Swedish Clean Air and Climate Research Program SCAC

A research proposal from

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Objective and research questions

The overall objective of the Swedish Clean Air and Climate Research Program (SCAC) is:

To develop and improve the scientific basis for air pollution policies on national and international scales.

More precisely we have defined the following objectives:

- Develop tools and systems analysis approaches for combined cost-effective abatement of Swedish air pollution and Short Lived Climate Pollutants (SLCP) and considering long lived GHG. (WP1)
- Develop systematic methodologies and processes for air pollution emission projections and scenarios, given various climate and energy policies, and taking into account future policy needs and requirements. (WP2)
- Improve the robustness of Swedish air pollution emission projections and estimations of emission abatement potentials in particular for shipping, agriculture and industries (including EU-ETS). (WP2)
- Develop and validate methods for estimating respirable particulate levels, such as black carbon (BC) from different sources with appropriate time and spatial resolution to be used in epidemiological studies and health impact assessments. (WP3)
- Develop sector distributed air pollution projections and exposure-response functions for long-term exposure to respirable particulates (such as BC) from different sources with respect to morbidity and identify suitable health indicators. (WP 2 and WP3)
- Make health impact assessments and cost estimates focusing on case studies including scenarios for reducing exposures. (WP3)
- Estimate the direct and indirect radiative forcing (RF) of both cooling and warming, short-lived climate forcers for N Europe and the European Arctic. (WP4)
- Translate the radiative forcings from SLCP into surface temperature change. (WP4)
- Estimate the effects of ground level ozone on forest growth and carbon sequestration in N Europe. (WP4)
- Evaluate and suggest further development of concepts and methods for describing critical loads and ecosystems effects. (WP4)

The program will focus on improving existing concepts and modelling tools applied in air pollution policy development, negotiations and assessments, with a time perspective of the period 2030 to 2050. The emphasis is on incorporating new and improved scientific knowledge on human exposure and health effects, ecosystem exposure and effects, synergies and conflicts for air pollution and climate abatement including SLCP and robust systems and processes for emission projections and scenarios.

A number of research questions and objectives have been identified and will define the main research activities in the program. The project is organised in four work packages (WPs)

- Integrated Assessment Modelling (IAM) – Synergies and Conflicts,
- Air Pollution Projections and Scenarios,
- Health Effects from Air Pollution,
- Climate and Ecosystems Effects

with Integrated assessment Modelling (IAM) as a cross-cutting activity to ensure integration of research activities and results. The programme and the four WPs cover all the main topics defined in the call for proposal.

Current knowledge

International research, policy development and technological innovations in the field of air pollution have led to large improvements in air quality in Europe and elsewhere. These efforts have focused on both local and national scales but international cooperation within CLRTAP and the EU has been the main driving force for focusing research, setting common goals and targets and finding solutions. Despite all efforts, air pollution impacts on human health and the environment are projected to remain a problem in Europe in the foreseeable future (HTAP and TFIAM, 2012) and further reductions of emissions are required to reduce impacts. For this continued work innovative research efforts are needed to describe and quantify the negative impacts of air pollution, to develop new abatement measures and to provide models and tools to support cost-effective selections of policies and measures. Effects to human health is expected to be one of the key drivers and recently published studies show that health effects can occur at concentrations below the current (2005) WHO guidelines. There has also been an increasing interest in health effects endpoints other than mortality such as cardiovascular diseases and adverse effects on lung function in children

Another important topic for future scientific support to air pollution policies is the link to climate change, partly with focus on the influence of climate change-driven abatement strategies on air pollution emissions and partly via the joint issue of SLCP which affect climate, human health and ecosystems. The links between climate change and air pollution requires research efforts both to better characterise emissions and effects of SLCP but also on methods and tools used for emission projections and for assessing cost-effectiveness in abatement strategies. Finally, ecosystems effects are still significant in Europe, in particular eutrophication effects from nitrogen deposition and ozone effects to crops and forests. How to describe these effects in terms of critical loads and critical concentrations need further consideration.

National emission projections are based on a range of models for e.g. economic growth, demand for energy and transport but there is currently no common ground for evaluation of interdependencies and uncertainties. The need for further knowledge of uncertainties has been highlighted in Wagner & Amann (2012) and Rypdal and Flugsrud (2001), and this emphasises the need for transparency and consistency in the preparation of emission projections to be used for policy support.

Research aimed at improving the scientific basis for regulating air pollution needs to be defined and evaluated in relation to IAM to allow incorporation into the commonly applied policy tools. The IIASA GAINS models system is currently used for both air pollution and climate policy support and is continuously developed and improved to take into account new sectors and abatement measures (Amann et al., 2013; Wagner et al., 2013). Following increasing complexities in policies (e.g. interactions between climate, energy and air pollution policies), new model components need to be developed and uncertainties and robustness in the model system need to be continuously assessed.

Integrated Assessment modelling - Synergies and conflicts

For a number of years focus for air pollution emission reductions has been on cleaner fuels, combustion technologies and end of pipe measures. By using optimisation procedures the most cost effective technical options are to a large extent already defined and implemented in the EU, and the further potential for emission reductions by technical measures is relatively low for e.g. SO_2 (3%) and NO_X (13%) (Amann et al., 2013). For climate, technological solutions will be far from sufficient for reaching the long term GHG emission targets (e.g Netherlands Environmental Assessment Agency, 2009; UK HM Government, 2009). Other solutions, such as behavioural changes are highlighted as necessary and have been evaluated as options to reduce GHG emissions (e.g. Faber, 2012). The theoretical foundations for how to quantify and model more types of measures is also improving (Darnton, 2008; Morton & Griffiths, 2012). However, there is still a need to translate knowledge on non-technical measures and behavioural changes into practice (Allcott & Mullainathan, 2010) as well as modelling and exploring the impacts on air pollution from these climate measures.

The potential to realise global co-benefits of air pollution abatement and short term temperature increases has been identified (Kuylenstierna et al., 2011, Shindell et al., 2012; Rafaj et. al., 2012). In a Nordic study some results indicated that there also can be conflicts between climate change and air pollution policies (Åström et al., 2013).

Projections and scenarios

National official Swedish projections of emissions of air pollutants and GHG are regularly reported to EU, CLRTAP and the UNFCCC following mandatory reporting requirements (EC, 2004; UNECE, 2009; EMEP/EEA, 2009; UNFCCC, 2000). In summer 2013 the new EU MMR (Monitoring Mechanism Regulation; EC, 2013) will most likely enter into force, replacing the current procedure (280/2004/EC). The MMR only covers GHG under the UNFCCC but needs to be coordinated with the overall process for developing national projections also for air pollutants.

National air pollution projections are also used for assessing the national environmental objectives and for validating the IIASA baseline scenarios, used as policy support in international negotiations within EU and CLRTAP (Åström et al., 2013). The Swedish EPA is responsible for the compilation of national official projections, based on input from a number of authorities and information sources (Ministry of the Environment, 2009; www.naturvardsverket.se; Kindbom et al 2007; Kindbom et al 2008; Gustafsson & Jerksjö, 2011; Gustafsson et al., 2012). Presently this work is scattered and without a common ground and understanding of the need from end-users. Emission projections are always modelled or based on hypothetical expectations of future developments and consequently include a fairly large degree of uncertainty. Sensitivity analysis can be used to identify parameters that have a significant impact on the resulting emission projections and for assessing the contributions from inputs to the total uncertainty in outcomes (http://ipsc.jrc.ec.europa.eu/?id=752, EMEP/EEA, 2009, DG CLIMA, 2012, Rypdal & Flugsrud, 2001).

Ex post analyses of previously reported projections are rarely performed, and thus there is no learning process established where the causes for variations in projections are analysed and evaluated. Presently EEA is undertaking a study on EU member states reporting of projections for 2010 under the NEC Directive and Monitoring Mechanism (Sporer, 2013).

Health effects

Health effects of air pollution are a key driver for future control of air pollution. The recent report on global burden of disease points to the importance of air pollution as a health hazard globally (Lim et al., 2012). Policy development has so far been mainly based on epidemiological studies on mortality but more recently there has been an increasing interest in other endpoints. Long-term exposure to air pollution has been associated with an increased risk of cardiovascular disease, partly by inducing systemic inflammation (Brook et al., 2010). The inhalable fraction of ambient particulate is considered to be responsible for most of the adverse health effects. However, the evidence is not conclusive on which particulate characteristics or sources are responsible for the effects. Available studies mainly implicate

BC but data on coarse particles are limited (WHO, 2013). Studies have not detected substantial deviations from linearity or provided evidence of thresholds.

Adverse health effects of ambient air pollution are prominent in children (Gruzieva, 2012). For example, in a series of publications based on the BAMSE birth cohort from Stockholm exposure to air pollution from road traffic during the first year of life has been related to asthma, allergic sensitization and lung function disturbances up to 12 years of age. Unfortunately, there are no studies on effects by air pollution exposure during infancy on development of asthma, allergy or lung function with follow-up until adolescence or adulthood.

Some studies indicate that exposure to air pollution negatively affects pregnancy outcome, such as the risk of low birth weight and prematurity (Slama et al. 2009; Olsson et al. 2012; Olsson et al. 2013). Since one of the major components of the foetal programming hypothesis is growth disturbance, as indicated by a low birth weight, this raises concerns that negative effects by air pollution in utero may also be of importance for adverse health effects later in life.

Assessments of health effects are strongly dependent on tools for linking exposure to sources and control measures. Models need to have appropriate time and space resolution (Gidhagen et al., 2013). Accurate estimation of concentrations of relevant air pollutants is essential for assessment of exposure-response relationships, and generally requires retrospective exposure data to study health effects of long-term exposure.

Health Impact Assessment (HIA) is used as a method to describe impacts of the current situation, future scenarios and policy options (Johansson et al., 2009; Orru et al., 2009). HIA is used at global, European (Andersson et al., 2009; Orru et al., 2013), national (Forsberg et al., 2005) and local levels (Omstedt et al., 2011) and can be included in broader cost-benefit analyses. A limitation is still the uncertainties in the exposure-response functions for the effect of PM, and the lack of generally accepted exposure-response functions for many important morbidity endpoints.

Currently the main-stream economic valuation of health impacts caused by air pollution is limited. Certain health impacts are not yet monetised. Also, some non-lethal health impacts such as cardiovascular disease are most often valued according to the cost of incidence, e.g. cost of cardiac hospital admissions (Holland et al., 2011)

Climate and ecosystem effects

The two acronyms SLCF – Short-lived Climate Forcers, and SLCP – Short-lived Climate Pollutants have been introduced in recent years to represent chemical components that have relatively short residence time in the atmosphere - a few days to a few decades (Quinn et al., 2008; Ramanathan and Xu, 2010). The focus is on agents that exert a warming effect (mainly BC and ozone), but short-lived components include also cooling agents where the influence on climate by aerosols depends on the chemical composition, size distribution and mixing state of the aerosol as well as the underlying surface. UNEP/WMO (2011) estimated that broad implementation of 16 existing emission reduction measures targeting BC and tropospheric ozone would reduce global warming by 0.5°C in 2050 and would improve the chance of not exceeding the 2°C target, but only if long-lived GHG such as CO_2 were simultaneously addressed.

The uncertainties in net climate forcing from BC-rich sources are substantial; largely due to lack of knowledge about cloud interactions with both black carbon and co-emitted organic carbon (Bond et al., 2013). Simulated global burdens of BC differ by more than a factor of two between models and the calculated average residence time range from 4.9 to 11.4 days (Schulz et al. 2006). Differences in burdens of BC over the Arctic exceed a factor of five. It is therefore important to try to further constrain and improve model simulations of aerosol compounds including BC. Furthermore, estimates of the direct (aerosol scattering or absorption of solar radiation) or indirect (modification of cloud physical and optical properties) RF from a change in the aerosol concentration are highly uncertain (IPCC, 2007). Translating aerosol RF into an actual surface temperature change is also not straight-forward; areas subjected to a positive aerosol forcing may not necessarily experience a surface temperature increase and vice versa (Shindell and Faluvegi, 2009). Mid- and high-latitude areas are also influenced by aerosol emission trends in the tropics as heat fluxes transfer some of the influence of forcings between tropics and extra-tropics.

Ozone represents an important threat to forest growth in the Northern Hemisphere and the impacts of current ozone levels on the growth are well established (Wittig et al., 2009) as are the impacts on Swedish forests (Karlsson et al., 2009). A first estimate showed that current ozone levels may reduce forest carbon sequestration in some northern and central European countries in the order of 10 % (Karlsson, 2012). A remaining uncertainty is the quantification of the ozone impacts on the growth of mature forests under field conditions.

The current target values set for ozone impacts on human health and vegetation impacts within the national environmental objective “Clean Air” are exceeded by far (Swedish EPA, 2012 rapport 6500). In future control strategies the aspects of ecosystems and health effects need to be considered together with the effects on climate.

The methodology to calculate critical loads (Nilsson and Grennfelt, eds. 1988) has evolved over time depending on the availability of detailed regional data and increased process understanding. At the same time, the gap between actual deposition and critical loads has decreased which has led to increased requirements for accuracy and reliability in the concepts and models used. The methodology has also developed with regards to the criteria for critical load calculation and multiple connections to chemistry-biology. Ecosystem effects examined include toxicity to fish and benthos, the ratio between base cations and aluminium in the soil water linked to toxicity to roots and also changes in the species composition of the ground vegetation layer. A dynamic concept (target loads, Jenkins et al., 2003) was developed to complement the critical load for acidification.

Theory and methods

WP 1 Integrated assessment modelling - Synergies and conflicts

WP1 will have an important interactive role both supporting and initiating the work in the other WP’s, but also in collecting, evaluating and synthesizing the work from the other WP’s to finally deliver results in support of policies.

Key research questions:

- Which technical and non-technical measures are available and will they be sufficient to reach national climate and air quality objectives?
- What are the discrepancies between results obtained with the GAINS model using different health and climate indicators and those from more topic-specific models? Do these discrepancies influence cost efficient abatement strategies obtained by GAINS? Which further developments would be needed to increase the applicability and robustness of the GAINS model?
- Which are the best tools and strategies to reach co-beneficial and cost effective abatement strategies in Sweden for a better air quality and reduced climate change 2030 and 2050?

Non-technical measures (NTM)
In WP 1 we will combine the methods for emission projections developed in WP2 in the light of the damage cost estimates developed in WP 3, to prepare relevant emission scenarios under different policy conditions and the implementation of non-technical measures. The NTM activity will by using case studies highlight the prerequisites for expanding the abatement option database in models such as the GAINS model. State-of-the-art, opportunities and barriers will be analysed and discussed.

Cost optimisation
The GAINS optimization routines will be used to analyse different pathways for cost-optimal emission control in Sweden. This analysis will highlight further potential for cost effective emission reductions, as well as further potential for realizing synergies and avoiding conflicts between objectives related to air pollution, climate and SLCP in Sweden. Cost effective emission abatements have been identified on a European scale, in relation to air pollution impacts (Amann et al., 2013). In order to analyse the economic benefits in Sweden of a better integration of air & climate abatement strategies we will adapt and develop national versions of the cost-optimization routines in the GAINS model (Wagner et al., 2013) using *i.a*. the results from WP3 and WP4. Efforts will be made to compare the SLCP aspects with the cost-effectiveness of other climate measures. We will also analyse potential concepts and prerequisites for an integrated cost optimisation of GHG and SLCP.

Synergies and conflicts
As a final activity in WP1, other non-cost related aspects of air pollution and climate synergies & conflicts will be explored. This activity will be performed in close collaboration with WP3 and WP4. The collaboration with WP3 will create opportunities for comparing different types of local abatement measures with national measures. WP4 cooperation will make it possible to compare efficiency and impact of SLCP abatement measures with various model concepts (GAINS, MATCH and NorESM). Important topics for the comparison relates to climate metrics and uncertainty related to specific SCLPs such as BC (Aamaas et al., 2012; Bond et al., 2013).

Through synthesis of results from WP2, 3 and 4 methodologies will be developed for the evaluation of co-beneficial robust abatement strategies that is consistent on local to European scales having 2030 and 2050 as time horizons.

WP2 Emission projections and scenarios
In WP2 the aim is to develop procedures for scientifically and technically sound projections and scenarios of emissions of air pollution and GHG. Compatibility with the official national systems is a key prerequisite.

Key research questions:

- What are the roles and needs of different stakeholders' and how can these be included in a conceptual model for future systematic and consistent emission projections?
- How will variations in the input of key parameters affect predicted emissions? What are the underlying assumptions and uncertainties in the tools used to develop emission scenarios? What limitations do these pose on the scenarios?
- Can time trend data on industrial energy use and economic value added provide robust estimates for emission projections from industrial activities?
- Will emission abatement in the North Sea and/or Baltic Sea regions provide a more cost-effective option to reduce environmental impacts in Sweden than national land-based emission reductions in 2020?

- How can alternative projections on agricultural activities affect key environmental aspects such as the Swedish nitrogen budgets and emissions of NH_3 and CH_4?

Analysis of current and future needs for projections.

The research will be based on an analysis of the required background data and other information needed for projections on different level of detail and geographical scales, and for different purposes, such as on the national environmental objectives, local and regional planning, international policy processes including international reporting. As a necessary framework, to ensure coordination/consistency between projections, WP2 will compile and structure international requirements for reporting of national projections within CLRTAP, EU and UNFCCC. The role and needs from national stakeholders will also be investigated. In this process the different sector splits and technology dependencies need to be carefully assessed.

Sensitivity analysis of projections.

Methods for sensitivity analysis of projections will be chosen based on a literature review (e.g. Wagner and Amann, 2012; Rypdal and Zhang, 2000; Rypdal and Flugsrud, 2001), and applied to Swedish data. A sensitivity analysis will be made for those explanatory factors with the highest potential, which will provide a range of likely future emissions for any particular projection or scenario. It will also provide information on which input parameters and assumptions that contribute most to the variations in the outcome. For the ex-post analysis of Swedish projections findings from an on-going study by EEA will be taken into account (Sporer, 2013). Swedish projections reported in the past will be compared and causes for different outcomes will be analysed. Findings from the ex post analysis will be fed into the sensitivity analysis and into the development of the conceptual model for a future systematic process for development of projections and scenarios.

Conceptual model

Based on the stakeholder analysis, a conceptual model for data and information flow, institutional cooperation, and procedures for quality control (IPCC, 2000), documentation and evaluation will be developed. In support of the conceptual model, basic requirements for data storage, handling and communication will be defined. The system should permit update or further refinement of previous projections and be a basis for scenario development and for sensitivity and uncertainty analysis. It should also support deeper analysis of projections and scenarios. For modelling ambient air exposures and health impact it is important to describe emissions with appropriate resolutions in geographic and temporal scales.

Filling knowledge gaps and improving GAINS model scenarios.

Historical data on energy use and economic value added in selected process industries will be collected and analysed with respect to their correlation to production of goods. The possibility to use historical correlations as an indicator of future correlation will be adjusted for by reviewing impacts of past and future policy instruments of relevance (Mansikkasalo & Michanek, 2011). Tests will be made based on recent projections on energy and economic value (Berg et al., 2012; Swedish Energy Agency, 2013).

An inventory of current knowledge and remaining knowledge gaps related to shipping in GAINS will be performed. This inventory will provide information on key uncertainties and research needs related to future emissions, abatement costs and emission dispersion.

Potential agricultural activities, NH_3 emissions and impacts will be analysed by parameter analysis in the GAINS scenarios based on the correlation between agricultural production, livestock, manure, and land use (Britz & Witzke, 2012; Sutton et al., 2011; Swedish Board of Agriculture, 2012). The results will be compared with the estimated use of emission control technologies and emission abatement potential from other sources (Oenema et al., 2012) and will provide useful input to the on-going scientific discussion on N management and future food consumption (Sutton et al., 2011; Åström et al., 2013).

WP 3 Health effects

Exposure-response relationships for different air pollutant components are a key element in the development of criteria for health impact assessments. The knowledge on such relationships is limited, in particular for morbidity, which makes prioritization of cost-effective preventive measures uncertain.

Key research questions:

- Which particle metrics (e.g. BC and PM10) and which source contributions (e.g. tail pipe emissions, road dusts, residential wood combustion) are relevant for the estimation at residential addresses of individuals included in the epidemiological studies used for assessment of exposure-response functions?
- What are the overall uncertainties in the calculated particulate concentrations and source contributions of different components?
- Which exposure-response functions for non-lethal health effects of exposure to air pollution can be estimated, with particular focus on cardiovascular diseases, lung function and pregnancy outcome?
- Which health effects can be used as indicators of air pollution related effects and how should they be expressed?
- What is the health impact following exposure to locally emitted and long-range transported pollutants in Gothenburg, Stockholm and Umeå and for the whole population of Sweden?
- What are the societal costs of health effects due to air pollution, considering different scenarios for projected changes in exposures and cost-effectiveness of different abatement strategies?

Exposure modelling as input to epidemiological studies

A methodology for long-term retrospective exposure modelling will be developed for Gothenburg, Stockholm and Umeå for the period from 1990 to 2012. This development will include splitting the total concentrations of PM10, PM2.5 and BC into long-range and within city contributions from traffic exhaust, traffic road wear, ship exhaust, residential wood combustion and other source contributions assuring consistency and relevance of sector emission evolutions against available data and emission factors (in collaboration with WP2). Time-weighted average concentrations of relevant particulate air pollution components at residential addresses will be estimated during the period of follow-up according to a previously developed methodology. The address information is transformed to geographical coordinates using a property register. Together with emission inventories and dispersion models outdoor concentrations are estimated of selected pollutants from different emission sources over time at relevant geographical locations.

Estimation of exposure-response functions

The estimation of exposure-response functions will focus on cardiovascular disease, lung function and pregnancy outcome. Cardiovascular diseases include primarily myocardial infarction and stroke, where data on morbidity and mortality are available from the National Patient and Mortality Registers, respectively. A meta-analyses will be performed based on subjects from nine adult cohorts in Gothenburg, Stockholm and Umeå, totalling about 60 000 subjects. For pregnancy outcome the study will be restricted to Stockholm and include about 120 000 births. Studies on lung function include 6 800 adults from Gothenburg and more than 4 000 children from Stockholm. The studies have a sufficient statistical power to precisely assess exposure-response relationships.

Health impact assessment and damage costs

The program will result in exposure-response functions for long-term exposure to particles in total and with respect to different fractions. We will use these in HIA calculations to see how sensitive the results are to the inclusion of more source specific estimates. The program will also bring more information on exposure-response functions for less studied endpoints, such as respiratory effects in children and birth outcome. Exposure-response functions proposed in the WHO reports will be updated with more recent publications. Our case-studies will deal with local interventions such as new bypass roads in Umeå and differentiated congestion tax in Stockholm and Gothenburg. By extending the exposure simulations to cover the entire country, health impact assessments will be possible for the Swedish population showing the consequences of national and international interventions, as transformed in WP2 to emissions scenarios. We will use the SIMAIR scenario tool (Omstedt et al. 2011) for the case studies.

Following the development of new exposure-response functions and health indicators for non-lethal health effects in WP3, we will analyse the costs for society of these specified health impacts. The methods and data used will depend to a large extent on which exposure-response functions and health indicators that are developed within the programme. Most likely, literature reviews on willingness-to-pay studies, and in some cases gathering of primary data on health care costs will be used as data sources.

WP 4 Climate and ecosystem effects

In WP4 the goal is to develop a capability to analyse the robustness and usefulness of different relations (metrics) for climate and ecosystem impacts used in IAMs.

Key research questions are:

- How well is climate change described by climate indicators currently applied in IAMs? Do inaccuracies affect development of policies strategies?
- How to estimate the indirect climate effects mediated by negative impacts of ground level ozone on forest growth and carbon sequestration in northern Europe.
- Which concepts and methods for describing ecosystems effects should be used for policy development in the future?

SLCP distribution and radiative forcing

The CTM MATCH (Robertson et al., 1999; Andersson et al., 2007), extended with size-resolved aerosol dynamics of SALSA (Kokkola et al., 2008) will be set up over the northern hemisphere with a focus on N Europe and the European Arctic. The model will be evaluated and improved using satellite information as well as relevant observations from existing European monitoring networks and previous research projects. The direct and indirect aerosol cloud albedo RF will be estimated using the MATCH-SALSA-RCA4 framework developed in the first phase of the CLEO research program funded by the Swedish EPA (www.cleoresearch.se). To examine the reliability and usefulness of RF as a measure of climate impact, we will make complementary use of the Earth System Model (ESM) NorESM (Kirkevåg et al., 2013). An ESM has the advantage of simulating the full interaction between SLCPs and climate so that an emission change can be tracked through the whole climate system; from emission to concentration change, to RF and further down to a temperature or precipitation change. A CTM, on the other hand, has the advantage to be computationally less demanding, thereby allowing analysis of a wider range of emission scenarios, a higher spatial resolution and use of observed meteorology. NorESM will be evaluated in a similar manner as MATCH-SALSA-RCA4 and a comparison of present-day RF estimates from the two model systems will be made.

Evaluation of climate metrics for SLCP

Fully coupled ocean-atmosphere simulations will also be conducted using NorESM for the 21st century for different scenarios of SLCP emissions and concentrations (using input from WP2). Specific aims of the simulations will be a) estimate feedbacks between a changing climate and SLCP concentrations and the resulting effect on direct and indirect RF b) translate RF values into effects on surface temperature. Finally we will set up a framework where we can compare climate effects accounted for in GAINS with effects simulated in both the ESM and CTM simulations for a the same emission scenario. The work addressing co-benefits of air pollution and climate mitigation will be coordinated with the EU FP7-projects ECLIPSE and PEGASOS for analysis of metrics, emissions and model evaluation.

Forest ozone exposure and effects on carbon sequestration

For ecosystem impacts, the most important knowledge gap is the quantification of the negative impacts of ozone on the growth of mature forest trees under field conditions. This will be improved by using dendrochronology measurements of historic, yearly growth of forest stands across Sweden in combination with epidemiological statistical methods and information on ozone exposure and other variables influencing forest growth. Epidemiological methods to quantify ozone impacts on forest growth will be explored for matured trees. A first attempt to use the epidemiological approach by Karlsson et al. (2006) demonstrated significant negative impact of ozone on stem growth, but the relationships could not be quantified due to the co-linearity problem (ozone and meteorology). Hence, larger datasets are required. An epidemiological ozone impact assessment will be applied based on dendrochronology investigations of 20 years of forest growth at approximately 15 sites within the SWETHRO network across Sweden (http://www.krondroppsnatet.ivl.se/). For these sites, information will be available for the yearly load of other pollutants besides ozone, meteorology, soil moisture and stand and soil conditions.

Review of critical load calculations

For effects of deposition of air pollutants, the concept of critical loads is well established within the CLRTAP. However, the calculations of critical loads have shifted over time due to variations in methodology (Spranger et al., 2008). These variations can be i.a, be attributed to shifting deposition calculations both for historical estimates and for future prediction backward and forward in time and the influence of other factors such as forestry and climate. There is thus a need to compare and analyse the differences in currently employed models and to propose a methodology to calculate critical loads that guarantees protection of target organisms. On the national level the methodologies for critical load calculations also need to be compatible with the Swedish assessment criteria for acidification and eutrophication.

Practical relevance

The results from the program are of relevance for many stakeholders. These include in particular the Swedish Government and the Swedish Environmental Protection Agency (NV), but also local and regional authorities, EU, CLRTAP Arctic Council and the Climate and Clean Air Coalition (CCAC). There are also several national agencies and industrial organisations for which the results will be of high relevance. These include The National

Board of Health and Welfare, Swedish Energy Agency, Swedish Forestry Board, Swedish Transport Association, Swedish Board of Agriculture, Swedish Agency for Marine and Water Management, and industrial organisations and federations for e.g. energy, transport, pulp and several industrial branches. The communication activities (see below) will also to a large extent be directed to these stakeholders.

For the main stakeholder for the program we see the following practical applications of the results:

- Improved scientific knowledge on criteria and measures for the fulfilment of the National Environmental Objectives Clean Air, Reduced Climate Impact, Zero Eutrophication and Natural Acidification Only
- Tools for assessments and cost-effective measures for improved local air quality
- New data on morbidity effects from atmospheric pollutants including population effects and cost estimates of morbidity.
- Abatement costs of air emissions in relation to environmental and health benefits for national sectors (traffic, energy, industry, agriculture etc.)
- Support to Swedish positions in international air pollution and climate negotiations, including EU, CLRTAP, CCAC, Arctic Council and UNFCCC
- Improved knowledge of integrated assessment modelling and assessment studies (CLRTAP and its subsidiary bodies, WHO, IPCC etc.)

Organisation

The program is organized in four work packages: WP1, IAM - synergies and conflicts; WP2, Emission projections and scenarios; WP3, Exposure and health effects; WP4, Impact on climate and ecosystems. In addition to the scientific work packages, a separate WP for coordination and communication is also included. The structure of the program is presented schematically in Figure 1.

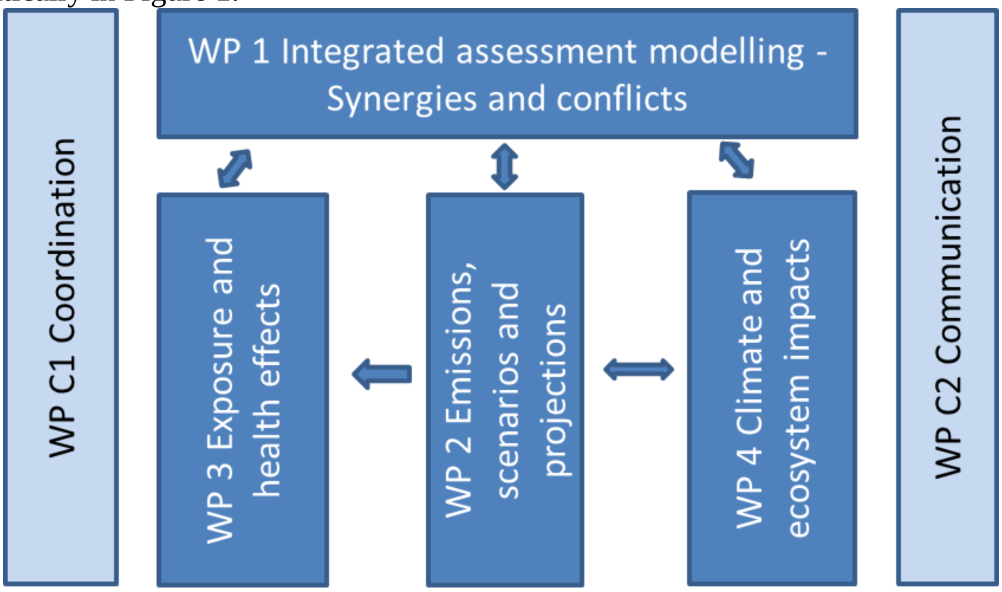

Figure 1. Structure of the SCAC research program

Program Steering Committee

The Program Steering Committee (PSC) will consist of the coordinator (including deputy), all WP leaders, the program communicator and representatives for the Swedish Environmental

Protection Agency and one additional representative of SMHI and IVL respectively. The PSC will be responsible for all decisions concerning the program, for reporting of progress and taking any necessary action to solve problems and delays in the project. All communication activities will also be discussed and coordinated in the PSC.

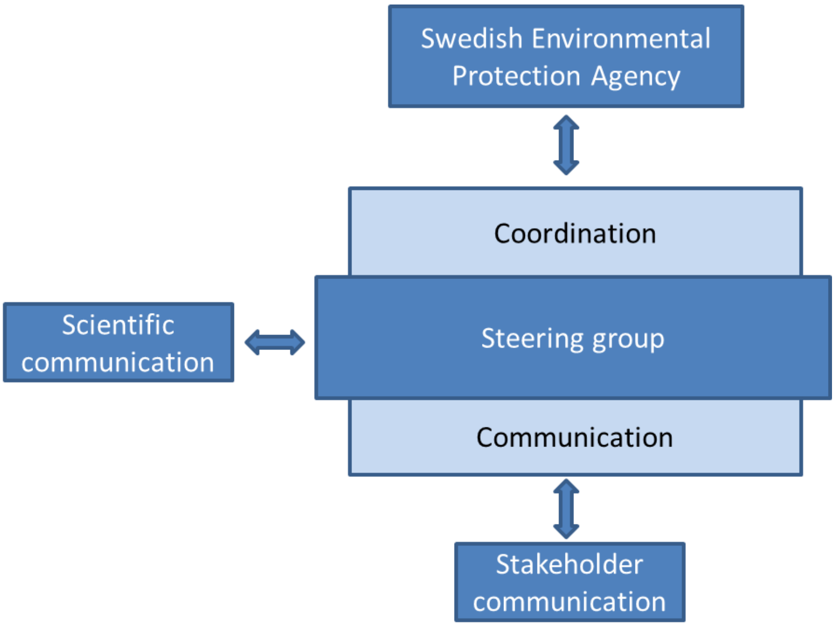

Figure 2. Structure for coordination and communication

Coordination groups
In order to ensure sufficient coordination with other programs and activities within the field of urban and regional air quality management at the participating organisations IVL and SMHI, one program coordinating group will be organised at each institute. For IVL it will also include links to program activities such as CLEO and for SMHI to activities such as SMHI's role as coordinator for national SLCP activities. A list of all members of the coordination groups and their networks is provided in Table 1 below.

The communication with other partners will be achieved via internal WP communication, emails and annual program conferences.

External networks

Program participants are active in a large number of networks and international research programs related to research and policy issues on air pollution and climate. A summary of the main networks and how program participants are involved is given in Table 1 below. Additional information on on-going research project involving the SCAC partners is provided on the proposal portal.

Table 1. Examples of external networks and international projects where SCAC participants are involved

Name	Function	Networks and projects
Peringe Grennfelt, IVL	Program coordination	Chair WG on Effects under CLRTAP. EMEP Bureau
John Munthe, IVL	Applicant, Deputy coordinator, coord. with relevant research at IVL	EMEP Steering Body. Miljöforskningsberedningen.
Lars Gidhagen, SMHI	Coordination with relevant air quality and research activities at SMHI	Co-ordinator FP7-ICT SUDPLAN – Sustainable Urban Development Planner for Climate Change Adaptation
Karin Sjöberg, IVL	Coordination with relevant air quality activities at IVL	AQUILA Network of Air Quality Reference Laboratories. Task Force on Measurements and Modelling.
HC Hansson, SU	WP 1 co-lead	Partner in FP7 projects PEGASOS, ACTRIS and SIOS. Participant in CRAICC, a Nordic Council top level research initiative. Active in the Swedish SLCP initiative.
Stefan Åström, IVL	WP 1 co-lead	Task Force and national network on IAM. LIAISE network of excellence
Karin Kindbom, IVL	WP 2 co-lead	Task Force on Emission Inventories and Projections. Expert in the UNFCCC international review programme
David Segersson, SMHI	WP 2 co-lead	National and international projects on emission inventories.
Göran Pershagen, KI	WP 3 co-lead	WP leader or partner in several EU projects, such as ESCAPE, TRANSPHORM and MeDALL
Gerd Sällsten, GU	WP 3 co-lead	FORMAS- and FAS-funded projects on air pollution incl. IVL and int. partners. WHO expert air pollution assessment.
Annica Ekman, SU	WP 4 co-lead	EU project PEGASOS. Member of climate modelling development groups for NorESM and EC-Earth.
Joakim Langner, SMHI	WP 4 co-lead	AMAP expert group on BC and trop. O_3. National co-ordination support to Env. ministry on SLCP and CCAC
Erik Swietlicki, LU	Coordination with research activities at LU	EU FP7 Infrastructure ACTRIS, VR Strategic Research Area MERGE (Climate modelling) and several other projects on SLCP. Swedish reference group at IMO for standardization of BC measurements."

Communication

Objective

The primary objective and purpose of the SCAC communication is to support the program by communicating the research results to national and international stakeholders and others mentioned under “Practical relevance”. Furthermore, coordinating the communication from stakeholders back to participating researchers will be of equal importance. The common communication with the scientific community in terms of papers and presentations at conferences etc. will be part of the scientific work packages and is not presented here.

Communication of research results is an essential part of SCAC and a communication plan will be developed as a first step when the program is commenced. Some important items of the communication activities will be:

- A program web site for general information about the program as well as a restricted website for sharing data and documents within the program
- Communication with national stakeholders. Mainly the Swedish EPA but also national, regional and local authorities as well as other stakeholders such as industry, NGOs. Dedicated workshops and a final conference will be arranged.
- Communication via external networks (see above)
- Fact sheets and brochures
- Press releases (if relevant)

Preliminary communication activities

Activity	Periodicity	Target group
Web page in English (and Swedish)	Month 1 and continuously	Public, Scientific community and Experts, Media, SCAC research team
Reference list of all communication activities	Continuously	
Progress reports	Yearly	Swedish Environmental Protection Agency
Internal information	Yearly	SCAC research team
News letter	Yearly	Scientific community, experts and stakeholders
Contacts with national stakeholders.	Continuously	National stakeholders
Organisation of stakeholder seminars	1-2 workshops	Scientific community and experts, the SCAC researchers and media
Final synthesis and seminar	End of program	Scientific community, experts, stakeholders, and media

Activity plan

WP 1 Integrated Assessment Modelling - Synergies and conflicts					
Activity	**Start***	**End***	**D***	**Description**	**Partner**
1:1. Emission inventories & scenarios	1	6	D1.1	Review of uncertainty & assumptions in current data and future projections	IVL, ITM
1:2. Non-technical measures (NTM) in AP abatement costs	1	2	D 1.2	Analyses options for considering NTM in abatement cost estimates	IVL ITM
1:3. AP/SLCP cost optimization models Sweden	1	8	D1.3	Analyses cost optimal emission abatement in Sweden	IVL, IIASA, ITM
1:4. Cost-optimal AP/SLCP/LLGHG abatement	18	24	D1.4	Analyses opportunities for multi-emission cost optimization	IVL, IIASA
1:5. Conflicts and synergies	18	24	D1.5.1	Produce sets of SLCP emission levels to WP3, 4	
	20	36	D1.5.2	Analyses remaining conflicts and synergies in Sweden, partly based on WP3 and WP4 results	IVL, ITM

WP 2 Emission projections and scenarios					
Activity	**Start***	**End***	**D***	**Description**	**Partner**
2:1. Analysis of current and future needs for projections	1	12	D 2.1	An analysis and compilation of requirements and needs for projections from stakeholders for different purposes, levels of detail and on different geographical scales, including necessary background information	IVL, SMHI
2:2. Sensitivity analysis of projections	1	18	D 2.2	Sensitivity analysis and ex-post analysis of Swedish projections identifying and quantifying important input parameters impacting projections results	IVL, SU
	1	20	D 2.3	A methodology for, and role of, sensitivity analysis of projections in a future Swedish system for projections	IVL, SMHI
2:3. Conceptual model	1	30	D 2.4	A conceptual model for future systematic and consistent development of Swedish emission projections and scenarios	IVL, SMHI, LU
2:4 Knowledge gaps GAINS scenarios	1	12	D 2.5	Uncertainty and discrepancy report on emission inventories, emission modelling & measurement to WP1	IVL
	1	30	D 2.6	Improved representation in emissions from process industries, shipping and agriculture in the GAINS model	IVL, LU
2:5. Emission projections/scenarios		10 18	D 2.7 D 2.8	Spatially distributed emissions as input to exposure simulations in Stockholm, Gothenburg and Umeå 1990-2010 as input to WP3 Spatially distributed national emission scenarios as input to WP 3 HIA	SMHI, IVL

WP 3 Health Effects					
Activity	**Start***	**End***	**D***	**Description**	**Participants**
3:1. Exposure modelling	1	12	D 3.1	Models developed for local particulate level measures with high spatial resolution in Gothenburg, Stockholm and Umeå, facilitating analyses of health effects related to specific sources in Activity 2	SMHI, SLB
3:2 Estimation of exposure-response functions	6	20	D 3.2	Estimates of exposure-response functions for cardiovascular effects, lung function and pregnancy outcomes based on cohorts in Gothenburg, Stockholm and Umeå, including evaluation of new health indicators for air pollution effects	KI, GU Sahl, UmU
3:3 HIA and damage costs	12	26	D 3.3	HIA, focusing on non-lethal effects and case-studies in Gothenburg, Stockholm and Umeå, as well as on scenarios for future air pollution levels and population exposure based on emission scenarios from WP2	UmU, KI, SMHI, IVL
	12	26	D 3.4	Damage cost estimation of health effects related to air pollution, also including analyses of the cost-effectiveness of different abatement strategies, supplied to WP1	

WP 4 Climate and Ecosystems Effects					
Activity	**Start***	**End***	**D***	**Description**	**Participants**
4:1. SLCP distribution and radiative forcing	1	26	D 4.1	Report documenting evaluation of ESM and CTM model simulations of SLCPs for current climate and emissions using available observations.	SMHI, SU, LU
		36	D 4.2	Manuscript documenting and comparing RF estimates for SLCP from ESM and CTM simulations.	
4:2 Evaluation of climate metrics for SLCP	1	24	D 4.3	Report on climate effects of SLCP emissions from ESM simulations.	SU, SMHI, LU
		30	D 4.4	Report on results of comparison and analysis of climate effects accounted for in GAINS with effects simulated in both the ESM and CTM simulations for the same emission scenario.	
4:3 Forest ozone exposure and effects on carbon sequestration	1	26	D 4.5	Report on suggestions for improvements of the descriptions of ozone impacts on forest carbon sequestration in GAINS to WP1.	IVL, GU
		34	D 4.6	Manuscript on ozone impacts on forest growth in Sweden over the last 20 years.	
4:4 Review of critical load calculations	6	24	D 4.7	Discussion paper, workshop and workshop report on methodology to calculate critical loads.	IVL
WP C1 Coordination					
Activity	**Start***	**End***	**D***	**Description**	**Participants**
C:1. Administrative coordination.	1	36		Contractual and financial issues between the funding agency and the program partners Formal reporting to the funding agency.	IVL + all partners
C:2 Scientific coordination	1	36		Scientific coordination of the program - Progress reports - Evaluation of scientific progress - Handling of changes in project plans - PSC meetings and minutes - Coordination with relevant activities at partner institutions	IVL + all partner

Budget

	Totalt	IVL	SMHI	KI	GU Sahl	UU	SU ITM	SU MISU	SLB	Gu BioEnv	GU Geo	IIASA	LU	Externt
SCAC Budget	25000	7545	5030	2150	1960	2060	1225	2380	490	350	450	530	100	730
WP C1 Coordination	785	630											15	140
WP C2 Communication	740	440											10	290
WP 1	**4175**													
Activity 1:1. Emission scenarios	300	160					140							
Activity 1:2. Economic instruments for realising implementation of non-technical measures for emission reductions	670	670												
Activity 1:3. Review and test projection models and methods: Prospects for future GHG/AP/SLCP Abatement cost optimization Sweden	160	40										120		
Activity 1.4. Review and test projection models and methods: GAINS vs climate models and HIA (Cost-optimal AP emission reductions in Sweden)	1370	870					130					370		
Activity 1:5. Analysis of conflicts and synergies	1675	770					905							
WP 2	**3780**													
Activity 2:1 Analysis of current and future needs for projections, Stakeholder analysis	610	510	100											
Activity 2:2 Sensistivity analysis and ex post analysis of	615	465					50							100
Activity 2:3 Development of conceptual model and system as a basis for future work with projections and scenarios	1010	590	200										20	200
Activity 2:4 Knowledge gaps, national adaptation of GAINS	955	900										40	15	
Activity 2:5 Emission projections/scenarios to be used in other	590	100	490											
WP 3 Health	**8810**													
Activity 3:1 Exposure modelling	1960		1470						490					
Activity 3:2 Exposure quantification	5490			1860	1960	1670								
Activity 3:3 HIA and damage costs	1360	290	390	290		390								
WP 4 Climate and ecosystem impacts	**6710**													
Activity 4:1 SLCP distribution and radiative forcing	2400		2380										20	
Activity 4:2 Evaluation of climate metrics for SLCP	2400							2380					20	
Activity 4.3 Forest ozone and effects on carbon sequestration	1520	720								350	450			
Activity 4.4 Ecosystemindicators: Synthesis	390	390												

Note: Partner LU is participating as an in-kind contribution with research contributions to Activities 1:1, 2.3., 2:4, 4:1 and 4:2. Assigned budget for LU will cover travel costs for meetings for LU partners and specific contributions to individual activities.

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