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Climate influencing emissions, scenarios and mitigation options at Svalbard

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Preface

Arctic surface air temperatures have increased at almost twice the global average rate over the past century (AMAP, 2008; IPCC, 2007). The temperature increase is accompanied by changes in the seasonal patterns as earlier and longer melting seasons, increasing melt along the rim of the Greenland ice sheet, and large reductions in summer sea ice in the central Arctic Ocean (ACIA, 2005; IPCC, 2007). These changes in the Arctic are strongly interlinked with climate change on the global level.

Norway has national interest in the Arctic, and acknowledges the need for science based evaluation of potential effects of climate change in this region. In this context, the Norwegian Ministry of the Environment (MD) commissioned the Norwegian Pollution Control Authority (SFT) to conduct a study on mitigation opportunities with regard to emission sources and scenario assessments associated with climate forcing at Svalbard. The work has been undertaken together with the University Centre in Svalbard (UNIS) and the Norwegian Institute for Air Research (NILU).

This report documents an evaluation of past, present and future climate influencing emissions from Svalbard. In addition, mitigation options are given both at the short- (2012) and at the long- (2025) term.

The sun arrives in Longyearbyen, Svalbard. Photo: Roland Kallenborn.

Authors:

- *Vigdis Vestreng*; Climate and Pollution Agency (Klif)
- *Roland Kallenborn*; University Centre in Svalbard (UNIS) and Norwegian Institute for Air Research (NILU)
- *Elin Økstad*; Climate and Pollution Agency (Klif)

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Abbreviations and units

ACIA	Arctic Climate Impact Assessment
AMAP	Arctic Monitoring and Assessment Programme
BC	Black carbon
CO_2	Carbon dioxide
CH_4	Methane
EC	Elemental carbon also black carbon or soot
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
Klif	Climate and Pollution Agency (Klima- og forurensningsdirektoratet)
LNS	Leonhard Nilsen og Sønner AS
LYR	Longyearbyen
MD	Miljøverndepartmentet (Norwegian Ministry of the Environment)
MGO	Marine gas oil
n.a.	Not analysed
NIBR	Norsk institutt for by- og regionsforskning (Norwegian Institute for urban- and regional research)
NILU	Norsk institutt for luftforskning (Norwegian Institute for Air Research)
NO_X	Nitrogen oxides ($NO+NO_2$)
NPRA	Vegdirektoratet (National Public Road Authorities)
NP	Norsk Polarinstitutt (The Norwegian Polar Institute)
NorACIA	Norwegian Arctic climate Impact Assessment: National follow-up of ACIA
OC	Organic carbon
ppb_v	Parts per billion by volume
ppm_v	Parts per million by volume
SFT	Statens forurensningstilsyn (Norwegian Pollution Control Authority)
SINTEF	Selskapet for industriell og teknisk forskning (Norwegian Industrial and Technological Research institute)
SSB	Statistisk sentralbyrå (Statistics Norway)
SO_2	Sulphur dioxide
UNFCCC	United Nations Framework Convention on Climate Change
UNIS	University Centre in Svalbard

Executive summary

The goal of this study was to establish an emission inventory and emission scenarios for climate influencing compounds at Svalbard, as a basis to develop strategies for emission reduction measures and policies.

Emissions for the years 2000-2007 have been estimated for the Svalbard Zone. This area, covering about 173 000 km^2, ranges from 10 °E to 35 °E longitude and 74 °N to 81 °N latitude (Figure 1). In addition, air and ship transport between Tromsø at the Norwegian mainland and Svalbard has been included.

Pollutants considered in our inventory are carbon dioxide (CO_2), methane (CH_4), Sulphur dioxide (SO_2), Nitrogen oxides (NO_x as NO_2), and for the first time also estimates of black carbon (BC, soot) and organic carbon (OC) have been included. Our results show that emissions of all pollutants have increased over the time span 2000-2007 (Figure 2), and are expected to increase also in the future if additional measures are not implemented (Figure 12). The emissions from Svalbard are miniscule compared to emission released from the Norwegian mainland and waters (1% in the case of CO_2). Even so, local releases of climate influencing compounds in the vulnerable Arctic may turn out to make a difference both with respect to adverse environmental effects and to climate change.

Emissions have been estimated for all activities of any significance taking place at and around Svalbard. Combustion sources as well as fugitive emissions of methane are included. The main sectors are coal mining, energy production and transportation. Pollution from 28 sub sectors related to these activities has been estimated. The scope of this work differs from that covered by national inventories since emission estimates are based on the fuel consumed and include emissions from international shipping and aviation. Fuel consumption data were collected from local authorities, institutions and industry. Emission factors have been selected from relevant literature.

Marine transportation contributes substantially (90%) to emissions of particulate matter (BC, OC) and NO_x in 2007, and is the second largest source of CO_2 (40%). Energy production is the largest source of CO_2 (50%) and SO_2 (90%), while nearly all methane is released in relation to coal mining. The high contribution of climate influencing emissions from cruise traffic is one of the main findings in this study. 20% of the total CO_2 emissions in 2007 and 40% of NO_x and particulate matter originates from cruise ships.

Local emissions of BC contributes significantly (20%) to the total deposition at Svalbard. Black carbon is important for global warming both as a compound that heats the atmosphere, and as a contributor to accelerated melting when deposited on snow and ice. Preventing snow and ice melting at Svalbard and in the rest of the Arctic region is a key factor to ensure a sustainable future.

A qualitative uncertainty analysis has been performed. The results indicate that the data quality is best for recent years. A key uncertainty is related to the lack of reliable measurements and consumption figures from the coal fired power plant in Barentsburg. Measurements of emissions related to marine transport and the diesel based power production in Svea would also be beneficial to raise the confidence in emission estimates further.

To increase the understanding of important drivers for the growth of climate related compounds, emission scenarios for both the short- (2012) and the long-term (2025) were developed. Different growth rates were defined by the historical development of activities as well as from published studies on the future society development at Svalbard.

According to our results, a steep increase in emissions of climate related compounds both in the short- and in the long-term can be expected for the coming years if steps are not taken in order to reduce the emissions.

Emissions of climate influencing pollutants will continue to grow by about 30% towards 2012 even if the current plans to reduce the Norwegian coal production to half the 2007 level are realized. The emission increase is caused by the assumed growth in activities related mainly to tourism and research. In the long-term, it is shown how developments particularly in the mining and tourist activities may change emissions between 2012 and 2025. While exhaustion coal reserves and thereby abandonment of Norwegian mining activities at Svalbard will bring CO_2 emissions down below 2007 levels, a potential doubling of the tourist related activities will cause emissions to increase significantly (25%).

Some measures and mitigation options are discussed. Local electric power production and marine transport activities (tourist cruises and coal shipping) have been identified as predominant emission sources. Thus, for regulation purposes aiming at short-term effects, these major emission sources should be targeted.

Short-term mitigation options:

- Improve and renew technology and install appropriate filters at the power plants
- Initiate energy saving measures
- Introduce cleaner fuel types and exhaust filtration for marine vessels

Long-term mitigation options:

- Centralize coal based electric power production and implement carbon capture and filter technologies
- Develop and implement local applicable technologies utilizing renewable (solar and tidal) and carbon neutral energy

The emission estimates and scenarios developed in this study are of sufficient quality and detail to provide a basis for future mitigation strategies. Such strategies can take advantage of our holistic approach and take into account possible co-benefits and trade-offs between pollutants when specific measures to reduce the total climate and environmental effects are further evaluated. In order to evaluate environmental and climatic effects of the emissions from Svalbard, dispersion modeling could be performed.

Sammendrag

Hensikten med denne rapporten var å utarbeide et utslippsregnskap og utslippsscenarier for Svalbard av stoffer som påvirker klimaet, og således frambringe et grunnlag for utarbeidelse av strategier for utslippsreduserende tiltak og politikkutforming.

Utslipp for årene 2000-2007 er estimert for Svalbardsonen. Dette området som dekker rundt 173 000 km^2, ligger mellom 10 °Ø og 35 °Ø lengdegrad og 74 °N og 81 °N breddegrad (Figur 1). I tillegg er fly- og skipstransport mellom Tromsø på det norske fastland og Svalbard inkludert.

Forurensning som er tatt i betraktning i utslippsregnskapet vårt er karbondioksid (CO_2), metan (CH_4), svoveldioksid (SO_2), nitrogenoksider (NO_x uttrykt som NO_2), og for første gang har også estimater av sot (BC) og organisk karbon (OC) blitt inkludert. Våre resultater viser at utslipp av alle forurensningskomponentene har økt i tidsrommet 2000-2007 (Figur 2), og de er forventet å øke også i framtiden dersom det ikke gjøres ytterligere tiltak (Figur 12). Utslippene fra Svalbard er svært små sammenlignet med utslippene fra det norske fastland og havområder (1% for CO_2). Allikevel kan lokale utslipp av stoffer som påvirker klimaet i det sårbare Arktis vise seg å utgjøre en forskjell både med hensyn til skadelige miljøeffekter og klimaendringer.

Utslipp fra alle aktiviteter av betydning som finner sted på og rundt Svalbard er blitt estimert. I tillegg til utslipp fra forbrenning, er flyktige utslipp av metan inkludert. Hovedsektorene er kullgruvedrift, energiproduksjon og transport. Forurensning fra 28 undersektorer relatert til disse aktivitetene er beregnet. Omfanget av arbeidet avviker fra det som er dekket av det nasjonale utslippsregnskapet fordi utslippsestimatene er basert på forbruk av energivarer og inkluderer utslipp fra internasjonal sjøfart og luftfart. Forbruksdata ble innhentet fra lokale myndigheter, institusjoner og industri. Utslippsfaktorer ble valgt ut fra relevant litteratur.

Marin transport bidrar betydelig (90%) til utslipp av partikler (BC, OC) og NO_x i 2007, og er den nest største kilden til CO_2-utslipp (40%). Energiproduksjon er den største kilden til CO_2-utslipp (50%) og SO_2 (90%), mens nesten all metan slippes ut i forbindelse med kullutvinningen. Det høye bidraget av klimarelaterte utslipp fra cruistrafikken i området er et av hovedfunnene i denne studien. 20% av de totale CO_2 utslippene i 2007 og 40% av NO_x og partikkel utslippet stammer fra cruiseskip.

Lokale utslipp bidrar betydelig (20%) til den totale avsetningen av sot på Svalbard. Sot er en viktig parameter når det gjelder global oppvarming både fordi sot bidrar til oppvarming av atmosfæren og fordi det bidrar til å akselerere smeltingen når det avsettes på snø og is. Å forhindre snø- og issmelting på Svalbard og i resten av Arktis er en nøkkelfaktor for å sikre en bærekraftig fremtid.

En kvalitativ usikkerhetsanalyse er blitt utarbeidet. Resultatene indikerer at datakvaliteten er best for de senere år. Størst usikkerhet er knyttet til mangelen på pålitelige målinger og forbruksdata fra det kullfyrte kraftverket i Barentsburg. Målinger av utslipp relatert til skipstrafikk samt til den dieselbaserte kraftproduksjonen i Svea vil også kunne heve kvaliteten på utslippsestimatene ytterligere.

Utslippsscenarier både for kort (2012) og lang (2025) sikt ble utviklet for å anskueliggjøre hvordan de klimarelaterte utslipp kan endre seg framover. Ulike vekstrater ble definert basert

på den historiske utviklingen i aktivitetsnivåene samt fra publiserte studier og rapporter som omhandler den fremtidige samfunnsutviklingen på Svalbard.

I følge våre resultater, må vi forvente at utslippene av klimarelaterte stoffer øker kraftig både på kort og lang sikt dersom det ikke foretas grep for å redusere utslippene.

Utslipp av klimarelatert forurensning vil fortsette å øke med rundt 30% mot 2012 selv om de nåværende planene for halvering av den norske kullproduksjonen fra 2007 nivå realiseres. Utslippene øker på grunn av den antatte veksten i aktiviteter relatert til turisme og forskning. Rapporten viser også hvordan utviklingen spesielt innen gruvedrift og turisme, kan komme til å endre utslippene mellom 2012 og 2025. Mens uttømming av kullreservene og derigjennom nedleggelse av all norsk gruveaktivitet på Svalbard vil bringe utslippene av CO_2 ned under 2007 nivå, så vil en potensiell fordobling av turistrelaterte aktiviteter medføre en betydelig (25%) utslippsøkning.

Mulige utslippsreduserende tiltak er omtalt. Elektrisk kraftproduksjon lokalt og marin transport (turistcruise og kulltransport) er definert som betydelige utslippskilder. Tiltak som kan redusere effekten av utslippene på kort sikt bør derfor fokusere på disse store utslippskildene.

Mulige kortsiktige tiltak:

- Forbedre og fornye teknologi og installere egnede filtre ved kraftverkene
- Initiere energisparingstiltak
- Introdusere renere drivstoff og eksosfiltre for skip

Mulige langsiktige tiltak:

- Sentralisere den kullbaserte elektriske kraftproduksjonen, iverksette karbonfangst og ta i bruk egnede filterteknologier
- Utvikle og iverksette bruk av lokalt tilpasset teknologi som benytter fornybar energi (sol og tidevann) og karbonnøytral energi

Utslippsestimatene og scenariene utviklet i dette studiet er av tilstrekkelig kvalitet og detaljerte nok til å danne grunnlaget for fremtidige utslippsreduserende strategier. Disse strategiene kan dra nytte av vår helhetlige tilnærming ved å vurdere hvordan utslippsreduserende tiltak vil påvirke den samlede miljø- og klimabelastningen. Det kan gjøres spredningsmodellering for å vurdere nærmere miljø- og klimaeffekter av utslippene på Svalbard.

1. Introduction and background

1.1 Climate gas emissions in the arctic region

Climate related environmental change is considered today as one of the most prominent global threats for the environment and human populations. In order to prevent the global average ambient air temperature to increase more than 2 ºC compared to pre-industrial times, the concentration of CO_2 has to be kept below 400 ppm_v (IPCC, 2007). Preliminary CO_2 monitoring results from the Norwegian Zeppelin atmospheric observatory at Svalbard shows that CO_2 concentrations are already well above 385 ppm_v (SFT, 2009). The concentration has increased with 0.6% from 2007 to 2008, and by approximately 8% since 1988.

While global warming may provide humanity with its greatest challenge of this century, Arctic warming is considered the premier environmental challenge of the forthcoming decades. The snow and ice covering large parts of the Arctic acts like a mirror and reflects most of the incoming solar energy back to space. By contrast, open oceans and bare soils absorb most of the solar energy. Melting of snow and ice thus enhance the temperature and leads to increased melting. This self induced continued warming can result in very rapid climatic changes when approaching a threshold or tipping point. Methane is released from thawing permafrost. Such natural releases of methane will contribute to an accelerated global warming. Continued anthropogenic emissions of greenhouse gasses are expected to contribute significantly to the already observed changes in the Arctic ecosystems. Recent reports clearly indicate that large changes in ecosystem compositions with tremendous implications for the human populations of the North must be expected in the Arctic (ACIA, 2005; IPCC, 2007; McDonalds et al. 2005).

The Svalbard treaty from 1920 defines the Norwegian part of the Arctic to include all islands between 10° - 35° E and 74°- 81° N, as well as sea areas within the territorial boundary of 12 nautical miles (about 22 km) and the atmosphere above (St. meld. Nr. 22). The Arctic archipelago of Svalbard (between 74 and 81 ° N latitude) is thus under the jurisdiction of Norway (Figure 1). Svalbard covers a total land area of 62 050 km² and consists of several islands, with Spitsbergen as the largest. Approximately 60% of Svalbard is year around covered by snow and ice. The total population at Svalbard in 2009 is 2573 distributed by 2140 inhabitants in the Norwegian settlements of Longyearbyen, Svea and Ny-Ålesund, 423 in the Russian settlement at Barentsburg and 10 at the Polish station in Hornsund (http://www.ssb.no/emner/02/befsvalbard/tab-2009-10-22-01.html).

The Norwegian government acknowledges that it is an important national obligation to evaluate the current status and future developments of climate change within the Norwegian part of the Arctic. Norway has therefore been an active partner within the Arctic Council project, Arctic Climate Impact Assessment (ACIA). This project is currently followed up by a national surveillance program for climate impact assessment in northern regions (NorACIA), based upon the recommendations of ACIA and coordinated by the Norwegian Polar Institute in Tromsø. Norway also recently chaired the Arctic Council, and issued a White paper on Svalbard in 2009 (St.meld. nr. 22, 2009).

Figure 1: Svalbard and surrounding areas covered in this study. (Source: Norwegian Polar Institute)

The vulnerable Arctic environment makes the local nature highly susceptible even for minor climatic changes. In order to minimize the expected future warming in the Arctic regions, reductions in global CO_2 emissions are inevitable. But even if fossil fuels would be banned for usage today, the expected reduction in global warming would probably not occur quickly enough to preserve the Arctic environment as we know it today, due to the slow removal of CO_2 from the atmosphere.

Mitigation actions targeting the emission reduction of short-lived climate pollutants may provide a feasible solution with immediate impact for improving the environmental conditions. The results from recent research indicates that short-lived components with significant climate forcing effects like black carbon, ozone, and methane have nearly the same (80%) temperature impact on the Arctic as CO_2 over the past century (AMAP, 2008; Quinn et al., 2008). Targeting these shorter-lived components, especially black carbon and ozone, also has the potential to delay the onset of spring melt, which has happened earlier and earlier in the Arctic in recent years.

In this context it is important not only to abate global emissions of greenhouse gases, but to prevent increase in emissions of short-lived pollutants also from local sources within the Arctic itself.

1.2 Scope of study

This evaluation concerns assessment of emissions from within the Svalbard Zone. The Svalbard Zone covers roughly 173 000 km^2 from around 10 °E to 35 °E longitude and 74 °N to 81 °N latitude (Figure 1). In addition, for aviation and marine emissions, movements between Tromsø at the Norwegian mainland and Svalbard (Svea and Longyearbyen) have been included. Norwegian obligations to reduce emissions under international agreements (e.g. the Gothenburg and Kyoto Protocols) include emissions from Svalbard. The delimitation of our work differs from that which is requested by official reporting to national and international bodies on two important points. Firstly, we have estimated emissions based on the amount of fuel used within the Svalbard zone, and not on the amount of fuel sold. Secondly, we have attempted to include all emissions which take place in the Svalbard zone in our inventory, thus not restricted the calculations to national emissions only. This means for instance that we included also international cruise traffic around the archipelago and international flights.

The inventory covers emissions of carbon dioxide (CO_2), methane (CH_4), sulphur dioxide (SO_2), black carbon (BC) and organic carbon (OC), as well as nitrogen oxides ($NO+NO_2$). We have aimed at capturing releases of all climate influencing compounds, and not only the greenhouse gases (CO_2 and CH_4), in order to give a more complete picture of the mitigation options. Nitrogen oxides (NO_x) are vital in the formation of ozone, which is in itself a greenhouse gas. While most of the pollutants covered are known to contribute to a warming of the atmosphere, sulphur dioxide is an aerosol precursor and can be converted to sulphate aerosols in the atmosphere. These particles scatter the sunlight, thus contribute to a cooling of the earth's surface. Black carbon, often referred to as elemental carbon or soot, is often emitted along with organic carbon. While BC absorbs solar energy, and thereby heats the atmosphere, the physical properties of the large range of compounds called organic carbon (OC) are less well defined. Current scientific understanding is that OC has an overall cooling effect of the atmosphere, and might therefore offset some of the global warming (e.g. Bond et al., 2004). The importance of BC is further enhanced due to the ability to lower the reflectivity (albedo) of the snow and ice covered surface. This will in turn lead to increased warming and melting, and thereby establish an important positive feedback effect as the dark land or ocean surfaces below the ice and snow cover trigger increased warming.

The major anthropogenic emission sources at Svalbard are coal mining, energy production and transportation. Our inventory covers emissions from Longyearbyen, Svea, Barentsburg, the research stations in Ny-Ålesund and Hornsund, as well as releases from marine and air transportation. The coal mining activities in Svea and Barentsburg include in addition to the coal production, transportation with heavy duty vehicles, stationary machinery, as well as transportation of coal related products on marine vessels. Electricity and central heating plants in the settlements are associated with consumption of coal and diesel. Transportation is divided in land based transportation (private cars, heavy duty vehicles and snow scooters), shipping (cruise, research vessels, goods, coal) and aviation (domestic, international and local). For coal production only methane (CH_4) and associated carbon dioxide (CO_2) emissions were estimated, since no emissions of other pollutants were assumed for this source. Natural emissions of methane as well as emissions of black carbon from coal transportation and storage in uncovered piles could be substantial (Walter, 2007; Myhr, 2003) but are not included here.

Emission inventories for the years 2000-2007, as well as scenarios for 2012 and 2025 have been developed and assessed. In addition, recommendations for possible mitigation options are presented.

2. Data sources, methodology and assumptions

Emissions were estimated by multiplication of the activity data with the appropriate emission factors. Emission factors are assumed constant over time, thus emission and fuel consumption trends coincide. This chapter documents the data sources for activity data and emission factors employed in this study, as well as the assumptions made in the emissions calculations

2.1 Activity data

The activity data was provided by municipal authorities, local industry, tourist agencies and research institutions and supplemented by other sources of information. A questionnaire on the consumption of fossil fuel and emission profiles for Svalbard 2000-2007 (Appendix 1) was sent to 15 institutions. Only half of the institutions completed and returned the questionnaire. The response rate must be regarded as low, however, additional information was provided on request from seven institutions which were not included in the survey in the first place. There were some gaps in the data provided. These gaps were filled by interpolation and extrapolation of available data. In addition coal production and monitoring data reported to Statistics Norway (SSB) 2000-2006 have been included. Data for 2007 are preliminary estimates. We regard the basis for emission estimation as good to fair depending on activity and location. Data quality is further discussed in section 5.4.

Appendix 2 lists the emission categories included, information sources as well as the assumptions made to distribute the fuel consumption between different technologies. The activity data are available as supplementary information upon request.

2.2 Emission factors

The majority of the emission factors applied in this study is taken from the report on the National Norwegian Emission Inventory (SSB, 2007). In addition, information was included from the IPCC recommendations for national greenhouse gas inventories (IPCC, 1996) and a state of the science paper on emissions of particulate matter (Bond et al., 2004). The emission factors are listed in Appendix 3.

3. Main results on emission trends and sector distribution

All components, except CH_4, are continuously increasing over the time period 2000-2007 as shown in Figure 2 and 3. The total annual emissions for the period 2000 – 2007 are listed in Table 1.

Carbon dioxide emissions (brown) increased by around 28%, NO_x (green) and BC (Figure 3, blue) by about 55% while SO_2 and OC emissions moderately increased by 8-10% over the time span covered. The emissions of methane shows large inter annual variation due to the strong dependency of the amount of coal produced. The large drop in emissions of methane in 2005 is due to a fire in the Svea mine resulting in an eight months closure of the mine.

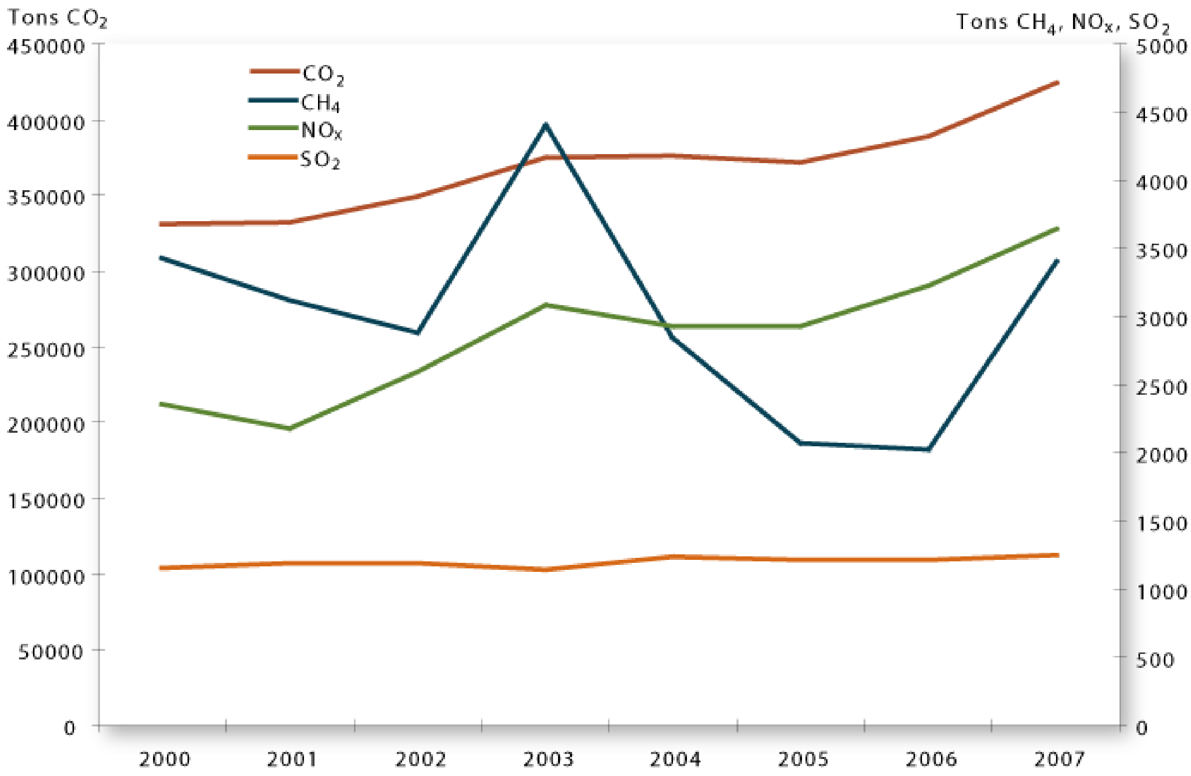


Figure 2: Total emissions of CO_2, CH_4, NO_2 and SO_2 at Svalbard 2000-2007. Unit: Tons

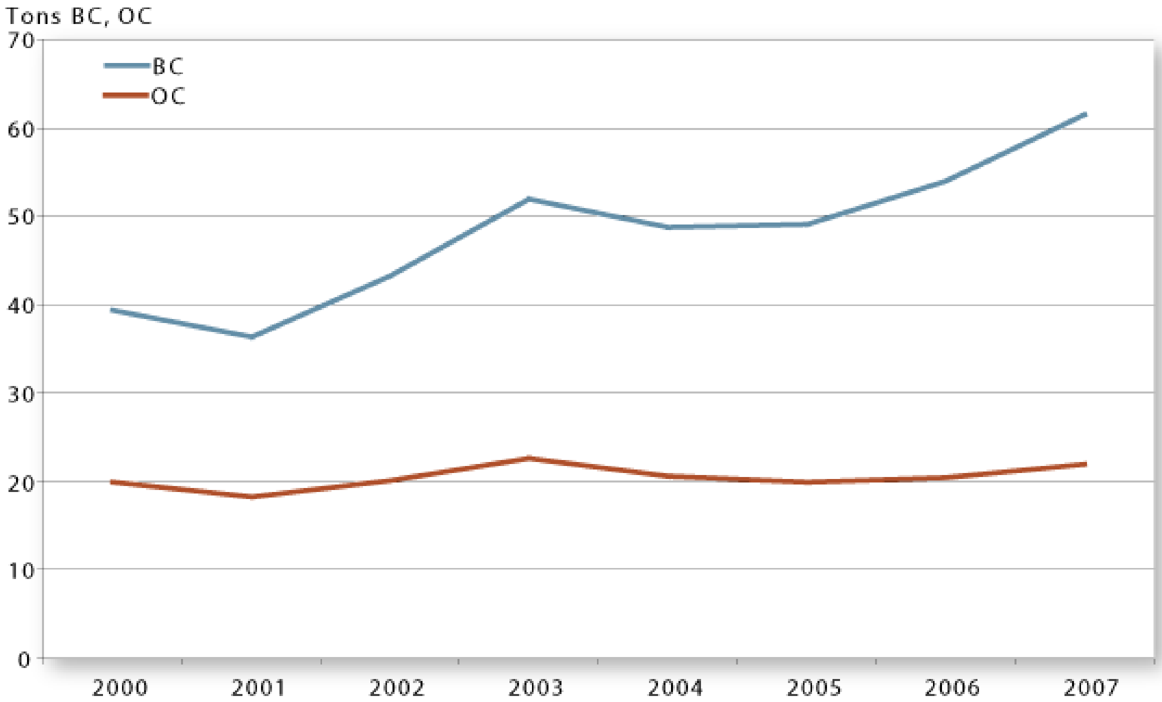


Figure 3: Total emissions of BC and OC at Svalbard 2000-2007. Unit: Tons

In 2007, the total CO_2 and CH_4 emission estimates for Svalbard listed in Table 1 is about 1% and 2% of the Norwegian mainland emissions respectively. The SO_2 and NO_x emissions at Svalbard account for about 6% and 2%. Emission estimates for BC and OC are not available from the official Norwegian emission inventory. Kupianinen and Klimont (2007) estimate about 12 and 22 kilotons BC and OC for Norway in year 2000, thus the contribution from Svalbard is 0.6% and 0.1% respectively.

Table 1: Total of climate influencing emissions within the Svalbard zone 2000-2007. Unit: Tons

	2000	2001	2002	2003	2004	2005	2006	2007
CO_2	330637	331960	349793	375361	376011	371273	388397	424787
CH_4	3428	3114	2884	4405	2841	2075	2024	3400
SO_2	1159	1191	1187	1138	1242	1213	1212	1255
NO_x	2360	2177	2592	3087	2930	2928	3232	3643
BC	39	36	43	52	49	49	54	61
OC	20	18	20	23	21	20	20	22

Table 2 shows the source distribution of emissions at the most aggregated sector level. Marine transport is a dominant sector for all pollutants assessed except for SO_2 and methane. With regards to CH_4 almost 100% of the emissions originate from coal production, while 92% of SO_2 emissions are caused by energy production. Energy production is the main source for CO_2 emissions (50%).

Table 2: Main emission source categories within the Svalbard zone in 2007[1]. Unit: Percent

Sector/ Component	CO_2	CH_4	SO_2	NO_x	BC	OC
Coal production	2	**98**	NE	NE	NE	NE
Energy production	**50**	1	**92**	7	1	0
Land based transport	3	0	0	2	5	16
Marine transport	**42**	1	8	**90**	**93**	**83**
Aviation	3	0	0	1	1	1

Appendix 4 displays 2007 emissions of all pollutants estimated in this study at three different levels of aggregation. This overview allows for a more refined key source analysis. Emission sources adding up to 95% of the total is highlighted in bold in Appendix 5.

For CO_2, coal based energy production is the largest source (42%) followed by marine international cruises (15%), marine coal transportation from Svea (13%), diesel based energy production (7%), marine expedition cruises (5%), marine research vessels (3%), marine goods transport at Svea (3%), land based heavy duty vehicles transport (3%), aviation scheduled domestic (3%) and marine administration and surveillance (1%).

Key sources for SO_2 are in addition to coal based energy production (91%), marine international cruises and marine coal transport from Svea (both 3%). Marine activity generate most of the NO_x emissions distributed on international cruise (32%), coal transportation in Svea (30%), expedition cruise (10%), research vessel activity (7%), goods transportation in Svea (6%), administration and surveillance (2%) and coal transport from Barentsburg (2%). In addition coal based energy production contributes with 6%.

Key categories for black and organic carbon emissions are marine international cruises and marine coal transport from Svea (about 30% each), expedition cruises (10%), research vessels and goods transport to Svea (6%), heavy duty vehicles (4%) and administration and surveillance off shore (2%). The largest difference in emission distribution between BC and OC is the high (12%) emissions of organic carbon from 2-stroke snow scooters.

4. Results by source sectors

4.1 Coal production

Svea, Longyearbyen (Gruve 7) and Barentsburg are locations where commercial coal mining takes place at Svalbard. Store Norske Spitsbergen Kulkompani (SNSK) re-opened the Sveagruva mine for commercial coal production in 2001 after a long period with limited activity. Pyramiden (the second largest coal mine on Svalbard) was closed in 1998. For the coal production and emission data we have relied on data reported to SSB from SNSK and Trust Artikuguol, which operates the mines and monitor the production and emissions. Figure 4 shows that the production in Svea/LYR is higher than in Barentsburg for all years and about thirty times higher in 2007 when the differences were the largest. While the coal production in Barentsburg decreased by more than a factor 3 between 2000 and 2007, the production in

[1] NE: Not estimated

Svea has increased substantially (more than a factor 5). The drop in production in Svea/LYR in 2005 is caused by a fire in the Svea mine which delayed the production for almost one year (Figure 4).

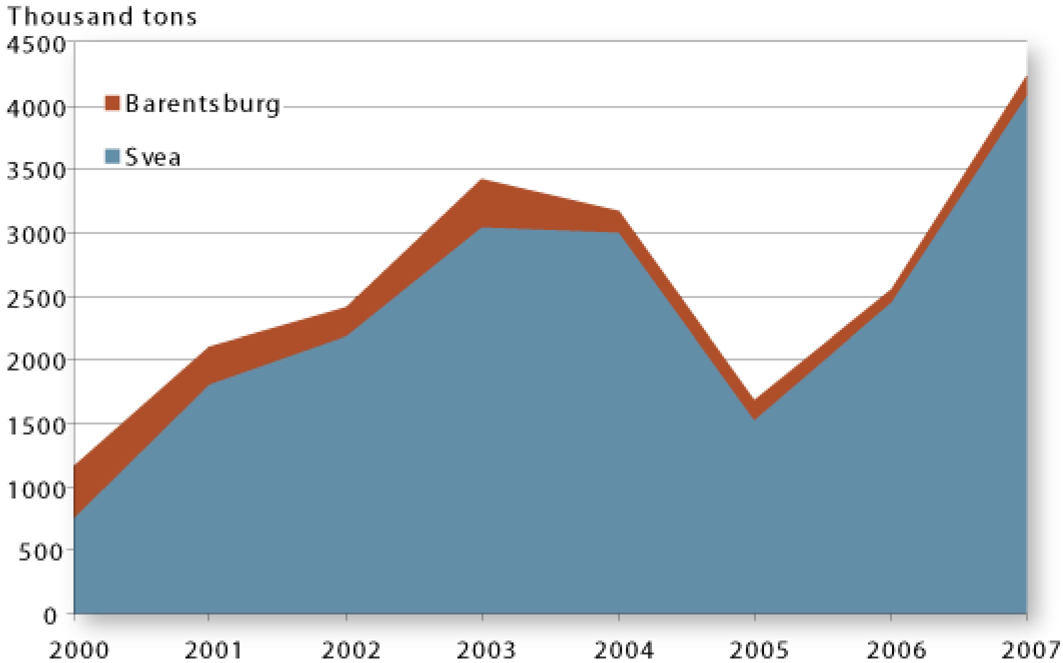


Figure 4: Annual coal production in Svea/LYR and Barentsburg 2000-2009. Unit: Thousand tons coal

Figure 5 shows how the trend in CH_4 emissions vary with the coal production, and that total emission are at about the same level in 2007 as in 2000 (3.4 thousand tons). Even though the coal production is much higher in Svea than in Barentsburg for all years, the associated emissions of methane are much lower in Svea up until 2003. The amount of methane emitted per unit coal produced is about 7 tons CH_4/thousand tons coal produced in Barentsburg and only around 0.5 in Svea/LYR (IMC Technical Services Limited, 2000; Bergfald & Co, 2000). The reason for this is most likely due to the difference in location of the mines and differences in geology. The Svea mine sits above sea level while the mine in Barentsburg is located below sea level. The rock at Svea is porous and therefore methane has been aired through many years. Between 2000 and 2007, Svea contributes with between 11 and 70% of total CH_4 emissions from coal production.

CO_2 emissions are derived from emitted CH_4 data by accounting for the difference in molecular weight between the two gases (factor 2.74), in accordance with the UNFCCC accounting system. The emissions of CO_2 in Barentsburg in year 2000 and 2007 are thus about 8 and 3 thousand tons respectively while the emissions in Svea/LYR are around 1 to 6 thousand tons. The highest total CO_2 emission originated from coal mining at Svalbard was calculated for 2003 at about 12 thousand tons.

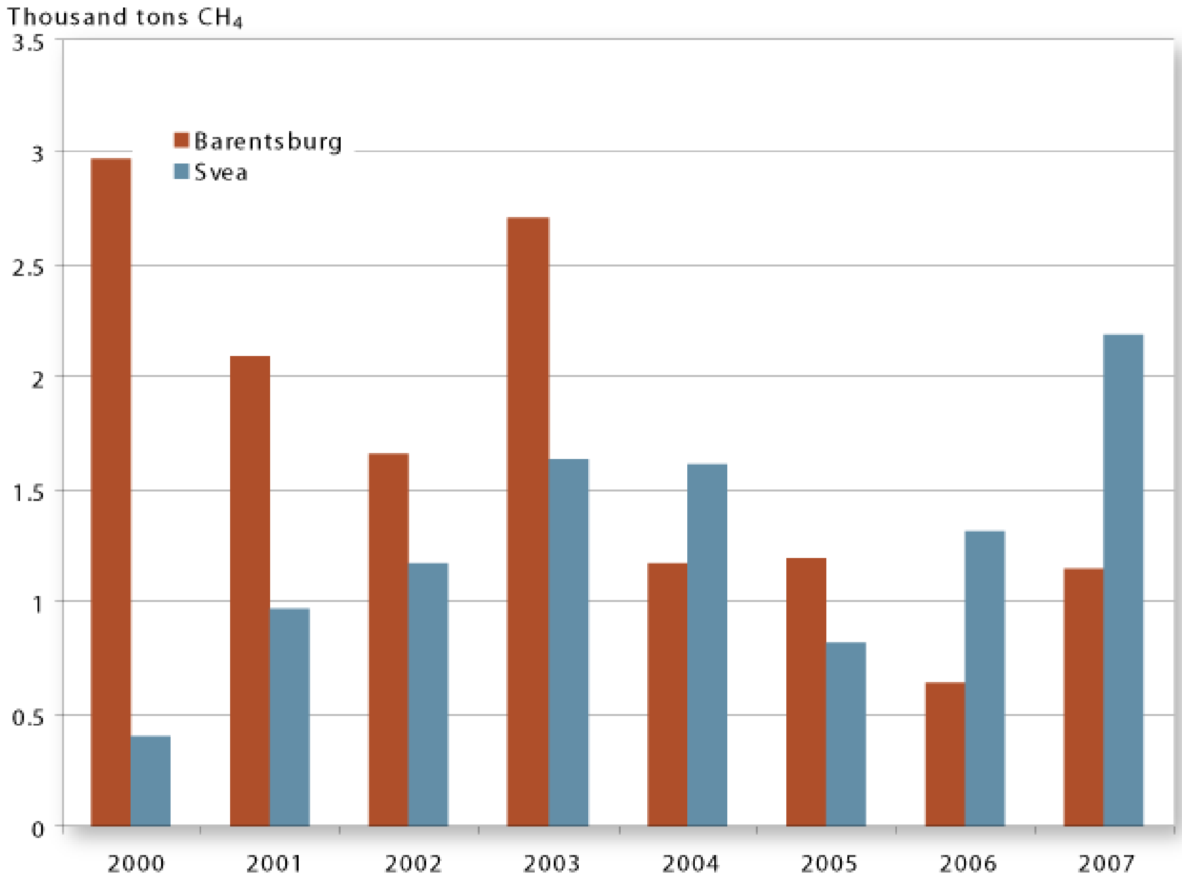


Figure 5: Methane emissions 2000-2007 from Svea/LYR and Barentsburg. Unit: Thousand tons CH_4

4.2 Energy production

Coal is the primary fuel for the local production of electricity and heat at Svalbard. The power plants are located in Longyearbyen and Barentsburg. Diesel is used in Svea, Ny-Ålesund, Longyearbyen, Hornsund and at Bjørnøya, Hopen and Isfjord radio. Emissions from the three latter are not included in this study. These plants supply energy mainly for electricity, for the mining activities, as well as to the local households and official buildings including the airport in Longyearbyen. Figure 6 shows the annual consumption of coal and diesel at Svalbard for energy production. The trend in coal consumption is rather stable at about 70 thousand tons. The annual variability is due to variation in consumption at Longyearbyen, while the reported consumption at Barentsburg is rather stable. The annual consumption of coal for energy production in Barentsburg is reported to be about 45 thousand tons per year, which amounts to 60-70% of the coal used in power plants at Svalbard. The large and stable coal consumption reported from Barentsburg, despite a declining population and coal production suggests both a high degree of uncertainty in the reported data and less effective technology solutions in the Russian power plant. In addition to the coal based energy production, electricity supply is provided through diesel generators mainly in the Svea mine (around 80% of the diesel consumed), but also in Ny-Ålesund and Hornsund. In Longyearbyen, diesel based energy production is only used as a back-up to secure energy supply in cases where the coal driven power plant is exceeding the capacity or during emergency situations, maintenance and service periods. Due to capacity restrictions in the coal based energy production during the past years, diesel generator based electricity has however frequently been used for energy supply in Longyearbyen. The Longyearbyen authorities (Bydrift) have firm plans to establish a bio-diesel driven generator system for electricity production and heating as a back-up system. The research station in Ny-Ålesund fully relies on energy production by diesel generators. In Hornsund, electricity is produced by small diesel generators whereas heating is provided through coal combustion. For Barentsburg, no detailed information about consumption of diesel for energy production is available, and we have assumed that diesel is used for transportation only.

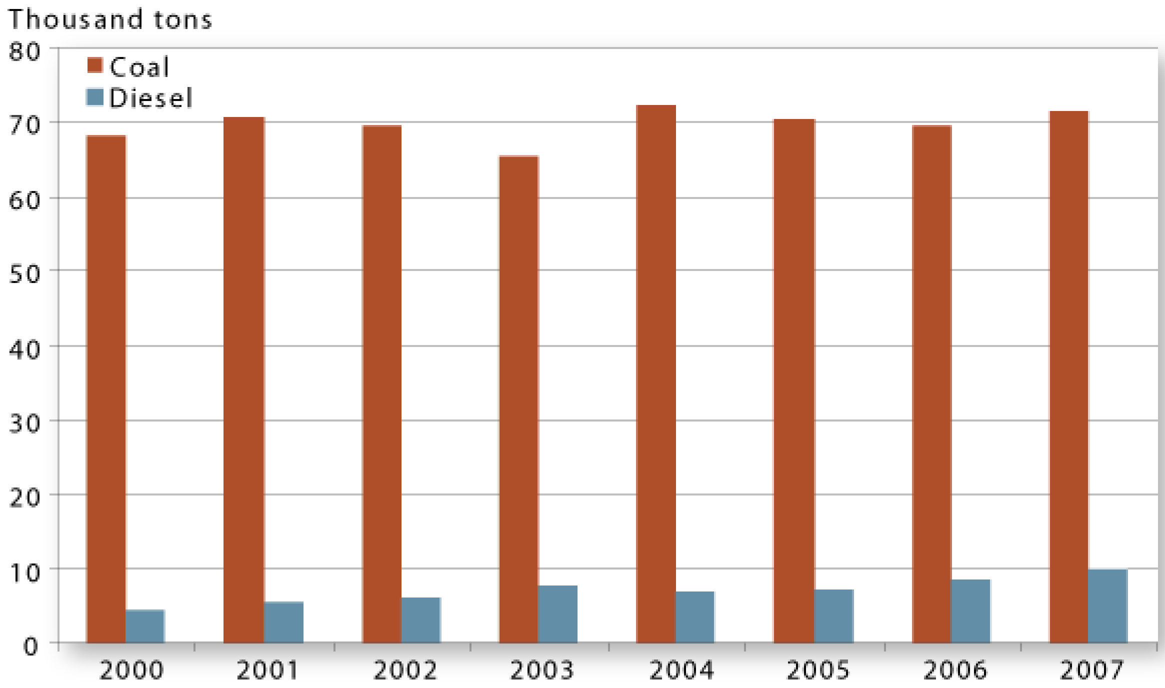


Figure 6: Annual consumption of coal and diesel for energy production 2000-2007. Unit: Thousand tons.

Emissions originating from coal based energy production show a rather stable trend over the time span 2000 to 2007 in line with the coal consumption (Figure 6). The CO_2 emissions are relatively constant at about 180 thousand tons, while the SO_2 emissions stay at about 1 thousand tons. The diesel based emissions more than double over the time interval 2000-2007 causing emissions of CO_2 from energy production to increase from 186 thousand tons in 2000 to 212 thousand tons in 2007.

4.3 Land based transport

The distribution of gasoline and diesel consumption upon the different vehicle classes considered in this study is shown in Figure 7. Heavy duty vehicles used for coal transportation consume by far most fuel. The trend varies considerably and mostly in line with the coal production over the years. The other modes of transportation except 2-stroke vehicles (snow scooters) increased the consumption of fuels between 2000 and 2007. There are several assumptions behind the trends and levels in estimated fuel consumption based on the number of registered vehicle (Appendix 2). It is therefore reassuring that the gasoline consumption in Longyearbyen could to some extent be verified by the sold amount of gasoline as reported by Leonhard Nilsen & Sønner AS (LNS). The difference in consumption figures increases however from 2000 to 2007. Since our estimates are increasingly higher than the LNS data, one possible explanation could be that the actual annual snow scooter driving distance has increased particularly from 2005 onwards, and not remained constant at 3000 km as we have assumed. The diesel consumption from LNS could not as readily be used for validation of results, as there is no information on distribution by technology related to these consumption figures. Thus a large amount of the diesel could well have been sold for energy production and not for land based transportation.

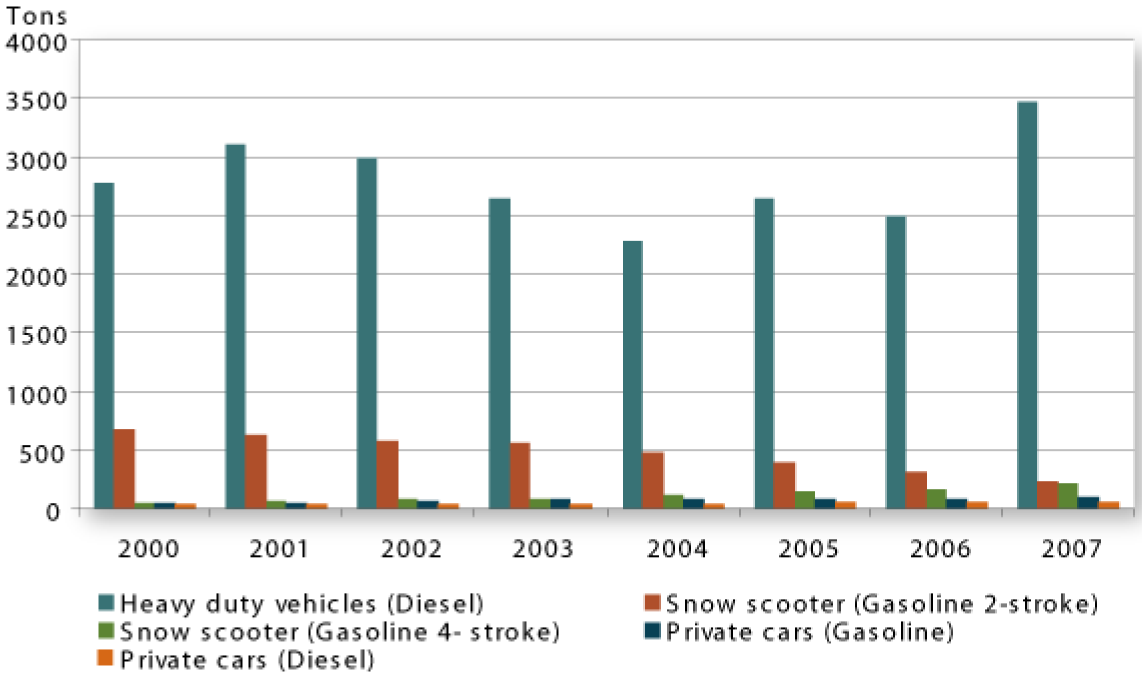


Figure 7: Consumption of gasoline and diesel for different vehicles classes at Svalbard 2000-2007. Unit: Tons.

For 2-stroke driven snow scooters, a rapid decrease from 2175 tons CO_2 emissions in 2000 to 743 tons in 2007 was calculated. A corresponding increase for 4-stroke driven snow scooters on Svalbard from 145 tons in 2000 to 645 tons in 2007 was estimated. Although for 2007 only 20% of the total snowmobile on Svalbard is considered to be 2-stroke engine driven, the CO_2 emission contribution of 2-stroke driven snow scooters in 2007 is still higher than for the 4-stroke engines (743 tons versus 645 tons). This demonstrates clearly the benefits of the modern 4-stroke catalyst technology. The estimated emission rates for 2-stroke snow scooters might however be overestimated based on a recently published study on emission profiles for volatile organic compounds (VOC) from snow scooters at Svalbard (Reimann et al. 2009). The authors postulated that around 52% of the gasoline used as fuel in 2-stroke engine driven snow scooters are leaving the engine unburned through the exhaust, while in our study we assume that all the fuel is combusted. The direct release of fuel has the potential for considerable local contamination along the major snow scooter tracks on Svalbard (Reimann et al. 2009).

4.4 Marine transport

Consumption of marine gas oil and diesel has grown rapidly between 2000 and 2007 as shown in Figure 8. The emissions from this sector have been increasing accordingly. All emissions from marine transport are estimated in this study assuming either marine diesel (cruise) or marine gas oil (coal and goods transport) as the main fuel type.

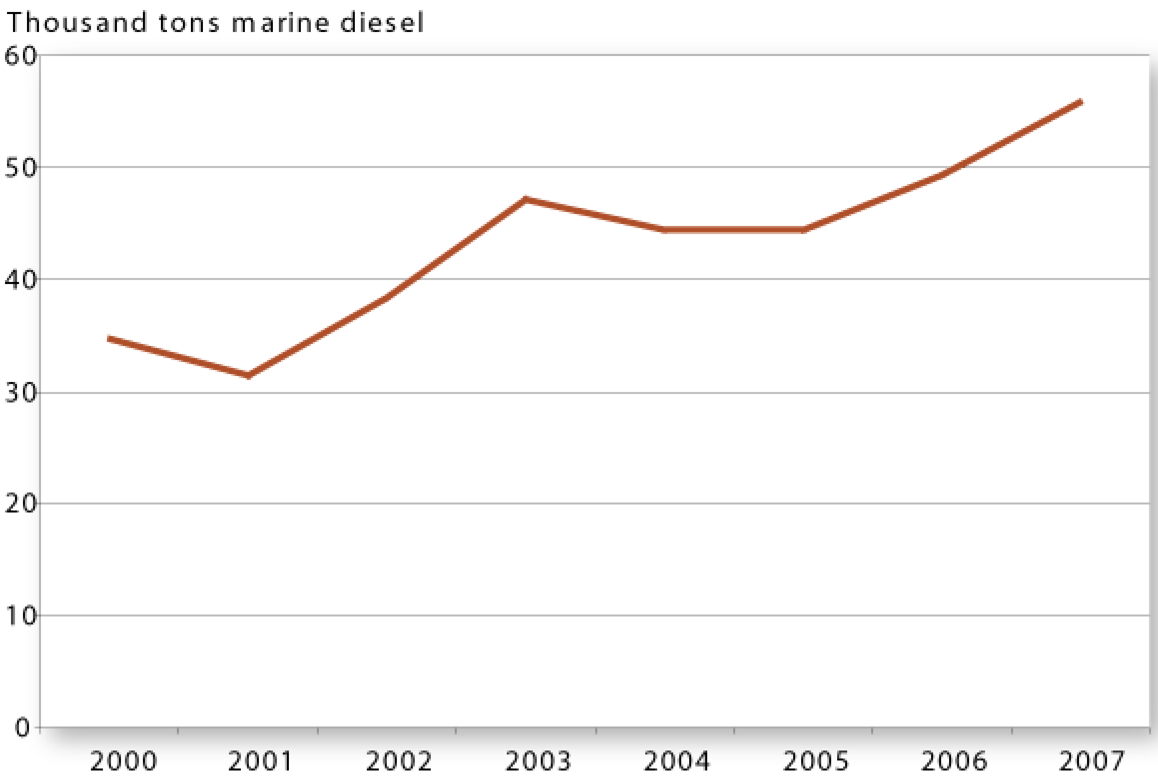


Figure 8: Consumption of marine diesel and MGO for transportation in the Svalbard zone 2000-2007. Unit: Thousand tons

However, Zahl Transport AS informed us later that their vessels are running on heavy bunker oil. If transport vessels (Panamax-class) are in reality utilizing heavy bunker oils (i.e. IF380) as fuel for their engines, this will result in a considerable increase of emissions particularly for sulphur dioxide as discussed in section 5.4 of this report.

Figure 9 illustrates the trend and level of the emission of NO_x from ship based activities in the Svalbard zone from 2000 to 2007 based on marine diesel and MGO consumption. The dominant source is international cruise ships, followed by coal transport from Svea. The increase in international cruises (76%) mimics the increased interest for tourist programs on Svalbard as is an easily accessible settlement with suitable infrastructure available for tourist visits in the Arctic. Since 2002, a considerable increase in annual emissions from research vessel activities has taken place. These emissions have more than doubled between 2000 and 2007. This increase demonstrates the central role of Svalbard has as a working ground for national and international Arctic research activities. In addition, the launch of the International Polar Year in 2007 (IPY 2007-2009) will most likely contribute significantly to the increase in research activities around Svalbard. Climate related emissions from goods shipping are mainly associated with vessels moving to and from Longyearbyen. Little activity on ship-based goods transport is reported from the Port authorities until 2004. However, a considerable increase is registered for 2005 – 2007 (Figure 9).

Marine transport is also an important source of CO_2, BC and OC emissions. These emissions are distributed over the sectors in the same way as the NO_x, and with the same growth rates.

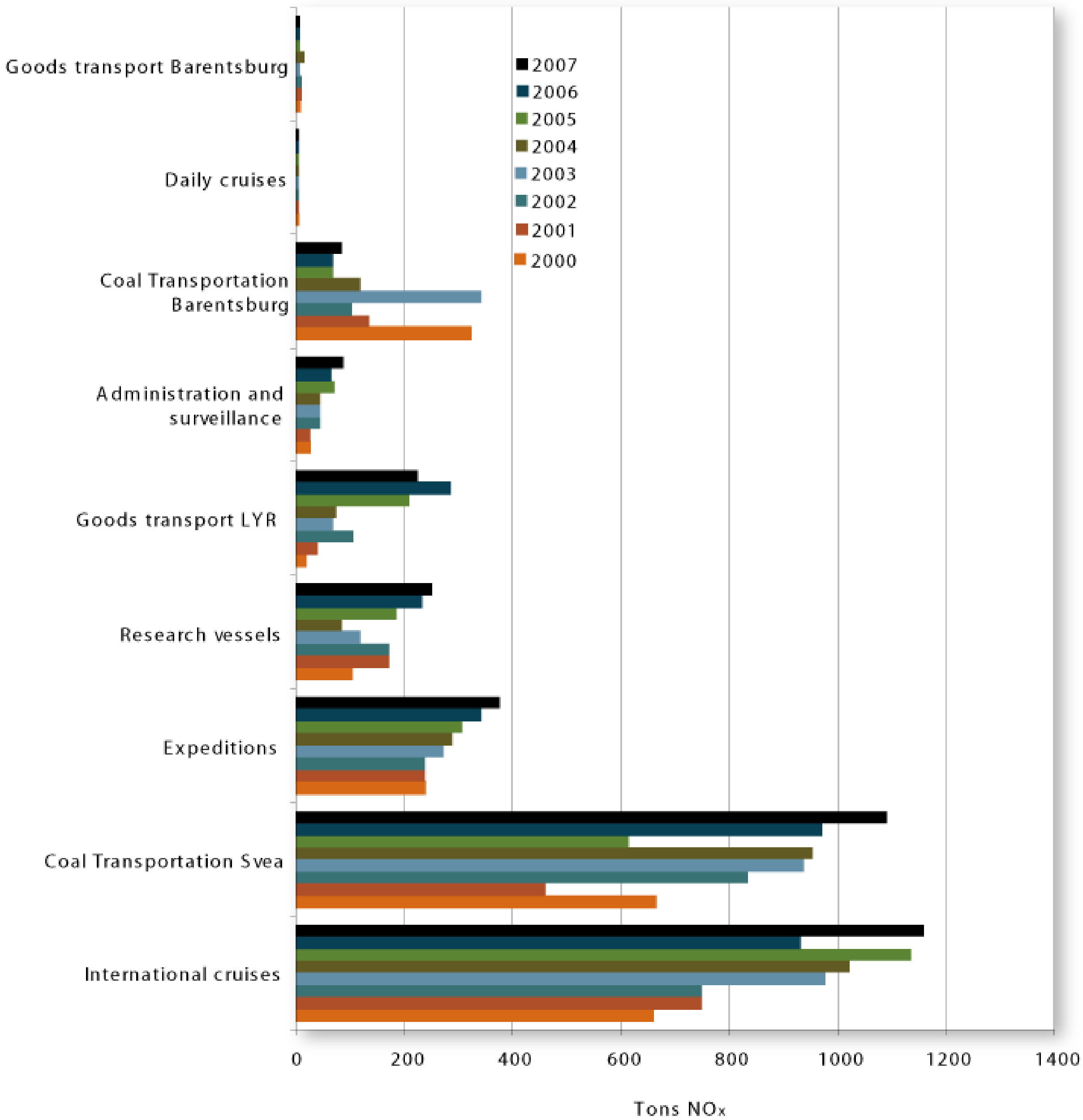


Figure 9: NO_x emissions from Marin transport by sector at Svalbard 2000-2007. Unit: Tons NO_2

4.5 Emissions from aviation

The settlements in Longyearbyen and Barentsburg are the largest communities on Svalbard with a registered population of around 2000 and 500 inhabitants, respectively (www.sysselmannen.no). In the Sveagruva coal mining production site, around 300 SNSK employees (miners) are living and working throughout the year. Most of the workers in Svea are officially registered as Longyearbyen inhabitants. A daily airplane shuttle service provided by "Lufttransport AS" with two Dornier Do228 carriers allows the SNSK employees to move back and forth between their homes in Longyearbyen and their working place in Svea, usually in bi-weekly shifts. Also Barentsburg provides airborne shuttle service based on helicopter transportation for their employees (SPARC MI-8MT Type helicopter) to Svalbard airport in Longyearbyen, where scheduled domestic flights to the mainland Norway are utilized for further transportation. Despite the strong dependency on air transport at Svalbard, aviation is not a key sector for other pollutants than CO_2 (Appendix 5). We have however to keep in mind that only the distance from Tromsø to Svalbard is accounted for in the category "domestic scheduled flights". There are regular direct flights from Oslo during the tourist season, and we can also assume that some of the passengers from Tromsø are arriving by air from other destinations. Thus, the emissions from aviation would probably double if other more progressive assumptions would have been chosen as the basis for the assessment.

The consumption of jet 1A fuel or kerosene over the activities considered is shown in Figure 10. The consumption estimates based on Avinor data and our assumptions (Appendix 2) are comparable but 15% higher than estimates from SAS for scheduled flights from Longyerbyen to Tromsø. This increases the confidence in our calculations of fuel consumption. The CO_2 emissions are however 64% lower in our calculation than in the estimates received from the SAS. As we did not have access to the emission factors employed by SAS, we decided not to change our emissions factors taken from the documentation of the Norwegian emission inventory (Appendix 2).

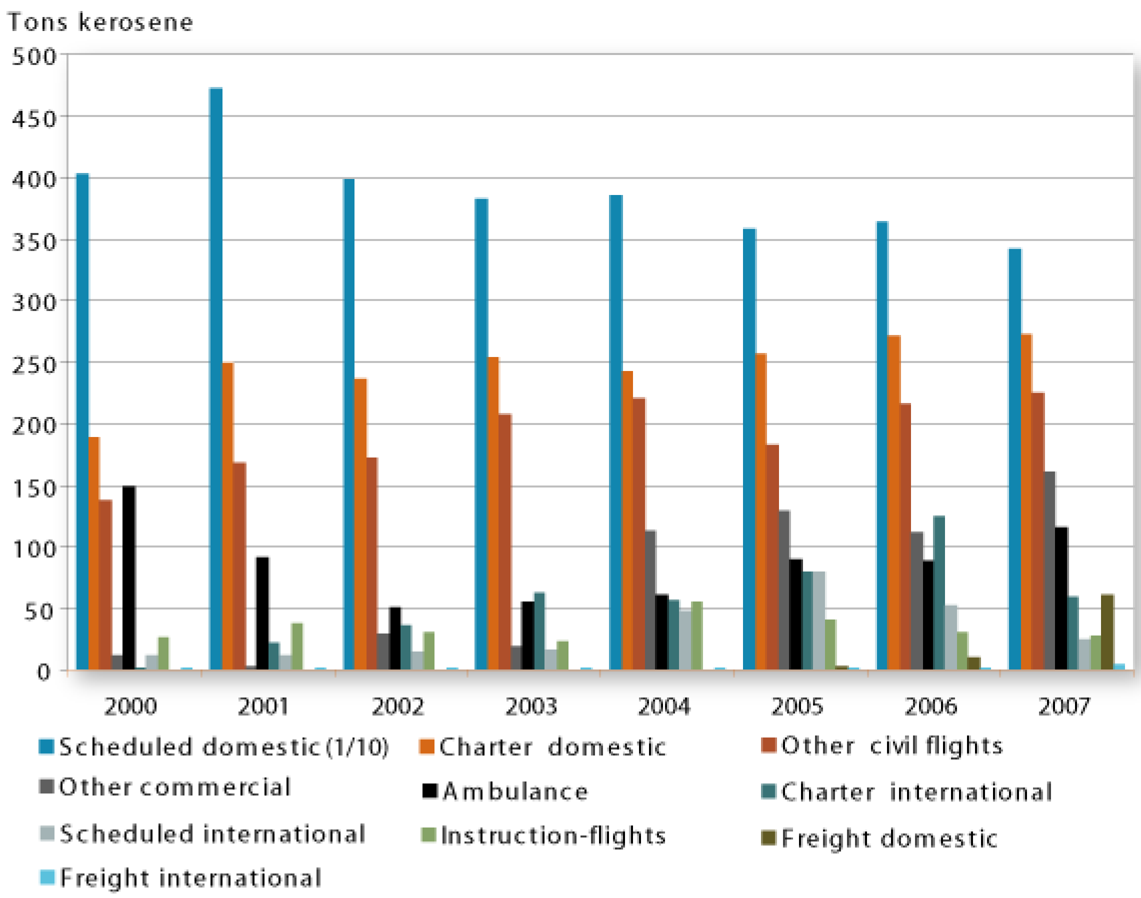


Figure 10: Consumption of kerosene over different aviation activity sectors 2000-2007. Note that the consumption by scheduled domestic flights is displayed as ten times lower than the actual consumption. Unit: Tons kerosene.

The fuel consumption in the largest sectors in 2007, scheduled domestic flights, is more than ten times higher than the emissions in other sectors, and is displayed accordingly in Figure 10. This sector has been decreasing by 15% since year 2000. The decrease is partly compensated through the steady increase in the three following sectors, domestic charter, civil flights and commercial flights, resulting in an overall stable aviation trend between 2000 and 2007. According to the consumption data available from Avinor the domestic and international freight activities have increased dramatically the last two years (2006-2007) (Figure 10). Scheduled international flights seems on the other hand a decreasing trend from 2005 onwards.

The reduction in scheduled flights' fuel consumption and the corresponding decrease in emissions reflect a decreasing number of flights and an improvement in the cabin factor (number of passengers per flight). It is also possible that the aircrafts have become more fuel efficient, but this has not been taken into account in this study.

5. Discussion of results

5.1 Impacts of local emissions

Local emissions of black carbon are estimated to 61 tons or 0.0076‰ of the global BC budget of 8 Tg (Bond et al. 2004) in this study. Even so, local releases of BC at Svalbard particularly during spring, but also in periods where long-range transported emissions are not readily deposited at Svalbard, might be important. Black carbon is important for global warming both as a compound that heats the atmosphere, and as a contributor to accelerated melting when deposited on snow and ice. BC has a relatively short life time in the atmosphere (about 7 days), and much of the emission from distance source are deposited well before it reaches the Svalbard zone. In addition, the cold Arctic front may in summer prevent long-range transported air masses to enter the Arctic. During winter, the arctic front lies further to the south (50ºN) compared to summer times (70º N) allowing more long-range transported BC to enter the atmosphere over the Arctic. On the other hand, deposition of BC during winter is generally low due to little scavenging in the stable Arctic winter atmosphere. Thus most of BC is deposited in late winter-early spring and at a time when the sun has arrived in the far north, but the snow melt has not yet really started. Deposition of BC during this period will therefore have the most powerful effect on decreasing the albedo and increasing snow melt.

The most recent publication documenting the Norwegian emission inventories for GHG and air pollutants were released in May 2009 from SFT/SSB (http://www.ssb.no/klimagassn). The GHG have in general increased steadily from 1990, but decreased for the first time in 2008 to a total of 53.8 million tons CO_2-equivalents. The GHG emissions reached an historical peak in 2007, with a total of 55.1 million tons CO_2-equivalents, with around 20 million tons of CO_2 -equivalents released from stationary combustion and 17 million tons from mobile combustion. The total emissions reported for Norway in 2007 was 55.8 million tons CO_2-equivalents. CO_2 contributed with 45 million tons to this total, and is the main contributor to the total GHG emissions. Emissions of CH_4 contributed with 210 000 tons, or 4.4 million ton CO_2-equivalents in 2007.

In this study we estimate emission from Svalbard at about 496 000 tons CO_2 equivalents in 2007 (Appendix 4). Thus the GHG emissions which take place at Svalbard is miniscule compared to the emissions from mainland Norway (about 1%). However, the vulnerable environment on the islands, including the vulnerability to local emissions should be taken into account when considering the need for measures.

Due to the rapid and continuous growth of the Norwegian population on Svalbard, the tourist activity and the increase of coal production during the past decade, a steep upwards trend has been found for the total emission rates for all compounds included in this study, except for methane, which has been slightly reduced (Table 3).

Table 3: Percentage emission increase per climate influencing compound in the period 2000 to 2007. Unit: Percent

CO_2	CH_4	SO_2	NO_x	BC	OC
28	-1	8	54	56	10

The steep increase in the estimated climate influencing emissions are directly associated with increasing energy demand to supply the communities. In addition, releases are mainly related to tourist-, research- and industrial activities and to keep the complex infrastructures continually working.

5.2 Comparison with other emission estimates

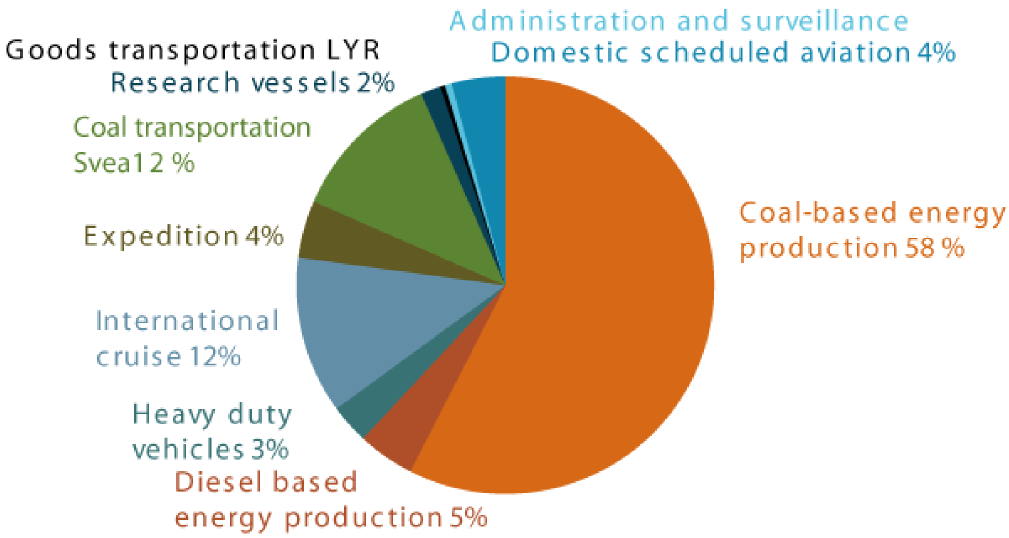
A recent study by Aamaas (2009) sheds light to the importance of local emissions contribution to environmental deposition and possible adverse effects on Svalbard. His work analyses snow samples from selected areas at Svalbard, and concludes that long-range transport of BC contributes in average with 240 tons/year to the local deposition. Our work indicates that about 20% of the total deposition is due to emissions from local sources. Aamaas (2009) estimated 11.2% decrease in albedo due to local BC emissions at Svalbard. Neither Aamaas, nor this study assesses pollution from open coal piles and transport pathways. Myhr (2003) found that about 54 tons of coal dust was released from one of the largest coal piles at Svalbard. While coal dust could also contribute to the melting of snow and ice, the amount of emissions should not be compared to the releases of BC which is defined as the light absorbing part of particulate matter released by incomplete combustion.

Complimentary determination of the proportion of atmospheric long-range transport of black carbon is based upon the continuous monitoring program at the Zeppelin Mountain research station (Ny-Ålesund) in combination with campaign based aethalometer measurements. Eleftheriadis et al. (2004; 2009) found that the annual average concentration of BC in air from long-range transport is 39 ng/m^3 ($nano=10^{-9}$). Svalbard covers approximately 61000 km^2. If we assume long-range transport of BC to occur below 10km, the total air volume is $6.1*10^{14}$ m^3 and the long-range BC component of BC in air approximately 24 tons. Local emissions will then constitute more than 70% of the total BC deposition.

Statistics Norway (SSB) has published emission estimates from Svalbard for selected years between 1991 and 2003 (http://www.ssb.no/emner/00/00/20/nos_svalbard/nos_d330/tab/042.html). The emissions in year 2000 of CO_2, CH_4, SO_2 and NO_x estimated in our study are a factor 3 (SO_2) to 10 (CH_4) higher than the emissions reported by SSB. This is most likely because the delimitation of the emission area is different in the two studies with respect to international cruise and air transport. Different assumptions on coal consumption for energy production particularly in Barentsburg and lower emission factors may also contribute to the identified differences.

5.3 Spatial distribution of climate related emissions

The variation in sector distribution of CO_2 emissions from 2000 to 2007 (Figure 11), might serve as an example on how structural changes in the society is reflected in the temporal distribution of emissions.



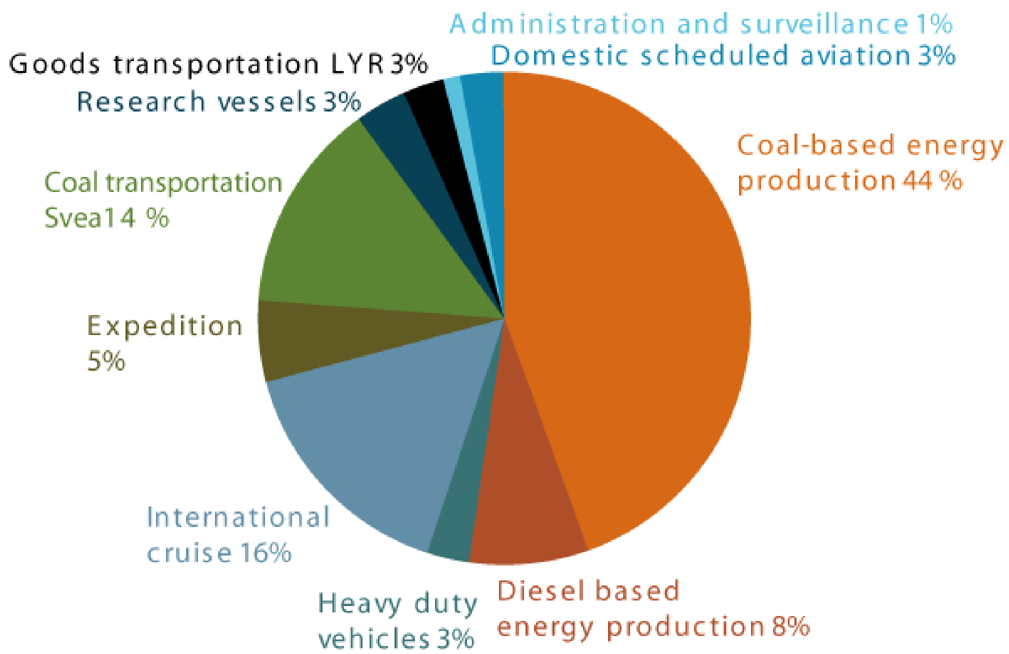


Figure 11: CO_2 emissions distribution of key sectors at Svalbard for the year 2000 top and 2007 bottom. Unit: Percent

From 2000 to 2007 there has been an increase in the contribution of CO_2 emissions from international cruise and all other marine transport related activities as well as diesel based energy production at the expense of emissions from coal based energy production (Figure 11). This change in annual emission patterns (2000 – 2007) mimics the change in population structure and needs for energy and non-industrial infrastructure support on Svalbard towards a more diverse community approaching the demands and requirements as they are established on mainland Norway today.

A complete spatial distribution of emissions is out of the scope for this study, but some guidance is provided below. The geographical distribution of emissions will necessarily depend on the pollutant in question. A rough estimate gives a distribution of emissions from coal based energy production at about 70% in Barentsburg, 5% in Longyearbyen and 25% in Svea. In the case of emissions from coal mining in recent years, Svea dominates (about 60%) followed by Barentsburg (34%) and Longyearbyen (6%). It should be kept in mind that this distribution is closely related to thus vary with the mining activity. There has not been any activity in Barentsburg since 2008, and according to current plans, the mine will not be opened until 2010. Due to the fire in Svea, there was no mining there in 2005. In Longyearbyen, Gruve 7 was closed in 2009, but is planned to open again in 2010. Ships emissions could be allocated only to the ports in Barentsburg, Longyearbyen and Ny-Ålesund as a first approximation. From July 2008, reports on positions were requested also for vessels in the Svalbard waters. This documentation will, thus, provide good possibilities to refine the spatial distribution of marine emissions in the future.

5.4 Uncertainty considerations

Emission estimates and scenarios will always be associated with uncertainties and, thus, seldom reflect the accurate pollution situation. Uncertainty relates both to the amount of fuel consumed by a certain activity, to the emission factors and the level of abatement technologies in place. The uncertainty estimates for Norwegian total emissions of compounds included in this study ranges from 3-4% in the case of CO_2 and SO_2, to 12-14% for NO_x and CH_4. Uncertainty by sector could be substantially higher due to the more limited potential for error compensation. In this section we have highlighted important areas of uncertainty in our emission estimates for Svalbard.

Area of coverage

The delimitation of the transport activities influences significantly the outcome of this assessment. Our estimates are conservative in the sense that emissions from aviation and shipping south of Tromsø (70 °N latitude) have been neglected. To further illustrate this point; if flights and boat trips from Oslo had been included, the distance travelled by boat or air would have been about three times longer, and with a substantial increase in emissions.

Activity data

This study has made an attempt to improve the completeness and accuracy of the fuel consumption data at Svalbard by collecting this information from local authorities and industries. Even so, the completeness of activity data particularly for historical years was sometimes rather sparse. Gaps in the reported data had to be filled e.g. by interpolation between adjacent years. This adds to the overall uncertainty of our inventory and indicates that the emission data quality is higher for more recent years than for earlier years. With respect to the geographical distribution of uncertainty, the quality of data received from Barentsburg is regarded rather poor as e.g. coal consumption figures did not vary as much as one could expect from year to year. The consumption of coal for energy production in Barentsburg as was reported by Trust Arktikugol to be 45000 tons annually. Other reports from Trust Arktikugol and communication with SSB indicate that the coal consumption could be as low as 30000 tons. The total emissions would in this case be substantially lower for all years and compounds than calculated for our study (e.g. around 9% in the case of CO_2 and 19% for SO_2 in 2007)

Efforts have been made to validate the reported fuel consumption data by comparison with other data sources (e.g. for aviation and land based transportation) and with measurements (e.g. from the power plants), but this has not always been possible.

Emission factors

Most of the emission factors used in this study have been selected from the documentation of the Norwegian emission inventory (Appendix 3). The same emission factors have been used for the whole time series and for all locations (e.g. both for Barentsburg and Longyearbyen). This is a simplification, as emission factors are dependent on sulphur content, and cleansing technology, and may vary with time and location. Local measurements are needed in order to raise the confidence in our emission inventory further.

We have compared our emissions estimates from energy production with measurements performed at the power plant in Longyearbyen in 2007 (Heie and Hatling; 2007). Our results compare well with measurements for SO_2 both in 2000 and 2007. Estimates for NO_x are however about 25% lower compared to the measurements. Infrequent point measurements are not a guarantee to get high quality data, and efforts are under way to extend the measurement program. Measurements from the coal fired power plant in Barentsburg have not been available for this study. Such measurements are needed in order to enhance the confidence in emission estimates from the energy sector. The diesel consumption for energy production in Svea is substantial (8200 tons in 2007), and measurements related to this activity would be beneficial to further improve the data quality.

The true emission factors for marine vessels will depend on their operation modes. Vessels within the Svalbard zone operate in general under lower temperatures than elsewhere. Tourist cruise ships might have frequent stops and start-ups. These two factors alone could clearly contribute to increase the emission factors compared to the global average emission factors for marine vessels employed in our study. Local measurements of emissions from marine vessels operating in the Svalbard zone could turn out to be a key parameter when considering abatement measures.

The uncertainty in emission estimates for particulate matter is generally assumed to be much higher than for the other pollutants included here (Monks et al., 2009). Measurements related to “dust”, interpreted here as Total Suspended Particulate matter (TSP), have been performed at the power plant in Longyearbyen. Black carbon (BC) or soot is however related only to light absorbing part of the particles. According to Kupiainen and Klimont (2004) the fraction of BC in TSP is less than 0.3%. Our estimates of BC from the energy production in Longyearbyen (0.17 tons in 2007) are less than 0.1% of the dust measurements (223 tons in 2007).

We have performed a sensitivity analysis to see how the results change if a different set of emissions factors than those adapted from Bond et al. (2004) had been applied. Kuipiainen and Klimont (2007) developed emission factors for BC and OC considered to be European specific. A comparison between the emission factors we have applied and those recommended by Kuipiainen and Klimont (2007) shows that emission factors applied in this study generally fall within their emission factor ranges, with a few exceptions (Table 7). The emission factors we have applied for coal combustion are low compared to the uncontrolled emission factors published by Kuipiainen and Klimont (2007). They underline however that if the plant is equipped with particulate matter (PM) abatement devices, emission factors could be substantially lower. The plant in Longyearbyen is equipped with multi-cyclone removal of PM. In addition the emissions of OC from passenger cars estimated in this study could be low. In conclusion, our estimates for BC and OC seem to be on the conservative side. There is however a large spread in emission factors depending on fuels, technologies and degree of abatement, and it is recommended to obtain local measurements for stationary sources as well as better emission factors for the marine activities in order to decrease the uncertainty in emission estimates of BC and OC.

Table 7: Comparison of emission factors. Unit g/kg

	This study based on Bond et al (2004)		K&K (2007)		Remarks K&K (2007)
	BC	OC	BC	OC	
Industry and power plants	0.0265	0.0079	0.0043-0.0341	0.0008-0.0150	Diesel regularly maintained-heavy fuel oil uncontrolled
	0.0065	**0**	0.1124-6.0415	0.0562-4.9175	Hard coal. Large uncontrolled automatic feed to small old manual boilers
Heavy duty vehicles	0.8514	0.2709	0.2585-1.4654	0.1293-0.9051	Diesel. EURO II to uncontrolled
Light duty vehicles	0.0434	**0.0459**	0.0399-0.8780	0.0711-11.8360	Gasoline. EURO II to uncontrolled
Marine transport	1.0217	0.3251	0.4741-1.9894	0.3017-1.3398	Diesel to heavy fuel oil

Our estimates for shipping of coal from the ports at Svalbard were made by emission factors applicable for marine gas oil (MGO). In a later stage of our study, we were informed that many of the "PANAMAX" type vessels (defined as vessels of a size that can safely pass through the Panama channel) involved in this activity actually applied heavy bunker oil (HBO) as fuel. Recalculation of the emission estimates with HBO resulted in an increase in SO_2 emissions by a factor 8 from this sector (compared to MGO). Emissions of CO_2, NO_x, BC, and OC will remain as estimated for MGO, while emissions of methane will be reduced (by a factor 4) due to the less volatile nature of HBO compared to MGO (Appendix 3). The Norwegian Ministry on the Environment restricted in 2009 the use of heavy fuel oil within the Svalbard national parks (http://www.regjeringen.no/pages/2237191/forskrift_tungolje.pdf). It is essential not only for the emission of pollutants, but also for the environmental implications of an accident with leakage of heavy fuel oil, that these regulations are followed by all vessels in the Svalbard waters.

A comparison between our results and emission estimates from Scandinavian Airlines (SAS), available on the SAS web page, indicates that the emission factors we have applied for scheduled flights might be too low. Further evaluations are needed to find out if this is indeed the case. It is expected that detailed information will become available from the airlines when aviation is included in the European Trading System in 2010. This information could then be reviewed for potential implementation and improvements of national inventories for aviation.

6. Scenario evaluation

6.1 Basis for the scenario development

In order to realistically assess the environmental impacts of future emissions and to allow politicians and other decision makers to initiate the right actions to prevent adverse effects and maintain a sustainable environment, it is important that the input parameters reflects as closely as possible the actual future development. Short- (until 2012) and long-term (until 2025) scenarios of climate related emissions are developed and analysed here. The scenarios developed for this study are based on the historical growth rates per sector (Appendix 6) and the expected future social and infrastructure development as discussed in recent reports by the Norwegian Institute for Urban and Regional Research (NIBR, 2008a; 2008b). In addition, the author team had continuous contact with all relevant institutions and companies at Svalbard during the study. Company and institution strategies and considerations which were found relevant for the future emissions of climate influencing compounds have thus been implemented in the scenarios.

Some potential important developments have not explicitly been explored in the scenario evaluation:

- Implications of the ongoing financial crisis;
- Increased marine transport through the North East passage and through the central Arctic ocean if global warming and melting ice opens new cargo routes;
- Potential future petroleum related activities in the Svalbard waters

NIBR (2008a) anticipate that the population in the Norwegian settlement Longyearbyen will continue to grow in the following decades. In addition, mining activities at Svalbard, as an important backbone of the population structure on Svalbard will continue. In this situation, increasing demands for energy and infrastructure is foreseen. There is also an increasing interest of the international tourist industry on "destination Svalbard", and new research activities and infrastructures are also foreseen to be established. If no further measures to abate emissions from these activities are taken, considerable increase in emissions must be expected.

We have developed three short-term (2012) and three long-term (2025) scenarios. The basis for and results of these scenarios are described in more detail in the following sections.

6.2 Short-term scenario development (2012)

Three short-term scenarios (S1-S3) were developed as outlined in Table 4. It is further assumed that all 2-stroke snow scooters are phased out by 2012.

Table 4: Characteristics of short-term (2012) scenarios

Scenario	Characteristics
S1: Continuous growth	A continuous growth from 2007 based on the 5-years average growth between 2002 and 2007.
S2: Industrial stagnation	SNSK has firm plans to reduce and stabilize annual coal production at about 2.5 million tons. This has been included in the scenario as well as a stagnation of the coal production in Barentsburg due to anticipated limitations in coal reserves. Projections for coal shipping and energy production are adjusted accordingly. All activities not directly related to the mining industry (e.g. tourism) continue to grow with the same growth rates as in S1.
S3: Curbed growth	Growth rates are modified after a recent study on future social and infrastructure development (NIBR, 2008a). The mining industry and related activities are kept at the same level as in S2.

The “Continuous growth” scenario is based on a linear continuation to 2012 of the average emission growth between 2002 and 2007 (Appendix 6). In the “Industrial stagnation” scenario, we incorporated information from SNSK (Nils Bjerg Tokheim, pers. communication) highlighting that the company is aiming at stabilizing coal production for the next years to around 2.0 - 2.5 million tons per year. This is about half the 2007 production, thus a considerable decrease in emissions compared to 2007 can be envisaged accompanied by a reduction in coal transportation and energy production in the years to come. Emissions in other sectors remain equal to the “Continuous growth” scenario.

The “Curbed growth” scenario takes the historical overall growth in activity of 4% (Appendix 6), modified by a study undertaken by NIBR (NIBR, 2008a) into account as well as industrial stagnation. In the “Curbed growth” scenario we aim to avoid a too strong dependence upon historical emissions per sector as they may fluctuate considerably. In addition, the growth in activity level between 2002 and 2007 is historically high (the overall growth was for instance only 2% in the period 2000-2005), and may lead to unrealistic high emissions for the near future. Table 5 tabulates the growth rates between 2007 and 2012 in the social, economic and infrastructure development in Longyearbyen as presented in NIBR (2008a).

According to NIBR (2008a), most sectors experience an average annual growth of about 1%. The increase in research and development is however foreseen to increase considerably more (about 6%). We have based our Curbed growth (S3) scenario particularly on the development foreseen in population (about 2%) and in the employment sector “Research and Development”. “Tourism related business” is by NIBR only estimated to grow by 1% per year towards 2012. However, tourist business related port calls have in average increased by 9% per year between 2002 and 2007 according to the Norwegian White Paper no. 22 (St. meld. Nr. 22, 2009). This growth is comparable to our historical emission growth (Appendix 6). We have anticipated a weaker increase in emissions for the years to come, yet a stronger increase (4% per year) in emission than for most other sectors.

Table 5: Projected population and employment development in Longyearbyen until 2012 under the continuous growth scenario (based on NIBR 2008a)

Man-labour years per main employment sectors [Number of years]	2007	2008	2009	2010	2011	2012	Overall Growth 2007-2012 [%]	Average Annual Growth [%]
Governmental activities	78	79	79	80	80	80	3	0.5
Community related activities	161	165	166	168	169	171	6	1.2
Research and Development	111	117	124	130	138	146	32	6.3
Students[2]	145	140	120	130	140	150	3	0.7
Mining	484	513	513	513	513	513	6	1.2
Tourism related business	211	213	216	218	220	222	5	1.0
Total	**1190**	**1227**	**1218**	**1239**	**1260**	**1282**	**8**	**1.5**
General developments								
Population in Norwegian settlements [persons]	2055	2131	2156	2183	2211	2241	9	1.8

The future development of society structures, industrial activities as well as infrastructure development in Barentsburg is more difficult to assess. Currently a population of 423 inhabitants is registered in Barentsburg compared to 2140 in Longyearbyen (http://www.ssb.no/emner/02/befsvalbard/tab-2009-10-22-01.html). Our approach has been to modify the Longyearbyen data in Table 5 to develop a scenario also for this settlement.

For increase in the research activity we foresee a smaller annual increase (5%) than the NIBR data would imply because parts of the research activity is not necessarily emission intensive. Diesel driven generators for energy production are foreseen replaced by modern bio-diesel technology in Longyearbyen around 2010. Due to uncertainties linked to the timing of this abatement measure in Longyearbyen, the effect of this measure has only been taken into account in the long-term scenarios.

The annual growth rates over the 5-year period 2007-2012 as applied for S3 is shown in Appendix 7. It should be pointed out here that the method applied to project emissions from the base year 2007 and onwards to 2012 and 2025 (mostly annual percentage changes), implies that the percentage emission change per sector between 2007 and a given scenario will remain the same for all the climate influencing pollutants considered. Because the sectoral distribution of emissions differs (e.g. Appendix 5), the percentage change in total emissions may still differ considerably.

6.3 Long-term scenario developments (2025)

In order to evaluate the effect on the emissions of long-term variations in the emission drivers, a time horizon up to 2025 was chosen. Three scenarios (L1-L3) were developed from the 2012 "Curbed growth" S3 scenario as outlined in Table 6. In addition to a continued growth scenario (L1), we have explored the effects on future emissions of an abandonment of all Norwegian mining activity (L2), as well as a strong increase in tourist related activities (L3). The motivation for choosing the two latter examples is given in Norwegian White Paper no.

[2] Adjusted according to recent (June 2009) information about the future activity level at the University at Svalbard (UNIS)

22 (St. meld. Nr. 22, 2009), which discusses the limitation in coal reserves at Svalbard and a possible inclusion of Svalbard on UNESCO's cultural heritage list. It is anticipated that the latter could increase the tourism at Svalbard further.

We have for all scenarios assumed that introduction of bio-diesel in Longyerbyen will reduce emissions from energy production by diesel by 60%. Diesel generators are planned replaced by modern bio-diesel technology in Longyearbyen. We anticipate that bio-diesel will be used only in the back-up electric power production and heating between 2012 and 2025. The original plan to establish bio-diesel power production also in Ny-Ålesund has recently been abandoned (Rune Drange, personal communication). Thus a continued increase in diesel consumption for power production is assumed both in Ny-Ålesund and in Svea. The 2012 "curbed growth" (S3) scenario was chosen as a starting point for the long-term scenarios because there were not found evidence for a rapid growth in neither economy nor coal production in the short-term.

Table 6: Characteristics of long-term (2025) scenarios

Scenario	**Characteristics**
L1: Continuous growth	A continuous growth equal to that for the short-term S3 scenario is assumed for all emission sectors at Svalbard.
L2: No SNSK mining	After 2012 a complete stop of the SNSK mining activities is assumed. Corresponding developments in energy production, marine coal and goods transport etc. is applied. Other activities stagnate at the 2012 S3 level.
L3: Doubling of tourism	Activities related to tourism have been doubled compared to the S3 scenario. Other activities stagnate at the 2012 S3 level.

In the long-term scenario L1, the growth rates defined for emissions up to 2012 in the S3, curbed growth scenario are continued (Appendix 7). Scenario L2 assumes that all Norwegian mining are abandoned, related activities are reduced but that activities in other sectors remain at 2012 S3 level. The last scenario explores the implications of a doubling in the tourism at Svalbard, while non-tourist related activities stagnate at 2012 S3 level.

6.4 Overall results on scenarios

In the "continuous growth" scenario, S1, emissions of climate influencing compounds increase between 8% (SO_2) and 70% (CH_4) (Table 7). Emissions of climate influencing pollutants will continue to grow towards 2012 even if coal production drops to half the 2007 level (scenario S2) as shown in Table 7 and illustrated for CO_2 emissions in Figure 12. The increase of about 30% is caused by growth in activities not directly related to coal mining like tourism and research. An exception is the releases of methane, which due to its strong dependency upon coal production, are reduced both the "Industrial stagnation" (scenario S2) and the "Curbed growth" (S3) scenarios (not shown). Curbing all emission sectors (scenario S3), has a considerably larger mitigating effect than reducing emissions from the mining industry alone. The anticipated phasing out of 2-stroke gasoline snow scooters by 2012 cause emissions of OC to decrease in the S3 scenario.

Table 7: Overview of scenarios. Percentage changes 2007-2012 and 2012 (S3) and 2025 for different short-term (S1-S3) and long-term (L1-L3) scenarios[3]. Unit: Percent

	2007-2012			2012-2025		
Component/scenario	**S1**	**S2**	**S3**	**L1**	**L2**	**L3**
CO_2	37	26	4	24	-9	26
CH_4	70	-33	-34	1	-59	1
SO_2	8	6	2	10	-1	5
NO_x	58	37	1	46	-10	53
BC	60	39	2	49	-10	56
OC	48	29	-10	50	-10	57

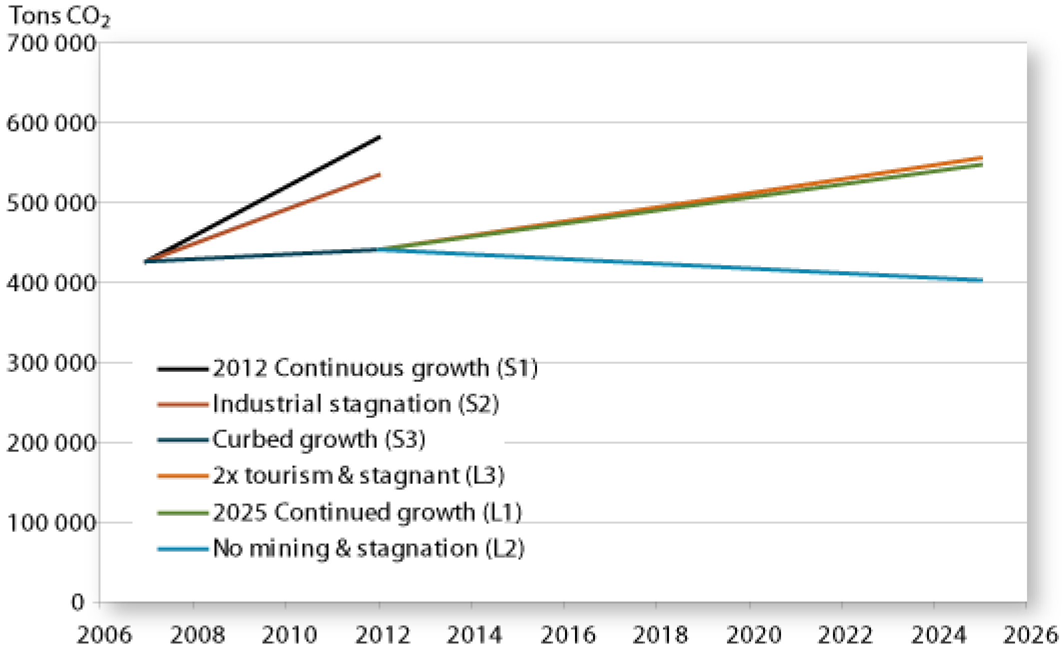


Figure 12: Development of CO_2 emissions at Svalbard under different scenarios

In the long-term L1 scenario, the growth towards 2025 is comparable to that found for the short-term "continuous growth" (S1) scenario, except for methane. The L1 takes into account the planned reduced coal production from Svea/LYR, which cause methane emissions to increase only slightly between 2012 and 2025 (1%). If all Norwegian mining is abandoned by 2025, but activities not directly related to the coal production are kept at the 2012 level (scenario L2), emissions of all pollutants are reduced in 2025 compare to 2012. Further, all climate influencing emissions, except SO_2, will in this scenario drop below the 2007 level by 2025 (Figure 12). SO_2 emissions fluctuate less than emissions of other pollutants. This is due to its strong dependency on energy production from coal, which does not vary considerably due to the continued demand for energy. The emission reductions obtained by a termination of all Norwegian mining activities at Svalbard are most likely underestimated as the coal mining industry is the major backbone of the social and economic structures for Svea and Lonyearbyen. Mining activities provide infrastructures and indirect employment (service providers etc.) for the majority of the population in Longyearbyen (NIBR 2008b).

[3] A negative number indicates a decrease

Doubling the tourist activity at Svalbard (scenario L3), while keeping all other sectors at 2012 level increases emissions by 2025 more than in the "Continued growth" scenario (L1) for all pollutants but SO_2 and methane (Figure 12). The reason is that CH_4 and SO_2 emissions are more affected by changes in production and combustion of coal than by the marine cruise activity.

6.5 Detailed results

This section focuses on the results of CO_2 and black carbon. Detailed results per sector for all compounds can be found in Appendix 8. Figure 13 shows the CO_2 emissions in 2007 together with the three short-term scenarios. Due to the expected increase cruise traffic, marine transport is the sector which experiences the steepest growth. The growing Svalbard population as well as strong demands from the mining industry and research infrastructures for continuous electric power supply, is followed by increases in electric power production also in the years to come. Consequently, the CO_2 emissions associated with coal based energy production are projected to increase accordingly in all the short-term scenarios. Marine transport and energy production together are estimated to contribute more than 90% to the total CO_2 2012 emissions in all three scenarios. This makes variations in other sectors less important.

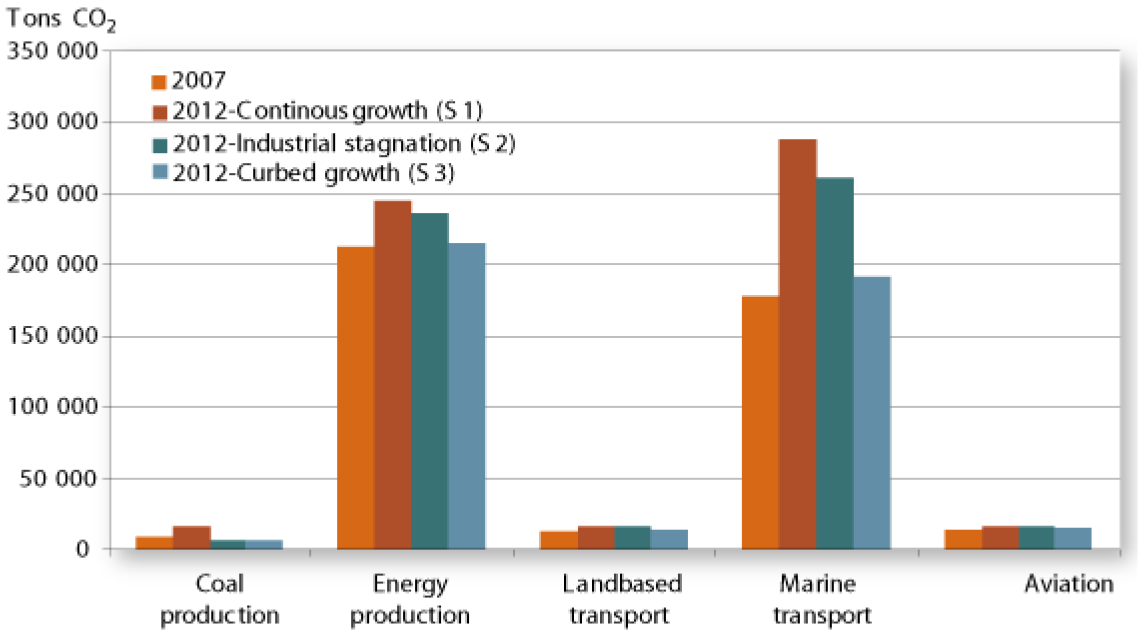


Figure 13: Short-term (2012) projection of CO_2 emissions at Svalbard

The largest variation in the three long-term scenarios is found for marine transport (Figure 14). Even though our scenarios are not likely to represent the real future emissions, this result points to the importance of marine transport when considering mitigation of climate influencing pollutants at Svalbard.

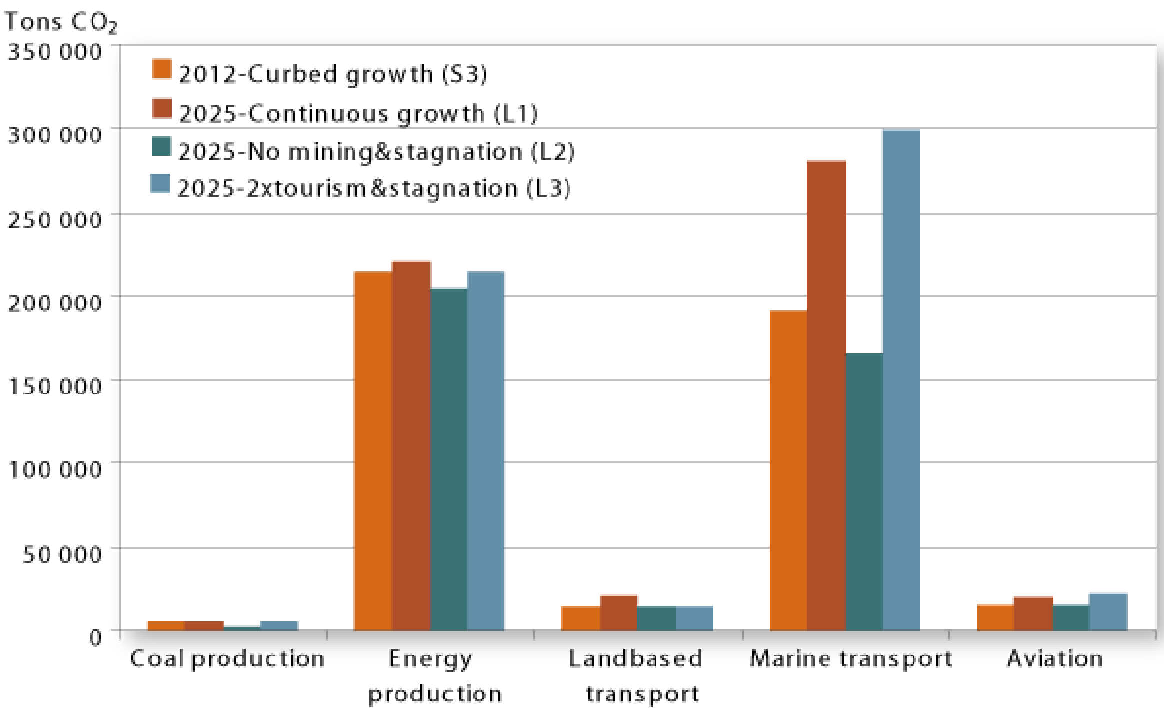


Figure 14: Long-term (2025) projection of CO_2 emissions at Svalbard

In comparison, close down of the Norwegian mines (scenario L2) results according to our rough estimates in a total reduction in methane and CO_2 of about 43 000 tons CO_2 equivalents from 2012 level (not shown). This is significantly less than the variation in long-term CO_2 scenarios for marine transport.

Cruise ships and coal transport are the two major sources of BC pollution at Svalbard and its surrounding waters. The share of BC emissions from cruise vessels increases considerably in our scenarios. In 2007, 45% of the BC emissions were emitted from cruise vessels, while 60% and nearly 70% originate from this source in the L1/L2 and L3 scenarios respectively (Appendix 8).

It is not unlikely that some of the marine emissions are deposited in the open ocean. Still the significance of this source to the deposition of black carbon on ice and snow in the Norwegian Arctic should not be underestimated. Eleftheriadis et al. (2009) establish by trajectory analysis that the main source regions for BC at Svalbard is northern and central Russia. However, emissions are also transported from Europe and USA. The long-range transport of BC from these regions, and possibly also Russia, may be considerably lower in the future due to reduction in emissions. Thus, the share of local to long-range contribution may increase further from today's estimate of around 20%. On the other hand, there are indications that climate change induced alteration in the atmospheric circulation may cause an increased transport of pollution northwards. A warmer climate at Svalbard would also allow more long-range transported BC to be deposited during winter. It will in either case be important to restrict additional local BC pollution.

7. Discussion of measures and mitigation options

Measures to fulfill a vision about a future Svalbard without releases of CO_2 is outlined in a report by SINTEF (2007). The aim of this section is to outline options for mitigation strategies to reduce the impacts of climate influencing emissions released at Svalbard based on the emission estimates and scenarios derived in the present study, and focused on technological measures. We believe that the emission estimates and scenarios are of sufficient quality and detail to provide a basis for possible future work on the analysis of measures.

7.1 Possible short-term mitigation options

In the short-term (until 2012) it is essential to find abatement options that reduce or at least curb the emissions in an effective way. The largest sources for climate influencing emissions are electric power plants, coal transportation and international tourist cruises. These sources are assumed to be abated most efficiently with technological measures in the short term. Long-term priorities (until 2025) can have a stronger focus on infra structure changes and priorities for the development of new society structures.

Due to required upgrading and administrative plans to alter the state of the technology for power supply facilities in selected settlements, some rather immediate changes are already in the pipeline. Based upon reports available from Bydrift Longyearbyen as well as status reports from Barentsburg, the power plants have now reached the limits of their capacity. Thus, the electricity providing infrastructure for both Longyearbyen and Barentsburg needs increased capacity and modernization already today. With these requirements as a forceful driver, a rather quick transfer to a cleaner power production seems feasible to achieve. In addition, replacement of back-up power supply systems in Longyearbyen with bio-diesel driven generator technology is under way according to Bydrift Longyearbyen. Thus, reduction in future emissions may be expected due to upgrading and replacing of currently used machinery.

In our analysis of climate influencing emissions at Svalbard three emission sources are identified as the major contributors to the total emissions in 2007 (Table 2):

- Shipping and cruise activities (CO_2 = 42%, NO_X = 90 %, BC=93%, OC=83%)
- Local coal and diesel based electric power supply (CO_2 = 50%, SO_2 = 92 %)
- Mining activities (CH_4 = 98 %)

Technology up-grades in these three sectors will have the potential of immediate and large reductions of the local emissions. A set of mitigation options which may immediately reduce emissions if implemented is listed below. We emphasis that further work on the feasibility of measures is required before any recommendations can be given.

Options to reduce emissions from shipping activities
Shipping activities around Svalbard (e.g. tourist cruises and coal transportation) are identified as the largest emission source for most of the pollutants evaluated. A possible mitigation option is a transition of fuel types from heavy bunker fuel to marine diesel and marine gas-oil for all maritime transportation. In addition, emissions can be reduced by the introduction of

filter systems and selective catalytic reduction (SCR) or other types of technology improvements. A third option is transfer from marine diesel to gas.

Options to reduce emissions from energy production

Emission from energy production is high, thus this sector has a large potential for immediate emission reductions of CO_2 and sulphur emissions. A transfer from coal to non local energy sources as main fuel for the power plants might lead to increased emissions associated with the transportation of fuels. Therefore, also in the future it might turn out to be optimal to rely on a combination of modern technology and fuel in combination with locally produced coal.

Modernisation of existing outdated technology would in the short-term contribute to reduction of emissions. The handling and storage of potential waste materials from filtration activities should preferably be done locally in order to avoid increased emissions from transportation and waste treatments. A transfer from traditional diesel to second generation bio-diesel is a mitigation option for diesel based power supply.

In addition, industries, consumers and the local communities should be made familiar with and be given incentives to follow general knowledge on how to minimize the energy consumption (National Norwegian ENØK rules).

Options to reduce emissions from mining activities

The local mining industry is the predominant source of methane. Due to the closed character of the Svalbard mines, the CH_4 emission from coal mining activities is expected to escape mainly through the ventilation systems in the mines at Svea and Longyearbyen. Development of a CH_4-filter system in the mine ventilation system seems like a solution to reduce the venting of methane. Possible technological solutions could be developed and explored.

With respect to emissions of coal dust during storage in open piles unprotected by the wind (not included in our study), closed environment controlled storage facilities would reduce the emissions. Transport emissions of coal dust could probably also be minimized if the truck loads were protected.

Other short term mitigation options for reduced emissions

Land-based transportation and stationary machinery, mainly employed within the local industry is identified as a significant emission source for some pollutants (Table 2). A combined filter system for the removal of particulate materials as well as adapted catalytic technology based on today's technological standard for the removal of polluting compounds from the exhaust of the heavy duty vehicles and large stationary machinery would reduce emissions. Likewise, climate influencing emissions would be reduced if all new vehicles at Svalbard follow the EURO standards. High standards for handling and maintenance of vehicles would further reduce harmful emissions.

2-stroke engine technology without catalytic or filter systems removing harmful components from the exhaust could be phased out in order to reduce the hazardous emissions.

7.2 Possible long-term actions

Long term priorities might be focused on the more complex structural improvements including infrastructures. In order to achieve and sustain a minimum of climate influencing emission at Svalbard, both the consciousness and the acceptance of the local communities, including research and industry, is mandatory for a long lasting effect. In addition, strategies must be in place to ensure that emission rates are kept low.

A main outcome of an earlier study (SINTEF, 2007) was that development of modern filter technology for the separation and collection of CO_2 and other pollutants from the exhaust plume of the power plants (CCS) should be encouraged, and adequate technologies should be applied in the electric power plants at Svalbard. Drilling is currently ongoing to investigate if the geological formations close to Longyerbyen are suitable for storing CO_2. If CCS turns out to be a feasible mitigation option at Svalbard, emission reductions would benefit from an inclusion of the power plant in Barentsburg (contributing up-to 70% to the emission from the energy production sector).

Centralizing the energy distribution network for all major settlements including Barentsburg with electric energy is another mitigation option which could result in a considerable reduction of environmentally harmful emissions.

The development of new technologies adapted to the local Arctic environmental conditions should be encouraged, and could include filter techniques, carbon capture from large emission sources, application of gas and fuel cells. In addition, the development of local applicable technologies utilizing renewable energy sources should be given priority in the future. Application of solar-, and tidal energy should be evaluated and eventually adapted.

With respect to the shipping activities around Svalbard, continued transition from marine diesel to gas and possibly other fuel types like hydrogen and fuel cells, together with implementation of state-of-the-art technology would further reduce the emissions.

7.3 Implications and perspectives

This study on climate influencing pollutants emitted locally at Svalbard concludes that today’s emission rates will continue to increase in the future unless additional measures are taken. Appropriate and sustainable measures should be given priority, which are also considering the needs and the growth potential for the local populations at Svalbard including both the demands for industrial progression, social needs and municipality related aspects. Today, the mining industry is the predominant societal pillar at Svalbard both for the Norwegian and the Russian settlements.

The coal reserves at Svalbard are anticipated to last until approximately 2030 (SNSK, 2008). Total reserves are estimated to around 63 million tons with about 31 million tons accessible from the Svea mining site. With the recent planned annual production volume of 2.5 million tons per year, the Svea reserves will be exhausted in 12 years and the total coal reserves on Svalbard will allow processing coal for the next 25 years. Technological solutions in combination with education of the local populations as well as centralizing the largest local emissions sources have the potential to reduce the emissions considerably. How large reductions specific measures might cause and the cost of measures involved is out of scope of this study. The work documented here could therefore be continued in order to have a better basis for policy development of both short and long term strategies. In this respect, dispersion modeling studies based on the novel emission inventories presented to study the effects of local emissions as well as cost-benefit analyses to prioritize between measure highlighted and possibly other mitigation options could be performed.

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Appendices

Appendix 1: Questionnaire on the consumption of fossil fuel and emission profiles

Questionnaire distribution to the authorities and important local acteurs on Svalbard including tourist agencies. industrial infrastructures. municipalities and R&D infrastructures

Data information on the consumption of fossil fuel and emission profiles for Svalbard

Roland Kallenborn (status 03.10.2008)

Consumption information

Please provide information on amount [t/ L / m3] usage

Institution/ company								
Name								
Contact person								
e-mail								
phone								
Gasoline	**Annual average values**							
Additional information (percentage distribution)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Used for electricity production								
Used for usual transportation (scooter/ cars)								
Used for heavy transportation (lorries. heavy production equipment)								
Used for other type of applications (Specify)								
SPECIFICATION	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**

Diesel									
Additional information (percentage distribution)									
Used for electricity production									
Used for usual transportation (scooter/ cars)									
Used for heavy transportation (lories. heavy production equipment)									
Used for other type of applications (Specify)									
Coal									
Additional information (percentage distribution)									
Used for electricity production									
Used for other type of applications (Specify)									
Annual roduction (kt)									
CO_2 emission information available									
CO_2 emission through Electric power production									
CO_2 emission through coal mine activities									
(production. refinement. storage and maintenance)									
NO_x emission information available									
NO_x emission through Electric power production									
NO_x emission through coal mine activities									
(production. refinement. storage and maintenance)									
Transportation and shipping									
Cruise ships (arrivals)									
Number of passengers registered									
Cruise ships (average duration: days/ h per ship)									
Average emission CO_2 per ship during cruise around Svalbard									
Average emission NO_X per ship during cruise around Svalbard									

SPECIFICATION	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Estimated fuel consumption								
Transportation and freighters								
Transport ships (arrivals)								
Estimated fuel consumption								
Average emission CO_2 per ship around Svalbard								
Average emission NO_X per ship around Svalbard								
Additional information (optional)								
CH_4 (Methane) emission estimates via mining activities								
CH_4 (Methane) emission estimates via electric power production								
CH_4 (Methane) emission estimates through heating of houses and facilities								
CH_4 (Methane) emission estimates via other activities (specify)								

Appendix 2: Activity data - Information sources and assumptions

Sector	Fuel/Activity	Information source	Assumptions
Coal production	Svea, Barentsburg, Longyerbyen	SSB, 2007	All date were directly used as provided by SFT (2008)
Energy production	*Coal:* Local domestic? coal combustion	Bydrift Longyearbyen, Hornsund , Trust Arktikugol and SMS	No assumptions
	Diesel: Consumption in large generators. Bio-diesel under development	Kingsbay, Bydrift-Longyearbyen	No assumptions
Land based Transport	*Diesel:* Private cars, heavy duty vehicles	Fuel consumption statistics (LNS) and vehicle registration (AutoSys)	40% Diesel driven private cars 100% Heavy duty vehicles **Private cars:** Annual average distance [km]: 2500 Average consumption [L/100 km]: 5 **Heavy duty vehicles:** annual average distance [km]: 100 000 Average consumption [l/100 km]: 30
	Gasoline: private cars, snow scooters (2-stroke engine), snow scooters (4-stroke engine	Consumption statistics (LNS) and vehicle registration (NPRA: AutoSys)	60% Gasoline driven private cars during the entire evaluation period. Snowmobile (SM); year 2000: 100% 2-stroke engine driven; 10% annual increase of 4-stroke driven SM; 2007: 30% 2-stroke, 70%-4-stroke SM **Private cars:** Annual average distance [km]: 2500 Average consumption [L/100 km]: 8 **Snowmobiles (2-stroke engines):** Average annual distance: 3000 km Average consumption [L/km]: 30 **Snowmobile (4-stroke engines):** Annual average distance [km]: 3000 Average consumption [L/100 km]: 6
Aviation	*Jet-1-A/Kerosene:* Scheduled flights, charter, Freight, ambulance, instruction flights, other civil flights	AVINOR statistics, supplementary information from SAS and the local carriers	**Scheduled flights (domestic and international):** Distance/ leg: Tromsø – Longyearbyen Flight time [min]: 90 ***Carrier: Boeing 737-800*** Fuel consumption/leg [L]: 4938 **Transportation/ others:** Distance/ leg: Tromsø – Longyearbyen Flight time [min]: 90 ***Carrier: CRJ200 and BA146*** ***Fuel consumption: 1200 kg/h*** Fuel consumption/leg [L]: 1800 **Charter/ local transportation** (Do228 + SuperPuma helicopter): ***Carrier: Do228*** Average flight time/d [min]: 60 Average annual flight time [d]: 200 Average consumption [L/ h]: 293 ***Carrier: SuperPuma (Helicopter):*** Average flight time/d [min]: 40 Average annual flight time [d]: 150 Average consumption [L/ h]: 620 ***Carrier: MI 8 MT (SPARC)***

Sector	Fuel/Activity	Information source	Assumptions
			Average flight time/d [min]: 40 Average annual flight time [d]: 150 Average consumption [L/ h]: 620 **Average flight activities (local)** **(*60% Fixed wing + 40% helicopter*)** Average flight time [h/a]: 8000 Average consumption [L/h]: 424
Shipping	*Heavy Bunker oil, MGO, Marine diesel:* **Tourist activities**: International and daily cruises, Expeditions	Bykaia statistics (port authorities) and input from Tourist information (Svalbard Reiseliv)	**International cruises (large vessels > 500 passengers):** Average cruise duration in the Svalbard zone [d]: 4 Large vessels, MGO consumption [t/d]: 100 **Expeditions (medium size vessels > 80 passengers):** *Extended topic focused tourist activities:* Average cruise duration in the Svalbard zone [d]: 12 Medium vessels, MGO consumption [t/d]: 30 **Daily cruises (local activities: 30 -100 passengers:** Duration of the annual season [d]: 153 Cruise duration/d [h]: 6 MGO consumption [T/d]: 1 [kg/h]: 41.7
	Heavy bunker oil, MGO, Marine diesel: **Research activities:** Research vessels	Bykaia statistics, with supplementary information provided by the Norwegian Polar Institute (LANCE) and the University Centre in Svalbard (UNIS)	Average cruise duration in the Svalbard zone [d]: 6 Average MGO consumption [T/d]: 10
	Bunker oil, MGO, Marine diesel: **Transportation of coal**	Based on SNSK statistics (Svea, Longyearbyen) and information provided by Trust Arktikugol	Carrier: PANAMAX vessel, Average size 50 000 BWT Heavy bunker consumption [T/d]: 70 Average cruise duration Tromsø – Svalbard round trip [d]: 4
	Bunker oil, MGO, Marine diesel: **Transportation of goods**	http://www.zahltransport.no/ and www.norbjorn.no	Carrier (Norbjørn/ Greenfrost), size: 3 000 BWT Norbjørn: MGO consumption: [T/d]: 20 Average cruise duration Tromsø – Svalbard round trip [d]: 3 Greenfrost: Heavy bunker oil consumption: Annual consumption: 1040 T

Appendix 3: Emission factors and references per sector, fuel and pollutant

Sector (fuel) / pollutant	CO_2 [kg/kg]	CH_4 [g/kg]	SO_2 [g/kg]	NO_x [g/kg]	BC[k] [g/kg]	OC[k] [g/kg]
4-stroke vehicles (Gasoline)	3.13[a]	1.07[c]	0.01[a]	8.30[d]	0.0434	0.0459
2-stroke vehicles (Gasoline)	3.18[b]	5.85[d]	0.01[a]	2.74[d]	0.7125	11.2575
Heavy duty vehicles (Diesel)	3.17[a]	0.10[c]	0.03[a]	23.70[d]	0.8514	0.2709
Power production (Diesel)	3.17[b]	0.40[e]	0.80[h]	2.50[i]	0.0265	0.0079
Power production (Coal)	2.52[a]	0.28[e]	16.00[a]	3.00[i]	0.0065	0
Aviation (Jet 1A/ Kerosene)	3.15[a]	0.19[j]	0.28[a]	6.85[j]	0.0980	0.0280
Shipping (Heavy oil)	3.20[a]	0.23[f]	13.60[h]	60.80[f]	1.0217	0.3251
Shipping (Marine diesel)	3.17[a]	0.80[g]	1.80[h]	56.76[g]	1.0217	0.3251
Shipping (Marine gas oil)	3.17[a]	0.80[g]	1.80[h]	60.80[f]	1.0217	0.3251

References:

a. Statistics Norway (2007). Norwegian Emission Inventory. Table B1. p. 131

b. IPCC (1996) Guidelines for National Greenhouse gas inventories: Reference manual.

c. Statistics Norway (2007) Norwegian Emission Inventory. Table B11. p. 134

d. Statistics Norway (2007) Norwegian Emission inventory. Table B10. p. 134.

e. Statistics Norway (2007) Norwegian Emission Inventory. Table B22. p.138

f. Statistics Norway (2007) Norwegian Emission Inventory. Table B 13. p.135

g. Statistics Norway (2007) Norwegian Emission Inventory. Table B 14. p.136

h. Statistics Norway (2007) Norwegian Emission Inventory. Table B 3. p.132

i. Statistics Norway (2007) Norwegian Emission Inventory. Table B 26. p.139

j. Statistics Norway (2007) Norwegian Emission Inventory. Table B 7. p.133

k. Bond et al. (2004)

Appendix 4: Distribution of emissions within the Svalbard zone in 2007.

Unit: Tons

Sector / Component	CO_2	CH_4	SO_2	NO_x	BC	OC
COAL PRODUCTION	**9120.715**	**3328.728**	**NE**	**NE**	**NE**	**NE**
Svea/LYR	5981.771	2183.128	**NE**	**NE**	**NE**	**NE**
Barentsburg	3138.944	1145.600	**NE**	**NE**	**NE**	**NE**
ENERGY PRODUCTION	**211976.304**	**24.028**	**1153.599**	**239.680**	**0.727**	**0.079**
Coal	180438.300	20.049	1145.640	214.808	0.464	0.000
Diesel	31538.004	3.980	7.959	24.872	0.263	0.079
LANDBASED TRANSPORT	**12846.089**	**2.037**	**0.103**	**86.503**	**3.173**	**3.595**
Gasoline	1703.024	1.696	0.005	3.185	0.180	2.643
Passenger cars	315.053	0.108	0.001	0.835	0.004	0.005
Snow scooters, 4-stroke	645.316	0.221	0.002	1.710	0.009	0.009
Snow scooters, 2-stroke	742.655	1.367	0.002	0.639	0.166	2.629
Diesel	11143.065	0.341	0.098	83.318	2.993	0.952
Passenger cars	156.955	0.005	0.001	1.174	0.042	0.013
Heavy duty vehicles	10986.111	0.336	0.096	82.145	2.951	0.939
MARITIME TRANSPORTATION	**177059.558**	**44.684**	**100.539**	**3286.425**	**57.066**	**18.157**
Cruise	85953.758	21.692	48.807	1539.033	27.703	8.814
International	64668.000	16.320	36.720	1157.904	20.842	6.632
Expedition	20922.000	5.280	11.880	374.616	6.743	2.146
Day	363.758	0.092	0.207	6.513	0.117	0.037
Coal transportation	61244.400	15.456	34.776	1174.656	19.739	6.281
Svea/LYR	56806.400	14.336	32.256	1089.536	18.309	5.825
Barentsburg	4438.000	1.120	2.520	85.120	1.430	0.455
Research vessels	13123.800	3.312	7.452	251.712	4.230	1.346
Goods transportation	12172.800	3.072	6.912	233.472	3.923	1.248
Svea/LYR	11792.400	2.976	6.696	226.176	3.801	1.209
Barentsburg	380.400	0.096	0.216	7.296	0.123	0.039
Administration and surveillance	4564.800	1.152	2.592	87.552	1.471	0.468
AVIATION	**13784.721**	**0.811**	**1.225**	**29.995**	**0.429**	**0.123**
Scheduled	10861.200	0.639	0.965	23.634	0.338	0.097
Domestic	10785.600	0.635	0.959	23.469	0.336	0.096
Internationanal	75.600	0.004	0.007	0.165	0.002	0.001
Charter	1048.420	0.062	0.093	2.281	0.033	0.009
Domestic	860.119	0.051	0.076	1.872	0.027	0.008
International	188.301	0.011	0.017	0.410	0.006	0.002
Freight	204.577	0.012	0.018	0.445	0.006	0.002
Domestic	190.799	0.011	0.017	0.415	0.006	0.002
International	13.778	0.001	0.001	0.030	0.000	0.000
Other	962.058	0.057	0.086	2.093	0.030	0.009
Commercial	507.493	0.030	0.045	1.104	0.016	0.005
Ambulance	367.416	0.022	0.033	0.799	0.011	0.003
Instruction	87.149	0.005	0.008	0.190	0.003	0.001
Other Civil	708.467	0.042	0.063	1.542	0.022	0.006
Svalbard TOTAL	**424787.387**	**3400.288**	**1255.466**	**3642.603**	**61.294**	**21.954**
Svalbard emissions/capita (Total: 2338)	181.688	1.454	0.537	1.558	0.026	0.009
Norwegian mainland TOTAL	45000000	210000	19700	193500	NE	NE
Norwegian mainland emissions/capita (Total: 4737171)	9.499	0.044	0.004	0.041	NE	NE
Svalbard emission in percent of Norwegian mainland	0.944	1.619	6.373	1.882	NE	NE

Appendix 5: Key source analysis of emission source categories at Svalbard in 2007.

Key sources in bold. Unit: Percent

Component/Sector	CO_2	CH_4	SO_2	NO_x	BC	OC
COAL PRODUCTION	2.147	**97.895**	NE	NE	NE	NE
ENERGY PRODUCTION	49.902	0.707	91.886	6.580	1.185	0.360
Coal	**42.477**	0.590	**91.252**	**5.897**	0.756	0.000
Diesel	**7.424**	0.117	0.634	0.683	0.429	0.360
LANDBASED TRANSPORT	3.024	0.060	0.008	2.375	5.167	16.377
Gasoline	0.401	0.050	0.000	0.087	0.293	12.039
Passenger cars	0.074	0.003	0.000	0.023	0.007	0.021
Snow scooters, 4-stroke	0.152	0.006	0.000	0.047	0.015	0.043
Snow scooters, 2-stroke	0.175	0.040	0.000	0.018	0.271	**11.975**
Diesel	2.623	0.010	0.008	2.287	4.875	4.337
Passenger cars	0.037	0.000	0.000	0.032	0.069	0.061
Heavy duty vehicles	**2.586**	0.010	0.008	2.255	**4.806**	**4.276**
MARINE TRANSPORTATION	41.682	1.314	8.008	90.222	92.950	82.705
Cruise	20.235	0.638	3.888	42.251	45.122	40.149
International	**15.224**	0.480	**2.925**	**31.788**	**33.948**	**30.207**
Expedition	**4.925**	0.155	0.946	**10.284**	**10.983**	**9.773**
Day	0.086	0.003	0.016	0.179	0.191	0.170
Coal transportation	14.418	0.455	2.770	32.248	32.151	28.608
Svea/LYR	**13.373**	0.422	**2.569**	**29.911**	**29.821**	**26.535**
Barentsburg	1.045	0.033	0.201	**2.337**	2.330	2.073
Research vessels	**3.089**	0.097	0.594	**6.910**	**6.889**	**6.130**
Goods transportation	2.866	0.090	0.551	6.409	6.390	5.686
Svea/LYR	**2.776**	0.088	0.533	**6.209**	**6.191**	**5.508**
Barentsburg	0.090	0.003	0.017	0.200	0.200	0.178
Administration and surveillance	**1.075**	0.034	0.206	**2.404**	**2.396**	**2.132**
AVIATION	3.245	0.024	0.098	0.823	0.699	0.558
Scheduled	2.557	0.019	0.077	0.649	0.550	0.440
Domestic	**2.539**	0.019	0.076	0.644	0.547	0.437
Internationanal	0.018	0.000	0.001	0.005	0.004	0.003
Charter	0.247	0.002	0.007	0.063	0.053	0.042
Domestic	0.202	0.001	0.006	0.051	0.044	0.035
International	0.044	0.000	0.001	0.011	0.010	0.008
Freight	0.048	0.000	0.001	0.012	0.010	0.008
Domestic	0.045	0.000	0.001	0.011	0.010	0.008
International	0.003	0.000	0.000	0.001	0.001	0.001
Other	0.226	0.002	0.007	0.057	0.049	0.039
Commercial	0.119	0.001	0.004	0.030	0.026	0.021
Ambulance	0.086	0.001	0.003	0.022	0.019	0.015
Instruction	0.021	0.000	0.001	0.005	0.004	0.004
Other Civil	0.167	0.001	0.005	0.042	0.036	0.029
TOTAL	100.000	100.000	100.000	100.000	100.000	100.000

Appendix 6: Emissions and scenarios for CO_2 2000-2007, 2012, 2025.

Emission unit: Tons. Growth rates in percent

Source sectors/Years	2000	2001	2002	2003	2004	2005	2006	2007	Growth rate 2002-2007	Average Annual Growth rate 2002-2007	2012-Continous growth (S1)	2012-Industiral stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	1 104	2 661	3 203	4 475	4 408	2 234	3 608	5 982	87	17	13 312	3 672	3 672	3 672	**0**	3 672
Coal production: Barentsburg	8 142	5 729	4 542	7 419	3 204	3 280	1 757	3 139	-31	-6	2 282	2 282	2 282	2 282	2 282	2 282
Energy production Coal	171 884	177 713	175 093	164 676	181 996	177 311	175 587	180 438	3	1	186 014	186 014	184 995	197 387	184 995	184 995
Energy production: Diesel	13 831	17 308	19 058	24 645	21 481	22 917	27 007	31 538	65	13	58 357	49 603	29 597	22 972	**19 527**	29 597
Passenger cars: Gasoline	176	178	206	235	252	265	277	315	53	11	523	523	331	377	331	331
Passenger cars and heavy duty vehicles: Diesel	8 906	9 958	9 569	8 491	7 333	8 506	8 026	11 143	16	3	13 101	13 101	12 918	18 970	12 918	12 918
Snow scooters: 2-stroke gasoline	2 175	1 991	1 851	1 794	1 513	1 287	997	743	-60	-12	392	392	0	0	0	0
Snow scooters: 4-stroke gasoline	145	196	254	261	359	477	508	645	154	31	2 468	2 468	785	1 307	785	1 569
Marine Transport: Tourist cruises	50 450	55 522	55 522	70 104	73 591	80 882	71 372	85 954	55	11	144 591	144 591	104 576	174 127	104 576	209 152
Marine Transport: Research vessels	5 326	8 939	8 039	6 277	4 375	9 700	12 173	13 124	63	13	23 809	23 809	16 750	31 584	16 750	16 750
Marine Transport: Coal transportation Svea and Barentsburg	51 481	31 066	48 818	66 570	55 919	35 504	54 144	61 244	25	5	78 503	50 944	50 944	50 944	**25 472**	50 944
Marine Transport: Administration and surveillance	1 331	1 331	2 282	2 378	2 378	3 709	3 424	4 565	100	20	11 359	11 359	5 040	6 520	**5 040**	6 048
Marine Transport: Goods Barentsburg/ Supply LYR and Svea	1331	2663	6086	3994	4565	11222	15216	12 173	100	20	30 290	30 290	13 440	17 386	**13 440**	16 128
Aviation: Sheduled flights	12726	14906	12575	12083	12121	11516	11617	10 861	-14	-3	9 460	9 460	11 992	15 512	11 992	17 987
Aviation: charter flights	599	855	861	997	944	1060	1244	1048	22	4	1 297	1 297	1 215	1 785	1 215	1 823
Aviation: Freight and other	1028	944	891	962	1423	1401	1440	1875	110	22	5 088	5 088	2 070	2 678	2 070	2 070
TOTAL	**330 637**	**331 960**	**348 849**	**375 361**	**375 860**	**371 273**	**388 398**	**424 787**	22	4	**580 844**	**534 892**	**440 606**	**547 502**	**401 392**	**556 266**

Appendix 7: Assumption for scenario developments

Category	Sub-category	Annual growth	Remarks
Coal production	Longyearbyen/Svea		Reduction in and stabilization of coal production by 2012 at 2.5 million T/a. That is half the production in 2007, and implies about 10% decrease annually 2007-2012.
	Barensburg		2012 production remaining at 2007 level
Energy production	Coal	0.5 %	Reduced according to coal production
	Diesel	2%	Equal to population growth, but reduced by15% due to reduced coal production. After 2012, 60% drop in diesel consumption due to installations of new bio-diesel generators Longyearbyen.
Landbased transportation	Passenger cars: Gasoline	1%	According to population growth, but diesel vehicles increase more than gasoline
	Passenger cars and heavy duty vehicles: Diesel	3%	
	Snow scooters: 2-stroke		2-stroke engines phased out by 2012
	Snow scooters: 4-stroke	4%	Overall growth
Marine Transport	Tourist cruises	4%	Overall growth
	Research vessels	5%	Comparable to growth in R&D
	Coal transportation Svea and Barentsburg		Reduced by 50% from 2007 to 2012 S2&S3. A further 50% reduction in the 2025 L 2 scenario.
	Administration and surveillance	2%	According to population growth
	Goods Svea, LYR, Barentsburg	2%	According to population growth
Aviation	Scheduled flights	2%	According to population growth.
	Charter flights	3%	According to population growth. Larger increase in charter than scheduled flights.
	Freight and other transportation	2%	According to population growth

Appendix 8: Emissions and scenarios for climate influencing compounds per sector 2000-2007, 2012 and 2025.

Unit: Tons

CO2

Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	5 981.77	13 311.73	3 671.60	3 671.60	3 671.60	0.00	3 671.60
Coal production: Barentsburg	3 138.94	2 282.06	2 282.06	2 282.06	2 282.06	2 282.06	2 282.06
Energy production Coal	180 438.30	186 014.05	186 014.05	184 994.59	197 386.68	184 994.59	184 994.59
Energy production: Diesel	31 538.00	58 356.83	49 603.31	29 597.43	22 972.46	19 526.59	29 597.43
Passenger cars: Gasoline	315.05	522.75	522.75	331.12	376.85	331.12	331.12
Passenger cars and heavy duty vehicles: Diesel	11 143.00	13 100.54	13 100.54	12 917.79	18 970.21	12 917.79	12 917.79
Snow scooters: 2-stroke gasoline	742.65	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	645.00	2 468.25	2 468.25	784.74	1 306.65	784.74	1 569.48
Marine Transport: Tourist cruises	85 953.76	144 590.56	144 590.56	104 575.89	174 126.54	104 575.89	209 151.78
Marine Transport: Research vessels	13 124.00	23 808.84	23 808.84	16 749.92	31 584.47	16 749.92	16 749.92
Marine Transport: Coal transportation Svea and Barentsburg	61 244.00	78 502.94	50 944.04	50 944.04	50 944.04	25 472.02	50 944.04
Marine Transport: Administration and surveillance	4 564.80	11 358.68	11 358.68	5 039.91	6 519.66	5 039.91	6 047.89
Marine Transport: Goods Barentsburg/ Supply LYR and Sve	12 172.80	30 289.82	30 289.82	13 439.75	17 385.76	13 439.75	16 127.71
Aviation: Sheduled flights	10 861.20	9 459.63	9 459.63	11 991.64	15 512.47	11 991.64	17 987.46
Aviation: charter flights	1 048.42	1 297.40	1 297.40	1 215.41	1 784.86	1 215.41	1 823.11
Aviation: Freight and other	1 875.10	5 087.52	5 087.52	2 070.26	2 678.11	2 070.26	2 070.26
Svalbard TOTAL	**424787**	**580452**	**534499**	**440606**	**547502**	**401392**	**556266**

CH4

Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	2183.13	4858.29	1340.00	1340.00	1340.00	0.00	1340.00
Coal production: Barentsburg	1145.60	832.87	832.87	832.87	832.87	832.87	832.87
Energy production: Coal	20.05	20.67	20.67	20.55	21.93	20.55	20.55
Energy production: Diesel	3.98	7.36	6.26	3.73	2.90	2.46	3.73
Passenger cars: Gasoline	0.11	0.18	0.18	0.11	0.13	0.11	0.11
Passenger cars and heavy duty vehicles: Diesel	0.34	0.40	0.40	0.40	0.58	0.40	0.40
Snow scooters: 2-stroke gasoline	1.37	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	0.22	0.84	0.84	0.27	0.45	0.27	0.54
Marine Transport: Tourist cruises	21.69	36.49	36.49	26.39	43.94	26.39	52.78
Marine Transport: Research vessels	3.31	6.01	6.01	4.23	7.97	4.23	4.23
Marine Transport: Coal transportation Svea and Barentsburg	15.46	19.81	15.46	15.46	15.46	15.46	15.46
Administration and surveillance	1.15	2.87	2.87	1.27	1.65	1.27	1.53
Marine Transport: Goods (LYR, Svea and Barentsburg)	3.07	7.64	7.64	3.39	4.39	3.39	4.07
Aviation: Sheduled flights	0.64	0.56	0.56	0.71	0.91	0.71	1.06
Aviation: charter flights	0.06	0.08	0.08	0.07	0.11	0.07	0.11
Aviation: Freight and other	0.11	0.30	0.30	0.12	0.16	0.12	0.12
Svalbard TOTAL	**3400**	**5794**	**2271**	**2250**	**2273**	**908**	**2278**

SO2

Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	NE	NE	NE	NE	NE	NE	NE
Coal production: Barentsburg	NE	NE	NE	NE	NE	NE	NE
Energy production: Coal	1 145.64	1 181.04	1 181.04	1 174.57	1 253.25	1 174.57	1 174.57
Energy production: Diesel	7.96	14.73	12.52	7.47	5.80	4.93	7.47
Passenger cars: Gasoline	0.001	0.002	0.002	0.001	0.001	0.001	0.001
Passenger cars and heavy duty vehicles: Diesel	0.10	0.11	0.11	0.11	0.17	0.11	0.11
Snow scooters: 2-stroke gasoline	0.002	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	0.002	0.008	0.008	0.003	0.004	0.003	0.005
Marine Transport: Tourist cruises	48.81	82.10	82.10	59.38	98.87	59.38	118.76
Marine Transport: Research vessels	7.45	13.52	13.52	9.51	17.93	9.51	9.51
Marine Transport: Coal transportation Svea and Barentsburg	34.78	44.58	22.29	22.29	22.29	11.14	22.29
Administration and surveillance	2.59	6.45	6.45	2.86	3.70	2.86	3.43
Marine Transport: Goods (LYR, Svea and Barentsburg)	6.91	17.20	17.20	7.63	9.87	7.63	9.16
Aviation: Sheduled flights	0.97	0.84	0.84	1.07	1.38	1.07	1.60
Aviation: charter flights	0.09	0.12	0.12	0.11	0.16	0.11	0.16
Aviation: Freight and other	0.17	0.45	0.45	0.18	0.24	0.18	0.18
Svalbard TOTAL	**1255**	**1361**	**1337**	**1285**	**1414**	**1272**	**1347**

NOx							
Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	NE	NE	NE	NE	NE	NE	NE
Coal production: Barentsburg	NE	NE	NE	NE	NE	NE	NE
Energy production: Coal	214.81	221.45	221.45	220.23	234.98	220.23	220.23
Energy production: Diesel	24.87	46.02	39.12	23.34	18.12	15.40	23.34
Passenger cars: Gasoline	0.83	1.39	1.39	0.88	1.00	0.88	0.88
Passenger cars and heavy duty vehicles: Diesel	83.32	97.96	97.96	96.59	141.84	96.59	96.59
Snow scooters: 2-stroke gasoline	1	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	1.71	6.54	6.54	2.08	3.46	2.08	4.16
Marine Transport: Tourist cruises	1 539.03	2 588.95	2 588.95	1 872.47	3 117.80	1 872.47	3 744.94
Marine Transport: Research vessels	251.71	456.64	456.64	321.26	605.77	321.26	321.26
Marine Transport: Coal transportation Svea and Barentsburg	1 174.66	1 505.68	752.84	752.84	752.84	376.42	752.84
Administration and surveillance	87.55	217.86	217.86	96.66	125.05	96.66	116.00
Marine Transport: Goods (LYR, Svea and Barentsburg)	233.47	580.95	580.95	257.77	333.46	257.77	309.33
Aviation: Sheduled flights	23.63	20.58	20.58	26.09	33.75	26.09	39.14
Aviation: charter flights	2.28	2.82	2.82	2.64	3.88	2.64	3.97
Aviation: Freight and other	4.08	11.07	11.07	4.50	5.83	4.50	4.50
Svalbard TOTAL	**3643**	**5758**	**4998**	**3677**	**5378**	**3293**	**5637**

BC							
Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	NE	NE	NE	NE	NE	NE	NE
Coal production: Barentsburg	NE	NE	NE	NE	NE	NE	NE
Energy production: Coal	0.46	0.48	0.48	0.48	0.51	0.48	0.48
Energy production: Diesel	0.26	0.49	0.41	0.25	0.19	0.16	0.25
Passenger cars: Gasoline	0.004	0.007	0.007	0.005	0.005	0.005	0.005
Passenger cars and heavy duty vehicles: Diesel	2.99	3.52	3.52	3.47	5.10	3.47	3.47
Snow scooters: 2-stroke gasoline	0.17	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	0.01	0.03	0.03	0.01	0.02	0.01	0.02
Marine Transport: Tourist cruises	27.70	46.60	46.60	33.70	56.12	33.70	67.41
Marine Transport: Research vessels	4.23	7.67	7.67	5.40	10.18	5.40	5.40
Marine Transport: Coal transportation Svea and Barentsburg	19.74	25.30	12.65	12.65	12.65	6.33	12.65
Administration and surveillance	1.47	3.66	3.66	1.62	2.10	1.62	1.95
Marine Transport: Goods (LYR, Svea and Barentsburg)	3.92	9.76	9.76	4.33	5.60	4.33	5.20
Aviation: Sheduled flights	0.34	0.29	0.29	0.37	0.48	0.37	0.56
Aviation: charter flights	0.03	0.04	0.04	0.04	0.06	0.04	0.06
Aviation: Freight and other	0.06	0.16	0.16	0.06	0.08	0.06	0.06
Svalbard TOTAL	**61**	**98**	**85**	**62**	**93**	**56**	**98**

OC							
Source sectors/Scenarions	2007	2012-Continous growth (S1)	2012-Industrial stagnation (S2)	2012-Curbed growth (S3)	2025-Continuous growth (L1)	2025 - No mining& stagnation (L2)	2025-2xtourism& stagnation (L3)
Coal production: LYR and Svea	NE	NE	NE	NE	NE	NE	NE
Coal production: Barentsburg	NE	NE	NE	NE	NE	NE	NE
Energy production: Coal	0	0	0	0	0	0	0
Energy production: Diesel	0.08	0.15	0.12	0.07	0.06	0.05	0.07
Passenger cars: Gasoline	0.005	0.008	0.008	0.005	0.006	0.005	0.005
Passenger cars and heavy duty vehicles: Diesel	0.95	1.12	1.12	1.10	1.62	1.10	1.10
Snow scooters: 2-stroke gasoline	2.63	0	0	0	0	0	0
Snow scooters: 4-stroke gasoline	0.01	0.04	0.04	0.01	0.02	0.01	0.02
Marine Transport: Tourist cruises	8.81	14.83	14.83	10.72	17.86	10.72	21.45
Marine Transport: Research vessels	1.35	2.44	2.44	1.72	3.24	1.72	1.72
Marine Transport: Coal transportation Svea and Barentsburg	6.28	8.05	4.03	4.03	4.03	2.01	4.03
Administration and surveillance	0.47	1.16	1.16	0.52	0.67	0.52	0.62
Marine Transport: Goods (LYR, Svea and Barentsburg)	1.25	3.11	3.11	1.38	1.78	1.38	1.65
Aviation: Sheduled flights	0.10	0.08	0.08	0.11	0.14	0.11	0.16
Aviation: charter flights	0.01	0.01	0.01	0.01	0.02	0.01	0.02
Aviation: Freight and other	0.02	0.05	0.05	0.02	0.02	0.02	0.02
Svalbard TOTAL	**22**	**31**	**27**	**20**	**29**	**18**	**31**

KLIMA- OG FORURENSNINGS-DIREKTORATET

Klima- og forurensningsdirektoratet
Postboks 8100 Dep, 0032 Oslo
Besøksadresse: Strømsveien 96
Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@klif.no
Internett: www.klif.no

Utførende institusjon	ISBN-nummer
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Oppdragstakers prosjektansvarlig	Kontaktperson i Klima- og forurensningsdirektoratet	TA-nummer
Signe Nåmdal	Vigdis Vestreng	2552/2009
		SPFO-nummer

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Forfatter(e)

Vigdis Vestreng; Klima- og forurensningsdirektoratet
Roland Kallenborn; Universitetssenteret på Svalbard og Norsk institutt for luftforskning
Elin Økstad; Klima- og forurensningsdirektoratet

Tittel - norsk og engelsk

Norwegian Arctic Climate - Climate influencing emissions, scenarios and mitigation options at Svalbard

Norsk Arktis klima– Klimarelaterte utslipp, scenarier og utslippsreduserende tiltak på Svalbard

Sammendrag – summary

Utarbeidelse av utslippsregnskap og utslippsscenarier for Svalbard av stoffer som påvirker klimaet, som grunnlag for strategier vedrørende utslippsreduserende tiltak og politikkutforming.

Development of emission inventories and scenarios for climate influencing compounds at Svalbard, as a basis to develop strategies for emission reduction measures and policies.

4 emneord	4 subject words
Svalbard – klima - utslipp - tiltak	Svalbard – Climate - Emissions - Measures

Klima- og forurensningsdirektoratet
Postboks 8100 Dep,
0032 Oslo
Besøksadresse: Strømsveien 96

Telefon: 22 57 34 00
Telefaks: 22 67 67 06
E-post: postmottak@klif.no
www.klif.no

Om Klima- og forurensningsdirektoratet

Klima- og forurensningsdirektoratet (Klif) er fra 2010 det nye navnet på Statens forurensningstilsyn. Vi er et direktorat under Miljøverndepartementet med 325 ansatte på Helsfyr i Oslo. Direktoratet arbeider for en forurensningsfri framtid. Vi iverksetter forurensningspolitikken og er veiviser, vokter og forvalter for et bedre miljø.

Våre hovedoppgaver er å:

- redusere klimagassutslippene
- redusere spredning av helse- og miljøfarlige stoffer
- oppnå en helhetlig og økosystembasert hav- og vannforvaltning
- øke gjenvinningen og redusere utslippene fra avfall
- redusere skadevirkningene av luftforurensning og støy

TA-2552 /2009

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