REPORT

Estimating air pollution emission abatement potential in Sweden 2030

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Report Summary

Project title

Åtgärdspotential för luftutsläpp till 2030 (NV-04257-12)

Project sponsor

Swedish Environmental Protection Agency, Swedish Clean air Research Programme

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Title and subtitle of the report

Estimating air pollution emission abatement potential in Sweden 2030

Summary

The two principal aims with this project was to adjust the discrepancy between Swedish official air pollution emission projections and scenarios for Sweden developed by other international institutions, and to analyse the emission abatement potential in Sweden by 2030.
Data used to support the Swedish official emission projections was collected and reformatted to enable a comparison with scenario data for Swedish emissions developed by IIASA. The results of this comparison were discussed with IIASA during the bilateral consultation carried out as a part of the on-going revision of the EU Thematic Strategy for Air Pollution. In parallel to this consultation, the potential for further emission abatement in Sweden by 2030 was analysed by interviewing representatives of power plants and large industrial facilities.
The comparison with IIASA emission scenarios for Sweden identified that much of the differences between Swedish projections and IIASA emission scenarios originate from the transport sector, small scale domestic combustion in households, as well as from burning of agricultural waste. The potential for NO_x emission abatement was estimated for the sectors: power plants; refineries; pulp & paper industries; and the iron & steel industry. If all plants in these sectors were to use the best available technology in 2030, NO_x emissions could be reduced by some 13 kton NO_x, or ≈38% of the 35 kton emissions projected from these sectors by 2030. Abatement costs could in this project only be estimated for 2.3 kton. For these, the abatement cost would be ≈170 million Swedish crowns per year.

Keyword

Air pollution, emission abatement, emission scenario

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Abstract

This report presents the results from the project "Åtgärdspotential för luftutsläpp till 2030 / Emission abatement potential for air pollution in Sweden by 2030", financed by the Swedish Environmental Protection Agency and the Swedish Clean Air Research Programme (SCARP). The main objective of the project was to support Sweden´s position in the on-going revision of the EU Thematic Strategy for Air Pollution (TSAP) including the bilateral consultations on emission projections and abatement potentials. There were two specific aims in the project. One was to adjust the discrepancy between Swedish official air pollution emission projections and the scenarios for Sweden developed by other international institutions. The other aim was to analyse the emission abatement potential in Sweden by 2030. The air pollutants initially considered were NO_x, SO_2, NH_3, $PM_{2.5}$, and NMVOC.

An extensive background data compilation covering the sectors contributing to air pollutant emissions in Sweden was performed. The data compilation served to provide a data set in a GAINS model[1] format identical to the data set used in the development of the officially reported Swedish emission projection. Data on energy demand and supply, transport activities, and industrial as well as agricultural activities were collected from the Swedish Energy Agency, the Swedish Road Administration and the Swedish Environmental Protection Agency, as well as directly from the project responsible for producing the official Swedish emission projection (SMED[2]). Having acquired this dataset, the data was re-aggregated and re-allocated to fit the GAINS model format, which was necessary for a fruitful comparison with the IIASA baseline scenario and the bilateral consultation with IIASA. The comparison had its main focus on the pollutants NO_x and $PM_{2.5}$, and the sectors transport and small scale domestic combustion in households. It was not feasible to cover all sectors and all pollutants during the bilateral consultation, although some additional comparisons were made (inter alia NMVOC).
During the bilateral consultation it was identified that there are differences between the Swedish emission projection and the IIASA baseline scenario in reported (base year data) and projected data on fuel use, emission factors, and use of emission control technologies in the road and non-road transport sectors. There is also a difference in the assumed boiler structure (and type of boilers) for domestic small scale domestic combustion. The use of emission control technologies in large scale combustion plants also differs between national estimates and IIASA calculations. We also noted that emissions from burning of agricultural waste are included in the IIASA baseline scenario but not in the Swedish emission projection. Burning of agricultural waste is in the IIASA baseline scenario was assigned around 1 kton of $PM_{2.5}$ emissions, or some 5 % of the total projected Swedish $PM_{2.5}$ emissions in 2030.

[1] The GAINS model assesses strategies that reduce emissions of multiple air pollutants and greenhouse gases at least costs, and minimize their negative effects on human health, ecosystems and climate change (http://www.iiasa.ac.at/web/home/research/researchPrograms/GAINS.en.html ,as of 2013-04-04)
[2] http://www.smed.se/, as of 2013-04-04

In order to estimate the current and future use of emission control technologies and the emission abatement potential for stationary combustion in Sweden interviews were performed using email questionnaires with representatives for the 111 Large Combustion Plants (LCP) mandated to report official environmental information in accordance with the European Pollutant Release and Transfer Register (EPRTR) directive. The interview answers were translated and aggregated to a suitable format. These aggregated interview answers were then used as a basis for estimating a national use of NO_x emission control technologies in Sweden in large scale combustion. As an indication of the potential for further emission reductions in Sweden beyond the Swedish emission projection we calculated the maximum technical feasible emission abatement (MTFR) potential from LCP:s and other combustion plants in Sweden. This potential was calculated as the difference between actual emission reductions derived from the questionnaire answers and the MTFR technological ambition level as specified in an ambitious IIASA scenario. We used the projected Swedish energy balance in the Swedish emission projection as basis for the emission calculations. $PM_{2.5}$ emission abatement potential for small scale domestic combustion was estimated by replacing the emission factor used in the Swedish emission projection with the emission factor used in the IIASA baseline scenario.

Regarding the estimated emission abatement potential, the interview answers provided support to estimate NO_x emission abatement potential. For the other pollutants, the answers were not possible to translate into quantitative estimates. NO_x emission abatement potential was estimated for the sectors: power plants; refineries; pulp & paper industries; and the iron & steel industry. Emission abatement costs were calculated for some sectors. If all plants in these sectors were to use the best available technology in 2030, as defined in IIASA TSAP report #1[3], NO_x emissions would in our central analysis be reduced by some 13 kton NO_x, or ≈38% of the 35 kton expected from these sectors by 2030. In a sensitivity analysis, the corresponding NO_x emission abatement was 10 kton (33%). For the sectors where we could estimate emission abatement costs, the additional annual abatement costs for reducing 2.3 kton of NO_x emissions would be ≈170 million Swedish crowns, when calculated with the GAINS model[4] method. Unit abatement cost was some 71 Swedish crowns / kg NO_x. In order to get an additional comparison we discussed the results with IIASA experts. The comparative results calculated by IIASA experts based on scenarios in the IIASA TSAP report #10[5], gave a NO_x emission abatement potential of 9 kton, or 20% of the 44 kton NO_x emissions expected in the IIASA scenario. The IIASA results for the sectors where emission abatement costs were calculated was an emission reduction potential of 6.6 kton of NO_x to a cost of ≈260 million Swedish crowns, corresponding to an average 39 Swedish crowns / kg NO_x (ranging between 22 – 184 crowns for the subsectors). The difference between the 35 kton NO_x in the Swedish projection and the 44 kton NO_x calculated in the IIASA scenario are caused mainly by different perspectives on the expected use of emission control technology in 2030, but also by different projections on economic activity and fuel use in the sectors, and by different approaches to allocation emission between sectors.

[3] (Amann et al., 2012)
[4] http://www.iiasa.ac.at/web/home/research/researchPrograms/GAINS.en.html, as of 2013-07-08
[5] (Amann et al., 2013)

Estimated NO_x emission reduction potential and abatement costs in Swedish large stationary installations 2030 – Central analysis (incl. cost efficiency in sensitivity analysis)

Sector	Most prominent measures	BSL emissions	MTFR emissions	Emission reduction	Reduction cost	Aggregated cost efficiency	Cost efficiency in sensitivity
		kton	kton	kton	MSEK	SEK / kg NO_x	SEK / kg NO_x
Power plants	Combustion modification, selective- and non-selective catalytic reduction	9.8	7.5	2.3	166	71	(117)
Refineries	Process-related measures: Selective- and non-selective catalytic reduction	0.33	0.32	0.01	4	446	(735)
Industry, process & energy related emissions	Pulp & Paper and Iron & Steel measures: Combustion modification, selective- and non-selective catalytic reduction	25.2	14.0	11.2	*	*	*
Total		35.3	21.8	13.5			

*No emission abatement costs are calculated for emission reduction from processes in this version of the GAINS model

For industrial emission sources we could not disaggregate emissions or estimate emission abatement costs. For the other sectors, the cost efficiency range provided a rough estimate on the cost efficiency if the emission reduction potential (due to different economic and energy development) would be on the lower range of the potential. Our results indicated that the most cost effective NO_x emission abatement will be available in power plants 2030.

The overall conclusion drawn from the bilateral consultation with IIASA was that some of the discrepancies between the IIASA baseline scenario and the Swedish official emission projection can be avoided by adjusting the IIASA baseline scenario to better represent specific Swedish conditions. This solution applies mainly to the use of emission control technologies in vehicles in 2010 for the transport sector and the boiler structure and use of emission control for small scale domestic combustion in households. The discrepancy in emission factors for the transport sector would need further motivation before adjustment of the IIASA baseline scenario. Other differences, such as growth in fuel use and future renewal of the vehicle fleet, are scenario-specific and should for consistency not be adjusted in an effort to make emission levels calculated in the IIASA baseline scenario to better match the emission levels in the Swedish emission projection.
It can also be concluded that there is additional potential for Swedish NO_x emission abatement in the sectors: power plants; refineries; pulp & paper industries; and the iron & steel industry, in 2030. It is also likely that there will be additional Swedish $PM_{2.5}$ emission abatement potential from small scale domestic combustion. The results from the interviews with representatives of the LCP:s indicated that there are differences between the IIASA

baseline scenario and the plant-specific information regarding the current and future use of emission control technologies in Sweden. This report has focused mainly on technical end-of-pipe emission abatement potential for some of the Swedish pollution sources, and the pollutants NO_x and $PM_{2.5}$. Further analysis is needed to develop a complete national estimate for SO_2, NO_x, NH_3, $PM_{2.5}$ as well as NMVOC.

Thanks to the bilateral consultation and the adjustments made at IIASA after this consultation, the largest part of the discrepancy between the Swedish emission projection and following IIASA scenarios are mainly due to different views between Sweden and the European Commission on future economic growth, fuel prices, energy demand, and turnover of the vehicle fleet.

Contents

Introduction

This report present the results from the project "Åtgärdspotential för luftutsläpp till 2030 / Emission abatement potential for air pollution in Sweden by 2030", financed by the Swedish Environmental Protection Agency and the Swedish Clean Air Research Programme (SCARP). The project was performed as support to the Swedish positions during the on-going (2013) review of the EU Thematic Strategy on Air Pollution (TSAP) (European Commission, 2005), and the EU National Emissions Ceilings Directive (NEC) (Official Journal of the European Union, 2001).

To support this revision, the European Commission (EC) is preparing decision support for the EU member states. Parts of this decision support are air pollution emissions-, and emission control cost scenarios for the EU countries and the following air pollutants: Sulphur dioxide (SO_2), Nitrogen oxides (NO_X), Ammonia (NH_3), Non-Methane Volatile Organic Compounds (NMVOC), and fine particulate matter ($PM_{2.5}$). However, these scenarios are not aligned with corresponding Swedish projections and needs further national review and alignment. To facilitate the TSAP & NEC revision process the EC arranged the opportunity for the EU member states to participate in bilateral consultations with the International Institute for Applied System Analysis (IIASA) during autumn 2012. During these bilateral consultations results and assumptions in the IIASA scenarios could be reviewed by national experts for potential adjustments. For an active Swedish participation in the revision of the TSAP & NEC it is therefore necessary to perform a detailed comparison between the IIASA scenarios and the Swedish emission projection, and to suggest adjustments where suitable. It is also important to estimate the Swedish emission abatement potential in 2030.

There were two principle aims with this project. The first was to review and adjust the discrepancy between the emission scenarios produced by IIASA and the official Swedish emission projections. The identified causes for the discrepancies between the scenario and projection should then serve as input to an adjusted IIASA scenario for Sweden. The IIASA scenario and the Swedish projection should be aligned with respect to emission factors and the use of emission control technologies. The second aim was to analyse the Swedish emission abatement potential in 2030. The overall objective with the project was that that the results from this project would be useful as a part of the Swedish decision support during the revision of the TSAP & NEC.
The key research questions were the following:

- What are the main sources for discrepancies between Swedish official air pollution emission projections and emission projections/scenarios for Sweden developed by international institutions? How can these discrepancies be avoided?
- What is the emission abatement potential on top of already expected emission reductions in Sweden by 2030?

Background

The emission scenarios developed as decision support are created in the GAINS model, which is developed by IIASA (Amann et al., 2004, 2008). The IIASA scenarios discussed during the bilateral consultations are presented in the IIASA TSAP report #1 (Amann et al., 2012). During the summer 2012, Sweden developed new air pollution emission projections up until the year 2030 (Gustafsson et al., 2012). These projections served as basis for the Swedish participation in the bilateral consultation with IIASA and will serve as basis for the Swedish position in the review of the TSAP and NEC during 2013.

As seen in Table 1 and Table 2 below, there are discrepancies between the baseline scenario in Amann et al. (2012) and the projection in Gustafsson et al. (2012). These discrepancies have an impact on which emission levels that can be considered as baseline emission levels in 2030, but also on which further emission abatement potential that exists in Sweden in 2030. They will therefore affect the Swedish position during the review of the TSAP and NEC. In this report, to increase readability, the baseline scenario in Amann et al. (2012) is referred to as "IIASA BSL scenario", and the projection in Gustafsson et al. (2012) is referred to as "SWE BSL projection".

Table 1: Air pollution emission trends for Sweden and % change from 2005 in the IIASA BSL scenario

Pollutant	2000	2005	2010		2020		2030	
	kiloton (kton)	Kton	kton	Change (%)	kton	Change (%)	Kton	Change (%)
SO_2	44	35	30	-16%	26	-25%	26	-27%
NO_x	258	210	157	-25%	92	-56%	70	-67%
$PM_{2.5}$	35	32	26	-18%	21	-33%	21	-32%
NH_3	57	54	50	-7%	52	-4%	53	-2%
NMVOC	269	205	156	-24%	119	-42%	115	-44%

Table 2: Air pollution emission trends for Sweden and % change from 2007 in the SWE BSL projection

Pollutant	2000	2005	2007		2020		2030	
	Kton	Kton	kton		kton	Change (% from 2007)	Kton	Change (% from 2007)
SO_2	-	-	33		28	-15	29	-12
NO_x	-	-	168		106	-37	82	-51
$PM_{2.5}$	-	-	29		23	-21	22	-24
NH_3	-	-	53		48	-9	48	-9
NMVOC	-	-	192		147	-23	135	-30

Differences in projections as the ones presented above are in themselves nothing unusual, since emissions of the considered pollutants to a large extent depends on factors such as economic growth and expected fuel use etc.
There are previous experiences with linking Swedish emission projections with IIASA scenarios. In (Åström, Lindblad, & Kindbom, 2013), a systematic approach was developed that enabled translation of Swedish energy- and transport projections to a format that enabled comparison with IIASA scenarios.

Our project group participated with informal support to the Swedish position during the EU coordination leading to the revised Gothenburg protocol on May 4 2012[6]. At the time, the project group identified that the largest avoidable discrepancies between Swedish emission projections and IIASA emission scenarios for Sweden were for the pollutants NO_x and $PM_{2.5}$ and the sectors transport and small scale domestic combustion in households. Discrepancies were also large for NMVOC, but there were little room for improving the discrepancies mainly due to differences in methodological approach.

There is to this date very little aggregated data on the current and future use of emission control technologies in Sweden. This lack of data has impeded the possibility to perform appropriate comparisons with IIASA scenarios, since this information is a very important parameter when calculating emissions.

6 http://www.unece.org/index.php?id=29858, as of 2013-02-19

Materials and Method

This project consisted mainly of two parts. The first part involved the detailed review of, and bilateral consultation on, discrepancies between the SWE BSL projection and the IIASA BSL scenario. The second part involved the estimation of an emission abatement potential in Sweden in 2030. The analyses required slightly different approaches, so the method description is in this report presented separately for these two parts. The analyses were also subject to a number of delimitations.

Delimitations

This project was restricted with respect to the pollutants and sectors possible to analyse. Therefore, during the preparations for the bilateral consultation with IIASA we therefore chose to focus mainly on the air pollutants and sectors identified as most important during the previously performed informal support to the Swedish position during the EU coordination leading to the revised Gothenburg protocol.

We reviewed emission levels, emission factors and use of emission control technologies for both the IIASA BSL scenario and the SWE BSL projection. The potential causes for discrepancies in emissions of SO_2 and NH_3 were disregarded since it was estimated that Sweden would not have large problems achieving any potential NEC directive emission ceiling for these pollutants in 2030. Discrepancies in NMVOC emissions were, except for some sector specific details, disregarded due to large differences between the IIASA and Swedish methods and input data used to calculate NMVOC emission scenarios. These differences made comparisons too time consuming to be covered in this project.

When estimating the emission abatement potential in Sweden, we focused on emission abatement potential in Large Combustion Plants (LCP) and similar combustion plants. Because of this, the pollutants of concern were NO_x, $PM_{2.5}$, and SO_2, since emissions of NMVOC and NH_3 are small from these plants. We also estimated $PM_{2.5}$ emission abatement potential from small scale domestic combustion in households, since previously mentioned experience had shown large discrepancies and room for improvement there. Furthermore, the calculated emission abatement potential only included the potential made available by end-of-pipe emission control technologies known today. Other options, such as structural measures, behavioural changes, energy efficiency improvements, or fuel shifts were not considered.
Other relevant information is that we focused on the years 2005 and 2030. However, data or projections for the years 2007, 2010 and 2020 were sometimes used as support.

Review of discrepancies between SWE BSL projection and IIASA BSL scenario

In order to review causes for the discrepancies in the estimates for Swedish emissions in 2030 we compiled background data used in the SWE BSL projection and converted the data to a GAINS model format. The converted data and results then served as a common platform for comparison with the IIASA BSL scenario.

Data compilation

The background data used in the SWE BSL projection originate from a number of different reports and sector-specific modelling activities. Much of the background data needed for the review were available in reports, but detailed data obtained by personal communication were often needed as complement.

The data compilation in this project was based on the following sources of information:

- The macro-economic projections developed by the Swedish National Institute for Economic Research (NIER) (Berg, Forsfält, & Nilsson, 2012)
- The Swedish Energy system projections as reported by the Swedish Energy Agency (SEA) (Swedish Energy Agency, 2013), and with details from personal communication (Swedish Energy Agency, personal communication, 2012)
- The detailed description of transport projections as calculated by the Swedish Transport Administration (STA) with respect to fuel use, vehicle vintage, emissions, and emission factors for the road transport and Non-road Mobile Machinery (NRMM) sectors (excluding shipping). Data for the road transport sector were produced with the Swedish version of the HBEFA model[7], while data for the NRMM sector was produced by an independently developed tool (Swedish Transport Administration, personal communication, 2012a,b).
- Detailed background material on agricultural activities from the Swedish EPA used in the projection of NH_3 emission projections (Swedish EPA, personal communication, 2012).
- Detailed descriptions and background material for Sweden on fuel use, emission factors, and emissions compiled for the SWE BSL projection (SMED, personal communication, 2012).

On an aggregated level, the background data show that the Swedish economy is estimated to grow by some 2% per year from 2009 – 2030, where the service sector will account for most of the growth (Berg et al., 2012). Until 2030, the total energy use will increase by 5.2% to 2383 PetaJoules (PJ) from 2007 levels (Swedish Energy Agency, 2013). This growth is largely supplied by a growth in bio fuel use. This increase is caused by larger electricity and heat demand in industry. Energy used for transport and heating & cooling in

[7] http://www.hbefa.net/e/index.html, as of 2013-04-04

buildings will however decrease. For road transport, the energy demand will decrease from 281 PJ in 2005 to 251 PJ in 2030 (Swedish Transport Administration, personal communication, 2012a). The number of animals in the agricultural sector, as well as the crop land and pasture areas, will decline slightly by 2030 (Swedish EPA, personal communication, 2012).

Data treatment

The classification of fuels and sectors differs between the GAINS model approach and the SEA approach. It was necessary to re-allocate the SEA data on energy content in fuels and sectors. Most important was that the GAINS model does not include energy produced in heat pumps and that the energy content in process gases (coke gas etc.) are classified as gas in the SEA approach, while it is classified as coal in the GAINS model approach. Furthermore, the GAINS model separates between new and existing power plants and between boilers and other combustion for industry. The SEA does not provide this type of information. We therefore used the shares (% of total installations) of new and existing power plants, and the shares of boilers and other combustion for industry, already specified in the IIASA BSL scenario as basis when converting Swedish data to a GAINS model format. The specific conversion of data into a GAINS model format followed the method presented in Lövblad and Kindbom (2008) and Åström et al. (2013). The scenario-specific data used for re-allocation and re-aggregation in Åström et al. (2013) were updated with corresponding data from the IIASA BSL scenario.

National data and emission calculations in the GAINS model

The national data in a GAINS model format were then uploaded to the GAINS model[8]. When data on emission factors differed between the Swedish estimates and GAINS model estimates we calculated emissions independent of the GAINS model but used the same method as in the GAINS model. The emissions were calculated by using the following equation:

Equation 1: Calculation of emissions in the GAINS model

$$E_i = \sum_{j,k,m} E_{i,j,k,m} = \sum_{j,k,m} A_{i,j,k} ef_{i,j,k} (1 - eff_m) X_{i,j,k,m}$$

Where:

i,j,k,m	Country, sector, fuel, abatement option
Ei	Emissions in country i
A	Activity (ex fuel use) in country i
Ef	"Raw gas" emission factor
effm	Reduction efficiency of the abatement option
X	Implementation rate of the considered option

(Amann et al., 2004)

[8] http://gains.iiasa.ac.at/gains/EUN/index.login?logout=1, as of 2013-01-23

Swedish data on *A*, and *Ef* were provided in the data compilation process. For the road and non-road transport sectors also Swedish data on eff_m and *X* were compiled. For other sectors, we used information on eff_m and *X* from the IIASA BSL scenario. The values of these parameters were then compared between the IIASA BSL scenario and the SWE BSL projection. When no updated national data were available, the IIASA BSL scenario was used to fill data gaps. Information for the following GAINS model sectors were updated with national data:

Road transport (updates include: fuel use, emission factors, vehicle vintage)

- Non-road mobile machinery (fuel use, emission factors, vehicle vintage)
- Energy use in stationary combustion (power plants, industry, domestic sector, fuel conversion sector)
- Single household boiler structure (implied emission factor)
- Agricultural activities (cattle stock)

The term 'implied emission factor' describes the resulting emission factor of a certain pollutant after emission control technologies are installed and used. In the equation above, the implied emission factor (IEF) corresponds to: IEF = ef(1-eff).

Estimating emission abatement potential

When estimating the emission abatement potential in Sweden we first performed a screening of available data. During the screening we identified that emission abatement potentials in 2030 best could be estimated for the LCP: s (NO_x, $PM_{2.5}$, and SO_2) and for small scale domestic combustion in households ($PM_{2.5}$). The estimated emission abatement potentials in LCP:s were based on officially available data together with interpreted interview results and GAINS model calculations. The estimated emission abatement potential in small scale domestic combustion in households was based on comparison of the background data used in the IIASA BSL scenario and the SWE BSL projection. In this section we first present data and methods for the potential in the LCP:s, followed by a presentation of data and methods for the potential in small scale domestic combustion.

Emission abatement potential in LCP:s

Following the European Pollutant Release and Transfer Register (EPRTR), officially reported data on energy use and emissions of pollutants are compiled and made easily available ((Official Journal of the European Union, 2006) IVL, personal communication, 2012). LCP:s are mandated to report their fuel use and emissions according to the EU LCP directive (Official Journal of the European Union, 2001). Given the significant share of Swedish emissions from large scale combustion (including LCP:s), and the available information from the EPRTR register[9] we selected the Swedish LCP:s for further analysis when estimating emission abatement potential in Sweden. The EPRTR documentation for

[9] http://prtr.ec.europa.eu/, as of 2013-07-10

the Swedish LCP:s in 2010 is available at the EIONET web page[10] and this information was used as basis for telephone and e-mail interviews with product or environmental managers at the plants. The respondents were, after an initial contact and presentation of the project, asked to answer an e-mail questionnaire. From the submitted answers to the email questionnaires, information on use of emission control technologies in large combustion plants was acquired. The questions posed were the following (translated from Swedish):

1) *Is your plant built, or has undergone a large scale renovation, after 2000?*
2) *What emission reduction techniques do you use today to reduce emissions, mainly of SO_2, NO_X, PM and NMVOC (answer for the emissions that are present at your plant)?*
3) *Are these emission reduction techniques installed on the whole, or parts of, the plant? If parts of the plants – how much?*
4) *Do you have plans to expand or upgrade the emission reduction technology that you are currently using, until the year 2020 and/or 2030?*
5) *Do you have an opinion of the technical limitations regarding the installation of the most effective emission reduction technology available today on the market? If so, what are the limitations? How much influence do they have?*
6) *If the cost of installation and maintenance would not be of consideration, which technical limitations do you believe exists in 2025/2030 that would inhibit the use of best available technology to reduce emissions?*

The answers from representatives of the plants were interpreted, translated, and aggregated before conversion of results into a GAINS model format. For each plant, information on plant specifics, fuel use, installed emission control technology, and future expected investment in control technologies, served as a basis for conversion and aggregation to the corresponding sector, fuel, and emission control technology in the GAINS model. The conversion and aggregation of data required expert estimates derived in collaboration with IIASA (personal communication, 2012). Furthermore, the EPRTR data on fuel used in the paper and pulp sector were complemented with information from relevant environmental reports[11]. This step ensured that the questionnaires covered some 60 % of total fuel use (520 PJ) in large scale combustion plants.
When the interview answers and the plant specific information from the EPRTR register had been converted into a GAINS model format, we calculated the use of emission control technologies (interview answers) expressed as a percentage of total fuel used for each fuel and sector (EPRTR register) (X_m in the equation below). For all the LCP plants we could calculate a current and future Swedish 'emission control strategy' for the LCP:s. In the questionnaire we asked for information on the use of emission control technologies and constraints with respect to further investments in emission control technologies for the LCP: s. From these answers we could calculate X in Equation 1 for the LCP emission

[10] http://rod.eionet.europa.eu/obligations/9/deliveries?id=9&tab=deliveries&d-4014547-p=2, as of 2012-07-01
[11] http://miljodatabas.skogsindustrierna.org/si/main/query.aspx?l1=report&query=rpt-respondent-2010, as of 2013-02-22

control technologies considered in the GAINS model. The sector-specific implementation rate (X) of a specific emission control technology ($_m$) for any given fuel and sector combination was calculated as:

$$X_m = \frac{\sum A_m}{A} * 100$$

Where:

X_m	Implementation rate of technology *m* in the specific sector [% of fuel use in sector]
A_m	Fuel used in plants with installed technology *m* in the specific sector [PJ]
A	Total fuel use in the specific sector [PJ]

As an example: if 100 PJ of natural gas is combusted in each of 15 power plants, and 9 of these plants have installed selective catalytic reduction (SCR) to reduce NO_x emissions, the SCR implementation rate in power plants using gas would correspond to:
X_{SCR} = (9*100/15*100)*100 = 60%.

As mentioned above, all the calculated X_m together constituted a Swedish 'emission control strategy' for LCP:s. We assumed that this emission control strategy could be generalised to other combustion processes in the energy and industry sectors. These calculations were then assumed to be representative for the use of emission control technologies in the year 2010, even though the interviews took place in 2012. This implied that any investments in control technology made between the period 2010 and 2012 would be considered as introduced already in 2010. We used interview answers also to quantify expected future changes in the implementation rates of emission control technologies, (i.e. changes over time in the control strategy).

The questionnaire based emission control strategy for LCP and other plants was then used to calculate emissions of air pollutants (Equation 1). Emissions were calculated by using the energy projections from both the Swedish Energy Agency (Swedish Energy Agency, 2013) and the IIASA BSL scenario. In order to estimate an emission abatement potential in 2030, the calculated emissions for 2030, based on our information on X_m was compared with calculated emissions resulting from a maximised implementation of emission control technologies in the sector, X_{MIR} (Maximum Implementation Rate). X_{MIR} can be considered as a technical ceiling for installations. Information on X_{MIR} for 2030 is given as a scenario specification (boundary condition) in the IIASA BSL scenario. When X_{MIR} estimated from the interviews were lower than the corresponding X_{MIR} in the IIASA BSL scenario we used the value for X_{MIR} as indicated by the interviews. Similarly, when X_{MIR} in the IIASA BSL scenario was lower than the questionnaire based X_m, we used the X_m value given from the questionnaire answers. This could happen at times due to the way the X_{MIR} values are calculated (IIASA, personal communication 2012).

The Swedish reporting supporting the Swedish BSL projection does not compile plant specific data on emission control technologies. We therefore assumed that emission calculations based on the interview answers would be incompatible with both the Swedish

BSL projection and the IIASA BSL scenario for Sweden. The questionnaire answers were only used to estimate the emission abatement potential in 2030 for stationary combustion.

Small scale domestic combustion

The $PM_{2.5}$ emission abatement potential was estimated for small scale domestic combustion sources, primarily from households. This estimation was based on the discrepancy in 'implied emission factor' in 2030 between the SWE BSL projection and the IIASA BSL scenario. This difference has three major reasons, but it was not possible to determine which of the reasons that was most important. First of all, Sweden use a method to estimate $PM_{2.5}$ emission factors that produce low emission factors (measuring $PM_{2.5}$ concentration in hot flue gases instead of cold) compared to some international emission factors (EMEP/EEA air pollutant inventory guidebook[12]). Secondly, IIASA assume a quicker turnover rate of domestic boilers than in the SWE BSL projection. Thirdly, IIASA assume a different implementation rate of emission control (ESP or pellets) than in the SWE BSL projection. In our estimate of the emission abatement potential for $PM_{2.5}$ from small scale domestic combustion we basically used the difference between the implied emission factor in the SWE BSL projection and in the IIASA BSL scenario as an indication of the abatement potential. This difference was then applied to the SWE BSL projection on wood combustion in the domestic sector for 2030 in order to calculate a $PM_{2.5}$ emission abatement potential from small scale domestic combustion.

[12] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009, as of 2013-03-01

Results

Since this report aims at providing negotiation support to the Swedish EPA in their participation in the EU review of the NEC directive, this result section focuses on the major identified differences between the SWE BSL projection and the IIASA BSL scenario and on the identified emission abatement potential. It is important to recognize that one of the outcomes of this project is the adjustment of the EC scenarios developed by IIASA. These adjusted scenarios were presented by IIASA during the EC Stakeholder Expert Group meeting on the 3rd of April 2013[13] (Amann et al., 2013). Our key results presented in this chapter focus on the most important differences between the SWE BSL projection and the IIASA BSL scenario, and on the potential to reduce emissions from selected sectors (including a summary of the questionnaire results).

Most important identified differences between the SWE BSL projection and IIASA BSL scenario

During the bilateral consultation with IIASA we focused the projection/scenario comparison on three sectors: small scale domestic combustion; road transport; and non-road transport. The differences of relevance presented here are the differences for the year 2030. The notes from the bilateral consultation are presented in Appendix 1 to this report.

Small scale domestic combustion

There were significant differences in $PM_{2.5}$ emission projections between the IIASA BSL scenario and the SWE BSL projection. The background data check revealed that the difference in emissions was caused by differences in bio fuel activity data as well as in emission factors, see Table 3.

Table 3: $PM_{2.5}$ emissions from small scale domestic combustion 2030 – data comparison

Scenario	Activity data fuel wood [PJ]	Implied emission factor [kt/PJ]	Emissions [kt]
SWE BSL projection	55	0.11	6.05
IIASA BSL scenario	32	0.06	1.92

13 https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp?FormPrincipal:_idcl=FormPrincipal:_id3&FormPrincipal_SUBMIT=1&id=ecb7ee66-1473-410f-b5d4-fbfcbff1d91f&javax.faces.ViewState=rO0ABXVyABNbTGphdmEubGFuZy5PYmplY3Q7kM5YnxBzKWwCAAB4cAAAAAN0AAEycHQAKy9qc3AvZXh0ZW5zaW9uL3dhaS9uYXZpZ2F0aW9uL2NvbnRhaW5lci5qc3A=, as of 2013-04-04

In the SWE BSL projection, the implied emission factor for small scale domestic combustion is presented directly. In the IIASA BSL scenario, the factor is constructed from information on type of boilers in Sweden, emission factors for unabated emission, and the use of emission control technologies, as well as the emission removal efficiencies for the emission control technologies. The reason to the difference in emission factors should be a consequence of differences in these parameters. However, no Swedish information that would allow for a comparison was available in this project. Table 4 however, presents the assumed change in combustion technology in the IIASA BSL scenario.

Table 4: 2020 – 2030 Share of fuel wood use in small scale domestic combustion in the IIASA BSL scenario

Combustion technology	% of fuel wood use				
	2000	2005	2010	2020	2030
Fireplaces	6	6	5	4	4
Cooking stoves	0	0	0	0	0
Heating stoves	14	13	12	11	11
Boilers (manual feed)	40	36	30	12	12
Boilers (automatic feed)	40	45	54	74	74

Furthermore, there is no update of $PM_{2.5}$ emission factors for the projection years in the SWE BSL projection, the emission factors are identical over the period 2010 – 2030 (Gustafsson et al., 2012).

Road transport

The SWE BSL projection and the IIASA BSL scenario differed on all key parameters. The SWE BSL projection implies a much larger shift to diesel passenger vehicles than the IIASA BSL scenario. Furthermore, the SWE BSL projection includes higher NO_x and $PM_{2.5}$ emission factors for all Euro emission control technologies. The SWE BSL projection also includes an ageing effect on the emission factors. Furthermore, the IIASA BSL scenario assume a much higher renewal rate of both diesel and gasoline vehicles. The difference in both projected fuel use and renewal rate of vehicles is to a large extent dependent on external assumptions on economic growth and fuel prices. A technical specification of how the road transport sector is represented in the SWE BSL projection is found in Appendix 2 to this report.

Non-road Mobile Machinery (excl. shipping)

The situation in the Non-road Mobile Machinery sector was similar to the situation in the road transport sector, but less pronounced. As for road transport, the differences in projected fuel use and renewal rate of vehicles are dependent on external assumptions on economic growth and fuel prices. A technical specification of fuel use, emissions and use of emission control technology in the NRMM sectors are specified in Appendix 2 to this report.

Other sectors

Emissions from burning of agricultural waste, which is banned in Sweden, are included in the IIASA BSL scenario but not in the SWE BSL projection. It is included in the IIASA BSL scenario since satellite monitoring identifies current practice of burning of agricultural waste in Sweden (IIASA, personal communication, 2012). Burning of agricultural waste is in the IIASA BSL scenario associated with ≈1 kton of $PM_{2.5}$ emissions, or some 5 % of the total $PM_{2.5}$ emissions in 2030. The non-conclusive discussion on NMVOC is presented in Appendix 1.

Identified emission abatement potentials

In this section we present results from our analysis on emission abatement potentials in Sweden by 2030. As presented earlier our initial focus in this project was on the pollutants NO_x, $PM_{2.5}$, SO_2, NH_3, and NMVOC. For the estimation of emission abatement the focus was primarily on NO_x, $PM_{2.5}$, and SO_2. These are the pollutants of concern when analysing emission abatement potential from stationary combustion. However, the email questionnaire answers on which we based emission abatement potential from large combustion plants provided non-conclusive results for the pollutants $PM_{2.5}$ and SO_2. This was probably because of problems in the process of converting answers to a GAINS model format. We could therefore not calculate $PM_{2.5}$ or SO_2 emission abatement potential from this sector. Presented in this chapter are our results on NO_x emission abatement potential from large scale combustion and $PM_{2.5}$ emission abatement potential from small scale domestic combustion, as well as summarised information on the email questionnaires.

Large scale combustion

Based on:

- the activity data from the SWE BSL projection,
- the 'bottom-up' aggregation and conversion of questionnaire answers,
- and the maximum technical feasible use of emission control technologies as specified in Amann et al. (2012),

we estimate the emission abatement potential for emissions caused by energy use in industry, refineries, power plants, as well as by pulp & paper and refinery processes in 2030 to be 13 kton, as presented in Table 5:

Table 5: Estimated NO_x emission abatement potential from large combustion plants in Sweden 2030

Pollutant	Abatement potential 2030 [kton]	Abatement potential 2030 [% of sector emissions]
NO_x	13 (10)	≈38 (33)

These emissions would be abated mainly by increased use of combustion modifications and SCR technologies.

The SWE BSL emission projection for the corresponding sectors is ≈39 kton NO_x in 2030. By using questionnaire answers, GAINS model emission factors, and the activity data supporting the SWE BSL projection we could reproduce ≈35 kton NO_x emissions from these sectors with a similar emission trajectory from 2010. The divergence was likely caused by different sectorial splits between the Swedish emission inventory system and the IIASA GAINS model. The IIASA BSL scenario estimates that the sectors will emit ≈36 kton NO_x in 2030, but following a different emission trajectory from 2010. When substituting the energy projection supporting the IIASA BSL scenario for the energy projection in the SWE BSL projection, the emission calculation resulted in ≈31 kton NO_x emissions from these sectors.
When calculating the maximum technical feasible abatement potential, the questionnaire based emission projection could be reduced to 22 kton NO_x, implying an emission abatement potential of 13 kton NO_x. The same emission reduction potential was given in the comparable IIASA MTFR scenario. The emission abatement potential in the adjusted IIASA BSL scenario resulted in a reduction potential of 10 kton. Given the impact of different energy projections, we estimated that a lower emission abatement potential of 10 kton (33%) was motivated. In order to get an additional comparison we discussed the results with IIASA experts. The comparative results in Amann et al. (2013) show a NO_x emission abatement potential of 9 kton, or 20% of the 44 kton NO_x emissions expected in the reports main scenario. Furthermore, the comparison for the sectors where emission abatement costs were calculated, was an emission reduction potential of 6.6 kton of NO_x to a cost of ≈260 million Swedish crowns, corresponding to an average 39 Swedish crowns / kg NO_x (ranging between 22 – 184 crowns for the subsectors). The difference between the 35 kton NO_x in the Swedish projection and the 44 kton NO_x calculated in Amann et al. (2013) are caused mainly by different perspectives on the expected use of emission control technology in 2030, but also by different projections on economic activity and fuel use in the sectors, and by different approaches to allocation emission between sectors. Detailed results from the central analysis are presented in Table 6.

Table 6: Estimated NO_x emission reduction potential and abatement costs in Swedish large stationary installations 2030 – Central analysis (incl. cost efficiency in sensitivity analysis)

Sector	Most prominent measures	BSL emissions	MTFR emissions	Emission reduction	Reduction cost	Aggregated cost efficiency	Cost efficiency in sensitivity
		kton	kton	kton	MSEK	SEK / kg NO_x	SEK / kg NO_x
Power plants	Combustion modification, selective- and non-selective catalytic reduction	9.8	7.5	2.3	166	71	(117)
Refineries	Process-related measures: Selective- and non-selective catalytic reduction	0.33	0.32	0.01	4	446	(735)
Industry, process & energy related emissions	Pulp & Paper and Iron & Steel measures: Combustion modification, selective- and non-selective catalytic reduction	25.2	14.0	11.2	*	*	*
Total		35.3	21.8	13.5			

*No emission abatement costs are calculated in this version of the GAINS model for emission reduction from processes

For industrial emission sources we could not disaggregate emissions or estimate emission abatement costs. For the other sectors, the cost efficiency range provided a rough estimate on the cost efficiency if the emission reduction potential (due to different economic and energy development) would be on the lower range of the potential. Our results indicated that the most cost effective NO_x emission abatement will be available in power plants 2030.

Small scale domestic combustion

During the bilateral consultation it was recognised that one major reason for the difference in emission projections originates from the representation of fuel combustion technologies. There was also a difference in to what extent emission abatement technologies were considered. By adjusting the mix of boilers / stoves / fireplaces as well as the use of emission control technologies in 2030 we calculated the emission abatement potential of $PM_{2.5}$ to be 2.7 kton, as presented in Table 7:

Table 7: Estimated $PM_{2.5}$ emission abatement potential from domestic small scale combustion in Sweden 2030

Pollutant	Abatement potential 2030 [kton]	Abatement potential 2030 [% of sector emissions]
$PM_{2.5}$	2.7	45

This emission abatement potential assumed that the major reason for the difference in implied emission factors between the IIASA BSL scenario and the SWE BSL projection was due to the relative shares of combustion equipment and use of emission control technologies.

Other results – Interview answers

Of the 140 plants representatives we contacted, 111 representatives answered the questionnaire (79% response rate).

From the first question in the questionnaire, 1) "*Is your plant built, or has undergone a large scale renovation, after 2000?",* we found out if the plants are existing (EX) or new (NEW) plant, according to the GAINS representation of power plants (Where EX indicates a plant constructed prior to 2000, or not having undergone a large scale reconstruction after 2000). The most common answer from those who said "yes" was that they had been refurbishing the plant. For example "yes, there is an on-going large project where three old boilers have been demolished and is being replaced by a new bio-boiler" was a typical type of answer.

The result showed that of the 111 plants for which answers were received 50 plants were EX (45%). Most plants, 61 plants (55%), were NEW, meaning built after or had undergone a large scale renovation after 2000. 24 plants, out of the 111 plants asked, were industry plants (IN) and 3 plants were refineries (CON).

Table 8: Example of questionnaire results - The mix of old and new large plants in 2012

Sector	Total	EX (built before 2000)	NEW (built after 2000)
Power plants (PP sector)	84	41	43
Industries (IN sector)	24	8	16
Refineries (CON sector)	3	1	2
Sum:	111	50	61

From the second and third question in the questionnaire 2) *"What emission reduction techniques do you use today to reduce emissions, mainly SO_2, NO_X, PM and NMVOC (answer for the emissions that are present at your plant)?"* and 3) *"Are these emission reduction techniques installed on the entire, or parts of, the plant? If parts of the plant – how much of the flue gases are controlled?"* - we identified which emission abatement technologies that were in use.

Of the 111 responses, 12 (11%) responded with a "no" and/or "no special purification techniques". However, most respondents answered that they have purification techniques installed, as well as an indication of which reduction techniques they use.

Question 4 in the survey 4) *"Do you have plans to expand or upgrade the emission reduction technology that you are currently using, until the year 2020 and/or 2030?"* If yes, which emission reduction technology will/would you update to? On this question, many of the respondents answered “no” (38 of 111) or “no plans”/”no plans today” (38 of 111). 32% (35 of 111) respondents answered that they have plans to expand or upgrade the emission reduction technology at the plants until 2020/2030.

The last questions in the questionnaire were 5) *“Do you have any idea of the technical limitations you have regarding the installation of the most effective emission reduction technology available today on the market? If so, what are the limitations? How much influence do they have?”* and 6*) “If the cost of installation and maintenance would not be required to take into account, what technical limitations do you believe exists in 2025/2030 for an installation of the best available technology to reduce emissions?”*.

These two last questions gave information about if there were any technical limitations or not, meaning if the plant had reached a Maximum Technical Feasible Reduction (MTFR) or not. 34 of 111 respondents (31%) answered that they have limitations, out of which 15 are plants constructed before the year 2000. The other respondents, 77 of 111, answered that they don’t have any technical limitations, or “don’t know”.

Discussion

In this study we explored reasons to differences in emission projections between the SWE BSL projection and the IIASA BSL scenario. These differences were discussed with IIASA and adjusted for. We also estimated further emission abatement potentials, based on interview studies and own modelling. From this project, three major conclusions can be drawn.

Conclusion 1: Swedish and IIASA emission projections differ in results

In this report we have shown how the values for important parameters such as fuel use and emission factors often differ between Swedish and IIASA projections. These differences are causing differences in emission projections for the pollutants and sectors studied in this report. Important is that assumptions outside the actual emission calculations cause a large part of the differences. Examples of such differences are projections on economic growth, fuel prices, or other sector specific assumptions such as development of the vehicle fleet. Because of the above mentioned reasons and because of differences in methods for estimating emission projections, the most relevant parameter when comparing scenarios and projections is the implied emission factor (IEF). The IEF gives information about emission factors and estimated use of control technologies (regardless of whether this estimation is implicit or explicit).

Conclusion 2: Some of the differences between Swedish projections and IIASA scenarios are scenario-specific, but others can be avoided

The comparison between Swedish and IIASA projections also identified where differences could be avoided. This comparison also reasserted that some differences are to be expected when comparing different scenarios. Different scenarios imply differences in expected economic growth, fuel use, fuel prices etc., all of which has an impact on emissions.

Conclusion 3: Swedish projected emissions of NO_x and $PM_{2.5}$ in 2030 can be further reduced, but more research is needed.

We showed that NO_x emissions in 2030, as projected in the SWE BSL projection, could be reduced by some 13 (10) kton if a maximum technical emission abatement solution would be applied to selected pollution sources by 2030. These 13 kton were to be considered only as a technical potential associated mainly with end-of-pipe emission removal technologies. In this number there was no consideration of the economic aspects, neither was there any consideration to structural measures etc. that could alter the emission abatement potential. The emission abatement potential could in this project only be done satisfactory for LCP plants and similar plants and processes associated with these. As presented earlier, several steps of adaptation of interview answers were needed, each step contributing with some additional uncertainty. In order to generalise questionnaire results we completed the EPRTR data with data on the use of Black Liquor, based on relevant environmental reports[14]. This completion allowed the data to represent some ≈60 % (350 out of 520 PJ)

[14] http://miljodatabas.skogsindustrierna.org/si/main/query.aspx?l1=report&query=rpt-respondent-2010, as of 2013-02-22

of the total energy use in stationary combustion in Swedish industry and power plants. With the exception of the paper & pulp and refinery processes there was no extrapolation of interview answers to other industrial sectors. The reason to include paper & pulp and refinery processes was that the LCP register does not separate energy related emissions from process related emissions. Since refineries and pulp and paper mills are included in the LCP register, their process emissions were as well.

For $PM_{2.5}$, we explored the possibility to reduce the projected emissions in the SWE BSL projection by reviewing emissions from small scale domestic combustion mainly in households. Our key assumption was that parts of the difference in the implied emission factor between the SWE BSL projection and the IIASA BSL scenario was due to different implicit assumptions on the type of boilers in use and the type of emission control technologies in place. Given this assumption we estimated the potential as equal to the difference in the implied emission factor between the SWE BSL projection and the IIASA BSL scenario. This gave us a $PM_{2.5}$ emission abatement potential from this sector corresponding to ≈2.7 kton in 2030.

In the work done by IIASA in the TSAP reports (Amann et al., 2012, 2013), there is no exploration of further emission abatement in the transport sector. This sector could very well be subject for further emission reductions by 2030 in Sweden. It is also important to continue to explore other emission abatement options than technical end-of-pipe options, which are dominating the GAINS model. Important examples of measures and options are structural changes, behavioural changes, and measures with climate and air pollution co-benefits.

Thanks to the bilateral consultation and the adjustments made at IIASA after this consultation, the largest part of the discrepancy between the Swedish emission projection and following IIASA scenarios (Amann et al., 2013) are due to different views between Sweden and EC on future economic growth, fuel prices, energy demand, and turnover of the vehicle fleet.

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Appendix 1: A summary of the Sweden / IIASA bilateral consultation, 121108

General introduction

During this bilateral consultation we focused on clarifying differences in activity data, use of emission control technologies, emission factors and emissions for the air pollutants considered in the revision of the EU TSAP. The data and scenarios compared was the GAINS model PRIMES_REF_2050 scenario and the latest submitted Swedish emission inventory & projection as reported from the Swedish consortium SMED to the Swedish EPA in September 2012.

Based on experiences from a similar exercise performed in March 2012, when preparing the final proposal for a revised UNECE CLRTAP GBG protocol, some key pollutants and sectors were given special attention. These were:

- NO_x, $PM_{2.5}$, and NMVOC emissions from mobile sources
- $PM_{2.5}$ emissions from small scale domestic combustion

Other aspects covered were:

- The energy balance for stationary emission sources in the PRIMES_REF_2050 scenario
- $PM_{2.5}$ emissions from agricultural waste burning in Sweden
- NMVOC emissions from other than mobile sources

The following text presents the conclusions from this bilateral consultation and presents the todo-list following the consultation. In the following text, "Swedish" implies data or projections from the Swedish emission inventory and/or projection.

Conclusions

Adaptation of Swedish inventory & projection

- The Swedish energy statistics for the TRA_RD & TRA_OT sectors are not in line with the energy statistics for Sweden from Eurostat. The reason for this will be checked and it will be made assured that the fuel use at least corresponds to the fuel used given by the Swedish Energy Agency. This is task is performed by IVL.
- Following this, the emission factors specified per Euro class will be calculated by IVL for NOx, $PM_{2.5}$, NMVOC. Special communication is needed with the Swedish Road Administration.
- Sweden will look into emissions from fires, an activity not allocated any $PM_{2.5}$ emission factor in the Swedish emission inventory or projections.
- Sweden will try to send written motivation for the emfac, development of fuel use, and age class distribution in the TRA_RD sector to IIASA. Try implies that IVL is

not in possession of this documentation. This will have to come from VTI and/or the Swedish road administration.

    - What are the reasons for the large increase in the share of diesel vehicles up until 2030 (LD4C)?

Adaptation of the PRIMES_REF_2050 scenario

The PRIMES_REF_2050 scenario will be adjusted in the following manner

- The Swedish representation of Euro standards will be used for the TRA_RD & TRA_OT sectors for the years 2005 & 2010 (IVL submit numbers to IIASA). The age distribution of vehicles will develop in accordance with the PRIMES_REF_2050 trend lines.
- The Swedish technology specific emission factors for the TRA_RD & TRA_OT sectors will be implemented in the PRIMES_REF_2050 scenario. Since Sweden includes 'ageing' of emission control technologies, the technology specific emission factor for the year with the highest relative use of this technology will be chosen as a 'year-independent proxy' for submission to IIASA. We also noted that differences in emission factors for road transport can be caused by:
    - Different assumptions about the mix of urban, rural and highway driving
    - Differences in assumed fuel efficiency of vehicles.
- Sweden needs to motivate the emission factors used for road transport before changes in the IIASA emission factors will be made.
- The Swedish 'split' of vehicle gasoline use will be replicated in the TRA_RD sector for the scenario years (IVL submit numbers to IIASA)
- The Swedish 'split' of vehicle diesel use will be replicated in the TRA_RD sector for the year 2005 & 2010 only (IVL submit numbers to IIASA)
- There will probably be a slight shift in the allocation of MD use in the TRA_OT & TRA_OTS sectors following the 'split' in the Swedish numbers.
- The DOM_FWD implied emission factor from the Swedish emission inventory & projection will be the basis for the corresponding boiler shares & emission control strategy in the PRIMES_REF_2050 scenario.
- IVL will aim at re-allocating BC1 fuel use into peat use (BC2) with the potentially corresponding change in emission factors.
- IVL will aim at introducing black liquor as a subset of the FWD currently given in the PRIMES_REF_2050 scenario.

These adjustments WILL NOT imply that the PRIMES_REF_2050 scenario calculates the same emission levels for the years 2020, 2025, and 2030 as in the Swedish emission projection (submitted in Sept 2012). The emission levels for 2005 and 2010 will however be very similar. But we will be fairly sure that the absolute majority of the future discrepancy will come from the different views on the development of fuel use and the vintages of vehicles (fleet turnover). That is, we will have very similar 'scenario independent' input data, but different energy scenarios. This naturally lead to different emission levels.

Other TODO:s

1. For VOC, other big differences in emissions are to be found in the asphalt paving + NMVOC emissions from paper & pulp
2. Another topic is VOC emissions from solvents

Appendix 2 – Road and non-road transport characteristics

				Vehicle vintage (% of fuel used)				**Fuel use per vintage class (PJ)**				PM2.5 EMFAC (kton / PJ)	NOX EMFAC (kton / PJ)
Activity Unit	Acti-vity	Sector	Techno-logy	2010	2020	2025	2030	2010	2020	2025	2030		
[PJ]	MD	TRA_RD_HDB	NOC	1%	0%	0%	0%	0.34	0.00	0.00	0.00	0.04	0.87
[PJ]	MD	TRA_RD_HDB	HDEUI	2%	0%	0%	0%	0.79	0.01	0.00	0.00	0.03	0.66
[PJ]	MD	TRA_RD_HDB	HDEUII	16%	0%	0%	0%	2.40	0.04	0.01	0.00	0.01	0.71
[PJ]	MD	TRA_RD_HDB	HDEUIII	38%	3%	0%	0%	3.49	0.29	0.05	0.01	0.01	0.55
[PJ]	MD	TRA_RD_HDB	HDEUIV	18%	5%	2%	1%	0.66	0.52	0.20	0.15	0.00	0.48
[PJ]	MD	TRA_RD_HDB	HDEUV	27%	29%	7%	1%	2.94	3.30	0.80	0.12	0.00	0.37
[PJ]	MD	TRA_RD_HDB	HDEUVI	0	64%	91%	98%	0.96	7.28	10.45	11.29	0.00	0.04
[PJ]	MD	TRA_RD_HDT	NOC	3%	1%	0%	0%	3.12	0.58	0.33	0.17	0.03	0.81
[PJ]	MD	TRA_RD_HDT	HDEUI	0%	0%	0%	0%	0.61	0.12	0.07	0.05	0.02	0.63
[PJ]	MD	TRA_RD_HDT	HDEUII	15%	4%	2%	1%	16.23	3.24	1.67	0.81	0.01	0.68
[PJ]	MD	TRA_RD_H	HDEUIII	39%	13%	6%	3%	24.51	9.68	4.93	2.51	0.01	0.51

				Vehicle vintage (% of fuel used)				**Fuel use per vintage class (PJ)**				PM2.5 EMFAC (kton / PJ)	NOX EMFAC (kton / PJ)
Activity Unit	Acti-vity	Sector	Techno-logy	2010	2020	2025	2030	2010	2020	2025	2030		
		DT											
[PJ]	MD	TRA_RD_HDT	HDEUIV	24%	9%	4%	2%	5.87	6.95	3.36	1.67	0.00	0.39
[PJ]	MD	TRA_RD_HDT	HDEUV	21%	29%	16%	7%	13.61	21.41	12.60	6.12	0.00	0.26
[PJ]	MD	TRA_RD_HDT	HDEUVI	0	44%	71%	87%	2.86	33.09	56.82	73.16	0.00	0.03
[PJ]	GSL	TRA_RD_LD4C	NOC	5%	2%	1%	1%	13.92	1.18	0.88	0.52	0.00	0.41
[PJ]	GSL	TRA_RD_LD4C	LFEUI	9%	1%	0%	0%	14.61	0.72	0.29	0.17	0.00	0.31
[PJ]	GSL	TRA_RD_LD4C	LFEUII	16%	3%	1%	0%	20.62	2.05	0.51	0.20	0.00	0.16
[PJ]	GSL	TRA_RD_LD4C	LFEUIII	18%	6%	2%	0%	23.62	4.24	1.05	0.26	0.00	0.03
[PJ]	GSL	TRA_RD_LD4C	LFEUIV	51%	39%	17%	5%	56.23	28.34	11.20	2.85	0.00	0.04
[PJ]	GSL	TRA_RD_LD4C	LFEUV	0%	22%	18%	9%	10.77	15.97	12.04	5.11	0.00	0.05
[PJ]	GSL	TRA_RD_LD4C	LFEUVI	0	27%	60%	84%	0.35	19.33	39.20	49.41	0.00	0.05
[PJ]	MD	TRA_RD_LD4C	NOC	0%	0%	0%	0%	0.15	0.03	0.01	0.01	0.05	0.24
[PJ]	MD	TRA_RD_LD4C	MDEUI	1%	0%	0%	0%	1.11	0.03	0.02	0.01	0.04	0.21

				Vehicle vintage (% of fuel used)				**Fuel use per vintage class (PJ)**				PM2.5 EMFAC (kton / PJ)	NOX EMFAC (kton / PJ)
Activity Unit	Acti-vity	Sector	Techno-logy	2010	2020	2025	2030	2010	2020	2025	2030		
[PJ]	MD	TRA_RD_LD4C	MDEUII	5%	0%	0%	0%	2.91	0.12	0.02	0.02	0.03	0.24
[PJ]	MD	TRA_RD_LD4C	MDEUIII	13%	1%	0%	0%	4.44	0.63	0.13	0.03	0.01	0.22
[PJ]	MD	TRA_RD_LD4C	MDEUIV	81%	11%	3%	1%	8.70	8.04	2.16	0.42	0.00	0.23
[PJ]	MD	TRA_RD_LD4C	MDEUV	0%	32%	13%	4%	15.17	23.81	9.86	2.74	0.00	0.26
[PJ]	MD	TRA_RD_LD4C	MDEUVI	0	56%	84%	96%	0.65	42.01	62.85	72.21	0.00	0.09
[PJ]	GSL	TRA_RD_LD4T	NOC	14%	6%	4%	3%	0.74	0.06	0.04	0.02	0.00	0.69
[PJ]	GSL	TRA_RD_LD4T	LFEUI	13%	3%	2%	1%	0.60	0.03	0.01	0.01	0.00	0.54
[PJ]	GSL	TRA_RD_LD4T	LFEUII	24%	8%	3%	1%	0.82	0.08	0.03	0.01	0.00	0.23
[PJ]	GSL	TRA_RD_LD4T	LFEUIII	15%	9%	5%	2%	0.46	0.09	0.04	0.01	0.00	0.03
[PJ]	GSL	TRA_RD_LD4T	LFEUIV	32%	32%	15%	7%	0.69	0.32	0.12	0.04	0.00	0.03
[PJ]	GSL	TRA_RD_LD4T	LFEUV	1%	22%	20%	10%	0.19	0.22	0.16	0.06	0.00	0.05
[PJ]	GSL	TRA_RD_LD4T	LFEUVI	0	19%	51%	76%	0.00	0.19	0.42	0.49	0.00	0.06
[PJ]	MD	TRA_RD_LD4T	NOC	1%	0%	0%	0%	0.46	0.07	0.03	0.02	0.11	0.46

				Vehicle vintage (% of fuel used)				**Fuel use per vintage class (PJ)**				PM2.5 EMFAC (kton / PJ)	NOX EMFAC (kton / PJ)
Activity Unit	Acti-vity	Sector	Techno-logy	2010	2020	2025	2030	2010	2020	2025	2030		
[PJ]	MD	TRA_RD_LD4T	MDEUI	8%	1%	0%	0%	1.87	0.15	0.06	0.04	0.06	0.42
[PJ]	MD	TRA_RD_LD4T	MDEUII	14%	1%	0%	0%	2.53	0.21	0.03	0.01	0.04	0.32
[PJ]	MD	TRA_RD_LD4T	MDEUIII	34%	8%	2%	0%	4.80	1.54	0.39	0.08	0.03	0.37
[PJ]	MD	TRA_RD_LD4T	MDEUIV	41%	22%	8%	2%	3.39	4.41	1.61	0.39	0.01	0.27
[PJ]	MD	TRA_RD_LD4T	MDEUV	2%	37%	23%	9%	3.42	7.58	4.55	1.68	0.00	0.27
[PJ]	MD	TRA_RD_LD4T	MDEUVI	0	32%	66%	88%	0.00	6.52	13.18	17.01	0.00	0.10
[PJ]	GSL	TRA_RD_M4	NOC	100%	100%	100%	100%	1.28	1.50	1.54	1.59	0.01	0.13

NRMM sector

Energy use in NRMM in the SWE BSL projection (TeraJoule)

Row Labels	2005	2010	2015	2020	2025	2030
1.AA.2.F\Machinery	19 590	22 557	20 787	20 690	20 184	19 678
TRA_OT_CNS	19 590	22 557	20 787	20 690	20 184	19 678
GSL	280	286	283	283	283	283
MD	19 310	22 271	20 504	20 407	19 901	19 395
1.AA.3.E\Off-road vehicles and other machinery	3 947	4 218	4 044	4 044	4 044	4 044
TRA_OT	3 947	4 218	4 044	4 044	4 044	4 044
GSL	1 017	1 015	1 017	1 017	1 017	1 017
MD	2 930	3 203	3 027	3 027	3 027	3 027
1.AA.4.B\Mobile	5 056	5 317	5 230	5 315	5 261	5 208
TRA_OT_LD2	5 056	5 317	5 230	5 315	5 261	5 208
GSL	3 329	3 853	3 681	3 758	3 658	3 559
MD	1 728	1 464	1 549	1 557	1 603	1 649
1.AA.4.C\Mobile	16 677	17 758	16 115	15 584	15 089	14 593
TRA_OT_AGR	16 677	17 758	16 115	15 584	15 089	14 593
GSL	1 042	1 228	1 103	1 090	1 092	1 094
MD	15 635	16 530	15 012	14 495	13 997	13 499
1.AA.5.B\Military use	3 105	2 422	3 463	3 463	3 463	3 463
TRA_OT_LB	3 105	2 422	3 463	3 463	3 463	3 463
GSL	2 353	1 803	2 878	2 878	2 878	2 878
MD	752	619	585	585	585	585
Grand Total	**48 375**	**52 272**	**49 639**	**49 096**	**48 041**	**46 985**

NOx emissions in NRMM in the SWE BSL projection (kton)

	2005	2010	2015	2020	2025	2030
1.AA.2.F\Machinery	13	11	7	3	2	1
TRA_OT_CNS	13	11	7	3	2	1
GSL	0	0	0	0	0	0
MD	13	11	7	3	2	1
1.AA.3.E\Off-road vehicles and other machinery	2	2	2	1	1	1
TRA_OT_LB	2	2	2	1	1	1

	2005	2010	2015	2020	2025	2030
GSL	0	0	0	0	0	0
MD	2	2	2	1	1	1
1.AA.4.B\Mobile	2	2	1	1	1	1
TRA_OT_LD2	2	2	1	1	1	1
GSL	0	1	1	1	1	1
MD	1	1	1	0	0	0
1.AA.4.C\Mobile	13	10	8	5	5	4
TRA_OT_AGR	13	10	8	5	5	4
GSL	0	0	0	0	0	0
MD	13	10	7	5	4	4
1.AA.5.B\Military use	1	1	1	1	1	1
TRA_OT_LB	1	1	1	1	1	1
GSL	1	0	1	1	1	1
MD	0	0	0	0	0	0
Grand Total	**31**	**26**	**19**	**12**	**11**	**9**

Vehicle vintage (expressed as % of fuel use)

Activity	Sector	Technology	2005	2010	2015	2020	2025	2030
GSL	TRA_OT_AGR	NOC	97	84	71	59	47	36
GSL	TRA_OT_AGR	LFEUI	3	5	5	5	5	3
GSL	TRA_OT_AGR	LFEUII		11	24	36	48	61
MD	TRA_OT_AGR	NOC	53	27	16	10	7	5
MD	TRA_OT_AGR	CAGEUI	17	13	10	6	6	5
MD	TRA_OT_AGR	CAGEUII	30	24	18	12	11	9
MD	TRA_OT_AGR	CAGEUIII		36	29	20	18	13
MD	TRA_OT_AGR	CAGEUIV			17	12	10	8
MD	TRA_OT_AGR	CAGEUV			10	40	48	60
GSL	TRA_OT_CNS	NOC	97	84	71	59	47	36
GSL	TRA_OT_CNS	LFEUI	3	5	5	5	5	3
GSL	TRA_OT_CNS	LFEUII		11	24	36	48	61
GSL	TRA_OT_CNS	LFEUIII	0	0	0	0	0	0
MD	TRA_OT_CNS	NOC	48	26	13	7	5	4
MD	TRA_OT_CNS	CAGEUI	23	14	8	3	2	0
MD	TRA_OT_CNS	CAGEUII	29	24	14	8	3	2
MD	TRA_OT_CNS	CAGEUIII		36	29	18	10	7
MD	TRA_OT_CNS	CAGEUIV			18	12	7	2
MD	TRA_OT_CNS	CAGEUV			18	52	73	85
GSL	TRA_OT_LB	NOC	54.81107	55.35544	31.40234	26.14698	21.06092	16.30632

Activity	Sector	Technology	2005	2010	2015	2020	2025	2030
GSL	TRA_OT_LB	LFEUI	1.695188	3.294967	2.211432	2.215846	2.240524	1.35886
GSL	TRA_OT_LB	LFEUII	0	7.248927	10.61488	15.95409	21.50903	27.63016
GSL	TRA_OT_LB	LFEUIII	0	0	0	0	0	0
GSL	TRA_OT_LB	LFEUIV	0	0	0	0	0	0
GSL	TRA_OT_LB	LFEUV	0	0	0	0	0	0
GSL	TRA_OT_LB	LFEUVI	43.49374	34.10066	55.77135	55.68308	55.18953	54.70466
MD	TRA_OT_LB	NOC	52	41	38	32	30	28
MD	TRA_OT_LB	HDEUI	21	14	8	3	2	0
MD	TRA_OT_LB	HDEUII	27	20	14	8	3	2
MD	TRA_OT_LB	HDEUIII		25	20	18	8	6
MD	TRA_OT_LB	HDEUIV			10	9	7	4
MD	TRA_OT_LB	HDEUV			10	30	50	60
MD	TRA_OT_LB	HDEUVI	0	0	0	0	0	0
GSL	TRA_OT_LD2	NOC	98.9	95	92	88	85	82
GSL	TRA_OT_LD2	MMO2I	0.4	1	1	1	1	1
GSL	TRA_OT_LD2	MMO2II	0.7	4	7	11	14	17