Appendix

SCARP
Swedish Clean Air Research Program
Frisk luft i Sverige

Detailed reports from projects

August 2009

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Area 1 Exposure and health effects

Area coordinator: Göran Pershagen, KI

Project 1.1. Exposure to traffic related air pollution in early life, lung function and airway disease in 8-yearold children

Project leader: Tom Bellander

General Objective: The aim of this study is to assess the impact of life-time exposure to traffic-related air pollutants and heating-related air pollutants on lung function, wheezing, asthma and allergic sensitisation, in children at the age of eight

The project is progressing well. All outcome data for the children up to 8 years of age is available in data sets ready for analysis. Addresses for homes, daycare and schools up to age 8 have been retrieved, revised and geocoded. Dispersion modelling has been performed. Epidemiological analysis and reporting is ongoing. An abstract to the International Society for Environmental Epidemiology conference 2009 has been submitted.

This project is a good example of cross-fertilisation between health and air pollution groups within SCARP. Co-operation with the Department of occupational and environmental health, Stockholm county council; SLB-analysis, Stockholm municipality.

Phase II

This project will continue in 2010-12 by incorporating outcome data from the 12-year follow-up of the cohort, and subsequently air pollution data for the 8-12 year period. The research questions remain the same as well as the principle methods involved. Longer follow-up of symptoms and not clear-cut chronic conditions, and varying exposures will further increase the wealth of the dataset and allow for a better understanding of the relation between air pollution and different aspects of airway disease in children.

For SCARP Phase 2 we propose funding with 200 000 SEK 2010, 200 000 SEK 2011, and 300 000 SEK 2012. The costs will be dominated by salaries for junior researchers

Project 1.2. Short-term health effects in susceptible subgroups, using newly developed source specific local time series of air pollution

Project leader: Tom Bellander

General Objective: The aim of the project is to further explore the association between short-term variation in health effect and air pollution in sensitive subgroups. It will apply the best available exposure assessment technique to time series of cardiovascular outcomes

Although productive, this project is behind schedule. This is mainly due to delays in related projects, but in part also because the reorganisation of the Stockholm Centre of Public Health into Karolinska School of Public Health. The related projects are now all in the analysis phase or further, and we foresee a more stable personnel situation the coming period.

The substudy of patients with cardioverter defibrillators (ALVA) has been concluded and a report has been published. The substudy of inflammatory markers (AIRGENE) has been concluded and has resulted in several publications. The data preparation of the substudy on sensitive subpopulations in Stockholm county (SENSI) and the exposure-only analysis have been concluded.

Planned activities 2009:, Basic analysis and reporting of the SENSI data set. Test runs with local time series. Further analysis of all included data sets.

Phase II

This project builds on other, to date only partly reported projects, and is therefore delayed. The use of local time series needs to be somewhat revised, in order to circumvent problems related to colinearity between local time series data and variables that should be incorporated in temporal analysis of health outcome data.

We therefore propose a no-cost extension of this project to 2012, and that no further funding is allocated during SCARP Phase 2. The costs will be dominated by salaries for junior researchers.

Written publications:

Ljungman PL, Berglind N, Holmgren C, Gadler F, Edvardsson N, Pershagen G, Rosenqvist M, Sjögren B, Bellander T. Rapid effects of air pollution on ventricular arrhythmias. Eur Heart J. 2008 Dec;29(23):2894-901. Epub 2008 Nov 12.

Peters A, Greven S, Heid IM, Baldari F, Breitner S, Bellander T, Chrysohoou C, Illig T, Jacquemin B, Koenig W, Lanki T, Nyberg F, Pekkanen J, Pistelli R, Rückerl R, Stefanadis C, Schneider A, Sunyer J, Wichmann HE; AIRGENE Study Group. Fibrinogen genes modify the fibrinogen response to ambient particulate matter. Am J Respir Crit Care Med. 2009 Mar 15;179(6):484-91. Epub 2009 Jan 8.

Peters A, Greven S, Heid IM, Baldari F, Breitner S, Bellander T, Chrysohoou C, Illig T, Jacquemin B, Koenig W, Lanki T, Nyberg F, Pekkanen J, Pistelli R, Rückerl R, Stefanadis C, Schneider A, Sunyer J, Wichmann HE; AIRGENE Study Group.

Fibrinogen genes modify the fibrinogen response to ambient particulate matter. Am J Respir Crit Care Med. 2009 Mar 15;179(6):484-91. Epub 2009 Jan 8.

Oral presentations etc:

Ljungman PLS, Bellander T, Schneider A, et al. Effect Modification of Interleukin-6 Response to Ambient Carbon Monoxide Levels by Fibrinogen and Interleukin-6 Polymorphisms Conference Information: 20th Annual Conference of the International-Society-for-Environmental-Epidemiology, OCT 12-16, 2008 Pasadena, CA

Peters A, Schneider A, Greven S, et al. Air pollution and inflammatory response in myocardial infarction survivors: Gene-environment interactions in a high-risk group 10th International Inhalation Symposium, MAY 31-JUN 03, 2006 Hannover, GERMANY

Ruckerl R, Greven S, Ljungman P, et al Air pollution and inflammation (IL-6, fibrinogen, CRP) in myocardial infarction survivors 19th Annual Conference of the International-Society-for-Environmental-Epidemiology, SEP 05-09, 2007 Mexico City, MEXICO

Peters A, Greven S, Heid I, et al.Title: SNPs in the fibrinogen gene cluster modify fibrinogen response to ambient particulate matter 19th Annual Conference of the International-Society-for-Environmental-Epidemiology, SEP 05-09, 2007 Mexico City, MEXICO

Sviatlana Panasevich, Karin Leander, Mats Rosenlund, Petter Ljungman, Tom Bellander, Ulf de Faire, Göran Pershagen, Fredrik Nyberg. Long- and short-term air pollution exposure and markers of inflammation and coagulation in a population sample from Stockholm. 21th Annual Conference of the International-Society-for-Environmental-Epidemiology, Aug 24-29, 2009 Dublin, Ireland.

Annette Peters, Regina Hampel, Melanie Kolz, Susanne Breitner, Tom Bellander, Juha Pekkanen, Francesco Forastiere, Jordi Sunyer, Klea Katsouyanni, Thomas Illig, Wolfgang Koenig, Alexandra Schneider, Iris M. Heid. Air Pollution and Inflammation: Gene-Environment Interactions in Myocardial Infarction Survivors. 21th Annual Conference of the International-Society-for-Environmental-Epidemiology, Aug 24-29, 2009 Dublin, Ireland.

Project 1.3. "Health effects of short-term and cumulative seasonal exposure to road dust and wood smoke particles at real-world exposure conditions"

Project leader: Bertil Forsberg, Yrkes- och miljömedicin, Umeå Universitet

During the first years, 2006-2008, we conducted two 10-week panel studies in Umeå focussing on road dust PM and ozone in spring and two panel studies focusing on wintertime PM in Lycksele, where wood burning for house heating is common. In both settings one panel was an asthma panel and one was a panel of highly exposed outdoor workers (postmen and parking guards). In all four studies the panelists (15-25 subjects) came to measure exhaled NO (eNO) one or several days per week. Participants in the asthma panels also recorded daily symptoms, medication and measured lung function. We have started with analyses of effects on eNO, and presented preliminary results for the asthma panel from Umeå at the ERS Congress in Berlin in October 2009. We are during 2009 finalizing the air pollution database and are working on the symptom data. In 2010-2011 we will analyze effects on lung function and study road dust PM and eNO in asthmatic children from highly exposed schools. We followed the study plan and have had additional funding, ALF Grants, from the University Hospital. This project will increase our understanding of the respiratory effects of different types air pollution, especially the effects of road dust, which are very policy relevant in Sweden.

Phase II

For Project 1.3. "Health effects of short-term and cumulative seasonal exposure to road dust and wood smoke particles at real-world exposure conditions" the original activity plan is still valid, and the budget request is the same (we got 238 000 SEK/yr). In 2010 we plan to conduct the final analyses and write the papers on the findings from our adult panels. In addition the panel study on road dust and acute respiratory effects in asthmatic school children in Umeå will be done in 2010, with analyses following in 2011.

Project 1.4. "Long-term exposure to traffic exhaust and incidence of obstructive airway disease in a prospective cohort – co-funding

Project leader: Bertil Forsberg, Yrkes- och miljömedicin, Umeå Universitet

Until now we have studied the association between motor-vehicle exhaust and asthma incidence in adults from the three Swedish cities in the RHINE (Respiratory Health in Northern Europe) cohort study from the first 9 years of follow up. We have used alternative exhaust indicators; NO2, NOx, PMexhaust and traffic flow. The first ever paper in the international literature on adult onset asthma and NOx level outside the home is published (Modig L et al, ERJ, 2009) and included in a doctoral thesis. Another paper on asthma and PMexhaust from this project is also under preparation. The next steps are to study the effect on the asthma severeness (score) and on the incidence of rhinitis in the same population. We also need to update the address information and want to do another follow up in 2010/11 and double the follow-up period. This study has only had limited economic support from SCARP. Most of the funding for this air pollution study came from EMFO (Emissionsforskningsprogrammet) and some from the Asthma and Allergy Foundation. SCARP is from January 2009 the only funding organization. This project is quite unique in its analyses of long-term exposure to traffic pollution and development of chronic respiratory morbidity in adults. The traffic related asthma incidence in adults will likely be an important part in future analyses of health costs.

Phase II

For Project 1.4. "Long-term exposure to traffic exhaust and incidence of obstructive airway disease in a prospective cohort – *co-funding* we now plan a study of rhinitis incidence in the existing cohort, which can be done with the same minor level of economic support (60 000SEK/yr) since we have most of the data needed. The new follow up we mentioned in the original application is planned to take part in 2010 and will give us 20 years of follow-up information from approx. 8000 participants in the three cities. The new follow up will include a new more detailed exposure assessment, a postal questionnaire and a clinical follow up of symptomatic and a random sample.

It would be very helpful to have this follow up partly funded by SCARP, for example the exposure modeling.

Potential new studies

We have 2009 started some air pollution studies involving 26 000 respondents from 4 Swedish cities (Umeå, Uppsala, Stockholm and Gothenburg) in the GA2LEN Study of asthma and allergies. The first results will be presented at meeting during the autumn (ISEE in Dublin, ERS in Vienna). We would now like to establish a long-term study of road dust and exhaust particles using this survey as the starting point. pollution.

Publications

Modig L, Torén K, Janson C, Jarvholm B, Forsberg B. Vehicle exhaust outside the home and onset of asthma among adults. Eur Respir J. 2009 Jun;33(6):1261-1267.

Project 1.5. Is exposure to particulate air pollution associated with exhaled nitric oxide and blood markers of inflammation?

Project leader: Anna-Carin Olin, AMM, Sahlgrenska Akademin

The major aim with the present project was to elucidate the relation between exposure to air pollution and the fraction of exhaled nitric oxide, a marker for airway inflammation as well as inflammatory markers in blood. The project is running well in accordance with this aim;

We have now finished the basic clinical examination of 6600 individuals with NO in exhaled air, spirometry, blood tests for inflammation markers in blood and genetic analysis, and a series of questionnaires. Home addresses for the first 3600 examined individuals have been included in a model of acute and cumulative exposure to air pollution by Bertil Forsberg's research group in Umeå.

We have analyzed data for the 2200 first investigated individuals and found that NO formation in the peripheral airways is increased by increased ozone concentrations in outdoor air, measured at central measuring station, if one takes into account the cumulative exposure 3, 12 hours and 5 days before the examination. We also saw a smaller increase in NO levels after exposure to high particulate levels (PM10). We found however no effect of exposure to air pollution in biomarkers reflecting the central airways. A manuscript is almost ready and will be sent in August 2009, and the results will be presented at two international conferences 2009.

Analysis of inflammatory markers in blood has started and will be finished September 2009 as well as analysis of polymorphism of genes that control the formation of important anti-oxidant enzymes as well as NO-forming enzymes that may affect the risk of developing airway inflammation. Analyses of these data will be initiated autumn 2009. We have also received a grant for a PhD-student included in a PhD-program for Health and Environment from Västra Götaland County that will work with this material.

No further funding has, at present, been approved to cover the costs for further clinical examinations in the basic study and these have therefore been stopped temporarily. This will limit the power of the study, and further funding have been applied for from VR.

In addition to what was described in the initial program, a follow-up study has been initiated. All participants receive 4 years after the initial study a mailed questionnaire, including on emerging respiratory problems. So far, 3700 individuals received the form and around 90% have responded to this. In this dataset, which will be expanded until all subjects are included, we will hope to able to analyze the incidence of respiratory symptoms in relation to chronic exposure to air pollution and including potential genetic susceptibility.

Phase II

In accordance with the original plan, we want to use funds from Scarp to proceed with further analysis of the collected material in the Apollo study, including both project 1.5 and 1.6. For this purpose, we intend to employ a post-doc from the research group in Umeå, Lars Modig, for two years on partial time. From the 2012 we hope to appoint an additional post-doc. The grant will further cover some of the costs for an epidemiology assistant partly employed for the project, assisting in analyses and handling of data-bases.

Budget 900 000 + 100 000 SEK that only partly will cover these costs.

New proposals

Longitudinal analyses of the association between new onset respiratory symptoms and chronic exposure to air pollution within the cohort.

Expanding the analyses of genetic polymorphisms for certain anti-oxidants and NOSI-III in order to include another 4400 subjects.

Expanded exposure assessment for noise within the cohort.

Project 1.6. Is long term exposure to particulate air pollution associated with an increased risk for ischemic heart disease

Project leader: Anna-Carin Olin, AMM, Sahlgrenska Akademin

The main aim with the present project was to examine whether exposure to different types of air pollution increase the risk for myocardial infarction. The grant was aimed to be used for further design the study and further grant applications.

During the period we have discussed and defined the design of two studies;

- A cross-over design to study the effect of acute exposure to air pollution and risk of acute myocardial infarction or angina pectoris.

- In order to study the effect of chronic exposure (5 years), where participants in Apollon study (see project 1.4) will serve as control subjects, the risk to fall ill with acute myocardial infarction or angina pectoris will be analyzed in a case-control study.

We have included 650 consecutive patients who fell ill with acute myocardial infarction or acute angina pectoris during the period 2001-2003 in the Gothenburg region as well as 3600 controls. Acute exposure to PM10, PM2, NOx and ozone days before the infarction/event has been modeled for each individual on the basis of residence, in collaboration with Bertil Forsberg, Occupational and Environmental Umeå. Assessment and modeling of chronic exposure to air pollution still have to be performed.

Genetic polymorphism of important anti-oxidant enzymes, in accordance with the study 2.3, are currently being analyzed, and its modifying effect on any risk will be analyzed.

For further analyses of these data we have received a grant for a PhD-student, included in a PhD-program for Health and Environment from Västra Götaland County. We have also received a grant from Formas for analyses of these data (P.I Fredrik Nyberg). We are also currently applying for money for a post-doc student, to expand the analyses of these data and further exposure assessment including data from study 1.5.

Project 1.7. Cohort study on total public health burden related to long term-exposure to air pollution

Project leader: Göran Pershagen, Karolinska Institutet

General Objective: Assess relation between long-term exposure to ambient air pollution and total public health burden, primarily involving effects on cardiovascular and respiratory morbidity and mortality.

The project has progressed according to plan. A cohort has been established in Stockholm county including about 25 000 subjects from four subcohorts with detailed information on risk factors and outcomes. An extensive air pollution measurement program supported by the EU is ongoing to validate the exposure assessment methodology. A residential history from 1991 will be obtained from all study subjects as a basis for the exposure assessment, involving some 50 000 addresses. Ethical approval for the extended project is being sought.

It should be realized that the limited funding by the Swedish EPA covers only a minor part of the resources required for the project and additional long-term funding is needed. Complementary funding has already been received from the Swedish Heart and Lung Foundation and a proposal is currently under review at the Swedish Council for Working Life and Social Research.

Phase II

A residential history from 1991 will be obtained from all study subjects as a basis for the exposure assessment, involving some 50 000 addresses. Follow-up in myocardial infarction, stroke, cancer and mortality registers will enable estimation of exposure response relationships as well as assessment of the public health burden.

Funding requested: 1 300 kkr för Phase II (700 kkr less than originally, but these 700 kkr are transferred to project 1.1)

Project 1.8. Long term exposure to traffic related air pollution and genetic susceptibility in relation to myocardial infarction

Project leader: Göran Pershagen, Karolinska Institutet

General Objective: Assess interactions between traffic related air pollution and genetic susceptibility in relation to myocardial infarction.

The project has progressed according to plan. A manuscript is in press indicating that long-term exposure to ambient air pollution increases the levels of some markers of systemic inflammation (IL-6, CRP). The analysis was based on the control subjects in the SHEEP study, which are also included in the gene-environment interaction analyses. Another manuscript is under preparation on interactions between genetic variants (polymorphisms) in genes involved in inflammation or coagulation and ambient air pollution in relation to the risk of myocardial infarction. Genotyping of the relevant genes has already been performed. The original project will be concluded in 2009 and gene-environment studies on cardiovascular disease will continue in the cohort study described in project 1.7.

Phase II: This project finishes during Phase I.

Written publication: Panasevich S, Leander K, Rosenlund M, Ljungman P, Bellander T, de Faire U, Pershagen G, Nyberg F. Associations of long- and short-term air pollution exposure with markers of inflammation and coagulation in a population sample. Occupational and Environmental Medicine (in press).

Oral presentation: Panasevich S, Leander K, Rosenlund M, Ljungman P, Bellander T, de Faire U, Pershagen G, Nyberg F. Long- and short-term air pollution exposure and markers of inflammation and coagulation in a population sample from Stockholm. Presentation på konferens anordnad av "International Society for Environmental Epidemiology" i Dublin 25-29 Aug 2009.

Project 1.9. DISOZPOLL; Diesel and ozone effects on the cardiovascular system

Project leader: Thomas Sandström, Lung och allergikliniken, Norrlands universitetssjukhus, 901 85 Umeå, thomas.sandstrom@lung.umu.se

General Objective: : To increased the understanding of how ozone and diesel exhaust interacts with the lungs, leading to events in the cardiovascular system that are linked to the increased health effects related to these pollutants

Controlled ozone and diesel exhaust chamber exposures and sampling and measurements of cardiovascular and respiratory effects in human research subjects.

Continued experimental research with diesel and ozone exposure studies in healthy, COPD and cardiovascular disease. Several experimental series performed and a series of papers produced. One dissertation; Håkan Törnqvist in the project.

Continued focused research on mechanisms behind the adverse cardiovascular and respiratory effects by diesel exhaust together with interventive studies in order to diminish the adverse effects.

Additional staff: A Blomberg, S Barath, H Törnqvist, M Gonzalez, A Johansson, F Holmström, MC Ledin, M Sehlstedt, J Bosson, J Pourazar, AB Lundström, E Roos-Engstrand, M Lundbäck.

Co-operation: DE Newby, N Mills, K Donaldson, A Lucking

Stakeholders: Naturvårdsverket, Vägverket, WHO, Health Effects Institute, Fordonsindustrin, oljeindustrin, patientföreningar

Written publications:

Törnqvist H, Mills NL, Gonzalez M, Miller MR, Robinson SD, Megson IL, Macnee W, Donaldson K, Soderberg S, Newby DE, Sandstrom T, Blomberg A. Persistent Endothelial Dysfunction Following Diesel Exhaust Inhalation in Man. Am J Respir Crit Care Med. 2007 Aug 15; 176;395-400.

Mills N, Törnqvist H, Gonzalez MC, Vink E, Robinson SD, Söderberg S, Boon NA, Donaldson K, Sandström T, Blomberg A, Newby DE. Ischemic and Thrombotic Effects of Dilute Diesel Exhaust Inhalation in Men with Coronary Heart Disease. New England Journal of Medicine, Sept 13; 357:1075-82.

Cruts B, van Etten L, Tornqvist H, Blomberg A, Sandström T, Mills NL, Borm PJ. Exposure to diesel exhaust induces changes in EEG in human volunteers. Part Fibre Toxicol. 2008 Mar 11;5(1):4

Bosson J, Barath S, Pourazar J, Behndig AF, Sandström T, Blomberg A, Ädelroth E. Diesel exhaust exposure enhances the ozone induced airway inflammation in healthy humans. Eur Respir J. 2008 Jun;31(6):1234-40.

Löndahl J, Pagels J, Boman C, Swietlicki1 E, Massling A, Rissler J, Blomberg A, Bohgard M, Sandström T. Deposition of biomass combustion aerosol particles in the human respiratory tract. Inhal Toxicol, Aug;20(10):923-33.

Mills NL, Robinson SD, Fokkens PHB, Leseman DLAC, Miller MR, Anderson D, Freney EJ, Heal MR, Donovan RJ, Blomberg A, Sandström T, MacNee W, Boon NA, Donaldson K, Newby DE, Cassee FR. Exposure to concentrated ambient particles does not affect vascular function in patients with coronary heart disease. Environ Health Perspect, Jun;116(6):709-15.

Lucking AJ, Lundback M, Mills NL, Faratian D, Barath SL, Pourazar J, Cassee FR, Donaldson K, Boon NA, Badimon JJ, Sandström T, Blomberg A, Newby DE. Diesel exhaust inhalation increases thrombus formation in man. Eur Heart J. 2008 Oct 24. [Epub ahead of print]

Lucking AJ, Lundback M, Mills NL, Faratian D, Barath SL, Pourazar J, Cassee FR, Donaldson K, Boon NA, Badimon JJ, Sandstrom T, Blomberg A, Newby DE. Diesel exhaust inhalation increases thrombus formation in man. Eur Heart J. 2008 Dec;29(24):3043-51. Epub 2008 Oct 24.

Mills NL, Donaldson K, Hadoke PW, Boon NA, MacNee W, Cassee FR, Sandström T, Blomberg A, Newby DE. Adverse cardiovascular effects of air pollution. Nature Clin Pract Cardiovasc Med. 2009 Jan;6(1):36-44. Epub 2008 Nov 25.

Oral presentations etc: Several lectures at national and international meeting and also to be given at the annual SCARP meeting

Project 1.10. PMMECH – Mechanisms behind particulate matter air pollution induced toxicological effects

Project leader: Thomas Sandström, Lung och allergikliniken, Norrlands universitetssjukhus, 901 85 Umeå, thomas.sandstrom@lung.umu.se

General Objective: To increase the understanding of how source, size and chemical characteristics of particulate matter pollution contributes to adverse cellular and biomedical events, linked to adverse health effects.

Collection of air pollution PM and physical and chemical characterisation together with toxicological analyses are under way. An extended literature search has been performed in order to achieve state-of-the-art knowledge in the research area.

Air pollution particle sampling and characterisation regarding physical and chemical properties. Analyses of biomedical mechanisms behind health effects in bronchial mucosal biopsy samples as well as in-vitro systems. Continued detailed studies of mechanisms behind particulate matter effects in the lungs, heart and blood system. Identification of new pathways mediating adverse effects. Further mechanistic research including interventive activities.

Additional staff: Maj-Cari Ledin, Maria Sehlstedt, Jamshid Pourazar, Anders Blomberg.

Co-operation: FJ Kelly, FR Cassee, I Mudway, DE Newby, A Bucht

Stakeholders: Naturvårdsverket, Vägverket, WHO, Health Effects Institute, Fordonsindustrin, oljeindustrin, patientföreningar

Written publications:

Gerlofs-Nijland ME, Dormans JA, Bloemen HJ, Leseman DL, John A, Boere F, Kelly FJ, Mudway IS, Jimenez AA, Donaldson K, Guastadisegni C, Janssen NA, Brunekreef B, Sandström T, van Bree L, Cassee FR. Toxicity of coarse and fine particulate matter from sites with contrasting traffic profiles.Inhal Toxicol. 2007 Oct;19(13):1055-69.

Pourazar J, Blomberg A, Frew AJ, Kelly FJ, Wilson SJ, Davies D, Sandström T. Diesel exhaust increases EGFR and phosphorylated C-terminal Tyr 1173 in the bronchial epithelium. Particle Fiber Toxicol, 2008 May 6;5:8-.

Bosson J, Pourazar J, Forsberg B, Adelroth E, Sandstrom T, Blomberg A. Ozone enhances the airway inflammation initiated by diesel exhaust. Respir Med. 2007 Jun;101(6):1140-6.

Mills NL, Robinson SD, Fokkens PHB, Leseman DLAC, Miller MR, Anderson D, Freney EJ, Heal MR, Donovan RJ, Blomberg A, Sandström T, MacNee W, Boon NA, Donaldson K, Newby DE, Cassee FR. Exposure to concentrated ambient particles does not affect vascular function in patients with coronary heart disease. Environ Health Perspect, Jun;116(6):709-15.

Lucking AJ, Lundback M, Mills NL, Faratian D, Barath SL, Pourazar J, Cassee FR, Donaldson K, Boon NA, Badimon JJ, Sandström T, Blomberg A, Newby DE. Diesel exhaust inhalation increases thrombus formation in man. Eur Heart J. 2008 Oct 24. [Epub ahead of print]

Mills NL, Donaldson K, Hadoke PW, Boon NA, MacNee W, Cassee FR, Sandström T, Blomberg A, Newby DE. Adverse cardiovascular effects of air pollution. Nature Clin Pract Cardiovasc Med. 2009 Jan;6(1):36-44. Epub 2008 Nov 25.

Oral presentations etc: Several given at research seminars

Projekt 1.11 Woodpart-2. A human experimental study using wood smoke for studies of acute effects of particulate air pollution on inflammation, coagulation and oxidative stress.

Project Leader: Gerd Sällsten, Occupational and Environmental Medicine, Sahlgrenska Academy

The specific aims are to find out whether effects of wood smoke on airway inflammation and blood coagulation found in a recently performed study (Barregard et al 2006) can be repeated at lower levels of particles and if the effects differ in relation to the fraction of ultrafines (UFP < 100 nm) in the smoke.

Activity 2006-07: Chamber experiments, analysis of biological samples and filters from air sampling, start of evaluating the exposure and some of the biomarkers. Activity 2007-2009: Further evaluation of some of the biomarkers and exposures. A PhD student, Leo Stockfelt (AT-läkare), is involved in this project. Evaluation will continue in 2009 and we will start writing the first manuscript in 2009. There will probably be at least two publications from this human chamber experiment. Two articles related to this project have been published (Barregard L 2008, Danielsen PH 2008) and another one, has been submitted. Five oral presentations have been held during 2008-2009, both in Sweden and at an international conference (ICOH, Cape Town 2009). The project has proceeded as expected. The project is well integrated in the SCARP programme for example by collaboration with Thomas Sandström's group in Umeå. The issue of wood smoke is important for policy makers.

Funding: 2010 250 kkr, 2011, 250 kkr and, 2012 250 kkr, in total 750 kkr

Publications:

Barregard L, Sällsten G, Andersson L, Almstrand A-C, Gustafson P, Andersson M, Olin A-C. Experimental exposure to wood smoke: Effects on airway inflammation and oxidative stress. Occup Environ Med 2008:65:319-24

Danielsen PH, Bräuner EV, Barregard L, Sällsten G, Wallin M, Olinski R, Rozalski R, Möller P, Loft S. Oxidatively damaged DNA and its repair after experimental exposure to wood smoke in healthy humans. Mutat Res 2008:642:37-42.

Kochbach Bölling A, Pagels J, Yttri KE, Barregard L, Sällsten G, Schwartze PE, Boman C. Health effects of residential wood smoke particles: the iomportance of combustion conditions and physicochemical particle characteristics. Manuscript

Phase II

The project has proceeded as expected and follows the original activity plan. In the years 2010-2012 the main focus will be on evaluation of data and preparation of manuscripts. There will probably be at least two publications from this human chamber experiment. The project is well integrated in the SCARP programme, for example by collaboration with Thomas Sandström's group in Umeå.

Funding requested

2010 250 kkr, 2011 250 kkr and, 2012 250 kkr in **total 750 kkr**

Project 1.12. Health effects of long range transported particles: a population study using air mass trajectories.

Project Leader: Gerd Sällsten, Occupational and Environmental Medicine, Sahlgrenska Academy

The aim is to test if the risk of myocardial infarction (MI) in Gothenburg increases on days when the origin of the air mass is from certain specific areas in Europe. It is still unclear which properties of PM are significant for toxicity. The role of the origin of the air masses is unknown.

We have modified the original investigation to study the effect of air pollutants from both local and distant sources on the risk of myocardial infarction among Swedish men and women in a case-crossover study.

An oral presentation was held at the ISEE/ISEA conference 2008. We have sent grant applications to FAS in 2008 and in 2009 (both were rejected) as well as to FORMAS in 2009. We propose a case-crossover study to examine the impact of air mass origin (and PM levels) on health outcomes. We will use 30,000 cases of MI in Gothenburg in 1987-2005. In the first step we will examine long distance transported vs. locally generated PM. For 8,000 days over 23 years we will collect trajectories showing the origin (e.g. continental, Nordic or marine) of the air masses. Climate data and air pollution levels (SO_2, NO_x, NO_2 and particles (soot, PM_{10})) on the date of onset of illness (lag 0 and lag 1) are also utilized. In the case-crossover design, a number of "control days" are identified for each individual. Individual risk factors stable over time need not be considered in the analysis, since each individual acts as "his or her own control". We will have 85% power to show a relative risk of 1.05 for continental air masses.

This project received a small amount of money (176 kSEK) from SCARP in the past years, which covers some planning activities. A PhD student already receives his salary from a research school and another co-worker is covered by a post-doc grant from FAS. In order to continue this project we would need further funding (2.2 MSEK). If further funding is provided the project will be well integrated in the SCARP programme for example by collaboration with IVL. A grant application has been sent to FORMAS in 2009.

Publications:

Molnar P, Barregard L, Sällsten G. Particle number and NOx concentrations n Gothenburg – Present levels and changes over time due to traffic planning. Oral presentation at ISEE/ISEA conference, Pasadena, US, 2008.

Phase II

The aim is to test if the risk of myocardial infarction (MI) in Gothenburg increases on days when the origin of the air mass is from certain specific areas in Europe. It is still unclear which properties of PM are significant for toxicity. The role of the origin of the air masses is unknown.

We have modified the original investigation to study the effect of air pollutants from both local and distant sources on the risk of myocardial infarction among Swedish men and women in a case-crossover study. We will use 30,000 cases of MI in Gothenburg in 1987-2005. In the first step we will examine long distance transported vs. locally generated PM. For 8,000 days over 23 years we will collect trajectories showing the origin (e.g. continental, Nordic or marine) of the air masses. Climate data and air pollution levels (SO_2, NO_x, NO_2 and particles (soot, PM_{10})) on the date of onset of illness (lag 0 and lag 1) are also utilized. In the case-crossover design, a number of "control days" are identified for each individual. Individual risk factors stable over time need not be considered in the analysis, since each individual acts as "his or her own control". We will have 85% power to show a relative risk of 1.05 for continental air masses. A PhD student already receives his salary from a research school and another co-worker is covered by a post-doc grant from FAS. In order to continue this project we would need further funding (2.2 MSEK). A collaboration with IVL has been initiated and a grant application has been sent to FORMAS in 2009 (1.8 Mkr).

Funding requested

2010 150 kkr, 2011 150 kkr and, 2012 100 kkr in **total 400 kkr**

Area 2 Regional and national atmospheric models for particulate matter

Area coordinator: HC Hansson, ITM, Stockholms Universitet

Project 2.1 Chemical Modelling of Aerosol Formation

Project leader: David Simpson, EMEP MSC-W, Norwegian Meteorological Institute & Department of Radio & Space Science, Chalmers Institute of Technology

Summary

Subproject 2.1 aims at developing modules for aerosol chemical formation which are appropriate for 3D chemical transport models. The modules developed need to be computationally efficient but at the same time of useful quality when compared to more detailed models, and smog chamber data, and to atmospheric observations.

Sammanfattning
Syftet med delprojekt 2.1 är att utveckla modeller som beskriver bildning och tillväxt av atmosfäriska partiklar. De utvecklade modellerna ska gå att använda i 3-dimensionella kemiska spridningsmodeller (specifikt EMEP- och MATCH-modellerna). För att vara användbara behöver modellerna därför vara beräkningsmässigt effektiva men samtidigt av tillräckligt bra kvalitet jämfört med mer detaljerade modeller och i god överensstämmelse med observationer av partiklarnas kemi och fysik vid atmosfäriska förhållanden.

Work performed during Phase I

In recent years a number of new studies have become available which necessitate revisions and new testing of the EMEP secondary organic aerosol (SOA) scheme. As shown in Simpson et al. (2007), assumptions concerning the vapour pressure of specific compounds can have pronounced effects on predicted SOA amounts. The Kamens group has presented new ideas for the α-pinene mechanism, including attempts at modelling so called oligomerization reactions in the particle phase (e.g., Li et al., 2007). A large number of new smog-chamber data has become available in recent years, allowing a better understanding of the dependencies of SOA formation upon initial conditions, NOx levels, light, relative humidity, and wall-losses (e.g., Pathak et al., 2007).

Collaboration with Richard Kamens (Univ North Carolina, Chapel Hill) has been initiated regarding the biogenic SOA models. Several different box-model chemistries have been implemented, as a first step towards an updated SOA scheme for use in the EMEP model. Adapted versions of schemes by Kamens et al. (Kamens et al., 1999, 2001, Li et al., 2007), and a number of different so called volatility basis set (VBS) models (e.g., Pathak et al., 2007) have been implemented as well as a recently parameterised 2-parameter (αK) model by Svendby et al. (2008).

Box-model results for the different model schemes have been compared to SOA yield data from a large number of published smog chamber studies. The results from the comparison were presented at the general assembly of the European Geosciences Union (EGU) in 2009 (Bergström & Simpson, 2009). The parameterised VBS (and 2-product) models are clearly superior to the semi-explicit chemical models when compared to smog chamber data. The simple VBS-based methods are promising and it is therefore of interest to test them also for modelling field measured SOA concentrations.

Collaboration with the Gas Phase and Aerosol Chemistry Group, of Urs Baltensperger, at the Laboratory of Atmospheric chemistry at Paul Scherrer Institut (PSI, Switzerland) was initiated during 2008 with the aim to evaluate and further develop the the EMEP α-pinene secondary organic aerosol module, using PSI reaction chamber data. Comparisons of the box-model versions of the EMEP SOA model to experiments performed at PSI show that for low (atmospherically relevant) concentration experiments all model versions strongly underestimate SOA formation. For higher precursor concentration experiments the total SOA concentration can be reasonably well reproduced by some model versions but the chemical speciation in the model is not in agreement with measurements. Further work, together with the experts at PSI, can hopefully resolve some of the problems. It seems likely that, in order to get model results in good agreement with the measurements substantial revisions of the chemistry schemes are needed.

The box model results have also been compared to detailed measurements from the EUROCHAMP project (from the AIDA, EUPHORE and PSI smog chambers). A SOA model/chamber experiment intercomparison exercise, within the framework of the EUROCHAMP project (http://www.eurochamp.org/eurochamp-1/), has been initialised. A first workshop was organised by the Joint Research Centre (JRC) Ispra in April 2009 and the SOA box models developed within the SCARP subproject 2.1 were compared to a number of chamber experiments of oxidation of α-pinene by ozone. About eight different European SOA models participate in the inter-comparison (ranging from parameterised 2-product models to "fully" explicit models taking into accounts millions of different chemical species). One of the preliminary conclusions from the first workshop is that relatively simple SOA models perform about as well as the most advanced models available. It is, however, clear that all the models have difficulties in reproducing some of the experimental data and also that further work is needed to better characterize chamber processes/artifacts, such as wall losses of volatile and semi-volatile compounds. It is clear that, at present, no "perfect" chemical model exists that can be used as a true reference model for even the relatively simple system of α-pinene oxidation by ozone.

Apart from box model simulations, several versions of the VBS methods (based on Lane et al., 2008 and Shrivastava et al., 2008) have also been implemented for use in the 3D-EMEP model and some first tests of these models (as well as the older Kam2x α-pinene model) have been performed on the European scale, comparing the results with detailed observational data from measurement campaigns (e.g., SORGA, Göte-2006, CARBOSOL). The first results were presented at the general assembly of the EGU in 2009 (Simpson et al., 2009). Some results are shown below, in Figure 2.1.3. The VBS based model results are very sensitive to assumptions regarding the (semi)volatility of anthropogenic VOC-emissions and chemical aging of SOA. Further validation against larger observational data sets will be needed before firm conclusions can be drawn. The VBS models are computationally efficient and they are interesting candidates for 3D modelling.

So far the work within subproject 2.1 has been mostly on SOA formation from terpenes. There is some evidence that also isoprene may be an important contributor to SOA and work has been initiated on isoprene chemistry in collaboration with Cornelia Richter, FZ Jülich. Initially the work has been focused on gas phase chemistry and updating the isoprene mechanism used in the EMEP model, using the latest available data on measured reaction rates and comparisons with the MCM model.

Objectives for Phase II

1. The models implemented within SCARP phase I will be further developed and evaluated against smog chamber data from the EUROCHAMP projects in collaboration with other modelling and smog chamber groups in Europe. The model intercomparison exercise initiated within EUROCHAMP-I will be continued during EUROCHAMP-II. This way the SOA models developed for 3D-application within the EMEP and MATCH models will be compared to both state-of-the art measurements and other advanced models.
2. Further work on evaluation of the simplified SOA schemes for use in 3D-models will be performed. The main future plans involve work making use of new data arising from recent field experiments, which include sufficient measurements to allow source-apportionment of the aerosol. Major data-sets involve the recent EMEP intensives and data from the EU EUCAARI project (Kulmala et al., 2009).
3. A parameterised cloud scheme for incorporation in 3-D models will be implemented. Detailed treatment of the chemistry is expected to be important for an accurate description of the aerosol size and chemical evolution over time (especially for remaining CCN population of dissipating clouds). The cloud scheme will also be used to estimate in-cloud scavenging of interstitial aerosol, rainout processes as well as effects on vertical distribution of aerosols resulting from cloud cycling. Aqueous uptake and processing of organic molecules will also be investigated to

determine the potential impact on secondary organic aerosol formation. The development will be based on the testing of different schemes with the detailed reference box model, SU-UHMA.

4. In recent years glyoxal has been identified as a potentially important SOA precursor (e.g., Volkamer et al., 2007). Collaboration with the group of Barbara Nozière (ITM, Stockholm) has been initiated during 2009 and we plan to investigate the importance of glyoxal further during SCARP Phase II. Modelling will be used to investigate the possible depletion of glyoxal in regions of Europe and to investigate the contribution of the glyoxal chemistry to the formation of SOA. The EMEP model's glyoxal predictions will be compared to the near-explicit Master Chemical Mechanism (MCM, http://mcm.leeds.ac.uk/MCM/). Then the importance of the suggested new reactions on glyoxal concentrations in the atmosphere, and on SOA formation will be tested.
5. The organic aerosol model developed in subproject 2.1 will be coupled to the EMEP/MATCH adapted SALSA model being developed within subproject 2.2. The goal being a computationally efficient 3D-version of the combined model.
6. In Phase I the focus has been mainly on *biogenic* SOA (from terpene oxidation). In phase II we plan to also look at the importance of *anthropogenic* SOA in more detail. Collaboration with Richard Kamens was initiated in 2008 regarding the biogenic SOA models. Kamens' group is also developing a condensed model scheme for SOA formation from anthropogenic hydrocarbon mixtures. If their work is successful adapted versions of their scheme will be tested for use with the EMEP SOA model.

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Project 2.2. Developing dynamic particle description including formation, growth and deposition

Project leader: Cecilia Bennet, SMHI

Summary

The overall goal of this sub-project is to provide an improved understanding of how the natural and anthropogenic emissions influence the number, mass and composition of the atmospheric particles with high spatial and temporal resolution. A suite of objectives have been identified in relation to aerosol dynamics modelling which is considered to be indispensable in order to meet the overall goal.

Sammanfattning

Det övergripande syftet med detta delprojekt är att förbättra vår förståelse av hur naturliga och antropogena utsläpp påverkar de atmosfäriska partiklarnas antal, massa och kemiska sammansättning, med hög temporal och spatial upplösning. Flera mål har identifierats som har relation till modellering av aerosoldynamik, som betraktas som nödvändig för att kunna svara mot det övergripande syftet.

Objectives and results from Phase I

2.2.1. *Agree with the other sub-projects in Area 2 upon the description of the general modelling structure, including the treatment of size distribution and the choice of the aerosol dynamics model to implement*
The descriptions of the general modelling structure have been agreed upon with ITM and EMEP. A well tested aerosol module, SALSA from FMI, Finland, was selected to be implemented in the two CTMs MATCH and EMEP.

2.2.2. *Making an outline of performance evaluation requirements.*
Evaluation of the aerosol model in phase I should be performed as a comparison of model output to monitoring data sampled at European rural sites. The comparisons should be made for number distribution, PM2.5, PM10 and secondary inorganic aerosol (SIA). More general recommendations for the evaluation of regional CTMs have been studied during the US-EU AQMEII workshop in Stresa, Italy, April 27-29 2009.

2.2.3. *Providing a summary of data requirements in order to perform model evaluation.*
Number distribution data from EMEP DE44 in Melpiz, Germany, SE12 Aspvreten in Sweden, FI50, Hyytiälä in Finland and NO01 Birkenes in Norway are used for the preliminary evaluation within phase I. For SIA, PM10 and PM2.5 all EMEP stations within a domain containing northern Europe are used.

2.2.4. *Reviewing the algorithms that are to embody the aerosol dynamics processes and the assumptions that are made to derive these algorithms and the limitations they might impose.*
The module SALSA (Kokkola et al. 2008) from FMI has been optimised to work fast enough to be implemented in large three dimensional models such as general circulation models or CTMs. So far the model has been tested with good results in the GCM ECHAM5 (Kokkola et al. 2009). In order to allow the use of the SALSA module in a regional CTM, two modifications have been made: Control of mass also for the larger particle fractions (not required in GCMs that focuses cloud formation) and inclusion of HNO3 and NHR (ISORROPIA).

Implement the aerosol dynamics module in the 3D CTM.
The SALSA algorithm is implemented in the MATCH-model. The EMEP-model has been installed and tested at SMHI, with the aim at preparing the computational environment for implementation of the SCARP-developments into the European policy model.

Objectives for Phase II

7. *Evaluation of the* SALSA-3D CTM system with regard to computational speed and parallelisation of the code.
8. Implementation of size resolved emissions as reported within the EUCAARI network and subproject 2.3.
9. Further development of the SALSA module in order to add oxidized and reduced nitrate and make a coupling to secondary organic aerosols from subproject 2.1. Implementation of a thermodynamic equilibrium model will be needed.
10. Evaluation with size resolved and chemically separated measurement data.

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Project 2.3. Construct emission databases for dynamic particle models and validate urban models concerning particle size distribution and chemistry

Project leader: Christer Johansson, ITM, Stockholms Universitet

Summary

This project has developed source specific particle-size resolved emission factors for both number and mass. The emission factors has been implemented in an emission database suitable for both urban and regional particle dynamic models, managed by TNO, that describe how the particle-size distribution develop and disperse over an urban area.

Sammanfattning

I detta projekt har vi tagit fram emissionsfaktorer för partikelantal och massa för olika källor i urban miljö och implementerat och implementerat dessa in en databas som administreras av TNO, vilket har skett inom ett EU-projekt EUCAARI. Emissionsfaktorerna beskriver hela partikelstorleksfördelningen och emissionsdatabasen skall appliceras i spridningsmodeller för att bedöma betydelsen av partikeldynamiska processer för partikelhalterna på olika skalor. Resultaten från modellberäkningarna på lokal skala (dvs områden <100 km) utgör sedan input för modellberäkningar på mesoskala (<1000 km) och regional skala (>1000 km).

Work performed within Phase 1

The general objective has been to develop source specific particle-size resolved emission factors for both number and mass suitable for both urban and regional particle dynamic models that describe how the particle-size distribution develop and disperse over an urban area. Focus has been on residential wood burning and road traffic, which are the dominating sources and the most important for population exposure. Particle number emission factors (EF) is needed for assessment of effects on human health and the Earth's climate. The size distribution of the aerosol emissions is crucial for evaluating the impact on both health and climate. The deposition of inhaled particles in the human lung depends strongly on the size of the particles, which also is of major importance for the effects on climate via the interaction with solar radiation, aerosol dynamical processes and cloud formation. Modelling of atmospheric aerosols from the emissions to the concentrations in the atmosphere requires particle size resolved emissions as input.

The work has contributed also to the European integrated project on aerosol cloud climate and air quality interactions (EUCAARI) and used to estimate European emissions from RWC (residential wood combustion) based on an inventory of appliances and estimates of biomass fuel consumption. An OC/EC emissions inventory for Europe has been developed. The emission data will be used as input to regional and global air quality and climate models part of EUCAARI.

Residential biomass burning

Generally, lower particle number EFs are reported for automatic stoves/burners compared to batch-wise appliances using wood logs, but the ranges of the EFs for different appliances largely overlap. Median values are 5.0×10^{13} (range $1.9\text{-}21 \times 10^{13}$) for 19 studies on manual wood stoves, 4.2×10^{13} (range $0.3\text{-}9 \times 10^{13}$) for 8 studies on automatic stoves/burners and 5.6×10^{13} (range $3\text{-}10^2 \times 10^{13}$) particles per MJ fuel, for 4 studies on manual boilers. Even though both the type of appliance and the way wood is burnt lead to large variations in total EFs as reflected in the ranges observed, median values for all appliances are within 30%. In all cases a single particle mode is observed for the number size distribution. Median values of all measured geometric mean diameters (GMD) are 80 nm (range 54-210 nm), 83 nm (range 50-130 nm) and 130 nm (70-130 nm) for the manual wood stoves, automatic stoves/burners and manual boilers, respectively. The geometric standard deviations (GSD) of particle size distributions (PSD) are similar (around 1.5) for all appliances. Particle number emissions tend to decrease as burning efficiency decrease (oxygen content is lowered). At the same time the modal diameter increases.

In batch-wise burning, particles are mainly composed of carbonaceous (soot and organics) material. In all kinds of batch fired wood log systems, the firing process is often a mixture of different combustion conditions, e.g. cold smouldering, flaming, air-starved and rather optimized periods. In contrast to batch-wise burning, automatic pellet or chip burning provide more stable and efficient burning conditions resulting in much less variability in emissions. During "optimal" combustion conditions most particle mass is due to alkali minerals (salts) and the fuel ash content and composition become important for the emissions.

Extrapolation of EFs from laboratory emission measurements to real world residential biomass burning emissions is connected with many uncertainties. Unfortunately, there are very few measurements of the number size distribution in residential areas. Two studies report observations in residential areas were batch-wise burning of wood logs in different types of boilers and stoves are the dominating particle sources. They indicate quite small temporal variations in GMD's and PSD's with mean GMD's (GSD) of 75 nm (1.8) and 67 nm (2.1), respectively. The values are within the ranges observed in the laboratory measurements of emissions, but possibly somewhat lower than expected since these observations represent aerosols where coagulation and condensational processes could have contributed to some particle growth.

Road traffic

The road traffic emissions review focus on real world measurements. Generally laboratory studies may under predict real world emission estimates. One reason is that the tests include a limited number of vehicles that may not include high emitting conditions such as acceleration or evaluation of high emitting vehicles. A number of different methods have been used for determination of vehicle exhaust EFs during real world conditions. These include measurements i) in the close vicinity to a road or in a street canyon, either using inverse modelling, CO and CO2 increments and assuming fuel consumption, or based on emissions of tracers such as CO or NOx, ii)- in road tunnels where vehicle numbers and ventilation rate is controlled. There is one study where EFs for a large urban area were derived from measurements of turbulent fluxes in a tower and estimating emission factors based on eddy correlation and traffic data. In measurements along streets and highways emission factors are usually measured several metres away from the exhaust and the rapid dilution make emission factors independent of coagulation processes, but they may depend on temperature and relative humidity due to condensational processes. Based on these studies it is concluded that road traffic exhaust EFs for HDV (diesel) are 6 to 70 times higher than LDV. Vehicle speed is important; up to a factor 8 times higher EF at 120 km/h compared to 50 km/h. Lower ambient temperature result in higher "effective" EF (2 times higher at -15oC compared to +15oC). Other important parameters are engine load and fuel type. So far there are not so many studies reporting size resolved emission factors for road traffic. In some studies a clear bimodal distribution is observed; a nucleation mode around 20 nm and a soot mode around 100 nm. The soot mode is particularly evident at sites with high diesel vehicle shares.

OC/EC Emissions inventoryfor Europe
The emission of anthropogenic particulate elemental carbon (EC) and organic carbon (OC) from Europe is calculated for the year 2005. The inventories are based on previous particulate matter (PM) inventories, especially the GAINS model. Representative EC and OC fractions are selected and applied to ~200 individual GAINS PM source categories and separated in < 1µm, 1-2.5 µm and 2.5-10 µm size classes. The total EC and OC emission is constrained by the amount of PM emitted which limits uncertainty. The largest OC source in Europe is residential combustion of wood and coal. EC emissions are dominated by road transport (diesel) and non-road transport (diesel and fuel oil). Total carbonaceous aerosol for Europe in 2005 amounts to ~2000 kt/yr of which ~10% is due to international shipping. The emissions are gridded on a 1/8 º x 1/16 º resolution (or approximately 7x 7 km) using especially prepared distribution maps.

Objectives for Phase II

This part of the project is finished and will not continue in phase II. The resource allocated for ITM will be used for the further development and testing of the box model SU-UHE, that will be used in the subprojects 2.1 and 2.2.

Publications

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Project 2.4. Aerosol OA sampling and ^{14}C analysis

Project leader: Kristina Stenström, *Division of Nuclear Physics, Lund University*

The general objective of the project is aerosol sampling and ^{14}C analysis for producing data to be used to develop and validate the OA module to be implemented in the 3D chemical aerosol model.

Carbonaceous aerosol may roughly be said to originate from three sources; combustion of fossil fuels, biomass burning and biogenic sources. The fossil fuel is ^{14}C-free due to its old age and biomass and biogenic aerosols have known ^{14}C content. Measuring ^{14}C in an aerosol sample may therefore separate fossil from contemporary carbon which is valuable in understanding the origin of ambient aerosols. ^{14}C analysis is performed by accelerator mass spectrometry (AMS) at Lund University. Within SCARP large efforts have been made to develop techniques to reduce the mass detection limit of carbon for ^{14}C analyses as far as possible. Currently we have reached below 25 μg of carbon.

Aerosol samples have been collected at the station Vavihill from April 2008 to May 2009 for various analyses. The OC/EC fractions of these samples (until May 2009) have been measured, and ^{14}C analysis of total carbon will start in August 2009. Efforts have been made to develop methods for analysis of ^{14}C in different fractions of the aerosol samples and will be further tested during autumn 2009. Research efforts are coordinated with EU FP6 IP EUCAARI and EU FP6 I3 EUSAAR and ^{14}C analysis has been made on samples from Norway and Italy. Stakeholders are FORMAS, EU FP6 IP EUCAARI and EU FP6 I3 EUSAAR, CAFE, CLPTAP and Swedish EPA.

Phase II

The plan for Phase II within SCARP is still valid (see 2nd revision of the proposal) and the budget remains (190 kSEK/year for year 4-6 for 14C analyses).

Area 3 Ecosystem impacts of air pollution – nitrogen and acidification

Area coordinator: John Munthe, IVL

General Objective: *:* The objective is to improve our understanding of short and long term effects of nitrogen deposition with respect to recovery from acidification, biodiversity and eutrophication and to provide scientific support for measures to reduce negative impacts on the environment.

Additional staff: Filip Moldan, John Munthe, Sofie Hellsten (IVL), Annika Nordin (SLU), Lars Högbom (Skogforsk), Cecilia Akselsson, Harald Sverdrup (Lund University), Salim Belyazid.

Co-operation: Umeå University, NitroEurope, Eurolimpacs

Stakeholders: Swedish EPA, Swedish Forest Agency, Swedish Energy Agency, CLRTAP (WGE, CCE), NitroEurope, Eurolimpacs

Project 3.1. Nitrogen cycling in forest ecosystems

Project leader: Cecilia Akselsson, Lund University

General Objective: The overall objective is to improve our understanding of short and long term effects of nitrogen deposition with respect to recovery from acidification, biodiversity and eutrophication. This forms as a basis for project 3.2 "Dynamic nitrogen model development and evaluation".

Activity progress, phase I:
Project 3.1 has contributed to networking between the different research groups within the SCARP Ecosystem cluster as well as with other research groups through conferences and workshops, e.g the N2007 conference in Brazil and the preparation and organization of the workshop: Nitrogen critical loads for terrestrial ecosystems in low deposition areas. Stockholm 29-30 March 2007 with 26 participants from Finland, Norway, Switzerland, The Netherlands, US and Sweden. The policy aspect has been present throughout the 3-years period, through close contact with stakeholders, policy-oriented workshops and related policy-oriented projects. A close cooperation between IVL, Lund University and Skogforsk has led to concrete ideas of further cooperation and far-reaching plans on common applications on N cycling and N retention.

In subproject 3.1 existing data from N addition experiments, national monitoring and forestry research have been compiled as related to the requirements for the dynamic modelling development in project 3.2. The cooperation between project 3.1 and 3.2 has been extensive in phase I, and will be further deepened in phase II.

In a cooperation between project 3.1 and project 3.2 a comprehensive literature review, Belyazid et al.: "Nitrogen cycling in boreal forest ecosystems - A review of current knowledge in order to improve the ForSAFE model", was performed, summarizing the present research status of important N processes as related to the dynamic ecosystem model ForSAFE. This review is an excellent basis for model development with emphasis on the N processes.

In a parallel literature review (Fuhrman et al. manuscript), a compilation of a Swedish N addition experiments at Skogaby, Billingsjön, Gårdsjön, Asa, Kågeröd, Tönnersjöheden, Toftaholm, Mangskog and Svartberget in Sweden has been performed. The sites were selected based on availability of data needed to describe the key processes to model the N cycling in these ecosystems, both across the ecosystem boundaries (inputs and outputs) and internal N cycling. This compilation was done with N cycling models in mind. It includes data published in opened literature, in reports and not published yet, obtained by involving site managers, when appropriate. The material will be used in Phase II for model runs, development and testing.

Project 3.1 has also contributed to an extensive analysis of N concentrations in soil water within the Throughfall monitoring network. Time series of 88 sites all over Sweden have been analysed, in order to investigate gradients of nitrate leaching from growing forests. This study, together with other national N approaches e.g. mass balance calculations and ForSAFE modelling, are presented in the strongly policy-oriented manuscript Akselsson et al.: "Assessing the risk of N leaching across a steep N deposition gradient in Swedish forests using different monitoring and modelling approaches" which will be submitted to a scientific journal in September 2009.

This part of the SCARP project is run in close collaboration with a newly ended Formas project "Where does added N go in N-rich forests", led by L. Högbom. Soil solutions have been sampled using tension lysimeters at three forest sites in southern Sweden, and analysed for inorganic and total N. The data reviles large differences in N retention capacity between sites of comparable N-deposition and stand age. The data also show that high forest production occur even at high (close to N saturation) N losses. Preliminary results have been presented at a conference in Brazil (2007). In addition the stable isotope ^{15}N has been added to the soil in order to follow where the added N goes. Presently, most of the soil solution samples has been analysed, and the results will be published during the autumn 2009. ^{15}N samples await analysis but will be conducted later this year.

Gathering and compilation of data from long-term N addition experiments (pine-heath, spruce-forest and mire) simulating low N deposition in north-Sweden, have resulted in a number of publications and manuscripts, e.g.. Forsum et al. 2008, Strengbom & Nordin, 2008, Wiedermann et al. 2007 & 2009, Nordin et al. manuscript, Ishida & Nordin manuscript. The main results include data on how plant – parasite interactions are affected by N deposition and can act as main driver for biodiversity changes.

Nitrogen addition to catchment G2 at Gårdsjön continued for all three years of the phase 1, thus completing a total of 18 years of treatment in March 2009. The results from Gårdsjön contributed to the synthesis by Evans et al., (2008) and Goodale et al., (submitted). Experimental data were used for model development and tests (Futter et al., 2009, Belyazid and Moldan, 2009). Apart from INCA-N and ForSAFE-Veg, the data were also used for modeling with MAGIC model, to provide material for tests in the ongoing development of nitrogen module in the MAGIC model.

Vegetation was surveyed at Gårdsjön in 1992, one year into the N addition experiment NITREX. The continuation of the N-addition within SCARP opened the possibility to resurvey the vegetation after 16 years of adding 40 kg N/ha/yr. The vegetation re-survey was undertaken in 2008. It was accomplished in co-operation with The Norwegian Forest and Landscape Institute, with additional funds provided by Naturvårdsverket. The results will be published on its own, but were also used in development of criteria for setting critical loads for nitrogen based on changes in vegetation in co-operation with project 3.2.

Phase II

The cooperation between project 3.1 and 3.2 has been extensive in Phase I, and will be further deepened in Phase II. In Phase II some funding will be transferred from project 3.3. in order to further strengthen project 3.1 and 3.2. This budget transfer will allow the following project activities in Phase II:

The effects of land use history, site quality, tree age and soil mycorrhiza on N leaching will be assessed based on the Throughfall Monitoring Network. Data will be compiled and prepared from the sites for dynamic modelling, in cooperation with project 3.2. The mycorrhiza part will be done in cooperation with the Ecology Department at Lund University. On-going work within the Throughfall Monitoring Network and adjacent projects will also be utilized.

The long-term low-dose N experiment in north Sweden will be continued. They will continue to produce data on biodiversity effects (including trophic interactions) of N enrichment. The experiments are unique since the N doses are realistically low, in a region with very low background N deposition. The long period (nearly 15 years) for which the experiments have been run makes it possible to study long-term effects of N enrichment and we have revealed that N enrichment affects several mechanisms previously not studied. For example, natural N_2-fixation of cyanobacteria harbored by forest mosses seem to be negatively affected by very low N input. Moreover, this low background N deposition area is well suited to study ecosystem recovery following decreased N input, and several such studies are planned to take place during Phase II. Also we will study interactive effects between N deposition and disturbance caused by forestry on forest biodiversity.

Another important issue for Phase II is to continue our representation in international collaborations and activities focusing on communication of the N problem to policy makers on national as well as international levels. Currently there are activities aiming at integrating the N deposition question with the carbon sequestration question, and N effects on biodiversity and waters is a focal issue. Upcoming is a workshop in Britain (ses http://initrogen.org/edinburg2009.0.html), and within Phase II we will take part in the workshop as well as the continued activities that will follow.

Written publications:

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Ishida, T. A., Nordin, A. Effects of nitrogen enrichment in two contrasting boreal forest types on the fungal community of Vaccinium roots. Submitted manuscript.

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Nordin, A., Wiedermann, M. M. , Ericson, L. Vaccinium snow blight fungi proliferate from nitrogen enrichment in a boreal forest. Manuscript.

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Akselsson, C. et al. Assessing the risk of N leaching across a steep N deposition gradient in Swedish forests. N2007 in Costa do Sauipe, Brazil, 1-5 October 2007.
Hellsten, S et al. Report from a workshop on effects of low N doses on N sensitive northern ecosystems, Stockholm, 29-30 March 2007. 23rd Task Force Meeting of the ICP Modelling and Mapping, Sofia, Bulgaria.
Högbom, L. et al. Nitrogen losses from nitrogen rich coniferous sites in Sweden. N2007 in Costa do Sauipe, Brazil, 1-5 October 2007.
Moldan, F., Response in soils, waters and vegetation after 18 years of increased N deposition: some issues in setting up the effect-based criteria. Oral presentation at 19th CCE Workshop and the 25th Meeting of the Task Force M&M, 11 - 15 May 2009, Stockholm, Sweden
Nordin et al. Responses of boreal vegetation to low N doses - empirical observations with implications for the N critical load. Results presented at the Stockholm N workshop in March 2007. 17th CCE Workshop of the ICP Modelling and Mapping, Sofia, Bulgaria (Oral presentation by S. Hellsten).
Nordin et al ***Workshop organizer and keynote speaker***. "Nitrogen critical loads for terrestrial ecosystems in low deposition areas" An expert workshop of the Convention on Long-range Transboundary Air Pollution (LRTAP) 29 – 30 March 2007 in Stockholm, Sweden funded by the Swedish Environmental Protection Agency in cooperation with UNECE/LRTAP Convention and the Swedish Clean Air Research Programme (SCARP).
Nordin et al Invited speaker 19th CCE Workshop and the 25th Meeting of the Task Force M&M, 11 - 15 May 2009, Stockholm, Sweden
Nordin et al Invited speaker Nitrogen Deposition and Natura 2000 Workshop COST 729 Mid-term Workshop 2009 Nitrogen Deposition and Natura 2000 Science & practice in determining environmental impacts 18-20 May, 2009 Brussels

Project 3.2. Dynamic nitrogen model development and evaluation

Project leader: John Munthe, IVL

General Objective: To evaluate and further develop dynamic models for nitrogen in forest ecosystems including-vegetation interactions, and to develop policy relevant tools such as critical loads to be used in national and international assessment and abatement activities on air pollution.

Activity progress, Phase I:

New concepts for calculating critical load of nitrogen have been developed based on vegetation effects. The workshop "Indicators for modelling critical load of N based on vegetation effects" in Gothenburg in September 2007 was central (Belyazid et al., 2007).

N dynamics in forest soils have been developed in the ForSAFE-VEG model in the first phase of SCARP. The model development was based on a thorough review of current knowledge about N transformation processes and pathways in forest ecosystems, including biota and soil (Belyazid et al, manuscript). The progress in N dynamics in the ForSAFE model focused on nitrogen transformation processes in soils in view of simulating the nitrification and denitrification processes as well as estimating N immobilization and gaseous emissions from soils. The new N processes module is based on the aerobic/anerobic balance in the soil, and uses climatic and chemical conditions to steer the rates on N transformation in the soil (Belyazid, 2008).

Experimental data from Gårdsjön were used for model setup and testing, and for evaluating the performance of the model on an integrated biogeochemical ecosystem including the composition of the ground vegetation (Belyazid and Moldan, 2009). This study was also used to investigate the feasibility of using changes in the ground vegetation to estimate critical loads of nitrogen deposition. The method developed in this study was included in the basis of the recommendations presented to Coordinating Centre on Effects (CCE) of the LRTAP convention.

The recommendations of the critical loads of deposition based on the composition on the ground vegetation as a biological indicator resulted in a follow up by the CCE that may lead to a European wide application of the prototype developed within SCARP. The method and testing of the critical loads estimation based on vegetation composition are described in Belyazid et al. (2009), and were presented as the keynote speech at the 19tth CCE Workshop on dynamic modelling of air pollution impacts and the further assessment of nitrogen effects, May 2009, in Stockholm.

SCARP also contributed to investigating the effects of climate change on forest ecosystems in Sweden, with a view of how the expected changes in climate will change carbon stocks in soils, affect growth and alter weathering rates (Belyazid, 2007). The results were used as part of the basis of the in-depth evaluation of the environmental quality objective of "Natural Acidification Only".

Further, the MAGIC model was calibrated to the Gårdsjön experiment, and identification of gaps in conceptual understanding of the treated catchment, in co-operation with a NitroEurope project on INCA-N modelling at Gårdsjön (Futter et al. 2009).

Phase II

Suggestion for Phase II: To test the dynamic model ForSAFE on the three experimental sites in southern Sweden in the Formas project "Where does added N go in N-rich forests" managed by Skogforsk, where long-term effects of chronic N addition are studied, and on a selection of Throughfall Monitoring Network sites, and to continue the development of ForSAFE based on the results from the tests and on the results from Phase I

MAGIC model has been chosen by Swedish Environmental Protection Agency as a recommended tool to do assessment of acidification of lakes and surface waters. A web-based interactive tool (www.ivl.se/MAGICbibliotek) has been developed to facilitate the assessment. Future leaching of inorganic nitrogen to surface waters is, however, a major source of uncertainty in model predictions, MAGIC model not withstanding. This uncertainty is in part due to uncertainty in future land use and future climate. Therefore further model development and testing is needed to define and to minimize uncertainties involved in predicting future N cycling. In the Phase II the work with MAGIC model will be continued in co-operation with ongoing research financed separately in Sweden and abroad (Norway, USA). The extensive available data from N addition experiment at Gårdsjön will continue to be one of the flag ship sites which provide opportunity to develop and test MAGIC and other models.

Written publications:

Belyazid, S, 2008. Nitrogen dynamics in soils - A new module for the SAFE model. Report for IVL.

Belyazid, S., 2007. "Potentiella effekter an klimatförändring på skogsekosystem: dynamiskmodell beräkningar med ForSAFE-Veg". IVL internal report.

Belyazid, S., Jönsson-Belyazid, U. and Akselsson, C. Nitrogen cycling in boreal forest ecosystems - A review of current knowledge in order to improve the ForSAFE model. Manuscript.

Belyazid, S., Nordin, A., Akselsson, C., Hellsten, S., Kronnäs, V., Moldan, F., Sverdrup, H., Braun, S., Emmet, B., Nygaard, P.H. & Beier, C. (2007): Report on the findings of the workshop: Indicators for modelling critical load of N based on vegetation effects. Workshop in Gothenburg ,Sweden, 3-4 September 2007.

Belyazid, S., Sverdrup, H., Kurz, D., Braun, S., Rhim, B. 2009. Estimating Critical Loads of Nitrogen deposition using the Composition of the Ground Vegetation as a biological indicator. report to the CCE, Swedish Environmental Protection Agency and the Swiss Federal Office for the Environment.

Oral presentations etc:

Belyazid, S. The Swedish experience in modeling changes in the ground vegetation: where from and where to. Workshop on Nitrogen critical loads for terrestrial ecosystems in low deposition areas in Stockholm, 29 - 30 March 2007.

Belyazid et al. Dynamic critical loads of nitrogen deposition based on changes in the composition of the ground vegetation. N2007 in Costa do Sauipe, Brazil, 1-5 October 2007. (Oral presentation by S. Hellsten)

Belyazid, S. Integrated modelling for simulating nitrogen deposition effects and estimating critical loads of nitrogen based on changes in the ground vegetation. Workshop on Integrated Assessment Modelling of Nitrogen, 28-30 Nov 2007.

Belyazid, S. A summary of recent and ongoing developments in Sweden in modelling Nitrogen effects on terrestrial ecosystems. Joint Expert Group on Dynamic modelling meeting, 24-26 Oct, 2007.

Jenkins, A. & Moldan F. Nutrient Nitrogen – Results and Key Conclusions. Presentation at Extended Bureau Meeting WGE, 28.-29. Aug. 2007.

Project 3.3. Future impacts of forestry, deposition and climate change

Project leader: Filip Moldan, IVL

General objective: To assess impacts of climate change, deposition and forestry on leaching of acidifying and eutrophying substances from forest soils.

Phase II

This project starts in Phase II of the programme. The main objective is to assess impacts on terrestrial and aquatic ecosystems of future deposition, climate change and forestry. The results from projects 3.1 and 3.2 will form the basis for the assessment together with experiences from on-going projects on climate change impacts and the ASTA programme. An important task is to identify relevant future scenarios for the three main driver's of future ecosystem change: atmospheric deposition, climate and land use. Experiences from project such as SWECLIM, ASTA and Eurolimpacs will be used for this purpose. 1.

This activity will combine, interpret and extrapolate in space and time output from projects 1 and 2. The task to evaluate the impacts of deposition, forestry and climate change on ecosystems could be broken down to three steps: i. summarising by what major mechanisms will the climate change, deposition and land use affect the ecosystems and in which way will these mechanisms act, 69 ii. to estimate scenarios of how the drivers of ecosystem changes such as temperature, deposition, storm frequency, precipitation, deposition or land use will develop in the future and, iii. through models evaluate the impact of the changes in drivers on ecosystems. The structure of this activity follows this concept with 3 sub-activities, one for each of the above-described steps. 3.1 Evaluation of climate change impact on ecosystem response This activity will draw heavily on the results of projects 1 and 2 as well as results from on-going research projects (e.g. EU project Eurolimpacs, www.eurolimpacs.ucl.ac.uk/). Experimental and field observations of impacts of forestry and climate change on S- and N-cycling in forest soils and runoff will be used to calibrate and test models. The models will then be applied to future scenarios of climate change and forestry. The national ASTA database and data from monitoring and inventories will be used to model future impact of N deposition over regional to national scales. Leakage of inorganic aluminium and possibly mercury will also be included in these activities. 3.2 Scenario development Based on knowledge of available scenarios for land-use, deposition and climate, integrated scenarios will be developed and selected for assessment using models developed in project 2. The scenarios will be based on an analysis of policies and implementation of policies on use of forest biomass, SWECLIM climate scenarios and deposition currently being developed in the Eurolimpacs project. 3.3 Scenario calculations of acidification, nitrogen cycling and vegetation response When mechanisms in which the climate and land use change are likely to affect ecosystems are summarised and conceptualised (4.1), when scenarios of future land use are developed and predictions of GCM are downscaled and broken down to actual change of drivers such as temperature or precipitation (4.2) the final step is the actual scenario analysis, evaluation of the model outputs, interpretation and extrapolation. This activity will take place in the final years of the programme and will provide a modelling assessment of several likely scenarios of climate and land use change on ecosystems with respect to acidification, nitrogen cycling, and vegetation.

References

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Belyazid, S. and Sverdrup H.. (2005). FORSAFE-VEG: Modelling integrated effects of air pollution, climate change and forest management on ground vegetation. Submitted for publication.

Eurolimpacs. Information available at www.eurolimpacs.ucl.ac.uk/

Moldan, F., Kjønaas, O. J., Stuanes, A., and Wright, R.F., in press. Increased nitrogen in runoff and soil following thirteen years of experimentally-increased nitrogen deposition to a coniferous-forested catchment at Gårdsjön, Sweden. Env. Poll. Accepted for publication.

Wallman, P., Svensson, M. G. E., Sverdrup, H. and Belyazid, S. (2004). ForSAFE - An integrated process-oriented forest model for long-term sustainability assessment. Forest Ecology & Management 207(1-2): 19-36

Area 4 Integrated assessment modelling

Area coordinator: Jenny Arnell, IVL

General Objective: The overall objective of this sub program is to provide a basis for optimisation and assessment of future air pollution policies in Sweden and Europe.

The scientific results from this area have mainly been published in reports and are not as in the areas 1-3 yet available in the scientific literature. In order to get an insight in the publications, we have added short summaries of these reports at the end of the description of achievements for area 4.

Project 4.1. Costs of non-technical measures in IAM models - theoretical considerations

Project leader: Mohammed Belhaj, IVL

This sub project has focussed on the evaluation of the procedures used for estimating costs of abatement measures in the current version of the GAINS model and to assess the effects of including more complete cost calculations and also the possibilities of including additional measures in the model. This subproject has worked with the theoretical aspects of GAINS and has provided a basis for the inclusion of the so called non-technical measures in GAINS Sweden (in subproject 4.2). The sub project has resulted in a report (Belhaj et al., 2009). This report consists of two parts, presented below:

GAINS and GAINS-Sweden, in which there is a presentation and a review of RAINS and GAINS including the cost optimisation function and the related constraints. Furthermore, this part consists of a suggestion of the functional form of the optimisation model of GAINS Sweden together with behavioural as well as transaction costs and their related constraints. This part ends with recommendations for consistent and credible GAINS estimations.

Cost effective measures for air pollution and GHG abatement: GAINS Sweden and the case of the transport sector. The online GAINS model is used in this part to assess emissions reduction potentials and their costs in the Swedish transport sector based on the following scenarios:

-10% renewable fuels, -Small cars (120 g CO2 / km), -Long Vehicles Trucks, as well as -Congestion charges.

The total emission reduction of CO2 using the different scenarios would be in the range of 5.5 million tons in 2020. However, except the GAINS' low resolution being the basis for the aggregated results, other parameters for a consistent assessment of health effects are suggested and discussed.

Publications:

Belhaj M. et al (2009) *Air pollution and Greenhouse gas emissions in Sweden: The transport sector*

Phase II - Project 4.1

One of the main objectives for phase II is the 'Assessment of transaction costs and review of their impacts in GAINS-Sweden costs effectiveness analysis'. As mentioned earlier, the research direction and title of the sub-projects will be reviewed at the phase II start-up meeting. However, the theoretical considerations concerning abatement costs will be subject to further research within phase II of SCARP-IAM.

Project 4.2. Inclusion of non-technical measures in the GAINS model

Project leader: Stefan Åström, IVL

The sub-project focuses on the practical implementation of activity changing and non-technical measures in modelling. Part of the research is done via establishment of a Swedish IAM model including test runs of the GAINS model. These latter project activities are further performed within sub-project 4.3.

Non-technical measures dealing with behavioural changes in the transport sector are not included in the current GAINS version. This subproject has been focusing on the integration of the so called non-technical measures in SCARP IAM with the transport sector as a case study. Calculations of effects of these measures on emissions and the associated costs have been made (The results are reported in: Belhaj et al, 2009, **Air pollution and Greenhouse gas emissions in Sweden: The transport sector)**. In addition to the study of behavioural changes in the transport sector, a study of potential energy reductions, energy efficiency improvements of the domestic sector in Europe has been performed. This study was carried out together with IIASA to be used as a basis for the development of scenarios for the on-going negotiations on a revised climate protocol.

Biofuels and the Swedish transport sector: Markal optimisation

The Markal model is used in this part to calculate emission reductions of CO_2 in the Swedish transport sector. A variety of fuels are included in the optimisation process i.e. gasoline, diesel, ethanol, biomethan (biogas and SNG), biodiesel (RME), methanol, DME, FT-diesel and hydrogen. In addition, electricity is loaded from the network to plug-in hybrids and pure electric vehicles. Based on cost effectiveness analysis CO2 emission reductions would be in the range of 3 million tons in 2020.

Impact of behavioural change in the Swedish transport sector

Modal choice and the Swedish transport sector are assessed in this part. Behavioural change strengthed by policy instruments as well as its impact on emission reductions of different pollutants are studied in this project using projections from The Swedish National Road Administration prognoses and long term elasticities. The projections from the road administration on CO_2 emissions in 2020 are estimated to be 3.3 million tons if only gasoline demand is concerned. When using long run elasticities the emission reduction of CO_2 in 2020 would be about 2 million tons following a price increase. Here emission reductions of CO2 are a result of increased gasoline price (all other things being constant).

Fuel efficiency improvements in buildings

In addition to the study of behavioural changes in the transport sector (sub-project 4.2), a study of potential energy reductions, energy efficiency improvements of the domestic sector in European countries have been performed. This study was carried out together with IIASA to be used as a basis for the development of scenarios for the on-going negotiations on a revised climate protocol. Within this subproject a detailed data set for the residential and commercial sector in the EU-27 countries as well as Norway, Switzerland and Turkey (EU-27+3) have been put together. The purpose was to gather national data for the EU-27+3 countries into the format suitable for the GAINS model used by IIASA. The data is then used in the European version of the GAINS model as a basis to estimate future emission abatement possibilities. Focus lies on energy use of heating, cooling, lighting and electrical appliance.

Publications:

Belhaj M. et al (2009) *Air pollution and Greenhouse gas emissions in Sweden: The transport sector*

Åström S, Maria L. Särnholm E. Söderblom J. Energy efficiency improvements in the European Household and Service sector - data inventory to the GAINS model. B1832, 2009

Phase II - Project 4.2

The phase II will further explore the transport sector and ways to include emission abatement measures into Integrated Assessment Models in a manner comparable to other more technical measures. - The title of the sub-project might change following the start-up meeting of phase II, but the focus on 'Additional assessment of the transport sector including behavioural and structural changes and their costs and incorporation of these in the other Swedish sectors', remain.

Project 4.3. Development of a GAINS Sweden

Project leader: Stefan Åström, IVL

The purpose of this sub project is to set up a direct link to IIASA and the relevant parts of the GAINS model covering Sweden, which allows the development of scenarios, introduction of new abatement measures and evaluate policies on energy on a National scale. The purpose of this subproject is also to make structural adjustments including specific inputs such as emission factors and activities on a Swedish level.

The approach is to develop a Swedish GAINS-model and calibrate it with the Swedish reporting of emission inventories and background data. Based on the fact that international cooperation is of great significance, an important part of this work has been performed in collaboration with the NIAM network (Network for Integrated Assessment Modelling) established under the UNECE Convention on Long-Range Transboundary Air Pollution. Several countries in Europe are developing national versions of the GAINS model or their own IAMs and NIAM is a forum for discussions of common issues related to data availability, design and performance of model systems and comparisons of different approaches. Training sessions for GAINS have also been arranged via NIAM. IVL has hosted the NIAM web site at: www.niam.scarp.se

The objective of this sub project has been to make possible structure adjustments and develop the GAINS model into a national version with possibilities of including specific input such as emission factors and activities on a Swedish level. By using the Swedish version of the GAINS model, a Swedish baseline projection to 2030 has been put together.

GAINS-SWE

During the first phase of the SCARP programme, the GAINS Sweden model (http://gains.iiasa.ac.at/gains/SE/index.login?logout=expired) has been initialised. The model is a similar version of the GAINS online (available for the UNFCCC annex 1 and the European version). The model allows a better description of Swedish emissions and control options via the option to adapt the emission factors used to calculate the emissions in the model. Furthermore, the model is about to be adapted to the available emission reporting format.

A Swedish emission baseline

The development of the GAINS Sweden modelling, allowing for better control of emission-related parameters also allow for the design of a Swedish baseline scenario calibrated with the GAINS model, which presents projections on energy use and emission up until 2030.

Publications:

Åström S, Lindblad M. A	*Swedish baseline for national energy-, transport- and agricultural projections to 2030 - input to the GAINS modelling under the UNECE LRTAP Convention, the Status report for the Swedish Environmental Protection Agency. 2009*

ApSimon H, Amann M., Åström S., Synergies in addressing air quality and climate change, accepted article in Climate Policy

Phase II - Project 4.3

The development of the Swedish GAINS model and a baseline scenario will continue in phase II. This work will also involve further setting of priorities and exploration of the GAINS model functionality and presentation of model results in collaboration with IIASA. The possibilities to increase the use of the, by IIASA, newly developed GHG Mitigation Efforts Calculator will also be explored. The possibilities to continuing the work with the challenges posed by emission abatement measures causing synergies or trade offs regarding emissions will continue. A larger collaboration with other areas of SCARP will be prioritised. The focus will be 'Further development of GAINS Sweden through extensive collaboration with IIASA and other SCARP sub-programmes such as area 1 and area 2'.

Project 4.4. Integrated assessment modelling at a national scale

Project leader: John Munthe, IVL

The sub-project activities aimed at Integrated Assessment Modelling at a national scale are focused on alternative emission scenarios as well as capacity building in Eastern European countries in collaboration with other projects.

Development of the Co-operation within the Convention on Long Range Transboundary Air Pollution – CLRTAP

A Swedish / Russian /Finnish collaboration project aimed at improving national capacities in GAINS modelling:

The Russian Federation (RF) is, like other EECCA countries, today a member of the LRTAP Convention (the Convention of Long Range Transboundary Air Pollution). To have a more active participation from the EECCA countries in the work of the Convention is becoming increasingly important as well as the development of agreements under the Convention and its protocols in order to safeguard a corresponding development within the EU and elsewhere in the world. At the international air pollution workshop "Saltsjöbaden III" in Gothenburg in March 2007, a special working group discussed obstacles and measures for promoting a larger attention to air pollution and related measures within the EECCA countries. A need for supporting activities directed specially to air pollution problems and related challenges was recognised, as well as procedural measures for enabling a closer co-operation aimed at concrete results. Based on these discussions and the fact that Sweden and Russia have a tradition to work together within this field, a joint project was elaborated:"Development of the Co-operation within the LRTAP Convention". The project so far has been implemented as planned in a Phase I and has compiled emission related data for 4 subjects of the Russian Federation in a format suitable for further scenario analysis with the GAINS online model. Furthermore, three GAINS model training sessions have been performed.

A Swedish low emission scenario

The SCARP IAM group has in collaboration with the project 'Nordic low emission scenarios in the GAINS model', adapted low emission scenarios into the GAINS online model. These scenarios show the impact of ambitious national energy policies.

Publications:

Åström, S., Lindblad M. A *Swedish scenario for national energy-, transport- and agriculture projections to half the energy use from 2005 to 2030 – input to the GAINS modelling under the UNECE LRTAP Conversion, the Status report from the Swedish Society for Nature*

Phase II - Project 4.4

The phase II of the project will continue the efforts to develop alternative national scenarios and present alternative emission futures and their environmental impacts. The possibilities for the SCARP IAM group to collaborate internationally with capacity building and information sharing between modelling groups will be considered and performed in collaboration with other projects or programmes. Of special interest for collaboration between the SCARP IAM and other projects or research groups are the NIAM and Eastern European countries.

Communication activities, conferences, workshops

During Phase I the subprogramme IAM have participated in a number of important activities, such as:

- Convention on long-range Transboundary Air Pollution, 8-10 June 2009, Netherlands

Presentations held:

The progress of the Network for National Integrated Assessment Modelling, Stefan Åström IVL

The Swedish energy and emission baseline scenario until 2030, Stefan Åström IVL

- Workshop GAINS-model training, 29 April 2009 at IVL Gothenburg

  - *GAINS online model workshop focused on SCARP IAM capacity building,*

- Tutorial workshop on the GAINS-model, 23-25 February 2009 at IIASA, Austria

  - *GAINS online model tutorial workshop, focused on EECCA country specialists (http://gains.iiasa.ac.at/index.php/other/past-meetings/158-gains-tutorial-workshop-february-23-25-2009)*

- Workshop, reducing the Environmental Impact of Transport with Behavioural Change, 8-9 January 2009, NAIM, London

Presentation held

  - *Behavioural change in the transport sector – the case of Sweden, Mohammed Belhaj and Stefan Åström, IVL*

- Air pollution and climate change – in cooperation for the best result, 12-13 November 2008, Stockholm

Presentations held

  - *The Swedish approach to combined control strategies within the Swedish EPA programme SCARP, Stefan Åström, IVL*
  - *Integrated judgment models, John Munthe, IVL*

- SCARP-presentation, SCARP annual meetings

Summaries of phase 1 reports and publications within Area 4

Åström S, Lindblad M. A Swedish baseline for national energy-, transport- and agricultural projections to 2030 - input to the GAINS modelling under the UNECE LRTAP Convention, the Status report for the Swedish Environmental Protection Agency. 2009

IVL has on assignment from the Swedish Environmental Protection Agency converted national energy-, transport- as well as agricultural projections into a format suitable for the Greenhouse Gas - Air Pollution Interactions and Synergy's (GAINS) model. The purpose of this status report is to describe the conversion procedure and to clarify uncertainties, adaptations and assumptions that have been deemed necessary to report Swedish projections until 2030 in a GAINS format. This project is performed by the project group involved in Integrated Assessment Modelling of the Swedish Clean Air Research Program (SCARP).

The international work on controlling emissions of air pollutants is to a large extent managed by the UNECE Convention on Long Range Transboundary Air Pollutants (CLRTAP). National projections on the member states emission-related activities are used by the Centre for Integrated Assessment Modelling (CIAM), which is hosted by the International Institute for Applied System Analysis (IIASA). The GAINS model is used for the international work with managing emissions of air pollutants within the CLRTAP, the EU Thematic Strategy on Air Pollutants (TSAP) and the EU work with managing emissions of greenhouse gases. The model also provides input to the work performed in the UNFCCC.

The conversions from Swedish projections into GAINS format is subject to a number of challenges. The main challenges involve the different perspectives on energy balance in GAINS and the SEA reporting as well as the different level of aggregation for fuels and sectors. The Swedish Long-term energy prognosis developed by the Swedish Energy Agency (SEA March 2009a) provide most of the input to conversion into GAINS format. However, the Swedish Environmental Protection Agency (SWEPA), The Swedish Road Administration and The Swedish emission inventory program (SMED) provided projections on agricultural activities, projected energy use for the road transport sector and non-road mobile, respectively. All projections and scenarios (except for the projections for electric vehicles) are consistent with the national basis for the air pollutant and greenhouse gas emission projections as reported by Sweden in March 2009. The projections take into account the Swedish policies adopted as of June 2008. This includes the feed-in of renewable energy via the Swedish electricity certificate system and CO_2 taxes inter ail. However, since the EU Climate & Energy package was not decided until December 2008 and adopted June 2009, the Swedish obligations under the EU Climate & Energy package were not introduced as a requirement in the scenario.

Åström, S., Lindblad M. A ***Swedish scenario for national energy-, transport- and agriculture projections to half the energy use from 2005 to 2030 – input to the GAINS modelling under the UNECE LRTAP Conversion, the Status report from the Swedish Society for Nature Conversion scenario. 2009***

IVL has on assignment from the Swedish Environmental Protection Agency converted the national energy-, transport- as well as agricultural projections (the Swedish baseline scenario) into a format suitable for the GAINS model. This baseline scenario is then used as background data to the projection Half energy and the whole welfare for 2030 from the Swedish Society for Nature Conversion (SNF 2008), which estimate an energy reduction that will half the energy use from 2005 to 2030 by using policy instruments and energy efficiency techniques. The purpose of this status report is to describe the conversion procedure and to clarify uncertainties, adaptations and assumptions that have been deemed necessary to report Swedish projection until 2030 in a GAINS format for the SNF scenario. The work with the SNF scenario is still ongoing and will be reported during the autumn 2009.

ApSimon H, Amann M., Åström S. ***Submitted article to Climate Policy*** **- Abstract**

Air quality is a serious concern for protection of human health and our natural environment. The pollutants contributing most to both local and transboundary air pollution problems are SO2, NOx, NH3, VOCs, and fine particulate matter, PM, and mostly originate from the same sources as greenhouse gases. There are thus strong interactions between strategies designed to improve air quality and those addressing climate change. This paper addresses these interactions, and the benefits of combined strategies with greater attention to the overall environmental impacts, and finding the "win-win" solutions. Illustrations are provided from development of policy in Europe under the UN ECE Convention on Long Range Transboundary Air Pollution, which is now inextricably linked with strategies to control greenhouse gases.

Åström S, Maria L. Särnholm E. Söderblom J. ***Energy efficiency improvements in the European Household and Service sector - data inventory to the GAINS model. B1832, 2009***

The emissions of greenhouse gases (GHG) and the growing concern for global warming and energy security are motivating increased European concern for energy demand reductions. As concerns for global warming and energy security increase the focus on emissions of GHG and energy demand, new sectors become more interesting as potential sources for cost effective solutions to further curbed emissions and decrease energy demand. Further improvements in the energy performance of buildings and equipment are important to Europe as means reducing energy demand as well as GHG. For both the residential sector and the service sector, heating and ventilation as well as air conditioning constitutes many of the total energies uses in these sectors, and there are large potentials for further improvements in the energy performance in the 'climate shell' of most European houses and buildings.

The International Institute for Applied System Analysis (IIASA) did invite the Swedish Environmental Research Institute (IVL) to participate in the process of producing detailed data sets for the residential and commercial sector in the EU-27 countries as well as Norway, Switzerland and Turkey (EU-27+3). The purpose was to gather national data for the EU-27+3 countries into the format suitable for the GAINS model used by IIASA. The data is then used in the European version of the GAINS model as a basis for estimates on future emission abatement possibilities.

In this study, detailed data of the residential and commercial sector energy use, energy demand reduction as well as energy demand reduction costs, building stocks, and control technologies have been compiled and converted into the format suitable for the GAINS model. Bottom-up projections have been calibrated with the EU projection currently used as a European baseline in the GAINS model. The study has been financed by the Swedish Energy Agency, FORMAS and the Swedish Environmental Protection Agency and was performed from October 2008 until March 2009.

Focus lies on two subsectors to the domestic sector, the residential and the commercial sector. It has been seen that energy use in this sector grow in many European countries' thanks to the increasing number of equipment in households and changing energy consumption patterns. Furthermore, the lifetime of buildings provides another dimension to the problem of energy demand management. The buildings constructed today is likely to stand for a hundred years, and the energy performance given to these buildings today will have a long impact on future energy demand as well as future energy bills.

The residential and commercial sectors in the Europe account for roughly 40 percent (the commercial sector accounted for 12 percentages and residential for 26 percentages) of the EU-27 final energy consumption in 2005. Half of this share origin from fossil fuels and is thereby directly causing fossil CO_2 emissions. The major service derived from energy consumption is to provide the service heat. For EU-27, the share of energy used for heat is approximately 70 percent units out of the mentioned above 40 percent. It is mainly considered that the residential and commercial sectors are subject to a wide variety of cost-effective options enabling a reduction of the fossil fuel use as well as reduction of energy used for heat purposes within the union.

The method for calculating GHG and air pollution mitigation options in the GAINS model is described in Cofala et al. (2008). The data inventory work performed in this project use follows the method described in Cofala et al. (2008) and is aimed at completing missing or incomplete data estimates in the GAINS model database. Data needed for implementation of the method on an EU-27+3 level are to a large extent collected from official statistical agencies such as Eurostat and UNECE, other international projects such as Odyssee, as well as national statistical offices and other official offices.

By the delivery of data sets to the GAINS model, and by using the methodology developed, the future importance of abatement measures in the residential and commercial sector can be further explored and comparisons can be made between countries. The compilation of the data set ensures that the methodology used in the different versions of the GAINS model to estimate emission reduction potentials are identical for all Annex 1-parties to the UNFCCC, which ensures harmonization of national estimates.

A closely related project is the Swedish / Russian /Finnish collaboration project aimed at improving national capacities in GAINS modelling:

Overall Objective with all project phases is to raise the awareness of the air pollution problem and to strengthen the political profile of CLRTAP activities in the RF. This should facilitate a continued and more active Russian participation in the work of the convention and constitute an important step towards a ratification of the Convention protocols (Gothenburg protocol inter alia). The project also aims at building capacity at the Ministry of Natural Resources and Ecology and responsible Russian authorities, for continued and enlarged work with IIASA: s GAINS model. Phase II Objectives are to:
1- Enable an increased scientific capacity of experts at SRI Atmosphere aimed at improved national communications with the LRTAP Convention and the GAINS model; 2- Complement emission inventories with additional data and projections required for policy analysis with the GAINS online model; 3- Enable the Russian Federation experts to provide credible policy analysis results to Russian decision makers and stake holders; 4- Establish a routine for communication of GAINS model results between SRI Atmosphere and the ministry responsible for CLRTAP in the RF.

Target Group is decision makers and experts at the Ministry of Natural Resources and Ecology of the RF, other responsible Russian authorities and experts of the JSC "SRI Atmosphere". The main planned activities for phase II are: A7: Further compilation of emission precursor data for the GAINS model SPET and Kola/Karelia region (6 subjects of RF); A8: Policy and scenario analysis with the GAINS model; A9: Study of transboundary air pollution impact on the GAINS model SPET and Kola/Karelia region (6 subjects of RF); A10: Study of pollutant depositions and critical load exceedance; A11:Ranking of sources to exceedance; A12: Communication of results for the regions and the Russian Federation to decision makers and other stake holders.

Summary of the main results from phase I of the project:
* Three GAINS model training sessions performed for 4-5 SRI experts.

* SO_2, NOx, PM and NH_3 Emission precursor activity data compiled for the St. Petersburg, Leningradskaja, Pskov and Novgorod subjects of the Russian Federation (referred to as SPET region in GAINS online model).
* Calibration of emission precursor activity data, control strategies and reported emission inventories for the subjects of RF initiated together with SYKE in Finland.
* The project has arranged one workshop for EECCA country officials and experts as well as Russian Federation Oblast country officials and experts, all in all 30 persons participated. The workshop was arranged as a side event to the TFHTAP session in St. Petersburg, Russia, on the 1st to 3rd of April 2009.
* SRI experts communicating project interim results at the SRI Workshop in St. Petersburg, Russia, April 2009, as well as on the UNECE TFIAM in Bilthoven, Netherlands, June 2009.

The second Phase (II) will continue the work initiated in phase I and will complete the activities related to modelling and data compilation with in-depth regional analysis, scenario analysis and will also focus even more on communication of results to national and international stakeholders involved in the LRTAP Convention.