty trucks - EURO I	19.00	7.59	29.20	MD-TRA_RD_HDT-HDEUI-[PJ]
Heavy duty trucks - EURO II	9.55	3.82	14.70	MD-TRA_RD_HDT-HDEUII-[PJ]
Heavy duty trucks - EURO III	9.28	2.78	13.30	MD-TRA_RD_HDT-HDEUIII-[PJ]
Heavy duty trucks - EURO IV	1.88	0.47	2.51	MD-TRA_RD_HDT-HDEUIV-[PJ]
Heavy duty trucks - EURO V	1.86	0.46	2.48	MD-TRA_RD_HDT-HDEUV-[PJ]
Heavy duty trucks - EURO VI	0.02	0.06	0.13	MD-TRA_RD_HDT-HDEUVI-[PJ]
Busses - uncontrolled	23.80	19.10	47.70	MD-TRA_RD_HDB-NOC-[PJ]
Busses - EURO I	18.20	7.26	27.90	MD-TRA_RD_HDB-HDEUI-[PJ]
Busses - EURO II	9.45	3.78	14.50	MD-TRA_RD_HDB-HDEUII-[PJ]
Busses - EURO III	8.92	2.68	12.70	MD-TRA_RD_HDB-HDEUIII-[PJ]
Busses - EURO IV	1.99	0.50	2.66	MD-TRA_RD_HDB-HDEUIV-[PJ]
Busses - EURO V	2.09	0.52	2.78	MD-TRA_RD_HDB-HDEUV-[PJ]
Busses - EURO VI	0.02	0.06	0.14	MD-TRA_RD_HDB-HDEUVI-[PJ]

Table B4. Transport sector - exhaust emissions, Diesel vehicles - off-road and shipping [mg/MJ]

Source	BC	OC	$PM_{2.5}$	Source code [Unit]
Agricultural tractors - uncontrolled	41.28	29.01	100.41	MD-TRA_OT_AGR-NOC-[PJ]
Agricultural tractors - Stage 1 control	23.36	16.42	56.83	MD-TRA_OT_AGR-CAGEUI-[PJ]
Agricultural tractors - Stage 2 control	10.55	7.41	25.66	MD-TRA_OT_AGR-CAGEUII-[PJ]
Agricultural tractors - Stage 3A control	10.55	7.41	25.66	MD-TRA_OT_AGR-CAGEUIII-[PJ]
Agricultural tractors - Stage 3B control	0.74	0.52	6.02	MD-TRA_OT_AGR-CAGEUIV-[PJ]
Agricultural tractors - Stage 4 control	0.70	0.49	6.02	MD-TRA_OT_AGR-CAGEUV-[PJ]
Agricultural tractors - Stage 5 control	0.66	0.46	2.21	MD-TRA_OT_AGR-CAGEUVI-[PJ]
Construction machinery - uncontrolled	46.49	21.13	95.09	MD-TRA_OT_CNS-NOC-[PJ]
Construction machinery - Stage 1 control	26.31	11.96	53.82	MD-TRA_OT_CNS-CAGEUI-[PJ]
Construction machinery - Stage 2 control	11.88	5.40	24.30	MD-TRA_OT_CNS-CAGEUII-[PJ]
Construction machinery - Stage 3A control	11.88	5.40	24.30	MD-TRA_OT_CNS-CAGEUIII-[PJ]
Construction machinery - Stage 3B control	0.84	0.38	5.71	MD-TRA_OT_CNS-CAGEUIV-[PJ]
Construction machinery - Stage 4 control	0.79	0.36	5.71	MD-TRA_OT_CNS-CAGEUV-[PJ]
Construction machinery - Stage 5 control	0.74	0.34	2.09	MD-TRA_OT_CNS-CAGEUVI-[PJ]
Rail - uncontrolled	31.19	17.50	68.46	MD-TRA_OT_RAI-NOC-[PJ]
Rail - Stage 1 control	20.80	11.67	45.66	MD-TRA_OT_RAI-TIWEUI-[PJ]
Rail - Stage 2 control	15.59	8.75	34.23	MD-TRA_OT_RAI-TIWEUII-[PJ]
Rail - Stage 3A control	4.68	2.62	10.27	MD-TRA_OT_RAI-TIWEUIII-[PJ]
Rail - Stage 3B control	0.94	0.52	2.05	MD-TRA_OT_RAI-TIWEUIV-[PJ]
Rail - Stage 4 control	0.92	0.52	4.11	MD-TRA_OT_RAI-TIWEUV-[PJ]
Rail - Stage 5 control	0.06	0.03	1.51	MD-TRA_OT_RAI-TIWEUVI-[PJ]
Other land based machinery - uncontrolled	35.03	24.61	85.20	MD-TRA_OT_LB-NOC-[PJ]
Other land based machinery - Stage 1 control	34.68	12.31	65.52	MD-TRA_OT_LB-HDEUI-[PJ]
Other land based machinery - Stage 2 control	19.92	6.64	35.29	MD-TRA_OT_LB-HDEUII-[PJ]
Other land based machinery - Stage 3A control	16.64	4.39	28.87	MD-TRA_OT_LB-HDEUIII-[PJ]
Other land based machinery - Stage 3B control	3.51	0.77	5.70	MD-TRA_OT_LB-HDEUIV-[PJ]
Other land based machinery - Stage 4 control	3.53	0.78	5.73	MD-TRA_OT_LB-HDEUV-[PJ]
Other land based machinery - Stage 5 control	0.04	0.10	0.29	MD-TRA_OT_LB-HDEUVI-[PJ]
Inland waterways - uncontrolled	30.65	21.54	74.55	MD-TRA_OT_INW-NOC-[PJ]
Inland waterways - Stage 1 control	20.44	14.37	49.73	MD-TRA_OT_INW-TIWEUI-[PJ]
Inland waterways - Stage 2 control	15.32	10.77	37.28	MD-TRA_OT_INW-TIWEUII-[PJ]
Inland waterways - Stage 3A control	4.60	3.23	11.18	MD-TRA_OT_INW-TIWEUIII-[PJ]
Inland waterways - Stage 3B control	0.92	0.65	2.24	MD-TRA_OT_INW-TIWEUIV-[PJ]
Inland waterways - Stage 4 control	0.90	0.64	4.47	MD-TRA_OT_INW-TIWEUV-[PJ]
Inland waterways - Stage 5 control	0.06	0.04	1.64	MD-TRA_OT_INW-TIWEUVI-[PJ]
Coastal shipping large - uncontrolled	7.51	5.28	18.28	MD-TRA_OTS_L-NOC-[PJ]
Coastal shipping large - combustion modification	7.31	3.25	18.28	MD-TRA_OTS_L-STLMCM-[PJ]
Coastal shipping medium - uncontrolled	7.51	5.28	18.28	MD-TRA_OTS_M-NOC-[PJ]
Coastal shipping medium - combustion modification	7.31	3.25	18.28	MD-TRA_OTS_M-STMCM-[PJ]

Table B5. Transport sector - exhaust emissions,Heavy Fuel Oil -shipping [mg/MJ]

Source	BC	OC	$PM_{2.5}$	Source code [Unit]
Coastal shipping large - uncontrolled …………………………………………	48.75	32.50	112.50	HF-TRA_OTS_L-NOC-[PJ]
Coastal shipping large - combustion modification ………………………	37.50	15.00	112.50	HF-TRA_OTS_L-STLHCM-[PJ]

More emission factors for $PM_{2.5}$, BC, OC used in GAINS and in the Norwegian emission inventory of BC and OC; by fuel-sector-technology, as per 28th of March.

Table B6. Domestic sector [mg/MJ]

	BC	OC	$PM_{2.5}$	TSP	Source code [Unit]
Heavy fuel oil-Residential, commercial, services, agriculture, etc.-No control-[10^15 Joules] ………………………………………………	6.8	0.4	9.5	38	HF-DOM-NOC-[PJ]
Liquefied petroleum gas-Residential, commercial, services, agriculture, etc.-No control-[10^15 Joules] ………………………	0.0	0.0	0.3	0.3	LPG-DOM-NOC-[PJ]
Medium distillates (diesel, light fuel oil)-Residential, commercial, services, agriculture, etc.-Good housekeeping: domestic oil boilers-[10^15 Joules] ………….	0.5	0.1	0.5	1.155	MD-DOM-GHDOM-[PJ]
Medium distillates (diesel, light fuel oil)-Residential, commercial, services, agriculture, etc.-No control-[10^15 Joules] ………………………	0.5	0.1	0.7	1.65	MD-DOM-NOC-[PJ]

Table B7. Transport sector - exhaust emissions [mg/MJ]

	BC	OC	$PM_{2.5}$	TSP	Source code [Unit]
Gasoline and other light fractions of oil (includes kerosene)-Other transport: air traffic - civil aviation-No control-[10^15 Joules] ……………….	0.065	0.215	0.356	0.43	GSL-TRA_OT_AIR-NOC-[PJ]
Medium distillates (diesel, light fuel oil)-Other transport: rail -No control-[10^15 Joules] ……….	31.19	17.5	68.46	76.07	MD-TRA_OT_RAI-NOC-[PJ]

Emission factors for $PM_{2.5}$, BC, OC used in GAINS; No fuel use- Industry process emissions, as per 13th of June 2012 (Mail from Kaarle Kupiainen)

Table B8. No fuel use-Ind. Process emission, Fuel-Sector-[Act.unit]

	PM_TSP	$PM_{2.5}$	PM_BC	PM_OC	BC%$PM_{2.5}$	OC%$PM_{2.5}$	Other%$PM_{2.5}$
Aluminum production - secondary-No control-[Mt] ……..	11 900	5 195	1	13	0.0 %	0.3 %	99.6 %
Bricks production-No control-[Mt] ……………………	400	400	150	100	37.5 %	25.0 %	30.0 %
Carbon black production-No control-[Mt] ……………………	1 778	1 440	1 100	0	76.4 %	0.0 %	23.6 %
Cement production-No control-[Mt] ……………………	130 000	23 400	50	220	0.2 %	0.9 %	98.6 %
Coke oven-No control-[Mt] ……………………	4 976	1 997	280	460	14.0 %	23.0 %	56.0 %
Glass production (flat, blown, container glass)-No control-[Mt] ……………………	3 250	2 958	2	20	0.1 %	0.7 %	99.1 %
Lime production-No control-[Mt] ……………………	100 000	1 400	50	350	3.6 %	25.0 %	63.9 %
Pig iron, blast furnace-No control-[Mt] ………………………	1 480	148	18	0	12.2 %	0.0 %	87.8 %
Crude oil & other products - input to Petroleum refineries-No control-[Mt] ……………………	122	96	0,15	0	0.2 %	0.0 %	99.8 %
Agglomeration plant - sinter-No control-[Mt] ……………………	8 563	557	5	26	0.9 %	4.7 %	93.0 %

Emission estimated for Norway using the GAINS-model; June 2012

Table B9. Emission of $PM_{2.5}$ by SNAP sectors [kt]

$PM_{2.5}$	2000	2005	2010	2020	2030
Combustion in energy and transformation industries ...	0.0	0.0	0.1	0.1	0.1
Non-industrial combustion	45.2	35.9	27.9	27.6	27.6
Combustion in manufacturing industry	5.4	1.0	0.9	1.1	1.2
Production processes	7.3	7.2	7.2	7.6	7.8
Extraction and distribution of fossil fuels	0.0	0.0	0.0	0.0	0.0
Solvent and other product use	0.0	0.0	0.0	0.0	0.0
Road transport	2.9	2.6	2.6	1.1	0.8
Non-road transport	3.4	3.6	3.8	2.5	2.2
Waste treatment and disposal	2.2	1.8	1.5	1.5	1.6
Agriculture	0.9	0.9	0.9	1.0	1.0
Sum	**67**	**53**	**45**	**43**	**42**

Table B10. Emission of BC by SNAP sectors [kt]

Black Carbon	2000	2005	2010	2020	2030
Combustion in energy and transformation industries ...	0.0	0.0	0.0	0.0	0.0
Non-industrial combustion	2.3	2.1	1.8	2.0	2.0
Combustion in manufacturing industry	0.2	0.0	0.0	0.0	0.0
Production processes	0.0	0.0	0.0	0.0	0.0
Extraction and distribution of fossil fuels	0.0	0.0	0.0	0.0	0.0
Solvent and other product use	0.0	0.0	0.0	0.0	0.0
Road transport	1.5	1.5	1.6	0.5	0.1
Non-road transport	1.4	1.5	1.6	1.0	0.9
Waste treatment and disposal	1.2	0.9	0.6	0.6	0.6
Agriculture	0.1	0.1	0.1	0.1	0.1
Sum	**7**	**6**	**6**	**4**	**4**

Table B11. Emission of OC by SNAP sectors [kt]

Organic Carbon	2000	2005	2010	2020	2030
Combustion in energy and transformation industries ...	0.0	0.0	0.0	0.0	0.0
Non-industrial combustion	22.4	17.3	13.0	12.5	12.1
Combustion in manufacturing industry	0.4	0.0	0.0	0.0	0.0
Production processes	0.0	0.0	0.0	0.0	0.0
Extraction and distribution of fossil fuels	0.0	0.0	0.0	0.0	0.0
Solvent and other product use	0.0	0.0	0.0	0.0	0.0
Road transport	0.9	0.7	0.6	0.4	0.4
Non-road transport	1.0	1.1	1.1	0.7	0.6
Waste treatment and disposal	0.5	0.4	0.4	0.4	0.4
Agriculture	0.2	0.2	0.2	0.2	0.2
Sum	**25**	**20**	**15**	**14**	**14**

Appendix C Emission factors

In the calculations the numbers are used with the highest available accuracy. In this tables though, they are only shown rounded off, which i some cases can lead to the result that the exceptions looks the same as the general factors.

For road traffic this general view of the emission factors only includes last years factors and not all time series.

Table C1. Emission factors gas. kg particle/tonne and BC/OC shares in per cent

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Natural gas ($1\ 000\ Sm^3$)	Direct-fired furnaces	0.122	0.122	7 % of TSP	75 % of TSP	Kupiainen and Klimont 2004
	Gas turbines	0.122	0.122	7 % of TSP	75 % of TSP	Kupiainen and Klimont 2004
	Boilers	0.122	0.122	7 % of TSP	75 % of TSP	Kupiainen and Klimont 2004
	Flares	0.856	0.856	0,684	0,12	McEwan 2011 for BC, CS for OC
Refinery gas	Direct-fired furnaces	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
	Boilers	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
	Flares	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
Blast furnace gas	Direct-fired furnaces	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
	Boilers	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
Landfill gas	Boilers	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
	Flares	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
Fuel gas	Direct-fired furnaces	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
	Boilers	0.144	0.144	7 % of TSP	75 % of TSP	Same share as natural gas
LPG	Boilers	0.136	0.136	7 % of $PM_{2.5}$	0	Appendix B
	Small stoves	0.136	0.136	7 % of $PM_{2.5}$	0	Appendix B
Biogas	Gas turbines	0.143	0.143	7 % of TSP	75 % of TSP	Kupiainen and Klimont 2004

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C2. Emission factors. kg particle component/tonne and BC/OC shares in percent of $PM_{2.5}$

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Kerosene (heating)	Boilers	0.296	0.037	81 % of $PM_{2.5}$	19 % of $PM_{2.5}$	Appendix B
	Small stoves	0.3	0.123	72 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B
	Small stoves, residencial sector	0.3	0.119	72 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B
Marine gas oil/ diesel	Direct-fired furnaces	1.579	1.5	40 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B
	Gas turbines	0.286	0.036	81 % of $PM_{2.5}$	19 % of $PM_{2.5}$	Appendix B
	Boilers	0.286	0.119	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
	Boilers, used in the industry sectors		0.036	81 % of $PM_{2.5}$	19 % of $PM_{2.5}$	Appendix B
Light fuel oils	Boilers	0.286	0.119	81 % of $PM_{2.5}$	19 % of $PM_{2.5}$	Appendix B
	Boilers, used in the industry sectors		0.036	81 % of $PM_{2.5}$	19 % of $PM_{2.5}$	Appendix B
	Small stoves	0.3	0.119	72 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C3. Emission factors for heavy distillate and heavy fuel oil for all sectores and sources. Factors dependent on sulphur content. kg particle component /tonne fuel and BC/OC shares in per cent of $PM_{2.5}$

Year	Fuel	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
1990 ……..	Heavy distilate	0.803	0.45	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1991 ……..	Heavy distilate	0.714	0.4	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1992 ……..	Heavy distilate	0.701	0.393	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1993 ……..	Heavy distilate	0.701	0.393	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1994 ……..	Heavy distilate	0.688	0.385	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1995 ……..	Heavy distilate	0.714	0.4	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1996-1997	Heavy distilate	0.663	0.371	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1998 ……..	Heavy distilate	0.688	0.385	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1999 ……..	Heavy distilate	0.701	0.393	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
2000-2010	Heavy distilate	0.714	0.4	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	The same shares as for heavy fuel oil
1990 ……..	Heavy fuel oil	1.35	0.761	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1991 ……..	Heavy fuel oil	1.339	0.754	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1992 ……..	Heavy fuel oil	1.316	0.741	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1993 ……..	Heavy fuel oil	1.304	0.735	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1994 ……..	Heavy fuel oil	1.19	0.671	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1995 ……..	Heavy fuel oil	1.053	0.593	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1996-1997	Heavy fuel oil	1.098	0.619	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1998 ……..	Heavy fuel oil	1.087	0.613	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
1999 ……..	Heavy fuel oil	1.11	0.625	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
2000-2010	Heavy fuel oil	1.201	0.677	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C4. Emission factors. kg particle component/tonne and BC/OC shares in per cent of $PM_{2.5}$

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Coal ……………	Direct-fired furnaces, industry	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Direct-fired f urnaces, public electricity and heat production	5.45	1.45	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Boilers, industry	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Boilers, agriculture	4.2	0.86	54 % of $PM_{2.5}$	9 % of $PM_{2.5}$	Appendix B
	Boilers, public electricity and heat production	5.45	1.45	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Small stoves	4.2	0.86	49 % of $PM_{2.5}$	40 % of $PM_{2.5}$	Appendix B
Coke	Direct-fired furnaces	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Boilers	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Small stoves	2.85	0.86	49 % of $PM_{2.5}$	40 % of $PM_{2.5}$	Appendix B
Petrol coke	Direct-fired furnaces	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Boilers	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Appendix B
	Small stoves	3.5	1.05	49 % of $PM_{2.5}$	40 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C5. Emission factors biomass kg particle component/tonne and BC/OC shares in per cent of $PM_{2.5}$

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Fuel wood ……..	Open fireplace	17.3	16.435	9 % of $PM_{2.5}$	48 % of $PM_{2.5}$	Appendix B, Fuelwood, Fireplace - uncontrolled
	.Small stoves, old technology- with nightfiring ……….	22.7	21.565	0.96	16.74	SINTEF 2013
	Small stoves, old technology, without nightfiring	17.4	16.53	1.01	12.89	SINTEF 2013
	Small stoves, new technology - with nightfiring ……….	13.4	12.73	0.86	10.47	SINTEF 2013
	Small stoves, new technology - without nightfiring	12.2	11.59	0.9	9.26	SINTEF 2013
Wood waste	Boilers	2.69	2.52	12 % of $PM_{2.5}$	13 % of $PM_{2.5}$	Appendix B, Fuelwood, Automatic medium size (>200 kW) boiler - uncontrolled
Black liquor	Boilers	0	0			
Wood pellets	Boilers ………….	2.69	2.52	16 % of $PM_{2.5}$	10 % of $PM_{2.5}$	Appendix B, Fuelwood, Manually loaded single house boiler, - replaced with pellet boiler
	Small stoves ……	1.1	1.1	3 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B, Fuelwood, Heating stove - pellet stove
Wood briquettes	Boilers ………….	2.69	2.52	32 % of $PM_{2.5}$	32 % of $PM_{2.5}$	Appendix B, Fuelwood, Manually loaded single house boiler
Charcoal	Small stoves	2.4	2.4	49 % of $PM_{2.5}$	40 % of $PM_{2.5}$	Appendix B, Hard coal, Heating stove - uncontrolled

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012 and Seljeskog, Goile et al. 2013

Table C6. Time series for variable emission factors1 for BC and OC from burning of wood in residensial sector. kg particle component /tonne wood

	1990	1996	1997	1998	1999	2000	2001	2002	2003
BC …………	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
OC ………..	16.22	16.22	16.23	16.23	16.24	16.23	16.24	16.24	16.22

	2004	2005	2006	2007	2008	2009	2010	2011
BC ………..	0.98	0.95	0.94	0.95	0.95	0.94	0.94	0.94
OC ………	16.10	14.05	13.86	13.73	13.54	13.39	13.23	13.15

Table C7. General emission factors waste kg /tonne and BC/OC shares in per cent

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Municipal waste …………	Boilers	0.05	0.05	0.9 % of TSP	0.15 % of TSP	Kupiainen and Klimont 2004
Special waste …………	Direct-fired furnaces	5.68	3.2	72 % av $PM_{2.5}$	4 % of $PM_{2.5}$	Appendix B, Heavy fuel oil-Residential, commercial, services, agriculture, etc.-No control
	Direct-fired furnaces - industry sector	4.06	1.4	72 % av $PM_{2.5}$	4 % of $PM_{2.5}$	Appendix B, Heavy fuel oil-Residential, commercial, services, agriculture, etc.-No control
	Boilers	5.68	3.2	72 % av $PM_{2.5}$	4 % of $PM_{2.5}$	Kupiainen and Klimont 2004
	Boilers, industry sector	4.06	1.4	72 % av $PM_{2.5}$	4 % of $PM_{2.5}$	Appendix B, Heavy fuel oil-Residential, commercial, services, agriculture, etc.-No control

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C8. Emission factors for aviation kg/tonnes and BC/OC shares in per cent of $PM_{2.5}$ for aviation

Fuel	Source	TSP	$PM_{2,5}$	BC	OC	Source for BC and OC
Jet kerosene …….	Jet/turboprop 0-100 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	…Jet/turboprop 100-1000 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	Jet/turboprop cruise	0.007	0.007	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
Jet kerosene …….	Helicopter 0-100 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	Helikopter 100-1000 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	Helicopter cruise	0.007	0.007	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
Aviation gasoline ……..	Small aircrafts 0-100 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	Small aircrafts 100-1000 m	0.025	0.025	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B
	Small aircrafts cruise	0.007	0.007	18 % of $PM_{2.5}$	60 % of $PM_{2.5}$	Appendix B

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C9. Emission factors for road traffic kg/tonnes

Source	Fuel	TSP kg/tonne	$PM_{2.5}$ kg/tonnes	BC kg/tonne	OC kg/tonne
	Motor gasoline	**0.053**	**0.053**	**0.012**	**0.034**
	Auto diesel	**0.455**	**0.455**	**0.325**	**0.113**
Passenger car ..	LPG	**0.075**	**0.075**	**0.023**	**0.034**
Other light duty	Motor gasoline	**0.100**	**0.100**	**0.022**	**0.064**
cars …………….	Auto diesel	**0.919**	**0.919**	**0.644**	**0.241**
	Auto diesel	**0.319**	**0.319**	**0.202**	**0.088**
Heavy duty	Natural gas	**0.000**	**0.000**	**0.000**	**0.000**
vehicles ………..	Biogas	**0.103**	**0.103**	**0.049**	**0.034**
Moped ………….	Motor gasoline	0	0	NE	NE
Motorcycle …….	Motor gasoline	0	0	NE	NE

Bold numbers are different for different years, but only the 2011 data are shown in this table
Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C10. General emission factors for other mobile sources and BC/OC shares in per cent of $PM_{2.5}$

Source	Fuel	TSP kg/tonne	$PM_{2.5}$ kg/tonnes	BC	OC	Source for BC and OC
Railway	Auto diesel	3.8	3.8	46 % of $PM_{2.5}$	26 % of $PM_{2.5}$	Appendix B
	Coal	1.6	0.82	2 % of $PM_{2.5}$	1 % of $PM_{2.5}$	Same share as direct-fired furnaces, coal, table C4.
Small boats 2 stroke	Motor gasoline	8	8	6 % of $PM_{2.5}$	82 % of $PM_{2.5}$	Same share as other Motorized equipment 2 stroke, motor gasoline
Small boats 4 stroke	Motor gasoline	1	1	18 of $PM_{2.5}$	60 of $PM_{2.5}$	Appendix B
	Auto diesel	4	4	41 of $PM_{2.5}$	29 of $PM_{2.5}$	Appendix B
Motorized equipment 2 stroke	Motor gasoline	8	8	6 % of $PM_{2.5}$	82 % of $PM_{2.5}$	Appendix B
	Auto diesel	8	8	41 of $PM_{2.5}$	29 of $PM_{2.5}$	Appendix B
	Motor gasoline	1	1	18 of $PM_{2.5}$	60 of $PM_{2.5}$	Appendix B
Motorized equipment 4t	Auto diesel	4	3.8	41 of $PM_{2.5}$	29 of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, light fuel oil
	Light fuel oils	7.1	6.75	41 of $PM_{2.5}$	29 of $PM_{2.5}$	Appendix B

BC and OC emissions from snow scooter are not estimated (NE).
Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C11. Exceptions from the general factors for other pollutants for motorized equipment 4 stroke

Fuel	Sectors	TSP kg/ tonne	$PM_{2.5}$ kg/ tonnes	BC	OC	Source for BC and OC
Auto diesel	Agriculture and forestry	7.1	6.75	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, auto diesel
Auto diesel, light fuel oils	Mining and quarrying	3.8	3.61	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, auto diesel
Auto diesel, light fuel oils	Other non-metallic mineral products	4.2	3.99	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, auto diesel
Auto diesel, light fuel oils	Construction	5.3	5.04	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, auto diesel
Auto diesel, light fuel oils	Public administration and defence	5.4	5.13	41 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Motorized equipment 4 stroke, auto diesel

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Table C12. General emission factors for navigation

	TSP kg/tonnes	$PM_{2.5}$ kg/tonnes	BC	OC	Source for BC and OC
Marine gas oil/diesel .	1.6	1.5	40 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Appendix B
Light fuel oils	1.6	1.5	40 % of $PM_{2.5}$	18 % of $PM_{2.5}$	Same share as other Marine gas oil/diesel
Heavy distillate	5.4	5.1	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Appendix B
Heavy fuel oil	5.4	5.1	43 % of $PM_{2.5}$	29 % of $PM_{2.5}$	Same share as other Heavy distilate
Natural gas (1 000 Sm^3)	0.032	0.032	50 % of $PM_{2.5}$	36 % of $PM_{2.5}$	See chapter 3.2.3

Source for emission factors TSP and $PM_{2.5}$: Sandmo, Bjønness et al. 2012

Appendix D Source classifications used in the Norwegian emission inventory

Table D1. Source classifications used in the national emission inventory

Stationary combustion		
Oil and gas extraction		
	Natural gas	
	Flaring	
	Diesel combustion	
	Gas terminals	
Manufacturing and mining		
	Refining	
	Manufacture of pulp and paper	
	Manufacture of mineral products	
	Manufacture of chemicals	
	Manufacture of metals	
	Other manufacturing	
Other industries		
Dwellings		
Incineration of waste and landfill gas		
Process emissions		
Oil and gas extraction		
	Venting, leaks, etc.	
	Oil loading at sea	
	Oil loading, on shore	
	Gas terminals	
Manufacturing and mining		
	Refining	
	Manufacture of pulp and paper	
	Manufacture of chemicals	
	Manufacture of mineral products	
	Manufacture of metals	
		Iron, steel and ferroalloys
		Aluminium
		Other metals
	Other manufacturing	
Petrol distribution		
Agriculture		
Landfill gas		
Solvents		
Road dust		
Other process emissions		
Mobile combustion		
Road traffic		
	Petrol engines	
		Passenger cars
		Other light vehicles
		Heavy vehicles
	Diesel engines	
		Passenger cars
		Other light vehicles
		Heavy vehicles
	Motorcycles, mopeds	
		Motorcycles
		Mopeds
Snow scooters		
Small boats		
Motorized equipment		
Railways		
Air traffic		
	Domestic < 1000 m	
	Domestic > 1000 m	
Shipping		
	Coastal traffic, etc.	
	Fishing vessels	
	Mobile oil rigs, etc.	

Table D2. UNFCCC/CRF[1] and EMEP/NFR source sector categories

CRF		NFR	
1A1a	Public Electricity and Heat Production	1A1a	Public electricity and heat production
1A1b	Petroleum refining	1A1b	Petroleum refining
1A1c	Manufacture of Solid Fuels and Other Energy Industries	1A1c	Manufacture of solid fuels and other energy industries
1A2a	Iron and Steel	1A2a	Iron and steel
1A2b	Non-Ferrous Metals	1A2b	Non-ferrous Metals
1A2c	Chemicals	1A2c	Chemicals
1A2d	Pulp, Paper and Print	1A2d	Pulp, paper and print
1A2e	Food Processing, Beverages and Tobacco	1A2e	Food processing, beverages and tobacco
1A2f	Other (oil drilling, construction, all other manufacturing industries)	1A2fi	Stationary combustion in manufacturing industries and construction: Other
1A3e	Other transportation/ Off-road vehicles and other machinery	1A2fii	Mobile Combustion in Manufacturing Industries and Construction
1C1a	International bunkers/ Aviation (1)	1A3ai(i)	International aviation (LTO)
		1A3ai(ii)	International aviation (Cruise) (1)
1A3a	Civil aviation (Domestic)	1A3aii(i)	Civil aviation (Domestic, LTO)
		1A3aii(ii)	Civil aviation (Domestic, Cruise) (1)
1A3b	Road transportation	1A3bi	Road transport: Passenger cars
		1A3bii	Road transport: Light duty vehicles
		1A3biii	Road transport: Heavy duty vehicles
		1A3biv	Road transport: Mopeds & motorcycles
		1A3bv	Road transport: Gasoline evaporation
		1A3bvi	Road transport: Automobile tyre and brake wear
		1A3bvii	Road transport: Automobile road abrasion
1A3c	Railways	1A3c	Railways
1C1b	International bunkers/ Marine (1)	1A3di(i)	International maritime navigation (1)
1A3d	Navigation	1A3dii	National navigation (Shipping)
1A3e	Other transportation/ Other non-specified	1A3e	Pipeline compressors
1A4a	Commercial/Institutional	1A4ai	Commercial / institutional: Stationary
1A3e	Other transportation/ Off-road vehicles and other machinery	1A4aii	Commercial / institutional: Mobile
1A4b	Residential	1A4bi	Residential: Stationary plants
1A3e	Other transportation/ Off-road vehicles and other machinery	1A4bii	Residential: Household and gardening (mobile)
1A4c	Agriculture/Forestry/Fishing	1A4ci	Agriculture/Forestry/Fishing: Stationary
		1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
		1A4ciii	Agriculture/Forestry/Fishing: National fishing
1A5a	Other stationary (including military)	1A5a	Other stationary (including military)
1A5b	Other, Mobile (including military)	1A5b	Other, Mobile (including military, land based and recreational boats)
1B1a	Fugitive emissions from fuels/ Coal mining and handling	1B1a	Fugitive emission from solid fuels: Coal mining and handling
1B1b	Fugitive emissions from fuels/ Solid Fuel Transformation	1B1b	Fugitive emission from solid fuels: Solid fuel transformation
1B2aiii	Fugitive Emissions from Fuels/ Oil/ Transport	1B2aiii	Transport
1B2aiv	Fugitive Emissions from Fuels/ Oil/ Refining / storage	1B2aiv	Refining / storage
1B2av	Fugitive Emissions from Fuels/ Oil/ Distribution of oil products	1B2av	Distribution of oil products
1B2b	Fugitive Emissions from Fuels/ Natural gas	1B2b	Natural gas
1B2c	Fugitive Emissions from Fuels/ Oil and natural gas/ Venting and Flaring	1B2c	Venting and flaring
2A1	Cement Production	2A1	Cement production
2A2	Lime Production	2A2	Lime production
2A3	Limestone and Dolomite Use	2A3	Limestone and dolomite use
		2A7a	Quarrying and mining of minerals other than coal
		2A7b	Construction and demolition
		2A7d	Other Mineral products
2A7→	Leca Production		
2A7→	Ore		
2B1	Ammonia Production	2B1	Ammonia production
2B2	Nitric Acid Production	2B2	Nitric acid production
2B4.1	Silicon Carbide	2B4	Carbide production
2B4.2	Calcium Carbide		
2B5.5	Methanol	2B5a	Other chemical industry
2B5→	Plastic		
2B5→	Production of Explosives		
2B5→	Sulphuric acid production		
2B5→	Titanium Dioxide Production		
2C1	Iron and Steel Production	2C1	Iron and steel production
2C2	Ferroalloys Production	2C2	Ferroalloys production
2C3	Aluminium Production	2C3	Aluminum production
2C4	Aluminium and Magnesium Foundries		
2C5	Metal Production/ Other	2C5e	Other metal production
2D1	Pulp and Paper	2D1	Pulp and paper
2D2	Food and Drink	2D2	Food and drink

2F	Consumption of Halocarbons and SF6		
2G	Industrial processes/ Other (Paraffin wax)	2G	Other production, consumption, storage, transportation or handling of bulk products
3A	Paint Application	3A1	Decorative coating application
		3A2	Industrial coating application
		3A3	Other coating application
3B	Degreasing and Dry Cleaning	3B1	Degreasing
		3B2	Dry cleaning
3C	Chemical Products, Manufacture and Processing	3C	Chemical products
3D	Solvent and other product use/ Other	3D1	Printing
		3D2	Domestic solvent use including fungicides
		3D3	Other product use
4A1	Enteric fermentation/ Cattle/ Mature Dairy Cattle Mature Non-Dairy Cattle Young Cattle		
4A3	Enteric fermentation/ Sheep		
4A4	Enteric fermentation/ Goats		
4A6	Enteric fermentation/ Horses		
4A8	Enteric fermentation/ Swine		
4A9	Enteric fermentation/ Poultry		
4A10	Enteric fermentation/ Other		
4B1a	Manure management/ Cattle/ Mature Dairy Cattle Mature Non-Dairy Cattle Young Cattle	4B1a	Cattle dairy
4B3	Manure management/ Sheep	4B3	Sheep
4B4	Manure management/ Goats		
4B6	Manure management/ Horses		included in 4B13
4B8	Manure management/ Swine	4B8	Swine
4B9	Manure management/ Poultry	4B9b	Broilers
4B10	Manure managemen/ Other		included in 4B13
4B12	Manure managemen/ Liquid Systems		
4B13	Manure management/ Solid Storage and Dry Lot	4B13	Other
4D1	Agricultural soils/ Direct soil emission	4D1a	Synthetic N-fertilisers
4D2	Agricultural soils/ Pasture, Range and Paddock Manure	4D2c	N-excretion on pasture range and paddock unspecified
4D3	Agricultural soils/ Indirect emissions		
4D4	Agricultural soils/ Other		
4F1	Field burning of agricultural wastes/ Cereals	4F	Field burning of agricultural wastes
		4G	Agriculture other
5	Land Use, Land Use Change and Forestry (2)		
6A1	Managed waste disposal on land	6A	Solid waste disposal on land
6B1	Industrial Wastewater	6B	Waste-water handling
6B2	Domestic and Commercial Waste Water		
6Cb→	Waste Incineration/ Incineration of hospital wastes	6Ca	Clinical wasteincineration
6Ca	Waste Incineration/ Biogenic	6Cc	Municipal waste incineration
6Cb→	Waste Incineration/ Incineration of corpses	6Cd	Cremation
6D	Waste/ Other	6D	Other waste(e)

(1) Memo items

(2) Land Use, Land Use Change and Forestry is calculated and documented by *Skog og landskap*

[1] Reporting in the CRF is more detailed for some source categories than shown in the table. In particular, emissions from energy use in 1A are reported by fuel.

Appendix E: Extended summary in Norwegian/ Sammendrag

Blant de viktigste miljøutfordringene i dag er å begrense menneskeskapte klimaendringer og å forbedre luftkvaliteten. Svevestøvets effekt på klimaendringer får stadig økende oppmerksomhet, dette skyldes oppvarming i Arktiske områder hvor det har stor betydning når det faller ned på snø og deretter fører til raskere smelting av is. Svevestøvet kan deles opp etter partikkelstørrelse. Fram til nå har utslippsstatistikken gitt tall for de tre partikkelfraksjonene: TSP ("totale utslipp av svevestøv") PM_{10} og $PM_{2,5}$, hvor PM_{10} og $PM_{2,5}$ er svevestøv med diameter henholdsvis mindre enn 10 og 2,5 µm

Denne rapporten viser hvordan man kan dele opp $PM_{2,5}$-utslippene i flere fraksjoner. $PM_{2.5}$-utslippene, kan deles inn i svart karbon (black carbon eller BC), organisk karbon (OC) og andre uorganiske forbindelser. Økt fokus på svart karbon og organisk karbon nasjonalt og internasjonalt har avdekket et behov for å vite hva som er de viktigste utslippskildene og hvor store utslippene er. Rapporten dokumenterer metoden som brukes for å beregne utslippet av svart karbon (BC) og organisk karbon (OC), kapittel 3. Kapittel 4 - 8 viser hvordan de ulike kildene av svart karbon og organisk karbon er beregnet. Kapittel 9 viser beregnet utslipp av BC og OC for perioden 1990-2011. Rapporten ser på de fleste kjente menneskeskapte utslipp av BC og OC.

Svart karbon regnes som en kortlevet klimadriver, dette er komponenter som bidrar til oppvarming og har relativt kort levetid i atmosfæren, fra noen få dager til 15 år. Svart karbon påvirker klimaet på mange måter, både direkte og indirekte. De mørke partiklene absorberer innkommende stråling fra solen, de kan fremme dannelsen av skyer som kan ha både avkjølende og oppvarmende effekt. Svart karbon som faller på overflaten av snø og is fremmer oppvarming og øker smelting av is. Nyere forskning antyder at svart karbon (BC) sannsynligvis er den nest viktigste bidragsyteren til global oppvarming, etter karbondioksid (CO_2) (UNEP. 2009).

BC dannes ved ufullstendig forbrenning av karbonholdige energivarer. Dette kan være menneskelig aktivitet som forbrenning av fossile brensler brukt til oppvarming, transport og i industrien. I tillegg dannes det noe utslipp av BC og OC ved enkelte industriprosesser og slitasje av vei, dekk og bremser. BC og OC kan også komme fra naturlige prosesser som skogbranner. I regnskapet har vi bare tatt med antropogene kilder.

De viktigste klidene for utslipp av svart karbon og organisk karbon er
- Oppvarming i husholdninger – vedfyring
- Bruk av dieselmotorer i veitrafikk og anleggsmaskiner
- Bruk av marin diesel i skip. Sjøfart og fiske
- Utslipp fra olje og gassutvinning, inklusiv fakling

Metode

Den nasjonale utslippsmodellen, er et omfattende system hvor beregningene av utslipp dels er basert på statistikk fra SSB eller andre og dels basert på utslippsmålinger/-beregninger fra Klima- og forurensningsdirektoratet (Klif).

Utslipp beregnes etter følgende formel:

Utslipp = aktivitet (A)* utslippsfaktor (EF)
Utslippsfaktoren er knyttet til av en bestemt kombinasjon av komponent, vare (bensin, kull osv) og kilde (kjel, ovn, brann, type motorredskap, skip)

Noen utslipp rapporteres direkte til Klif. Rapporterte tall erstatter da beregninger basert på energiforbruk og utslippsfaktor. For å unngå dobbelttelling blir det ikke beregnet utslipp basert på energiforbruk for disse bedriftene. Når utslippet beregnes blir aktivitetstall for disse punktkildene trukket ut, mens det rapporterte utslippet Eps inngår i utslippsregnskapet

$$Utslipp = [\ (A - Aps) \cdot EF] + Eps$$

I utslippsregnskap for svart og organisk karbon er det tatt utgangspunkt i dagens $PM_{2.5}$-regnskap. For alle kilder hvor det beregnes en verdi for $PM_{2.5}$ skal det vurderes om det også dannes BC og OC.

For kildene vedfyring i lukket ovn i husholdningene (Seljeskog, Goile et al. 2013) og for fakling av natur gass (McEwen and Johnson 2011) er det brukt egne utslippsfaktorer for svart og organisk karbon, uavhengig av $PM_{2.5}$-faktoren.

IIASA (International Institute for Applied Systems Analysis) har laget utslippsregnskap for svart karbon for de fleste land slik at det skal være mulig å gjøre sammenlikninger mellom landene. IIASA bruker utslippsfaktorer for ulike kombinasjoner av kilde og energivare, det gjøres tilpasninger til ulike land dersom land-spesifikk informasjon er tilgjengelig. SSB har tatt utgangspunkt i de beregningene IIASA har gjort for Norge og kombinert dette med det norske $PM_{2.5}$ regnskapet og de norske utslippsfaktorene for $PM_{2.5}$. Dette er gjort for å få et konsistent regnskap hvor ikke utslippet av svart karbon overstiger utslippet av $PM_{2.5}$.

SSB har valgt å bruke forholdet mellom utslippsfaktorene for BC/OC og $PM_{2.5}$ fra IIASA og multiplisere dette med de norske $PM_{2.5}$-faktorene. Der hvor det er brukt rapporterte utslipp av svevestøv er beregningene gjort på samme måte. Utslippet av svart og organisk karbon er da beregnet ved å multiplisere rapportert $PM_{2.5}$-utslipp med forholdet mellom BC/OC og $PM_{2.5}$ fra IIASA. For kilder hvor SSB ikke har funnet informasjon om forholdet mellom $PM_{2.5}$, BC og OC er det tatt utgangspunkt i at $PM_{2.5}$ består av svart karbon, organisk materiale og uorganiske komponenter.

$PM_{2.5}$ = BC + OM + uorganiske komponenter

Det er antatt at mengden uorganiske komponenter er 0 og at mengden svart karbon og organisk materiale er like store.

Resultater
http://www.ssb.no/natur-og-miljo/artikler-og-publikasjoner/utslipp-av-svart-og-organisk-karbon-til-luft

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Returadresse:
Statistisk sentralbyrå
NO-2225 Kongsvinger

Statistisk sentralbyrå

13/2013

Emission of black and organic carbon to air

Design: Siri Boquist

Avsender:
Statistisk sentralbyrå

Postadresse:
Postboks 8131 Dep
NO-0033 Oslo

Besøksadresse:
Kongens gate 6, Oslo
Oterveien 23, Kongsvinger

E-post: ssb@ssb.no
Internett: www.ssb.no
Telefon: 62 88 50 00

ISBN 978-82-537-8637-7 (trykt)
ISBN 978-82-537-8638-4 (elektronisk)
ISSN 1891-5906

ISBN 978-82-537-8637-7

9 788253 786377

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Statistics Norway